United States Environmental Protection Agency

The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition

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The Incidence and Severity of Sediment Contamination in Surface Waters of the United States

National Sediment Quality Survey
Second Edition

November 2004

United States Environmental Protection Agency
Office of Science and Technology
Standards and Health Protection Division
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DISCLAIMER

The *National Sediment Quality Survey* is a screening-level assessment of sediment quality that compiles and evaluates sediment chemistry and related biological data taken from existing databases. This document has no immediate or direct regulatory consequence. It does not in itself establish any legally binding requirements on the U.S. Environmental Protection Agency, states, tribes, other regulatory authorities, or the regulated community. It does not establish or affect legal rights or obligations or represent a determination of any party's liability. The data and information contained in this document, however, could be used in various EPA regulatory programs for priority setting or other purposes after further evaluation for program-specific criteria. Any future policies and/or actions to address contaminated sediments will have to be considered in the context of the budget process and competing demands for funding.

CONTENTS

TABLES

FIGURES

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EXECUTIVE SUMMARY

This report, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States: National Sediment Quality Survey,* Second Edition, describes the accumulation of chemical contaminants in river, lake, ocean, and estuary bottoms and includes a screening-level assessment of the potential for associated adverse effects on human and/or environmental health. The United States Environmental Protection Agency (EPA) prepared this report to Congress in response to requirements set forth in the Water Resources Development Act (WRDA) of 1992. WRDA directed EPA, in consultation with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE), to conduct a comprehensive national survey of data regarding the quality of aquatic sediments in the United States. Section 503(a) of WRDA required EPA to "compile all existing information on the quantity, chemical and physical composition, and geographic location of pollutants in aquatic sediment, including the probable source of such pollutants and identification of those sediments which are contaminated...." It further required EPA to "report to the Congress the findings, conclusions, and recommendations of such survey, including recommendations for actions necessary to prevent contamination of aquatic sediments and to control sources of contamination." In addition, Section 503(b) of WRDA requires EPA to conduct a comprehensive and continuing program to assess aquatic sediment quality. This program must establish methods and protocols for monitoring the physical, chemical, and biological effects of pollutants in aquatic sediment and of contaminated sediment. EPA submitted the first Report to Congress (EPA-823-R-97-006) on January 7, 1997.

To comply with Section 503(b), EPA's Office of Science and Technology (OST) (1) initiated the National Sediment Inventory (NSI), which is designed to compile sediment quality information from available electronic databases into one centralized, easily accessible location, and (2) developed the *National Sediment Quality Survey* report.

Description of the NSI

The NSI database includes approximately 4.6 million records of sediment chemistry, tissue residue, and toxicity data for more than 50,000 monitoring stations across the country. To efficiently collect usable information for inclusion in the NSI database, EPA sought data that were available in electronic format, represented broad geographic coverage, and represented specific sampling locations identified by latitude and longitude coordinates. Although EPA elected to evaluate in this report only data collected since 1990 (i.e., 1990 through 1999), data from before 1990 are maintained in the NSI database for comparison purposes. The initial *National Sediment Quality Survey* evaluated data from 1980 through 1993. At a minimum, EPA required that electronically available data include monitoring program, sampling date, latitude and longitude coordinates, and measured units for inclusion in the data evaluation. The NSI database includes data from the following data storage systems and monitoring programs:

- Selected data sets from EPA's Storage and Retrieval System (STORET)
- NOAA's Query Manager Data System
- State of Washington Department of Ecology's Sediment Quality Information System (SEDQUAL)
- Selected data sets from the U.S. Geological Survey's (USGS's) WATSTORE
- EPA's Environmental Monitoring and Assessment Program (EMAP)
- Data compiled for the previous report to Congress, 1990 through 1993
- Chesapeake Bay Program
- Upper Mississippi River System data compilation prepared by USGS

- Indiana Department of Environmental Management Sediment Sampling Program
- Oklahoma Reservoir Fish Tissue Monitoring Program, 1990 through 1998
- Houston Ship Channel Toxicity Study

National Sediment Quality Survey Report Objective

The objective of the *National Sediment Quality Survey* report is to develop screening-level assessment protocols to allow the identification of potentially contaminated sediment. The report is to be produced biennially for Congress, as well as the regions, states, and tribes, on the incidence and severity of sediment contamination nationwide. One objective of the original report, as well as this first update to that report, is to depict and characterize the incidence and severity of sediment contamination based on the *probability* of adverse effects to human health and/or the environment. As used in this report, the probability or potential for adverse effects reflects a range of situations where the analysis of a station's data might indicate adverse effects on aquatic life and/or human health. To accomplish this objective, EPA applied assessment protocols to existing available data in a uniform fashion. EPA intended to accurately depict and characterize the incidence and severity of sediment contamination based on the probability of adverse effects to human health and/or the environment. This was done through the use of a number of different measures of sediment quality (i.e., multiple lines of evidence). Information contained in this report may be used to further investigate sediment contamination on a national, regional, or site-specific scale. Further studies might involve toxicological investigations, risk assessment, analyses of temporal and spatial trends, feasibility of natural recovery, and source control.

The initial report presented a national baseline screening-level assessment of contaminated sediments from sediment quality data collected from 1980 through 1993 using a weight-of-evidence approach. This report presents the results of the screening-level assessment of the NSI data from 1990 through 1999. One major advantage of screening out older data (data collected prior to January 1, 1990) for this report is that it prevents the results from being unduly influenced by historical data when more recent data are available. However, this would not account for any decrease in sediment contaminant levels due to scouring, re-burial, natural attenuation, or active sediment remediation that have occurred since that sample was collected.

This report identifies locations where available data indicate that direct or indirect exposure to the sediment could be associated with adverse effects to aquatic life and/or human health. Further, even though this report focuses on data collected from 1990 through 1999, conditions might have improved or worsened since the sediment was sampled. This report does not and cannot provide a definitive assessment of the national condition or relative health of sediments across the country because the data were generally not collected in a randomized sampling approach. While this report does not provide an assessment of the "national condition" of contaminated sediments, it does evaluate data collected from 1980 through 1999 in the NSI database to assess changes in the extent and severity of sediment contamination over time for specific areas in the United States where sufficient data exist.

As mentioned above, this report provides a screening-level assessment outlining stations throughout the United States where the *probability* of adverse effects to human health and/or the environment exist. Because the data compiled for this report consist largely of non-random sampling events and do not provide complete national coverage, EPA has not developed a "national estimate" of the areal extent of contaminated sediments. Because the limitations of the data do not allow for a national estimate of the percentage of contaminated sediments, the report should not be used to estimate the national cost of potential sediment remediation or to prioritize sites for sediment remediation or risk management decisions based solely on the results of this report. Such decisions should be based on all available information, including the data reported in this report.

Evaluation Approach

Section 503 of WRDA 1992 defines *contaminated sediment* as “aquatic sediment which contains chemical substances in excess of appropriate geochemical, toxicological, or sediment quality criteria or measures; or is otherwise considered by the Administrator [of EPA] to pose a threat to human health or the environment....” The approach used to evaluate the NSI data focuses on the risk to benthic organisms exposed directly to contaminated sediments and the risk to human consumers of organisms exposed to sediment contaminants. EPA evaluated sediment chemistry data, chemical residue levels in edible tissue of aquatic organisms, and sediment toxicity data taken at the same sampling station (where available) using a variety of assessment methods.

The following measurement parameters and techniques were used alone or in combination to perform a screening-level assessment of the probability of adverse effects.[1]

Aquatic Life

- Comparison of sediment chemistry measurements to draft equilibrium partitioning sediment guidelines (ESGs) derived from final or secondary acute values and final or secondary chronic values.
- Comparison of the molar concentration of acid-volatile sulfides ([AVS]) in sediment to the molar concentration of simultaneously extracted metals ([SEM]) in sediment. (Under equilibrium conditions, sediment with [AVS] greater than [SEM] does not demonstrate toxicity from metals.)
- Estimation of the predicted proportion toxic from sediment chemistry observations using a logistic regression model.
- Comparison of the total ESG toxic unit for polycyclic aromatic hydrocarbons (PAHs) to final chronic or acute values.
- Toxicity based on acute or chronic solid-phase sediment toxicity data.

Human Health

- Comparison of theoretical bioaccumulation potential (TBP) values derived from sediment chemistry to
  - EPA cancer and noncancer risk levels or
  - Food and Drug Administration (FDA) tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.
- Comparison of fish tissue contaminant levels to
  - EPA cancer and noncancer risk levels or
  - FDA tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.

The sediment chemistry screening values used as the basis for comparison in this report are not regulatory criteria, site-specific cleanup standards, or remediation goals. Sediment chemistry screening values are reference values above which a sediment ecotoxicological assessment might indicate a potential threat to aquatic life. The sediment chemistry screening values include both theoretically and empirically derived values. The theoretically derived screening values (e.g., ESG, [SEM]−[AVS]) rely on the

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[1] A screening-level assessment typically identifies many potential problems that subsequently prove not to be significant upon further analysis (i.e., more conservative).

physical/chemical properties of sediment and chemicals derived to protect aquatic benthic organisms from direct toxicity due to that chemical or chemicals in the case of metals mixtures and PAH mixtures. The empirically derived or correlative approaches (e.g., predicted proportion toxic) rely on paired field and laboratory data to relate incidence of observed biological effects to the dry-weight sediment concentrations. Correlative screening values can relate measured concentration to a probability of association with adverse effects, but they do not definitively establish cause and effect for a specific chemical. Toxicity data were used to classify sediment sampling stations based on their demonstrated toxicity to aquatic life in laboratory bioassays.

Under an assumed exposure scenario, TBP and tissue residue data can indicate potential adverse effects on humans from the consumption of fish that become contaminated through exposure to contaminated sediment. TBP is an estimate of the equilibrium concentration (concentration that does not change with time) of a contaminant in tissues of aquatic organisms if the sediment in question were the only source of contamination to the organism. At present, the TBP calculation can be performed only for nonpolar organic chemicals. The TBP is estimated from the concentration of contaminant in the sediment, the organic carbon content of the sediment, the lipid content of the organism, and the relative affinity of the chemical for sediment organic carbon and animal lipid content. This relative affinity is measured in the field and is called a biota-sediment accumulation factor (BSAF, as discussed in detail in Appendix B). In practice, field-measured BSAFs can vary by an order of magnitude or greater for individual compounds depending on location and time of measurement. For this evaluation, EPA selected BSAFs that represent the central tendency, suggesting an approximate 50 percent chance that an associated tissue residue level would exceed a screening risk value.

The reader should exercise caution in evaluating the data in this report for a number of reasons. Uncertainty is associated with site-specific measures, assessment techniques, exposure scenarios, and default parameter selections. Many mitigating biological, chemical, hydrological, and habitat factors can affect whether sediment poses a threat to aquatic life or human health. Because of the limitations of the available sediment quality measures and assessment methods, EPA characterizes this evaluation as a screening-level analysis. A screening-level analysis typically identifies many potential problems that prove not to be significant upon further analysis. Thus, classification of sampling stations in this analysis is not meant to be definitive, but is intended to be inclusive of potential problems arising from persistent metal and/or organic chemical contaminants. For this reason, EPA elected to evaluate data collected from 1990 through 1999 and to evaluate each chemical or biological measurement taken at a given sampling station individually. The reader should keep in mind that a single measurement of a chemical at a sampling station, taken at any point in time over the past 10 years, might have been sufficient to categorize the sampling station as having an increased probability of association with adverse effects on aquatic life or human health.

In this report, EPA associates sampling stations with their “probability of adverse effects.” Each sampling station falls into one of three categories, or tiers:

Tier 1: Associated adverse effects on aquatic life or human health are probable.

Tier 2: Associated adverse effects on aquatic life or human health are possible.

Tier 3: No indication of associated adverse effects (any sampling station not classified as Tier 1 or Tier 2; includes sampling stations for which substantial data were available, as well as sampling stations for which limited data were available).

The potential risk of adverse effects on aquatic life and/or human health is greatest in areas with a multitude of contaminated locations. The assessment of individual sampling stations is useful for estimating the number and distribution of contaminated spots and the overall magnitude of sediment contamination in monitored waterbodies of the United States. However, a “hot spot” might not pose a significant threat to either the benthic community at large or consumers of resident fish because the spatial extent of exposure could be small. On the other hand, if many contaminated spots are located in close proximity, the spatial extent and probability of exposure are much greater. EPA examined sampling station classifications within watersheds to identify areas of probable concern (APCs) for sediment contamination, where the exposure of benthic organisms and resident fish to contaminated sediment might be more frequent. In this report, EPA defines watersheds by 8-digit USGS hydrologic unit codes, which are roughly the size of a county. Watersheds containing APCs are those in which 10 or more sampling stations were classified as Tier 1 and in which at least 75 percent of all sampling stations were categorized as either Tier 1 or Tier 2.

The definition of "area of probable concern" was developed for this report to identify watersheds for which further study of the effects and sources of sediment contamination, and possible risk reduction needs, would be warranted. Where data have been generated through intensive sampling in areas of known or suspected contamination within a watershed, the APC definition should identify watersheds that contain even relatively small areas that are considerably contaminated. This designation does not imply, however, that sediment throughout the entire watershed, which is typically very large compared to the extent of available sampling data, is contaminated. On the other hand, where data have been generated through comprehensive sampling, or where sampling stations were selected randomly or evenly distributed throughout a sampling grid, the APC definition might not identify watersheds that contain small or sporadically contaminated areas. A comprehensively surveyed watershed of the size typically delineated by a USGS cataloging unit might contain small but significant areas that are considerably contaminated, but the watershed might be too large in total area for 75 percent of all sampling stations to be classified as Tier 1 or Tier 2. Limited random or evenly distributed sampling within such a watershed also might not yield 10 Tier 1 sampling stations. Thus, the process used to identify watersheds containing APCs might both include some watersheds with limited areas of contamination and omit some watersheds with significant contamination. However, given the available data, EPA has concluded that the process represents a reasonable screening analysis to identify watersheds where further study is warranted.

Because the Tier 1, Tier 2, and Tier 3 evaluation benchmarks established in this report represent recent advances in sediment assessment techniques, they have been used in this report as a way to relate all the different data from all the different sources around the United States using common benchmarks. These benchmarks and interpretations used in this report, however, are not currently appropriate for use in EPA regulatory programs that have developed their own frameworks and regulatory requirements. They were not designed to be a substitute for the various EPA program regulatory frameworks and/or authorities. EPA's regulatory programs (e.g., Office of Solid Waste and Emergency Response, OSWER) have developed their own scientifically defensible approaches to sediment evaluation based on the needs of their programs, and they will continue to use their current regulatory frameworks when making decisions regarding potentially contaminated sediments (e.g., sediment remediation, sediment disposal).

Strengths and Limitations

For this report to Congress, EPA has compiled the most extensive database of sediment quality information currently available in electronic format. To evaluate these data, EPA has applied sediment assessment techniques using a multiple-lines-of-evidence approach recommended by national experts (Ingersoll et al., 1997). The evaluation approach uses sediment chemistry, tissue residue, and toxicity test results. The assessment tools employed in this analysis have been applied in North America, and results of these applications have been published in peer-reviewed literature. Toxicity test data were generated using established standard methods employed by multiple federal agencies. The evaluation approach addresses potential impacts on both aquatic life and human health. Some chemicals pose a greater risk to human health than to aquatic life; for others, the reverse is true. By evaluating both potential human health and aquatic life impacts, EPA has ensured that the most sensitive endpoint is used to assess environmental impacts.

There are two general types of limitations the reader should keep in mind in interpreting the results in this report to Congress—limitations of the compiled data and limitations of the evaluation approach. Limitations of the compiled data include the mixture of data sets derived from different sampling strategies, incomplete sampling coverage, the age and quality of data, and the lack of measurements of important assessment parameters. Limitations of the evaluation approach include uncertainties in the interpretive tools used to assess sediment quality (e.g., the propensity of certain chemicals to bioaccumulate and move through the aquatic food chain), use of assumed exposure potential in screening-level quantitative risk assessment (e.g., fish consumption rates for human health risk), and the subsequent difficulties in interpreting assessment results. These limitations and uncertainties are discussed in detail in Chapter 2 of this report under “Limitations of the NSI Data Evaluation.”

Data compiled for this report were generated using a number of different sampling strategies. Component sources contain data derived from different spatial sampling plans, sampling methods, and analytical methods. Most of the NSI data were compiled from nonrandom monitoring programs. Such monitoring programs focus their sampling efforts on areas where contamination is known or suspected to occur. Reliance on these data is consistent with the stated objective of this survey: to identify those sediments which are contaminated. However, one cannot accurately make inferences regarding the overall condition of the Nation's sediment, or characterize the “percent contamination,” using the data in the NSI database because of the incomplete national sampling coverage and because, in EPA’s view, uncontaminated areas are most likely substantially underrepresented.

Because this analysis is based only on readily available electronically formatted data, contamination problems exist at some locations where data are lacking. Conversely, older data might not accurately represent current sediment contamination conditions. The reliance on readily available electronic data has undoubtedly excluded a vast amount of information available from sources such as local and state governments and published academic studies. In addition, some data in the NSI database were not evaluated because of questions concerning data quality or because no locational information (latitude and longitude) was available. NSI data do not evenly represent all geographic regions in the United States, nor do the data represent a consistent set of monitored chemicals. More than two-thirds of all stations evaluated in the NSI database are in Washington, Virginia, California, Illinois, Florida, Wisconsin, New York, Texas, Oregon, and South Carolina. Each of these states has more than 500 monitoring stations. Other states of similar or larger size (e.g., Georgia, Pennsylvania) have far fewer sampling stations with data for evaluation. Individual stations may vary considerably in terms of the number of chemicals monitored. Some stations have data that represent a large number of organic and inorganic contaminants, whereas others have measured values for only a few chemicals. Thus, the inventory should not be construed as comprehensive even for locations with sampling data.

EPA recognizes that sediment is dynamic and that great temporal and spatial variability in sediment quality exists. Movement of sediment is highly temporal and dependent upon the physical and biological processes at work in the watershed. Some deposits redistribute, whereas others remain static unless disturbed by extreme events. Because the data analyzed in this report were collected over a relatively long period of time, conditions might have improved or worsened since the sediment was sampled. Consequently, this report does not provide a definitive assessment of the current condition of sediments but serves as a baseline for future assessments.

The lack of data required to apply some important assessment parameters hampered EPA’s efforts to determine the incidence and severity of sediment contamination. For example, the component databases contain a dearth of total organic carbon (TOC) and acid-volatile sulfide (AVS) measurements relative to the abundance of contaminant concentration measurements in bulk sediment. TOC and AVS are essential pieces of information for interpreting the bioavailability, and subsequent toxicity, of nonpolar organic and metal contaminants, respectively. In addition, matched sediment chemistry with toxicity tests and matched sediment chemistry with tissue residue data, were typically lacking. Also, because the evaluation approach outlined in this report needs to be applicable across the entire United States, various assumptions were made (e.g., assuming 1 percent organic carbon when none was reported, assuming the average individual consumes on average 17.5 grams of fish per day). Generally, the exposure assumptions and safety factors incorporated into toxicity assessments are intended to be protective of the majority of the general population associated with sediment contamination. However, these assumptions and factors might underestimate risks to populations of subsistence fishers and sensitive subpopulations (such as pregnant women, nursing mothers, and children).

It is important to understand both the strengths and limitations of this analysis to appropriately interpret and use the information in this report. The limitations do not prevent intended uses, and future reports to Congress on sediment quality will contain less uncertainty. To ensure that future reports to Congress accurately reflect current knowledge concerning the conditions of the Nation's sediment as our knowledge and application of science evolve, the NSI will develop into a periodically updated, centralized assemblage of sediment quality measurements and state-of-the-art assessment techniques.

Findings

EPA evaluated 19,398 sampling stations nationwide as part of the NSI data evaluation (Figure 1). Of the sampling stations evaluated, EPA classified 8,348 stations (43.0 percent) as Tier 1, 5,846 (30.1 percent) as Tier 2, and 5,204 (26.8 percent) as Tier 3. EPA has concluded that these results in all likelihood are not representative of the overall condition of sediment across the country. It could be that the overall extent of contaminated sediments and the corresponding adverse effects are much less. This is the case primarily because most of the NSI data were obtained from monitoring programs targeted toward areas of known or suspected contamination (i.e., sampling stations were not randomly selected).

The NSI sampling stations were located in 5,695 individual river reaches (or waterbody segments) across the contiguous United States, or approximately 8.8 percent of all river reaches in the country (based on EPA's River Reach File 1). A river reach can be part of a coastal shoreline, a lake, or a length of stream between two major tributaries ranging from approximately 1 to 10 miles long. As depicted in Figure 2, approximately 3.6 percent of all river reaches in the contiguous United States had at least one station categorized as Tier 1, almost 3 percent (2.9 percent) of reaches had at least one station categorized as Tier 2 (but none as Tier 1), and all of the sampling stations were classified as Tier 3 in about 2.3 percent of reaches. Looking at only the river reaches where sampling stations were evaluated, approximately 40 percent of the 5,695 river reaches evaluated had at least one sampling station categorized as Tier 1, approximately 33 percent of the river reaches evaluated had at least one station categorized as Tier 2 (but none as Tier 1), and all of the sampling stations in river reaches evaluated as Tier 3 in about 26 percent of the reaches had all sampling stations categorized as Tier 3.

Watersheds containing areas of probable concern for sediment contamination (APCs) are those that include at least 10 Tier 1 sampling stations and in which at least 75 percent of all sampling stations were classified as Tier 1 or Tier 2. The NSI data evaluation identified 96 watersheds throughout the United States as containing APCs (Figure 3 and Table 1; The map numbers listed on Table 1 correspond to the numbered watersheds identified in Figure 3). About 26 percent of the 370 eligible watersheds (96) contained an APC, or 4.2 percent of all the 2,264 watersheds in the United States. APC designation could result from expansive sampling throughout a watershed or from intensive sampling at a single contaminated location or a few contaminated locations. In comparison to the overall results presented in Figure 2, 23.9 percent of reaches in watersheds containing APCs have at least one Tier 1 sampling station and 18.3 percent have no Tier 1 sampling station but at least one Tier 2 sampling station. In many of these watersheds, contaminated areas may be concentrated in specific river reaches in a watershed.

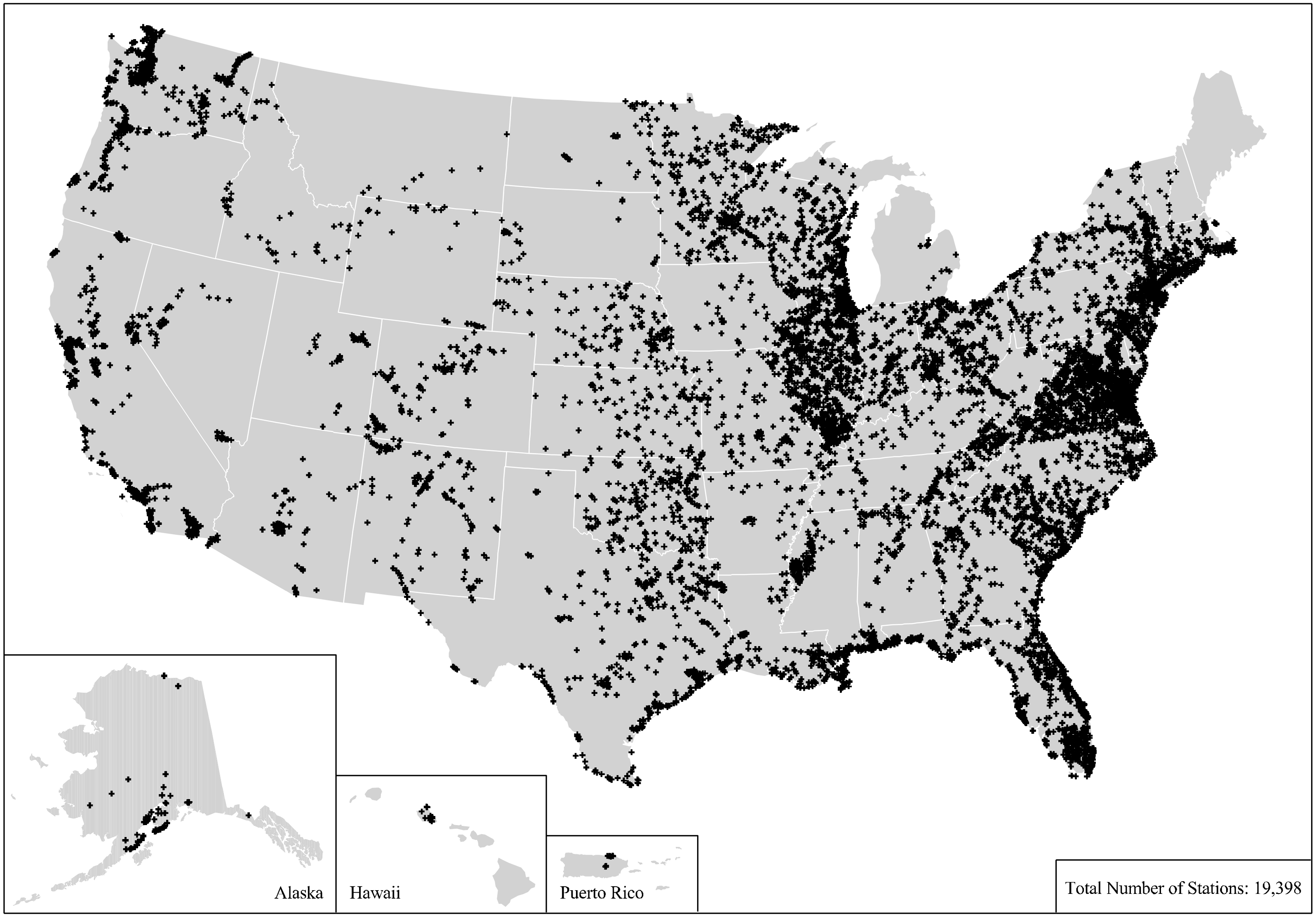

Figure 1. Location of All Evaluated Sampling Stations.

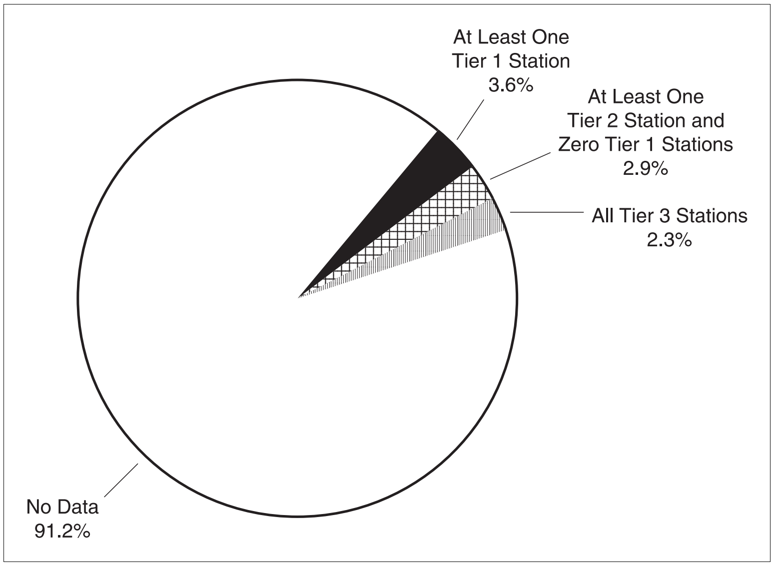

Figure 2. National Assessment: Percent of River Reaches that Include Tier 1, Tier 2, and Tier 3 Sampling Stations.

Within the 96 watersheds containing APCs across the country, 97 individual river reaches or waterbody segments have 10 or more Tier 1 sampling stations.

The evaluation results indicate that sediment contamination associated with probable or possible adverse effects on both aquatic life and human health exists. Overall, fewer stations were classified as Tier 1 using aquatic life evaluation parameters (5,006 stations) than were classified using human health evaluation parameters (6,385 stations). Of the stations classified as Tier 2, 4,439 stations were so classified using aquatic life evaluation parameters and 3,131 stations were so classified using human health evaluation parameters.

Recognizing the imprecise nature of some assessment parameters used in this report, Tier 1 sampling stations are distinguished from Tier 2 sampling stations based on the magnitude of a contaminant concentration in sediment or the degree of corroboration among the different types of sediment quality measures. In response to uncertainty in both biological and chemical measures of sediment contamination, environmental managers must balance Type I errors (false positives, i.e., sediment classified as posing a threat when in fact it does not) with Type II errors (false negatives, i.e., sediment that poses a threat but was not so classified). In screening analyses, the environmentally protective approach is to minimize Type II errors, which leave toxic sediment unidentified. To achieve a balance and to direct attention to areas most likely to be associated with adverse effects, Tier 1 sampling stations are intended to have a higher probability of posing an adverse effect (e.g., sediment posing a threat) and a balance between Type I and Type II errors. On the other hand, to retain a sufficient degree of environmental conservatism in screening, Tier 2 sampling stations are intended to have a very low number of false negatives in exchange for a large number of false positives.

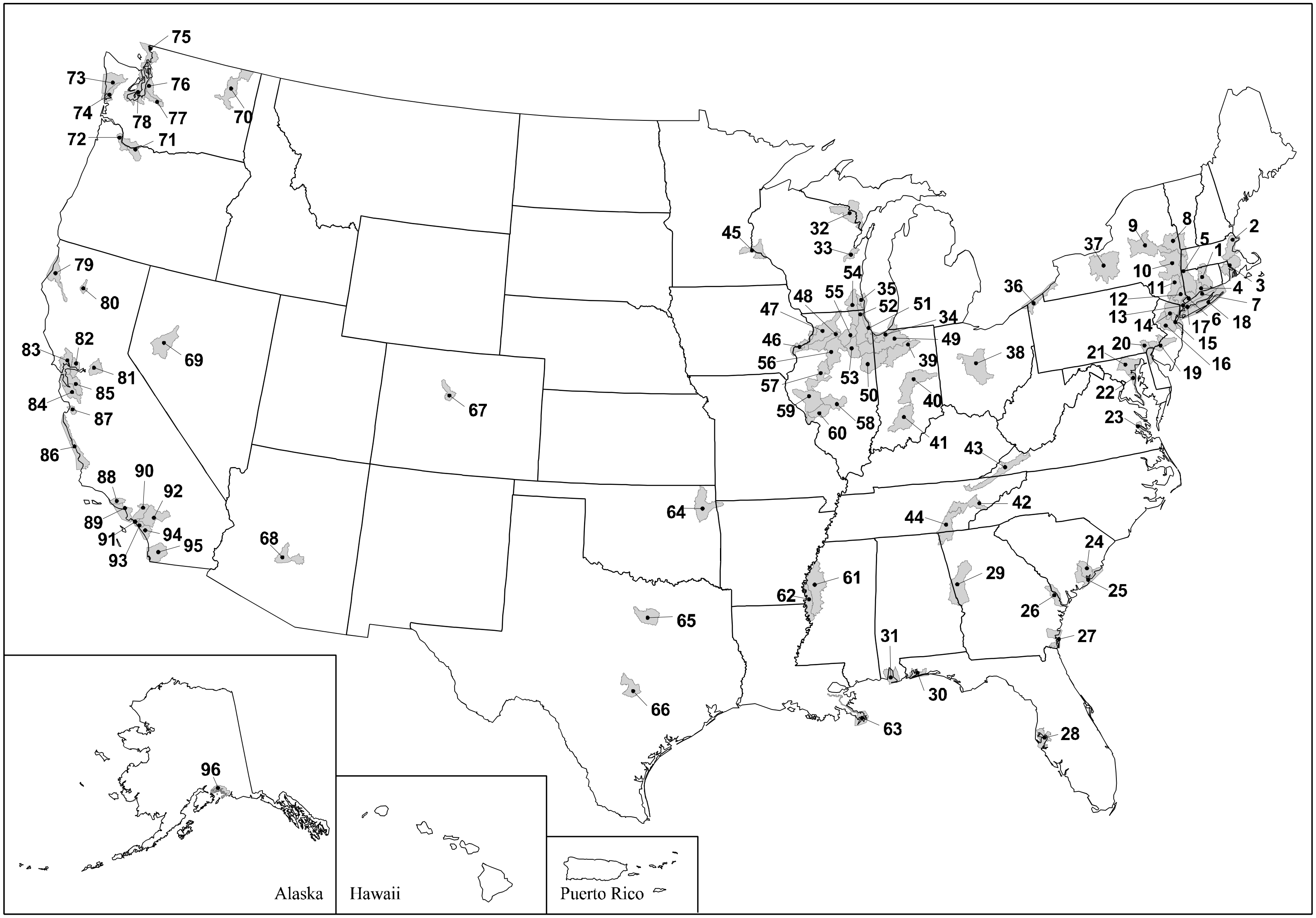

Figure 3. Watersheds Identified as Containing APCs.

Table 1. USGS Cataloging Unit Numbers and Names for Watersheds Containing APCs.

Map No.	Cataloging Unit Number	Cataloging Unit Name	Map No.	Cataloging Unit Number	Cataloging Unit Name
1	01080205	Lower Connecticut	49	07120001	Kankakee
2	01090001	Charles	50	07120002	Iroquois
3	01090004	Narragansett	51	07120003	Chicago
4	01100004	Quinnipiac	52	07120004	Des Plaines
5	01100005	Housatonic	53	07120005	Upper Illinois
6	01100006	Saugatuck	54	07120006	Upper Fox
7	01100007	Long Island Sound	55	07120007	Lower Fox
8	02020003	Hudson-Hoosic	56	07130001	Lower Illinois-Senachwine Lake
9	02020004	Mohawk	57	07130003	Lower Illinois-Lake Chautauqua
10	02020006	Middle Hudson	58	07130007	South Fork Sangamon
11	02020008	Hudson-Wappinger	59	07130011	Lower Illinois
12	02030101	Lower Hudson	60	07130012	Macoupin
13	02030102	Bronx	61	08030207	Big Sunflower
14	02030103	Hackensack-Passaic	62	08030209	Deer-Steele
15	02030104	Sandy Hook-Staten Island	63	08090100	Lower Mississippi-New Orleans
16	02030105	Raritan	64	11070209	Lower Neosho
17	02030201	Northern Long Island	65	12030102	Lower West Fork Trinity
18	02030202	Southern Long Island	66	12090205	Austin-Travis Lakes
19	02040202	Lower Delaware	67	14010002	Blue
20	02040205	Brandywine-Christina	68	15060106	Lower Salt
21	02060003	Gunpowder-Patapsco	69	16050203	Carson Desert
22	02060004	Severn	70	17020001	Franklin D. Roosevelt Lake
23	02080107	York	71	17080001	Lower Columbia-Sandy
24	03050201	Cooper	72	17090012	Lower Willamette
25	03050202	South Carolina Coastal	73	17100102	Queets-Quinault
26	03060109	Lower Savannah	74	17100105	Grays Harbor
27	03070203	Cumberland-St. Simons	75	17110002	Strait Of Georgia
28	03100206	Tampa Bay	76	17110012	Lake Washington
29	03130002	Middle Chattahoochee-Lake Harding	77	17110013	Duwamish
30	03140105	Pensacola Bay	78	17110019	Puget Sound
31	03160205	Mobile Bay	79	18010102	Mad-Redwood
32	04030108	Menominee	80	18020112	Sacramento-Upper Clear
33	04030204	Lower Fox	81	18040005	Lower Cosumnes-Lower Mokelumne
34	04040001	Little Calumet-Galien	82	18050001	Suisun Bay
35	04040002	Pike-Root	83	18050002	San Pablo Bay
36	04120101	Chautauqua-Conneaut	84	18050003	Coyote
37	04140201	Seneca	85	18050004	San Francisco Bay
38	05060001	Upper Scioto	86	18060006	Central Coastal
39	05120106	Tippecanoe	87	18060011	Alisal-Elkhorn Sloughs
40	05120201	Upper White	88	18070103	Calleguas
41	05120208	Lower East Fork White	89	18070104	Santa Monica Bay
42	06010201	Watts Bar Lake	90	18070106	San Gabriel
43	06010205	Upper Clinch	91	18070201	Seal Beach
44	06020001	Middle Tennessee-Chickamauga	92	18070203	Santa Ana
45	07040001	Rush-Vermillion	93	18070204	Newport Bay
46	07080101	Copperas-Duck	94	18070301	Aliso-San Onofre
47	07090005	Lower Rock	95	18070304	San Diego
48	07090007	Green	96	19020201	Eastern Prince William Sound

Section 503 of the WRDA of 1992 required EPA, as part of its program to assess sediment quality, to provide an assessment of aquatic sediment quality trends. The first Report to Congress suggested EPA “consider whether to design future evaluations of NSI data to determine the temporal trends of contamination.” In response, EPA evaluated surficial sediment data from the entire NSI database (data from 1980 through 1999). The evaluation of historical surficial sediment data is limited because of the heterogeneous nature of monitoring programs and available data. Nevertheless, the evaluation tended to show decreased or no change in sediment contamination in most regions where data were available.

The USGS National Water-Quality Assessment (NAWQA) program also examined trends in sediment contamination for a number of contaminants by reconstructing water-quality histories using lake and reservoir sediment cores from 22 locations nationally. Statistically significant increasing trends in total PAH concentrations occur at nine lakes, and significant decreasing trends were detected at two lakes. The analysis of the organochlorine compounds (pesticides and PCBs) showed that only a few locations had significant trends since 1975. Since 1965, however, significant decreasing trends in total DDT have occurred at 12 of the 22 lakes. Among the organochlorine compounds, dieldrin and chlordane have increased in almost as many lakes as they have decreased since 1975. The most consistent trend since the mid-1970s for any of the constituents tested is that all 22 lakes had statistically significant decreasing trends in lead concentrations. Two other trace elements had somewhat consistent trends; chromium and nickel each increased in only one lake and decreased in nine and eight lakes, respectively. Three other elements, arsenic, copper, and mercury, had significant trends in 10 or more lakes, all with more decreasing trends than increasing. The only trace element with more increasing trends than decreasing trends was zinc. Nine of the 19 urban lakes had increasing trends in zinc, and 4 lakes had decreasing trends.

Conclusions

The characteristics of the NSI data, as well as the degree of certainty afforded by available assessment tools, allow neither an absolute determination of adverse effects on human health or the environment at any location nor a definitive determination of the areal extent of contamination on a national scale. However, the evaluation results suggest that sediment contamination may be significant enough to pose potential risks to aquatic life and/or human health in some locations. EPA designed its evaluation methodology for this effort to develop a screening-level assessment of sediment quality. Further evaluation will be required to confirm that sediment contamination poses actual risks to aquatic life or human health for any given sampling station or watershed.

The results of the NSI data evaluation must be interpreted in the context of data availability. Many states and EPA regions appear to have a much greater incidence of sediment contamination than others. To some degree, this appearance reflects the relative abundance of readily available electronic data, not necessarily the relative incidence of sediment contamination.

Although the APCs were selected by means of a screening exercise, it is EPA’s view that they represent the highest priority for further ecotoxicological assessments, risk analysis, temporal and spatial trend assessment, and contaminant source evaluation because of the preponderance of evidence in these areas. Although the procedure for classifying APCs using multiple sampling stations was intended to minimize the probability of making an erroneous classification, further evaluation of conditions in watersheds containing APCs is necessary because the same mitigating factors that might reduce the probability of associated adverse effects at one sampling station might also affect neighboring sampling stations.

EPA chose the watershed as the unit of spatial analysis because many states and federal water and sediment quality management programs, as well as data acquisition efforts, are centered on this unit. This choice reflects the growing recognition that activities taking place in one part of a watershed can greatly affect other parts of the watershed, and that management efficiencies are achieved when viewing the watershed holistically. At the same time, EPA recognizes that contamination in some reaches in a watershed does not necessarily indicate that the entire watershed is affected. Further analysis should be conducted within APC watersheds to delineate sediment contamination. This will allow sediment management activities determined to be necessary be performed in the most cost effective and environmentally sound manner.

Watershed management is a critical component of community-based environmental protection using watershed or hydrologic boundaries to define the problem area. Many public and private organizations are joining forces and creating multidisciplinary and multijurisdictional partnerships to focus on water quality problems community by community and watershed by watershed. These watershed approaches are likely to result in significant restoration, maintenance, and protection of water resources throughout the United States. As was reported in the initial *National Sediment Quality Survey* in 1997, various programs across the United States as part of the National Estuary Program have used a watershed approach that has led to specific actions to address contaminated sediment problems. These include the Chesapeake Bay, Narragansett (RI) Bay, Long Island Sound, Puget Sound, New York/New Jersey Harbor, and San Francisco Bay Estuary programs. These specific programs have all recommended actions to reduce sources of toxic contaminants to sediment.

Continuing Challenges

The following are observations on continuing challenges to improve sediment quality assessment and management in the United States.

- ***Further Assessment of the Extent and Severity of Sediment Contamination in the 96 Targeted Watersheds Would Improve Contaminated Sediment Management Decisions.*** States and tribes, in cooperation with EPA and other federal agencies, should further evaluate the 96 watersheds containing APCs. In many cases, it is likely that much additional investigation and assessment has already occurred, especially in well-known areas at risk for contamination, and that some areas have been remediated. If active watershed management programs are in place, states and tribes may coordinate these evaluations within the context of current or planned actions. Future assessment efforts should focus on areas such as the waterbody segments located in the 96 watersheds containing APCs that had 10 or more sampling stations classified as Tier 1. The purpose of these efforts should be to gather additional sediment chemistry and related biological data, and to conduct further evaluation of data to determine human health and/or ecological risk, to determine temporal and spatial trends, to identify potential sources of sediment contamination and determine whether the appropriate source controls are being applied. Any future policies and/or actions to address contaminated sediments will have to be considered in the context of the budget process and competing demands for funding.
- ***Watershed Management Activities Would Create Multidisciplinary and Multijurisdictional Partnerships Focusing on Sediment Contamination.*** Addressing water issues within a given watershed or hydrologic boundaries—known as watershed management—is a critical component of community-based environmental protection. A watershed management framework requires a high level of inter-program coordination to consider all factors contributing to water and sediment quality problems and to develop integrated, science-based, cost-effective solutions that involve all the stakeholders. It is within the watershed framework, therefore, that federal, state, tribal, and local government agencies and industrial and citizens' groups can pool their common resources and coordinate their efforts to address their common sediment contamination issues. These watershed activities will support efforts such as monitoring and regulatory actions.
- ***Better Coordination of Contaminated Sediment Management and Research Activities Would Promote Application of Sound Science in Managing Contaminated Sediments.*** EPA developed

the *Contaminated Sediment Management Strategy* (USEPA, 1998a). Building on the *Strategy*, EPA's Contaminated Sediment Management Committee (CSMC) has developed the *Contaminated Sediment Action Plan*. This plan outlines the next steps for the Agency in the management of contaminated sediments. The multimedia, cross-program plan describes the commitments from the EPA program offices to develop and apply sound science in managing contaminated sediments. A key component of future coordination within EPA in addressing sediment contamination is the contaminated sediment assessment pilots. The Office of Solid Waste and Emergency Response (OSWER), the Office of Water (OW), and EPA's regional offices will initiate pilot projects to facilitate cross-program coordination on contaminated sediments. The pilot projects will bring a cross-Agency focus to identifying and assessing waters that are impaired by sediment contamination. The pilots will use the legal authorities and techniques available to satisfy the needs of both the Remedial Investigation/Feasibility Study (RI/FS) evaluations and Total Maximum Daily Load (TMDL) modeling. EPA is also developing an Agency-wide Contaminated Sediment Science Plan to identify and prioritize the Agency's contaminated sediment science needs.

- ***Better Monitoring and Assessment Tools Would Improve Contaminated Sediment Management.*** The sediment quality evaluation tools used and outlined in this report should be used as the basis for future contaminated sediment assessment methods. As sediment quality data become more available and the state of the science for sediment assessment continues to evolve, better assessment methods will also evolve. As new and better sediment screening values and biological assessment techniques become available and are proven to be reliable, EPA will incorporate these techniques into future NSI data evaluations.

- ***A Weight-of-Evidence Approach and Measures of Chemical Bioavailability in Sediment Monitoring Programs Would Improve the Assessment of Contaminated Sediment.*** The ideal assessment methodology would be based on matched data sets of multiple types of sediment quality measures to take advantage of the strengths of each measurement type and to minimize their collective weaknesses. As the state of science is constantly evolving, future sediment monitoring programs should collect tissue residue, biological effects (i.e., toxicity, histopathology), and biological community (e.g., benthic abundance and diversity) measurements whenever possible along with sediment chemistry data. Collection of data to measure chemical bioavailability is critical to the success of weight-of-evidence assessments. Where metals are expected to be a concern, sediment monitoring programs should collect AVS and SEM measurements. More accurate assessments will be possible if future monitoring programs include TOC measurements wherever organic chemicals are a concern.

- ***Increased Geographic Coverage in the NSI Database Would Refine a National Assessment of the Extent and Severity of Contaminated Sediment.*** The NSI database is currently limited in terms of the number of data sets it includes and the national coverage it provides. The focus of additional data additions will be (1) to obtain a greater breadth of coverage across the United States and (2) to increase the number of waterbodies evaluated. These types of data will be extremely useful in future analyses to assess changes in the extent and severity of sediment contamination over time. Upon completion of this report, EPA will make a concerted effort to accumulate more data for inclusion in the NSI database and for future *National Sediment Quality Survey* reports to Congress. This effort will begin its focus on areas (river reaches and watersheds) with minimal or no coverage outlined in this report. As part of this effort, EPA will broadly advertise its need for information on contaminated sediments. EPA also encourages third parties to send their information to STORET (www.epa.gov/STORET) so that it can be reflected in the next *National Sediment Quality Survey*. As part of the initial *National Sediment Quality Survey*, EPA included the data used for that report in its comprehensive GIS/modeling system, Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). EPA is working on getting the additional data in the NSI database into BASINS. In addition to this effort, EPA is also working with NOAA to incorporate the NSI database into Query Manager, which is a database program that can be used to access sediment data (chemistry, toxicity, and tissue residue data) for individual watersheds and allow the data to be queried and analyzed.

- ***Assessment of Atmospheric Deposition of Sediment Contaminants Would Improve Contaminated Sediment Management.*** The relative contribution of contaminants to the sediment from air deposition has been virtually unknown on a national scale, but could be significant. Under Section 112(m) of the Clean Air Act, the EPA in cooperation with NOAA has been conducting a program to assess the contributions and effects of hazardous air pollutants on the Great Lakes, Lake Champlain, the Chesapeake Bay, and near-coastal waters. The findings and conclusions from this program and others described in the third *Great Waters Report to Congress* will be incorporated into future iterations of the *National Sediment Quality Survey*.
- ***Prevention of Continuing Sources of Sediment Contamination is Important in Contaminated Sediment Management.*** Although sediment contamination is frequently the result of historical discharges of pollutants before the National Pollutant Discharge Elimination System (NPDES) regulatory program was established, there are still continuing sources of sediment contamination. Therefore, source control and pollution prevention are crucial items in preventing contaminated sediments. As outlined in EPA's *Contaminated Sediment Management Strategy*, EPA OW and other EPA program offices are working with non-governmental organizations and the States to prevent point and nonpoint source contamination from accumulating in sediments. Pollution prevention is a key element in reducing the sources of contaminants that can end up in the sediments, potentially resulting in adverse effects to aquatic life or human health. Pollution prevention has been shown to reduce costs, as well as pollution risks, through source reduction and recycling/reuse techniques. Additionally, EPA has developed and is implementing a national multimedia strategy (under the cross-agency PBT Program) for the reduction of persistent, bioaccumulative, toxic chemicals (PBTs), which generally accumulate in sediments. EPA is forging a new approach to reducing risks from and exposures to priority PBT pollutants. This approach, focused on increased coordination among EPA and regional programs also requires the significant involvement of stakeholders, including international, state, local, and tribal organizations, the regulated community, environmental groups, and private citizens.
- ***Better Coordination and Communication with External Stakeholders and Other Federal Agencies Would Improve the Contaminated Sediment Management Process.*** Sediment contamination is a concern to stakeholders throughout the United States. EPA will work closely with other Federal Agencies (e.g., USACE, NOAA, USGS) to compile and evaluate data in the NSI database as well as the development of future reports. Additionally, EPA will reach out to the public as we compile additional sediment quality data in the NSI database and develops the next report to Congress. During the next year, EPA anticipates setting up "listening sessions" to gather information that can be used for future reports to Congress. During these sessions, EPA will be searching for additional data for the NSI database and subsequent reports, taking recommendations on how to improve the report, and establishing better and more effective ways to keep the public and interested stakeholders informed.

This report and future *National Sediment Quality Survey* reports will provide environmental managers at the federal, state, tribal, and local levels with valuable information. The NSI database and this report can assist local watershed managers by providing data and by demonstrating the application of a multiple-lines-of-evidence approach for identifying and screening contaminated sediment locations. It also allows researchers to draw on a large data set of sediment information to conduct new analyses that will continue to advance the science of contaminated sediment assessments, which ultimately can be applied at the local level to assist environmental managers in making sediment management decisions.

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ACRONYMS

AET	apparent effects threshold
ANOVA	analysis of variance
AOC	area of concern
APC	area of probable concern for sediment contamination
AQUIRE	Aquatic Toxicity Information Retrieval database
AVS	acid-volatile sulfide
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources (EPA modeling tool)
BHC	benzene hexachloride
BSAF	biota-sediment accumulation factor
CAA	Clean Air Act
CAS	Chemical Abstracts Service
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSMC	Contaminated Sediment Management Committee
CWA	Clean Water Act
DDD	p,p′-dichlorodiphenyldichloroethane
DDE	p,p′-dichlorodiphenyldichloroethylene
DDT	p,p′-dichlorodiphenyltrichloroethane
EMAP	Environmental Monitoring and Assessment Program
EPA	U. S. Environmental Protection Agency
EqP	equilibrium partitioning
ERDC	Engineer Research and Development Center
ERL	effects range-low value
ERM	effects range-median value
ESG	equilibrium sediment partitioning guideline
FAV	final acute value
FCV	final chronic value
FDA	Food and Drug Administration
FDEP	Florida Department of Environmental Protection
FFDCA	Federal Food, Drug and Cosmetic Act
FIELDS	fully integrated environmental location decision support system
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GCR/IHSC	Grand Calumet River, Indiana Harbor Ship Canal
GIS	geographic information systems
GLI	Great Lakes Initiative
GLNPO	Great Lakes National Program Office (U.S. Environmental Protection Agency)
GLWC	Great Lakes Water Quality Wildlife Criterion
GMAV	genus mean acute value
HAP	hazardous air pollutants
HQ	hazard quotient
HUC	hydrologic unit code
LOE	lines of evidence
LRM	logistic regression model
MACT	Maximum Available Control Technology
MARPLOT	Mapping Applications for Response, Planning, and Local Operational Tasks
MDD	minimum detectable difference

MDR	minimum data requirements
MOU	Memorandum of Understanding
MPRSA	Marine Protection, Research, and Sanctuaries Act
NAWQA	National Water-Quality Assessment Program (U.S. Geological Survey)
NLFWA	National Listing of Fish and Wildlife Advisories
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSI	National Sediment Inventory database
NS&T	National Status and Trends Program (National Oceanic and Atmospheric Administration)
OECA	Office of Enforcement and Compliance Assurance (U.S. Environmental Protection Agency)
ORD	Office of Research and Development (U.S. Environmental Protection Agency)
OST	Office of Science and Technology (U.S. Environmental Protection Agency)
OSWER	Office of Solid Waste and Emergency Response (U.S. Environmental Protection Agency)
OW	Office of Water (U.S. Environmental Protection Agency)
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEL	probable effects level
PSWQA	Puget Sound Water Quality Authority
PBT	persistent, bioaccumulative, and toxic
QA/QC	quality assurance/quality control
QSAR	quantitative structure-activity relationship
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
REMAP	Regional Environmental Monitoring and Assessment Program
RF1	River Reach File 1
RI/FS	Remedial Investigation/Feasability Study
ROD	Record of Decision
SAB	Science Advisory Board
SAV	secondary acute value
SCV	secondary chronic value
SEDQUAL	Sediment Quality Information System
SEM	simultaneously extracted metals
SETAC	Society of Environmental Toxicology and Chemistry
SMAV	species mean acute value
SQAL	sediment quality advisory level
STORET	Storage and Retrieval System
TBP	theoretical bioaccumulation potential
TCDD	tetrachlorodibenzo-*p*-dioxin
TEF	toxic equivalency factor
TEL	threshold effects level
TIE	toxicity identification evaluation
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

WQC	water quality criteria
WRDA	Water Resources Development Act

GLOSSARY

Acid-volatile sulfide (AVS): Reactive solid-phase sulfide fraction that can be extracted by cold hydrochloric acid. Appears to control the bioavailability of most divalent metal ions because of the sulfide ions' high affinity for divalent metals, resulting in the formation of insoluble metal sulfides in anaerobic (anoxic) sediments.

Acute toxicity: Immediate or short-term response of an organism to a chemical substance. Refers to generalized toxic response with lethality usually being the observed endpoint.

Benthic organisms: Species living in or on the bottom of streams, rivers, or oceans.

Bioaccumulation: The net accumulation of a chemical substance by an organism as a result of uptake from all environmental sources.

Bioavailability: The fraction of chemical present that is available for uptake by aquatic organisms.

Biological community: An assemblage of organisms that are associated in a common environment and interact with each other in a self-sustaining and self-regulating relationship.

Biological effects correlation approach: A method for relating the incidence of adverse biological effects to the dry-weight sediment concentration of a specific chemical at a particular site based on the evaluation of paired field and laboratory data. Exceedance of the identified level of concern concentration is associated with a likelihood of adverse organism response, but it does not demonstrate that a particular chemical is solely responsible.

Cataloging unit: Sometimes referred to as a hydrologic unit; corresponds to a watershed that was delineated by the U.S. Geological Survey. A watershed is an area that drains ultimately to a particular watercourse or body of water. Each cataloging unit, as used in this report, is uniquely identified with an 8-digit hydrologic unit code (HUC). There are approximately 2,100 such 8-digit cataloging units in the contiguous United States, which are, on average, somewhat larger than counties.

Chronic toxicity: Response of an organism to repeated, long-term exposure to a chemical substance. Typical observed endpoints include growth expressed as length and weight.

Combined sewer overflow: A discharge of a mixture of storm water and untreated domestic wastewater that occurs when the flow capacity of a sewer system is exceeded during a rainstorm.

Contaminated sediment: Sediment that contains chemical substances at concentrations that pose a known or suspected threat to aquatic life, wildlife, or human health.

Demersal species: Swimming organisms that prefer to spend the majority of their time on or near the bottom of a waterbody.

Divalent metals: Metals that are available for reaction in a valence state of two (i.e., carrying a positive electric charge of two units).

Ecosystem: An ecological unit consisting of both the biotic communities and the nonliving (abiotic) environment, which interact to produce a system that can be defined by its functionality and structure.

Equilibrium concentration: The concentration at which a system is in balance due to equal action by opposing forces within the system. When the partitioning of a nonionic organic chemical between organic carbon and pore water and the partitioning of a divalent metal between solid and solution phases are assumed to be at equilibrium, an organism in the sediment is assumed to receive an equivalent exposure to the contaminant from water only or from any equilibrated phase. The pathway of exposure might include pore water (respiration), sediment carbon (ingestion), sediment organism (ingestion), or a combination of routes.

Equilibrium partitioning (EqP) approach: Approach used to relate the dry-weight sediment concentration of a particular chemical that causes an adverse biological effect to the equivalent free chemical concentration in pore water and to that concentration sorbed to sediment organic carbon or bound to sulfide. Based on the theory that the partitioning of a nonionic organic chemical between organic carbon and pore water and the partitioning of a divalent metal between the solid and solution phases are at equilibrium.

Hydrology: A science dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil, and in the atmosphere.

Logistic regression model: An empirically derived model that relies on matching field-collected sediment chemistry and biological effects (e.g., sediment toxicity) data. Unlike other empirical methods (which result in sediment quality guidelines), the logistic regression model yields an estimate of the probability of observing sediment toxicity for a given sediment chemistry observation.

Molar concentration: The ratio of the number of moles (chemical unit referring to the amount of an element having a mass in grams numerically equal to its atomic weight) of solute (the substance being dissolved or that present in the smaller proportion) in a solution divided by the volume of the solution expressed in liters.

Monotonic trend: Trend that exists between two variables, such as concentration and time, when concentration generally increases (i.e., does not decrease) or decreases (i.e., does not increase) with time. The relationship between the two variables may be linear or nonlinear.

National Sediment Inventory (NSI): A national compilation of sediment quality data and related biological data. Results of the evaluation of data from the NSI serve as the basis for the report to Congress on the incidence and severity of sediment contamination across the country (i.e., the *National Sediment Quality Survey*).

Nonionic organic chemicals: Compounds that do not form ionic bonds (bonds in which the electrical charge between bonded atoms in the compound is unequally shared). Nonionic compounds do not break into ions when dissolved in water and therefore are more likely to remain in contact with and interact with sediment compounds or other compounds in water.

Nonpoint source pollution: Pollution from diffuse sources without a single point of origin or pollution not introduced into a receiving stream from a specific outlet. Such pollutants are generally carried off the land by storm water runoff. Sources of nonpoint source pollution include atmospheric deposition, agriculture, silviculture, urban runoff, mining, construction, dams and channels, inappropriate land disposal of waste, and saltwater intrusion.

Nonpolar organic chemicals: Compounds that do not exhibit a strong dipole moment (there is little difference between the electrostatic forces holding the chemical together). Nonpolar compounds tend to be less soluble in water. In aquatic systems, nonpolar chemicals are more likely to be associated with sediments or other nonpolar compounds than with the surrounding water.

Pelagic species: Species living in the open water or in the open ocean away from the shore or coastline.

Point source pollution: Pollution contributed by any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged.

Quantitative structure-activity relationship (QSAR) technique: A tool based on the premise that a relationship exists between the molecular structure and physical, chemical, or biological activity, such as molar volume, boiling point, or toxicity.

River Reach: A stream segment between the consecutive confluences of a stream. Most river reaches represent simple streams and rivers, while some river reaches represent the shoreline of wide rivers, lakes, and coastlines. EPA's River Reach File 1 (RF1) was completed for the contiguous United States in the mid-1980s and includes approximately 68,000 river reaches. The average length of a river reach is 10 miles. Neither the more detailed version of the Reach File (RF3) nor the National Hydrography Dataset (NHD) was used for the National Sediment Inventory.

Sampling station: A specific location associated with latitude and longitude coordinates where data have been collected. Multiple sampling stations can have the same latitude and longitude coordinates if labeled with a different station identification code for sampling performed on different dates or by different sponsoring agencies.

Simultaneously extracted metals (SEM): Metal concentrations that are extracted during the same analysis in which the acid-volatile sulfide (AVS) content of the sediment is determined.

Solid-phase toxicity test: A toxicity test in which test organisms are exposed directly to sediments. Sediments are carefully placed in the exposure chamber and the chamber is then filled with clean water. Resuspended particles are allowed to settle before initiation of exposure. Solid-phase toxicity tests integrate multiple exposure routes, including chemical intake from dermal contact with sediment particles as well as ingestion of sediment particles, interstitial water, and food organisms.

Theoretical bioaccumulation potential (TBP): An estimate of the equilibrium concentration of a contaminant in tissues if the sediment in question were the only source of contamination to the organism. TBP is estimated from the organic carbon content of the sediment, the lipid content of the organism, and the relative affinities of the chemical for sediment organic carbon and animal lipid content.

Total organic carbon (TOC): A measure of the organic carbon content of sediment expressed as a percentage. Used to normalize the dry-weight sediment concentration of a chemical to the organic carbon content of the sediment.

U.S. Environmental Protection Agency (EPA) risk levels: Levels of contaminant concentrations in an exposure medium that pose a potential carcinogenic risk (e.g., 10^{-5}, or a 1 in 100,000 extra chance of cancer over a lifetime) and/or noncancer hazard (i.e., exceeds a reference dose). Used in this document to estimate human health risk associated with the consumption of chemically contaminated fish tissue.

U.S. Food and Drug Administration (FDA) tolerance/action or guideline levels: FDA has prescribed levels of contaminants that will render a food “adulterated.” The establishment of action levels (levels of food contaminants to which consumers can be safely exposed) or tolerances (regulations having the force of law) is the regulatory procedure that FDA uses to control environmental contaminants in the commercial food supply.

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CHAPTER 1
INTRODUCTION

What Is the *National Sediment Quality Survey*?

The Water Resources Development Act (WRDA) of 1992 directed the U.S. Environmental Protection Agency (EPA), in consultation with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE), to conduct a comprehensive national survey of data regarding the quality of sediments in the United States. Section 503 of WRDA 1992 required EPA to "compile all existing information on the quantity, chemical and physical composition, and geographic location of pollutants in aquatic sediments, including the probable sources of such pollutants and identification of those sediments which are contaminated...." Section 501(b)(4) of WRDA 1992 defines *contaminated sediment* as "aquatic sediment which contains chemical substances in excess of appropriate geochemical, toxicological or sediment quality criteria or measures; or is otherwise considered by the Administrator [of EPA] to pose a threat to human health or the environment...." Section 503 further required EPA to "report to Congress the findings, conclusions, and recommendations of such survey, including recommendations for actions necessary to prevent contamination of aquatic sediments and to control sources of contamination." In addition, Section 503(b) requires EPA to conduct a comprehensive and continuing program to assess aquatic sediment quality. This program must establish methods and protocols for monitoring the physical, chemical, and biological effects of pollutants in aquatic sediment and of contaminated sediment. EPA must submit a report to Congress every 2 years on the finding of the monitoring required under the Act.

To comply with this mandate, EPA's Office of Science and Technology (OST) initiated the National Sediment Inventory (NSI) database. The goals of the NSI are to compile sediment quality information from available electronic databases, develop screening-level assessment protocols to identify potentially contaminated sediment, and produce biennial reports to Congress as well as the EPA regions, states, and tribes on the incidence and severity of sediment contamination nationwide. To ensure that future reports to Congress accurately reflect the latest conditions of the Nation's sediment as science evolves, the NSI database will develop into a regularly updated, centralized aggregation of sediment quality measurements.

In 1997 EPA published the first report, titled *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*, volumes 1 through 3. The first volume, *The National Sediment Quality Survey* (USEPA, 1997), presented a national baseline screening-level assessment of contaminated sediments based on sediment quality data collected from 1980 through 1993 using a weight-of-evidence approach. The purpose of the initial *National Sediment Quality Survey,* as well as this first update to that report, is to depict and characterize the incidence and severity of sediment contamination based on the *probability* of adverse effects to human health and/or the environment, and the information provided could be used to further investigate sediment contamination on a national, regional, or site-specific scale. Volume 2 of the first report presented data summaries for watersheds that had been identified as containing areas of probable concern for sediment contamination, and Volume 3 presented a screening analysis to identify probable point source contributors of sediment pollutants.

For this current *National Sediment Quality Survey*, OST added to the data compiled in the initial NSI database additional data from across the country currently stored in large electronic databases and covering the years up through 1999. This effort required a substantial synthesis of multiple formats and the coordinated efforts of many federal and state environmental information programs that maintain relevant data. Data from many sampling and testing studies have not yet been incorporated into the NSI database and therefore are not evaluated in this *National Sediment Quality Survey*. Thus, it is highly likely that additional locations ranging from relatively pristine to extensive sediment contamination do not appear in the NSI database and are therefore not evaluated in the *National Sediment Quality Survey*. As data management systems and access capabilities continue to improve, EPA anticipates that a greater amount of data will be incorporated into the NSI database and subsequent *National Sediment Quality Survey* reports to Congress.

This report presents the results of the screening-level assessment of the NSI data from 1990 through 1999. For this assessment, OST examined sediment chemistry data, tissue residue data, and sediment toxicity test results. The purpose of this assessment was to determine whether potential adverse effects from sediment contamination exist currently or existed over the past 10 years at distinct monitoring locations throughout the United States. The initial *National Sediment Quality Survey* report to Congress used all the data available from 1980 through 1993 to develop a baseline assessment. Because of the biennial reporting requirements associated with this report, EPA wanted to "window in" on a regular time frame for including data. One major advantage of screening out older data (data collected prior to January 1, 1990) is that it prevents the results presented in this report from being unduly influenced by historical data when more recent data are available. However, this would not allow for the results of any decrease in sediment contaminant levels due to scouring, re-burial, natural attenuation, or active sediment remediation that have occurred since that sample was collected.

This report identifies locations where available data indicate that direct or indirect exposure to the sediment could be associated with adverse effects to aquatic life and/or human health. Even though this report focuses on data collected from 1990 through 1999, conditions might have improved or worsened since the sediment was sampled. Additionally, the data were generally not collected in a randomized sampling approach. Consequently, this report does not and cannot provide a definitive assessment of the national condition or relative health of sediments across the country. Even though this report does not provide an assessment of the "national condition" of contaminated sediments it does,. however, evaluate data from 1980 through 1999 in the NSI database to assess changes in the extent and severity of sediment contamination over time for specific areas in the United States where sufficient data exist.

This *National Sediment Quality Survey* and future iterations of this report will provide environmental managers at the federal, state, tribal and local levels with valuable information. The NSI database and this report can assist local watershed managers by providing additional data that they might not have, demonstrating the application of a multiple-lines-of-evidence approach for identifying and screening contaminated sediment locations. It also allows researchers to draw on a large data set of sediment information to conduct new analyses that will continue to advance the science of contaminated sediment assessments and ultimately can be applied at the local level to assist environmental managers in making sediment management decisions. Any future policies and/or actions to address contaminated sediments will have to be considered in the context of the budget process and competing demands for funding.

This *National Sediment Quality Survey* provides a screening-level assessment of data collected from 1990 through 1999 and contained in the NSI database. Chapter 1 provides the intent of this report and background information on sediment quality issues. Chapter 2 is an overview of the assessment methodology used to evaluate the NSI data (from 1990 through 1999) to identify potentially contaminated sediment locations. Chapter 3 contains the results of the evaluation on the national, regional, and state levels. Chapter 4 presents the methods used and the results of a temporal trend analysis of sediment contamination over time. Chapter 5 provides a discussion of the results and observations on continuing challenges to improve sediment quality assessment and management in the United States. Several appendices present detailed descriptions of both the data in the NSI database and the approaches used to evaluate the data:

Appendix A:	National Sediment Inventory Field Description
Appendix B:	Description of Evaluation Parameters Used in the NSI database Evaluation

Appendix C:	Values Used for Chemicals Evaluated
Appendix D:	Species Characteristics Related to NSI Bioaccumulation Data
Appendix E:	Trend Analysis Case Studies
Appendix F:	Comparison of Watersheds Containing APCs

Why Is Contaminated Sediment an Important National Issue?

In response to the need for national guidance on addressing contaminated sediments, EPA released its Contaminated Sediment Management Strategy in 1998. This document establishes four goals to manage the problem of contaminated sediment and it describes actions the Agency intends to take to accomplish those goals. The goals are as follows: (1) prevent the volume of contaminated sediment from increasing; (2) reduce the volume of existing contaminated sediments; (3) ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner; and (4) develop scientifically sound sediment management tools for use in pollution prevention, source control, remediation, and dredged material management.

Contaminated sediments may be directly toxic to aquatic life or can be a source of contaminants for bioaccumulation in the food chain. A wide range of physical, chemical, and biological factors have the potential to influence the bioavailability of sediment contaminants. The bioavailability of contaminants in sediment is a function of the type of chemical and the chemical speciation, as well as the behavior and physiology of the organism. The two basic routes of exposure for organisms are (1) transport of dissolved contaminants in pore water across biological membranes and (2) ingestion of contaminated food or sediment particles with subsequent transport across the gut. For upper-trophic-level species, ingestion of contaminated prey is the predominant route of exposure, especially to hydrophobic chemicals. Uptake through ingestion of or direct exposure to water or sediment can also be important depending on the trophic level of the organism and the physical-chemical characteristics of the contaminant (USEPA, 2000a).

Contaminated sediment poses ecological and/or human health risks in many watersheds throughout the United States. Even in areas where EPA water quality criteria (WQC) are not exceeded, adverse effects have been observed in organisms in or near the sediments (Chapman, 1989). Because many chemicals of anthropogenic origin (e.g., pesticides, polycyclic aromatic hydrocarbons [PAHs], and chlorinated hydrocarbons) tend to sorb to sediments and organic materials, these chemicals also end up concentrating in the sediment, which acts as a reservoir. Although concentrations of chemicals in sediment may be several orders of magnitude higher than those in the overlying water, bulk sediment concentrations have not been strongly correlated to bioavailability (Burton, 1991). Nevertheless, sediment contamination can have many detrimental effects on an ecosystem, some of which are evident and others more discrete or unknown. For example, benthic invertebrate communities can be totally lost or converted from sensitive to pollution-tolerant species. These tolerant species process a variety of materials, and their metabolic products can also be different. These differences mean that ecosystem functions such as energy flow, productivity, and decomposition processes might be significantly altered (Griffiths, 1983). Loss of any biological community in the ecosystem can indirectly affect other components of the system. For example, if the benthic community is significantly changed, nitrogen cycling might be altered such that forms of nitrogen necessary for key phytoplankton species are lost and the phytoplankton are replaced with blue-green algae (cyanobacteria) capable of nitrogen fixation. Other effects from sediment contamination are direct, as observed in the Great Lakes where top predator fish have become highly contaminated from consuming bottom-feeding fish and benthic invertebrates that are laden with sediment-associated pollutants, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), mercury, and pesticides. Documented adverse ecological effects from contaminated sediments include fin rot, increased tumor frequency, and reproductive toxicity in fish, as well as a decrease in aquatic ecosystem biodiversity (USEPA, 1998a). Effects on ecosystem processes have been very dramatic in areas affected by acid precipitation and acid mine drainage, which contribute to pollutant loadings to waterbodies. In most areas receiving pollutant loadings, however, the effects are difficult to observe and require use of various assessment tools, such as benthic macroinvertebrate community analysis, chemical testing, quantification of habitat characteristics, and toxicity testing (Burton and Scott, 1992).

As described above, sediment contamination can adversely affect the health of organisms and provide a source of contaminants to the aquatic food chain (Lyman et al., 1987). For example, fin rot and a variety of tumors have been found in fish living above sediments contaminated by PAHs located near a creosote plant on the Elizabeth River in Virginia. These impacts have been correlated with the extent of sediment contamination in the river (Van Veld et al., 1990). Human and wildlife consumption of finfish and shellfish that have accumulated contaminants in their tissue (bioaccumulation) is an important human health and wildlife concern. In fact, fish consumption represents the most significant route of aquatic exposure of humans to many metals and organic compounds (USEPA, 1992). Most sediment-related human exposure to contaminants is through indirect routes that involve the transfer of pollutants out of the sediments and into the water column or aquatic organisms. Many surface waters have fish consumption advisories or fishing bans in place mostly due to mercury, PCBs, chlordane, dioxins, and DDT and its metabolites (DDD and DDE), which are commonly found in sediments. Based on EPA's 2002 National Listing of Fish and Wildlife Advisories database (NLFWA) there are 2,800 fish advisories in the United States for the types of contaminants often found in contaminated sediments. These advisories affect more than 544,000 river miles, 71 percent of the Nation's coastal waters, and more than 95,000 lakes, including 100 percent of the Great Lakes.

Additional examples of direct impacts of contaminated sediment on wildlife and humans have been noted. Bishop et al. (1995, 1999) found good correlations between a variety of chlorinated hydrocarbons in the sediment and concentrations in bird eggs. These researchers found that this relationship indicated that the female contaminant body burden was obtained locally, just before egg laying. Other studies by Bishop et al. indicated a link between exposure of snapping turtle (*Chelydra s. serpentina*) eggs to contaminants (including sediment exposure) and developmental success (Bishop et al., 1991, 1998). Other investigations of environmentally occurring persistent organics have shown bioaccumulation and a range of effects in the mudpuppy, *Necturus maculosus* (Bonin et al., 1995; Gendron et al., 1997). In the case of humans there is only anecdotal evidence from cases like Monguagon Creek, a small tributary to the Detroit River, where incidental human contact with the sediment resulted in a skin rash (Zarull et al., 1999).

In addition to human health and ecological impacts, contaminated sediments can cause severe economic impacts. Economic risk might be felt by the transportation, tourism, and fishing industries. In one Great Lakes harbor (Indiana Harbor Ship Canal), navigational dredging has not been conducted since 1972 "due to the lack of an approved economically feasible and environmentally acceptable disposal facility for dredged materials" from the Indiana Harbor Ship Canal (USACE, 1995). The accumulation of sediment in this canal has increased costs for industry. Ships carrying raw materials have difficulty navigating in the harbor and canal. In addition, ships come into the harbor loaded at less than optimum vessel drafts. There is also restricted use of various docks, requiring unloading at alternative docks and double handling of bulk commodities to the preferred dock. These problems are causing increased transportation costs for waterborne commerce in this Canal, estimated in 1995 at $12.4 million annually (USACE, 1995).

How Significant Is the Problem?

In the first Report to Congress, EPA found that every state in the country had at least one sampling location that was classified as having probable adverse effects to aquatic life or human health, indicating a geographically diverse problem. Other more geographically targeted studies have attempted to quantify the extensiveness of sediment contamination. For example, studies conducted on sediment from the Great Lakes area have demonstrated that contaminated sediments are of great concern to humans and wildlife that live in the Great Lakes Basin. Years of industrial and municipal discharges, combined sewer overflows, and urban and agricultural nonpoint source runoff have contributed to the creation of vast amounts of highly polluted sediments that pose serious human and ecological health risks (USEPA, 2000b). Sediments have been collecting on the bottoms of the Great Lakes since they were formed by glacial scouring and melting. Even after cleanup efforts began in the late 1960s, little attention was paid to the toxics that accumulated in the bottom sediments. The first priority was to stop the discharge of new contaminants into waterways, and little concern was paid to sediments (USEPA, 2000b). It was not until the early 1980s that environmental problems caused by sediment contamination began to generate interest in the Great Lakes.

EPA's Great Lakes National Program Office (GLNPO) has reported that polluted sediment is the largest major source of contaminants in Great Lakes rivers and harbors entering the food chain, including the current 42 Areas of Concern (AOC) designated by the United States and Canada, the Parties to the Great Lakes Water Quality Agreement (Figure 1-1). Over the past several years, Great Lakes stakeholders have moved forward in the pursuit of sediment remediation. In the years 1997-2002, almost 2.3 million cubic yards of contaminated sediment has been removed from the U.S. Great Lakes Basin (EPA/GLNPO, March, 2004).

Numerous statutes, including the Clean Water Act (CWA), the Marine Protection, Research, and Sanctuaries Act (MPRSA or Ocean Dumping Act), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), authorize programs that address contaminated sediments (USEPA, 1998a). First, the disposal of material resulting from navigational dredging in the Nation's waters is regulated under either the CWA (Section 404) or the MPRSA, depending on the location of the disposal site. Although it is estimated that only 5 to 10 percent of the material dredged each year is not suitable for open water disposal due to contamination, there are widespread concerns among the public regarding the effect of contaminated dredged material disposal. The difficulty associated with finding alternative disposal options for contaminated dredged material often results in project delays, additional costs, and significant controversy.

CERCLA provides one of the most comprehensive authorities available to EPA to obtain sediment cleanup, reimbursement of EPA cleanup costs, and compensation to natural resource trustees for damages to natural resources affected by contaminated sediments. Removal actions and enforcement actions can be brought at both National Priorities List (NPL) and non-NPL sites. To date, about 300 sites (approximately 20 percent) on the Superfund NPL appear to have some kind of contaminated sediment. EPA has made decisions at almost 50 percent of these sites to address that contamination. Most of the sites are small, but a few sites are quite large.

In addition, under CWA Section 303(d), EPA and the states may address contaminated sediments in developing Total Maximum Daily Loads (TMDLs). TMDLs identify the loading capacity of waters not meeting water quality standards. TMDLs allocate the receiving waters' pollutant loading capacity among point and nonpoint sources of pollutants of concern. Based on the states' 1998 lists of impaired waters, about 36,000 TMDLs will need to be developed for about 20,000 impaired waterbodies throughout the United States. Based on the TMDL tracking system with the 1998 data, only 32 impaired waterbodies were specifically identified as impaired by contaminated sediments. However, about 21 percent of the TMDLs are for pollutants that are also often found in contaminated sediments (e.g., PCBs, mercury, pesticides). It is very likely that these TMDLs will require some analysis for the contribution of pollutants from contaminated sediments.

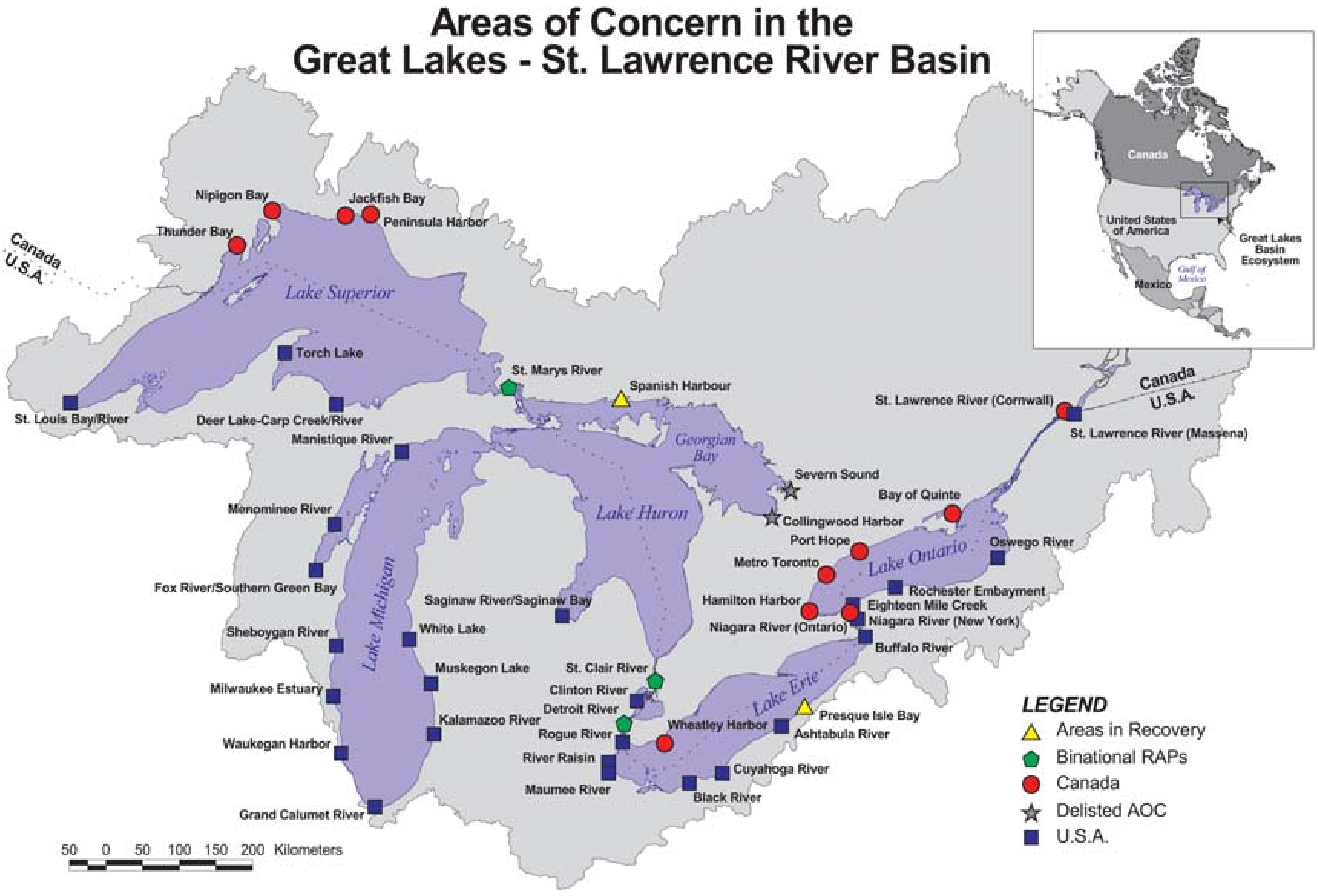

Figure 1-1. Areas of Concern in the Great Lakes–St. Lawrence River Basin.

Source: http://www.on.ec.gc.ca/water/raps/map_e.html; Environment Canada

In 1994 the National Oceanic and Atmospheric Administration (NOAA) released its *Inventory of Chemical Concentrations in Coastal and Estuarine Sediments* (NOAA, 1994). This study characterized 2,800 coastal sites as either "high" or "hot," based on the contaminant concentrations found at the sampling locations. NOAA did not use risk-based screening values for its analysis. Using the National Status and Trends Mussel Watch data set, "high" values were defined as the mean concentration for a specific chemical plus one standard deviation. NOAA's "high" values correspond to about the 85th percentile of contaminant concentration. "Hot" concentrations were defined as those exceeding five times the "high" values. Most of the "hot" sites were in locations with high ship traffic, industrial activity, and relatively poor flushing, such as harbors, canals, and intercoastal waterways (NOAA, 1994). Mercury and cadmium exceeded the NOAA "hot" thresholds at a greater percentage of sites where they were measured (about 7 percent each) than other sediment contaminants (USEPA, 1998a).

In selected areas throughout 25 estuaries and marine bays along the Atlantic, Gulf of Mexico, and Pacific coasts, NOAA performed toxicity tests on 1,543 surficial sediment samples collected from 1991 through 1997. The toxicity of each sample was determined by exposing amphipods to bulk sediments for 10 days and measuring their survival. These 1,543 samples collectively represented a total area of approximately 7,300 square kilometers. Toxicity was observed in samples that represented approximately 6 percent of the combined area (Long, 2000). Using similar tests conducted on samples collected in different, but overlapping study areas, EPA estimated that about 7 percent of the combined estuarine area sampled was toxic. The northeastern and southwestern estuaries displayed the most severe toxicity generally, and toxicity was observed the least in southeastern and northwestern areas. However, extensive portions of the Pacific coast have not been tested using the same methods. Toxicity was considerably much more widespread (25 to 39 percent), however, when the results of two sublethal sediment toxicity tests were evaluated (Long, 2000).

As part of EPA's Environmental Monitoring and Assessment Program (EMAP), sediment samples were collected to assess toxicity on a regional scale in streams and rivers in the Mid-Atlantic United States in 1994, 1997, and 1998 and in the Colorado Rocky Mountains in 1994 and 1995. Sample sites were selected randomly using a probability design so that the results could be extrapolated for the entire region. Toxicity was evaluated on these samples by exposing an amphipod (*Hyalella azteca*) to bulk sediment and measuring lethality and growth. In 1994 approximately 5.7 percent of the Mid-Atlantic stream length (10,700 kilometers out of 188,700 kilometers) was found to have toxic sediments. In 1997 and 1998 sediments from about 8.7 percent (21,830 kilometers out of 250,500 kilometers) of Mid-Atlantic stream length were found to be toxic. In the Southern Colorado Rockies, an estimated 422 kilometers (6.4 percent) of the 6,600 kilometers of target stream length had toxic sediments (Lazorchak et al., 1999).

CHAPTER 2
METHODOLOGY

In the first report to Congress, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States: National Sediment Quality Survey* (USEPA, 1997), EPA noted that it faced two primary challenges in achieving the short-term goals of the *National Sediment Quality Survey* and fulfilling the mandate of WRDA 1992, as described in the introduction to this report. Those two challenges remain in this first update to the *National Sediment Quality Survey*. The first challenge is to compile a database of consistent sediment quality measures suitable for all regions of the country. The second is to identify scientifically sound methods to determine whether a particular sediment is "contaminated" based on the definition set forth in the statute.

In many known areas of contamination, visible and relatively easy-to-recognize evidence of harmful effects on resident biota is concurrent with elevated concentrations of contaminants in sediment. In most cases, however, less obvious effects on biological communities and ecosystems are far more difficult to identify and are frequently associated with varying concentrations of sediment contaminants. In other words, bulk sediment chemistry measures are not always indicative of toxic effect levels. Similar concentrations of a chemical can produce widely different biological effects in different sediments. This discrepancy occurs because toxicity is influenced by the extent to which chemical contaminants bind to other constituents in sediment. These other sediment constituents, such as organic ligands and inorganic oxides and sulfides, are said to control the bioavailability of accumulated contaminants (Di Toro et al., 1990). Toxicant binding, or sorption, to sediment particles suspends the toxic mode of action in biological systems (Swartz et al., 1995). Because the binding capacity of sediment varies, the degree of toxicity exhibited also varies for the same total quantity of toxicant.

The five general categories of sediment quality measurements are sediment chemistry, sediment toxicity, community structure, tissue chemistry, and pathology (Power and Chapman, 1992). Each category has strengths and limitations for a national-scale sediment quality assessment. To be efficient in collecting usable data of similar types, EPA sought data that were available in electronic format, represented broad geographic coverage, and represented specific sampling locations identified by latitude and longitude coordinates.

As described previously, sediment chemistry measures alone might not accurately reflect risk to the environment. However, EPA has developed assessment methods that combine contaminant concentrations with measures of the primary binding phase to address bioavailability for certain chemical classes, under assumed conditions of thermodynamic equilibrium (USEPA, 2000c). Other methods, which rely on statistical correlations of contaminant concentrations with incidence of adverse biological effects, also exist (Barrick et al., 1988; FDEP, 1994; Field et al., 1999; 2002; Ingersoll et al., 2001; Long et al., 1995; MacDonald et al., 1996). In addition, fish tissue levels can be predicted by using sediment contaminant concentrations along with independent field measures of chemical partitioning behavior and other known or assigned fish tissue and sediment characteristics. EPA can evaluate risk to consumers from predicted and field-measured tissue chemistry data using established dose-response relationships and standard consumption patterns (USEPA and USACE, 1998). Evaluations based on tissue chemistry circumvent the bioavailability issue while also accounting for other mitigating factors such as metabolism. The primary difficulty in using field-measured tissue chemistry is relating chemical residue levels to a specific sediment, especially for those fish species which typically forage across great distances.

Sediment toxicity, community structure, and pathology measures are less widely available than sediment chemistry and fish tissue data in the broad-scale electronic format EPA sought for the NSI database. Traditionally sediment toxicity data have been expressed as percent survival in comparison to a control for indicator organisms exposed to the field-sampled sediment in laboratory bioassays (ASTM, 2002a, 2002b, 2002c; USEPA, 1994a, 1994b, 2000d). More recently, as indicated in the data collected for this report, sublethal measurements (e.g., reduction in survival, growth, and reproduction) are being used (Ingersoll et al., 2001). These sublethal endpoints are more prevalent in this update to the first *National Sediment Quality Survey* report. Although these measures account for bioavailability and the antagonistic and synergistic effects of pollutant mixtures, they do not identify specific contaminants responsible for observed toxicity. Indicator organisms also might not represent the most sensitive species. Community structure measures, such as fish abundance and benthic diversity, and pathology measures are potentially indicative of long-term adverse effects, yet there are a multitude of mitigating physical, hydrologic, and biological factors that might not relate in any way to chemical contamination.

Studies have been conducted evaluating the ecological relevancy between response endpoints (i.e., reduction in growth of *Hyalella azteca*) and the ecological resources to be protected (i.e., the indigenous benthic community). Burton et al. (1996) compared results from laboratory sediment toxicity tests to colonization of artificial substrates exposed in situ to contaminated sediments. Survival and growth of *Hyalella azteca* and *Chironomus tentans* in laboratory exposures negatively correlated to percent chironomids and percent tolerant taxa colonizing artificial substrates in the field. Schlekat et al. (1994; Canfield et al., 1994, 1996) also reported general good agreement between sediment toxicity tests with *Hyalella azteca* and benthic community responses.

An important goal of this report is to evaluate data collected throughout the United States in an attempt to describe the ecological integrity of sediments in the Nation's waterways. Ideally, the assessment methodology used to accomplish this task would be based on matched data sets of all five types of sediment quality measures described above to take advantage of the strengths of each measurement type and to minimize their collective weaknesses in a weight-of-evidence approach. Unfortunately, such a database does not exist on a national scale, nor is it typically available on a smaller scale. The statutory definition of contaminated sediments in WRDA 1992 enables EPA to identify locations where sediment chemistry measures exceed "appropriate geochemical, toxicological, or sediment quality criteria or measures." By the same statutory definition, based on screening values (e.g., EPA risk levels for fish tissue consumption) or availability of control samples for purposes of comparison, EPA can also use tissue chemistry and sediment toxicity measures to identify aquatic sediments that "otherwise pose a threat to human health or the environment." Without appropriate comparable reference conditions, EPA believes that it cannot accurately evaluate community structure or pathology measures to identify contaminated sediments based purely on the statutory definition.

For the first report to Congress, the following measurement parameters and techniques were used alone or in combination to perform a screening-level assessment of the probability of adverse effects:[1]

Aquatic Life

- Comparison of sediment chemistry measurements to sediment chemistry screening values.
    - Draft sediment quality criteria (SQCs)
    - Sediment quality advisory levels (SQALs)

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[1] A screening-level assessment typically identifies many potential problems that prove not to be significant upon further analysis (i.e., more conservative).

  - Effects range-median (ERM) and effects range-low (ERL) values
  - Probable effects levels (PELs) and threshold effects levels (TELs)
  - Apparent effects thresholds (AETs)
- Comparison of the molar concentration of acid-volatile sulfides ([AVS]) in sediment to the molar concentration of simultaneously extracted metals ([SEM]) in sediment. (Under equilibrium conditions, sediment with [AVS] greater than [SEM] will not demonstrate toxicity from metals.)
- Lethality based on sediment toxicity data

Human Health

- Comparison of theoretical bioaccumulation potential (TBP) values derived from sediment chemistry to:
  - EPA cancer and noncancer risk levels or
  - Food and Drug Administration (FDA) tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.
- Comparison of fish tissue contaminant levels to
  - EPA cancer and noncancer risk levels or
  - FDA tolerance, action, or guidance values in the absence of, or if more stringent than, EPA levels.

For the first report to Congress, EPA evaluated more than 21,000 sampling stations nationwide as part of the NSI data evaluation. Of the sampling stations evaluated, 5,521 stations (26 percent) were classified as Tier 1; 10,401 (49 percent) were classified as Tier 2; and 5,174 (25 percent) were classified as Tier 3.

For the current analysis in this update, EPA evaluated sediment chemistry, tissue chemistry, and sediment toxicity data, taken at the same sampling station, individually and in combination using a variety of assessment methods. Because of the limitations of the available sediment quality measures and assessment methods, EPA characterizes this identification of contaminated sediment locations as a screening-level analysis. A screening-level analysis typically identifies many potential problems that prove not to be significant upon further analysis. Thus, classification of sampling stations in this analysis is not meant to be definitive, but rather is intended to indicate potential problems arising from persistent metal and organic chemical contaminants.

The first report to Congress used all data available from 1980 through 1993 for developing a baseline assessment. Because of the regular reporting requirements associated with this report, EPA wished to “window in” on a regular time frame for including sediment chemistry, tissue residue, and sediment toxicity data. The principal advantage of screening out older data (data collected before January 1, 1990) is to prevent the results presented in this report from being unduly influenced by historical data when more recent data are available. EPA recognizes, however, that this “time windowing” will result in locations that have no evaluation provided in this document even though data are available in the NSI database. For the current analysis, EPA elected to evaluate data collected from 1990 through 1999 and to evaluate each chemical or biological measurement taken at a given sampling station individually. The methodology used for the current analysis has been modified to take advantage of scientific advances since the release of the first *National Sediment Quality Survey*. Similar to the previous analysis, sampling data obtained at a sampling station during the past 10 years for an individual chemical might result in the sampling station’s being associated with adverse effects on aquatic life or human health. The final section in Chapter 3 presents a comparison based on applying the methodology presented in this chapter to the data used for the first *National Sediment Quality Survey*.

EPA recognizes that sediment is dynamic and that great temporal and spatial variability in sediment quality exists. This variability can be a function of sampling (e.g., a contaminated area might be sampled one year, but not the next) or a function of natural events (e.g., floods can move contaminated sediment from one area to another, bury it, or deposit it on the floodplain). Movement of sediment is highly temporal and depends on the physical and biological processes at work in the watershed. Some deposits redistribute, whereas others remain static unless disturbed by extreme events.

In this report EPA associates sampling stations with their "probability of adverse effects on aquatic life or human health." Each sampling station falls into one of three categories (tiers): associated adverse effects on aquatic life or human health are probable (Tier 1); associated adverse effects on aquatic life or human health are possible (Tier 2); or no indication of associated adverse effects (Tier 3). A Tier 3 sampling station classification does not necessarily imply a zero or minimal probability of adverse effects; it implies only that available data (which might be substantial or limited) do not indicate an increased probability of adverse effects. Recognizing the imprecise nature of the numerical assessment parameters, Tier 1 sampling stations are distinguished from Tier 2 sampling stations based on the magnitude of a sediment chemistry measure or the degree of corroboration among the different types of sediment quality measures.

The remainder of this chapter presents a description of the NSI data, an explanation of the data evaluation approach, and the strengths and limitations of the data evaluation used for this *National Sediment Quality Survey*.

Description of NSI Data

The NSI database includes data from numerous data storage systems and monitoring programs. These systems and programs are listed below along with the percentage of stations that make up the NSI database.

- Selected data sets from EPA's Storage and Retrieval System (STORET) (35 percent of sampling stations)
  - U.S. Army Corps of Engineers (USACE)
  - EPA
  - States
- NOAA's Query Manager Data System (18.5 percent of sampling stations)
  - Including NOAA's National Status and Trends Program
- State of Washington Department of Ecology's Sediment Quality Information System (SEDQUAL) (16.5 percent of sampling stations)
- Selected data sets from the U.S. Geological Survey's (USGS's) WATSTORE (13.5 percent of sampling stations)
- EPA's Environmental Monitoring and Assessment Program (EMAP) (6.5 percent of sampling stations)
- Data compiled for the previous report to Congress (4.8 percent of sampling stations)
- Chesapeake Bay Program (2.4 percent of sampling stations)

- Upper Mississippi River System data compilation prepared by USGS (1.1 percent of sampling stations)
- Other sampling programs (1.7 percent of sampling stations)
  - Indiana Department of Environmental Management Sediment Sampling Program
  - Oklahoma Reservoir Fish Tissue Monitoring Program, 1990 through 1998
  - Houston Ship Channel Toxicity Study

Although EPA elected to evaluate data collected since 1990 (i.e., 1990 through 1999), data from before 1990 are maintained in the NSI database. At a minimum, EPA required that electronically available data include monitoring program, sampling date, latitude and longitude coordinates, and measured units for inclusion in the data evaluation. Additional information about available data fields is presented in Appendix A of this report.

The types of data contained in the NSI database include the following:

- Sediment chemistry: Measurement of the chemical composition of sediment-associated contaminants.
- Tissue residue: Measurement of chemical contaminants in the tissues of organisms.
- Toxicity: Measurement of the lethal or sublethal effects of contaminants in environmental media on various test organisms.

The NSI database represents a compilation of environmental monitoring data from a variety of sources. Most of the component databases are maintained under known and documented quality assurance and quality control procedures. EPA's STORET database, however, is intended to be a broad-based repository of data. Consequently, the quality of the data in STORET, in terms of both database entry and analytical instrument error, is unknown and probably varies a great deal depending on the quality assurance management associated with specific data submissions.

Inherent in the diversity of data sources are contrasting monitoring objectives and scope. Component sources contain data derived from different spatial sampling plans, sampling methods, and analytical methods. For example, most data from EPA's EMAP program represent sampling stations that lie on a standardized grid over a given geographic area, whereas data in EPA's STORET most likely represent state monitoring data sampled from locations near known discharges or thought to have elevated contaminant levels. In contrast, many of NOAA's National Status and Trends Program data represent sampling stations purposely selected because they are removed from known discharges.

From an assessment point of view, STORET data might be useful for developing a list of contaminated sediment locations but might overstate the general extent of contaminated sediment in the Nation by focusing largely on areas most likely to be problematic. On the other hand, analysis of EMAP data might result in a more balanced assessment in terms of the mix of contaminated sampling stations and uncontaminated sampling stations. Approximately one-third of the sampling stations in the NSI database are from the STORET database. Reliance on these data is consistent with the stated objective of this survey—to identify those sediments which are contaminated. Realizing that uncontaminated areas are most likely substantially underrepresented and that the data in the NSI database do not provide a complete national coverage, EPA does not believe it is appropriate to make inferences regarding the overall condition of the Nation's sediment or characterizing the "percent contamination" using the data in the NSI database.

NSI data do not evenly represent all geographic regions in the United States, as mentioned above; nor do the data represent a consistent set of monitored chemicals. For example, several of the databases are targeted toward marine environments or other geographically focused areas. Table 2-1 presents the number of stations evaluated per state (including District of Columbia and Puerto Rico). More than two-thirds of all stations evaluated in the NSI database are in Washington, Virginia, California, Illinois, Florida, Wisconsin, New York, Texas, Oregon, and South Carolina. Each of these states has more than 500 monitoring stations. Other states of similar or larger size (e.g., Georgia, Pennsylvania) have far fewer sampling stations with data for evaluation. Figures 2-1, 2-2, and 2-3 depict the location of monitoring stations with data collected from 1990 through 1999 for sediment chemistry, tissue residue, and toxicity data, respectively. Individual stations may vary considerably in terms of the number of chemicals monitored. Some stations have data that represent a large number of organic and inorganic contaminants, whereas others have measured values for only a few chemicals. Thus, the inventory should not be construed as comprehensive even for locations with sampling data. The reliance on readily available electronic data has undoubtedly led to exclusions of a vast amount of information available from sources such as local and state governments and published reports. Other limitations, including data quality issues, are included in the Conclusions and Discussion chapter of this report.

Table 2-1. Number of Stations Evaluated in the NSI by State.

Region 1	Connecticut	121	Region 6	Arkansas	34
	Maine	0		Louisiana	396
	Massachusetts	127		New Mexico	167
	New Hampshire	4		Oklahoma	292
	Rhode Island	18		Texas	600
	Vermont	5			
Region 2	New Jersey	492	Region 7	Iowa	113
	New York	753		Kansas	119
	Puerto Rico	10		Missouri	194
				Nebraska	157
Region 3	Delaware	234	Region 8	Colorado	133
	District of Columbia	6		Montana	11
	Maryland	290		North Dakota	33
	Pennsylvania	216		South Dakota	32
	Virginia	1,577		Utah	56
	West Virginia	105		Wyoming	29
Region 4	Alabama	173	Region 9	Arizona	123
	Florida	1,157		California	1,535
	Georgia	263		Hawaii	18
	Kentucky	63		Nevada	76
	Mississippi	187			
	North Carolina	291			
	South Carolina	576			
	Tennessee	164			
Region 5	Illinois	1,370	Region 10	Alaska	290
	Indiana	233		Idaho	38
	Michigan	30		Oregon	599
	Minnesota	339		Washington	4,336
	Ohio	441			
	Wisconsin	772			

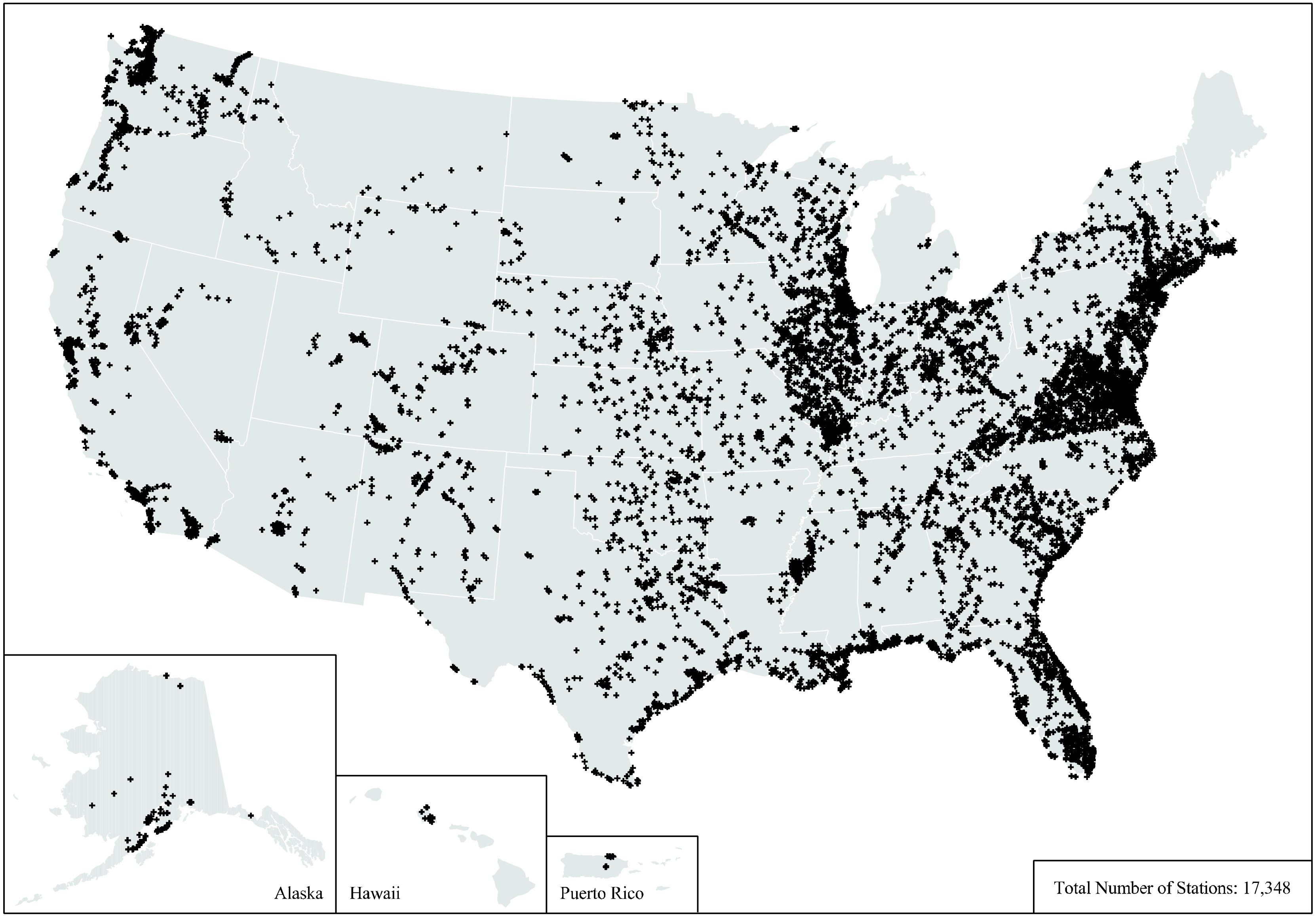

Figure 2-1. NSI Sediment Sampling Stations Evaluated.

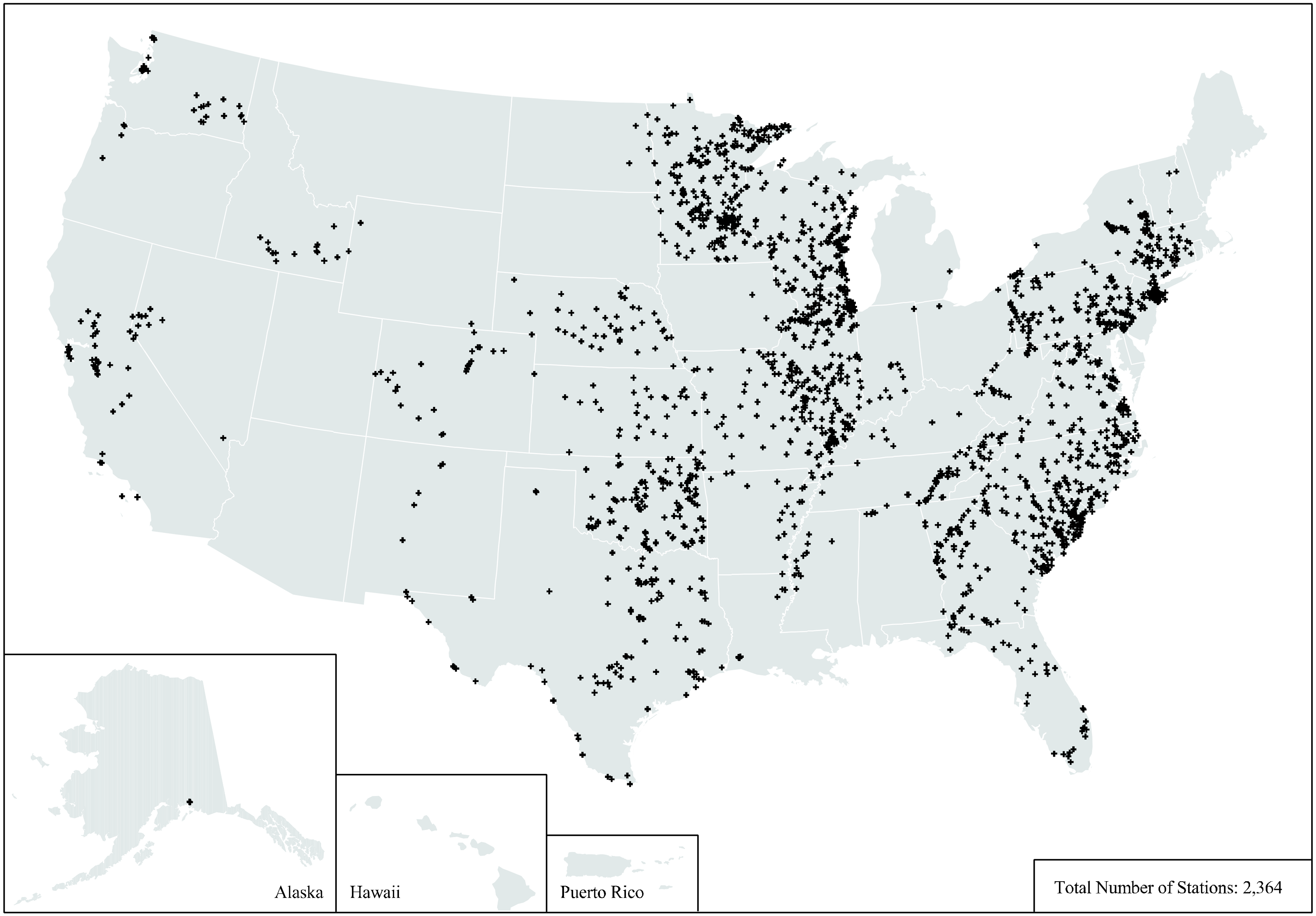

Figure 2-2. NSI Tissue Residue Sampling Stations Evaluated.

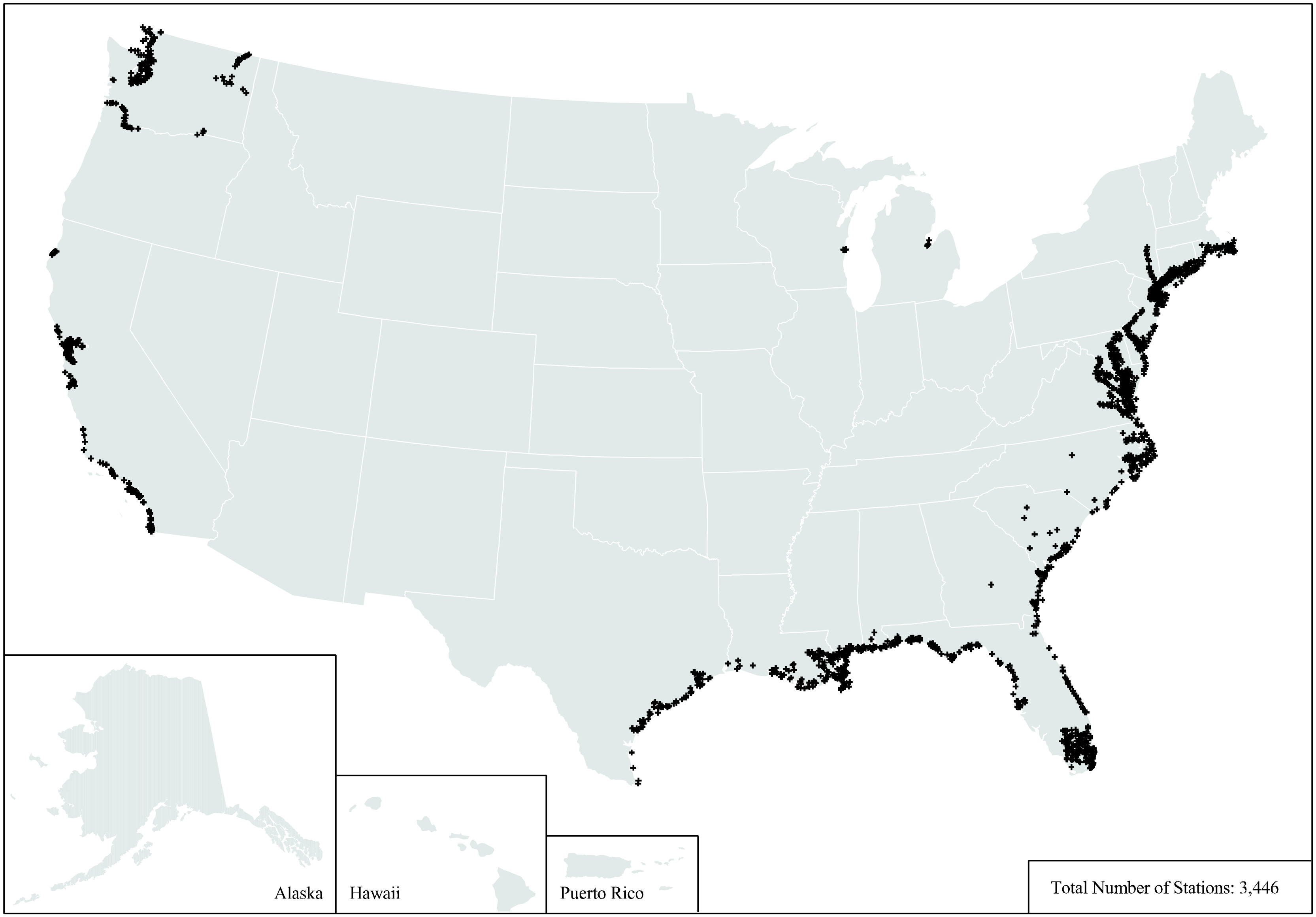

Figure 2-3. NSI Toxicity Test Sampling Stations Evaluated.

NSI Data Evaluation Approach

The methodology developed for this report for classifying sampling stations according to the probability of adverse effects on aquatic life and/or human health from sediment contamination relies on measurements of sediment chemistry (surficial), sediment toxicity, and contaminant residue in tissue. The approach used to evaluate the NSI data focuses on the protection of benthic organisms from exposure to contaminated sediments and the protection of humans from the consumption of fish that bioaccumulate contaminants from sediment. Table 2-2 presents the classification scheme used in the evaluation of the NSI data. Each component, or evaluation benchmark, of the classification scheme is numbered on Table 2-2. Each evaluation benchmark is discussed under a section heading cross-referenced to these numbers.

EPA analyzed the NSI data by evaluating each benchmark in Table 2-2 measurement by measurement and sampling station by sampling station. Each sampling station was associated with a “probability of adverse effects” by combining benchmarks as shown in Table 2-2. Because each individual measurement was considered independently except for divalent metals, PCBs, and DDT, whose concentrations were summed, and PAHs, whose effect was analyzed as a mixture, a single observation of elevated concentration could place a sampling station in Tier 1 (associated with probable adverse effects). Any sampling station not meeting the requirements to be classified as Tier 1 or Tier 2 was classified as Tier 3. Sampling stations classified as Tier 3 include those for which substantial data were available without evidence of adverse effects, as well as sampling stations for which limited data were available to determine the potential for adverse effects.

Applying individual evaluation benchmarks to various measurements independently could lead to different site classifications. If one evaluation benchmark indicated Tier 1 but another evaluation benchmark indicated Tier 2 or Tier 3, a Tier 1 classification was assigned to the sampling station. For example, if a sampling station was categorized as Tier 2 based on all sediment chemistry data but was categorized as Tier 1 based on toxicity data, the station was placed in Tier 1. This principle also applies to evaluating multiple contaminants within the same evaluation benchmark. For example, if the evaluation of sediment chemistry data placed a sampling station in Tier 1 for PCBs and in Tier 2 for metals, the station was placed in Tier 1.

Recognizing the imprecise nature of some assessment benchmarks used in this report, Tier 1 sampling stations are distinguished from Tier 2 sampling stations based on the magnitude of a contaminant concentration in sediment or based on the degree of corroboration among the different types of sediment quality measures. This approach of integrating several assessment methods has been described as the most desirable approach for assessing the effects of contaminants associated with sediments (Ingersoll et al., 1996; 1997; 2001; Long and Morgan, 1990; MacDonald et al., 1996; USEPA, 2000d). In response to uncertainty in both biological and chemical measures of sediment contamination, environmental managers must balance Type I errors (false positives: sediment classified as posing a threat when in fact it does not) with Type II errors (false negatives: sediment that poses a threat but was not classified as such). In screening analyses, the environmentally protective approach is to minimize Type II errors, which would leave toxic sediment unidentified. To achieve a balance and to direct attention to areas most likely to be associated with adverse effects, Tier 1 sampling stations are intended to have a higher probability of posing an adverse effect (e.g., sediment posing a threat) and a balance between Type I and Type II errors. On the other hand, to retain a sufficient degree of environmental conservatism in screening, Tier 2 sampling stations are intended to have a very low number of false negatives in exchange for a large number of false positives.

Table 2-2. NSI Data Evaluation Approach.

Sampling Station Classification	Data Used to Determine Classifications				
	Sediment Chemistry		**Tissue Residue**		**Toxicity**
Tier 1: Associated Adverse Effects on Aquatic Life or Human Health Are Probable	Sediment chemistry value exceeds a draft equilibrium partitioning sediment guideline (ESG) derived from a final or secondary acute value (FAV or SAV)[a] **1**	**OR**	Tissue levels of chemicals with a log $K_{ow} \geq 5.5$ in samples[d] that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels **12**	**OR**	Toxicity demonstrated by one solid-phase sediment test resulting in (1) < 75% control-adjusted survival, (2) freshwater invertebrate (*Hyalella azteca*) sublethal toxicity < 90% control-adjusted length, or (3) freshwater invertebrate (*Hyalella azteca*, *Chironomus tentans,* and *Chironomus riparius*) sublethal toxicity < 70% control-adjusted weight **15**
	OR [SEM]−[AVS] > 5 for the sum of molar concentrations of Cd, Cu, Ni, Pb, Zn, and ½ x Ag[b] **2**				
	OR Any sample with a predicted proportion toxic ≥0.5 using a logistic regression model **3**				
	OR Sum PAH ESG toxicity unit (draft) derived from FAV > 1[a,c] **4**				**OR** Any sample meeting the benchmark described under Tier 2 for toxicity using at least two different species **16**
	OR Sediment chemistry TBP exceeds EPA's human health cancer risk of 10^{-4} or a noncancer hazard quotient (HQ) of 10[a] **5**				
	OR For chemicals with log $K_{ow} < 5.5$, sediment chemistry TBP exceeds EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels[a] **6**	**AND**	Tissue levels of chemicals with a log $K_{ow} < 5.5$ in samples[d] that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/ action/guidance levels **13**		
Tier 2: Associated Adverse Effects on Aquatic Life or Human Health Are Possible	Sediment chemistry value exceeds a draft ESG derived from a final or secondary chronic value (FCV or SCV)[a] **7**	**OR**	Tissue levels of chemicals with a log $K_{ow} < 5.5$ in samples[d] that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels **14**	OR	Toxicity demonstrated by one solid-phase sediment test resulting in (1) < 90% control-adjusted survival (but ≥ 75% control-adjusted survival), (2) freshwater invertebrate (*Hyalella azteca*) sublethal toxicity < 95% control-adjusted length (but ≥ 90% control-adjusted length), or (3) freshwater invertebrate (*Hyalella azteca*, *Chironomus tentans, and Chironomus riparius*) sublethal toxicity < 90% control-adjusted weight (but ≥70% control-adjusted weight) **17**
	OR [SEM]−[AVS] = 0–5 for the sum of molar concentrations of Cd, Cu, Ni, Pb, Zn, and ½ x Ag[b] **8**				
	OR Any sample with a predicted proportion toxic≥ 0.25 but < 0.5 using a logistic regression model **9**				
	OR Sum PAH ESG toxicity unit (draft) derived from FCV > 1[a,c] **10**				
	OR Sediment chemistry TBP exceeds EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels[a] **11**				
Tier 3: No Indication of Associated Adverse Effects	Any sampling station not categorized as Tier 1 or Tier 2. Available data (which may be very limited or quite extensive) do not indicate a likelihood of adverse effects on aquatic life or human health.				

[a] If total organic carbon (TOC) is not reported, a default value of 1% was assumed. For ESG-based methods if the reported TOC is less than 0.2%, a default TOC value of 0.2% was used.

[b] Metals: Cd = cadmium, Cu = copper, Ni = nickel, Pb = lead, Zn = zinc, Ag = silver.

[c] Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene used to compute ESG toxicity unit.

[d] Only those species considered benthic (demersal), nonmigratory (resident), and edible by human populations are included in human health assessments.

For this NSI data evaluation EPA opted to analyze data collected since 1990 with valid latitude and longitude coordinates. The numbered evaluation benchmarks used in the NSI data evaluation are briefly described below. A detailed description of the evaluation benchmarks is presented in Appendix B.

As noted in the first footnote to Table 2-2, if the total organic carbon (TOC) was not reported, a default of 1 percent was assumed. This assumption was based on a literature review performed during the preparation of the first report to Congress. TOC values can range from 0.1 percent in sandy sediments to 1 to 4 percent in silty harbor sediments and 10 to 20 percent in navigation channel sediments (Clarke and McFarland, 1991). Long et al. (1995) reported an overall mean TOC concentration of 1.2 percent from data compiled from 350 publications for their biological effects database for marine and estuarine sediments. Ingersoll et al. (1996) reported a mean TOC concentration of 2.7 percent for inland freshwater samples. Based on this review of TOC data, EPA selected a default TOC value of 1 percent for this evaluation. Consistent with the screening-level application, this value should not lead to an underestimate of the bioavailability of associated contaminants in most cases.

Sediment Chemistry Data

The sediment chemistry screening values used as the basis for comparison in this report are not regulatory criteria, site-specific clean up standards, or remediation goals. Sediment chemistry screening values are reference values above which a sediment ecotoxicological assessment might indicate a potential threat to aquatic life. The sediment chemistry screening values used to evaluate the NSI data for potential adverse effects of sediment contamination on aquatic life include values based on theoretical calculations and empirically/statistically derived values. The theoretically based values rely on the physical/chemical properties of sediment and chemicals to predict the level of contamination that would not cause an adverse effect on aquatic life. The empirically/statistically derived screening values are based on estimating the probability that a sediment toxicity test would indicate significant toxicity using multiple chemical measures of 37 target chemicals.

The theoretically based screening values used in the evaluation of NSI data include draft ESGs developed by EPA. These include: dieldrin, endrin, 32 nonionic organics, mixtures of PAHs, and metal mixtures. The use of each of these screening values in the evaluation of the NSI data is described below. Another theoretically based evaluation benchmark, the theoretical bioaccumulation potential (the TBP, which was used for human health assessments), is also described below.

Sediment Chemistry Values Exceed EPA Draft Equilibrium Partitioning Sediment Guideline (ESG) [1, 7]

EPA developed draft ESGs using the equilibrium partitioning (EqP) approach (described in detail in Appendix B) for linking bioavailability to toxicity. This approach accounts for the varying biological availability of chemicals in different sediments and permits the incorporation of the relevant biological effects concentration. The approach enables the derivation of a guideline that is causally linked to the specific chemical, is applicable across sediments, and is protective of benthic organisms. The EqP theory asserts that a nonionic chemical in sediment partitions between sediment organic carbon, interstitial (pore) water, and benthic organisms. At equilibrium, if the concentration in any one phase is known, the concentration in the others can be predicted. EPA has developed different draft ESGs based on final or secondary acute or chronic values to reflect the differing degrees of data availability and uncertainty. These draft ESGs are expressed as a concentration of a chemical in sediment and are derived to protect aquatic benthic organisms from direct toxicity due to that chemical (or chemicals in the case of metals mixtures and PAH mixtures). The draft ESG for nonionic organics applies only to sediments that have at least 0.2 percent organic carbon. For samples with TOC less than 0.2 percent, a default TOC value of 0.2 percent was used.

Comparison of AVS to SEM Molar Concentrations [2, 8]

The use of the total concentration of a trace metal in sediment as a measure of its toxicity and its ability to bioaccumulate is problematic because different sediments exhibit different degrees of bioavailability for the same total quantity of metal (Di Toro et al., 1990; Luoma, 1983). These differences have been reconciled by relating organism toxic response (mortality) to the contaminant concentration in the sediment interstitial water (Adams et al., 1985; Di Toro et al., 1990). AVS is one of the major chemical components that control the activities and availability of metals in interstitial waters of anoxic (lacking oxygen) sediments (Meyer et al., 1994).

A large reservoir of sulfide exists as iron sulfide in anoxic sediment. Sulfide reacts with several divalent transition metal cations (cadmium, copper, mercury, nickel, lead, and zinc) and predominantly monovalent silver to form highly insoluble compounds that are not bioavailable (Allen et al., 1993, Ankley et al., 1991, Berry et al., 1999, Carlson et al. 1991). It follows in theory, and with verification (Di Toro et al., 1990), that divalent transition metals do not begin to cause toxicity in anoxic sediment until the reservoir of sulfide is used up (i.e., the molar concentration of metals exceeds the molar concentration of sulfide), typically at relatively high dry-weight metal concentrations. This observation has led to a laboratory measurement technique for calculating the difference between simultaneously extracted metal (SEM) concentration and acid-volatile sulfide (AVS) concentration from field samples to determine potential toxicity (Ankley et al., 1991, Carlson et al. 1991).

To evaluate the potential effects of metals on benthic species, the molar concentration of AVS ([AVS]) was compared to the sum of SEM molar concentrations ([SEM]) for six metals: cadmium, copper, nickel, lead, zinc, and silver. Molar concentrations of cadmium, copper, nickel, lead, and zinc are comparable with AVS on a one-to-one basis. Because silver exists predominantly as a monovalent metal, half the molar concentration of silver is compared with the molar AVS concentration. Mercury was excluded from AVS comparison because other important factors play a major role in determining the bioaccumulation potential of mercury in sediment. Specifically, under certain conditions mercury binds to an organic methyl group and is readily taken up by living organisms.

Sediment with measured [SEM] in excess of [AVS] does not necessarily exhibit toxicity. This is because other binding phases can tie up metals. However, research indicates that sediment with [AVS] in excess of [SEM] will not be toxic from metals, and the greater the [SEM]-[AVS] difference, the greater the likelihood of toxicity from metals. Analysis of toxicity data for freshwater and saltwater sediment amphipods (crustaceans) from EPA's Environmental Research Laboratory in Narragansett, Rhode Island, revealed that 80 to 90 percent of the sediments were toxic at [SEM]-[AVS] > 5 (Hansen, 1995; see also Hansen et al., 1996a; 1996b). Thus, EPA selected [SEM]-[AVS] = 5 as the demarcation line between Tier 1 and Tier 2. For the purpose of this evaluation, where [SEM]-[AVS] was greater than 5, the sampling station was classified as Tier 1. If [SEM]-[AVS] was between zero and 5, the sampling station was classified as Tier 2. If [SEM]-[AVS] was less than zero, or if AVS or the six AVS metals were not measured at the sampling station, the sampling station was classified as Tier 3 unless otherwise classified by another benchmark.

There are several important factors to consider in interpreting the [SEM]-[AVS] difference. First, all toxic SEMs present in amounts that contribute significantly to the [SEM] sum should be measured. Because mercury presents special problems, however, it is not included in the current SEM analysis. Second, if the AVS content of sediment is low, as in fully oxidized sediments, the metal-binding capacity of the sediment decreases and the method will not work (Adams et al., 1992; Zhuang et al., 1994). Most benthic macroorganisms, including those used in toxicity tests, survive in sediments that have a thin oxidized surface layer and then an anoxic layer. The anoxic layer can have significant AVS concentrations that would reduce the metal activity to which these organisms are exposed (Di Toro et al., 1992). Third, AVS varies spatially in sediment—vertically with depth and horizontally where patches of an appropriate carbon source occur under low-oxygen conditions for the sulfate-reducing bacteria. Finally, AVS can vary when sediments are oxygenated during physical disturbance and seasonally as changes in the productivity of the aquatic ecosystem alter the oxidation state of sediment and oxidize metal sulfides; therefore, the toxicity of the metals present in the sediment also changes over time (Howard and Evans, 1993).

Selection of an [SEM]-[AVS] difference sufficiently high to place a sediment in the Tier 1 classification requires careful consideration because the relationship between organism response and the [SEM]-[AVS] difference of sediment depends on the amount and kinds of other binding phases present. Using freshwater and saltwater sediment amphipod toxicity data, researchers at EPA's Environmental Research Laboratory in Narragansett, Rhode Island, plotted [SEM]-[AVS] versus the percentage of sediments with a higher [SEM]-[AVS] value that were toxic. For this analysis, the researchers defined toxicity as greater than 24 percent mortality. Analysis of these data reveals that between 80 percent and 90 percent of the sediments were toxic at [SEM]-[AVS] = 5. The running average mortality at this level was between 44 percent and 62 percent (Hansen, 1995). EPA's Office of Science and Technology selected [SEM]-[AVS] = 5 as the demarcation line between the higher (Tier 1) and intermediate (Tier 2) probability categories.

Predicted Proportion Toxic from Sediment Chemistry [3, 9]

The empirically based or correlative screening values used in the previous NSI data evaluation rely on paired field and laboratory data to relate the incidence of observed biological effects to the dry-weight sediment contamination of a specific chemical. The empirically based or correlative screening values include the effects range-median (ERM)/effects range-low (ERL) values, probable effects level (PEL)/threshold effects level (TEL), and apparent effects thresholds (AET) (Barrick et al., 1988; Long et al., 1995; MacDonald et al., 1996). Field et al. (1999, 2002) developed an alternative method for the evaluation of sediment quality by using a logistic regression model in place of the correlative screening values used in the first *National Sediment Quality Survey*. The logistic regression model approach is similar to other empirical approaches for deriving screening values because it relies on matching field-collected sediment chemistry and biological effects (e.g., sediment toxicity or benthic invertebrate community structure effects) data. In contrast to other approaches to developing screening values, however, the logistic regression model approach does not develop threshold values. Instead, it develops models that enable users to select the probability of observing sediment toxicity that corresponds to their specific objectives or to estimate the probability of observing effects at a particular chemical concentration (Field et al., 1999). This model (described in detail in Appendix B) is used to predict the probability of observing specific toxic effects—for selected toxicity test endpoints and a wide range of concentrations—for individual contaminants. Using the sediment chemistry and toxicity data, individual logistic models were developed for each contaminant, and the slope and intercept values were calculated using the maximum likelihood approach.

A total of 37 chemicals are included in the logistic regression model. For the NSI data evaluation, the probability of toxic effects was computed for the various contaminants from individual logistic regression equations. The predicted proportion toxic was then estimated from the maximum probability of toxic effects using a regression equation. When the maximum predicted proportion toxic for any sample was $\geq$ 0.5, the sampling station was assigned to Tier 1. When the maximum predicted proportion toxic was $\geq$ 0.25 but $<$ 0.5, the sampling station was classified as Tier 2. Other sampling stations with available data for chemicals included in the logistic regression model were classified as Tier 3 unless otherwise classified by another benchmark.

PAH-Based ESG Toxicity Unit Exceed Screening Benchmark [4, 10]

The $\Sigma \mathrm{ESGTU}_{\mathrm{PAH}}$ model estimates the probability of toxic effects in PAH-contaminated sediments by using equilibrium partitioning, the quantitative structure-activity relationship (QSAR) technique, toxic unit, additivity, and concentration-response models (Swartz, 1999; Swartz et al.,1995). The model predicts the probability of acute sediment toxicity to marine and estuarine amphipods caused by a combination of PAHs. EPA's draft ESG recommends an approach for summing the toxicological contributions of mixtures of 34 PAHs in sediments to determine whether their concentrations in any specific sediment are acceptable for the protection of benthic organisms from PAH toxicity. Because PAHs occur in sediments as mixtures and their toxicities in water, tissues, and sediments are additive or nearly additive (Di Toro and McGrath, 2000), considering their toxicities on an individual basis would result in guidelines that are underprotective. For this reason, EPA recommends the use of combined toxicological contributions of the PAH mixture in evaluating sediments.

Because many monitoring and assessment efforts measure a smaller group of PAHs, such as 13 or 23 PAHs, EPA has recommended adjustment factors to relate these smaller subsets to the expected concentration of the 34 PAHs. The total Equilibrium Partitioning Sediment Guideline Toxic Unit (ΣESGTU)—based on the final chronic or acute value—is used to classify sampling stations as Tier 1 or Tier 2 (described in detail in Appendix B). For use in determining the uncertainty in predicting $\Sigma ESGTU_{FCV,TOT}$ from data sets consisting of 13 or 23 PAHs, EPA combined two data sources that measured the 34 PAHs and treated the data set as a single data source. In doing this data combination, a data set containing both alkylated and parent PAHs with their correlative relationships was generated. Based on the relative distributions of the $\Sigma ESGTU_{FCV,TOT}$ to the $\Sigma ESGTU_{FCV}$ for the 13 PAHs, EPA recommended various multiplication factors to achieve various degree-of-confidence levels. Table B-3 in Appendix B presents the relative distribution of the multiplication factors. The NSI data evaluation targeted 13 PAHs and used the EPA-recommended multiplication factor of 2.75 to obtain an accurate estimation of the ΣESGTU. However, for this data evaluation not all 13 PAHs were required to be measured at any one station for that station to be considered for tier classification. Based on the sensitivity analysis done, it was observed that this variation from the EPA-recommended practice did not dramatically change the total number of station tier classifications. This analysis applies only to sediments that have at least 0.2 percent organic carbon. For samples with TOC less than 0.2 percent, a default TOC value of 0.2 percent was used.

Sediment Chemistry TBPs Exceed Screening Benchmark [5, 6, 11]

This evaluation benchmark addresses the risk to human consumers of organisms exposed to sediment contaminants. The TBP is an estimate of the equilibrium concentration (concentration that does not change with time) of a contaminant in tissues if the sediment in question were the only source of contamination to the organism. At present, the TBP calculation can be performed only for nonpolar organic chemicals. The TBP is estimated from the concentration of contaminant in the sediment, the organic carbon content of the sediment, the lipid content of the organism, and the relative affinity of the chemical for sediment organic carbon and animal lipid content. This relative affinity is measured in the field and is called a biota-sediment accumulation factor (BSAF). In practice, field-measured BSAFs can vary by an order of magnitude or greater for individual compounds depending on location and time of measurement. For this evaluation, EPA selected BSAFs that represent the central tendency, suggesting an approximate 50 percent chance that an associated tissue residue level would exceed a screening risk value.

In the evaluation of NSI data, if a calculated sediment chemistry TBP value exceeded a screening value derived using the EPA risk assessment methodology (i.e., EPA's human health cancer risk of 10^{-4} or a noncancer hazard quotient [HQ] of 10, evaluation benchmark 5), the station was classified as Tier 1. Individual chemical risk levels were considered separately; that is, risks from multiple contaminants were not added.

For chemicals with an octanol-water partition coefficient (log K_{ow}) < 5.5, the following benchmark was used: if a calculated sediment chemistry TBP value exceeded a screening value derived using EPA's human health cancer risk of 10^{-5} or a noncancer HQ of 1 or the Food and Drug Administration's (FDA's) tolerance/action/guidance level (evaluation benchmark 6, Table 2-2), and if a corresponding tissue residue level for the same chemical in demersal, resident, and edible species at the same sampling station also exceeded one of those screening values (evaluation benchmark 13, Table 2-2), the station was classified as Tier 1. Individual chemical risk levels were considered separately; that is, risks from multiple contaminants were not added. In this assessment, both sediment chemistry and tissue residue samples must have been taken from the same sampling station. If tissue residue levels for the same chemical for a demersal, resident, and edible species at the same sampling station did not exceed standard EPA risk levels or FDA levels or there were no corresponding tissue data, the sampling station was classified as Tier 2.

In addition, for all chemicals irrespective of their octanol-water partition coefficient, when the sediment chemistry TBP exceeded stated EPA risks or FDA guidelines shown in Table 2-2, the sample stations were classified as Tier 2. If neither TBP values nor fish tissue residue levels exceeded the appropriate EPA risk levels given in Table 2-2 or the FDA guidance levels, or if no chemicals with TBP values, EPA risk levels, or FDA levels were measured, the sampling station was classified as Tier 3 unless otherwise classified by another benchmark. A detailed description of the methods used to develop TBP values and to determine the EPA risk levels used in this comparison is presented in Appendix B.

Tissue Residue Data [12, 13, 14]

Tissue residue data were used to assess potential adverse effects on humans from the consumption of fish that become contaminated through exposure to contaminated sediment. Only those species considered benthic, nonmigratory (resident), and edible by human populations were included in human health assessments. A list of species included in the NSI database and their characteristics is presented in Appendix D.

For chemicals with a log $K_{ow} \geq 5.5$, if the tissue residue levels in demersal, resident, and edible species exceeded EPA risk screening values (i.e., EPA's human health cancer risk of 10^{-5} or a noncancer HQ of 1 or the FDA tolerance/action/guidance level), the station was classified as Tier 1.

For chemicals with a log $K_{ow} < 5.5$, both a tissue residue level exceeding an FDA tolerance/action/guidance level or stated EPA risk level and a sediment chemistry TBP value exceeding that risk/tolerance level for the same chemical were required to classify a sampling station as Tier 1. If tissue residue levels exceeded FDA levels or EPA risk levels but corresponding TBP values were not exceeded at the same station (or there were no sediment chemistry data from that station), the sampling station was classified as Tier 2. If neither fish tissue levels nor TBP values exceeded EPA risk levels or FDA levels, or if no chemicals with TBP values, EPA risk levels, or FDA levels were measured, the sampling station was classified as Tier 3 unless otherwise classified by another benchmark.

Toxicity Data [15, 16, 17]

Toxicity data were used to classify sediment sampling stations based on short- or long-term sediment toxicity tests. Nonmicrobial sediment toxicity tests based on survival and on variation in length or weight were evaluated. For all of the endpoints (i.e., survival and variations in length or weight), the test results were "adjusted" to compare against a control test for the same species (described in more detail in Appendix B). Toxicity test results that lacked control data were excluded. EPA has standardized testing protocols for marine and freshwater toxicity tests (USEPA, 1994a, 1994b, 2000d, 2001a).

For the NSI data evaluation, only solid-phase bulk sediment toxicity tests, with test durations of 7 or more days, were considered. Calculated values of the percentage of species surviving were reported by individual databases. These percentages were based on values adjusted for a control sample. Sampling stations with tests resulting in less than 75 percent of the control-adjusted survival in marine and freshwater species were classified as Tier 1. Similar to the results reported for percent survival, calculated values of the percentage variation in length and weight were reported in various studies. These percentage values were also reported as adjusted for a control test. Sample stations with freshwater invertebrates (*Hyalella azteca*) that indicated sublethal toxicity by lengths of less than 90 percent of the control-adjusted length or with freshwater invertebrates (*Hyalella azteca*, *Chironomus tentans*, and *Chironomus riparius*) that indicated sublethal toxicity by weights of less than 70 percent of the control-adjusted weight were classified as Tier 1.

Stations were classified as Tier 2 based on benchmarks similar to those established for Tier 1 classification, but with lower threshold values. Toxicity tests resulting in less than 90 (but ≥ 75) percent of the control-adjusted survival for both marine and freshwater species were classified as Tier 2. Sampling stations with freshwater invertebrates (*Hyalella azteca*) that indicated sublethal toxicity by lengths of less than 95 (but ≥ 90) percent of the control-adjusted length or with freshwater invertebrates (*Hyalella azteca*, *Chironomus tentans*, and *Chironomus riparius*) that indicated sublethal toxicity by weights of less than 90 (but ≥ 70) percent of the control-adjusted weight were classified as Tier 2.

A station could be classified as Tier 2 by the benchmark stated above based on more than one test species. When a station was classified as Tier 2 based on results from two or more species from that station, the tier classification for that station was upgraded to Tier 1.

Evaluation Using EPA Wildlife Criteria

In addition to the evaluation parameters described above and presented in Table 2-2, EPA conducted an assessment of NSI data based on a comparison of sediment chemistry TBP values and fish tissue values to EPA wildlife criteria developed for the Great Lakes. Wildlife criteria based solely on fish tissue concentrations were derived for EPA wildlife criteria for water that are presented in the *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife: DDT; Mercury; 2,3,7,8-TCDD; PCBs* (USEPA, 1995). EPA has developed wildlife criteria for four contaminants: DDT, mercury, 2,3,7,8-TCDD, and PCBs. The method used to adjust these wildlife criteria for the NSI data evaluation is explained in detail in Appendix B. This sediment evaluation was comparable to the sediment chemistry TBP (evaluation benchmarks 6 and 11, Table 2-2), and the tissue evaluation was comparable to benchmarks 13 and 14 from Table 2-2. This evaluation was not included with the results of evaluating the NSI data based on the other parameters. The results of evaluating NSI data based on wildlife criteria are presented in Chapter 3.

Strengths of the NSI Data Evaluation

For this report to Congress, EPA has compiled the most extensive database of sediment quality information currently available in electronic format. To evaluate these data, EPA has applied sediment assessment techniques in a multiple-lines-of-evidence approach recommended by national experts (Ingersoll et al., 1997). The evaluation approach uses sediment chemistry, tissue residue, and toxicity test results. The assessment tools employed in this analysis have been applied in North America, and results have been published in peer-reviewed literature. Toxicity test data were generated using established standard methods employed by multiple federal and state agencies. The evaluation approach addresses potential impacts on both aquatic life and human health.

Because of the complex nature of the reactions among different chemicals in different sediment types, in water, and in tissues, no single sediment assessment technique can be used to adequately evaluate potential adverse effects from exposure to all contaminants. Uncertainties and limitations are associated with all sediment quality evaluation techniques. To compensate for those limitations, EPA has used multiple assessment techniques, singularly and in combination, to evaluate the NSI data. For example, EPA applied draft equilibrium partitioning sediment guidelines for nonionic organics, for mixtures of

PAHs, and for five divalent metals. The screening values used to evaluate the NSI data include both theoretical and correlative approaches. The theoretical approaches (e.g., draft ESGs and TBPs) are based on the best information available concerning how chemicals react in sediments and organisms and how organisms react to those chemicals. The correlative approach (i.e., logistic model) is based on matched sediment and biological data gathered in the field and in the laboratory, and it provides substantial evidence of actual biological effects from sediments.

As stated above, the NSI data evaluation approach includes assessments of potential impacts on both human health and aquatic life. Some chemicals pose a greater risk to human health than to aquatic life; for others, the reverse is true. By evaluating both potential human health and aquatic life impacts, EPA has ensured that the most sensitive endpoint is used to assess environmental impacts.

Because sediment chemistry data are not the only indicators of potential environmental degradation due to sediment contamination, the NSI data evaluation approach also includes evaluations of fish tissue residue and toxicity data. If high levels of PCBs, dioxins, or other highly hydrophobic organic chemicals (commonly found associated with sediments) were measured in fish tissue at a given sampling station, the station could be categorized as Tier 1 with no corroborating sediment chemistry data. For other chemicals, high concentrations in tissues alone were not sufficient to categorize a sampling station as Tier 1; corroborating sediment chemistry data were also required. For a sampling station to be categorized as Tier 1 based on toxicity data alone, only solid-phase tests were analyzed.

Limitations of the NSI Data Evaluation

This methodology was designed for the purpose of a screening-level assessment of sediment quality. A considerable amount of uncertainty is associated with the site-specific measures, assessment techniques, exposure scenarios, and default parameter selections. Therefore, the results of evaluating particular sampling stations based on this methodology should be followed up with more intensive assessment efforts, when appropriate (e.g., for waterbodies with multiple Tier 1 sampling stations located in APCs). Two types of limitations are associated with the evaluation of the NSI data: limitations associated with the data themselves and limitations associated with the evaluation of the data.

Limitations of Data

The NSI database is a multimedia compilation of environmental monitoring data obtained from a variety of sources, including state and federal government offices. Inherent in the diversity of data sources are contrasting monitoring objectives and scopes, which make comparison of data from different data sets difficult. For example, several of the databases contain only information from marine environments or other geographically focused areas. The potential for inconsistencies in measured concentrations of contaminants at different stations exists for samples taken from different monitoring programs. For example, sampling different age profiles in sediments, applying different sampling and analysis methods, and sampling for different objectives can affect the results of the NSI data evaluation. The surficial samples analyzed in this report vary because many different sampling devices are used depending on water depth and study objectives. For this report, samples were included when the reported lower depth was no greater than 30 cm and the reported upper depth was less than 2 cm, not reported, or left blank. It is important to note that it is relatively common for monitoring programs that focus on surficial sediment samples to not report sample depth. Therefore, because unreported or blank sample depths are relatively common, they were assumed to be surficial samples for this report. Although some monitoring programs identified sampling and laboratory methods, this information is rarely provided with the data. In addition, some data sets included in the NSI database were not peer-reviewed (e.g., some data sets from EPA's STORET). Furthermore, each monitoring program used unique sampling and analysis protocols. For example, PCBs are measured by nearly all of the monitoring programs but were analyzed and reported as aroclor-specific data, congener-specific data, total PCBs, or a combination of these.

The only quality assurance/quality control (QA/QC) information required for data to be included in the NSI database was information on the source of the data and the location of the sampling station. Available information on several types of QA/QC procedures that can influence the quality of the data and can be used to check the quality of data was included in the NSI database. None of this information was required before a data set could be included in the NSI database; however, most of the component databases are maintained under known and documented QA/QC procedures. For the 19,470 stations evaluated in this report, approximately 97 percent contain sufficient information in the database to allow the user to contact an agency, contact an investigator, or reference a report to obtain the available QA/QC information. Data reporting was also inconsistent among the different data sources. Inconsistencies that required resolution included the lack or inconsistent use of Chemical Abstract Service (CAS) numbers, analyte names, species names, and other coding conventions, as well as the lack of detection limits and associated data qualifiers (remark codes). The evaluation of toxicity data required the presence of control data. Depending on the data source, control data were not regularly reported with the data and could not be evaluated.

Some of the data analyzed for the tier classification were compiled as early as 1990 (the analyzed data cover the period of 1990 through 1999) and might not reflect current conditions. Emissions of many prominent contaminants have declined, and significant remediation efforts have taken place at many locations since that time. In addition, dredging, burial, natural attenuation, and scouring might have removed contaminants from some sampling stations. Unlike the first report to Congress, this analysis did include a temporal assessment of trends in sediment contaminant levels using data from 1980 through 1999, but it cannot be considered comprehensive and is applicable to only the locations where data were collected and evaluated.

Some data parameters are consistently absent throughout the NSI database. (Refer to Appendix A, Table A-1, for information on the number of NSI database stations at which the various types of data were compiled.) For example, only 10 percent of the stations with sediment chemistry data had associated toxicity data. For many of the fish tissue data included in the NSI database, the species was not identified. Also, assessment parameters other than sediment chemistry, sediment toxicity, and tissue residue, such as benthic macroinvertebrate data, are not included in the NSI database and therefore not used in the evaluation process.

The unavailability of matching sediment chemistry and tissue residue data also limited the NSI data evaluation. In several instances, fish tissue was not analyzed for the same suite of chemicals for which sediment was analyzed. Spatial and temporal limitations of the data might have directly affected the analysis. Although some sediment chemistry and tissue residue data might have been collected in the same or very similar sampling stations, if the station names were not identical, the data could not be treated as if they were collected from the same location. This very likely resulted in an underestimate of the number of Tier 1 stations identified based on potential human health effects. The underestimate occurred because exceedances of sediment TBP and tissue levels (EPA risk levels and FDA levels) at the same sampling station were required to categorize stations as Tier 1.

The lack of consistency among the different monitoring programs in the suite of chemicals analyzed also represents an area of uncertainty in the NSI data evaluation. Certain databases contain primarily information describing concentrations of metals or pesticides, whereas others contain data describing concentrations of nearly every chemical monitored in all of the NSI data. Many monitoring programs use a screening list of chemicals that are indicator pollutants for contaminated sediments. Thus, many of the specific chemicals assessed in the NSI data evaluation are not measured in every sample. In addition, certain classes of in-place sediment contaminants might not be recognized as causing significant impacts and thus are not routinely measured.

Information describing local background levels of sediment contaminants was usually not presented with the data included in the NSI database and thus was not considered when the significance of elevated contaminant concentrations in sediment was evaluated. Background conditions can be important in an evaluation of potential adverse effects on aquatic life because ecosystems can adapt to their ambient environmental conditions. For example, high metals concentrations in samples collected from a particular station might occur from natural geological conditions at that location, as opposed to the effects of human activities.

Most data are associated with a specific location and collected from a nonrandom sampling design. As a result, establishing the extent of contaminated sediment within a waterbody is not possible because it is difficult to assess the extent to which a monitoring station represents a larger segment of a waterbody. Furthermore, the NSI data are geographically biased. More than two-thirds of all stations evaluated in the NSI database are in Washington, Virginia, California, Illinois, Florida, Wisconsin, New York, Texas, Oregon, and South Carolina. Each of these states has more than 500 monitoring stations. Finally, EPA did not verify reported latitude and longitude coordinates for each sampling station.

During the development of this report, several reviewers highlighted locations or areas throughout the United States with contaminated sediments either not included in this report or having limited coverage. These comments indicated that sediment chemistry, sediment toxicity, or tissue residue data (or various combinations of these) are available from the following areas: tribal waters (e.g., Minnesota Chippewa Tribal lakes); the Chesapeake Bay; the State of Ohio; the New England area; the State of New York (e.g., data from the New York State Department of Environmental Conservation); the State of Washington (e.g., Commencement Bay, Spokane River); the Great Lakes and its tributaries; and Superfund sites where risks to human health and/or the environment have been linked to sediment contamination. As pointed out in the Executive Summary and Chapter 5 of this report, EPA will make a concerted effort to accumulate more data for inclusion in the NSI database and for future *National Sediment Quality Survey* reports to Congress. The areas and locations mentioned above will be a high priority in this effort.

Limitations of Approach

Sediment Chemistry Screening Values

As indicated in the first *National Sediment Quality Survey*, there are gaps in our knowledge concerning sediment-pollutant chemistry (especially bioavailability) and direct and indirect effects on aquatic biota. The certainty with which sediment toxicity can be predicted for each chemical using the various screening values included in the NSI database evaluation can vary significantly based on the quality of the available data and the appropriateness of exposure assumptions. For example, the draft ESGs are based on either secondary or final acute/chronic values, which are not equivalent even though they were developed using the same methodology. Draft ESGs based on final acute/chronic values are based on the highest-quality toxicity and octanol/water partitioning data, which have been reviewed extensively. Some draft ESGs based on secondary acute/chronic values have also undergone extensive field validation experiments. However, other draft ESGs based on secondary acute/chronic values are in many cases based on a less extensive toxicity data set and have not been field-validated.

The bioavailability of metals in sediment is addressed by the comparison of the molar concentration of sulfide anions (i.e., acid-volatile sulfide [AVS]) to the molar concentration of metals (i.e., simultaneously extracted metals [SEM]). To apply the [SEM]−[AVS] difference to indicate positive bioavailability and toxicity for this evaluation, EPA used laboratory data that indicated the probability of observed toxic effects at various [SEM]−[AVS] levels. Based on these data, EPA defined the Tier1 level as [SEM]−[AVS] > 5. Thus, this use of [SEM]−[AVS] represents a hybrid of a theoretical approach and a correlative approach. Currently, the [SEM]–[AVS] difference is most usually considered an indicator of when metals are not bioavailable; however, some data have shown that metal bioaccumulation occurs where the [SEM]–[AVS] predicts no adverse effect. Differences in dietary exposures, applicability of equilibrium partitioning theory to sediment assessments, and varying redox conditions in some anaerobic sediment might limit the general applicability of the [SEM]–[AVS] method. Despite these limitations, EPA's Science Advisory Board (SAB, 2000) indicated that the [SEM]–[AVS] method "may be particularly useful to prioritize sites requiring attention ...."

Only those chemicals for which sediment chemistry screening values (i.e., draft ESGs) are available were evaluated in the analysis of NSI data. Therefore, the methodology could not identify contamination associated with chemical classes such as ionic organic compounds (e.g., alkyl phenols) and organometallic complexes (e.g., tributyl tin).

Biological effects correlation approaches like the logistic model are based on the evaluation of paired field and laboratory data that relate adverse biological effects to the dry-weight chemical concentrations for a particular sample. Although the predicted proportion toxic is computed from individual or multiple chemical observations, it does not demonstrate that a particular chemical is solely responsible. In fact, a given sample typically contains a mixture of chemicals that contribute to observed adverse effects to some degree. For this reason, these correlative approaches are better at predicting toxicity in complex mixtures of contaminants in sediment.

Another concern is the application of screening values based on freshwater data (draft ESGs) and those based on saltwater data alone (logistic model) to evaluate sediment contaminant concentrations in the NSI database from both freshwater and saltwater habitats. Freshwater organisms exhibit tolerance to toxic chemicals similar to that of saltwater species when tested in their respective water; however, estuarine organisms might be less tolerant if osmotically stressed (Rand, 1995). Thus, the relative toxicity of a chemical in water (i.e., its chronic threshold water concentration) is usually within an order of magnitude for saltwater and freshwater species, although final chronic values and proposed sediment quality guidelines values are usually slightly higher for saltwater species. Ingersoll et al. (1996) reported similar reliability and predictive ability between marine and freshwater guidelines. The logistic model, as used in this assessment, was developed using only saltwater acute toxicity data.

Additional false positive and false negative classifications of risk to aquatic life from sediment contaminant concentrations could occur when a default value for organic carbon content is applied. Draft ESGs are based on the partitioning of a chemical between organic carbon in the sediment and pore water at equilibrium. Because the organic carbon content of most sediment samples in the NSI database is unknown, these sediment samples were assumed to contain 1 percent organic carbon. TOC can range from 0.1 percent in sandy sediments to 1 to 4 percent in silty harbor sediments and from 10 to 20 percent in navigation channel sediments (Clarke and McFarland, 1991). Long et al. (1995) reported an overall mean TOC concentration of 1.2 percent from data compiled from 350 publications for their biological effects database for sediments. Ingersoll et al. (1996) reported a mean TOC concentration of 2.7 percent with a 95 percent confidence interval of only 0.65 percent. In contrast, the concentration ranges of contaminants normalized to dry-weight typically varied by several orders of magnitude. Therefore, normalizing dry-weight concentrations to a relatively narrow range of TOC concentrations had little influence on relative concentrations of contaminants among samples.

Uncertainty associated with the equilibrium partitioning theory for developing draft ESGs includes the degree to which the equilibrium partitioning model explains the available sediment toxicity data (USEPA, 1993b). An analysis of variance using freshwater and saltwater organisms in water-only and sediment toxicity tests (using different sediments) was conducted to support development of the draft sediment guidelines. This analysis indicated that varying the exposure medium (i.e., water or sediment) resulted in an estimate of variability that should be used for computing confidence limits for the draft ESGs. The methodology used to derive the octanol/water partitioning coefficient and the final chronic value can also influence the degree of uncertainty associated with the draft ESGs. Differences in the response of water column and benthic organisms, as well as limitations in understanding the relationship of individual and population effects to community-level effects, have also been noted (Mancini and Plummer, 1994). Site-specific modifications to screening values derived using the equilibrium partitioning model have been recommended to better address chemical bioavailability and species sensitivities (USEPA, 1993a). Sediment chemistry screening values developed using the equilibrium partitioning approach also do not address possible synergistic, antagonistic, or additive (except in the case of PAHs and metals, as outlined in this chapter and Appendix B) effects of contaminants.

Toxicity Data

Differences in toxicity responses between tube building and burrowing sediment species have been reported in the literature and stem from differences in the degree and type of exposure to sediment contaminants. However, the overall assessment should not be affected to a significant extent by this issue. Both types of species are prevalent members of the benthos across the country and therefore, responses of both types of species is useful in the assessment process. Also, in many of the test methods used, tube-building organisms will be exposed to sediment for some length of time prior to being able to make a tube and so, at least initially, would be exposed to sediment pollutants in a similar manner as burrowing species.

Fish Tissue Screening Values

The approach used to assess sediment chemistry data for the potential for contaminants to accumulate in fish tissue also represents a theoretical approach with field-measured components. In addition to applying a site-specific or default organic carbon content, the TBP calculation includes a field-measured biota-sediment accumulation factor (BSAF) to account for the relative affinity of a chemical for fish tissue lipids or sediment organic carbon. The BSAF will account for the effects of metabolism and biomagnification in the organism in which it is measured. The primary limitation of this approach is the applicability of a field-measured BSAF, or a percentile from a distribution of values, at a variety of sites where the conditions might vary.

TBPs were assumed to be equivalent to levels detectable in fish tissue. However, this approach might not completely account for biomagnification in the food chain, especially when using a BSAF derived from a benthic organism. In addition, it is assumed that sediment does not move, that contaminant sources other than sediment are negligible, that fish migration does not occur, and that exposure is consistent. The TBP calculation assumes that various lipids in different organisms and organic carbon in different sediments are similar and have distributional properties similar to the field-measured values used to derive BSAFs. Other simplifying assumptions are that chemicals are similarly exchanged between the sediments and tissues and that compounds behave alike, independent of site conditions other than organic carbon content. In reality, physical-chemical processes (e.g., diffusion through porous media and sediment mixing) can vary and limit the rate at which chemicals can exchange with bottom sediments. Uptake of contaminants by aquatic organisms is also a kinetic (rate-controlled) process that can vary and be slowed, for example, by awkward passage of a bulky molecule across biological membranes. Also, a BSAF of 1 (thermodynamic equilibrium) was used to estimate TBPs for many nonpolar organics. This BSAF might overestimate or underestimate the bioaccumulative potential for certain nonpolar organic chemicals because it is assumed that there is no metabolic degradation or biotransformation of such chemicals. Site-specific organic carbon content was often not available, leading to additional uncertainty concerning the comparability of BSAFs among different locations. Because of these factors, actual residue levels in fish resulting from direct and/or indirect exposure to contaminated sediment might be higher or lower.

There is therefore uncertainty regarding sampling station classifications based on comparison of estimated TBPs with FDA tolerance/action/guideline levels and EPA risk levels.

TBPs could not be calculated for polar organic compounds or heavy metals. Therefore, sampling stations could not be classified using FDA levels or EPA risk levels for those chemicals using a TBP approach (although fish tissue monitoring data are often available for many stations).

Uncertainties and numerous assumptions are associated with exposure parameters and toxicity data used to derive EPA risk levels and FDA tolerance/action/guideline levels. For example, the derivation of EPA risk levels is based on the assumption that an individual consumes on average 17.5 g/day of fish caught from the same site over a 70-year period. A consumption rate of 17.5 g/d is chosen to be protective of the majority (i.e., 90 percent) of the population (Appendix B). Also, the TBP calculation for human health assessments assumes that fish tissue contains 3 percent lipid. This value is intended to be indicative of the fillet rather than the whole body. Generally, the exposure assumptions and safety factors incorporated into toxicity assessments might overestimate risks to the general population associated with sediment contamination but might underestimate risks to populations of subsistence or recreational fishers and sensitive subpopulations (such as pregnant women, nursing mothers, and children).

Whereas the Tier 1, Tier 2, and Tier 3 evaluation benchmarks established in this report represent recent advances in sediment assessment techniques, they have been used in this report as a way to relate all the different data from all the different sources around the United States using common benchmarks. Therefore, the Tier 1, Tier 2, and Tier 3 benchmarks and interpretations used in this report are not currently appropriate for use in EPA regulatory programs that have developed their own frameworks and regulatory requirements, and they were not designed to be a substitute for the various EPA program regulatory frameworks and/or authorities. EPA's regulatory programs (e.g., Office of Solid Waste and Emergency Response - OSWER) have developed their own scientifically defensible approaches to sediment evaluation based on the needs of their programs, and they will continue to use their current regulatory frameworks when making decisions regarding potentially contaminated sediments (e.g., sediment remediation, sediment disposal).

Other Limitations

Because a numerical score was not assigned to each sampling station to indicate the level of contamination associated with that station, it is not possible to determine which of the stations in Tier 1 should be considered the "most" contaminated. Such a numerical ranking system was intentionally not used for the NSI data evaluation because EPA does not believe that such ranking is appropriate for a screening-level analysis such as this, given the level of uncertainty.

CHAPTER 3
FINDINGS

This chapter presents the results of the evaluation of NSI data based on the methodology described in Chapter 2. This discussion includes a summary of the results of national and regional assessments. These summary results do not include locations with contaminated sediment not identified in the NSI database. The data compiled for the NSI database are primarily from large national electronic databases. Data from many sampling and testing studies have not yet been incorporated into the NSI database. Thus, there are additional locations with sediment contamination that do not appear in this summary. The final section in this chapter evaluates the data used for the first report to Congress by applying the methodology presented in Chapter 2.

National Assessment

EPA evaluated a total of 19,398 sampling stations nationwide as part of the NSI data evaluation (Figure 3-1). The evaluation included data collected from 1990 through 1999. Of the sampling stations evaluated, 8,348 stations (43.0 percent) were classified as Tier 1; 5,846 (30.1 percent) were classified as Tier 2; and 5,204 (26.8 percent) were classified as Tier 3 (Table 3-1). As described in more detail later, the frequency of Tier 1 classification based on the evaluation of all NSI data is greater than that based on the evaluation of data sets derived from purely random sampling. This suggests that state monitoring programs (accounting for most of the NSI data) have tended to focus their sampling efforts on areas where contamination is known or suspected to occur.

The national distribution of Tier 1 sampling stations is illustrated in Figure 3-2. The distribution of Tier 1 stations depicted in Figure 3-2 must be viewed in the context of the distribution of all sampling stations depicted in Figure 3-1. Table 3-1 presents the number of sampling stations in each tier by EPA region. The greater number of Tier 1 and Tier 2 sampling stations in some regions is to some degree a function of a larger set of available data. Although there are 10 times more Tier 1 stations in EPA Region 4 (southeastern states) than in EPA Region 8 (mountain states), there are also 8 times more Tier 3 stations in Region 4.

The NSI database sampling stations were located in 5,695 individual river reaches (Table 3-1) throughout the contiguous United States (based on EPA's River Reach File 1; Bondelid and Hanson, 1990). In the contiguous United States, there are 64,591 reaches representing approximately 1 million miles of coastal shorelines, lake shorelines, or lengths of stream between two major tributaries. NSI database sampling stations were located in about 8.8 percent of all river reaches identified in the contiguous United States (Tables 3-1 and 3-2). Approximately 77.6 percent of the 5,695 reaches had one or two NSI database sampling stations. Less than 4 percent of the 5,695 reaches had more than 10 NSI database sampling stations. About 3.6 percent of all river reaches in the United States contained at least one sampling station classified as Tier 1 (Figure 3-3). Around 2.9 percent of all reaches contained at least one sampling station classified as Tier 2 (but none as Tier 1). In 2.3 percent of reaches in the contiguous United States, all of the sampling stations were classified as Tier 3. EPA has not cataloged river reaches (at the River Reach 1 level) outside the contiguous United States (e.g., Alaska, Hawaii, Puerto Rico), and some sampling stations in the ocean were not linked to a specific reach. Sampling bias toward areas of known or suspected contamination might be more pronounced in some regions than in others and could be related to the relative extent of sampling.

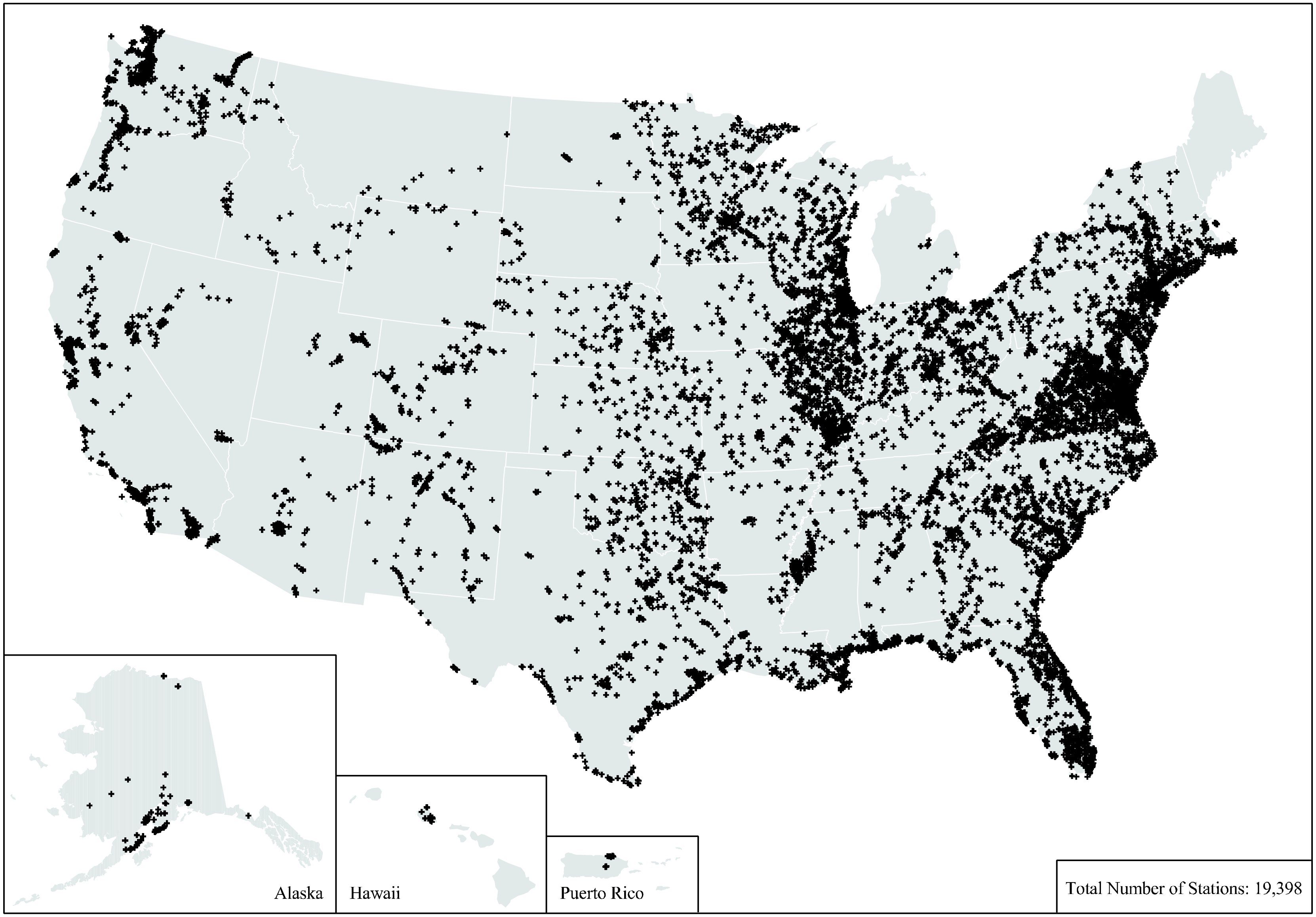

Figure 3-1. Location of All Evaluated Sampling Stations.

Table 3-1. National Assessment: Evaluation Results for Sampling Stations and River Reaches by EPA Region.

	Station Evaluation							River Reach Evaluation[a]							
		Tier 1		Tier 2		Tier 3									
EPA Region (State)	Total Number of Stations Evaluated	No.	%[b]	No.	%[b]	No.	%[b]	No. of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	No. of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
Region 1 (CT, ME, MA, NH, RI, VT)	275	182	66.2	64	23.3	29	10.5	28	97	23	5	125	2,764	4.5	4.3
Region 2 (NJ, NY, PR)	1,255	901	71.8	228	18.2	126	10.0	13	217	102	45	364	1,845	19.7	17.3
Region 3 (DE, DC, MD, PA, VA, WV)	2,428	714	29.4	809	33.3	905	37.3	103	385	313	301	999	3,388	29.5	20.6
Region 4 (AL, FL, GA, KY, MS, NC, SC, TN)	2,874	841	29.3	1,022	35.6	1,011	35.2	15	444	461	301	1,206	10,078	12.0	9.0
Region 5 (IL, IN, MI, MN, OH, WI)	3,185	1,146	36.0	1,095	34.4	944	29.6	—	532	401	316	1,249	6,151	20.3	15.2
Region 6 (AR, LA, NM, OK, TX)	1,489	425	28.5	392	26.3	672	45.1	—	226	222	289	737	7,577	9.7	5.9
Region 7 (IA, KS, MO, NE)	583	134	23.0	239	41.0	210	36.0	—	94	161	136	391	4,915	8.0	5.2
Region 8 (CO, MT, ND, SD, UT, WY)	294	79	26.9	95	32.3	120	40.8	—	59	77	68	204	13,860	1.5	1.0
Region 9 (AZ, CA, HI, NV)	1,752	1,040	59.4	429	24.5	283	16.2	18	156	63	40	259	4,686	5.5	4.7
Region 10 (AK, ID, OR, WA)	5,263	2,886	54.8	1,473	28.0	904	17.2	290	177	121	49	347	10,462	3.3	2.8
Total for United States[e]	19,398	8,348	43.0	5,846	30.1	5,204	26.8	467	2,298	1,891	1,506	5,695	64,591	8.8	6.5

[a] River reaches based on EPA River Reach File (RF1). RF1 does not include data outside the contiguous United States.

[b] Percent of all NSI stations evaluated in the region.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one region, the total number of reaches in each category for the country might not equal the sum of reaches in the regions.

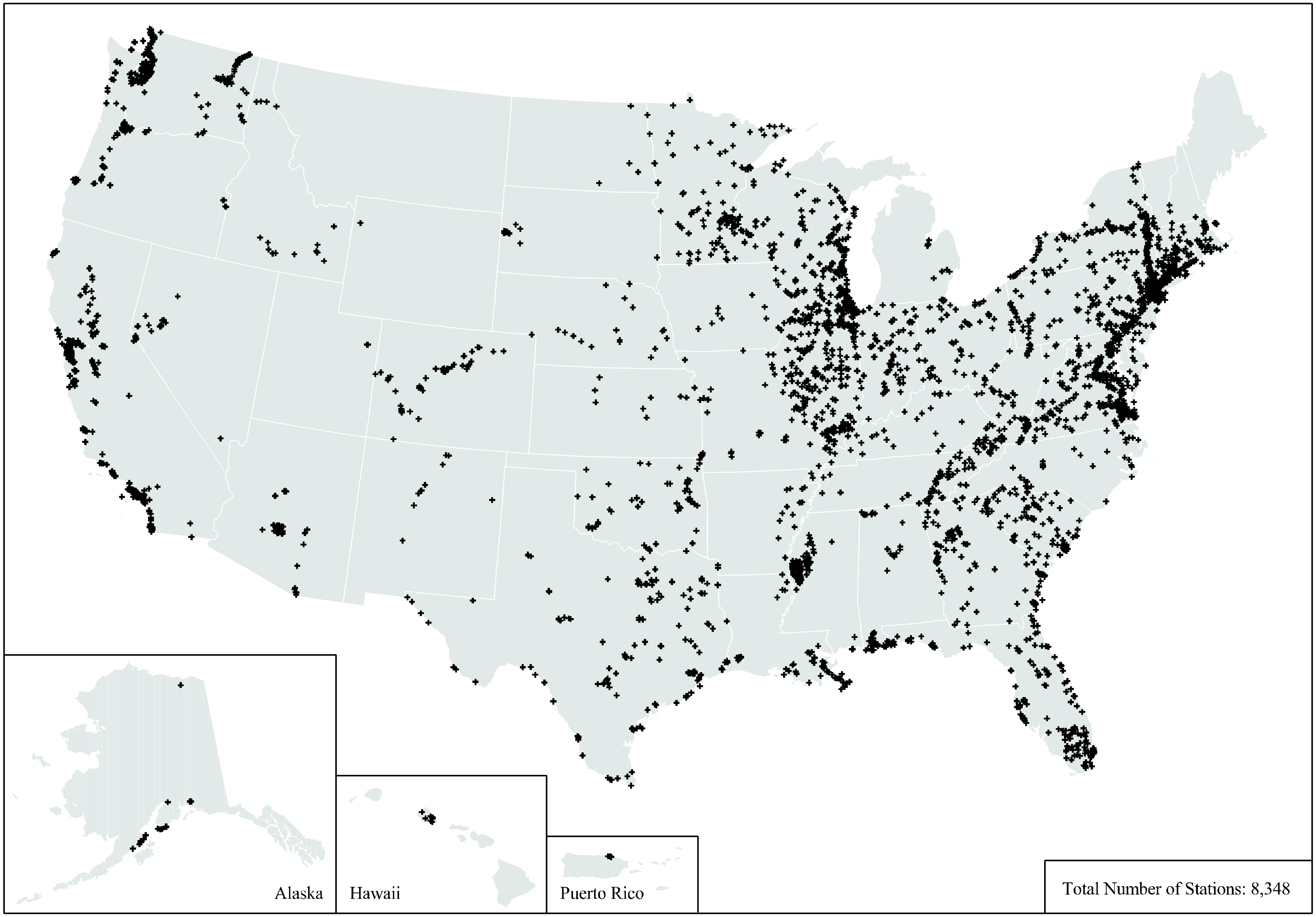

Figure 3-2: Sampling Stations Classified as Tier 1 (Associated Adverse Effects Are Probable).

Table 3-2. Regions 1–10: River Reach and Watershed Evaluation Summary.

EPA Region (State)	River Reach Evaluation[a]					Watershed Evaluation					
	Total Number of River Reaches	River Reaches With at Least One Tier 1 Station	River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	River Reaches With All Tier 3 Stations	River Reaches With No Data	Total Number of Watersheds	Watersheds Containing APCs	Watersheds With at Least One Tier 1 Station	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	Watersheds With all Tier 3 Stations	Watersheds With No Data
Region 1 (CT, ME, MA, NH, RI, VT)	2,764	97 (3.5%)	23 (0.8%)	5 (0.2%)	2,639 (95.5%)	62	9 (14.5%)	13 (21.0%)	6 (9.7%)	0 (0.0%)	34 (54.8%)
Region 2 (NJ, NY, PR)	1,845	217 (11.8%)	102 (5.5%)	45 (2.4%)	1,481 (80.3%)	71	17 (23.9%)	35 (49.3%)	3 (4.2%)	3 (4.2%)	13 (18.3%)
Region 3 (DE, DC, MD, PA, VA, WV)	3,388	385 (11.4%)	313 (9.2%)	301 (8.9%)	2,389 (70.5%)	126	7 (5.6%)	96 (76.2%)	11 (8.7%)	4 (3.2%)	8 (6.3%)
Region 4 (AL, FL, GA, KY, MS, NC, SC, TN)	10,078	444 (4.4%)	461 (4.6%)	301 (3.0%)	8,872 (88.0%)	307	13 (4.2%)	142 (46.3%)	57 (18.6%)	25 (8.1%)	70 (22.8%)
Region 5 (IL, IN, MI, MN, OH, WI)	6,151	532 (8.6%)	401 (6.5%)	316 (5.1%)	4,902 (79.7%)	278	25 (9.0%)	144 (51.8%)	31 (11.2%)	19 (6.8%)	59 (21.2%)
Region 6 (AR, LA, NM, OK, TX)	7,577	226 (3.0%)	222 (2.9%)	289 (3.8%)	6,840 (90.3%)	402	4 (1.0%)	117 (29.1%)	69 (17.2%)	44 (10.9%)	168 (41.8%)
Region 7 (IA, KS, MO, NE)	4,915	94 (1.9%)	161 (3.3%)	136 (2.8%)	4,524 (92.0%)	238	1 (0.4%)	60 (25.2%)	72 (30.3%)	29 (12.2%)	76 (31.9%)
Region 8 (CO, MT, ND, SD, UT, WY)	13,860	59 (0.4%)	77 (0.6%)	68 (0.5%)	13,656 (98.5%)	385	1 (0.3%)	34 (8.8%)	41 (10.6%)	31 (8.1%)	278 (72.2%)
Region 9 (AZ, CA, HI, NV)	4,686	156 (3.3%)	63 (1.3%)	40 (0.9%)	4,427 (94.5%)	288	19 (6.6%)	41 (14.2%)	19 (6.6%)	15 (5.2%)	194 (67.4%)
Region 10 (AK, ID, OR, WA)	10,462	177 (1.7%)	121 (1.2%)	49 (0.5%)	10,115 (96.7%)	355	10 (2.8%)	48 (13.5%)	29 (8.2%)	21 (5.9%)	247 (69.6%)
Total for United States[b]	64,591	2,298 (3.6%)	1,891 (2.9%)	1,506 (2.3%)	58,896 (91.2%)	2,264	96 (4.2%)	658 (29.1%)	302 (13.3%)	168 (7.4%)	1,040 (45.9%)

[a] River reaches based on EPA River Reach File (RF1). RF1 does not include data outside the contiguous United States.

[b] Because some reaches and watersheds occur in more than one region, the total number of reaches and watersheds in each category for the country might not equal the sum of reaches or watersheds in the regions.

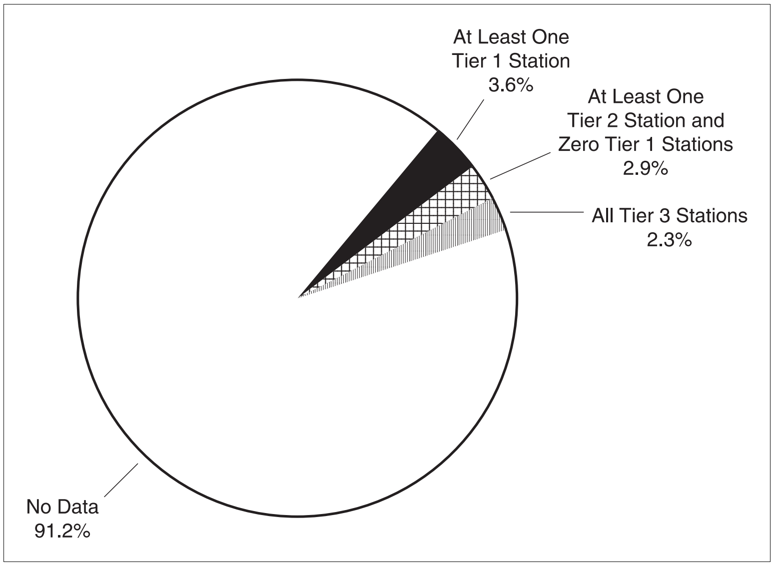

Figure 3-3. National Assessment: Percent of River Reaches that Include Tier 1, Tier 2, and Tier 3 Sampling Stations.

Not all sampling programs target only sites of known or suspected contamination. The NSI database includes data from EPA's Environmental Monitoring and Assessment Program (EMAP), which uses a probabilistic sampling design; that is, the sampling locations are randomly selected. The percentage of sampling stations placed in each tier based on these data alone differs considerably from the percentage of sampling stations in each tier based on an evaluation of all the data in the NSI database. Smaller percentages of EMAP sampling stations are categorized as Tier 1 (33.4 percent for EMAP compared to 43.0 percent for all NSI database sampling stations), greater percentages are categorized as Tier 2 (41.9 percent for EMAP compared to 30.1 percent for all NSI database stations), and comparable percentages are categorized as Tier 3 (24.8 percent for EMAP and 26.8 overall). For comparison, the NSI database also contains data from the National Oceanic and Atmospheric Administration's National Status and Trends Program (NS&T). The NS&T does not target known or suspected contaminated sites. Greater percentages of NS&T sampling stations are categorized as Tier 1 (55.5 percent for NS&T compared to 43.0 percent for all NSI database sampling stations), similar percentages are categorized as Tier 2 (32.9 percent for NS&T compared to 30.1 percent for all NSI database stations), and smaller percentages are categorized as Tier 3 (11.6 percent for NS&T compared to 26.8 percent for all NSI database stations). These differences might also reflect the lower detection limits of more sensitive analytical chemistry techniques, the sensitivity of Tier 2 evaluation parameters, and the nearly ubiquitous presence of low to intermediate levels of contamination in the areas sampled by these programs.

Table 3-3 presents the number of sampling stations categorized by tier for the different evaluation parameters described in Table 2-2 and organized by aquatic life and human health effects. Most stations (87.9 percent) are evaluated using the logistic regression model. Nearly 75 percent of the stations are evaluated using the sediment-based human health assessment. The draft ESG and draft PAH toxicity unit analyses are applied to 65.2 and 48.7 percent of the stations, respectively. The reduced percentages of NSI database stations evaluated with the draft ESG and draft PAH toxicity unit analyses can typically be tied to the absence of analytical results for the appropriate organic chemicals (i.e., PAHs), which might be typical of monitoring programs that targeted metals or PCBs. Only 17.8 percent of the stations were evaluated using sediment toxicity analysis.

Table 3-3. Tier Classification Summary.

Tier Evaluation Parameter	Table 2-2 Evaluation Parameter Reference	Number of Stations			
		Total	Tier 1	Tier 2	Tier 3
Aquatic Life Assessment					
Draft ESG analysis	**1, 7**	12,649	69	228	12,352
SEM analysis	**2, 8**	739	10	205	524
Logistic regression model analysis	**3, 9**	17,056	4,513	6,415	6,128
Draft PAH toxicity unit analysis	**4, 10**	9,442	545	1,144	7,753
Toxicity analysis	**15, 17**	3,446	745	858	1843
Toxicity demonstrated in two or more species classified as Tier 2	**16**	n/a	54	n/a	n/a
Human Health Assessment					
Sediment chemistry TBP exceeds EPA's human health cancer risk of 10^{-4} or a noncancer hazard quotient (HQ) of 10	**5**	14,484	5,372	n/a	n/a
Sediment chemistry TBP exceeds EPA's human health cancer risk of 10^{-5} or a noncancer HQ of 1, or FDA's tolerance/action/guidance levels	**11**		n/a	3,236	5,876
Tissue levels of chemicals with a log $K_{ow} \geq 5.5$ in samples that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels	**12**	2,364	1,133	n/a	n/a
Tissue levels of chemicals with a log $K_{ow} < 5.5$ in samples that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels	**14**		n/a	563	668
Tissue levels and sediment chemistry TBP of chemicals with a log $K_{ow} < 5.5$ in samples that exceed EPA's human health cancer risk of 10^{-5}, a noncancer HQ of 1, or FDA's tolerance/action/guidance levels	**6 and 13**	n/a	46	n/a	n/a
Total[a]		19,398	8,348	5,846	5,204

[a] Because stations might be evaluated by more than one criterion, the sum of the number of stations evaluated under each criterion might not be equal to the total number of stations.

Many of the 19,398 evaluated stations were assessed using more than one of the evaluation parameters. About 38 percent of the stations classified as Tier 1 (3,171 stations) were classified as Tier 1 based on more than one of the evaluation parameters. About 31 percent of the stations classified as Tier 2 (1,817 stations) were classified as Tier 2 based on more than one of the evaluation parameters. Of the remaining 5,177 stations classified as Tier 1 based on only one evaluation parameter, 1,597 stations were classified as Tier 1 based on the logistic regression model, 2,286 stations were classified as Tier 1 based on the sediment chemistry TBP's exceeding risk levels, and 980 stations were classified as Tier 1 based on tissue risk levels. Of the remaining 4,029 stations classified as Tier 2 based on only one evaluation parameter, 2,389 were classified as Tier 2 based on the logistic regression model and 1,042 were classified as Tier 2 based on the sediment chemistry TBP's exceeding risk levels. About 62 of the stations classified as Tier 3 were classified as Tier 3 based on more than one evaluation parameter. Of the remaining 1,970 stations classified as Tier 3 based on only one evaluation parameter, 1,161 were classified as Tier 3 based on the logistic regression model and 530 stations were classified as Tier 3 based on the sediment chemistry TBP's not exceeding risk levels. Overall, fewer stations were classified as Tier 1 using aquatic life evaluation parameters (5,006 stations) than were classified using human health evaluation parameters

(6,385 stations). Of the stations classified as Tier 2, 4,439 stations were classified as Tier 2 using aquatic life evaluation parameters and 3,131 stations were classified as Tier 2 using human health evaluation parameters. Additionally, the chemicals most often associated with Tier 1 designation using both sediment chemistry TBP and tissue residue evaluation parameters were determined. Based on tissue residue data, PCBs, DDTs, chlordane, dioxins, and hexachlorobenzene are the leading chemicals associated with Tier 1 designation looking at probable adverse effects to human health in this report. Looking at sediment chemistry TBP evaluation parameters also for probable adverse effects to human health, PAHs, PCBs, DDTs, dieldrin, and dioxins are the leading chemicals associated with Tier 1 designation in this report. It is important to note that this report, as stated earlier, provides a screening-level assessment that identifies potential problems for further study. A screening-level analysis typically identifies problems that prove not to be significant upon further analysis. Therefore, further studies (e.g., risk assessment, toxicological evaluations) would need to be conducted to determine whether sediment contaminants are resulting in adverse effects to aquatic life and/or human health as well as the cause(s) of those adverse effects.

Two important issues in interpreting the results of sampling station classification are naturally occurring “background” levels of chemicals and the effect of chemical mixtures. Site-specific naturally occurring (or background) levels of chemicals might be an important risk management consideration in examining sampling station classification. This is most often an issue for naturally occurring chemicals like metals and PAHs. In addition, although the sediment chemistry screening levels for individual chemicals are used as indicators of potential adverse biological effects, other co-occurring chemicals (which might or might not be measured) can cause or contribute to any observed adverse effect at specific locations.

To help judge the effectiveness of the NSI data evaluation approach, EPA examined the agreement between sediment chemistry and toxicity test results for the 2,999 NSI database sampling stations where toxicity data existed so sediment chemistry data for aquatic health could be evaluated. The toxicity test data indicate whether significant lethality to indicator organisms occurs as a result of exposure to sediment. About two-thirds (67.9 percent) of the stations classified as Tier 1 based on aquatic life effects from sediment chemistry data evaluation were classified as Tier 1 or 2 based on toxicity test results. About 43.6 percent of the stations classified as Tier 2 based on aquatic life effects from sediment chemistry data were classified as Tier 1 or 2 based on toxicity test results. Less than one-fourth (23.4 percent) of the stations classified as Tier 3 based on aquatic life effects from sediment chemistry data were classified as Tier 1 or 2 based on toxicity test results. These results are generally consistent with the range of predicted proportion toxic used to classify a station as Tier 1, 2, or 3. The results also demonstrate, in part, the differing sensitivities of varying test organisms and endpoints.

During an initial screening of the NSI data, EPA noted data quality problems that might have affected all or many of the data reported in a given database. The data review process included steps to review the incoming data for consistency. The steps included confirmation of metadata such as sample date, qualifying codes, chemicals analyzed, and range checks. Typical problems encountered included the reporting of multiple results for a single chemical, inconsistent reporting units, the absence of remark codes, and inconsistencies between tables that reported sample-level information and chemical results. Databases with obvious quality problems were not included in the NSI data evaluation. Also, if a database included in the NSI database did not have associated locational information (latitude/longitude), data in that database were not included in the NSI data evaluation. Other data were organized in a manner that prevented simple electronic manipulation or were not provided in an electronic format, precluding their use in this assessment. In general, these data were associated with small geographic areas. It is likely that this data exclusion led to not identifying certain Tier 1 and 2 stations, and possibly additional APCs. It is also likely that this data exclusion led to not identifying certain Tier 3 stations as well. However, it is not likely that this data exclusion would have substantively changed the conclusions and discussion presented in this report.

Watershed Assessment

The potential risk of adverse effects to aquatic life and human health is greatest in areas with a multitude of contaminated locations. The assessment of individual sampling stations is useful for estimating the number and distribution of contaminated spots and the overall magnitude of sediment contamination in monitored waterbodies of the United States. However, a single "hot spot" might not pose a great threat to either the benthic community at large or consumers of resident fish because the spatial extent of exposure could be small. On the other hand, if many contaminated spots are located in close proximity, the spatial extent and probability of exposure are much greater. EPA examined sampling station classifications within watersheds to identify areas of probable concern for sediment contamination (APCs), where the exposure of benthic organisms and resident fish to contaminated sediment might be likely. In this report, EPA defines watersheds by 8-digit U.S. Geological Survey (USGS) hydrologic unit codes (cataloging units), which are roughly the size of a county. In the United States and Puerto Rico, there are 2,264 watersheds.

Watersheds containing APCs are those which include at least 10 Tier 1 sampling stations and in which at least 75 percent of all sampling stations were classified as either Tier 1 or Tier 2. The definition of an APC requires that a watershed include at least 10 sampling stations because at least 10 must be classified as Tier 1. About 16.3 percent of the watersheds (370 of 2,264) met this requirement and thus were eligible to contain an APC. These dual criteria were based on empirical observation of the data in the first *National Sediment Quality Survey* report to Congress and are maintained for this evaluation. The definition of *area of probable concern* was developed to identify watersheds for which further study of the effects and sources of sediment contamination, and possible risk reduction needs, would be warranted. Where data have been generated through intensive sampling in areas of known or suspected contamination in a watershed, the APC definition should identify watersheds that contain even relatively small areas that are considerably contaminated. This designation does not imply, however, that sediment throughout the entire watershed, which is typically very large compared to the extent of available sampling data, is contaminated. For example, the Lower Mississippi–New Orleans watershed has been identified as containing an APC. This designation is due to multiple Tier 1 stations identified in the lower Mississippi River rather than in the Mississippi River delta and nearshore areas. The delta and the nearshore areas are reported as one of the largest and documented healthy commercial and recreation fisheries in North America (Bob Engler, USACE/ERDC, personal communication, March 1, 2002), and they have only three Tier 1 stations, which by themselves would not qualify as an APC. On the other hand, where data have been generated through comprehensive sampling, or where sampling stations were selected randomly or evenly distributed throughout a sampling grid, the APC definition might not identify watersheds that contain small or sporadically contaminated areas. A comprehensively surveyed watershed of the size typically delineated by a USGS cataloging unit might contain small but significant areas that are considerably contaminated but might be too large in total area for 75 percent of all sampling stations to be classified as Tier 1 or Tier 2. In addition, limited random or evenly distributed sampling within such a watershed might not yield 10 Tier 1 sampling stations. Thus, the process used to identify watersheds containing APCs might include some watersheds with limited areas of contamination and omit some watersheds with significant contamination. Given available data, however, EPA has concluded that the process represents a reasonable screening analysis to identify watersheds where further study is warranted. NSI database sampling stations are located in 1,224 of the 2,264 watersheds, or approximately 54.1 percent of the total number of watersheds. The application of the above procedure identified 96 watersheds that contain APCs. These watersheds represent about 4.2 percent of all watersheds (96 of 2,264). The watershed analysis also indicated that 29.1 percent of all watersheds contain at least one Tier 1 sampling station, 13.3 percent contain at least one Tier 2 sampling station but no Tier 1 stations, and 7.4 percent contain all Tier 3 sampling stations (Figure 3-4). About 45.9 percent of all watersheds in the country did not include a sampling station. Table 3-4 provides a list of all watersheds that contain an

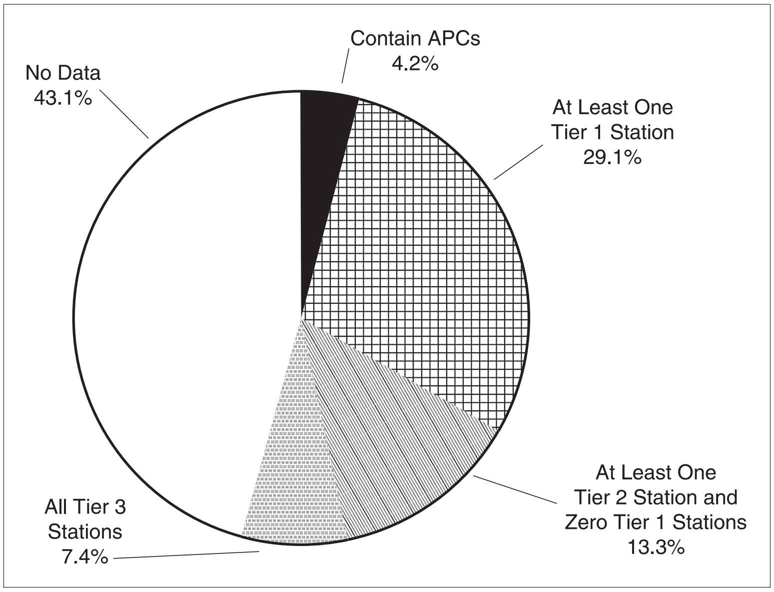

Figure 3-4. National Assessment: Watershed Classification.

APC. The location of these watersheds is shown on Figure 3-5. The name and cataloging unit number on Table 3-4 correspond to the labels on Figure 3-5.

Of the 370 watersheds with enough stations to potentially contain an APC, 25.9 percent (96 of 370) contained an APC. To some extent, the sampling effort does contribute to the number of Tier 1 stations. A simple statistical regression analysis of total number of sampling stations versus number of Tier 1 sampling stations for the 370 watersheds eligible to contain an APC (including at least 10 and up to 200 sampling stations) resulted in a statistically significant correlation coefficient (R-square) of 0.67. When a regression analysis of total number of sampling stations versus percentage of Tier 1 and Tier 2 stations is performed, however, the resulting correlation coefficient is 0.02, which indicates no correlation. Because of these dual criteria, the sampling effort does not overly contribute to APC designation. Of the 96 watersheds, 55 watersheds would have been identified as containing an APC if only aquatic life evaluation parameters had been evaluated. Sixty of the 96 watersheds containing an APC would have been identified if only human health evaluation parameters had been used. Thirty-six of these watersheds are in common. Seventeen of the 96 watersheds would not have been identified at all.

Table 3-4. USGS Cataloging Unit Numbers and Names for Watersheds Containing APCs.

Map No.	Cataloging Unit Number	Cataloging Unit Name	Map No.	Cataloging Unit Number	Cataloging Unit Name
1	01080205	Lower Connecticut	49	07120001	Kankakee
2	01090001	Charles	50	07120002	Iroquois
3	01090004	Narragansett	51	07120003	Chicago
4	01100004	Quinnipiac	52	07120004	Des Plaines
5	01100005	Housatonic	53	07120005	Upper Illinois
6	01100006	Saugatuck	54	07120006	Upper Fox
7	01100007	Long Island Sound	55	07120007	Lower Fox
8	02020003	Hudson-Hoosic	56	07130001	Lower Illinois-Senachwine Lake
9	02020004	Mohawk	57	07130003	Lower Illinois-Lake Chautauqua
10	02020006	Middle Hudson	58	07130007	South Fork Sangamon
11	02020008	Hudson-Wappinger	59	07130011	Lower Illinois
12	02030101	Lower Hudson	60	07130012	Macoupin
13	02030102	Bronx	61	08030207	Big Sunflower
14	02030103	Hackensack-Passaic	62	08030209	Deer-Steele
15	02030104	Sandy Hook-Staten Island	63	08090100	Lower Mississippi-New Orleans
16	02030105	Raritan	64	11070209	Lower Neosho
17	02030201	Northern Long Island	65	12030102	Lower West Fork Trinity
18	02030202	Southern Long Island	66	12090205	Austin-Travis Lakes
19	02040202	Lower Delaware	67	14010002	Blue
20	02040205	Brandywine-Christina	68	15060106	Lower Salt
21	02060003	Gunpowder-Patapsco	69	16050203	Carson Desert
22	02060004	Severn	70	17020001	Franklin D. Roosevelt Lake
23	02080107	York	71	17080001	Lower Columbia-Sandy
24	03050201	Cooper	72	17090012	Lower Willamette
25	03050202	South Carolina Coastal	73	17100102	Queets-Quinault
26	03060109	Lower Savannah	74	17100105	Grays Harbor
27	03070203	Cumberland-St. Simons	75	17110002	Strait Of Georgia
28	03100206	Tampa Bay	76	17110012	Lake Washington
29	03130002	Middle Chattahoochee-Lake Harding	77	17110013	Duwamish
30	03140105	Pensacola Bay	78	17110019	Puget Sound
31	03160205	Mobile Bay	79	18010102	Mad-Redwood
32	04030108	Menominee	80	18020112	Sacramento-Upper Clear
33	04030204	Lower Fox	81	18040005	Lower Cosumnes-Lower Mokelumne
34	04040001	Little Calumet-Galien	82	18050001	Suisun Bay
35	04040002	Pike-Root	83	18050002	San Pablo Bay
36	04120101	Chautauqua-Conneaut	84	18050003	Coyote
37	04140201	Seneca	85	18050004	San Francisco Bay
38	05060001	Upper Scioto	86	18060006	Central Coastal
39	05120106	Tippecanoe	87	18060011	Alisal-Elkhorn Sloughs
40	05120201	Upper White	88	18070103	Calleguas
41	05120208	Lower East Fork White	89	18070104	Santa Monica Bay
42	06010201	Watts Bar Lake	90	18070106	San Gabriel
43	06010205	Upper Clinch	91	18070201	Seal Beach
44	06020001	Middle Tennessee-Chickamauga	92	18070203	Santa Ana
45	07040001	Rush-Vermillion	93	18070204	Newport Bay
46	07080101	Copperas-Duck	94	18070301	Aliso-San Onofre
47	07090005	Lower Rock	95	18070304	San Diego
48	07090007	Green	96	19020201	Eastern Prince William Sound

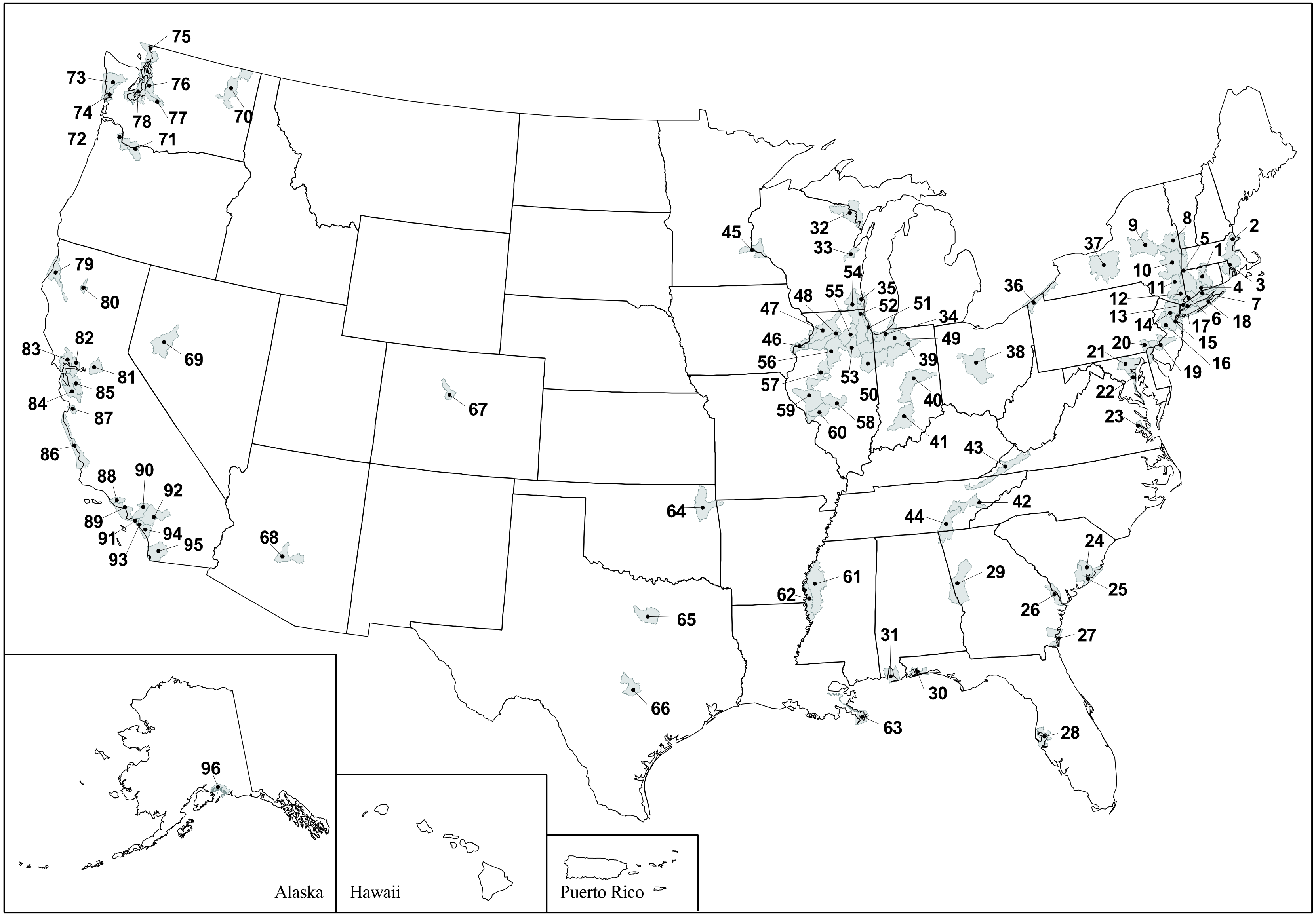

Figure 3-5. Watersheds Identified as Containing APCs.

APC designation within a watershed could result from either expansive sampling throughout a watershed or intensive sampling at a single contaminated location or a few such locations. In comparison to the overall results presented in Figure 3-3, sampling stations are located on an average of 34.1 percent of the reaches in watersheds containing APCs. On the average, 23.9 percent of reaches in watersheds containing APCs have at least one Tier 1 sampling station and 7.9 percent have no Tier 1 sampling station but at least one Tier 2 sampling station. In many of these watersheds, contaminated areas may be concentrated in specific river reaches in a watershed. Within the 96 watersheds containing APCs across the country, 97 individual river reaches or waterbody segments have 10 or more Tier 1 sampling stations (Table 3-5). These are localized areas in the watershed for which an abundance of evidence indicates potentially severe contamination. Because EPA's Reach File 1 was used to index the location of NSI database sampling stations, some sampling stations might not actually occur on the identified Reach File 1 stream, but rather on a smaller stream that is hydrologically linked or is relatively close to the Reach File1 stream.

The first report to Congress (USEPA, 1997) identified 96 watersheds with areas of probable concern (APCs) based on data collected from 1980 through 1993. Using the updated methodology described in Chapter 2 and the same APC definition, this second report identified 96 watersheds containing an APC based on data collected from 1990 through 1999. Appendix F compares the watersheds identified in the reports. Thirty-seven watersheds were identified in both reports as containing an APC because data were available on these watersheds from both time periods, 1980 through 1993 and 1990 through 1999. Of the remaining 59 watersheds with an APC in the previous report to Congress, 26 of the watersheds had fewer than 10 total monitoring stations with data evaluated, 26 watersheds had fewer than 10 Tier 1 stations, and 7 watersheds had less than 75 percent of the analyzed stations classified as Tier 1 or Tier 2 in the current report. Of the remaining 59 watersheds with an APC in the current analysis, 19 of the watersheds had fewer than 10 total monitoring stations with data evaluated, 36 watersheds had fewer than 10 Tier 1 stations, and 4 watersheds had less than 75 percent of the analyzed stations classified as Tier 1 or Tier 2 in the previous report to Congress. Appendix F also presents a detailed listing and geographical location of the watersheds summarized in the appendix. As indicated above, this disparity could be due to a lack of data collected in those watersheds identified as containing an APC in the first report but not containing an APC in this report. This difference could also be due to different stations' being evaluated in those watersheds that resulted in the APC designation in the first report than were evaluated in the same watersheds in the current report, and not designated as containing an APC in this report. Therefore, it should not be inferred that there are no ecological or human health impacts due to contaminated sediments for the stations located in watersheds that were designated as containing APCs in the first report but are not designated as such in this first update. Additional analysis should be conducted to determine the degree of impact due to contaminated sediments.

Contaminated Sediment CERCLA Sites and Their Relationship to Report Findings

Table 3-6 and Figures 3-6 and 3-7 present the name and location of 66 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund) sites in the United States where the risks to human health and/or the environment are unacceptable because of sediment contamination and for which, as of September 30, 2002, EPA has issued a Record of Decision (ROD) or Action Memo that describes the sediment remedy necessary to mitigate those risks. The table and figures do not include all sites where a sediment cleanup decision has been made, but only those that the CERCLA program has classified as Tier 1 sites. These Tier 1 CERCLA sites (not to be confused with the Tier 1 sampling stations identified in this report) are sites where the sediment action will address at least 10,000 cubic yards of contaminated sediment or an area of at least 5 acres. The CERCLA program will continue to track the progress at these sites to evaluate the effectiveness of the selected remedy and will

Table 3-5. River Reaches with 10 or More Tier 1 Sampling Stations Located in Watersheds Containing APCs.

Cataloging Unit Number	Cataloging Unit Name	RF1 Reach ID	RF1 Reach Name	Number of Tier 1 Stations	Total Number of Stations in Reach
01090001	Charles	01090001022	Boston Bay	16	32
02020003	Hudson-Hoosic	02020003031	Hudson River	16	16
		02020003056	Hudson River	16	16
		02020003057	Hudson River	29	33
		02020003078	Hudson River	67	67
02020008	Hudson-Wappinger	02020008031	Hudson River	12	12
02030101	Lower Hudson	02030101009	Hudson River	10	10
		02030101039	Hudson River	11	11
02030102	Bronx	02030102001	Long Island Sound	26	27
02030103	Hackensack-Passaic	02030103001	Hackensack River	17	21
		02030103010	Passaic River	105	106
		02030103023	Rockaway River	11	19
02030104	Sandy Hook-Staten Island	02030104001	Upper New York Bay	36	39
		02030104002	Newark Bay	62	74
		02030104004	Staten Island	24	29
02030201	Northern Long Island	02030201001	Upper Bay	10	11
		02030201003	Long Island Sound	17	17
		02030201004	Long Island Sound	10	11
		02030201005	Long Island Sound	15	18
02030202	Southern Long Island	02030202028	Jamaica Bay	31	41
02040205	Brandywine-Christina	02040205011	Christina River	71	147
		02040205013	Red Clay Creek	11	15
02060004	Severn	02060004002	Severn River	15	22
		02060004004	South River	15	22
03050201	Cooper	03050201030	Cooper River	18	27
		03050201034	Cooper River	11	12
03050202	South Carolina Coastal	03050202010	Ashley River	25	25
03100206	Tampa Bay	03100206009	Hillsborough Bay	28	34
		03100206019	Tampa Bay	11	14
03140105	Pensacola Bay	03140105011	Pensacola Bay	17	27
04030108	Menominee	04030108001	Menominee River	12	12
04040002	Pike-Root	04040002002	Lake Michigan	32	46
07080101	Copperas-Duck	07080101007	Mississippi River	12	14
		07080101008	Mississippi River	48	58
		07080101009	Mississippi River	12	19
		07080101020	Duck Creek	16	17
07090007	Green	07090007005	Green River	11	23
07120003	Chicago	07120003001	Chicago Sanitary Ship Canal	17	20
07120004	Des Plaines	07120004011	Des Plains River	13	23
		07120004016	Salt Creek	12	16
07120006	Upper Fox	07120006011	Fox River	10	14
08030207	Big Sunflower	08030207005	Big Sunflower River	14	14

Table 3-5. (Continued)

Cataloging Unit Number	Cataloging Unit Name	RF1 Reach ID	RF1 Reach Name	Number of Tier 1 Stations	Total Number of Stations in Reach
08030209	Deer-Steele	08030209003	Black Bayou	18	19
08090100	Lower Mississippi-New Orleans	08090100004	Mississippi River	18	18
12030102	Lower West Fork Trinity	12030102049	Mountain Creek Lake	11	12
12090205	Austin-Travis Lakes	12090205004	Colorado River	13	13
15060106	Lower Salt	15060106001	Salt River	20	28
		15060106026	Cave Creek	19	24
17080001	Lower Columbia-Sandy	17080001009	Columbia River	11	49
17090012	Lower Willamette	17090012017	Willamette River	54	97
		17090012018	Willamette River	42	49
		17090012019	Willamette River	125	197
		17090012026	Columbia Slough	11	26
17100102	Queets-Quinault	17100102040	Matheny Creek	50	74
		17100102042	Sams River	27	34
17100105	Grays Harbor	17100105022	Big Creek	86	86
		17100105025	Humptulips River, East Fork	14	14
17110002	Strait Of Georgia	17110002019	Bellingham Bay	71	104
		17110002022	Bellingham Bay	58	114
		17110002030	Strait Of Georgia	22	61
		17110002038	Fidalgo Island	12	43
17110012	Lake Washington	17110012001	Lake Washington Ship Canal	69	74
		17110012003	Lake Union	58	59
		17110012004	Lake Union	14	14
		17110012009	Lake Washington	24	45
17110013	Duwamish	17110013001	Duwamish Waterway	82	130
		17110013003	Elliot Bay	498	745
		17110013005	Green River	12	15
17110019	Puget Sound	17110019022	Sinclair Inlet	165	191
		17110019024	Sinclair Inlet	11	30
		17110019068	Budd Inlet	62	130
		17110019081	Chambers Creek	19	20
		17110019084	Puget Sound	31	45
		17110019085	Puget Sound	605	848
		17110019086	Puget Sound	198	257
		17110019087	Puget Sound	83	230
18010102	Mad-Redwood	18010102010	Arcata Bay	12	15
18040005	Lower Cosumnes-Lower Mokelumne	18040005005	Comanche Reservoir	15	36
18050002	San Pablo Bay	18050002002	San Pablo Bay	28	29
		18050002036	San Pablo Bay	14	20
18050004	San Francisco Bay	18050004001	San Francisco Bay	59	66
		18050004038	San Francisco Bay	10	14
		18050004049	San Francisco Bay	33	35

Table 3-5. (Continued)

Cataloging Unit Number	Cataloging Unit Name	RF1 Reach ID	RF1 Reach Name	Number of Tier 1 Stations	Total Number of Stations in Reach
18060006	Central Coastal	18060006015	Charro Creek	19	20
18070103	Calleguas	18070103009	Pacific Ocean	18	18
18070104	Santa Monica Bay	18070104001	Pacific Ocean	51	62
		18070104002	Dominguez Channel	13	13
		18070104003	Pacific Ocean	35	46
		18070104005	Pacific Ocean	10	10
18070106	San Gabriel	18070106021	Pacific Ocean	17	26
18070201	Seal Beach	18070201001	Pacific Ocean	38	59
18070203	Santa Ana	18070203001	Santa Ana River	27	85
18070204	Newport Bay	18070204002	San Diego Creek	15	23
		18070204005	Pacific Ocean	10	32
18070304	San Diego	18070304001	Pacific Ocean	41	49
		18070304008	San Diego Bay	13	19
		18070304014	San Diego Bay	139	169

Table 3-6. Contaminated Sediment CERCLA Sites.

Map ID	CERCLA Site	EPA Region	State
1	GE - Housatonic River	1	MA
2	Hocomonco Pond	1	MA
3	New Bedford	1	MA
4	Nyanza Chemical Waste Dump	1	MA
5	Sullivan's Ledge	1	MA
6	Loring Air Force Base	1	ME
7	Newport Naval Education & Training Center	1	RI
8	Pine Street Canal	1	VT
9	Burnt Fly Bog	2	NJ
10	Chemical Insecticide Corp.	2	NJ
11	Chemical Leaman Tank Lines, Inc.	2	NJ
12	Lipari Landfill	2	NJ
13	Alcoa Aggregation Site (Grasse River, Massena)	2	NY
14	Batavia Landfill	2	NY
15	FMC Corp. (Dublin Road Landfill)	2	NY
16	General Motors (Central Foundry Division) (Massena)	2	NY
17	Hooker (102nd Street)	2	NY
18	Hudson River PCBs	2	NY
19	Love Canal	2	NY
20	Marathon Battery Corp.	2	NY
21	Onondaga Lake	2	NY
22	Reynolds Metals Co. (Massena)	2	NY
23	Richardson Hill Road Landfill/Pond	2	NY
24	York Oil Co.	2	NY
25	E.I. du Pont de Nemours & Co., Inc. (Newport Pigment Plant Landfill)	3	DE

Table 3-6. (Continued)

Map ID	CERCLA Site	EPA Region	State
26	Halby Chemical Co.	3	DE
27	Metal Banks	3	PA
28	Dixie Caverns County Landfill	3	VA
29	Stauffer Chemical Co. (Cold Creek Plant)	4	AL
30	Triana/Tennessee River	4	AL
31	Koppers Co., Inc. (Charleston Plant)	4	SC
32	Sangamo Weston, Inc./Twelve-Mile Creek/Lake Hartwell PCB Contamination	4	SC
33	Ross Metals Inc.	4	TN
34	Outboard Marine Corp.	5	IL
35	Sangamo Electric Dump/Crab Orchard National Wildlife Refuge (USDOI)	5	IL
36	Yeoman Creek Landfill	5	IL
37	Allied Paper, Inc./Portage Creek/Kalamazoo River	5	MI
38	Ford Motor Co. (Monroe-River Raisin-Ford Outfall)	5	MI
39	Manistique River/Harbor	5	MI
40	Velsicol Chemical Corp. (Michigan)	5	MI
41	Fox River	5	WI
42	Sheboygan Harbor & River	5	WI
43	Southern Lakes Trap & Skeet Club	5	WI
44	Bayou Bonfouca	6	LA
45	Cleveland Mill	6	NM
46	Alcoa (Point Comfort)/Lavaca Bay	6	TX
47	Bailey Waste Disposal	6	TX
48	Nahant Marsh	7	IA
49	Eagle Mine	8	CO
50	Rocky Mountain Arsenal (U.S. Army)	8	CO
51	Silver Bow Creek/Butte Area	8	MT
52	Monticello Mill Tailings (U.S. DOE)	8	UT
53	Sharon Steel Corp. (Midvale Tailings)	8	UT
54	Concord Naval Weapons Station	9	CA
55	McCormick & Baxter Creosoting Co.	9	CA
56	Moffett Field Naval Air Station	9	CA
57	United Heckathorn Co.	9	CA
58	Ketchikan Pulp Company	10	AK
59	Bunker Hill (OU3 Coeur d'Alene Basin)	10	ID
60	McCormick & Baxter Creosoting Co. (Portland Plant)	10	OR
61	Commencement Bay, Nearshore/Tide Flats	10	WA
62	Harbor Island (Lead)	10	WA
63	Old Navy Dump/Manchester Laboratory (U.S. EPA/NOAA)	10	WA
64	Pacific Sound Resources	10	WA
65	Puget Sound Naval Shipyard Complex	10	WA
66	Wyckoff Co./Eagle Harbor	10	WA

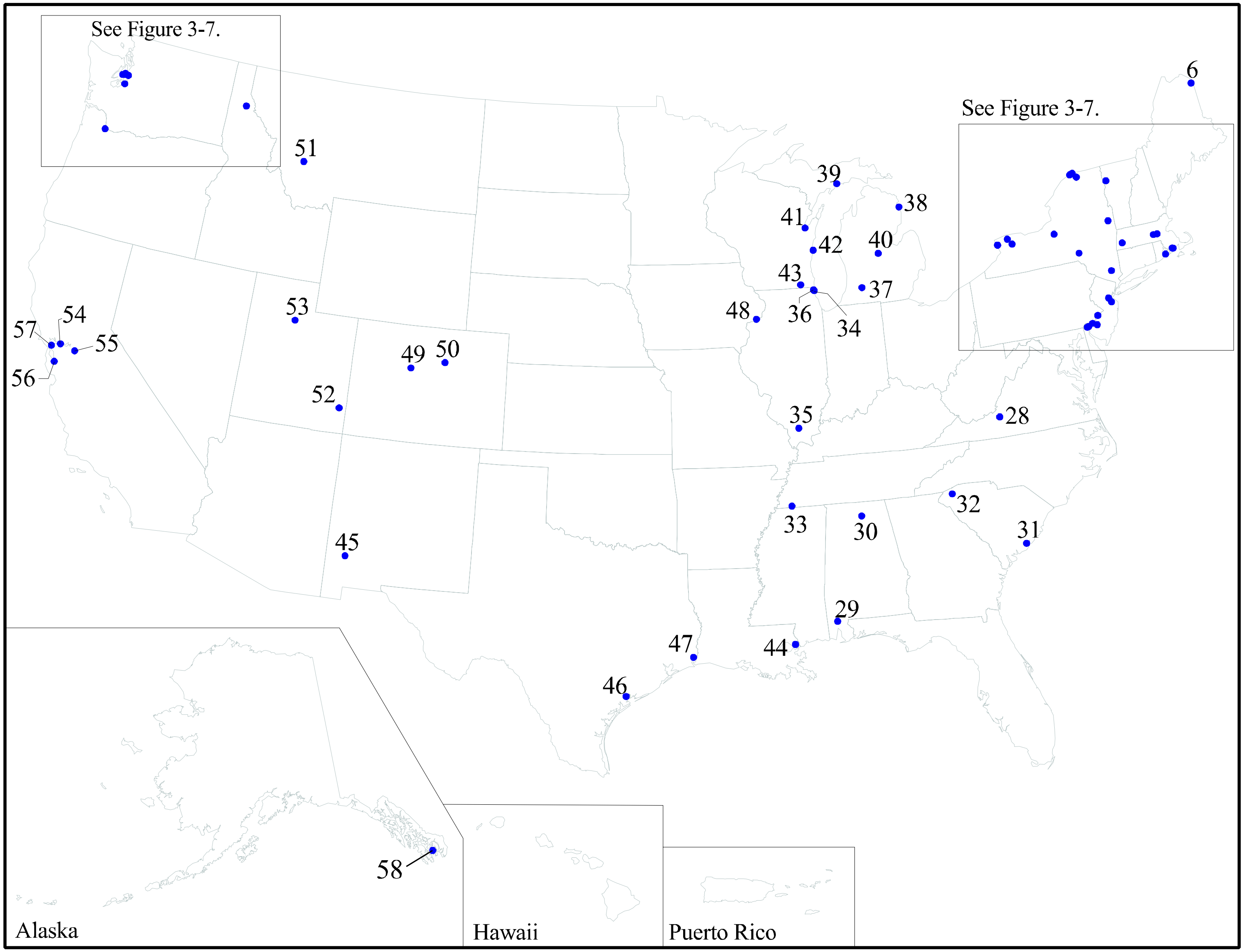

Figure 3-6. Contaminated Sediment CERCLA Sites.

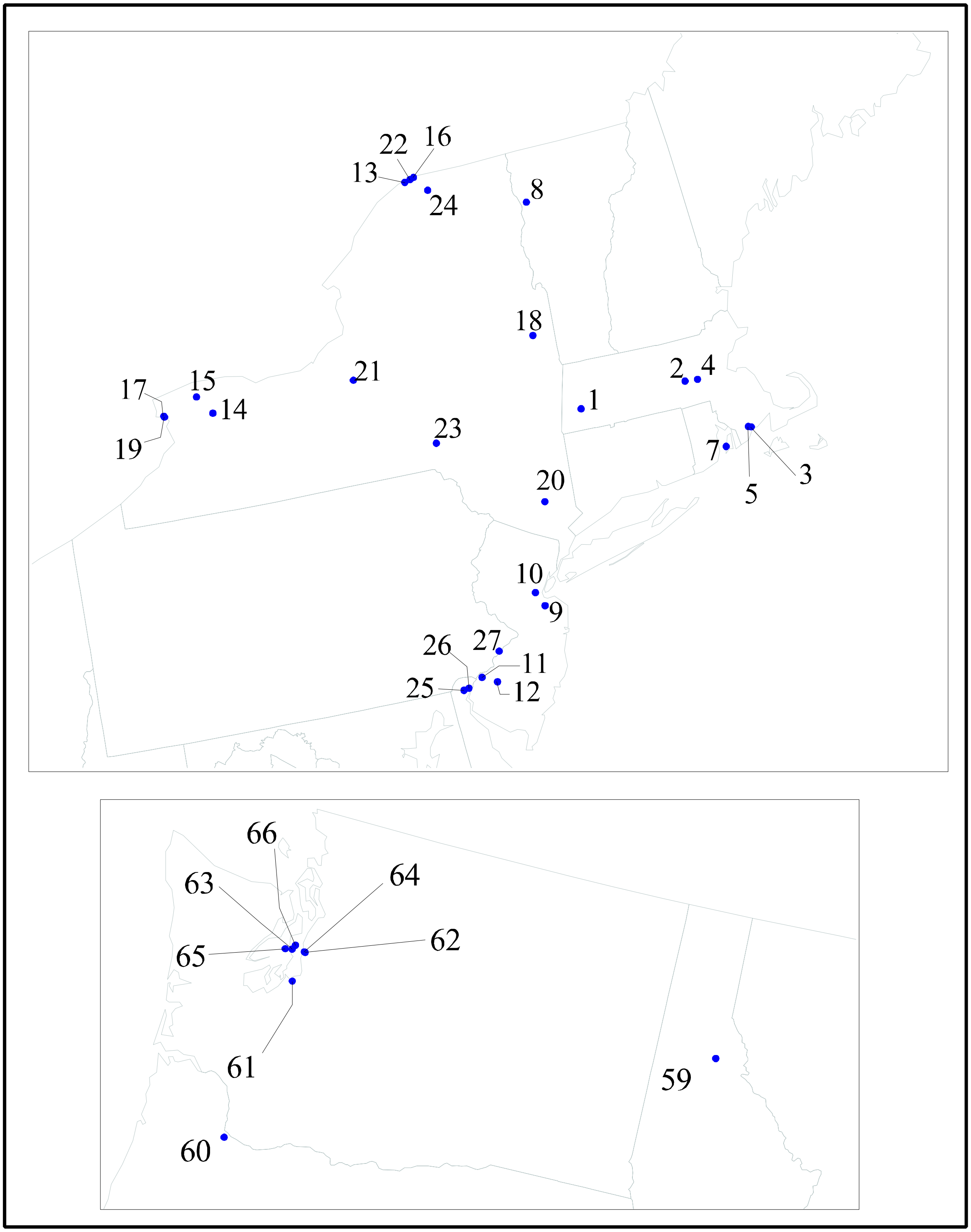

Figure 3-7. Contaminated Sediment CERCLA Sites for New England/Mid-Atlantic and Washington.

add more sites to the list as more decisions are made on the need to clean up other sites. More information on these sites can be found on the Internet at www.epa.gov/superfund/resources/sediment/sites.htm.

As outlined previously in the Watershed Assessment section, a total of 96 watersheds containing APCs have been identified throughout the United States. Twenty-eight of the 66 CERCLA sites are located in 18 of these watersheds containing APCs. There are 48 of the 66 CERCLA sites with no Tier 1 sampling stations within a 1-mile radius and 31 of the 66 CERCLA sites with no Tier 1 stations within 5 miles.

At the time of this report, the data associated with these CERCLA sites have not been compiled in the NSI database; however, several sampling stations in the database and evaluated in this report are close to these 66 CERCLA sites. For example 3,225 Tier 1, 2, and 3 sampling stations, out of the 19,398 stations evaluated in this report, are within 5 miles of the 66 sites, and 984 are within 1 mile of a CERCLA site. Of the 3,225 sampling stations, 2,257 are Tier 1 sampling stations (27 percent of all 8,348 Tier 1 stations) located within 5 miles of a CERCLA site; 719 of these Tier 1 sampling stations are located within 1 mile of a CERCLA site.

Wildlife Assessment

As described in Chapter 2, EPA conducted a separate analysis of the NSI data to determine the number of sampling stations where chemical concentrations of DDT, mercury, dioxin, and PCBs exceeded levels set to be protective of wildlife (i.e., EPA wildlife criteria). The wildlife criteria used in this evaluation were derived from those presented in the *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife: DDT; Mercury; 2,3,7,8-TCDD; PCBs* (USEPA, 1995) subtracting out exposure from direct water consumption. The only assumed route of exposure for this evaluation was the consumption of contaminated fish tissue by wildlife.

Data were available to evaluate a total of 14,420 NSI sampling stations using the wildlife criteria. Based on wildlife criteria alone, 30 sampling stations would be classified as Tier 1 (matched sediment chemistry and fish tissue data) and 3,284 sampling stations would be classified as Tier 2 (sediment chemistry TBP or fish tissue data). If wildlife criteria had been used to complete the national assessment, the number of Tier 1 stations would have remained at 8,348 stations, the number of Tier 2 stations would have increased from 5,846 to 6,158, and the number of Tier 3 stations would have decreased to 4,892. The change is related to 312 sampling stations classified as Tier 3 that would be classified as Tier 2 if the wildlife criteria were used.

The reason for the increase in Tier 2 stations when using wildlife criteria is twofold: (1) the wildlife criteria for DDT and mercury are significantly lower than the EPA risk levels used in the corresponding human health evaluations; (2) the lipid content used in the wildlife TBP analysis (10.31 percent for whole body) exceeded the lipid content used in the human health TBP analysis (3.0 percent for fillet). No additional sampling stations would be classified as Tier 1 based on wildlife criteria. For a sampling station to be classified as Tier 1, both sediment chemistry TBP and measured fish tissue concentrations taken from that sampling station had to exceed the wildlife criteria. At very few sampling stations in the NSI were both sediment chemistry and fish tissue levels for the same chemical measured. In those few cases where contaminants in both media were measured, there were no additional sampling stations (stations not already classified as Tier 1) where both the sediment chemistry TBP and fish tissue levels exceeded the wildlife criteria. Moreover, no sampling stations were classified as Tier 1 for exceedance of the wildlife criteria for mercury because sediment chemistry TBPs cannot be calculated for metals.

Regional and State Assessment

The remainder of this chapter presents more detailed results from the evaluation of NSI data for sampling stations in each of the 10 EPA regions and each state. The sections that follow present the number of Tier 1, Tier 2, and Tier 3 sampling stations in each region and state. Tables and figures similar to those presented in the national assessment of sampling station evaluation results and river reach evaluation results are included. Regional maps display the location of Tier 1 and Tier 2 sampling stations and APCs. The presentation format is identical for all regions.

These summary results do not include locations with contaminated sediment not identified in the NSI database. The data compiled for the NSI database are primarily from large national electronic databases. Data from many sampling and testing studies have not yet been incorporated into the NSI database. Thus, there are additional locations with sediment contamination that do not appear in this summary. On the other hand, data in this evaluation were collected between 1990 and 1999 and any single measurement of a chemical at a sampling station taken at any point in time during that period could result in classification of the sampling station in Tier 1 or Tier 2. Because the evaluation is a screening-level analysis, sampling stations that appear in Tier 1 or Tier 2 might not actually cause unacceptable impacts. In addition, management programs to address identified sediment contamination might already exist.

It is important to repeat here that some regions and states, as demonstrated in Table 2-1, have significantly more data compiled and evaluated in this report than do most other regions and states. For example, more than two-thirds of all stations evaluated in the NSI database are in Washington, Virginia, California, Illinois, Florida, Wisconsin, New York, Texas, Oregon, and South Carolina. Each of these states has more than 500 monitoring stations. This situation, to some degree, accounts for the relatively large number of sampling stations classified as Tier 1 in some regions and states.

EPA Region 1

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

EPA evaluated 275 sampling stations in Region 1 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 100 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 127 stations, placing them in Tier 2. For human health, data for 150 sampling stations indicated probable association with adverse effects (Tier 1), and data for 34 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 182 sampling stations (66.2 percent) as Tier 1, 64 (23.3 percent) as Tier 2, and 29 (10.5 percent) as Tier 3. The NSI database sampling stations in Region 1 were located in 125 separate river reaches, or 4.5 percent of all reaches in the region. About 3.5 percent of all river reaches in Region 1 included at least one Tier 1 station, 0.8 percent included at least one Tier 2 station but no Tier 1 stations, and 0.2 percent had only Tier 3 stations (Table 3-7). Table 3-8 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 9 watersheds containing APCs out of the 62 watersheds (14.5 percent) in Region 1 (Table 3-7). In addition, 21.0 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 9.7 percent had at least one Tier 2 station but no Tier 1 stations, and 0.0 percent had only Tier 3 stations; 54.8 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 1 are illustrated in Figure 3-8.

Within the 9 watersheds in Region 1 identified as containing APCs (Table 3-9), 32 waterbodies have at least 1 Tier 1 sampling station and 5 waterbodies have 10 or more Tier 1 sampling stations (Table 3-10). For those watersheds that contain APCs, Table 3-10 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-10, Boston Bay, Long Island Sound, the Atlantic Ocean, the Connecticut River, and the Housatonic River appear to have the most significant sediment contamination in Region 1.

Table 3-7. Region 1: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	2,764	Total Number of Watersheds	62
River Reaches With at Least One Tier 1 Station	97 (3.5%)	Watersheds Containing APCs	9 (14.5%)
		Watersheds With at Least One Tier 1 Station	13 (21.0%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	23 (0.8%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	6 (9.7%)
River Reaches With All Tier 3 Stations	5 (0.2%)	Watersheds With All Tier 3 Stations	0 (0.0%)
River Reaches With No Data	2,639 (95.5%)	Watersheds With No Data	34 (54.8%)

Table 3-8. Region 1: Evaluation Results for Sampling Stations and River Reaches by State.

State	Station Evaluation							River Reach Evaluation[a]							
	Total Number of Stations Evaluated	Tier 1		Tier 2		Tier 3		Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
		No.	%[b]	No.	%[b]	No.	%[b]								
Connecticut	121	103	85.1	15	12.4	3	2.5	28	57	6	1	64	215	29.8	29.3
Maine	—	—	—	—	—	—	—	—	—	—	—	—	1,675	0.0	0.0
Massachusetts	127	64	50.4	38	29.9	25	19.7	—	33	11	3	47	270	17.4	16.3
New Hampshire	4	4	100.0	—	0.0	—	0.0	—	4	2	—	6	283	2.1	2.1
Rhode Island	18	11	61.1	6	33.3	1	5.6	—	10	2	1	13	56	23.2	21.4
Vermont	5	—	0.0	5	100.0	—	0.0	—	5	6	—	11	375	2.9	2.9
Region 1[e]	275	182	66.2	64	23.3	29	10.5	28	97	23	5	125	2,764	4.5	4.3

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

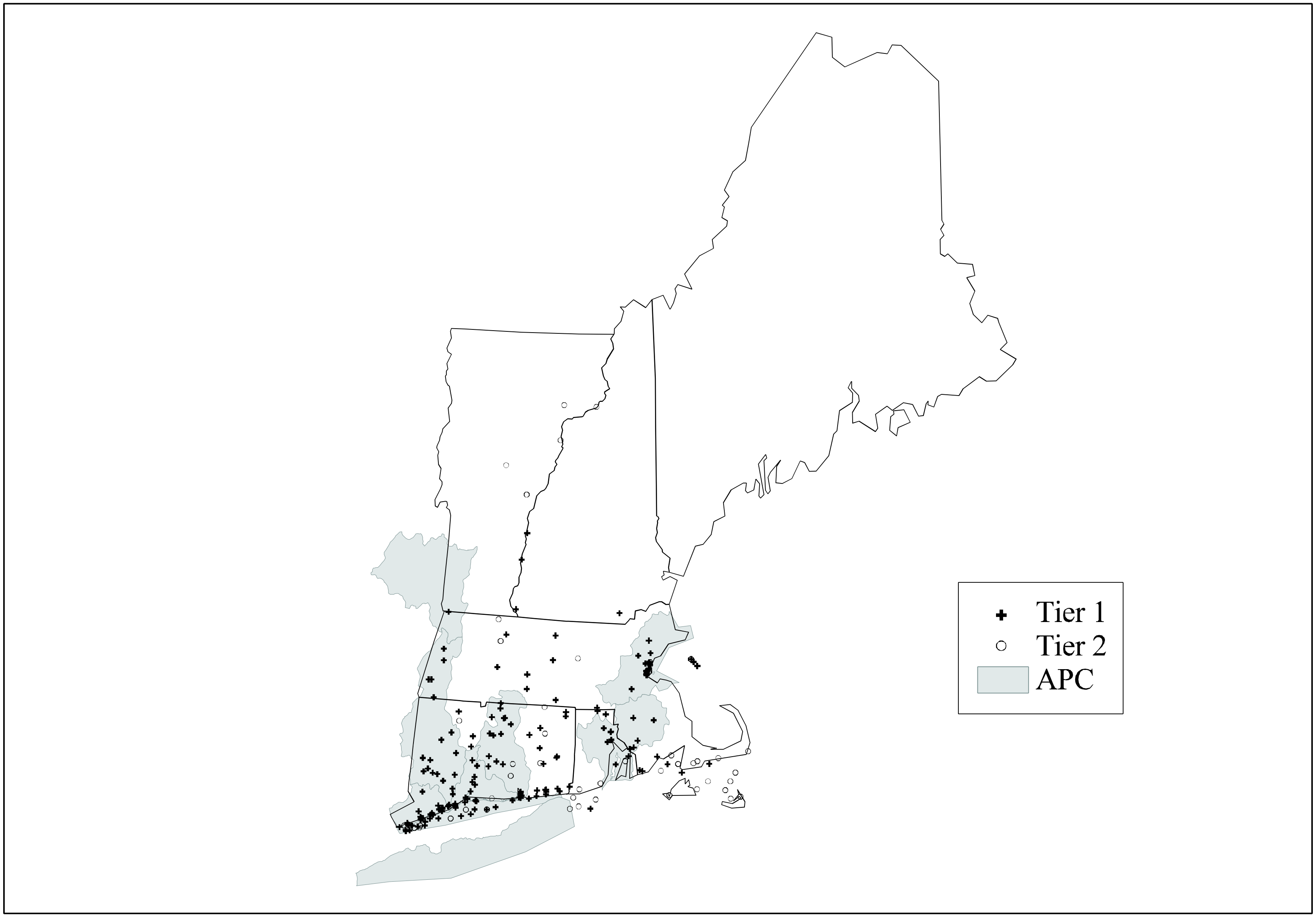

Figure 3-8. Region 1: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-9. Region 1: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)[a]	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
01080205	Lower Connecticut	CT, MA	19	17	2	0	100
01090001	Charles	MA	69	38	20	11	84
01090004	Narragansett	MA, RI	14	12	1	1	93
01100004	Quinnipiac	CT	13	12	1	0	100
01100005	Housatonic	CT, MA, NY	24	22	0	2	92
01100006	Saugatuck	CT, (NY)	19	18	1	0	100
01100007	Long Island Sound	CT, NY	31	23	7	1	97
02020003	Hudson-Hoosic	NY, MA, (VT)	163	155	8	0	100
02030202	Southern Long Island	NY, CT, NJ	85	47	21	17	80

[a] No data were available for states listed in parentheses.

Table 3-10. Region 1: Number of Tier 1 Stations in Region 1 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Boston Bay	24	Conanicut Island	1
Long Island Sound	15	Green River	1
Atlantic Ocean	13	Hoosic River	1
Connecticut River	11	Ipswich River	1
Housatonic River	11	Konkapot River	1
Quinnipiac River	5	Mattabesset River	1
Boston Harbor And Mystic River Area	4	Muddy River	1
Naugatuck River	4	Neponset River	1
Taunton River	3	Norwalk River	1
Woonasquatucket River	3	Rhode Island	1
Hockanum River	2	Rippowan River	1
Narragansett Bay	2	Saugatuck Reservoir	1
Pawtuxet River	2	Saugus River	1
Scanite River	2	Shepaug River	1
Bantam River	1	Still River	1
Coginchaug River	1	Windsor Brook	1

EPA Region 2

New Jersey, New York, Puerto Rico

EPA evaluated 1,255 sampling stations in Region 2 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 546 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 327 stations, placing them in Tier 2. For human health, data for 834 sampling stations indicated probable association with adverse effects (Tier 1), and 193 data for sampling stations indicated possible adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 901 sampling stations (71.8 percent) as Tier 1, 228 (18.2 percent) as Tier 2, and 126 (10.0 percent) as Tier 3. The NSI database sampling stations in Region 2 were located in 364 separate river reaches, or 19.7 percent of all reaches in the region. About 11.8 percent of all river reaches in Region 2 included at least one Tier 1 station, 5.5 percent included at least one Tier 2 station but no Tier 1 stations, and 2.4 percent had only Tier 3 stations (Table 3-11). Table 3-12 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 17 watersheds containing APCs out of the 71 watersheds (23.9 percent) in Region 2 (Table 3-11). In addition, 49.3 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 4.2 percent had at least one Tier 2 station but no Tier 1 stations, and 4.2 percent had only Tier 3 stations; 18.3 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 2 are illustrated in Figure 3-9.

Within the 17 watersheds in Region identified as containing APCs (Table 3-13), 76 waterbodies have at least 1 Tier 1 sampling station and 13 waterbodies have 10 or more Tier 1 sampling stations (Table 3-14). For those watersheds that contain APCs, Table 3-14 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-14, Hudson River, Passaic River, Long Island Sound, Newark Bay, Upper New York Bay, Jamaica Bay, Staten Island, Hackensack River, Atlantic Ocean, Mohawk River, Sandy Hook Bay, Rockaway River, and Upper Bay appear to have the most significant sediment contamination in Region 2.

Table 3-11. Region 2: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	1,845	Total Number of Watersheds	71
River Reaches With at Least One Tier 1 Station	217 (11.8%)	Watersheds Containing APCs	17 (23.9%)
		Watersheds With at Least One Tier 1 Station	35 (49.3%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	102 (5.5%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	3 (4.2%)
River Reaches With All Tier 3 Stations	45 (2.4%)	Watersheds With All Tier 3 Stations	3 (4.2%)
River Reaches With No Data	1,481 (80.3%)	Watersheds With No Data	13 (18.3%)

Table 3-12. Region 2: Evaluation Results for Sampling Stations and River Reaches by State.

State	Station Evaluation							River Reach Evaluation[a]							
	Total Number of Stations Evaluated	Tier 1		Tier 2		Tier 3		Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
		No.	%[b]	No.	%[b]	No.	%[b]								
New Jersey	492	341	69.3	102	20.7	49	10.0	—	62	45	21	128	304	42.1	35.2
New York	753	556	73.8	120	15.9	77	10.2	3	166	57	24	247	1,562	15.8	14.3
Puerto Rico	10	4	40.0	6	60.0	—	0.0	10	—	—	—	—	—	—	—
Region 2[e]	1,255	901	71.8	228	18.2	126	10.0	13	217	102	45	364	1,845	19.7	17.3

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

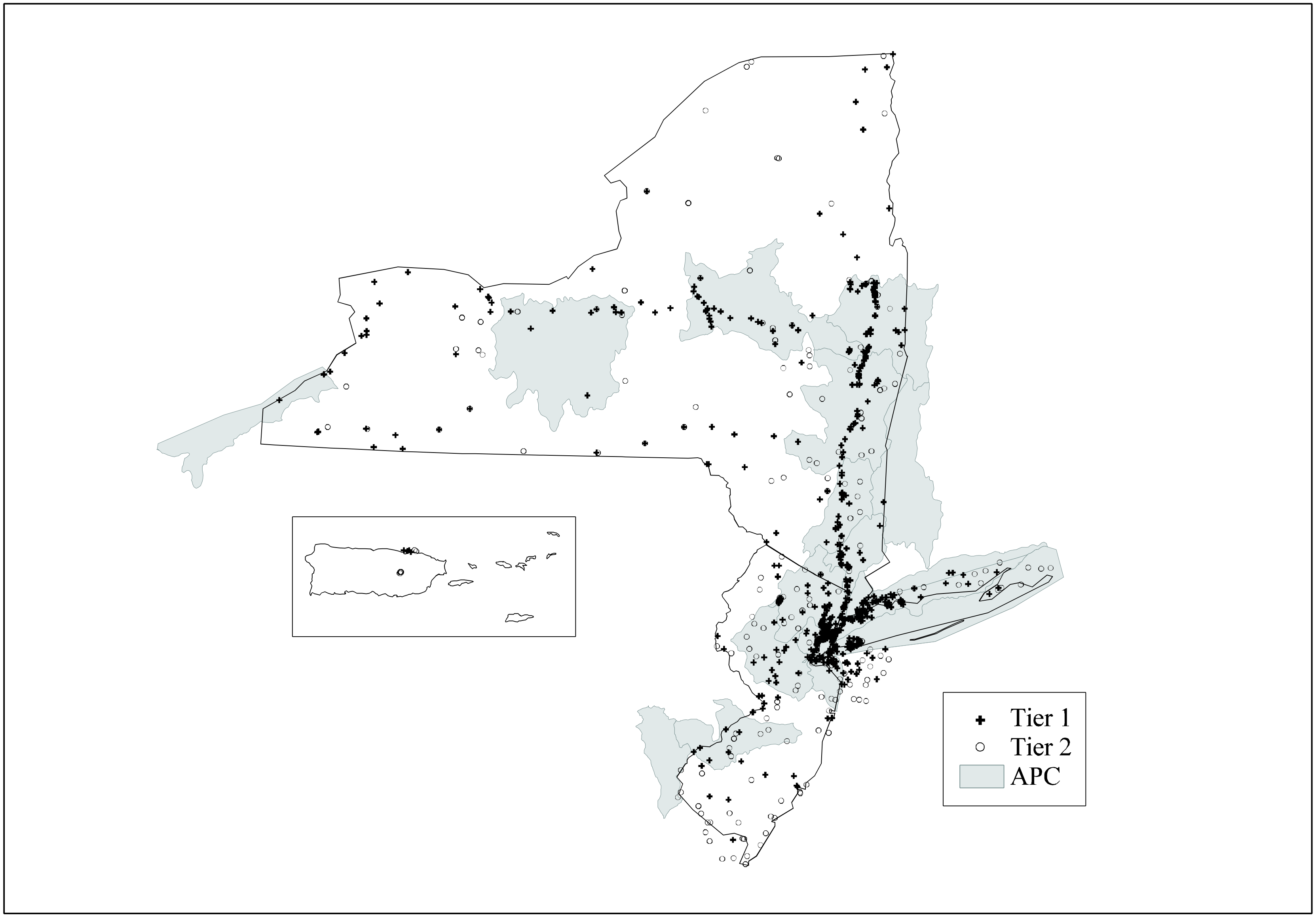

Figure 3-9. Region 2: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-13. Region 2: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)[a]	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
01100005	Housatonic	CT, MA, NY	24	22	0	2	92
01100007	Long Island Sound	CT, NY	31	23	7	1	97
02020003	Hudson-Hoosic	NY, MA, (VT)	163	155	8	0	100
02020004	Mohawk	NY	43	32	7	4	91
02020006	Middle Hudson	NY, (MA)	76	55	13	8	89
02020008	Hudson-Wappinger	NY	40	34	6	0	100
02030101	Lower Hudson	NJ, NY, (CT)	68	60	2	6	91
02030102	Bronx	NY	27	26	0	1	96
02030103	Hackensack-Passaic	NJ, NY	172	149	20	3	98
02030104	Sandy Hook-Staten Island	NJ, NY	194	155	31	8	96
02030105	Raritan	NJ	30	15	9	6	80
02030201	Northern Long Island	NY	75	62	9	4	95
02030202	Southern Long Island	NY, CT, NJ	85	47	21	17	80
02040202	Lower Delaware	NJ, PA	26	11	15	0	100
02040205	Brandywine-Christina	DE, PA, NJ, (MD)	220	109	67	44	80
04120101	Chautauqua-Conneaut	NY, OH, PA	16	13	2	1	94
04140201	Seneca	NY	20	11	4	5	75

[a] No data were available for states listed in parentheses.

Table 3-14. Region 2: Number of Tier 1 Stations in Region 2 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Hudson River	266	Beden Brook	1
Passaic River	111	Big Timber Creek, South Fork	1
Long Island Sound	74	Black Creek	1
Newark Bay	62	Canajoharie Creek	1
Upper New York Bay	36	Canopus Creek	1
Jamaica Bay	31	Cayadutta Creek	1
Staten Island	24	Cincinnati Creek	1
Hackensack River	17	Claverack Creek	1
Atlantic Ocean	16	Clyde River	1
Mohawk River	12	Cranbury Brook	1
Sandy Hook Bay	12	East Bay	1
Rockaway River	11	East Canada Creek	1
Upper Bay	10	Esopus Creek	1

Table 3-14. (Continued).

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
East River	9	Fall Creek	1
Sauquoit Creek	9	Flint Creek	1
Valatie Kill	7	Great Peconic Bay	1
Arthur Kill	6	Hohohus Brook	1
Lower Bay	6	Lake Erie, US Shore	1
Ninemile Creek	5	Little Peconic Bay	1
Delaware River	4	Manalapan Brook	1
Rahway River	4	Mud Creek	1
Saddle River	4	Neshanic River	1
Smithtown Bay	4	Onesquethaw Creek	1
Green Brook	3	Oriskany Creek	1
Hoosic River	3	Pennsauken Creek	1
Onondaga Lake	3	Pompton Creek	1
Raritan River	3	Ramapo River	1
Batten Kill	2	Raritan River, North Branch	1
Croton River	2	Raritan River, South Branch	1
Lisha Kill	2	Repaupo Creek	1
Millstone River	2	Seneca River	1
Normans Kill	2	Silver Creek	1
Onondaga Creek	2	Stony Brook	1
Raritan Bay	2	Swamp River	1
Vloman Kill	2	Walnut Creek	1
Walloomsac River	2	Wanaque Reservoir	1
Whippany River	2	Wappinger Creek	1
Amawalk Reservoir	1	Woodbury Creek	1

EPA Region 3

Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia

EPA evaluated 2,428 sampling stations in Region 3 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 405 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 836 stations, placing them in Tier 2. For human health, data for 458 sampling stations indicated probable association with adverse effects (Tier 1), and data for 363 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 714 sampling stations (29.4 percent) as Tier 1, 809 (33.3 percent) as Tier 2, and 905 (37.3 percent) as Tier 3. The NSI database sampling stations in Region 3 were located in 999 separate river reaches, or 29.5 percent of all reaches in the region. About 11.4 percent of all river reaches in Region 3 included at least one Tier 1 station, 9.2 percent included at least one Tier 2 station but no Tier 1 stations, and 8.9 percent had only Tier 3 stations (Table 3-15). Table 3-16 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

Table 3-15. Region 3: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	3,388	Total Number of Watersheds	126
River Reaches With at Least One Tier 1 Station	385 (11.4%)	Watersheds Containing APCs	7 (5.6%)
	Watersheds With at Least One Tier 1 Station	96 (76.2%)	
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	313 (9.2%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	11 (8.7%)
River Reaches With All Tier 3 Stations	301 (8.9%)	Watersheds With All Tier 3 Stations	4 (3.2%)
River Reaches With No Data	2,389 (70.5%)	Watersheds With No Data	8 (6.3%)

Table 3-16. Region 3: Evaluation Results for Sampling Stations and River Reaches by State.

State	Station Evaluation							River Reach Evaluation[a]							
	Total Number of Stations Evaluated	Tier 1		Tier 2		Tier 3		Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
		No.	%[b]	No.	%[b]	No.	%[b]								
Delaware	234	112	47.9	74	31.6	48	20.5	—	13	15	4	32	91	35.2	30.8
District of Columbia	6	2	33.3	3	50.0	1	16.7	—	6	2	—	8	16	50.0	50.0
Maryland	290	125	43.1	106	36.6	59	20.3	44	61	52	15	128	440	29.1	25.7
Pennsylvania	216	121	56.0	43	19.9	52	24.1	—	94	21	25	140	710	19.7	16.2
Virginia	1,577	313	19.8	556	35.3	708	44.9	59	204	227	252	683	1,330	51.4	32.4
West Virginia	105	41	39.0	27	25.7	37	35.2	—	47	27	12	86	1,000	8.6	7.4
Region 3[e]	2,428	714	29.4	809	33.3	905	37.3	103	385	313	301	999	3,388	29.5	20.6

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

This evaluation identified 7 watersheds containing areas of APCs out of the 126 watersheds (5.6 percent) in Region 3 (Table 3-15). In addition, 76.2 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 8.7 percent had at least one Tier 2 station but no Tier 1 stations, and 3.2 percent had only Tier 3 stations; 6.3 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 3 are illustrated in Figure 3-10A.

Within the 7 watersheds in Region 3 identified as containing APCs (Table 3-17), 25 waterbodies have at least 1 Tier 1 sampling station; 7 waterbodies have 10 or more Tier 1 sampling stations (Table 3-18). For those watersheds that contain APCs, Table 3-18 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-18, Christina River, Severn River, South River, Curtis Bay, Pamunkey River, Red Clay Creek, and Lake Erie shoreline appear to have the most significant sediment contamination in Region 3.

In 1993, EPA and its state partners in the Chesapeake Bay Program designed three toxics Regions of Concern in the entire 64,000 square mile Bay watershed, due to contaminated sediment. These areas were, and still are: the Elizabeth River, Baltimore Harbor and the Anacostia River. These designations have led to the creation and implementation of Regional Action Plans to address contamination in these areas. In 1999, the Chesapeake Bay Program published a characterization of the chemical contaminant effects on living resources in the tidal rivers of the Chesapeake Bay (Figure 3-10B) entitled *Targeting Toxics: A Characterization Report. A Tool for Directing Management and Monitoring Actions in the Chesapeake Bay's Tidal Rivers*. This characterization offers a more detailed picture of chemical contaminant problems in individual tidal rivers of the Chesapeake Bay watershed. This report, once again, confirmed the three Regions of Concern. However, in the *National Sediment Quality Survey*, the Anacostia River and the Elizabeth River were not singled out as Areas of Probable Concern because the larger watersheds containing these rivers did not have a sufficient number of contaminated areas overall to result in these watersheds being designated as Areas of Probable Concern (i.e., the percent of Tier 1 and 2 stations in the larger watersheds is less than 75%).

An additional 10 tidal areas were identified by the Chesapeake Bay Program as rivers with *potential* for adverse effects: Middle River (MD), Back River (MD), Magothy River (MD), Severn River (MD), the upper and middle Patuxent River (MD), upper and middle Potomac River (MD), Chester River (MD), and the lower James River (VA). These areas are not as contaminated as the three Regions of Concern, but deserve management attention. Although the Severn River watershed was designated as containing an Area of Probable Concern in the *National Sediment Quality Survey*, the Chesapeake Bay Program has a finer level of characterization, which distinguishes between highly contaminated sites like the Patapsco River and areas that have a lesser degree of contamination like the Severn River.

The York watershed (VA) was also classified as containing an Area of Probable Concern in this *National Sediment Quality Survey*. This designation is based primarily on a localized area at the mouth of the York River. The Chesapeake Bay Program also found localized contamination in this area, but, overall considered the data insufficient to characterize the entire river as having the potential for adverse effects. The Chesapeake Bay Program is working to fill data gaps in the tidal York River in order to further characterize it in the future.

The Chesapeake Bay Program *Toxics Characterization* will be further refined and updated in 2005. All data generated for this effort will be added to the *National Sediment Quality Survey*.

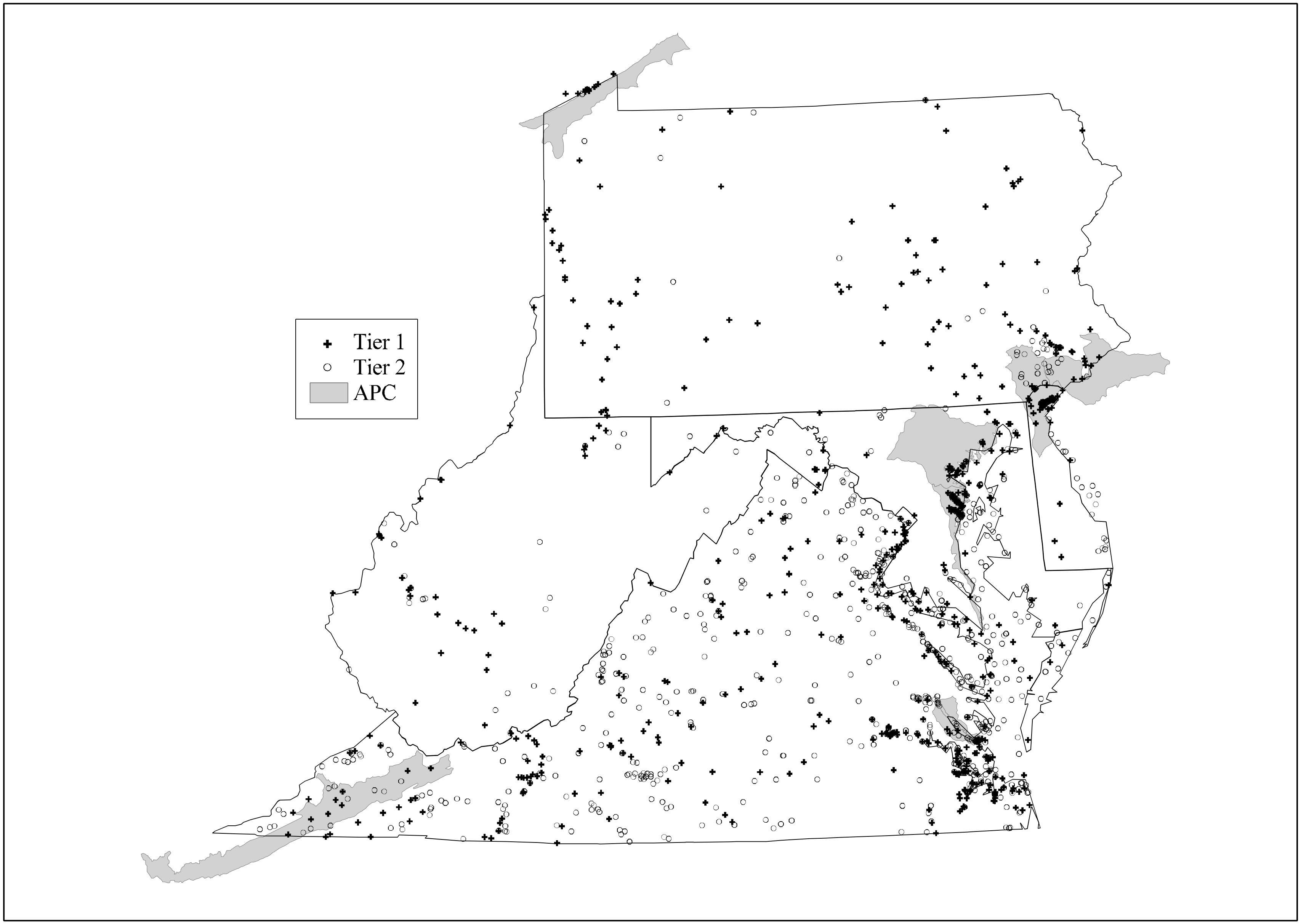

Figure 3-10A. Region 3: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-17. Region 3: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)[a]	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
02040202	Lower Delaware	NJ, PA	26	11	15	0	100
02040205	Brandywine-Christina	DE, (MD), PA, NJ	220	109	67	44	80
02060003	Gunpowder-Patapsco	MD, (PA)	32	22	8	2	94
02060004	Severn	MD	72	48	20	4	94
02080107	York	VA	67	16	35	16	76
04120101	Chautauqua-Conneaut	NY, OH, PA	16	13	2	1	94
06010205	Upper Clinch	TN, VA	27	10	11	6	78

[a] No data were available for states listed in parentheses.

Table 3-18. Region 3: Number of Tier 1 Stations in Region 3 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Christina River	82	Delaware River	3
Severn River	24	Queen Creek	3
South River	19	Bush River	2
Curtis Bay	13	Chesapeake-Delaware Canal	2
Pamunkey River	11	York River	2
Red Clay Creek	11	Clinch River, Corder Branch	1
Lake Erie, US Shore	10	Clinch River, North Fork	1
White Clay Creek	7	Darby Creek	1
Brandywine Creek	6	Guest River	1
Magothy River	5	Mudlick Creek	1
Black River	4	Stock Creek	1
Chesapeake Bay	3	White Clay Creek, East Branch	1
Clinch River	3		

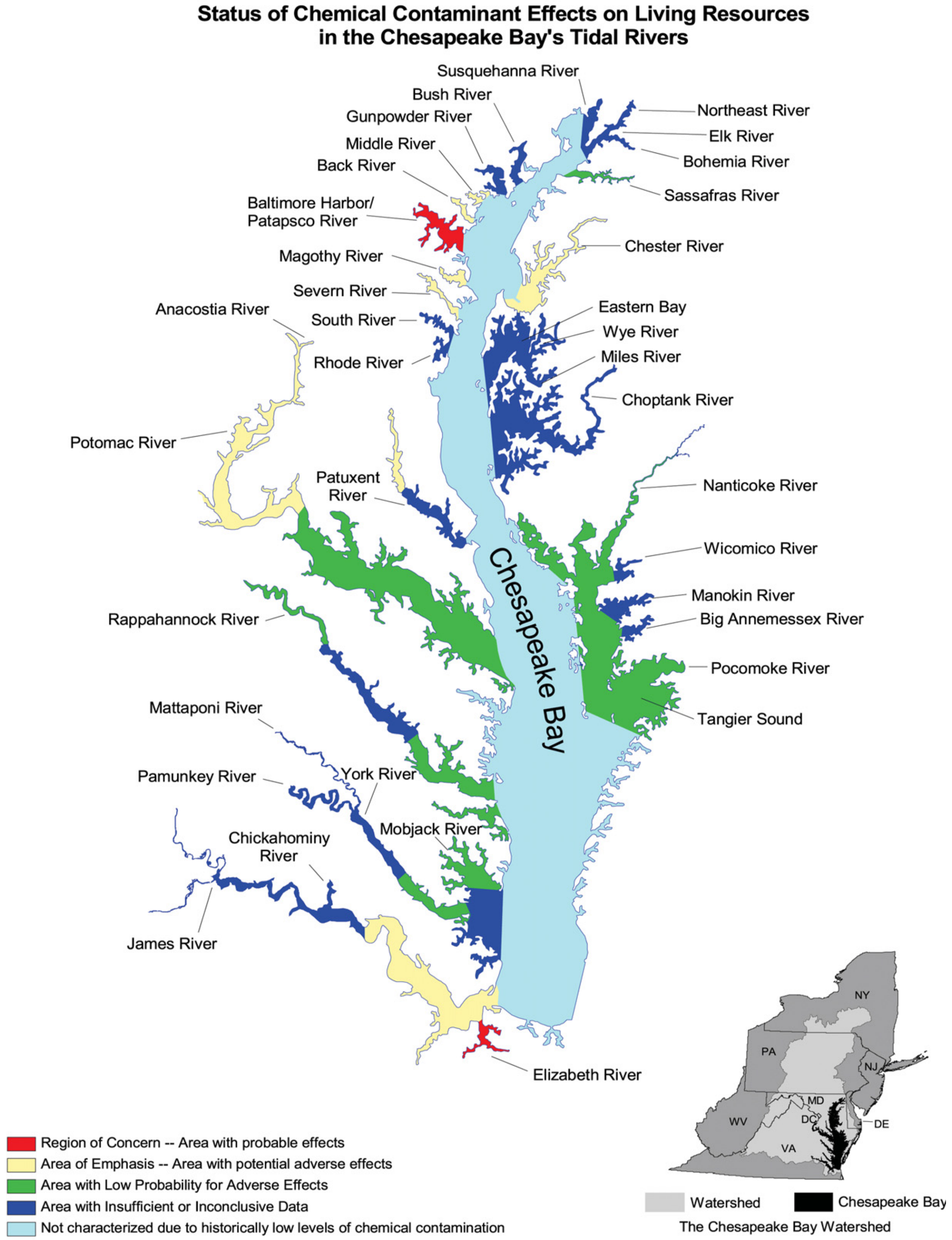

Figure 3-10B. Status of Chemical Contaminant Effects on Living Resources in the Chesapeake Bay's Tidal Rivers. Source: *Targeting Toxics: A Characterization Report. A Tool for Directing Management and Monitoring Actions in the Chesapeake Bay's Tidal Rivers.*

EPA Region 4

Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee

EPA evaluated 2,874 sampling stations in Region 4 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 437 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects were found at 918 stations, placing them in Tier 2. For human health, data for 623 sampling stations indicated probable association with adverse effects (Tier 1), and data for 762 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 841 sampling stations (29.3 percent) as Tier 1, 1,022 (35.6 percent) as Tier 2, and 1,011 (35.2 percent) as Tier 13. The NSI database sampling stations in Region 4 were located in 1,206 separate river reaches, or 12 percent of all reaches in the region. About 4.4 percent of all river reaches in Region 4 included at least one Tier 1 station, 4.6 percent included at least one Tier 2 station but no Tier 1 stations, and 3.0 percent had only Tier 3 stations (Table 3-19). Table 3-20 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 13 watersheds containing APCs out of the 307 watersheds (4.2 percent) in Region 4 (Table 3-19). In addition, 46.3 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 18.6 percent had at least one Tier 2 station but no Tier 1 stations, and 8.1 percent had only Tier 3 stations; 22.8 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 4 are illustrated in Figure 3-11.

Within the 13 watersheds in Region 4 identified as containing APCs (Table 3-21), 50 waterbodies have at least 1 Tier 1 sampling station and 12 waterbodies have 10 or more Tier 1 sampling stations (Table 3-22). For those watersheds that contain APCs, Table 3-22 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-22, Cooper River, Ashley River, Hillsborough Bay, Big Sunflower River, Black Bayou, Tennessee River, Pensacola Bay, Savannah River, Mobile Bay, Chattahoochee River, Turtle River, and Tampa Bay appear to have the most significant sediment contamination in Region 4.

Table 3-19. Region 4: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	10,078	Total Number of Watersheds	307
River Reaches With at Least One Tier 1 Station	444 (4.4%)	Watersheds Containing APCs	13 (4.2%)
		Watersheds With at Least One Tier 1 Station	142 (46.3%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	461 (4.6%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	57 (18.6%)
River Reaches With All Tier 3 Stations	301 (3.0%)	Watersheds With All Tier 3 Stations	25 (8.1%)
River Reaches With No Data	8,872 (88.0%)	Watersheds With No Data	70 (22.8%)

Table 3-20. Region 4: Evaluation Results for Sampling Stations and River Reaches by State.

	Station Evaluation							River Reach Evaluation[a]							
		Tier 1		Tier 2		Tier 3									
State	Total Number of Stations Evaluated	No.	%[b]	No.	%[b]	No.	%[b]	Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
Alabama	173	56	32.4	55	31.8	62	35.8	—	42	28	36	106	1,592	6.7	4.4
Florida	1,157	270	23.3	346	29.9	541	46.8	15	86	96	75	257	888	28.9	20.5
Georgia	263	115	43.7	117	44.5	31	11.8	—	95	57	27	179	1,707	10.5	8.9
Kentucky	63	24	38.1	27	42.9	12	19.0	—	31	30	18	79	1,276	6.2	4.8
Mississippi	187	97	51.9	52	27.8	38	20.3	—	35	13	13	61	995	6.1	4.8
North Carolina	291	33	11.3	150	51.5	108	37.1	—	35	109	57	201	1,456	13.8	9.9
South Carolina	576	169	29.3	218	37.8	189	32.8	—	100	109	74	283	1,110	25.5	18.8
Tennessee	164	77	47.0	57	34.8	30	18.3	—	59	45	19	123	1,490	8.3	7.0
Region 4[e]	2,874	841	29.3	1,022	35.6	1,011	35.2	15	444	461	301	1,206	10,078	12.0	9.0

[a] River reaches based on EPA River Reach File (RF1).
[b] Percent of all stations evaluated in the NSI in the state.
[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.
[d] No stations in these reaches were included in Tier 1.
[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

Table 3-21. Region 4: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

			Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
Cataloging Unit Number	Cataloging Unit Name	State(s)[a]	Total	Tier 1	Tier 2	Tier 3	
03050201	Cooper	SC	105	52	30	23	78
03050202	South Carolina Coastal	SC	60	33	18	9	85
03060109	Lower Savannah	GA, SC	68	20	45	3	96
03070203	Cumberland-St. Simons	GA	30	19	8	3	90
03100206	Tampa Bay	FL	70	41	18	11	84
03130002	Middle Chattahoochee-Lake Harding	AL, GA	26	21	4	1	96
03140105	Pensacola Bay	FL	59	20	25	14	76
03160205	Mobile Bay	AL	31	17	14	0	100
06010201	Watts Bar Lake	TN	19	16	3	0	100
06010205	Upper Clinch	TN, VA	27	10	11	6	78
06020001	Middle Tennessee-Chickamauga	GA, TN, (AL)	33	15	12	6	82
08030207	Big Sunflower	MS	38	38	0	0	100
08030209	Deer-Steele	MS, (LA)	24	23	1	0	100

[a] No data were available for states listed in parentheses.

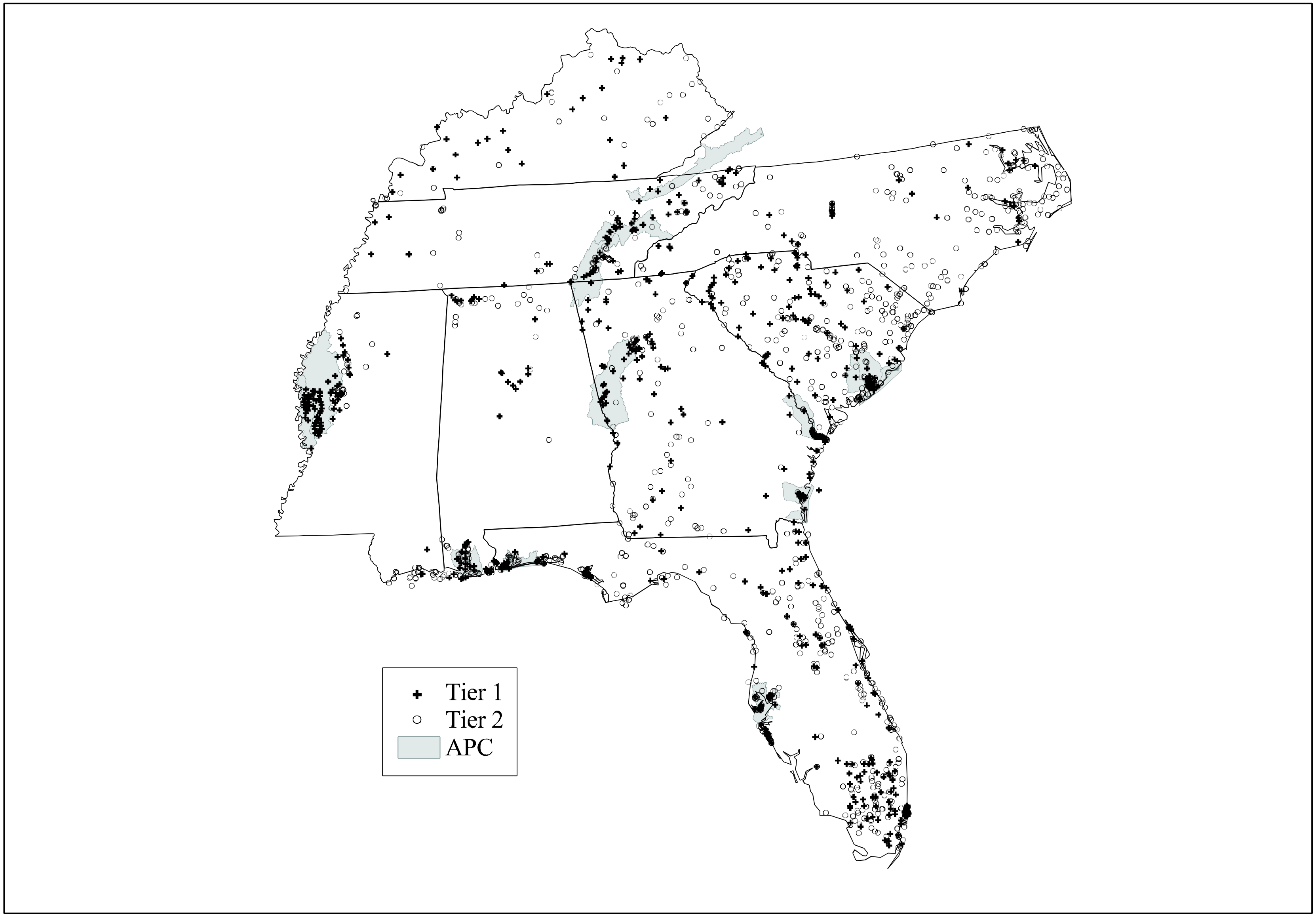

Figure 3-11. Region 4: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-22. Region 4: Number of Tier 1 Stations in Region 4 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Cooper River	45	Back River	1
Ashley River	28	Bullfrog Creek	1
Hillsborough Bay	28	Clinch River	1
Big Sunflower River	23	Cooper River, West Branch	1
Black Bayou	18	Cooper River/Charleston Harbor	1
Tennessee River	18	Cumberland River	1
Pensacola Bay	17	Deer Creek	1
Savannah River	17	Dorchester Creek	1
Mobile Bay	15	Fort Loudoun Lake	1
Chattahoochee River	13	Goose Creek	1
Turtle River	13	Hillabatchee Creek	1
Tampa Bay	11	Intracoastal Waterway	1
Watts Bar Lake	8	Jekyll Island	1
Bogue Phalia	7	Lake Harding	1
Little Sunflower River	6	Lake Moultrie	1
Atlantic Ocean	3	Lake Washington	1
Lake Chickamauga	3	Norris Lake	1
Savannah River, South Channel	3	Noses Creek	1
St. Simons Sound	3	Old Tampa Bay	1
Steele Bayou	3	Quiver River	1
Carpenter Creek	2	Santa Rosa Sound	1
Long Cane Creek	2	Silver Creek	1
Muddy Creek	2	St. Simons Island	1
Utoy Creek	2	West Chickamauga Creek	1
Wando River	2	West Pont Lake	1

EPA Region 5

Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

EPA evaluated 3,185 sampling stations in Region 5 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 606 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 1,052 stations, placing them in Tier 2. For human health, data for 888 sampling stations indicated probable association with adverse effects (Tier 1), and data for 647 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 1,146 sampling stations (36.0 percent) as Tier 1, 1,095 (34.4 percent) as Tier 2, and 944 (29.6 percent) as Tier 3. The NSI database sampling stations in Region 5 were located in 1,249 separate river reaches, or 20.3 percent of all reaches in the region. About 8.6 percent of all river reaches in Region 5 included at least one Tier 1 station, 6.5 percent included at least one Tier 2 station but no Tier 1 stations, and 5.1 percent had only Tier 3 stations (Table 3-23). Table 3-24 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 25 watersheds containing APCs out of the 278 watersheds (9.0 percent) in Region 5 (Table 3-23). In addition, 51.8 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 11.2 percent had at least one Tier 2 station but no Tier 1 stations, and 6.8 percent had only Tier 3 stations; 21.2 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 5 are illustrated in Figure 3-12.

Within the 25 watersheds in Region 5 identified as containing APCs (Table 3-25), 83 waterbodies have at least 1 Tier 1 sampling station and 12 waterbodies have 10 or more Tier 1 sampling stations (Table 3-26). For those watersheds that contain APCs, Table 3-26 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-26, Mississippi River, Fox River, Lake Michigan, Illinois River, Chicago Sanitary Ship Canal, Des Plains River, Menominee River, Salt Creek, White River, Duck Creek, Green River, and Kanakee River appear to have the most significant sediment contamination in Region 5.

Table 3-23. Region 5: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	6,151	Total Number of Watersheds	278
River Reaches With at Least One Tier 1 Station	532 (8.6%)	Watersheds Containing APCs	25 (9.0%)
		Watersheds With at Least One Tier 1 Station	144 (51.8%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	401 (6.5%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	31 (11.2%)
River Reaches With All Tier 3 Stations	316 (5.1%)	Watersheds With All Tier 3 Stations	19 (6.8%)
River Reaches With No Data	4,902 (79.7%)	Watersheds With No Data	59 (21.2%)

Table 3-24. Region 5: Evaluation Results for Sampling Stations and River Reaches by State.

	Station Evaluation							River Reach Evaluation[a]								
		Tier 1		Tier 2		Tier 3									
State	Total Number of Stations Evaluated	No.	%[b]	No.	%[b]	No.	%[b]	Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
Illinois	1,370	490	35.8	577	42.1	303	22.1	—	236	181	73	490	936	52.4	44.6
Indiana	233	130	55.8	74	31.8	29	12.4	—	73	39	15	127	561	22.6	20.0
Michigan	30	14	46.7	10	33.3	6	20.0	—	12	11	5	28	1,178	2.4	2.0
Minnesota	339	118	34.8	38	11.2	183	54.0	—	86	31	105	222	1,392	15.9	8.4
Ohio	441	71	16.1	240	54.4	130	29.5	—	51	99	50	200	1,056	18.9	14.2
Wisconsin	772	323	41.8	156	20.2	293	38.0	—	121	65	76	262	1,210	21.7	15.4
Region 5[e]	3,185	1,146	36.0	1,095	34.4	944	29.6	—	532	401	316	1,249	6,151	20.3	15.2

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

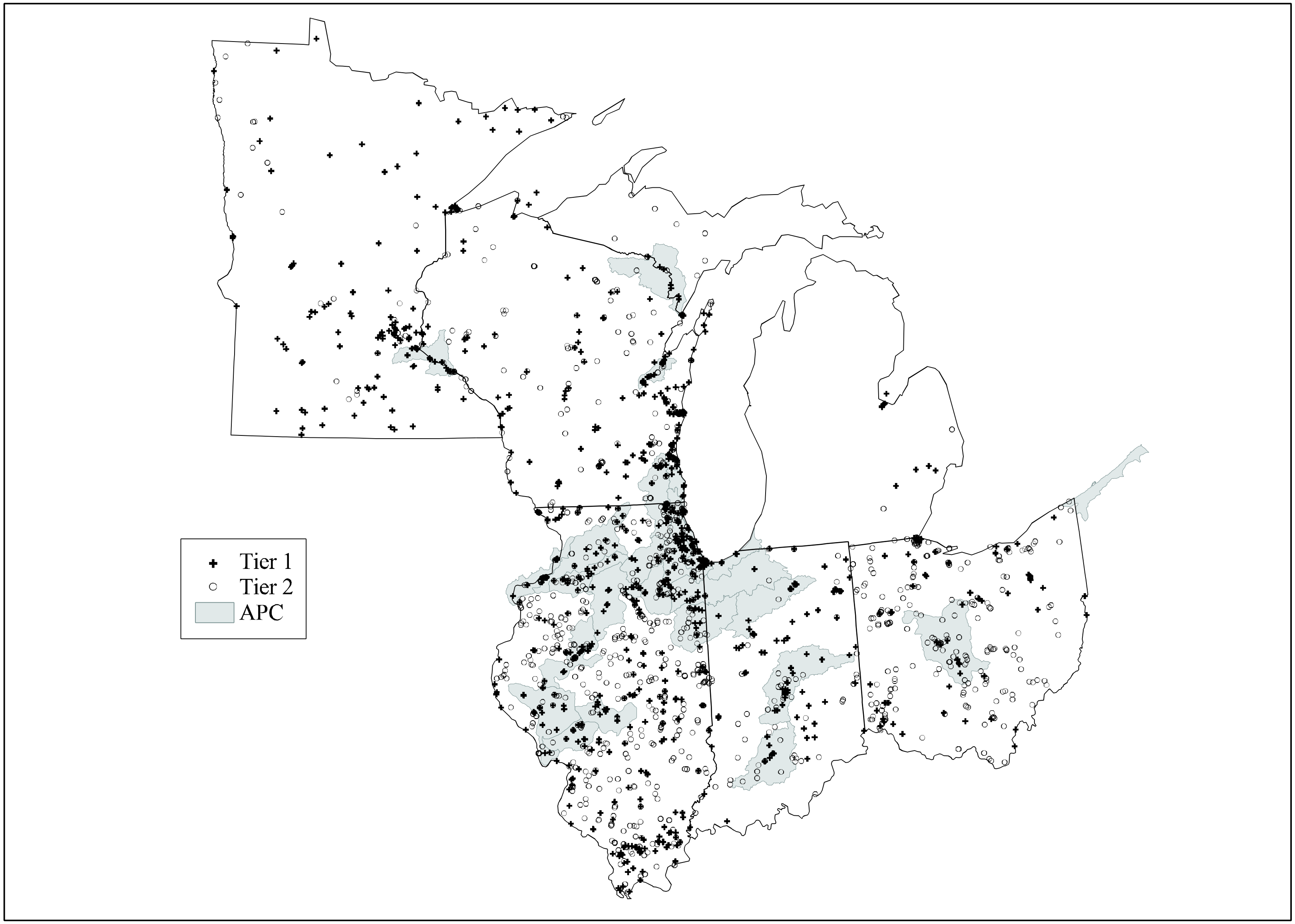

Figure 3-12. Region 5: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-25. Region 5: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)[a]	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
04030108	Menominee	MI, WI	21	18	2	1	95
04030204	Lower Fox	WI	26	16	5	5	81
04040001	Little Calumet-Galien	IL, IN, (MI)	24	22	1	1	96
04040002	Pike-Root	IL, WI	60	39	13	8	87
04120101	Chautauqua-Conneaut	NY, OH, PA	16	13	2	1	94
05060001	Upper Scioto	OH	50	10	32	8	84
05120106	Tippecanoe	IN	25	17	3	5	80
05120201	Upper White	IN	42	23	14	5	88
05120208	Lower East Fork White	IN	19	10	8	1	95
07040001	Rush-Vermillion	MN, WI	19	10	5	4	79
07080101	Copperas-Duck	IL, IA	136	99	22	15	89
07090005	Lower Rock	IL, (WI)	37	11	20	6	84
07090007	Green	IL	47	17	24	6	87
07120001	Kankakee	IL, IN, (MI)	34	20	10	4	88
07120002	Iroquois	IL, IN	29	10	18	1	97
07120003	Chicago	IL, IN	49	34	14	1	98
07120004	Des Plaines	IL, WI	81	40	37	4	95
07120005	Upper Illinois	IL	24	11	12	1	96
07120006	Upper Fox	IL, WI	81	31	37	13	84
07120007	Lower Fox	IL	26	10	13	3	88
07130001	Lower Illinois-Senachwine Lake	IL	12	11	1	0	100
07130003	Lower Illinois-Lake Chautauqua	IL	36	16	15	5	86
07130007	South Fork Sangamon	IL	16	12	4	0	100
07130011	Lower Illinois	IL	36	17	14	5	86
07130012	Macoupin	IL	19	10	9	0	100

[a] No data were available for states listed in parentheses.

Table 3-26. Region 5: Number of Tier 1 Stations in Region 5 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Mississippi River	43	Fall Creek	2
Fox River	38	Honey Creek	2
Lake Michigan	37	Jackson Creek	2
Illinois River	34	Lake Calumet	2
Chicago Sanitary Ship Canal	19	Mckee Creek	2
Des Plains River	18	Olentangy River	2
Menominee River	18	Otter Creek	2
Salt Creek	16	Sandy Creek	2
White River	16	Sangamon River, South Fork	2
Duck Creek	15	Ashwaubenon Creek	1
Green River	15	Blackberry Creek	1
Kanakee River	15	Buck Creek	1
Fox Lake	9	Burns Ditch	1
Wolf Lake	9	Cicero Creek	1
Little Calumet River	7	Du Page River, East Branch	1
Rock River	7	Du Page River, West Branch	1
Tippecanoe River	7	Eagle Creek	1
Deeds Creek	6	Exline Slough	1
Indiana Harbor Canal	5	Kent Creek, North Fork	1
Macoupin Creek	5	Kyte River	1
Mill Creek	5	Lake Muskego	1
Beaver Creek	4	Lake Springfield	1
Chicago River, North Branch	4	Leatherwood Creek	1
Hodges Creek	4	Macoupin Creek, Dry Fork	1
Iroquois River	4	Mauvaise Terre Creek	1
Lake Chautauqua	4	Mauvaise Terre Lake	1
Mazoon River	4	Mazon River, West Fork	1
Root River	4	Mud Creek	1
Sangchris Lake	4	Pewaukee Lake	1
Scioto River	4	Pike River	1
Yellow Creek	4	Pipe Creek	1
Calumet River	3	Portage-Burns Waterway	1
Calumet Sag Channel	3	Prairie Creek	1
Du Page River	3	Rock Creek	1
Horse Creek	3	Somonauk Creek	1
Indian Creek	3	Spring Creek	1
Lake Taylorsville	3	Sugar Run	1
Sugar Creek	3	Trim Creek	1
White River, East Fork	3	Vermillion River	1
Apple Creek	2	West Bureau Creek	1
Chicago Ship Canal	2	White Lick Creek	1
Elkhorn Creek	2		

EPA Region 6

Arkansas, Louisiana, New Mexico, Oklahoma, Texas

EPA evaluated 1,489 sampling stations in Region 6 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 187 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 394 stations, placing them in Tier 2. For human health, data for 330 sampling stations indicated probable association with adverse effects (Tier 1), and data for 209 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 425 sampling stations (28.5 percent) as Tier 1, 392 (26.3 percent) as Tier 2, and 672 (45.1 percent) as Tier 3. The NSI database sampling stations in Region 6 were located in 737 separate river reaches, or 9.7 percent of all reaches in the region. Three percent of all river reaches in Region 6 included at least one Tier 1 station, 2.9 percent included at least one Tier 2 station but no Tier 1 stations, and 3.8 percent had only Tier 3 stations (Table 3-27). Table 3-28 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 4 watersheds containing APCs out of the 402 watersheds (1.0 percent) in Region 6 (Table 3-27). In addition, 29.1 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 17.2 percent had at least one Tier 2 station but no Tier 1 stations, and 10.9 percent had only Tier 3 stations; 41.8 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 6 are illustrated in Figure 3-13.

Within the 4 watersheds in Region 6 identified as containing APCs (Table 3-29), 17 waterbodies have at least 1 Tier 1 sampling station and 3 waterbodies have 10 or more Tier 1 sampling stations (Table 3-30). For those watersheds that contain APCs, Table 3-30 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-30, the Mississippi River, the Colorado River, and Mountain Creek Lake appear to have the most significant sediment contamination in Region 6.

Although the Buffalo-San Jacinto watershed was not designated as containing an APC, a study of the Houston Ship Channel, its tributaries and side bays yielded useful data to characterize sediment quality (ENSR, 1995). The study found elevated levels of several contaminants and significant toxicity at several sites, including Patrick Bayou, which recently has been added to the National Priorities List (NPL). Other unpublished data collected primarily by the Superfund Program in Lavaca Bay, Texas (mercury) and Calcasieu Estuary, Louisiana (both priority pollutant organics and metals) demonstrates both sediment contamination and bioaccumulation is occurring in these watersheds.

Table 3-27. Region 6: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	7,577	Total Number of Watersheds	402
River Reaches With at Least One Tier 1 Station	226 (3.0%)	Watersheds Containing APCs	4 (1.0%)
		Watersheds With at Least One Tier 1 Station	117 (29.1%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	222 (2.9%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	69 (17.2%)
River Reaches With All Tier 3 Stations	289 (3.8%)	Watersheds With All Tier 3 Stations	44 (10.9%)
River Reaches With No Data	6,840 (90.3%)	Watersheds With No Data	168 (41.8%)

Table 3-28. Region 6: Evaluation Results for Sampling Stations and River Reaches by State.

	Station Evaluation							River Reach Evaluation[a]							
		Tier 1		Tier 2		Tier 3									
State	Total Number of Stations Evaluated	No.	%[b]	No.	%[b]	No.	%[b]	Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
Arkansas	34	13	38.2	15	44.1	6	17.6	—	18	15	5	38	883	4.3	3.7
Louisiana	396	128	32.3	97	24.5	171	43.2	—	38	40	40	118	886	13.3	8.8
New Mexico	167	10	6.0	48	28.7	109	65.3	—	11	37	44	92	941	9.8	5.1
Oklahoma	292	69	23.6	47	16.1	176	60.3	—	44	40	110	194	1,363	14.2	6.2
Texas	600	205	34.2	185	30.8	210	35.0	—	128	102	103	333	3,734	8.9	6.2
Region 6[e]	1,489	425	28.5	392	26.3	672	45.1	—	226	222	289	737	7,577	9.7	5.9

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

Table 3-29. Region 6: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
08090100	Lower Mississippi-New Orleans	LA	34	28	6	0	100
11070209	Lower Neosho	AR, OK	20	11	5	4	80
12030102	Lower West Fork Trinity	TX	31	19	10	2	94
12090205	Austin-Travis Lakes	TX	22	16	4	2	91

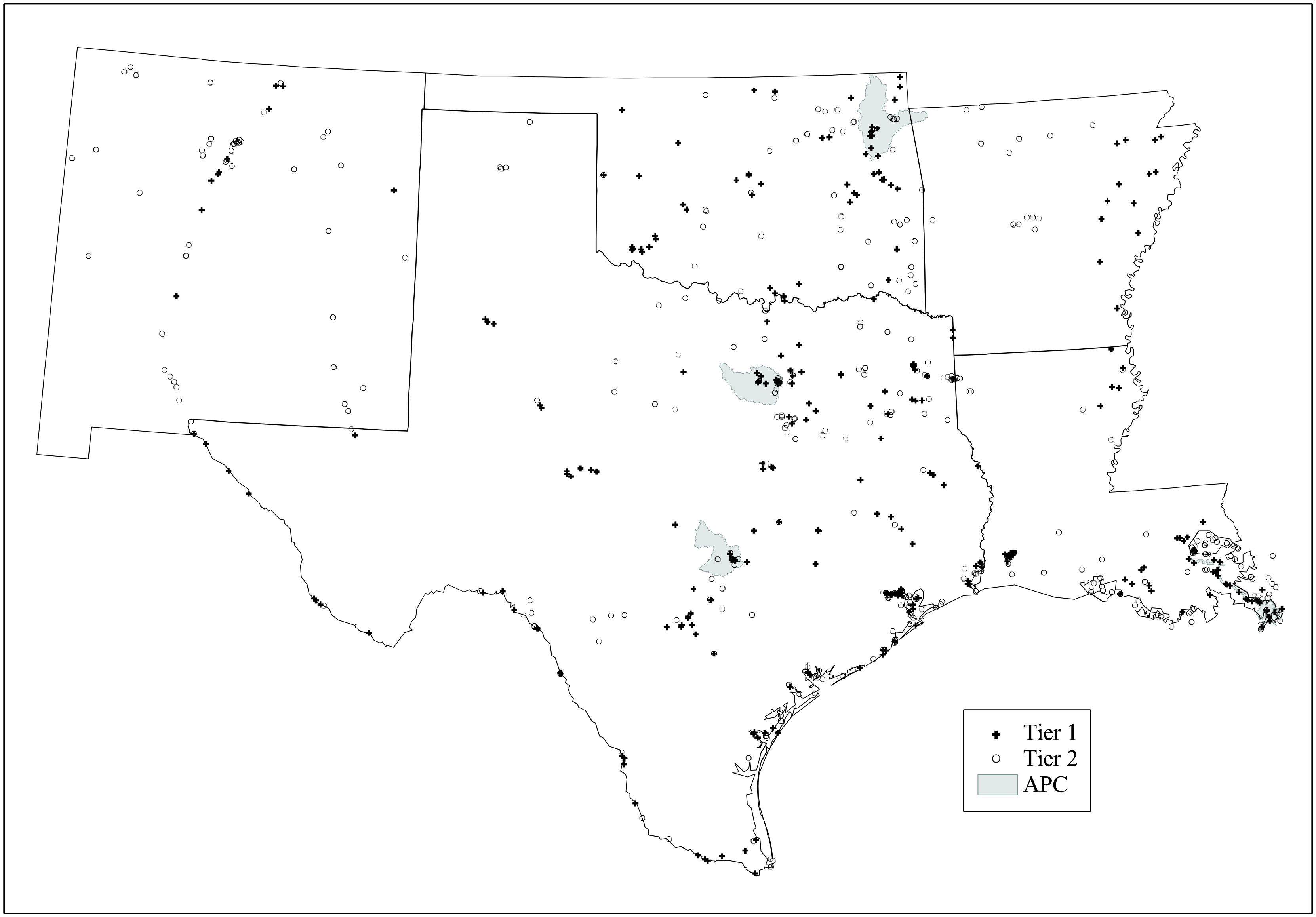

Figure 3-13. Region 6: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-30. Region 6: Number of Tier 1 Stations in Region 6 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Mississippi River	22	Barton Creek	1
Colorado River	14	East Bay	1
Mountain Creek Lake	11	Lake Austin	1
Neosho River	5	Lake Hudson	1
Trinity River, West Fork	4	Mississippi River, Pass Loutre	1
Gulf Of Mexico	3	Mississippi River, SW Pass	1
Pryor Creek	3	Mountain Creek	1
Big Fossile Creek	2	Rush Creek	1
Fort Gibson Lake	2		

EPA Region 7

Iowa, Kansas, Missouri, Nebraska

EPA evaluated 583 sampling stations in Region 7 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 73 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 165 stations, placing them in Tier 2. For human health, data for 106 sampling stations indicated probable association with adverse effects (Tier 1), and data for 125 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 134 sampling stations (23.0 percent) as Tier 1, 239 (41.0 percent) as Tier 2, and 210 (36.0 percent) as Tier 3. The NSI database sampling stations in Region 7 were located in 391 separate river reaches, or 8 percent of all reaches in the region. About 1.9 percent of all river reaches in Region 7 included at least one Tier 1 station, 3.3 percent included at least one Tier 2 station but no Tier 1 stations, and 2.8 percent had only Tier 3 stations (Table 3-31). Table 3-32 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 1 watershed containing APCs out of the 238 watersheds (0.4 percent) in Region 7 (Table 3-31). In addition, 25.2 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 30.3 percent had at least one Tier 2 station but no Tier 1 stations, and 12.2 percent had only Tier 3 stations; 31.9 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 7 are illustrated in Figure 3-14.

Within the one watershed in Region 7 identified as containing APCs (Table 3-33), 2 waterbodies have at least 1 Tier 1 sampling station and 1 waterbody has 10 or more Tier 1 sampling stations (Table 3-34). For those watersheds that contain APCs, Table 3-34 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-34, the Mississippi River appears to have the most significant sediment contamination in Region 7.

Table 3-31. Region 7: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	4,915	Total Number of Watersheds	238
River Reaches With at Least One Tier 1 Station	94 (1.9%)	Watersheds Containing APCs	1 (0.4%)
		Watersheds With at Least One Tier 1 Station	60 (25.2%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	161 (3.3%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	72 (30.3%)
River Reaches With All Tier 3 Stations	136 (2.8%)	Watersheds With All Tier 3 Stations	29 (12.2%)
River Reaches With No Data	4,524 (92.0%)	Watersheds With No Data	76 (31.9%)

Table 3-32. Region 7: Evaluation Results for Sampling Stations and River Reaches by State.

	Station Evaluation							River Reach Evaluation[a]							
		Tier 1		Tier 2		Tier 3									
State	**Total Number of Stations Evaluated**	**No.**	**%[b]**	**No.**	**%[b]**	**No.**	**%[b]**	**Number of Stations Not Identified by an RF1 Reach[c]**	**Reaches With at Least One Station in Tier 1**	**Reaches With at Least One Station in Tier 2[d]**	**Reaches With All Stations in Tier 3**	**Number of Reaches With at Least One Station Evaluated**	**Total Reaches in Region**	**Percent of All Reaches in Region With at Least One Station Evaluated**	**Percent of Reaches With at Least One Tier 1 or Tier 2 Station**
Iowa	113	59	52.2	35	31.0	19	16.8	—	24	24	13	61	1,204	5.1	4.0
Kansas	119	18	15.1	53	44.5	48	40.3	—	16	47	41	104	1,192	8.7	5.3
Missouri	194	40	20.6	89	45.9	65	33.5	—	42	42	29	113	1,403	8.1	6.0
Nebraska	157	17	10.8	62	39.5	78	49.7	—	18	52	54	124	1,270	9.8	5.5
Region 7[e]	583	134	23.0	239	41.0	210	36.0	—	94	161	136	391	4,915	8.0	5.2

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

Figure 3-14. Region 7: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-33. Region 7: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
07080101	Copperas-Duck	IL, IA	136	99	22	15	89

Table 3-34. Region 7: Number of Tier 1 Stations in Region 7 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Mississippi River	49	Duck Creek	1

EPA Region 8

Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming

EPA evaluated 294 sampling stations in Region 8 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 59 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 105 stations, placing them in Tier 2. For human health, data for 26 sampling stations indicated probable association with adverse effects (Tier 1), and data for 25 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 79 sampling stations (26.9 percent) as Tier 1, 95 (32.3 percent) as Tier 2, and 120 (40.8 percent) as Tier 3. The NSI database sampling stations in Region 8 were located in 204 separate river reaches, or 1.5 percent of all reaches in the region. Only 0.4 percent of all river reaches in Region 8 included at least one Tier 1 station, 0.6 percent included at least one Tier 2 station but no Tier 1 stations, and 0.5 percent had only Tier 3 stations (Table 3-35). Table 3-36 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 1 watershed containing APCs out of the 385 watersheds (0.3 percent) in Region 8 (Table 3-35). In addition, 8.8 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 10.6 percent had at least one Tier 2 station but no Tier 1 stations, and 8.1 percent had only Tier 3 stations; 72.2 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 8 are illustrated in Figure 3-15.

Within the 1 watershed in Region 8 identified as containing APCs (Table 3-37), 5 waterbodies have at least 1 Tier 1 sampling station and no waterbodies have 10 or more Tier 1 sampling stations (Table 3-38). For those watersheds that contain APCs, Table 3-38 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-38, the Blue River appears to have the most significant sediment contamination in Region 8.

Table 3-35. Region 8: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	13,860	Total Number of Watersheds	385
River Reaches With at Least One Tier 1 Station	59 (0.4%)	Watersheds Containing APCs	1 (0.3%)
		Watersheds With at Least One Tier 1 Station	34 (8.8%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	77 (0.6%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	41 (10.6%)
River Reaches With All Tier 3 Stations	68 (0.5%)	Watersheds With All Tier 3 Stations	31 (8.1%)
River Reaches With No Data	13,656 (98.5%)	Watersheds With No Data	278 (72.2%)

Table 3-36. Region 8: Evaluation Results for Sampling Stations and River Reaches by State.

State	Station Evaluation							River Reach Evaluation[a]							
	Total Number of Stations Evaluated	Tier 1		Tier 2		Tier 3		Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
		No.	%[b]	No.	%[b]	No.	%[b]								
Colorado	133	52	39.1	43	32.3	38	28.6	—	36	33	21	90	2,204	4.1	3.1
Montana	11	—	0.0	3	27.3	8	72.7	—	—	3	9	12	5,606	0.2	0.1
North Dakota	33	6	18.2	16	48.5	11	33.3	—	9	14	4	27	1,042	2.6	2.2
South Dakota	32	18	56.3	6	18.8	8	25.0	—	12	4	8	24	1,691	1.4	0.9
Utah	56	2	3.6	17	30.4	37	66.1	—	2	13	18	33	1,080	3.1	1.4
Wyoming	29	1	3.4	10	34.5	18	62.1	—	1	13	14	28	2,474	1.1	0.6
Region 8[e]	294	79	26.9	95	32.3	120	40.8	—	59	77	68	204	13,860	1.5	1.0

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

Figure 3-15. Region 8: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-37. Region 8: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
14010002	Blue	CO	15	15	0	0	100

Table 3-38. Region 8: Number of Tier 1 Stations in Region 8 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Blue River	8	Dillon Reservoir	1
Swan River	3	Tenmile Creek	1
Snake River	2		

EPA Region 9

Arizona, California, Hawaii, Nevada

EPA evaluated 1,752 sampling stations in Region 9 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 790 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 577 stations, placing them in Tier 2. For human health, data for 645 sampling stations indicated probable association with adverse effects (Tier 1), and data for 280 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 1,040 sampling stations (59.4 percent) as Tier 1, 429 (24.5 percent) as Tier 2, and 283 (16.2 percent) as Tier 3. The NSI database sampling stations in Region 9 were located in 259 separate river reaches, or 5.5 percent of all reaches in the region. About 3.3 percent of all river reaches in Region 9 included at least one Tier 1 station, 1.3 percent included at least one Tier 2 station but no Tier 1 stations, and 0.9 percent had only Tier 3 stations (Table 3-39). Table 3-40 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 19 watersheds containing APCs out of the 288 watersheds (6.6 percent) in Region 9 (Table 3-39). In addition, 14.2 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 6.6 percent had at least one Tier 2 station but no Tier 1 stations, and 5.2 percent had only Tier 3 stations; 67.4 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 9 are illustrated in Figure 3-16.

Within the 19 watersheds in Region 9 identified as containing APCs (Table 3-41), 36 waterbodies have at least 1 Tier 1 sampling station and 14 waterbodies have 10 or more Tier 1 sampling stations (Table 3-42). For those watersheds that contain APCs, Table 3-42 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-42, the Pacific Ocean, San Diego Bay, San Francisco Bay, San Pablo Bay, Santa Ana River, Comanche Reservoir, Salt River, Arcata Bay, Cave Creek, Charro Creek, San Diego Creek, Sacramento River, Suisun Bay, and Dominguez Channel appear to have the most significant sediment contamination in Region 9.

Table 3-39. Region 9: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	4,686	Total Number of Watersheds	288
River Reaches With at Least One Tier 1 Station	156 (3.3%)	Watersheds Containing APCs	19 (6.6%)
		Watersheds With at Least One Tier 1 Station	41 (14.2%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	63 (1.3%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	19 (6.6%)
River Reaches With All Tier 3 Stations	40 (0.9%)	Watersheds With All Tier 3 Stations	15 (5.2%)
River Reaches With No Data	4,427 (94.5%)	Watersheds With No Data	194 (67.4%)

Table 3-40. Region 9: Evaluation Results for Sampling Stations and River Reaches by State.

	Station Evaluation							River Reach Evaluation[a]							
		Tier 1		Tier 2		Tier 3									
State	Total Number of Stations Evaluated	No.	%[b]	No.	%[b]	No.	%[b]	Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
Arizona	123	70	56.9	35	28.5	18	14.6	—	15	15	9	39	1,169	3.3	2.6
California	1,535	935	60.9	353	23.0	247	16.1	—	132	32	32	196	2,655	7.4	6.2
Hawaii	18	10	55.6	1	5.6	7	38.9	18	—	—	—	—	—	—	—
Nevada	76	25	32.9	40	52.6	11	14.5	—	10	19	3	32	935	3.4	3.1
Region 9[e]	1,752	1,040	59.4	429	24.5	283	16.2	18	156	63	40	259	4,686	5.5	4.7

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

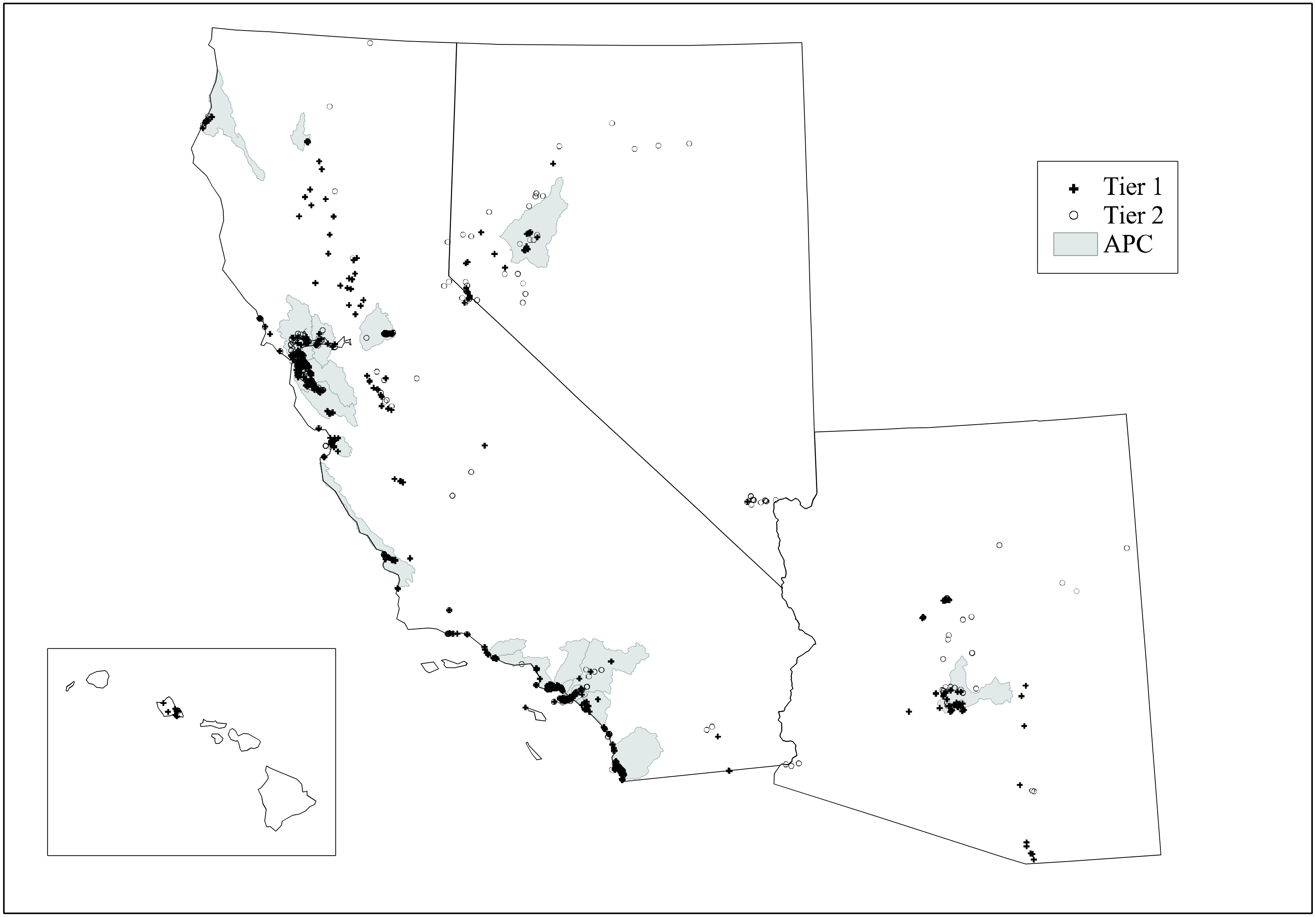

Figure 3-16. Region 9: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-41. Region 9: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
15060106	Lower Salt	AZ	52	39	13	0	100
16050203	Carson Desert	NV	19	14	5	0	100
18010102	Mad-Redwood	CA	26	20	4	2	92
18020112	Sacramento-Upper Clear	CA	25	23	2	0	100
18040005	Lower Cosumnes-Lower Mokelumne	CA	60	23	23	14	77
18050001	Suisun Bay	CA	27	16	8	3	89
18050002	San Pablo Bay	CA	101	69	28	4	96
18050003	Coyote	CA	32	25	7	0	100
18050004	San Francisco Bay	CA	130	113	16	1	99
18060006	Central Coastal	CA	54	25	22	7	87
18060011	Alisal-Elkhorn Sloughs	CA	34	25	9	0	100
18070103	Calleguas	CA	26	26	0	0	100
18070104	Santa Monica Bay	CA	132	109	21	2	98
18070106	San Gabriel	CA	34	21	11	2	94
18070201	Seal Beach	CA	59	38	18	3	95
18070203	Santa Ana	CA	98	30	53	15	85
18070204	Newport Bay	CA	74	36	20	18	76
18070301	Aliso-San Onofre	CA	19	17	1	1	95
18070304	San Diego	CA	278	208	47	23	92

Table 3-42. Region 9: Number of Tier 1 Stations in Region 9 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Pacific Ocean	261	Napa River	7
San Diego Bay	156	A Line Canal	5
San Francisco Bay	128	Alisal Slough	5
San Pablo Bay	60	Peters Canyon Wash	4
Santa Ana River	29	San Gabriel River	4
Comanche Reservoir	23	Aliso Creek	3
Salt River	20	Calleguas Creek	3
Arcata Bay	19	Los Penasquitos Canyon	3
Cave Creek	19	San Diego River	3
Charro Creek	19	San Juan Creek	3
San Diego Creek	16	Calero Reservoir	2
Sacramento River	15	Petaluma River	2
Suisun Bay	14	Arroyo Trabusco	1
Dominguez Channel	13	Humboldt Bay	1
Carson River	9	Oso Creek	1

Table 3-42. (Continued).

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Elkhorn Slu	9	San Dieguito River	1
Spring Creek	9	Suisun Creek	1
Alamitos Creek	8	Warm, E. Twin & Strawberry Cr Area	1

EPA Region 10

Alaska, Idaho, Oregon, Washington

EPA evaluated 5,330 sampling stations in Region 10 as part of the NSI database evaluation. Sediment contamination associated with probable adverse effects on aquatic life was found at 1,803 of these sampling stations, placing them in Tier 1; sediment contamination associated with possible adverse effects was found at 2,052 stations, placing them in Tier 2. For human health, data for 2,325 sampling stations indicated probable association with adverse effects (Tier 1), and data for 988 sampling stations indicated possible association with adverse effects (Tier 2). Overall, this evaluation resulted in the classification of 2,886 sampling stations (54.8 percent) as Tier 1, 1,473 (28.0 percent) as Tier 2, and 904 (17.2 percent) as Tier 3. The NSI database sampling stations in Region 10 were located in 347 separate river reaches, or 3.3 percent of all reaches in the region. About 1.7 percent of all river reaches in Region 10 included at least one Tier 1 station, 1.2 percent included at least one Tier 2 station but no Tier 1 stations, and 0.5 percent had only Tier 3 stations (Table 3-43). Table 3-44 presents a summary of sampling station classification and evaluation of river reaches for each state and for the region as a whole.

This evaluation identified 10 watersheds containing APCs out of the 355 watersheds (2.8 percent) in Region 10 (Table 3-43). In addition, 13.5 percent of all watersheds in the region had at least one Tier 1 sampling station but were not identified as containing APCs, 8.2 percent had at least one Tier 2 station but no Tier 1 stations, and 5.9 percent had only Tier 3 stations; 69.6 percent of the watersheds did not include a sampling station. The locations of the watersheds containing APCs and the Tier 1 and Tier 2 sampling stations in Region 10 are illustrated in Figure 3-17.

Within the 10 watersheds in Region 10 identified as containing APCs (Table 3-45), 48 waterbodies have at least 1 Tier 1 sampling station are 21 waterbodies have 10 or more Tier 1 sampling stations (Table 3-46). For those watersheds that contain APCs, Table 3-46 presents a list of all waterbodies that contain one or more Tier 1 sampling stations. Based on the information in Table 3-46, Puget Sound, Elliot Bay, Willamette River, Sinclair Inlet, Bellingham Bay, Big Creek, Duwamish Waterway, Lake Union, Lake Washington Ship Canal, Budd Inlet, Columbia River, Matheny Creek, Sams River, Lake Washington, Strait of Georgia, Chambers Creek, Roosevelt Lake, East Fork of Humptulips River, Fidalgo Island, Green River, and Columbia Slough appear to have the most significant sediment contamination in Region 10.

Table 3-43. Region 10: River Reach and Watershed Evaluation Summary.

River Reach Classification		Watershed Classification	
Total Number of River Reaches	10,462	Total Number of Watersheds	355
River Reaches With at Least One Tier 1 Station	177 (1.7%)	Watersheds Containing APCs	10 (2.8%)
		Watersheds With at Least One Tier 1 Station	48 (13.5%)
River Reaches With at Least One Tier 2 Station and Zero Tier 1 Stations	121 (1.2%)	Watersheds With at Least One Tier 2 Station and Zero Tier 1 Stations	29 (8.2%)
River Reaches With All Tier 3 Stations	49 (0.5%)	Watersheds With All Tier 3 Stations	21 (5.9%)
River Reaches With No Data	10,115 (96.7%)	Watersheds With No Data	247 (69.6%)

Table 3-44. Region 10: Evaluation Results for Sampling Stations and River Reaches by State.

State	Station Evaluation							River Reach Evaluation[a]							
	Total Number of Stations Evaluated	Tier 1		Tier 2		Tier 3		Number of Stations Not Identified by an RF1 Reach[c]	Reaches With at Least One Station in Tier 1	Reaches With at Least One Station in Tier 2[d]	Reaches With All Stations in Tier 3	Number of Reaches With at Least One Station Evaluated	Total Reaches in Region	Percent of All Reaches in Region With at Least One Station Evaluated	Percent of Reaches With at Least One Tier 1 or Tier 2 Station
		No.	%[b]	No.	%[b]	No.	%[b]								
Alaska	290	46	15.9	42	14.5	202	69.7	290	—	—	—	—	—	—	—
Idaho	38	17	44.7	12	31.6	9	23.7	—	16	13	7	36	3,298	1.1	0.9
Oregon	599	310	51.8	203	33.9	86	14.4	—	45	52	16	113	4,317	2.6	2.2
Washington	4,336	2,513	58.0	1,216	28.0	607	14.0	—	125	65	30	220	3,056	7.2	6.2
Region 10[e]	5,263	2,886	54.8	1,473	28.0	904	17.2	290	177	121	49	347	10,462	3.3	2.8

[a] River reaches based on EPA River Reach File (RF1).

[b] Percent of all stations evaluated in the NSI in the state.

[c] Stations not identified by an RF1 reach were located in coastal areas, open water areas, or areas where RF1 was not developed.

[d] No stations in these reaches were included in Tier 1.

[e] Because some reaches occur in more than one state, the total number of reaches in each category for the country might not equal the sum of reaches in the states.

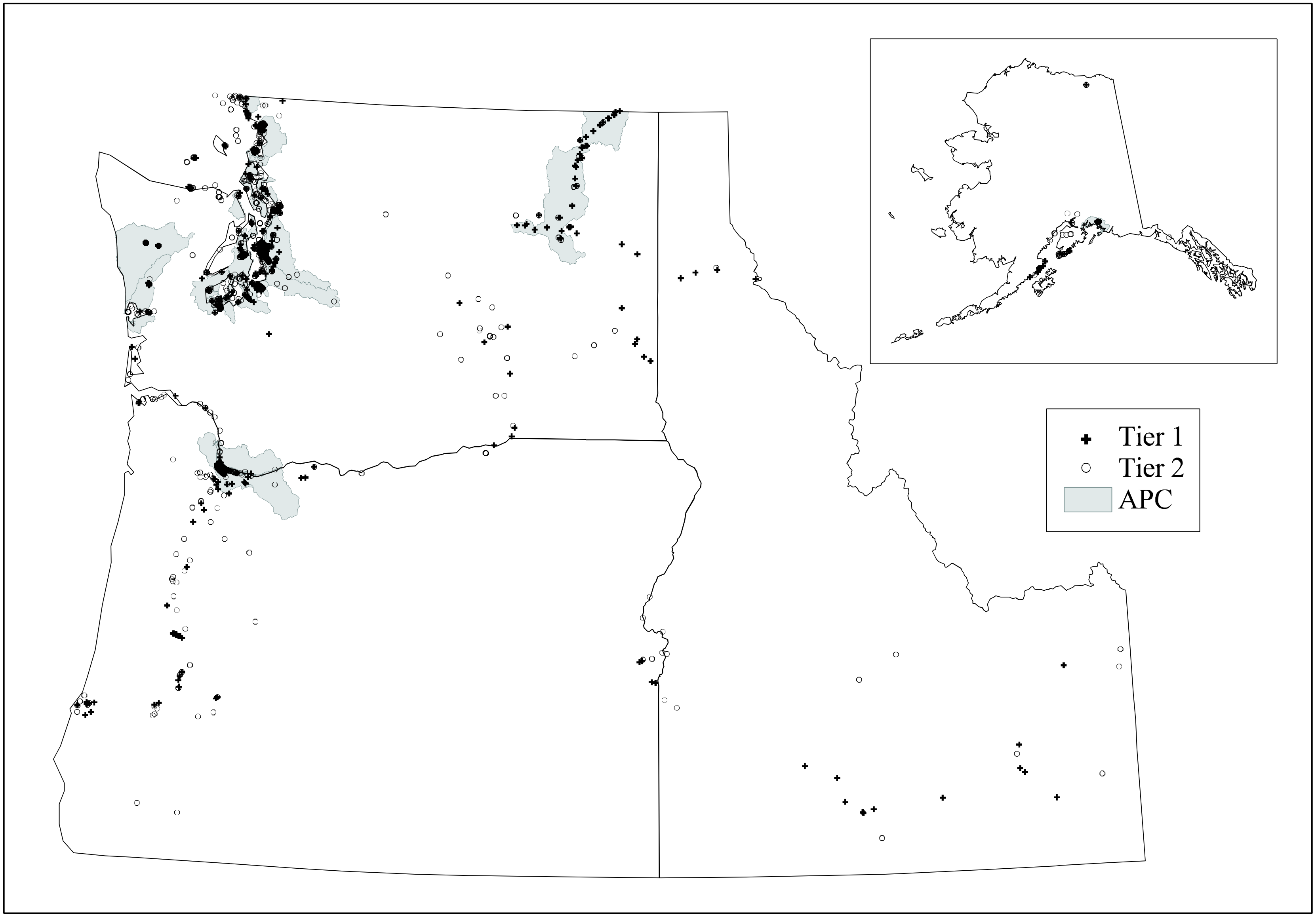

Figure 3-17. Region 10: Location of Sampling Stations Classified as Tier 1 or Tier 2 and Watersheds Containing APCs.

Table 3-45. Region 10: Watersheds Containing Areas of Probable Concern for Sediment Contamination.

Cataloging Unit Number	Cataloging Unit Name	State(s)	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3	
17020001	Franklin D. Roosevelt Lake	WA	66	52	9	5	92
17080001	Lower Columbia-Sandy	OR, WA	72	20	39	13	82
17090012	Lower Willamette	OR	382	243	96	43	89
17100102	Queets-Quinault	WA	108	77	23	8	93
17100105	Grays Harbor	WA	139	102	33	4	97
17110002	Strait Of Georgia	WA	443	184	179	80	82
17110012	Lake Washington	WA	216	179	30	7	97
17110013	Duwamish	WA	930	599	267	64	93
17110019	Puget Sound	WA	2135	1246	552	337	84
19020201	Eastern Prince William Sound	AK	31	10	15	6	81

Table 3-46. Region 10: Number of Tier 1 Stations in Region 10 That Are Located in Watersheds Containing APCs by Waterbody Name.

Waterbody	Number of Tier 1 Stations	Waterbody	Number of Tier 1 Stations
Puget Sound	926	Eld Inlet	8
Elliot Bay	498	Portage Bay	8
Willamette River	227	Camano Island	7
Sinclair Inlet	176	Vashon Island	7
Bellingham Bay	139	Whatcom Creek	6
Big Creek	86	Johnson Creek	5
Duwamish Waterway	86	Mercer Island	3
Lake Union	72	Panther Lake Ditch	3
Lake Washington Ship Canal	69	Sequalitchew Creek	3
Budd Inlet	62	Grays Harbor	2
Columbia River	51	Hammersley Inlet	2
Matheny Creek	50	Henderson Inlet	2
Sams River	27	Onion Creek	2
Lake Washington	26	Port Orchard	2
Strait Of Georgia	25	Port Susan	2
Chambers Creek	19	Cedar Creek	1
Roosevelt Lake	17	Chuckanut Creek	1
Humptulips River, East Fork	14	Indian Island	1
Fidalgo Island	12	Morey Creek	1
Green River	12	North Creek	1
Columbia Slough	11	Oakland Bay	1
Dyes Inlet	9	Sammish Bay	1
Whidbey Island	9	Sandy River	1
Bainbridge Island	8	Totten Inlet	1

Evaluation of Data from the 1997 *National Sediment Quality Survey* with Current Methodology

The data evaluation methodology (described in Table 2-2) was revised from the methodology used in the previous report to Congress to include new and updated analytical approaches. Modifications were made to the analysis used in determining the tier classification based on sediment chemistry, tissue residue, and toxicity data to take advantage of scientific advances since the release of the 1997 *National Sediment Quality Survey*. Biological effects concentration approaches were replaced with an alternative empirical method, namely, a logistic regression model that is used to estimate the predicted proportion toxic. EPA's draft ESGs derived from final or secondary acute values were also used in evaluating sediment chemistry data. In addition, EPA risk levels and PAH toxicity units were included to analyze sediment chemistry data. Moreover, for analyzing tissue residue data, all chemicals with log K_{ow} greater than 5.5 were evaluated instead of dioxins and PCBs only. Toxicity data were analyzed based on one solid-phase sediment toxicity test, replacing the requirement of two or more tests using two different species. Control-adjusted survival was considered for both marine and freshwater species, whereas control-adjusted length or weight was considered for selected freshwater species sublethal toxicity tests.

In view of the preceding changes to the evaluation methodology, EPA conducted an analysis of the data used to evaluate 21,096 stations in the first *National Sediment Quality Survey* using the current, revised methodology. This analysis allows comparison of the resulting tier classifications from both evaluation methodologies. The results of the tier classification using the previous and current methodology are presented in Table 3-47.

Table 3-47. Summary of Tier Classification Using Previous and Current Evaluation Methodologies With the NSI Data Evaluated in the 1997 *National Sediment Quality Survey*.

Tier	Previous Evaluation Methodology	Current Evaluation Methodology	Net Gain/Loss in Number of Stations
1	5,521	8,932	3,411
2	10,401	5,813	(4,588)
3	5,174	6,235	1,061
Total	21,096	20,980	(116)

There is a net increase of 3,411 Tier 1 stations and a net increase of 1,061 Tier 3 stations. These increases are the result of 4,588 Tier 2 stations being classified as Tier 1 or Tier 3 by the new methodology. This decrease in the number of Tier 2 stations (a total of 4,588 stations) equals the increase of 3,411 Tier 1 stations, the increase of 1,061 Tier 3 stations, and the loss of 116 stations previously analyzed and classified as Tier 3 but not analyzed by the new methodology.

All of the 116 stations not analyzed with the current methodology were previously classified as Tier 3 stations. Certain chemicals (such as phenol and pentachlorophenol) that were evaluated using biological effects correlation approaches are not analyzed by the new methodology because they do not have any evaluation criterion for sediment chemistry analysis. Also, in the previous analysis, a sensitivity analysis related to wildlife criteria was considered although not included in the final methodology. The wildlife criteria evaluation included species not normally eaten by humans (nonedible species). Rather than reporting different numbers of stations evaluated in the previous report, those stations that were not evaluated when the wildlife criteria evaluation was not included were simply classified as Tier 3. In the current methodology, stations with only tissue data from edible species are included in the analysis or station count.

Though there are net increases in the number of Tier 1 and Tier 3 stations, as shown in Table 3-47, a total of 171 stations previously classified as Tier 1 would be classified as Tier 2 and 12 stations previously classified as Tier 1 would be classified as Tier 3 (see Table 3-48). Similarly 1,412 stations classified as Tier 2 by the previous method would be classified as Tier 3. More than 3,500 stations previously classified as Tier 2 would be classified as Tier 1.

Table 3-48. Transition in Tier Classification Using Previous and Current Evaluation Methodologies With the NSI Data Evaluated in the 1997 *National Sediment Quality Survey*.

Tier Classification Using Previous Methodology	Tier Classification Using Current Methodology				Total
	Not Analyzed	1	2	3	
1	0	5,338	171	12	5,521
2	0	3,543	5,446	1,412	10,401
3	116	51	196	4,811	5,174
Total	116	8,932	5,813	6,235	21,096

A significant component of the increase in Tier 1 stations is the new classification methodology for sediment chemistry data, followed by tissue residue data and to a lesser extent by toxicity data. Changes in the sediment chemistry methodology can be attributed to the contribution of different chemicals, metals in particular, included in the logistic regression model, as well as the use of an EPA human health cancer risk of 10^{-4} or a noncancer hazard quotient (HQ) of 10. Increasing the ingestion rate from 6.5 grams per day to 17.5 grams per day also increased the proportion of Tier 1 stations. Including all chemicals with log K_{ow} greater than or equal to 5.5 in evaluating tissue residue, instead of dioxins and PCBs only, also contributed to the increase in Tier 1 stations. Finally, the previous methodology required two or more nonmicrobial acute toxicity tests using two different species for Tier 1 designation using toxicity data. Use of toxicity data in the current evaluation methodology was based on a single solid-phase sediment test without any restrictions on control data.

Of the 3,594 stations being classified as Tier 1 (3,543 Tier 2 stations and 51 Tier 3 stations; see Table 3-48), approximately 55.2 percent are so classified based on the logistic regression model, 47.8 percent based on the use of a higher EPA risk criterion (sediment TBP), around 7.5 percent are classified in a higher tier based on tissue residue analysis, and less than 3 percent are from other evaluation parameters. Of the 196 Tier 3 stations being classified as Tier 2 by the new methodology, more than 65 percent are so classified because of changes in the human health risk assessment for either tissue or sediment. Because stations may be evaluated by more than one criterion, the sum of the previous percentages exceeds 100.

CHAPTER 4

ASSESSMENT OF TRENDS IN SEDIMENT CONTAMINATION THROUGHOUT THE UNITED STATES

Introduction

The historical reconstruction of sediment contamination is a tool to improve measures for reducing sediment contamination as well as to provide feedback to estimate the success of pollution control techniques and regulations. Sediments can provide an invaluable record of transformations due to natural or anthropogenic processes. These transformations have typically occurred over time periods greater than what has been monitored and assessed. Within a stable environment, the sediment retains a record of all contaminant inputs that can be dated on the basis of the decay of naturally occurring radioisotopes associated with the sediment (Hermanson, 1991). The sediment chronology can be established by approximate reconstruction of historical events. Some of the common methods used are the use of radioactive decay products such as ^{210}Pb and ^{137}Cs, mineral magnetism, or correlation of sedimentary pollen or charcoal with historical records of logging or fires (Gubala et al., 1990). The depth distribution of the radioactive decay products in sediment cores provides valuable information on the period of sediment deposition. When the sediment cores are undisturbed, the activity of the radioactive product (e.g., ^{137}Cs) decreases exponentially toward the sediment-water interface (Bopp et al., 1998). By establishing a relationship between sediment depth and the time period, the history of the selected sediment components can be established.

One of the recommendations from the EPA report *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*, Volume 1: *National Sediment Quality Survey* (USEPA, 1997) was to “consider whether to design future evaluations of NSI data to determine the temporal trends of contamination.” To accurately assess potential trends in sediment contamination, it would be necessary to measure levels of the same contaminants in sediment collected throughout time at the same randomly selected locations (not concentrating solely on “hot-spots”). This approach could enable identification of patterns or trends in sediment contaminants over time. Trends identified using this approach would, however, be applicable only to the areas where data were collected and could not be extrapolated beyond those areas. Extrapolation is not possible because of variability resulting from factors such as land use patterns and historical anthropogenic activities. Despite the limitations imposed by the lack of routine monitoring information described above, EPA has developed an approach to provide the means for assessing changes in the extent and severity of sediment contamination over time for specific areas where sufficient data exist. To accomplish this, the data from the entire NSI database (data from 1980 through 1999) were evaluated. EPA’s approach and the results of the Agency’s analysis are discussed below. In addition to the trend assessment developed using the data from the NSI database, EPA has included information recently completed from the USGS National Water-Quality Assessment (NAWQA) program. To further evaluate potential trends in sediment contaminants, EPA has also conducted a literature review of studies conducted on sediment cores throughout the United States. This information is presented in Appendix E.

Database Trend Analysis

The NSI database contains more than 96,000 sediment samples collected from 41,594 sampling stations located in all 50 states, the District of Columbia, and Puerto Rico. These samples were collected from 1980 through 1999 and are associated with more than 3 million chemical and other sediment-related observations. Data from just under one-half (19,398) of the stations were collected after January 1, 1990, and these stations were classified into tiers as described earlier. The purpose of this analysis is to determine whether the severity of sediment contamination in areas where data were evaluated is changing with time. For this purpose, all applicable sediment chemistry data from 1980 through 1999 were considered for analysis. A variety of heterogeneous monitoring programs gathered the available data. These monitoring programs provide an adequate amount of data for assessing sediment contamination at single sampling stations and times. These programs do not provide, however, all the information needed for detecting trends in sediment contamination. Any of the factors described below can influence the analysis of trends:

- **Different/changing sampling and analytical methods over time.** During the past 20 years, a wide variety of sampling and analytical methods have been used to collect and analyze sediment chemistry data. Different monitoring programs often use different methods. Programs take advantage of new technology as improved methods become available. Differences in monitoring program objectives (e.g., screening versus detailed assessment) also lead to different methods of sampling and analysis.
- **Limited quality assurance/quality control (QA/QC) information.** Many of the historical data included in the NSI database are not associated with known data quality information. Although QA/QC and meta data are more frequently available for many data sets in the recent decade, it is still difficult, if not impractical, to apply more than a screening-level “use/don’t use” approach for assessing the quality of available data sets.
- **Monitoring strategies tend to focus on a single assessment.** To detect temporal trends, it is usually appropriate to have collected a time series of data (multiple observations over time) at a station or to have two or more random samples, each of which represents a different time period. About two-thirds of the sampling stations (27,676) in the NSI database are represented by only one sediment sample, and only 740 stations are represented by 10 or more observations spread across at least a 5-year period. Only programs similar to the EMAP/REMAP design provide suitable random samples. At this time, however, the NSI database includes data from only 1,828 EMAP stations collected from 1990 through 1995, and the data are limited to the coastal regions of 19 states.

Despite these limitations, this report presents the methodology and findings of a temporal trend assessment of surficial sediment contamination throughout the United States for areas for which data were evaluated.

The following steps were used to prepare the data for analysis:

1. **Compute the predicted proportion toxic for all sediment chemistry samples collected from 1980 through 1999.** Computing the predicted proportion toxic using the logistic model (described in detail in Appendix B) is a convenient approach for combining measurements from several different chemicals into one value per sample. For samples with only censored data (e.g., less thans and nondetects), the predicted proportion toxic was set to 0.10, which is 0.01 less than the minimum predicted proportion toxic from the logistic equation.

2. **Group samples based on latitude and longitude.** The latitude and longitude of each sample were rounded to the nearest 0.0001 degree. All samples from the same rounded latitude and longitude were then treated as if they had come from the same location. This would roughly correspond to assuming that stations within about 45 feet of each other are the same station. This allowed EPA to create data clusters, which have a time series of data at a single location.
3. **Average the predicted proportion toxic for a range of time periods** (1980–1983, 1984–1987, 1988–1991, 1992–1995, and 1996–1999). For each unique rounded latitude and longitude and time period, the average predicted proportion toxic was computed. (Each station could have only one value of predicted proportion toxic per time period.)
4. **Eliminate any data clusters where the predicted proportion toxic was not estimated in at least two of the time periods.** Based on a preliminary analysis of data contained in the NSI database, it was found that there were some major geographical shifts in data collection over the past 20 years. For example, during the early 1980s, a substantial amount of data was collected by the USGS in the Appalachian Mountains. In later years, USGS did not collect data in that region. This step eliminates the geographic diversity of the available data, but it also reduces the potential to compare geographically different data over time.

Application of this approach resulted in the availability of 4,153 stations for trend analysis. The locations of these stations in the contiguous United States are presented in Figure 4-1. There are clear geographical biases in the available data. These biases range from little to no data in some states to wide-scale monitoring across an entire state. Because of the data preparation step, each station could only have one value of predicted proportion toxic per time period. Table 4-1 presents the number of predicted proportion toxic observations (or stations) by time period and hydrologic region. For example, there are 89 stations with predicted proportion toxic observations in the Great Lakes hydrologic region (04) during the 1984 through 1987 time period. The location of hydrologic regions in the contiguous United States is presented in Figure 4-2. Hydrologic regions 19 and 20 represent Alaska and Hawaii, respectively.

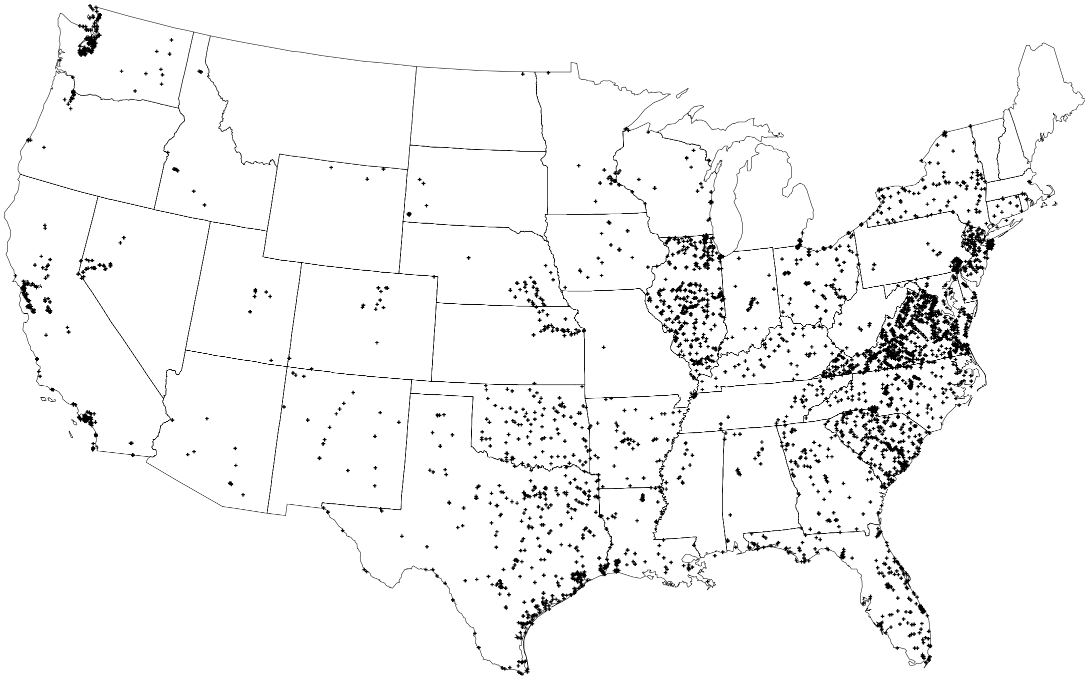

Figure 4-1. Locations of Data Clusters Used for Temporal Trend Analysis.

Table 4-1. Number of Predicted Proportion Toxic Observations Available for Trend Analysis After Data Preparation Step.

USGS Hydrologic Region	1980–1983	1984–1987	1988–1991	1992–1995	1996–1999
01	7	16	14	11	5
02	379	393	422	493	394
03	530	657	558	512	427
04	87	89	98	74	42
05	109	135	151	176	124
06	55	47	60	66	34
07	170	124	197	174	226
08	87	92	59	23	31
09	2	0	0	2	0
10	24	74	76	16	9
11	96	143	127	69	24
12	275	294	255	124	84
13	23	27	27	34	21
14	11	10	5	3	3
15	5	6	5	6	2
16	23	23	1	7	6
17	83	156	217	185	53
18	75	129	120	111	75
19	2	23	25	2	2
20	31	30	0	0	1

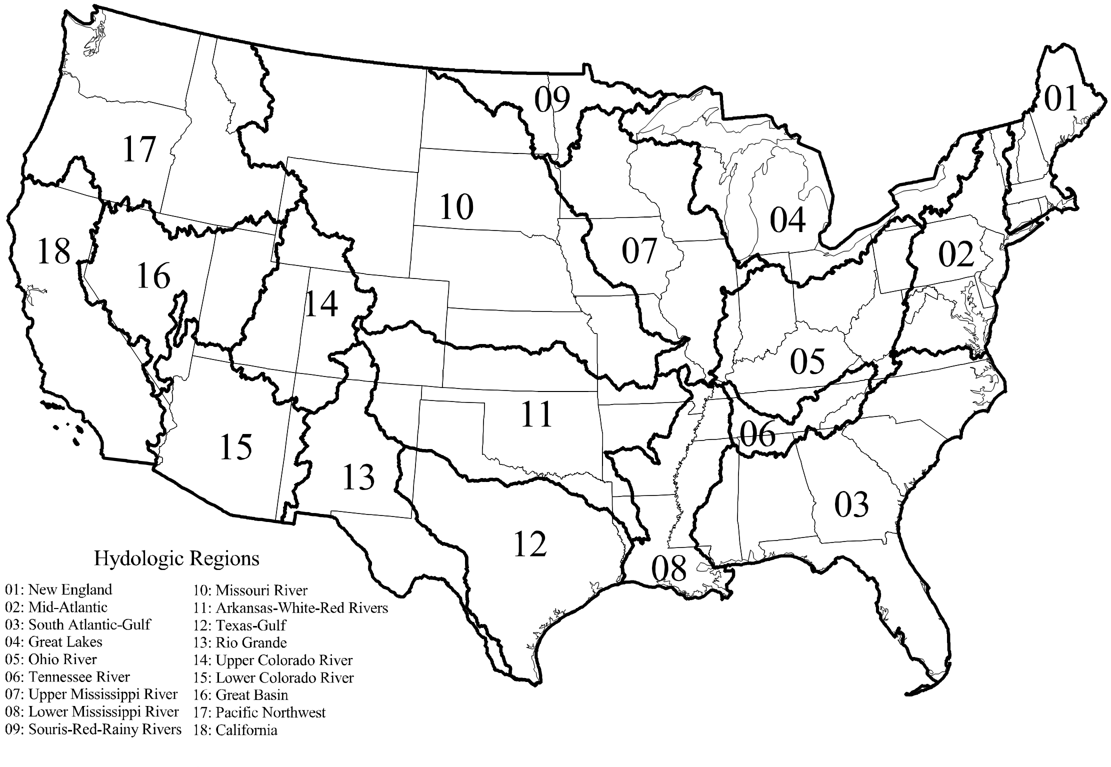

Figure 4-2. USGS Hydrologic Regions in Contiguous United States.

Because of the lack of data in hydrologic regions 01, 09, 10, 14, 15, 16, 19, and 20, individual statistics are not presented, but are included in national data where applicable.

To evaluate the effect of focusing the attention on those stations with more concentrated data sets, the same data preparation step was performed using only the 740 stations associated with 10 or more observations spread across at least a 5-year period. Of these 740 stations, 422 stations have data for four or five time periods and 231 stations have data for three time periods. The locations of these 740 stations are presented in Figure 4-3. Table 4-2 presents the number of predicted proportion toxic observations (or stations) by time period and hydrologic region. For example, there are 47 stations or predicted proportion toxic observations in the Mid-Atlantic hydrologic region (02) during the 1984 through 1987 time period.

Results

The logistic model classification scheme described earlier in this document was used to classify stations (i.e., predicted proportion toxic greater than 0.5 is Tier 1). Table 4-3 presents the classification of observations by tier, time period, and hydrologic region for the data clusters. Overall, the percentage of Tier 1 or Tier 2 stations ranges from 54 percent during the first time period, to 47 to 49 percent during the middle three time periods, to 40 percent for the last time period. It is also possible to discern the results in Table 4-3 by examining the box plots in Figure 4-4. Figure 4-5 is a comparable box plot figure for the concentrated data clusters.

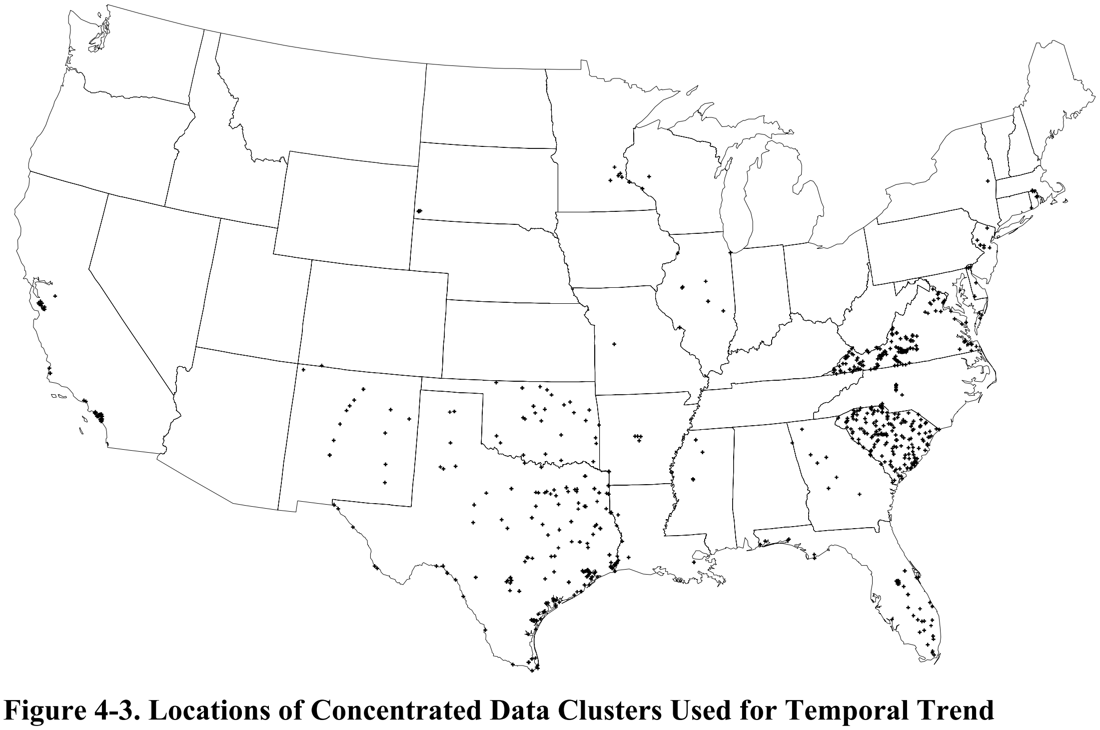

Figure 4-3. Locations of Concentrated Data Clusters Used for Temporal Trend Analysis.

Table 4-2. Number of Predicted Proportion Toxic Observations Available for Trend Analysis After Data Preparation Step From Concentrated Data Clusters.

USGS Hydrologic Region	1980–1983	1984–1987	1988–1991	1992–1995	1996–1999
01	6	6	6	6	3
02	51	47	53	57	49
03	213	241	266	241	232
04	0	0	1	1	1
05	30	27	35	31	30
06	25	25	25	20	16
07	10	15	17	9	5
08	1	1	8	7	0
10	1	7	7	0	0
11	40	45	45	31	8
12	115	137	141	65	45
13	18	20	19	24	17
14	1	2	2	2	2
18	39	37	44	32	31
20	17	17	0	0	0

Box plots provide a quick summary view of data. For each hydrologic region and time period, the 25th and 75th percentile is represented by the bottom and top of the box. The box represents the central 50 percent of the data and is equal to the interquartile range. The median is represented as a horizontal line in the box. The lines (or whiskers) extending from the bottom or top of the box show how stretched the distribution tails are. The length of the whiskers can extend to 1.5 times the interquartile range. Individual points outside the whiskers are plotted as circles and stars depending on whether the point exceeds three times the interquartile range.

Visual inspection of Figures 4-4 and 4-5 suggests that there might be some change in the predicted proportion toxic in some hydrologic regions and between some time periods. Two types of statistical tests are performed to evaluate these potential changes: the paired *t*-test and the Kolmogorov-Smirnov goodness of fit test. The paired *t*-test was selected to compare each combination of time periods for a shift in mean. Applying a two-sided paired t-test ($\alpha = 0.05$), it is possible to test for statistical differences between the different time periods. For example, it is possible to determine whether the mean predicted proportion toxic for 1984 through 1987 is the same as the mean predicted proportion toxic for 1980 through 1983 in hydrologic region 02. For each hydrologic region, there are 10 combinations of time periods (1984–1987 vs. 1980–1983, 1988–1991 vs. 1980–1983, ..., 1996–1999 vs. 1992–1995). The Kolmogorov-Smirnov two-sample (KS) test ($\alpha = 0.05$) is used to compare an entire distribution, unlike the *t*-test, which is a comparison of means. The KS test was used to compare the first and last time periods for each hydrologic region.

Table 4-3. Number of Observations Classified by Tier and Percentage of Observations Classified as Tier 1 or Tier 2 by Time Period and Hydrologic Region.

Tier 1	**Hydrologic Region**												**All Data**
YEAR	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**11**	**12**	**13**	**17**	**18**	
1980–1983	50	16	34	27	9	57	10	0	37	0	34	9	305
1984–1987	55	38	15	25	8	33	3	4	14	0	69	27	324
1988–1991	48	32	17	27	8	50	16	4	28	0	63	14	320
1992–1995	33	18	19	27	9	45	1	0	13	0	44	32	253
1996–1999	17	3	13	16	1	25	10	0	7	0	6	34	139
Tier 2	**Hydrologic Region**												**All Data**
YEAR	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**11**	**12**	**13**	**17**	**18**	
1980–1983	177	151	30	54	26	76	35	43	92	3	26	51	811
1984–1987	147	153	42	67	17	71	42	36	121	5	64	41	889
1988–1991	172	120	52	72	34	93	12	26	73	6	104	24	825
1992–1995	175	122	37	83	34	84	6	18	42	6	82	55	761
1996–1999	101	78	17	55	9	116	6	4	22	2	32	32	488
Tier 3	**Hydrologic Region**												**All Data**
YEAR	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**11**	**12**	**13**	**17**	**18**	
1980–1983	152	363	23	28	20	37	42	53	146	20	23	15	958
1984–1987	191	466	32	43	22	20	47	103	159	22	23	61	1,255
1988–1991	202	406	29	52	18	54	31	97	154	21	50	82	1,272
1992–1995	285	372	18	66	23	45	16	51	69	28	59	24	1,074
1996–1999	276	346	12	53	24	85	15	20	55	19	15	9	936
% Tier 1 or Tier 2	**Hydrologic Region**												**All Data**
YEAR	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**11**	**12**	**13**	**17**	**18**	
1980–1983	60%	32%	74%	74%	64%	78%	52%	45%	47%	13%	72%	80%	54%
1984–1987	51%	29%	64%	68%	53%	84%	49%	28%	46%	19%	85%	53%	49%
1988–1991	52%	27%	70%	66%	70%	73%	47%	24%	40%	22%	77%	32%	47%
1992–1995	42%	27%	76%	63%	65%	74%	30%	26%	44%	18%	68%	78%	49%
1996–1999	30%	19%	71%	57%	29%	62%	52%	17%	35%	10%	72%	88%	40%

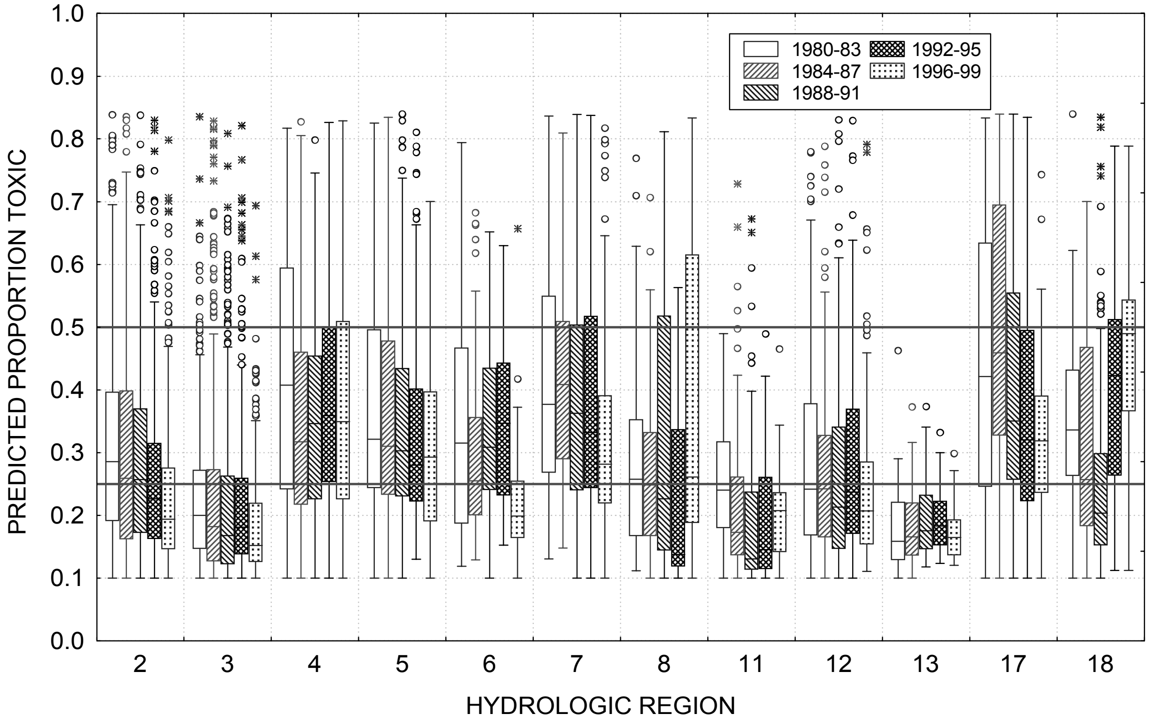

Figure 4-4. Box Plot of Predicted Proportion Toxic as a Function of Hydrologic Region for Data Clusters.

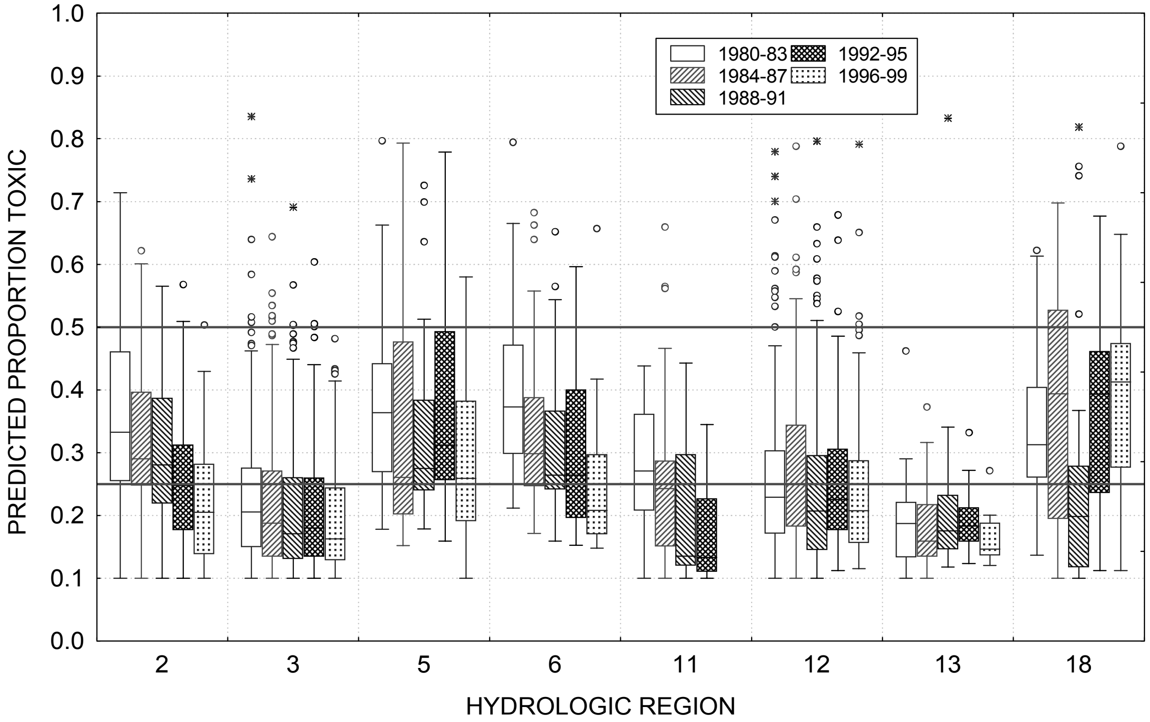

Figure 4-5. Box Plot of Predicted Proportion Toxic as a Function of Hydrologic Region for Concentrated Data Clusters.

In applying the paired *t*-test to all paired data, it was determined that of the 10 pairwise time period combinations, 9 showed a significant downward trend in the predicted proportion toxic for the data clusters. Eight of the 10 comparisons showed a significant downward trend in the predicted proportion toxic for the concentrated data clusters. Applying the KS test to all the data from the first and last time periods (1980–1983 vs. 1996–1999) showed a significant difference in the predicted proportion toxic between the two time periods for both the data clusters and the concentrated data clusters. The results of both of these tests suggest that sediment contamination (as measured by the predicted proportion toxic using the logistic model) is decreasing with time for all of the hydrologic regions evaluated. When looking at each hydrologic region, with sufficient data for the concentrated data clusters, the results suggest that there has been a slight decrease (Hydrologic Regions 02, 03, 05, 06, and 11) to no change (Hydrologic Regions 12, 13, and 18) in the levels of sediment contamination (as measured by the predicted proportion toxic using the logistic model). The results for individual hydrologic regions are presented in Table 4-4.

Box plots of the predicted proportion toxic associated with EMAP data are presented in Figure 4-6 for the four major regions for which EMAP data were available. Using an analysis of variance (ANOVA) test, it was determined that there were no significant differences in predicted proportion toxic for different years of data compiled in the Long Island/Hudson (L.I./Hud), New England, and Southeast regions. There is a significant difference (at the 95 percent confidence level) in predicted proportion toxic for different years of data collected along the Gulf Coast. Using a two-sample *t*-test, it was determined that the mean predicted proportion toxic in 1993 is less than the mean predicted proportion toxic in either 1991 or 1992, but the mean predicted proportions toxic in 1991 and 1992 are not significantly different.

Table 4-4. Summary of Statistical Tests Used to Compare Predicted Proportion Toxic Within Hydrologic Regions.

Hydrologic Region	Data Cluster				Concentrated Data Cluster			
	Paired *t*-test results for pairwise comparison of time periods			KS Test	Paired *t*-test results for pairwise comparison of time periods			KS Test
	Increasing	Decreasing	No change		Increasing	Decreasing	No change	
02	0	8	2	decrease	0	8	2	decrease
03	0	4	6	decrease	0	6	4	decrease
04	1	4	5	no trend				
05	0	2	8	decrease[a]	0	7	3	decrease
06	0	5	5	decrease[a]	0	7	3	decrease
07	0	6	4	decrease				
08	1	2	7	no trend				
11	0	6	4	decrease[a]	0	3	3	decrease[b]
12	0	7	3	decrease[a]	0	5	5	no trend
13	0	1	9	no trend	0	1	9	no trend
17	0	1	9	decrease[a]				
18	5	1	4	increase[a]	5	1	4	no trend
Overall	0	9	1	decrease	0	8	2	decrease

[a] There is a significant difference between the distributions from the two time periods; however, the cumulative density function overlaps. The result presented in the table corresponds to whether the maximum difference indicates a decrease or an increase in concentration. Conservatively, these results should be considered "inconclusive."

[b] Comparison performed between 1980–1983 and 1991–1995 data because of lack of 1996–1999 data.

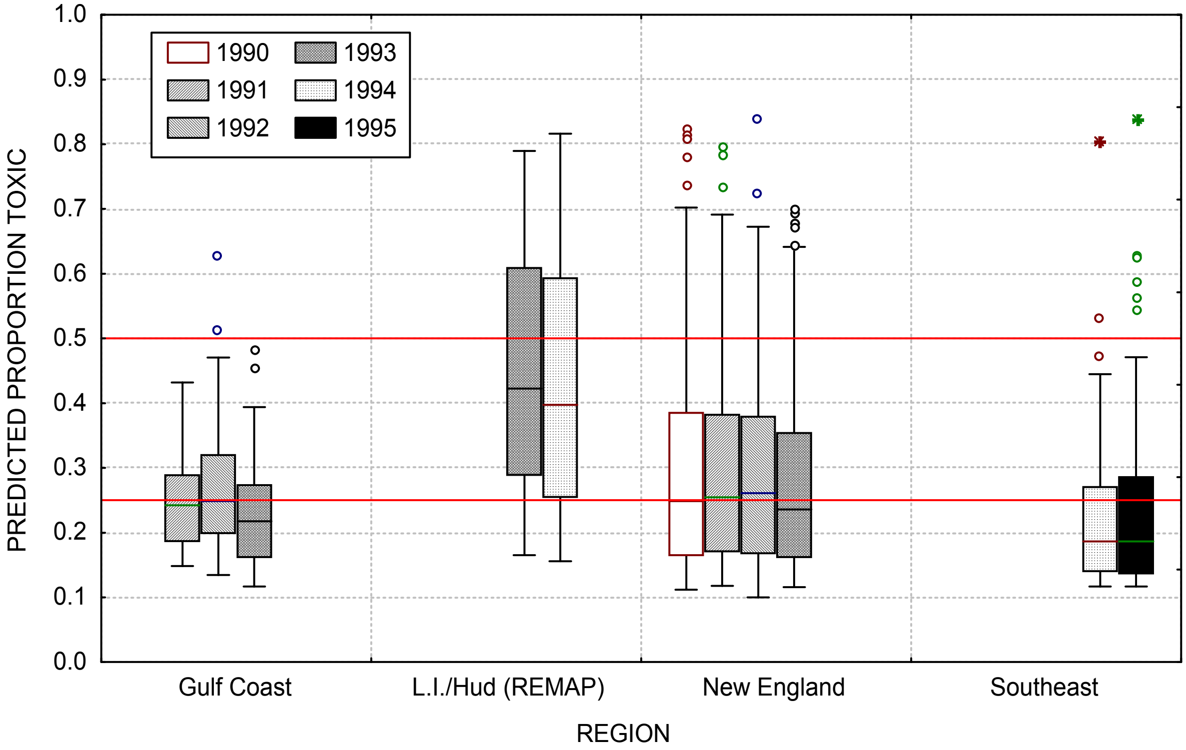

Figure 4-6. Box Plot of Predicted Proportion Toxic as a Function of Region for EMAP Data.

It is important to note here that this trend analysis does not address the issue of the current sediment quality in those regions outlined above. In other words, just because the data suggest that there has been a slight decrease in the levels of sediment contamination (as measured by the predicted proportion toxic using the logistic regression model) in the regions outlined above it does not mean that there is no risk to human health or aquatic life from the sediments.

Instead, it means only that the level of contaminants has slightly decreased. Further evaluations should be conducted to confirm the extent and severity of sediment contamination for any given site or watershed.

Sediment Core Analysis

The USGS NAWQA program is reconstructing water-quality histories using lake and reservoir sediment cores. The approach used for this assessment is paleolimnology—the use of age-dated sediment cores to reconstruct water quality histories using radioactive tracers and physical markers in the cores such as the pre-reservoir soil boundary in the reservoirs. Using this approach, trends in concentrations of numerous hydrophobic organic compounds (Eisenreich et al., 1989; Hites et al., 1981; Van Metre et al., 1997, 2000) and trace elements (Callender and Van Metre, 1997) have been identified in a variety of settings.

The NAWQA program is using paleolimnological methods to determine trends in metals and hydrophobic organic compounds in river basins (Callender and Van Metre, 1997; Van Metre et al., 1997). Sediment cores were collected from 1996 to 2000 in 15 reservoirs and 7 natural lakes in or near 15 U.S. cities (Table 4-5). Sites were chosen based on watershed land use to represent one of three general land use settings: older urban development (developed before about the 1940s) dominated by residential and commercial land uses; newer urban development characterized by rapid urbanization beginning in the 1950s or later; and reference sites with little or no development. Land use in the watersheds of these reservoirs and lakes ranges from undeveloped and protected forest to nearly 100 percent urban.

Contaminants analyzed in this program included major and trace elements (including arsenic, lead, mercury, and zinc), organochlorine pesticides (including DDT, chlordane, and dieldrin), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Van Metre et al. (n.d.) describe specific methods used for sediment collection, age dating, and the chemical analysis.

In this analysis, trends in concentrations of individual constituents were evaluated using Kendall's tau non-parametric statistical test to determine whether there was a statistically significant relationship between concentration and time from 1975 (trace elements) or 1970 (organic compounds) to the top of the core. The starting times for these evaluations were chosen for various reasons, including the passage of significant environmental legislation and establishment of new programs (e.g., the establishment of EPA in 1971). Other reasons for selecting this time frame include the promulgation and enforcement of regulations under the Clean Water Act and Clean Air Act and other actions such as the banning of DDT in 1972, restrictions of PCBs in 1971 and their banning in 1976, and the introduction of unleaded gasoline in the early 1970s.

Table 4-5. Sediment Core Locations.

Name	Location (major urban areas)
Lake Anne	Washington, DC
Lake Ballinger	Seattle, WA
Berkeley	Atlanta, GA
R.R. Canyon Lake	Los Angeles, CA
Great Salt Lake, Farmington Bay	Salt Lake City, UT
Lake Harriet	Minneapolis, MN
Lake Hemet	Los Angeles, CA
Lake Houston, South	Houston, TX
Lake Killarney	Orlando, FL
Lowrence Creek Lake	San Antonio, TX
Lake Mead, Las Vegas Bay	Las Vegas, NV
Newbridge Pond	New York City, NY
Orange Reservoir	Newark, NJ
Packanack Lake	Newark, NJ
Panola	Atlanta, GA
Palmer Lake, West Lobe	Minneapolis, MN
Sloans Lake	Denver, CO
Sand Lake	Orlando, FL
Town Lake	Austin, TX
Lake Washington	Seattle, WA
White Rock Lake	Dallas, TX
West Street Basin	Los Angeles, CA

Trends in concentrations of eight trace elements, nine individual PAHs, total PAH (the sum of 18 two- to seven-ringed parent PAHs and their alkylated homologues, excluding perylene [Van Metre et al., 2000]), 5 organochlorine pesticides, and total PCBs were tested. These elements and compounds were chosen for analysis because they all have sediment quality guidelines (McDonald et al., 2000) and include all of the constituents measured by NAWQA studies that have pronounced temporal trends in multiple sites (Callender and Van Metre, 1997; Van Metre and Callender, 1997; Van Metre et al., 1997; Van Metre et al., 2000).

The rank correlation test has at least two limitations as applied here. First, the data sets are small, averaging 8 and 14 samples for organic compounds and trace elements, respectively. Second, the test is for only monotonic trend; it does not identify constituents or sites showing nonmonotonic temporal variations such as peaks or valleys within the time period tested.

Results

Statistically significant increasing trends in total PAH concentrations occur at 10 lakes (at 90 percent confidence) and significant decreasing trends at two lakes (Figure 4-7). All 10 lakes with increasing

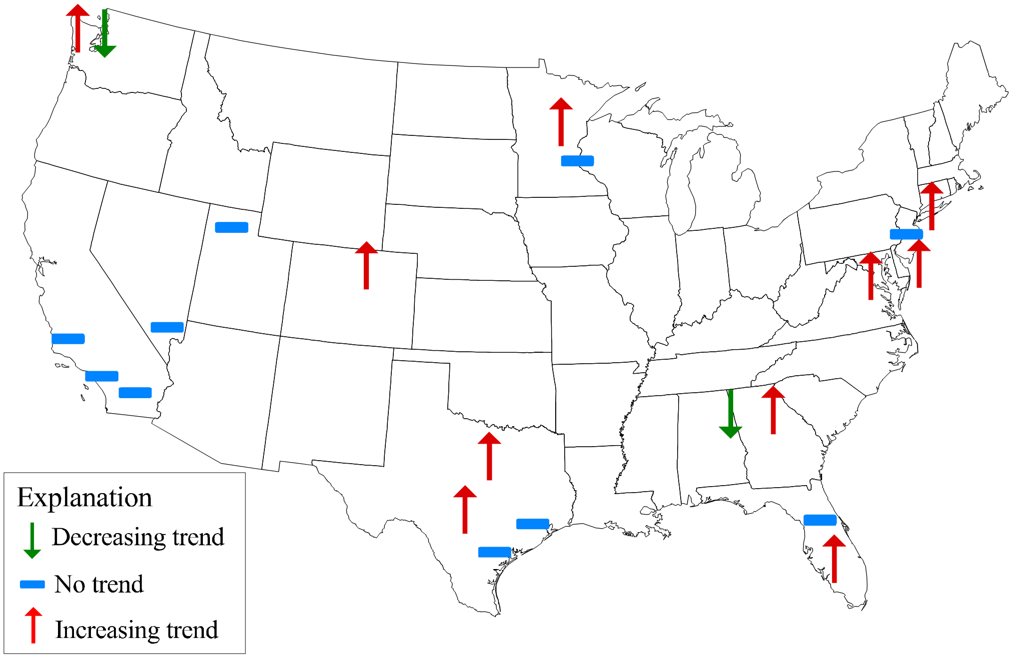

Figure 4-7. PAH Trends Throughout the United States Using Sediment Core Data from 1970 to Top of Core.

trends in PAHs are in urban watersheds. Of the 10 lakes that did not have significant trends, 2 are reference lakes (Sand and Hemet) and 6 of the other 8 are in stable urban watersheds (Lakes Harriet, West Street Basin, Great Salt Lake, and Packanak), are just beginning to urbanize (Lakes Houston and R.R. Canyon Lake), or are in high-erosion settings where urban effects are diluted (Lake Mead in addition to Lakes Houston and R.R. Canyon Lake).

The two lakes that had significant decreasing trends are Lake Washington in Seattle and Panola Reservoir, a small reference lake near Atlanta, Georgia. Lake Washington has older urban development in its watersheds, which might be related to the relatively higher concentrations of PAHs in older sediments. PAHs in some older urban areas have been shown to have decreased since highs in the 1940s through 1960s (Van Metre et al., 2000). Additionally, sewage inputs to Lake Washington ended in 1967 and the Asarco copper smelter in nearby Tacoma was closed in 1985. These changes could contribute to the decreasing trends in PAHs, and the closing of the smelter very likely contributes to the decreasing trends in most trace elements. The decreasing PAH trend at Panola Reservoir could be the result of improved emissions control, for example, on power plants; decreases in PAHs have been reported for other lakes in the eastern U.S. (Heit et al., 1988).

In Figure 4-8 a dramatic increase in PAH concentrations in White Rock Lake can be observed since urbanization of the watershed began in the 1950s. This pattern is repeated in lakes with urbanizing watersheds across the United States (Van Metre et al., 2000). PAHs are produced by combustion of fossil fuels (oil, coal, gasoline, diesel, and wood). They have many urban sources, including industrial and power plant emissions, car and truck exhaust, tires, asphalt roads, and roofs. These sources are reflected in the relationship between historical traffic data for greater Dallas and PAHs in the sediment core from White Rock Lake (Figure 4-8).

The analysis of the organochlorine compounds (pesticides and PCBs) showed decreasing trends, but fewer than expected considering the regulatory history of these compounds. Total DDT decreased in 12 of the 22 lakes (Figure 4-9) and PCBs decreased in 6 lakes and were not detected in 6 other lakes. In no lake did DDT or PCBs increase. One factor that could contribute to the lack of statistically significant trends is the combination of large variability among samples and small sample size. Another that is particularly relevant for PCBs and DDT and its metabolites is that concentrations have been decreasing exponentially in the environment since use peaked and began to decline in the 1960s (Van Metre et al., 1998). The period chosen here, beginning in 1970, is after peak concentrations and on the flatter portion of the exponential decrease, and therefore it might be less sensitive to detecting trends.

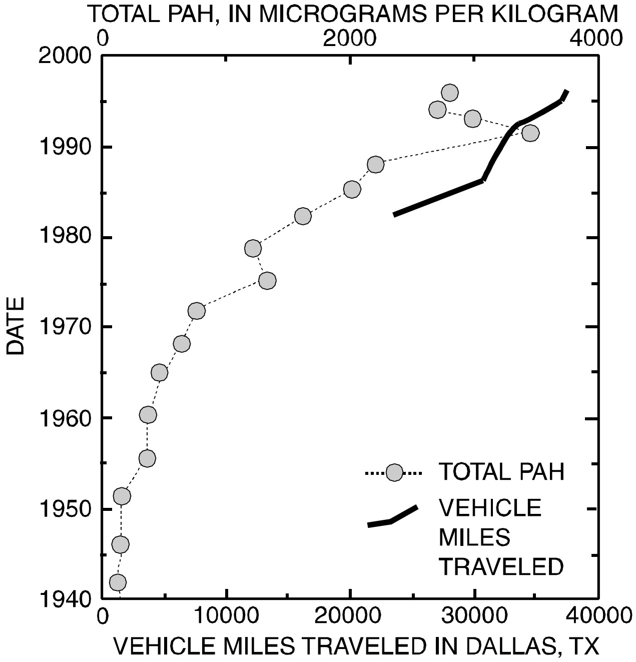

Figure 4-8. White Rock Lake PAH Concentrations.

Among the organochlorine compounds it is also notable that chlordane has increased in more lakes than is has decreased since 1970. The trend test showed one decreasing trend and four increasing trends. Chlordane was used as an agricultural pesticide in the United States from 1948 to 1978 and continued in urban use until 1988 (http://www.epa.gov/pbt/chlordane.htm). These trends, and lack of

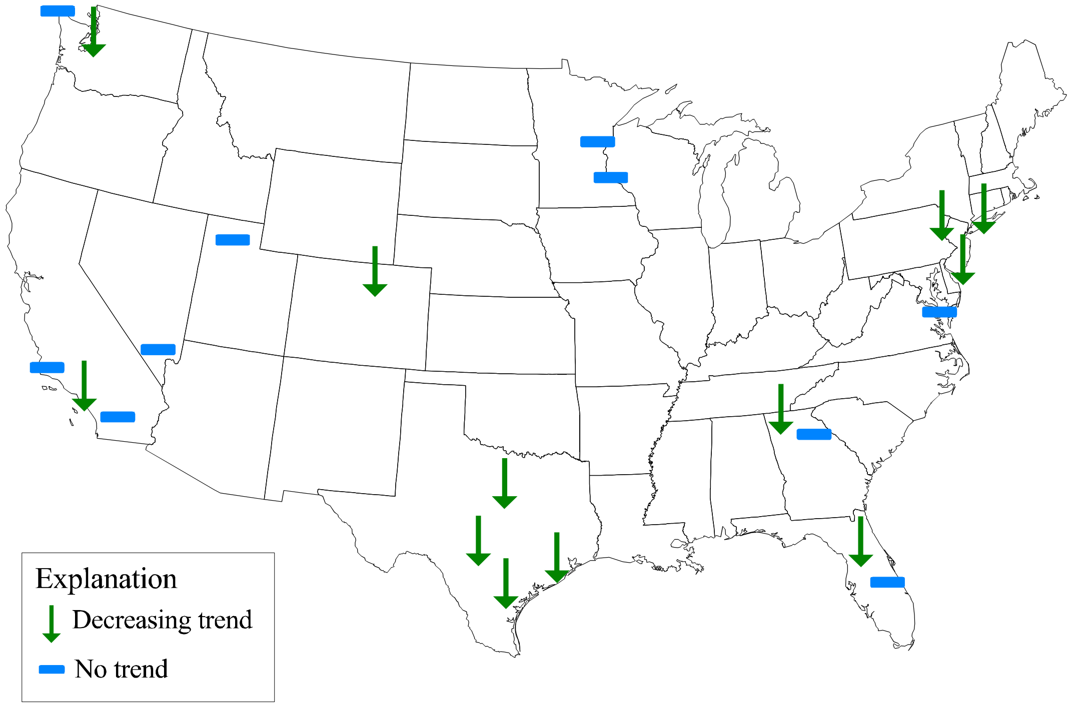

Figure 4-9. DDT Trends Throughout the United States Using Sediment Core Data from 1970 to Top of Core.

trends, suggest that more recent urban use of chlordane has caused increasing trends in some lakes or delayed the onset of significant decreases noted elsewhere for DDT and PCBs (Van Metre et al., 1998).

DDT use was widespread in the United States in the 1950s and 1960s, and sediment cores from many lakes show a large DDT peak in the early 1960s (Van Metre et al., 1998). Trends in total DDT (the sum of DDT and its breakdown products, DDD and DDE) closely follow historical use of DDT, as can be seen from the sediment core from White Rock Lake in Texas (Figure 4-10). The initial occurrence of the DDT in cores is usually in the 1940s, when widespread use began. Peak concentrations are from the late 1950s to the mid 1960s, when use peaked. DDT use declined in the 1960s and was eventually banned in 1972. Levels of DDT have been decreasing by about half every 10 years since the 1960s, although they are still at detectable levels in all but the most pristine lakes.

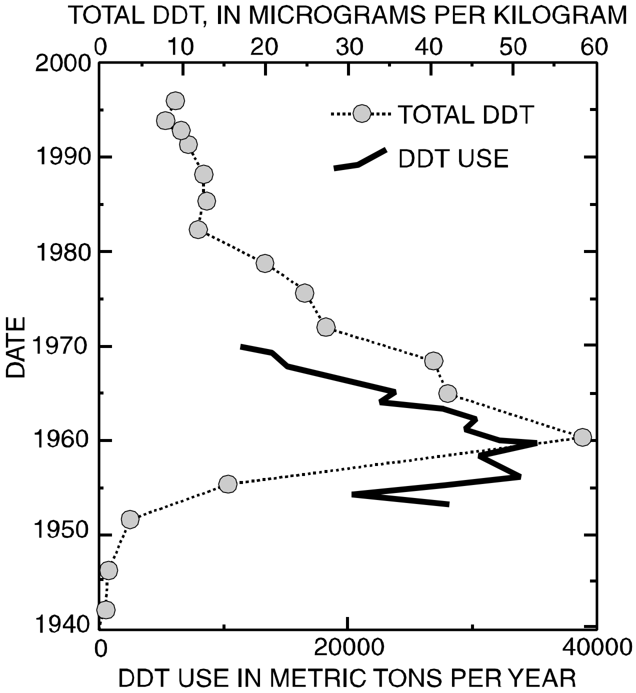

Figure 4-10. White Rock Lake DDT Concentrations.

The most consistent trend for any of the constituents tested is the decreasing trend in lead since the mid-1970s. Twenty-one of the 22 lakes, including the 3 reference lakes, had statistically significant decreasing trends (Figure 4-11). Decreasing trends in lead have been reported previously and have been attributed to the large reduction in

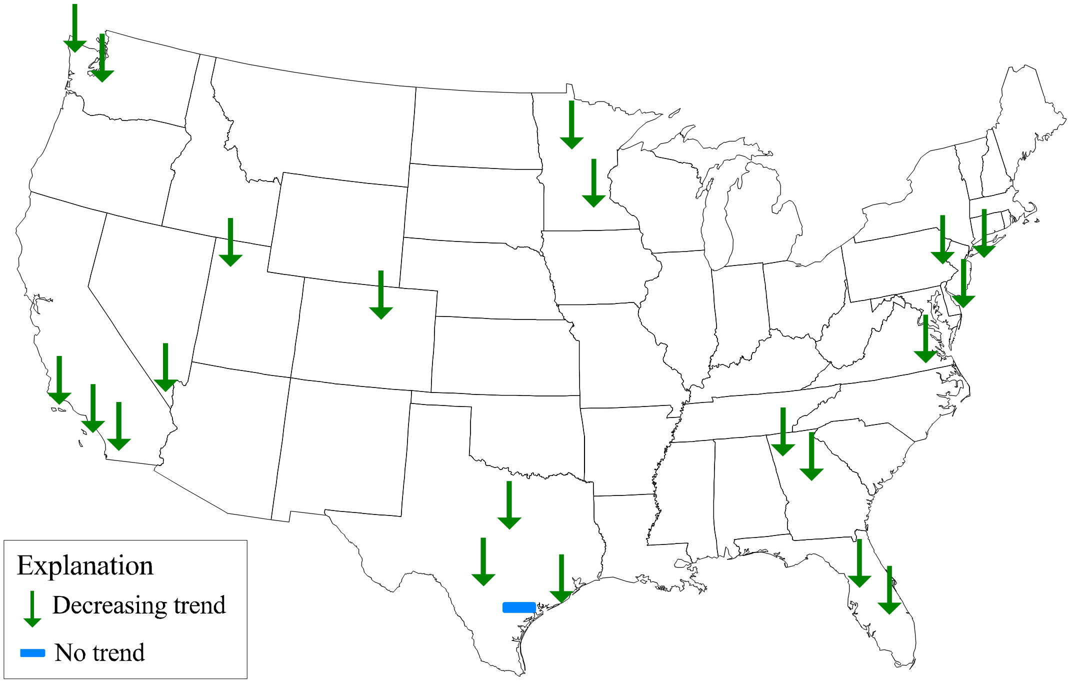

Figure 4-11. Lead Trends Throughout the United States Using Sediment Core Data from 1975 to Top of Core.

anthropogenic lead releases since the 1970s brought about by the switch to unleaded gasoline and, to a lesser extent, reductions in industrial and waste emissions (e.g. Callender and Van Metre, 1997). Significant trends in 21 of the 22 lakes tested, including the 3 reference lakes, indicates the strength of the gasoline lead signal in the U.S. environment. As shown in Figure 4-12, lead concentrations in the White Rock Lake sediment core track well with national atmospheric trends in lead. Two other trace elements had concentrations of somewhat consistent trends: chromium and nickel increased in zero and two lakes and decreased in 10 and 11 lakes, respectively. The only apparent pattern to these decreases is that they mostly occurred in the central and western United States, with the one exception of a decreasing trend in chromium in Lake Killarney in Orlando. Two other elements—copper and mercury—had significant trends in 10 or more lakes, with about equal numbers of decreasing and increasing trends. No clear regional or land use patterns are apparent for trends in these elements, or for the five sites with decreasing trends in cadmium.

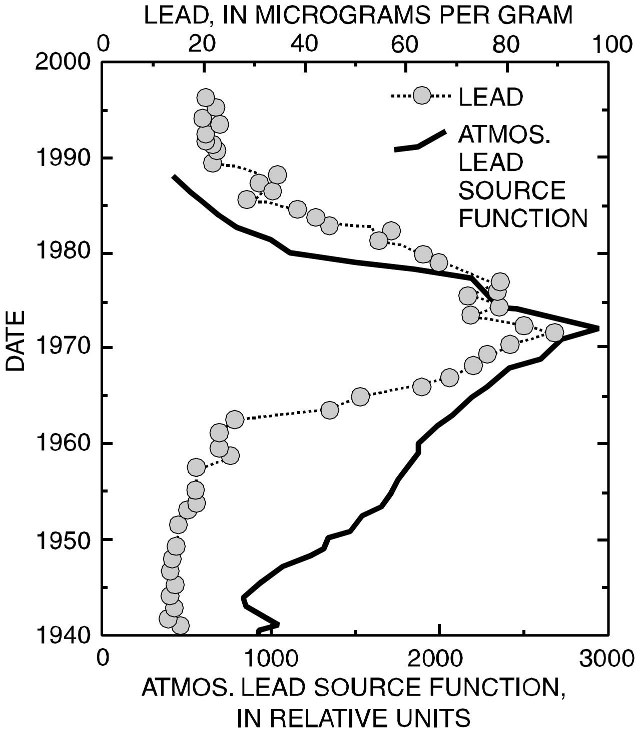

Figure 4-12. White Rock Lake Lead Concentrations.

The only trace element with more increasing trends than decreasing trends was zinc. Nine of the 19 urban lakes had increasing trends in zinc (at a 90 percent confidence level), and three had decreasing trends. Increasing levels of zinc in urban and urbanizing watersheds could be a result of the use of zinc in rubber tires and increasing levels of vehicle use on U.S. roads. The two lakes with decreasing trends in zinc, Lakes Washington and Great Salt Lake, are both in older urban areas. As noted above, Lake Washington had large historical inputs of metals from the Asarco smelter in Tacoma.

Additionally, this analysis of trends in sediment contamination using sediment cores does not address the issue of current sediment quality in the lakes and reservoirs discussed above. As was outlined earlier for the results of the trend analysis as measured by the logistic regression model using the NSI data (1980 through 1999), any decrease in levels of sediment contamination does not imply that there is no risk to human health or aquatic life from the sediments. Further evaluations should be conducted to confirm the extent and severity of sediment contamination for any given site or watershed.

Discussion

An assessment of the contamination of sediments in lakes, rivers, and estuaries using sediment cores is a useful tool to evaluate the water quality in these waters, as can be seen from the information provided above. In addition, sediment core analysis can be used as feedback to evaluate the impact of current legislation on reducing the level of contaminants in different waterbodies of the United States. A major limitation of the study of historical trend analysis is the post-depositional disturbance of the sediment by benthic organisms and other physical processes such as wave action and dredging. Researchers have used different sediment dating techniques to study the existence and extent of such disturbances.

Some of the most significant sources of persistent and toxic chemicals have been eliminated or reduced as the result of environmental controls put into place during the past two decades. In addition, effluent controls on industrial and municipal point source discharges and best management practices for the control of nonpoint sources have greatly reduced contaminant loadings to many rivers and streams. The results of better controls over releases of sediment contamination are evident from the case studies presented.

Metals and persistent organic chemicals are the contaminants most often associated with sediment contamination. Despite recent progress in controlling sediment contaminant releases to the different compartments of the environment, active sources of these contaminants still exist. These include nonpoint source loadings such as surface water runoff and atmospheric deposition, point source loadings, and resuspension of in-place sediment contaminants from historical sources. To achieve EPA's Contaminated Sediment Goals, it is evident from the information presented in this chapter that a combination of pollution prevention, source control, and continuous monitoring is essential.

CHAPTER 5
CONCLUSIONS AND DISCUSSION

The NSI database is EPA's largest compilation of sediment chemistry data (measuring the chemical concentration of sediment-associated contaminants); tissue residue data (measuring chemical contaminants in the tissue of organisms); and toxicity data (measuring the lethal and sublethal effects of contaminants in environmental media on various test organisms). This database contains environmental monitoring data from a variety of sources (e.g., state and federal monitoring programs) and includes more than 4.6 million analytical observations and 50,000 stations throughout the United States from 1980 through 1999. For this report, EPA presents the results of the screening-level assessment of the NSI data from 1990 through 1999. The purpose of this assessment was to determine whether potential adverse effects to aquatic life and/or human health from sediment contamination exist at present or existed over the past 10 years at distinct monitoring locations throughout the United States. One major advantage of screening out older data (data collected before January 1, 1990) is to prevent the results presented in this report from being unduly influenced by historical data when more recent data are available. This would not allow the results of any decrease in sediment contaminant levels due to scouring/redeposition, natural attenuation, navigational dredging, or active sediment remediation that have occurred since that sample was collected.

EPA evaluated a total of 19,398 sampling stations nationwide as part of the NSI data evaluation. Of these sampling stations, 8,348 stations (43.0 percent) were classified as Tier 1 (associated adverse effects on aquatic life or human health are probable); 5,846 stations (30.1 percent) were classified as Tier 2 (associated adverse effects on aquatic life or human health are possible); and 5,204 stations (26.8 percent) were classified as Tier 3 (no indication of associated adverse effects). As pointed out earlier in the document, many sampling programs target only sites of known or suspected contamination. This factor could contribute significantly to the high percentage of Tier 1 classifications. To further evaluate this, EPA conducted an evaluation using the same tiering methodology on data collected from EPA's EMAP. This program uses a probabilistic sampling design and selects sampling locations at random. The analysis revealed that 33.4 percent of EMAP sampling stations were classified as Tier 1, 41.9 percent were classified as Tier 2, and 24.8 percent were classified as Tier 3. This finding suggests that state monitoring programs (accounting for most of the NSI data) have tended to focus their sampling efforts on areas where contamination is known or suspected to occur. Further evaluation of the effects of nonrandom sampling design on the frequency of detecting contaminated sampling stations can be found in Swartz et al. (1995). They compared the percent of sediment sampling stations that exceeded PAH screening levels (ERL, SQC, AET) based on random sampling station selection (Virginian Province EMAP stations) to the percent of sampling stations that exceeded those levels based on sampling station selection on the basis of known PAH contamination (such as creosote-contaminated Eagle Harbor, Washington). The investigators found that the frequency of exceeding a sediment screening value in sampling stations known to be contaminated was 5 to 10 times greater than that for randomly selected sampling stations.

In addition to the baseline screening-level assessment of the extent and severity of sediment contamination throughout the United States, EPA also used the data in the NSI to evaluate potential trends in sediment contaminant levels throughout the country. Despite the various limitations imposed by a lack of routine monitoring information outlined in Chapter 4, EPA developed an approach to provide a means for assessing changes in the extent and severity of sediment contamination over time for specific areas where sufficient data exist in the NSI database. When looking at each hydrologic region (defined as a major geographic area containing either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf Region, which includes a number of rivers draining into the Gulf of Mexico) with sufficient data, focusing on stations with more concentrated data sets, the results suggest that there has been a slight decrease to no change in the levels of sediment contamination (as measured by the predicted proportion toxic using the logistic model) from 1980 through 1999. The results for these individual hydrologic regions are presented in Chapter 4. Also discussed in that chapter are the results from the USGS NAWQA program, which collected and analyzed sediment cores in lakes and reservoirs throughout the United States. Results from this analysis suggest that DDT (from 1965 through 1990) and lead (from 1970 through 1990) sediment concentrations displayed significant decreasing trends in several of the lakes and reservoirs (12 of 22 lakes for DDT and all 22 lakes for lead) throughout the United States. These decreases appear to be linked to the banning of DDT in 1972 and the switch to unleaded gasoline in the 1970s. This analysis of sediment cores also demonstrated a significant increase in sediment PAH levels that appears to be correlated with an increase in urbanization.

It is important to note here that these analyses of trends in sediment contamination do not address the issue of the current sediment quality in the areas outlined above. In other words, just because the data suggest that there has been a slight decrease in the levels of sediment contamination (as measured by the predicted proportion toxic using the logistic regression model or from the NAWQA study) in the regions or lakes and reservoirs outlined above it does not mean that there is no risk to human health or aquatic life from the sediments. Further evaluations should be conducted to confirm the extent and severity of sediment contamination for any given site or watershed.

The characteristics of the NSI data, as well as the degree of certainty afforded by available assessment tools, allow neither an absolute determination of adverse effects on human health or aquatic life at any location nor a determination of the areal extent of contamination on a national scale. The evaluation results strongly suggest, however, that sediment contamination is significant enough to pose potential risks to aquatic life and/or human health in various locations throughout the United States. The evaluation methodology was designed for the purpose of a screening-level assessment of sediment quality. Further evaluation should be conducted to confirm the extent and severity of sediment contamination for any given site or watershed.

Based on the number and percentage of sampling stations containing contaminated sediment within watershed boundaries, EPA identified a number of watersheds that contain areas of probable concern (APCs) for sediment contamination. About 26 percent of the 370 eligible watersheds (96) contained an APC, or 4.2 percent of all the 2,264 watersheds in the United States. Although the APCs were selected by means of a screening assessment, EPA believes that they represent the highest priority for further ecotoxicological assessment, risk analysis, and contaminant source evaluation because of the increased weight-of-evidence in these areas. Although the procedure for classifying APCs using multiple sampling stations was intended to minimize the probability of making an erroneous classification, further monitoring of conditions in watersheds containing APCs is necessary because the same mitigating factors that might reduce the probability of associated adverse effects at one sampling station might also affect neighboring sampling stations.

EPA chose the watershed as the unit of spatial analysis because many states and federal water and sediment quality management programs, as well as data acquisition efforts, are centered on this unit. This choice reflects the growing recognition that activities taking place in one part of a watershed can greatly affect other parts of the watershed, and that management efficiencies are achieved when viewing the watershed holistically. At the same time, EPA recognizes that contamination in some reaches in a watershed does not necessarily indicate that the entire watershed is affected. Further analysis should be conducted within that watershed to delineate sediment contamination, which would allow any sediment management activities determined to be necessary to be done in the most cost-effective and environmentally sound manner.

Watershed management is a critical component of community-based environmental protection using watershed or hydrologic boundaries to define the problem area. Many public and private organizations are joining forces and creating multidisciplinary and multijurisdictional partnerships to focus on water quality problems community by community and watershed by watershed. These watershed approaches are likely to result in significant restoration, maintenance, and protection of water resources throughout the United States. As reported in the initial National Sediment Quality Survey in 1997, various programs across the United States as part of the National Estuary Program have used a watershed approach that has led to specific actions to address contaminated sediment problems. These include the Chesapeake Bay, Narragansett Bay (Rhode Island), Long Island Sound, Puget Sound, New York/New Jersey Harbor, and San Francisco Bay Estuary programs. These specific programs have all recommended actions to reduce sources of toxic contaminants to sediment.

As part of EPA's Contaminated Sediment Action Plan, the Office of Solid Waste and Emergency Response, the Office of Water, and EPA's regional offices will initiate a pilot project to facilitate cross-program coordination on contaminated sediments. The pilot project will bring a cross-Agency focus to identifying and assessing waters that are impaired by sediment contamination. The pilots will use the legal authorities and techniques available to both programs to satisfy the needs of both the Remedial Investigation/Feasibility Study (RI/FS) evaluations and Total Maximum Daily Load (TMDL) modeling. The ultimate goal of the pilots is to develop more watershed-based approaches to identifying, assessing, and addressing, as necessary, contaminated sediments. EPA will work with other Federal agencies, States, and interested stakeholders as these pilots are identified and implemented.

Additional pilot projects are outlined under a Memorandum of Understanding (MOU) between EPA and the USACE. The purpose of the MOU, signed in July 2002, is to facilitate cooperation between the U.S. Department of the Army and EPA with respect to environmental remediation and restoration of degraded urban rivers and related resources in the United States. To begin an evaluation of this urban rivers cooperative approach, it is proposed that eight demonstration pilot projects be announced and undertaken during the next 12 months. The pilot projects will include, but not limited to, projects for water quality improvement, contaminated sediment removal and remediation, and riparian habitat restoration.

The remainder of this chapter presents some general conclusions about the extent and severity of sediment contamination in locations throughout the United States, as well as potential sources of sediment contaminants. It also looks at conclusions from other studies addressing the regional and national extent of sediment contamination. Finally, this chapter discusses other indications of sediment contamination.

Extent of Sediment Contamination

Based on EPA's evaluation, sediment contamination exists at levels where associated adverse effects are probable (Tier 1) in some locations in every region of the country. The waterbodies affected include streams, lakes, harbors, nearshore areas, and oceans. A number of specific areas in the United States had large numbers of sampling stations where associated adverse effects are probable. Puget Sound, Elliot Bay, Hudson River, the Pacific Ocean (near Santa Monica and San Diego), Willamette River, Sinclair Inlet, San Diego Bay, Bellingham Bay, San Francisco Bay, Sheboygan River, Passaic River, Christina River, Mississippi River, Big Creek (Grays Harbor), and Duwamish Waterway were among those locations. Based on the above list, several harbors appear to have some of the most severely contaminated sediments in the country. This finding is not surprising because major harbors have been affected throughout the years by large volumes of boat traffic, contaminant loadings from upstream sources, and many local point and nonpoint sources.

Thousands of waterbodies in hundreds of watersheds throughout the country contain sampling stations classified as Tier 1. Many of these sampling stations might represent isolated “hot spots” rather than widespread sediment contamination, although insufficient data were available in the NSI database to make such a determination. EPA’s River Reach File 1 (RF1) delineates the Nation’s rivers and waterways into segments or reaches of approximately 1 to 10 miles in length. Based on RF1, approximately 8.8 percent of all river reaches in the contiguous United States contained NSI sampling stations. More than 8,300 sampling stations in almost 2,300 river reaches across the country (3.6 percent of all reaches) were classified as Tier 1. About 5,850 sampling locations were classified as Tier 2. In total, almost 4,200 river reaches in the United States—approximately 6.5 percent of all river reaches—include at least one Tier 1 or Tier 2 station.

EPA cannot determine the areal extent or number of river miles of contaminated sediment in the United States from the data in the NSI because (1) the NSI database does not provide complete coverage for the entire nation; (2) sampling locations are largely based on a nonrandom sampling design; and (3) sediment quality can vary greatly within very short distances.

The results of the NSI data evaluation discussed in this report must be interpreted in the context of data availability. Many States and Regions appear to have a much greater incidence of sediment contamination than others. To some degree, this appearance reflects the relative abundance of readily available electronic data, not necessarily the relative incidence of sediment contamination. For example, 2,886 sampling stations in Region 10 (Alaska, Idaho, Oregon, Washington) are designated as Tier 1, whereas only 79 sampling stations in Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming) are designated as Tier 1. However, of the 19,398 sampling stations evaluated from 1990 through 1999 throughout the United States, only 1.5 percent (294) were located in Region 8 while 27.1 percent (5,263) were located in Region10. Therefore, although the absolute number of Tier 1 and Tier 2 stations in each state is important, relative comparisons of the incidence and severity of sediment contamination between states is not possible because the extent of sampling and data availability vary widely.

For a number of reasons, some potentially contaminated sediment sites were missed in this evaluation. The most obvious reason is that the NSI database does not include all the sediment quality data collected throughout the United States from 1990 through 1999. As pointed out in Chapter 2, several reviewers highlighted locations or areas throughout the United States with contaminated sediments either not included in this report or with limited coverage. EPA is continually updating the NSI database for future evaluations to provide better national coverage, and the areas and locations listed during this review will be a high priority for addition to the NSI database and subsequent reports. Moreover, some data in the NSI database were not evaluated because of questions concerning data quality or because information regarding the location of the samples (i.e., latitude and longitude) was not available.

Sources of Sediment Contamination

Toxic chemicals that accumulate in sediment and are associated with adverse effects to aquatic and human health enter the environment from a variety of sources. These sources can be separated into point sources and nonpoint sources. The term point source is defined by the Clean Water Act (CWA) and generally refers to any specific conveyance, such as a pipe or ditch, from which pollutants are discharged. In contrast, nonpoint sources do not have a single point of origin and generally include diffuse sources, such as urban areas or agricultural fields, that tend to deliver pollutants to surface waters during and after rainfall events. Some sources, such as landfills (including confined disposal facilities that contain dredged sediments) and mining sites, are difficult to categorize as point or nonpoint sources. Although these land areas represent discrete sources, pollution from such areas tends to result from rainfall runoff and leaching. Likewise, atmospheric deposition of pollutants, generally considered to be a nonpoint source of water pollution, arises from the emission of chemicals from discrete stationary and mobile points of origin. The CWA specifies water vessels and other floating craft as point sources although taken as a whole they function as a diffuse source.

Many point and nonpoint pollutant sources have been the subject of federal and other action over the past 25 years. The direct discharge of pollutants to waterways from municipal sewage treatment and industrial facilities requires a permit under the CWA. EPA has delegated the authority to issue such permits to many states. These permits contain technology-based and water quality-based pollutant discharge limits and monitoring requirements designed for the protection of the water column and are not designed for the protection of sediment quality. The disposal of sediment dredged to maintain navigation channels is managed under both the CWA and the Marine Protection, Research, and Sanctuaries Act (MPRSA) to ensure that unacceptable degradation from chemical pollutants in the dredged material does not occur at the disposal location. Emission standards and controls on stationary and mobile sources of air pollutants have also been established in federal regulations promulgated under the authority of the Clean Air Act (CAA). These actions have reduced emissions of gaseous compounds such as inorganic oxides, as well as pollutants that eventually enter waterbodies and accumulate in sediment. The Toxic Substances Control Act (TSCA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) have greatly reduced the toxic pollutant input to the environment through bans and use restrictions on many pesticides and industrial-use chemicals.

The combined impact of these actions has yielded improvements in water quality. A lag is evident in the improvement of sediment quality compared to water quality because of the persistent nature of many pollutants, especially since sediment acts as a reservoir for many contaminants. Other factors include the difficulty in monitoring and regulating most toxic bioaccumulative pollutants. As discussed earlier in this chapter and outlined in detail in Chapter 4, several hydrologic regions across the United States exhibited a slight decrease in the levels of sediment contamination (as measured by the predicted proportion toxic using the logistic model). One possible explanation as to why more regions did not exhibit decreasing trends or why more dramatic trends were not observed could be the underrepresentation of uncontaminated areas in the NSI database.

The feasibility and long-term success of sediment remediation approaches (natural recovery, dredging, or capping) depend on effective pollutant source control. For some classes of sediment contaminants, such as PCBs and organochlorine pesticides, use and manufacture bans or severe restrictions have been in place for many years. Past disposal of PCBs continues to result in evaporation of these contaminants from some landfills and leaching from soils, but most active PCB sources have been controlled. The predominant sources of organochlorine pesticides are runoff and atmospheric deposition from past applications on agricultural land, and occasional discharge from municipal treatment facilities. For other classes of sediment contaminants, active sources continue to contribute environmental releases. For example, the release of inorganic mercury from fuel burning and other incineration operations continues, as do urban runoff and atmospheric deposition of metals and PAHs. Although these releases to the environment still exist, great strides have been made in reducing such inputs. This is evident from the substantial reductions that have been recognized in air emissions resulting from the Maximum Available Control Technology (MACT) standards for Hazardous Air Pollutants (HAP), established under Section 112 and Section 129 of the Clean Air Act. Overall, the air toxics regulations will reduce air toxic emissions by more than 1.5 million tons per year. Tables 5-1 and 5-2 provide examples of emission reductions expected from some of the MACT standards.

Table 5-1. Example Estimated Mercury Emission Reductions Attributable to MACT.

Mercury Source Categories	1990 Inventory	Estimated Reductions
Coal-Fired Utility Boilers	25%	uncertain
Medical Waste Incinerators	24%	98%
Municipal Waste Combusters	20%	90%
Chlorine Production	6%	92%
Industrial Boilers	6%	25%

Table 5-2. Example Estimated Air Toxics Emission Reductions Attributable to MACT.

Municipal Waste Combuster	2001[a]	2005[b]
Dioxins/Furans	99%	99+%
Lead	77%	94%
Cadmium	68%	78%

[a] Large municipal waste combuster compliance date.
[b] Small municipal waste combuster compliance date.

Other Studies Evaluating the Extent of Sediment Contamination

In 2002, EPA completed the first National Coastal Condition Report (USEPA, 2002a). The report is available at EPA's Web site at http://www.epa.gov/owow/oceans/nccr/index.html, and copies are also available by calling 1-800-490-9198. Key contributors to this draft report were the National Oceanic and Atmospheric Administration (NOAA); the Department of the Interior, U.S. Fish and Wildlife Service; and several other local, state, and federal agencies.

One of the indicators used in the National Coastal Condition Report to assess the conditions of the Nation's coastal waters was sediment contamination. National and regional monitoring programs conducted by EPA (EMAP for estuaries [EMAP-E]), along with NOAA's National Status and Trends Program, provided the data evaluated in the sediment contamination indicator. This indicator was evaluated using the NOAA effects range-medium (ERM) and effects range-low (ERL) values (Long and Morgan, 1990), where ERM values are the concentrations of contaminants that will result in ecological effects 50 percent of the time and ERL values are the concentrations of contaminants that will result in ecological effects 10 percent of the time. An estuary was determined to be in "poor" condition if it exceeded one ERM value or five ERL values.

The geographic regions analyzed included the northeast coast, southeast coast, Gulf of Mexico, west coast, and Great Lakes. Although the objective of the report was to evaluate the condition of coastal resources (in this case primarily estuaries) on a national level, there is sufficient information to assess only northeastern, southeastern, and Gulf of Mexico estuaries. Partial assessments are possible for the west coast estuaries and the Great Lakes, and no assessment is currently possible for the estuarine systems of Alaska, Hawaii, and the island territories (USEPA, 2002a). Results from this report indicate that the overall condition of the sediments throughout the estuaries and the Great Lakes of the United States would generally be classified as poor. Probabilistic surveys conducted by EPA's EMAP-E, outlined in the National Coastal Condition Report, allowed for spatial estimates of ecological condition for the following regions: Northeast, Southeast, and Gulf of Mexico. This spatial estimate was expressed as a percent of degradation measured as the percentage of total estuarine surface area in the region (or nation).

Results from the northeast coast indicate that 41 percent of the estuaries are degraded as a result of sediment contamination. Results of the percent area degraded from the southeast coast and the Gulf of Mexico due to contaminated sediments are 13 percent and 43 percent, respectively. The national estimate of estuarine areas degraded due to contaminated sediments is 35 percent (USEPA, 2002a). Even though probabilistic surveys that allow for spatial estimates of sediment contamination were not conducted in the Great Lakes and in the west coast estuaries, existing monitoring data from various programs are available to assess the condition of the sediments. EPA's Great Lakes National Program Office (GLNPO) has determined that polluted sediments remain the largest major source of contaminants to the Great Lakes food chain and that more than 2,000 miles (20 percent) of shoreline is considered impaired because of sediment contamination. Studies conducted on the west coast show that sediment contaminant conditions in the Southern California Bight are poor. Using ERL and ERM values, it was determined that 67 percent of the sediments in the bight have contaminants that could potentially result in adverse ecological effects.

As highlighted in Chapter 1, NOAA performed toxicity tests on 1,543 surficial sediment samples collected from 1991 through 1997 from estuaries and bays along the Atlantic, Gulf of Mexico, and Pacific coasts. These samples encompassed an area of approximately 7,300 square kilometers. Toxicity was observed in samples that represented approximately 6 percent of the combined area (Long, 2000) when using amphipod lethality tests. Toxicity was considerably more widespread (25 percent to 39 percent), however, when the results of two sublethal sediment toxicity assays were evaluated (Long, 2000). It has been demonstrated that in some cases long-term sediment toxicity tests in which survival and growth are measured tend to be more sensitive than short-term tests, with chronic toxicity six times higher than acute toxicity as indicated for *Hyalella azteca* (Ingersoll et al., 2001).

Other Indications of Sediment Contamination

EPA's National Fish and Wildlife Contamination Program provides technical assistance to State, Federal, and Tribal agencies on matters related to health risks associated with dietary exposure to chemical contaminants in fish and wildlife. Human and wildlife consumption of finfish and shellfish that have accumulated contaminants in their tissue (bioaccumulation) is an important human health and wildlife concern. In fact, fish consumption represents the most significant route of aquatic exposure of humans to many metals and organic compounds (USEPA, 1992). Most sediment-related human exposure to contaminants is through indirect routes that involve the transfer of pollutants out of the sediment and into the water column or aquatic organisms. Many surface waters have fish consumption advisories or fishing bans in place because of mercury, as well as a group of bioaccumulative contaminants (PCBs, chlordane, dioxins, and DDT and its metabolites [DDD and DDE]) that are commonly found in sediments based on the NSI database. Based on EPA's 2002 National Listing of Fish and Wildlife Advisories (NLFWA) database there are 2,800 fish advisories in the United States for the types of contaminants (such as those listed above) often found in contaminated sediments. These advisories affect more than 544,000 river miles, 71 percent of the Nation's coastal waters, and approximately 95,000 lakes, including 100 percent of the Great Lakes. The number of advisories in the United States in 2002 represents a 7 percent increase over 2001. This increase in advisories issued by the states generally reflects an increase in the number of assessments of contaminants in fish and wildlife tissues.

Continuing Challenges

The following discussion presents observations on continuing challenges to improving sediment quality assessment and management in the United States. Any future policies and/or actions to address contaminated sediments will have to be considered in the context of the budget process and competing demands for funding. These observations build on the analyses completed in the first *National Sediment Quality Survey* and goals outlined in the EPA's 1998 *Contaminated Sediment Management Strategy*. They are as follows:

1. Further assessment of the extent and severity of sediment contamination in the 96 targeted watersheds would improve contaminated sediment management decisions.
2. Watershed management activities would create multidisciplinary and multijurisdictional partnerships focusing on sediment contamination.
3. Better coordination of contaminated sediment management and research activities would promote application of sound science in managing contaminated sediments.
4. Better monitoring and assessment tools would improve contaminated sediment management.
5. A weight-of-evidence approach and measures of chemical bioavailability in sediment monitoring programs would improve the assessment of contaminated sediment.
6. Increased geographic coverage in the NSI database would refine a national assessment of the extent and severity of contaminated sediment.
7. Assessment of atmospheric deposition of sediment contaminants would improve contaminated sediment management.
8. Prevention of continuing sources of sediment contamination is important in contaminated sediment management.
9. Better coordination and communication with external stakeholders and other federal agencies would improve the contaminated sediment management process.

Observation 1: Further Assessment of the Extent and Severity of Sediment Contamination in the 96 Targeted Watersheds Would Improve Contaminated Sediment Management Decisions

To characterize the incidence and severity of sediment contamination in the United States, EPA has developed and performed a screening-level analysis of the information in the NSI from 1990 through 1999, the results of which are presented in Chapter 3. The results of this assessment should not be used as justification for requiring sediment remediation actions at potentially contaminated sites. This evaluation of the NSI data was performed as a means of screening and targeting. Additional site-specific data and information is needed to expand the NSI data evaluation into a comprehensive assessment of the incidence and severity of sediment contaminant problems in the Nation's various watersheds.

Further investigation and assessment of contaminated sediment will improve contaminated sediment management decisions. States and tribes, in cooperation with EPA and other federal agencies, should proceed with further evaluation of the 96 watersheds containing areas of probable concern (APCs) for sediment contamination. Because this assessment uses data from the early 1990s through 1999, it is likely that additional investigation and assessment have already been conducted (especially in well-known areas of documented sediment contamination), and some areas might have been remediated. If active watershed management programs are in place, further evaluations can be coordinated within the context of current or planned actions (e.g., TMDL development or sediment remediation). Future monitoring and assessment efforts can focus on areas such as the 97 individual river reaches (or waterbody segments) located within the 96 watersheds containing APCs that had 10 or more stations categorized as Tier 1. The purpose of these efforts should be, to gather additional sediment chemistry data and related biological data (i.e., sediment toxicity, macrobenthic community analysis), as needed, and to conduct further assessments of the data to determine human health and ecological risk, determine temporal and spatial trends, and identify potential sources of sediment contamination and determine whether the appropriate source controls are being applied. Any existing data collected from the area of interest should be compiled and evaluated before additional assessment efforts begin. A helpful tool for delineating sediment contamination is a computerized sampling design program called the "Fully Integrated Environmental Location Decision Support" (FIELDS) system developed by EPA. This system is a set of software modules designed to simplify sophisticated site and contamination analysis. Each module is a self-contained unit that can be applied to a variety of scenarios. The modules allow discrete sampling points to be interpolated into a surface area. Important uses of these interpolated surface areas include delineating hot spots, calculating average concentrations, estimating contamination mass and volume, and developing post-remediation scenarios. More information on this system is available on the Internet at www.epa.gov/region5fields.

Additional monitoring and analysis of data from watersheds containing APCs (as well as watersheds not containing APCs) can also be used to track and document the effectiveness (or ineffectiveness) of sediment management actions that have been applied to address these areas over time. These trends will be useful in supplementing the results presented in Chapter 4 and could be reported in future reports to Congress. Comparisons to the 96 watersheds identified as APCs in the first *National Sediment Quality Survey* should not be made for potential trends in sediment contamination. Although the methodology used to designate APCs remained the same from the first report to this one, the methodology used to categorize sampling stations into the three tiers has been updated from the first *National Sediment Quality Survey*. Also, because the first report focused on data collected in the 1980s and this report focuses on data collected in the 1990s, the sampling stations did not necessarily overlap; that is, a watershed identified as having an APC in the first report might not have met the minimum data requirements to be identified as having an APC in this report. Comparisons between watersheds containing APCs identified in the first report and watersheds containing APCs in the current report are provided in Appendix F.

The plethora of data compiled in the NSI database indicate that many state and federal government monitoring programs already do a good job of gathering data at locations with known sediment contamination problems (including some of the 96 APCs), and additional monitoring at such locations might not be necessary. For other locations not previously targeted for focused monitoring, however, additional data might be required to adequately assess potential sediment contamination problems, especially in areas where significant human health exposures occur. In addition, in some cases it might be necessary to conduct baseline studies to determine where to focus monitoring activities. If during these studies it is determined that a biological impairment has occurred, a useful tool in discerning the cause or causes of that impairment is an EPA publication titled the *Stressor Identification Guidance Document* (USEPA, 2000e). That document is intended to identify stressors causing biological impairments in aquatic ecosystems, and it provides a structure for organizing the scientific evidence that supports the conclusions.

Observation 2: Watershed Management Activities Would Create Multidisciplinary and Multijurisdictional Partnerships Focusing on Sediment Contamination

As was recommended in the first *National Sediment Quality Survey* and highlighted in this update, watershed management is a critical component of community-based environmental protection using watershed or hydrologic boundaries to define the problem area. Many public and private organizations are joining forces and creating multidisciplinary and multijurisdictional partnerships to focus on water quality problems community by community and watershed by watershed. These watershed approaches are likely to result in significant restoration, maintenance, and protection of water resources throughout the United States. A watershed management framework (such as the one designed by the Chesapeake Bay Program) requires a high level of inter-program coordination to consider all factors contributing to water and sediment quality problems and to develop integrated, science-based, cost-effective solutions that involve all the stakeholders. It is within the watershed framework, therefore, that federal, state, tribal, and local government agencies; industry; and citizens' groups can pool their common resources and coordinate their efforts to address their common sediment contamination issues. These watershed activities will support efforts such as monitoring and regulatory actions.

One example of addressing sediment contamination using a watershed management approach is the Remedial Action Plan (RAP) process used in the Great Lakes areas of concern (AOCs). In 1972 the Great Lakes Water Quality Agreement was established between the United States and Canada. The Agreement addresses 43 AOCs recognized in the Great Lakes Basin. These AOCs were identified because they had impairment to one or more of the 14 beneficial uses recognized for the Great Lakes Basin. Identifying the AOCs led to the initiation of the RAP. The RAP outlines the activities necessary for all stakeholders to complete when addressing a known AOC. One RAP, for example, is for the Grand Calumet River/Indiana Harbor Ship Canal (GCR/IHSC) AOC. For the GCR/IHSC, all 14 beneficial uses were determined to be impaired, and contaminated sediments were associated with the majority of these impairments. As part of the RAP process for this AOC, a group of individuals was appointed to oversee the development of the Plan. This group, composed of representatives from industry, government (local, state, and federal), citizens' groups, and academia, also assisted in implementing the Plan. One watershed approach used by this group was the development of a matrix listing all actions occurring in the watershed that were associated (directly or indirectly) with the restoration of the impaired uses. This matrix is being used to assist in prioritizing activities, as well as tracking the success of actions taken to restore the beneficial uses. The RAP process might also be used to address areas of potential concern because it sets forth the indicators used to detect environmental degradation and the benchmarks for measuring progress.

Another example of watershed management/coordination is detailed in a recently signed Memorandum of Understanding (MOU) between EPA and the U.S. Army Corps of Engineers (USACE). As discussed earlier in this report, the purpose of this MOU is to facilitate cooperation between the U.S. Department of the Army and the EPA with respect to environmental remediation and restoration of degraded urban rivers and related resources in the United States. This MOU seeks to foster environmental quality to ensure the protection of public health, economic sustainability and community vitality. The MOU was entered into for the purpose of coordinating remedial, water quality, and environmental restoration activities under the Clean Water Act (CWA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and the various Water Resources Development Act (WRDA) authorities. The EPA and the USACE agreed to enter into watershed-specific agreements to coordinate remedial, water quality and environmental restoration activities under, but not limited to, the WRDA, CERCLA, RCRA, CWA, and other related authorities at locations where the parties agree that such cooperative arrangements are mutually beneficial. The success of this agreement will be evidenced by the efficient accomplishment of each agency's statutory requirements within areas of mutual concern in a timely manner and minimizing misunderstandings and duplication of effort.

This *National Sediment Quality Survey* provides an important and essential tool for targeting efforts to further investigate the 96 watersheds that contain APCs. It is also useful in highlighting areas of concern where there are known data gaps for additional analysis. As more data become available and the NSI database expands, the database will provide further information to help environmental managers better understand which of their watersheds have sediment contamination problems that pose the greatest risk to aquatic life and human health and will allow them to track progress as they address those problems. Also, as more data are added to the NSI database, researchers will have more site-specific information to draw upon to conduct new analyses that could lead to better assessments.

A vital component of watershed management is education and engagement of all stakeholders in government (federal, state, tribal, and local), industry, citizens' groups, and the community. As part of EPA's *Contaminated Sediment Action Plan*, the Agency will continue to solicit stakeholders' views on science and policy issues affecting contaminated sediment management to promote better decision-making. In May 2001 EPA sponsored a forum on managing contaminated sediments that brought together technical experts, stakeholders, and risk managers. EPA plans to hold additional meetings in the future to discuss the Agency's efforts and to address technical issues. As a part of the *Contaminated Sediment Action Plan*, EPA will continue its efforts to improve community involvement during the investigation and cleanup of contaminated sites. In addition to providing communities with technical assistance opportunities, a workshop will be held to identify methods to improve consideration of the societal and cultural impacts of both baseline contamination and remedial alternatives at contaminated sites.

Observation 3: Better Coordination of Contaminated Sediment Management and Research Activities Would Promote Application of Sound Science in Managing Contaminated Sediments

Coordination of contaminated sediment research and management activities would promote the use of sound science in managing contaminated sediment. One collaborative effort within EPA has been the establishment of a Contaminated Sediment Management Committee (CSMC). This committee was established to coordinate all the appropriate programs and their associated regulatory authorities involved in the management of contaminated sediments. The CSMC includes representation at the Office Director and Regional Division Director levels from EPA's Office of Solid Waste and Emergency Response (OSWER), Office of Water (OW), Office of Research and Development (ORD), and Office of Enforcement and Compliance Assurance (OECA) and many of the EPA regions. This committee developed the *Contaminated Sediment Action Plan* mentioned earlier. This multimedia, cross-program plan outlined the next steps for the Agency in the management of contaminated sediments. It described the commitments needed from the EPA program offices to develop and apply sound science in managing contaminated sediments.

Another collaborative effort to address contaminated sediments, as mentioned above, was the publication of the Agency's *Contaminated Sediment Management Strategy* (USEPA, 1998a). That document summarized EPA's understanding at the time of the extent and severity of sediment contamination (as was described in the 1997 *National Sediment Quality Survey* and accompanying NSI database); described the cross-program policy framework in which EPA intends to promote consideration and reduction of ecological and human health risks posed by sediment contamination; and identified actions that EPA believes are needed to bring about consideration and reduction of risks posed by contaminated sediments. The *Contaminated Sediment Action Plan* further supports activities outlined in the *Contaminated Sediment Management Strategy*, such as preventing sediment contamination as early as possible by continuing to emphasize identification and control of direct and indirect sources of significant contamination to waterbodies that can affect sediments.

EPA has also established a mechanism to develop and coordinate Agency office- and region-wide activities in the contaminated sediment area. This mechanism is the Contaminated Sediment Science Plan. Currently in draft form, the plan provides an analysis of the current Agency science activities (the contaminated sediments science activities database), identifies and evaluates the science gaps, and suggests a strategy for filling some of the highest priority gaps. EPA's Science Policy Council initiated the Contaminated Sediment Science Plan because contamination of sediments is a cross-Agency issue that needs a more comprehensive and higher level of coordination across the Agency. Additionally, this plan provides key recommendations for future Agency research and science activities in contaminated sediments. The document has undergone EPA Science Advisory Board peer review, as well as a public comment period. Currently the Agency is addressing the comments and revising the document. The Agency anticipates releasing the document in 2004.

A precedent-setting team has been established by EPA's Region 5 in the Great Lakes area. Contaminated sediments were designated as a Region 5 Environmental Priority in 1995 because of the extent and severity of the problem across the region, and therefore a Regional Contaminated Sediment Team was established. This team, formed with members representing a variety of regional programs and offices, coordinates all program/office efforts to address contaminated sediment sites and provide technical expertise to the region, state agencies, and others. Additional activity in the Great Lakes area include EPA's Great Lakes National Program Office (GLNPO). From 1993 through 2003, GLNPO awarded more than $15.7 million to various state and federal agencies, tribes, universities, and non-governmental organizations for sediment-related work. The Sediment Assessment and Remediation Team under GLNPO is responsible for providing the funding, technical support, and vessel support to assist contaminated sediment work in the Great Lakes watershed.

A key component of future coordination within EPA in addressing sediment contamination is initiation of the contaminated sediment assessment pilot projects described earlier. As part of EPA's *Contaminated Sediment Action Plan*, OSWER, OW, and EPA's regional offices will initiate pilot projects to facilitate cross-program coordination on contaminated sediments. The pilot projects will bring a cross-Agency focus to identifying and assessing waters that are impaired by sediment contamination. The pilots will use the legal authorities and techniques available to satisfy the needs of both the Remedial Investigation/Feasibility Study (RI/FS) evaluations and Total Maximum Daily Load (TMDL) modeling. The ultimate goal of the pilots is to develop more watershed-based approaches to identifying, assessing, preventing, and remediating contaminated sediments. EPA will work with other federal agencies, States, and interested stakeholders as these pilots are identified and implemented.

Observation 4: Better Monitoring and Assessment Tools Would Improve Contaminated Sediment Management

The *National Sediment Quality Survey* reports (the initial report published in 1997 and this current version) present analyses of sediment chemistry and biological data from numerous databases in an effort to identify the national incidence and severity of sediment contamination. Because the data were not generated by one single monitoring program specifically designed to provide this national picture, numerous obstacles had to be overcome to analyze these data with as little bias as possible and the most scientific validity possible.

To ensure effective quality assurance and quality control (QA/QC) management, monitoring programs should adopt standard sample collection and storage procedures. To assist in this, EPA has recently released *Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses* (USEPA, 2001b). Interference encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, can limit the ability of available methods to detect or quantify some analytes. There is a need for cost-effective methods sensitive enough (i.e., with low enough detection limits) to detect sediment contaminants and the chemical parameters that control the bioavailability of contaminants such as PCBs, dioxins, PAHs, metals, and pesticides. QA/QC management will be improved if databases include documentation of procedures used in collecting sediment and performing chemical and biological analyses. The modernization of federal and other data repositories to accommodate the storage of this QA/QC documentation should help facilitate this process.

Developing this report has shown the need for additional “tools” to assist in the assessment of contaminated sediments. Significant progress has been made in the development of better monitoring and assessment tools since the first *National Sediment Quality Survey* report was published in 1997, but more work still needs to be done in this area. Although EPA has recently released sediment toxicity test methods designed for evaluating sublethal effects (e.g., reduction in growth and reproduction) for some freshwater and marine/estuarine benthic species (USEPA, 2000d, 2001a), protocols using new test species must be developed to provide sensitive tests (with both lethal and sublethal endpoints) representing a greater range of species and habitat types. Also, when applicable, standardized methods for measuring sublethal endpoints should be developed for sediment toxicity test methods that currently provide information on lethal endpoints. In addition, field validation of new and existing sediment toxicity test methods is needed. Field validation determines the ecological significance of a reduction in growth or reproduction of organisms evaluated in the laboratory with sediments collected from the field. EPA is currently evaluating the ecological significance of its recently released freshwater sediment toxicity test methods by comparing the results of sediment toxicity assays of spiked sediments to results from benthic colonization trays spiked with the same sediment concentrations and placed in the field. Results of this comparison should be available in 2004.

One concern about traditional sediment toxicity assays is that the toxicity might be altered by manipulation of the sediment during its collection in the field and distribution into test vessels in the laboratory. One method that prevents this alteration is the use of *in situ* sediment toxicity test methods. This approach, which places the test organisms in the field instead of placing them in sediment brought back to the laboratory, has been used extensively in marine bioaccumulation studies using mussels. It is now being used effectively in sediment and storm water contamination studies using a host of test species (Bascombe et al., 1990; Ellis et al., 1993; Ireland et al., 1996; McCahon et al., 1991; Sasson-Brickson and Burton, 1991; Skalski et al., 1990). Further work is necessary to standardize these methods to allow this approach to be used throughout the Nation in monitoring programs.

Another tool needed for the assessment of contaminated sediments is the further development of sediment toxicity identification evaluation (TIE) procedures. Because sediment contaminants most commonly occur in mixtures, there is a need for procedures to determine which contaminant is responsible for the observed toxicity. Currently, EPA ORD is developing TIE methods capable of characterizing the toxicity of a sediment by identifying classes of toxic contaminants (e.g., metals, organics). More work is needed to improve upon these methods so that individual chemical contaminants can be identified. In addition, work is needed to conduct field validation studies to support the TIE method development.

One approach used to evaluate the data in the NSI is the use of numeric sediment screening levels or sediment quality guidelines. These values are based on concentrations of contaminants in sediment that are associated with potential adverse effects and have been proposed by a number of investigators around the world (Chapman, 1989; Field et al., 1999, 2002; Ingersoll et al., 1996, 2001; Long and Morgan, 1990; MacDonald et al., 1996, 2000; USEPA, 1992, 1997). Sediment quality guidelines are needed by EPA, states and tribes, and other federal agencies to assist in developing a weight-of-evidence approach in support of sediment quality assessments. With respect to numeric sediment screening levels, EPA's SAB has stated that within the framework of the known uncertainty, it appears that the equilibrium partitioning (EqP) method provides a useful sediment assessment tool. The SAB concluded that the method is sufficiently valid to be used in the regulatory process if the uncertainty associated with the method is considered, described, and incorporated. The SAB concludes that the EqP-derived criteria, if applied properly, are ready for publication and use (SAB, 1992).

Further field and laboratory studies would help evaluate the accuracy of chemical-specific sediment quality guidelines in different sediment types. The sediment screening levels and sediment quality guidelines developed to date have primarily focused on the protection of benthic organisms from direct toxicity and do not address the potential effects of bioaccumulative sediment pollutants (e.g., DDT and PCBs) that make their way up the food chain and can cause adverse human health effects. Additional work is needed to determine whether current screening levels for bioaccumulative contaminants in sediment are predictive of effects on sediment-dwelling organisms or on organisms that consume sediment-dwelling organisms. Also needed is the development and validation of additional sediment quality guidelines for bioaccumulative contaminants. The impact sediments have on wildlife through dermal contact and ingestion (food web transfers) is another area where more work is needed. Along with additional work on refining and developing sediment quality guidelines, a framework for the application of these values needs to be developed. In response to this need, a Society of Environmental Toxicology and Chemistry (SETAC)-sponsored Pellston workshop was held in August 2002. A description of approaches that can be used to integrate sediment quality guidelines into various sediment quality assessment frameworks using multiple chemical and biological lines of evidence is provided in the workshop summary (Wenning and Ingersoll, 2002).

The sediment quality evaluation tools described and used in this report should be used as the basis for future contaminated sediment assessment methods. As sediment quality data become more available and the state of the science for sediment assessment continues to evolve, assessment methods will also evolve. As new and better sediment screening values and biological assessment techniques become available and proven to be reliable, EPA will incorporate them into future NSI data evaluations.

Observation 5: A Weight-of-Evidence Approach and Measures of Chemical Bioavailability in Sediment Monitoring Programs Would Improve the Assessment of Contaminated Sediment

As stated in Chapter 2 of this report, the ideal assessment methodology would be based on matched data sets of multiple types of sediment quality measures to take advantage of the strengths of each measurement type and to minimize their collective weaknesses. For example, sediment chemistry can indicate the presence of contaminants but cannot definitively indicate an adverse effect. On the other hand, toxicity tests or benthic community surveys can indicate an adverse effect but cannot definitively implicate the causative contaminant. Matched sediment chemistry data and sediment toxicity tests, however, can provide a preponderance of evidence indicating a chemical cause of an adverse biological effect (Ingersoll et al., 1997). The sediment TIEs mentioned earlier are also an extremely valuable tool in attributing cause to the observed effect. Studies have shown that overall, an integration of several methods using the weight of evidence is the most desirable approach for assessing the effects of contaminants associated with sediment (Ingersoll et al., 1996; 1997; Long and Chapman, 1985; Long and

Morgan, 1990; MacDonald et al., 1996). The weight-of-evidence approach has been successfully incorporated into some existing sediment monitoring and management regulatory programs (e.g., Puget Sound Disposal Analysis and Washington State Sediment Management Standards). In response to this, monitoring and development of sediment management programs should be planned and implemented to support weight-of-evidence assessments.

Because the state of the science is constantly evolving, future sediment monitoring programs should collect tissue residue, biological effects (i.e., toxicity, histopathology), and biological community (e.g., benthic abundance and diversity) measurements whenever possible along with sediment chemistry data. These types of data are necessary to better assess actual adverse effects resulting from exposure to contaminated sediment. Matched sediment chemistry and tissue residue data should be collected where human exposures are a concern. In areas where aquatic life effects are a concern, monitoring programs should collect matched sediment chemistry data, biological effects data, and biological community measurements. There is a need to evaluate matched sediment chemistry and toxicity data to determine the predictive ability of sediment screening values to correctly classify sediment toxicity and minimize both Type I errors (falsely classifying a sample as toxic when it is not toxic) and Type II errors (falsely classifying a sample as nontoxic when it is toxic). Also, whenever possible, monitoring programs should use a randomized approach to select sampling stations. As stated in Chapter 5, the frequency of exceeding a sediment screening value in sampling stations known to be contaminated was 5 to 10 times greater than that for randomly selected sampling stations.

The collection of data to measure chemical bioavailability is critical to the success of weight-of-evidence assessments. Appropriate chemical bioavailability measures include acid-volatile sulfide (AVS) and simultaneously extracted metals (SEM) data and total organic carbon (TOC) data. AVS and SEM provide essential information for assessing the bioavailability of cationic metals in sediment. Where metals are expected to be a concern, sediment monitoring programs should collect AVS and SEM measurements. TOC provides information related to the bioavailability of nonionic organic contaminants. For the evaluation process used in this report, when TOC values were not reported, a default value was used for comparing measured sediment chemistry values to screening values.

This approach resulted in the possible overestimation or underestimation of potential impacts. More accurate assessments will be possible if future monitoring programs include TOC measurements wherever organic chemicals are a concern.

Observation 6: Increased Geographic Coverage in the NSI Database Would Refine a National Assessment of the Extent and Severity of Contaminated Sediment

The NSI database is limited in terms of the number of data sets it includes and the national coverage it provides. The data in the NSI used for the initial *National Sediment Quality Survey* published in 1997 consisted of approximately 2 million records for more than 21,000 monitoring stations across the country. There has been a significant increase in the amount of data compiled in the NSI database since the first report was published. At present, the expanded NSI database includes more than 4.6 million analytical observations for approximately 50,000 stations throughout the United States. For this report, EPA used data from the NSI for 1990 through 1999 and evaluated 19,398 stations that met the minimum data requirements to be evaluated. Over 50 percent of the monitoring stations evaluated for this report are in five states (California, Florida, Illinois, Virginia, and Washington). Despite the large number of sampling stations, only 8.8 percent of all river reaches in the contiguous United States contain one or more sampling stations that were evaluated for this report.

For this report, great strides were made in adding to the NSI database. Additional efforts to add data to the NSI database include the substantial work done by EPA's Region 1 and GLNPO. They have begun efforts to centralize sediment assessment data and integrate these data, incorporating the northeastern United States as well as the Great Lakes into the NSI database. EPA is continuing to compile additional sediment chemistry data and related biological data for future reports. The focus of the data additions will be to obtain a greater breadth of coverage across the United States and to increase the number of waterbodies evaluated. These types of data will be extremely useful in future analyses to assess the changes in the extent and severity of sediment contamination over time. Upon completion of this report, EPA will make a concerted effort to accumulate more data for inclusion in the NSI database and for use in future *National Sediment Quality Survey* reports to Congress. This effort will begin by focusing on areas (river reaches and watersheds) with minimal or no coverage in this report. As part of this effort, EPA will broadly advertise its need for information on contaminated sediments. EPA also encourages third parties to send their information to STORET (www.epa.gov/STORET) so that it can be reflected in the next *National Sediment Quality Survey*.

As part of the initial *National Sediment Quality Survey*, EPA included the data used for that report in its comprehensive geographic information system (GIS)/modeling system, Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). EPA will be putting the new data in the NSI database into BASINS. In addition to this effort, EPA is also working with the National Oceanic and Atmospheric Administration (NOAA) to incorporate the NSI database into Query Manager. Query Manager is a database program developed by NOAA's Office of Response and Restoration. It can be used to access sediment chemistry (surface and subsurface), sediment toxicity, and tissue chemistry data from the relational database for individual watersheds. Users can select from a menu of queries that sort and analyze the data in various ways to produce output tables. The selected data can be immediately displayed on maps using Mapping Application for Response, Planning, and Local Operational Tasks (MARPLOT), or the output tables from the queries can be saved in a variety of formats for use with other mapping software (e.g., ArcView) or other applications (e.g., spreadsheets, statistics packages, word processors). MARPLOT is a general-purpose desktop mapping program that was jointly developed by NOAA, the U.S. Coast Guard, and the Census Bureau. It allows the user to create, view, and modify maps quickly and easily and to link objects on maps to data in other programs.

The NSI database can be a powerful tool for program and water resource managers at the national, regional, state, watershed, and waterbody levels. It provides in a single location a wealth of information that could be very useful, especially with improved access and availability. All agencies should have access to the same data for decision-making in regional, state-level, and watershed-level management. EPA released the NSI database used in this report in early 2001 to give stakeholders a chance to use the data for their own purposes. As was discussed in the first report to Congress, increased access to data and information in the NSI database has many applications. At the national level, the data and associated information can demonstrate the need and provide the driving force for increased pollution prevention efforts. It can also demonstrate the need for safer or biodegradable chemicals and determine the relative risk compared to other problems to assist in prioritizing activities. At the state and watershed levels, better access to the information contained in the NSI can assist in educating and involving the public, setting goals and prioritizing activities and expenditures, and evaluating the adequacy and effectiveness of control actions, sediment remediation activities, and other management activities.

Observation 7: Assessment of Atmospheric Deposition of Sediment Contaminants Would Improve Contaminated Sediment Management

The relative contribution of contaminants to the sediment from air deposition is virtually unknown on a national scale, but is under study. Under Section 112(m) of the CAA, EPA in cooperation with NOAA has been conducting a program to assess the contribution and effects of hazardous air pollutants on the Great Lakes, Lake Champlain, the Chesapeake Bay, and near-coastal waters. This program is referred to as the Great Waters Program. As part of the program, EPA has supported air deposition monitoring, fate and transport modeling, bioaccumulation assessments, and sediment contamination modeling. National-scale deposition assessment modeling is under way. EPA has produced three reports to Congress documenting current knowledge about deposition of hazardous air pollutants to the Great Waters, including source identification and effects. The third report, *Deposition of Air Pollutants to the Great Waters: Third Report to Congress* (USEPA, 2000f), outlines programs under way to reduce air toxics but also calls for additional deposition monitoring to more fully assess the contribution to water, sediment, and fish tissue contamination. Findings and conclusions from these programs will be incorporated into future iterations of the *National Sediment Quality Survey*.

Observation 8: Prevention of Continuing Sources of Sediment Contamination is Important in Contaminated Sediment Management

Although sediment contamination is frequently the result of historical discharges of pollutants before the National Pollutant Discharge Elimination System (NPDES) regulatory program was established (USEPA, 1998a), there are still continuing sources of sediment contamination (as outlined in Chapter 5 of this report). Therefore, source control and pollution prevention are crucial items in preventing contaminated sediments. As outlined in EPA's *Contaminated Sediment Management Strategy*, OW and other EPA program offices are working with non-governmental organizations and the States to prevent point and nonpoint source contamination from accumulating in sediments.

Pollution prevention is a key element in reducing the sources of contaminants that can end up in the sediments, potentially resulting in adverse effects to aquatic life or human health. Pollution prevention has been shown to reduce costs as well as pollution risks through source reduction and recycling/reuse techniques. Under Section 6602(b) of the Pollution Prevention Act of 1990, Congress established a national policy for a hierarchy of environmental management (1) pollution should be prevented or reduced at the source, whenever feasible; (2) pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; (3) pollution that cannot be prevented or recycled should be treated in an environmentally safe manner, whenever feasible; and (4) disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner. The Pollution Prevention Act emphasizes that pollution prevention means source reduction and defines source reduction as any practice that (1) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; (2) reduces the threats to public health and the environment associated with the release of hazardous substances, pollutants, or contaminants; and (3) increases the efficiency of using raw materials, energy, water, or other resources, or protects natural resources by conservation.

Additionally, EPA has developed and is implementing a national multimedia strategy (under the cross-agency PBT Program) for the reduction of persistent, bioaccumulative toxic chemicals (PBTs), which typically accumulate in sediments. As is stated in the 1998 PBT strategy (USEPA, 1998b), EPA is forging a new approach to reducing risks from and exposures to priority PBT pollutants. This approach, focused on increased coordination among EPA and regional programs, also requires the significant involvement of stakeholders, including international, state, local, and tribal organizations, the regulated community, environmental groups, and private citizens. The four main elements of this approach are (1) develop and implement national action plans for priority PBT pollutants; (2) continue to screen and select more priority pollutants for action; (3) prevent the introduction of new PBTs; and (4) measure the progress of these actions.

If additional investigation reveals the need for actions to reduce the risks posed from the contaminated sediments, the preferred actions would depend on factors such as protectiveness, regulatory compliance, effectiveness, implementability, cost, and State and community acceptance. Additional guidance for addressing risks from contaminated sediments includes the *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (USEPA, 2002b) and the *Draft Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2002c).

Observation 9: Better Coordination and Communication with External Stakeholders and Other Federal Agencies Would Improve Contaminated Sediment Management Process

Sediment contamination is a concern to stakeholders throughout the United States. EPA will work closely with other federal agencies (e.g., USACE, NOAA, USGS) to compile and evaluate data in the NSI database as well as the development of future reports. Additionally, EPA will reach out to the public as EPA compiles additional sediment quality data in the NSI database and develops the next report to Congress. During the next year, EPA anticipates setting up “listening sessions” to gather information that can be used for future reports to Congress. During these sessions, EPA will be searching for additional data for the NSI database and subsequent reports, taking recommendations on how to improve the report, and establishing better and more effective ways to keep the public and interested stakeholders informed.

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APPENDIX A
NATIONAL SEDIMENT INVENTORY FIELD DESCRIPTION

The National Sediment Inventory (NSI) database is a national compilation of readily available data that has been compiled to evaluate the incidence of sediment contamination throughout the United States. Data sets with sediment chemistry, tissue residue, and toxicity data collected from 1980 through 1999 are included in the NSI. In all, data for more than 50,000 stations and 4.6 million analytical observations have been compiled. The data types available in the NSI are as follows:

- **Sediment chemistry.** Sediment chemistry data include detailed analytical results, analyte sampled, sampling date, qualifier for concentration, field and laboratory replication identifier, core depths, and grain size information. Percent organic carbon and acid-volatile sulfide content of sediments are also included when available.
- **Tissue residue.** Tissue residue data include detailed analytical results, analyte sampled, species, sex, tissue type, length, qualifier for concentration, field and laboratory replication identifier, and weight.
- **Toxicity.** Toxicity data include test species, dilution, endpoints (e.g., mortality), measured effect value, control-adjusted value, and test duration. Solid-phase and elutriate data are provided when available.

Table A-1 presents the total number of sampling stations at which each of these parameters was measured and the number of sampling stations for which coordinates (latitude and longitude) were available.

The NSI data are contained in a series of tables (see Table A-2) that correspond to the different data types described above. This organization is largely derived from NOAA's Watershed Database Management System. The purpose of this coordination between the NOAA Watershed Database Management System and the NSI is to facilitate data sharing. The primary table in the NSI is the station table. Each record in the table corresponds to a unique sampling station. The records in the station table can be related to tables for each type of data, such as sediment chemistry data or tissue residue data. These tables can then be related to additional look-up tables that include ancillary information such as chemical or species names. Figure A-1 illustrates the relationship between the station, sediment chemistry, tissue residue, and toxicity tables and the related look-up tables.

Table A-1. Number of Sampling Stations With Data Included in the NSI Evaluation.

Measurement Parameter	Total Number of Stations	Stations with Coordinates	
		Number of Stations	Percent of Total Number of Stations with Coordinates[a]
Sediment chemistry	40,335	36,684	81
Total organic carbon	16,407	13,936	31
Acid-volatile sulfide	2,714	2,172	5
Tissue residue	11,384	10,632	23
Toxicity	6,238	4,510	10
Elutriate phase	229		
Solid phase	10,980		
Sediment chemistry and tissue residue	3,110	3,078	7
Sediment chemistry and toxicity	5892	4386	10
Sediment chemistry, tissue residue, and toxicity	112	112	< 1

[a] Total number of stations with coordinates = 45,353.

Table A-2. Data Tables Available in the NSI.

Table Name	Table Description	Table Name	Table Description
(1)SITE	Site	(5c)CHEMTISS	Tissue residue
(2)STUDY	Study	(6)BIOSUMM	Biotoxicity
(3a)STATION	Station	(7a)BMASTER	Bioassay type
(3b)STUDYNOT	Study notes	(7b)BIO_INFO	Bioassay information
(3c)STUDYREF	Study reference	(8a)CHEMDICT	Dictionary of chemical codes
(4a)SAMPLE	Sediment sample	(8b)QUALIFY	Concentration qualifier
(4b)SMPSEDSB	Sediment core sample	(8c)SPECIES	Dictionary of species
(4c)SMPTISS	Tissue sample	(8d)TESTDICT	Dictionary of bioassays
(5a)CHEM	Surface sediment chemistry	(8e)TISSTYPE	Type of tissue
(5b)CHEMSB	Sediment core data		

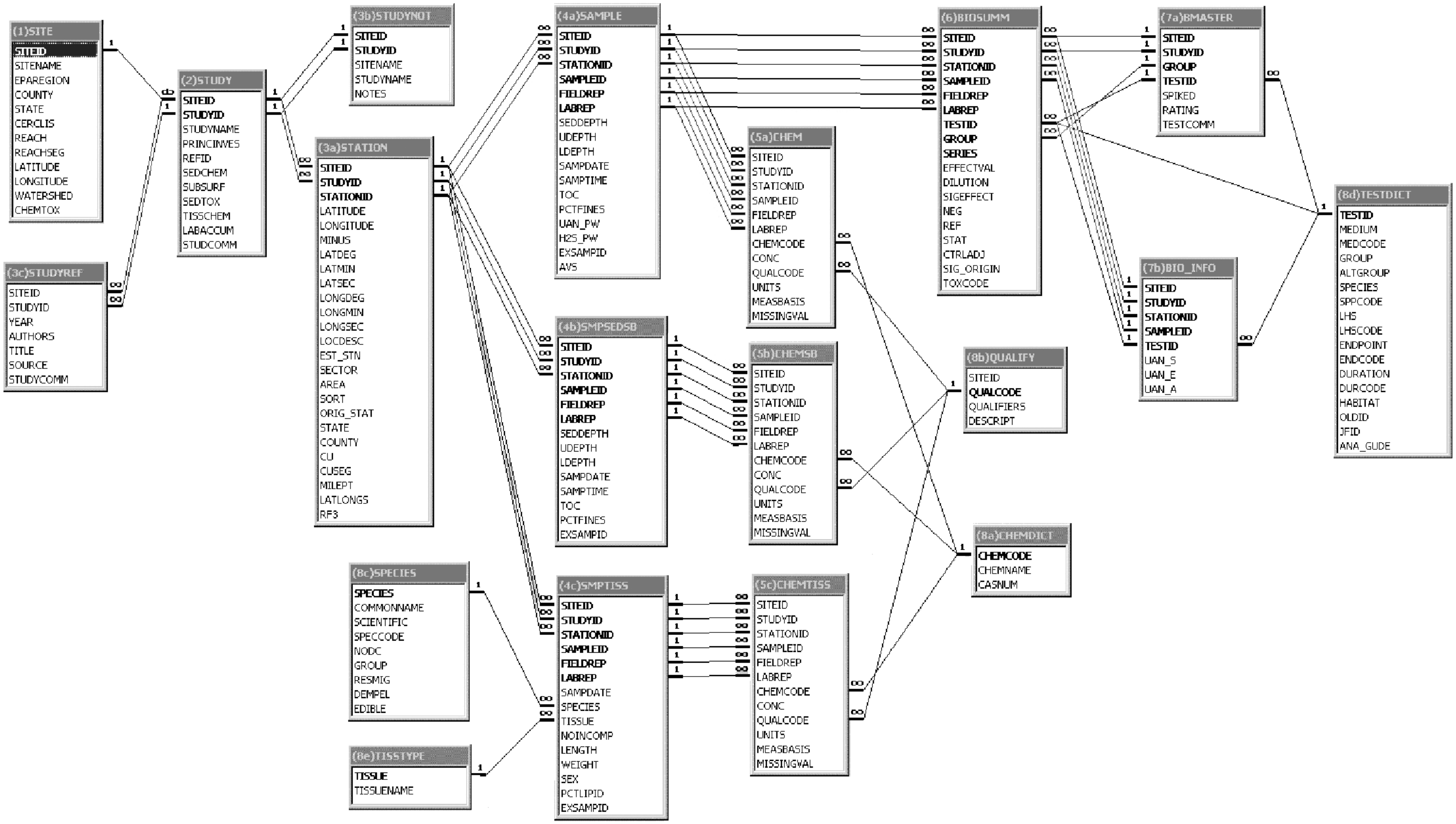

Figure A-1. Relationship Between the Station, Sediment Chemistry, Tissue Residue, and Toxicity Tables and the Related Look-up Tables.

The remainder of this section contains a listing of the field names and descriptions associated with each data table in the NSI.

(1)SITE	**Site**
SITEID	Site identifier
SITENAME	Descriptive name of site
EPAREGION	EPA region of site location: 11 for Canada
COUNTY	County
STATE	State
CERCLIS	CERCLIS number for site
REACH	USGS 8-digit hydrologic unit code
REACHSEG	EPA River Reach (v1) segment number for site
LATITUDE	General latitude for site location
LONGITUDE	General longitude for site location
WATERSHED	Watershed name for site location
CHEMTOX	Sediment chemistry and toxicity data for study, T or F?

(2)STUDY	**Study**
SITEID	Site identifier
STUDYID	Study identifier code
STUDYNAME	Short name for study
PRINCINVES	Study investigators
REFID	Internal reference ID
SEDCHEM	Surface sediment chemistry data, T or F?
SUBSURF	Subsurface sediment chemistry data, T or F?
SEDTOX	Sediment toxicity data, T or F?
TISSCHEM	Tissue chemistry for study, T or F?
LABACCUM	Tissue data from lab bioaccumulation tests, T or F?
STUDCOMM	Study comments

(3a)STATION	**Station**
SITEID	Site identifier
STUDYID	Study identifier code
STATIONID	Station identifier code
LATITUDE	Station latitude expressed in decimal degrees
LONGITUDE	Station longitude expressed in decimal degrees
MINUS	Internal use (to support conversion of longitude)
LATDEG	Station location expressed in degrees of latitude
LATMIN	Station location expressed in minutes of latitude
LATSEC	Station location expressed in seconds of latitude
LONGDEG	Station location expressed in degrees of longitude
LONGMIN	Station location expressed in minutes of longitude
LONGSEC	Station location expressed in seconds of longitude
LOCDESC	Station location description
EST_STN	Indication of derivation of latitude and longitude; selected from “reported,” “plotted,” or “assigned”
SECTOR	Internal use
AREA	Internal use

SORT	Internal use
ORIG_STAT	Original station identifier code assigned by source data set
STATE	State
COUNTY	County
CU	USGS 8-digit hydrologic unit code
CUSEG	EPA River Reach (v1) segment number
MILEPT	EPA River Reach (v1) mile point
LATLONGS	Source for reported latitude and longitude
RF3	EPA River Reach (v3) segment

(3b)STUDYNOT	**Study notes**
SITEID	Site identifier
STUDYID	Study identifier code
SITENAME	Descriptive name for site
STUDYNAME	Short name for study
NOTES	Memo field containing study notes

(3c)STUDYREF	**Study reference**
SITEID	Site identifier
STUDYID	Study identifier code
YEAR	Year of report
AUTHORS	Report authors
TITLE	Report title
SOURCE	Report source
STUDYCOMM	Short comment on study

(4a)SAMPLE	**Sediment sample**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
SEDDEPTH	Depth of sediment sample
UDEPTH	Upper depth of sediment collection in centimeters
LDEPTH	Lower depth of sediment collection in centimeters
SAMPDATE	Date sample collected
SAMPTIME	Time sample collected
TOC	Total organic carbon as percent
PCTFINES	Percent fines
UAN_PW	Un-ionized ammonia in porewater
H2S_PW	Hydrogen sulfide in pore water
EXSAMPID	Investigators' sample identifier
AVS	Acid-volatile sulfide in µmol/g sediment

(4b)SMPSEDSB	**Sediment core sample**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
SEDDEPTH	Depth of sediment sample
UDEPTH	Upper depth of sediment collection in centimeters
LDEPTH	Lower depth of sediment collection in centimeters
SAMPDATE	Date sample collected
SAMPTIME	Time sample collected
TOC	Total organic carbon as percent
PCTFINES	Percent fines
EXSAMPID	Investigators’ sample identifier

(4c)SMPTISS	**Tissue sample**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
SAMPDATE	Date sample collected
SPECIES	Code identifying species collected
TISSUE	Code identifying tissue collected
NOINCOMP	Number of organisms in composite
LENGTH	Length of organism in cm
WEIGHT	Weight of organism in grams
SEX	Sex of organism
PCTLIPID	Percent lipid
EXSAMPID	Investigators’ sample identifier

(5a)CHEM	**Surface sediment chemistry**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
CHEMCODE	Abbreviated chemical name
CONC	Measured concentration
QUALCODE	Assigned qualifier for concentration
UNITS	Units of concentration for chemical
MEASBASIS	Wet or dry weight indication
MISSINGVAL	Data missing, Y or N?

(5b)CHEMSB	**Sediment core data**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
CHEMCODE	Abbreviated chemical name
CONC	Measured concentration
QUALCODE	Assigned qualifier for concentration
UNITS	Units of concentration for chemical
MEASBASIS	Wet or dry weight indication
MISSINGVAL	Data missing, Y or N?

(5c)CHEMTISS	**Tissue residue**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
CHEMCODE	Abbreviated chemical name
CONC	Measured concentration
QUALCODE	Assigned qualifier for concentration
UNITS	Units of concentration for chemical
MEASBASIS	Wet or dry weight indication
MISSINGVAL	Data missing, Y or N?

(6)BIOSUMM	**Biotoxicity**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
FIELDREP	Field replicate number
LABREP	Laboratory replicate number
TESTID	Bioassay test code
GROUP	Bioassay test grouping
SERIES	Bioassay test series number
EFFECTVAL	Measured effect value
DILUTION	Dilution value
SIGEFFECT	Was effect significant, Y or N?
NEG	Negative control, Y or N?
REF	Reference sample, Y or N?
STAT	Used for statistical comparison, Y or N?
CTRLADJ	Control adjusted effect value
SIG_ORIGN	Original code from investigator for significant effect
TOXCODE	Character designation for toxic effect (T for toxic and N for nontoxic)

(7a)BMASTER	**Bioassay type**
SITEID	Site identifier
STUDYID	Study identifier
GROUP	Bioassay test grouping
TESTID	Bioassay test code
SPIKED	Sediment spiked with contaminant, Y or N?
RATING	Rating of bioassay test
TESTCOMM	Bioassay test comments

(7b)BIO_INFO	**Bioassay information**
SITEID	Site identifier
STUDYID	Study identifier
STATIONID	Station identifier
SAMPLEID	Sample identifier
TESTID	Bioassay test code
UAN_S	Un-ionized ammonia in sediment
UAN_E	Un-ionized ammonia in elutriate
UAN_A	Un-ionized ammonia

(8a)CHEMDICT	**Dictionary of chemical codes**
CHEMCODE	Abbreviated chemical name
CHEMNAME	Full chemical name
CASNUM	Chemical Abstracts Service (CAS) number

(8b)QUALIFY	**Concentration qualifier**
SITEID	Site identifier
QUALCODE	Assigned qualifier for concentration
QUALIFIERS	Not used
DESCRIPT	Description of QUALCODE

(8c)SPECIES	**Dictionary of species**
SPECIES	Species code
COMMONNAME	Commonly used name for organism
SCIENTIFIC	Scientific name for organism
SPECCODE	Numeric species code
NODC	10-digit National Oceanographic Data Center (NODC) code
GROUP	Species grouping
RESMIG	Whether species is resident or migratory
DEMPEL	Whether species is demersal or pelagic
EDIBLE	Whether species is edible by human populations

(8d)TESTDICT	**Dictionary of bioassays**
TESTID	12-digit bioassay test code
MEDIUM	Medium tested
MEDCODE	2-digit code for medium tested
GROUP	Bioassay species grouping
ALTGROUP	Alternate bioassay species grouping
SPECIES	Bioassay organism
SPPCODE	3-digit code for bioassay organism
LHS	Life history stage of organism
LHSCODE	Single digit code for life history stage
ENDPOINT	Bioassay test endpoint
ENDCODE	2-digit code for test endpoint
DURATION	Duration of test
DURCODE	4-digit code for duration of test
HABITAT	Habitat of test organism
OLDID	Formerly assigned test code
JFID	Not used (old identification code)
ANA_GUDE	Test included or not in NSI evaluation

(8e)TISSTYPE	**Type of tissue**
TISSUE	Description code of tissue collected
TISSUENAME	Description of tissue collected

APPENDIX B

DESCRIPTION OF EVALUATION PARAMETERS USED IN THE NSI DATA EVALUATION

Chapter 2 of this document presented an overview of the methodology used in the evaluation of the NSI data. This appendix describes in greater detail the screening values and other parameters used in the NSI data evaluation. The actual parameter values used are presented in Appendix C. For the purpose of discussion, the sediment evaluation parameters have been placed into two groups: (1) those used to assess potential impacts on aquatic life and (2) those used to assess potential impacts on human health.

Aquatic Life Assessments

To evaluate the potential threat to aquatic life from chemical contaminants detected in sediments, measured concentrations of contaminants were compared to sediment chemistry screening levels. The results of toxicity tests to indicate the actual toxicity of sediment samples to species of aquatic organisms were also evaluated for the *National Sediment Quality Survey*.

Sediment chemistry screening levels are reference values that provide evidence of sediment contaminant concentrations that could pose a significant threat to aquatic life based on statistical significance. Although the quantitative relationship between statistical significance and expected ecological effects is not fully understood, EPA presumes that these values are related to expected ecological effects, as is the presumption of other EPA assessment approaches (USEPA, 1985). Several different approaches, based on causal or empirical/statistical correlative methodologies, have been developed for deriving screening levels of sediment contaminants. Each of these approaches attempts to predict contaminant concentration levels to provide protection for benthic species, which are extrapolated to represent the entire aquatic community for this evaluation. For the purpose of this analysis, the screening tools selected include the following:

- EPA's draft equilibrium partitioning sediment guidelines (ESGs) for nonionic organics using an equilibrium partitioning approach (USEPA, 1992a, 2000a).
- EPA's draft ESGs for mixtures of polycyclic aromatic hydrocarbons (PAHs) using an equilibrium partitioning approach (USEPA, 1992a, 2000b).
- The sum of simultaneously extracted divalent transition metals concentrations minus the acid-volatile sulfide concentration ([SEM]−[AVS]), also based on an equilibrium partitioning approach (USEPA, 2000c).
- Logistic regression model (Field et al., 1999, 2002).

The principles behind the development of each of these sediment chemistry screening values are discussed below. The sediment toxicity tests are also briefly described in this section.

Equilibrium Partitioning Approaches

The potential toxicity of sediment-associated nonionic organic chemicals and divalent metals is indicated by the amount of the contaminant that is uncomplexed or freely available in the interstitial (pore) water. The bioavailability and toxicity of nonionic organic chemicals and divalent metals in sediments are mediated by several physical, chemical, and biological factors, including sediment grain size, particulate and dissolved organic carbon, and sulfide produced by sulfate-reducing bacteria (Di Toro et al., 1991, 1992; Howard and Evans, 1993; USEPA, 2000a). For nonionic organic chemicals, sorption to the organic carbon dissolved in the interstitial water and bound to sediment particles is the most important factor affecting bioavailability. Sulfide, specifically the reactive solid-phase sulfide fraction that can be extracted by cold hydrochloric acid (acid-volatile sulfide, or AVS), appears to control the bioavailability of most divalent metal ions because of the sulfide ions' high affinity for divalent metals, resulting in the formation of insoluble metal sulfides in anaerobic sediments (USEPA, 2000c).

When the concentrations of nonionic organic chemicals and divalent metals were measured in pore water extracted from spiked sediment and field-collected sediment used in toxicity tests, the biological effects observed in those tests occurred at similar pore water concentrations, even when different types of sediments were used, typically within a factor of 2 (Di Toro et al., 1991, 1992). Biological effects also occurred at similar concentrations in tests with different sediment types containing different amounts of organic carbon when (1) the dry-weight sediment concentrations of nonionic organic chemicals were normalized for organic carbon content (i.e., µg chemical/g_{oc}) and (2) when the difference between molar concentrations of simultaneously extracted metals ([SEM]) in the sediment exceeded the molar concentration of AVS ([AVS]) in the sediments by similar amounts. (The mortality of sensitive species increases in the range of 1.5 to 12.5 µmol of SEM per µmol of AVS.) Most importantly, the effects concentrations in the sediment could be predicted from the effects concentrations determined in water-only exposures to these chemicals. Most measurements of sediment chemical concentrations are made from whole sediment samples and converted to units of chemical per dry-weight of sediment because of the difficulties in extracting the pore water. However, when dry-weight concentrations of nonionic organics and metals were used to plot concentration- response curves of the toxicity of different sediments, biological effects occurred at different dry-weight concentrations when measured in different sediments (Luoma, 1983; USEPA, 2000a). To develop advisory levels for comparing the toxicity of different chemicals in different sediments, it was necessary to examine the role of organic carbon and other complexing factors in the bioavailability of chemicals in sediment.

In sediment, the partitioning of a nonionic organic chemical between organic carbon and pore water and the partitioning of a divalent metal between the solid and solution phases are assumed to be at equilibrium. The fugacity (activity) of the chemical in each of these phases is the same at equilibrium. Fugacity describes mathematically the rates at which chemicals diffuse or are transported between phases (Mackay, 1991). Hence, an organism in the sediment is assumed to receive an equivalent exposure from water only or from any equilibrated phase. The pathway of exposure might include pore water (respiration), sediment carbon (ingestion), sediment organism (ingestion), or a mixture of routes. The biological effect is produced by the chemical activity of the single phase or the equilibrated system (Di Toro et al., 1991). The equilibrium partitioning approach uses this partitioning theory to relate the dry-weight sediment concentration of a particular chemical that causes an adverse biological effect to the equivalent free chemical concentration in pore water and to the concentration sorbed to sediment organic carbon or bound to sulfide.

The processes that govern the partitioning of chemical contaminants among sediments, pore water, and biota are better understood for some kinds of chemicals than for others. Partitioning of nonionic hydrophobic organic compounds between sediments and pore water is highly correlated with the organic carbon content of sediments, but it does not account for all of the toxicity variation observed between sediment and water-only experimental exposures. Other factors that can affect biological responses are not considered in the model. The equilibrium partitioning approach has been tested using only nonionic organic chemicals with octanol/water partition coefficients (log K_{ow}s) between 3.8 and 5.3. However, because the theory should be applicable to nonionic organic chemicals with log K_{ow}s from 2.0 to 5.5 (Dave Hansen, EPA ORD-Narragansett, pers. commun., April 17, 1995), nonionic organic chemicals with log K_{ow}s in this range were evaluated for the analysis of NSI data. For trace metals, concentrations of sulfides and organic carbon have been identified as important factors that control the phase associations and, therefore, the bioavailability of trace metals in anoxic sediments. However, models that can use these factors to predict the bioavailability of trace metals in sediments are not fully developed (see below). Mechanisms that control the partitioning of nonionic and nonpolar organic compounds with log K_{ow}s of less than 2.0 or greater than 5.5 and polar organic compounds in sediments, and affect their toxicity to benthic organisms, are less well understood. Models for predicting biological effects from concentrations of such compounds have not yet been developed; therefore, these chemicals (with log K_{ow}s of less than 2.0 or greater than 5.5 and polar organic compounds) have not been evaluated using equilibrium partitioning approaches.

Draft Sediment Equilibrium Partitioning Sediment Guidelines (ESGs) for Nonionic Organics

The equilibrium partitioning model was selected for use in this assessment because of its ability to predict sediment contaminant concentrations that are protective for benthic aquatic life from direct toxicity due to that contaminant (or contaminants in the case of metal mixtures and PAH mixtures). The predominant phase for sorption of nonionic organic chemicals to sediment particles appears to be organic carbon for sediments in which the fraction of organic carbon (f_{oc}) is greater than 0.2 percent. When the fraction of organic carbon is less than 0.2 percent, other factors, such as particle size and sorption to nonorganic mineral fractions, play a relatively important role (Karickhoff, 1984).

The partitioning of a chemical between the interstitial water and sediment organic carbon is explained by the sediment/pore water partition coefficient for a chemical, K_p, which is equal to the organic carbon content of the sediment (f_{oc}) multiplied by the sediment particle organic carbon partition coefficient (K_{oc}). K_p is the ratio of the concentration of the chemical in the sediment to the concentration of the chemical in the pore water. Normalizing the dry-weight concentration of the chemical in sediment to organic carbon is as appropriate as using the interstitial water concentration of the chemical because organic carbon in the sediment can also bind the chemical and affect its bioavailability and toxicity. The particle organic carbon partition coefficient (K_{oc}) is related to the chemical's octanol-water partition coefficient (K_{ow}) by the following equation (Di Toro et al., 1991; Di Toro and McGrath, 2000):

$$\log K_{oc} = 0.00028 + 0.983(\log K_{ow})$$

The octanol/water partition coefficient for each chemical can thus predict the likelihood of the chemical to complex or sorb to organic carbon, when measured with modern experimental techniques that provide the most accurate estimate of this parameter. The concentration of the chemical on sediment particles (C_s) is then equal to the dissolved concentration of chemical (C_d) multiplied by the organic carbon content of the sediment (f_{oc}) and the particle organic carbon partition coefficient (K_{oc}), when f_{oc} is greater than 0.2 percent (USEPA, 2000a), thus normalizing the dry-weight sediment concentration of the chemical to the organic carbon content of the sediment:

$$C_s = C_d \, f_{oc} \, K_{oc}$$

The value for the dissolved concentration of chemical (C_d) is derived from the chronic or acute value in EPA's water quality criteria (GLI, 1995; USEPA, 1985). Freshwater and saltwater acute and chronic values are based on the results of acceptable laboratory tests conducted to determine the toxicity of a chemical in water to a variety of species of aquatic organisms, and they represent levels below which adverse effects are not expected. An evaluation of data from the water quality criteria documents and benthic colonization experiments demonstrated that benthic species have chemical sensitivities similar to those of water column species (Di Toro et al., 1991). Therefore, these guidelines can be used to protect benthic aquatic life from direct toxicity due to the specific contaminant(s).

EPA has developed draft equilibrium partitioning sediment guidelines (ESGs) for the protection of aquatic life for the 34 specific nonionic contaminants listed in Table B-1. In the NSI data evaluation, sediment chemistry values exceeding draft ESG guidelines derived from acute values were used to classify stations as Tier 1. Draft ESG guidelines obtained from chronic values were used for Tier 2 classification.

On a sediment organic carbon basis, the draft ESG,

$$ESG_{oc}\ (\mu g/g_{oc}) = K_{oc}\ (L/kg) \times [FCV, SCV]\ (\mu g/L) \times (10^{-3}\ kg_{oc}/g_{oc})$$

or

$$ESG_{oc}\ (\mu g/g_{oc}) = K_{oc}\ (L/kg) \times [FAV, SAV]\ (\mu g/L) \times (10^{-3}\ kg_{oc}/g_{oc})$$

where:

ESG_{oc} = draft ESG on a sediment organic carbon basis in $\mu g/g_{oc}$;

FCV or SCV = EPA aquatic life water quality criterion final or secondary chronic value in µg/L;

FAV or SAV = EPA aquatic life water quality criterion final or secondary acute value in µg/L; and

K_{oc} = organic carbon-water partitioning coefficient in L/kg.

K_{oc} is presumed to be independent of sediment type for nonionic organic chemicals, so that the draft ESG_{oc} is also independent of sediment type. Using a site-specific organic carbon fraction, f_{oc} (g_{oc}/g sediment), the draft ESG_{oc} can be expressed as a sediment-specific value: $ESG = (ESG_{oc})\ (f_{oc})$.

Draft Sediment Equilibrium Partitioning Sediment Guidelines (ESGs) for PAH Mixtures

Similar to the equilibrium partitioning approach used for nonionic organics, EPA has developed draft ESGs for PAH mixtures (USEPA, 2000b). The draft ESGs developed consider the toxicological contribution of mixtures of 34 PAHs in sediments to determine whether their concentrations in any specific sediment are acceptable for the protection of benthic organisms from PAH toxicity. The equilibrium partitioning theory, the narcosis theory, and the concept of additivity (Swartz, 1999; Swartz et al., 1995) are the technical foundation for the development of draft ESGs for PAH mixtures. Because different mixtures of PAHs occur in sediments, the above approach is justified for the derivation of draft ESGs for PAHs. PAHs are considered type 1 narcotic chemicals, and the toxicities of PAHs in sediment and tissues are additive or nearly additive (Di Toro et al., 2000). Consequently, consideration of their toxicities on an individual basis may result in arriving at an underprotective guideline.

Table B-1. EPA Aquatic Life Secondary Acute/Chronic Values (SAV/SCV), Final Acute/Chronic Values (FAV/FCV), Draft Equilibrium Partitioning Sediment Guideline (ESG), Log K_{ow}, and Log K_{oc} Values.

CAS Number	Chemical Name	Log K_{ow}	SAV (µg/L)	SCV (µg/L)	Log K_{oc}	Draft ESG for Tier 1 (µg/g_{oc})	Draft ESG for Tier 2 (µg/g_{oc})
71432	Benzene	2.13	815.4	45.5	2.094	100	5.7
319868	BHC, delta-	3.78	43.6	2.44	3.716	230	13
58899	BHC, gamma- (Lindane)	3.73	1.903[a]	0.08[b]	3.667	8.8	0.37
92524	Biphenyl	3.96	108.7	13.69	3.893	850	110
101553	Bromophenyl phenyl ether, 4-	5	27.69	1.538	4.915	2300	130
85687	Butyl benzyl phthalate	4.84	262.3	18.84	4.758	15000	1100
108907	Chlorobenzene	2.86	2271	127	2.812	1500	82
84742	Di-n-butyl phthalate	4.61	234	32.7	4.532	8000	1100
333415	Diazinon/Spectracide	3.7	0.1687[a]	0.04329[b]	3.637	0.73	0.19
132649	Dibenzofuran	4.07	366	20.4	4.001	3700	200
95501	Dichlorobenzene, 1,2-	3.43	259	14.39	3.372	610	34
541731	Dichlorobenzene, 1,3-	3.43	625	71.31	3.372	1500	170
106467	Dichlorobenzene, 1,4-	3.42	183.6	15.11	3.362	420	35
60571	Dieldrin	5.37	0.2874[a,c]	0.06589[b,c]	5.279	55	13
84662	Diethyl phthalate	2.5	3947	220	2.458	1100	63
115297	Endosulfan mixed isomers	4.1	0.1277	0.05059	4.031	1.4	0.54
959988	Endosulfan, alpha-	3.83	0.1277	0.05059	3.765	0.74	0.29
33213659	Endosulfan, beta-	4.52	0.1277	0.05059	4.443	3.5	1.4
72208	Endrin	5.06	0.1803[a,c]	0.05805[b,c]	4.974	17	5.5
100414	Ethylbenzene	3.14	6971	389	3.087	8500	480
67721	Hexachloroethane	4	211.9	11.77	3.932	1800	100
121755	Malathion	2.89	0.8884[a]	0.09671	2.841	0.62	0.067
72435	Methoxychlor	5.08	0.0962	0.0188	4.994	9.5	1.9
608935	Pentachlorobenzene	5.26	8.377	0.466	5.171	1200	69
79345	Tetrachloroethane, 1,1,2,2-	2.39	3698	719	2.350	830	160
127184	Tetrachloroethene	2.67	998	125	2.625	420	53
56235	Tetrachloromethane	2.73	4375	243.1	2.684	2100	120
108883	Toluene	2.75	3153	176	2.704	1600	89
8001352	Toxaphene	5.5	1.903[a]	0.039[b]	5.407	490	10
75252	Tribromomethane/Bromoform	2.35	2254	316.8	2.310	460	65
120821	Trichlorobenzene, 1,2,4-	4.01	699.5[a]	105.1	3.942	6100	920
71556	Trichloroethane, 1,1,1-	2.48	617	62.1	2.438	170	17
79016	Trichloroethene	2.71	4350	465	2.664	2000	210
108383	Xylene, *m*-	3.2	32.29	1.794	3.146	45	2.5

[a] FAV values. [b] FCV values. [c] In freshwater.

Using PAH-specific final chronic values (FCVs) or final acute values (FAVs), the effect concentration of a PAH in sediment ($C_{oc,PAHi,FCVi}$ or $C_{oc,PAHi,FAVi}$) on an organic carbon basis is calculated as the product of its FCV and K_{oc} or FAV and K_{oc}. The quotient of the organic carbon-normalized sediment concentration for a specific PAH ($C_{oc,PAHi}$) and the effect concentration of a PAH in sediment for a PAH-specific FCV ($C_{oc,PAHi,FCVi}$) or FAV ($C_{oc,PAHi,FAVi}$) is called the equilibrium partitioning sediment guideline toxic unit ($ESGTU_{FCVi}$) or ($ESGTU_{FAVi}$). The draft ESG for the mixture of PAHs is the sum of the $ESGTU_{FCVi}$ or $ESGTU_{FAVi}$ for all of the PAHs in the particular sediment. This sum is called $\Sigma ESGTU_{FCV}$ or $\Sigma ESGTU_{FAV}$ and is given by

$$\sum ESGTU_{FCV} = \sum ESGTU_{FCVi} = \sum \frac{C_{oc,PAHi}}{C_{oc,PAHi,FCVi}}$$

or

$$\sum ESGTU_{FAV} = \sum ESGTU_{FAVi} = \sum \frac{C_{oc,PAHi}}{C_{oc,PAHi,FAVi}}$$

Because the effect concentration of a PAH in sediment ($C_{oc,PAHi,FCVi}$ or $C_{oc,PAHi,FAVi}$) on an organic carbon basis is solubility-limited, a solubility constraint is applied to sediment concentrations when computing their individual contributions. The effect concentration is limited by the concentration in sediment organic carbon that is in equilibrium with the interstitial water at the aqueous solubility, called the maximum effect concentration $C_{oc,PAHi,MAX}$. Thus, only the contribution up to the maximum $C_{oc,PAHi,MAX}$ is considered in the $\Sigma ESGTU_{FCV}$ or $\Sigma ESGTU_{FAV}$ analysis for PAH mixtures.

For a particular sediment, if the $\Sigma ESGTU_{FCV}$ based on final chronic values for “total PAHs” exceeds 1.0, the station is classified as Tier 2. Similarly, if the $\Sigma ESGTU_{FAV}$ based on final acute value exceeds 1.0, the station is classified as Tier 1. For the NSI data evaluation, most data sets reported results for only 13 PAHs. However, for this data evaluation not all 13 PAHs were required to be measured at any one station for that station to be considered for tier classification. Based on the sensitivity analysis done, it was observed that this variation from the EPA-recommended practice did not dramatically change the total number of station tier classifications. Table B-2 presents the list of 13 PAHs analyzed in this *National Sediment Quality Survey* report.

Though EPA recommends the use of 34 PAHs to derive the total draft ESG toxicity unit, some monitoring programs measure only 13 or 23 PAHs instead of a total of 34 PAHs. To determine the uncertainty in predicting the total draft ESG toxicity unit from data sets consisting of 13 or 23 PAHs, two Environmental Monitoring and Assessment Program (EMAP) data sources that measured the 34 PAHs were evaluated. Using the combined data, EPA determined the factors for the total draft ESG toxicity unit for 34 PAHs from monitoring programs that measure only 13 or 23 PAHs. The relative distribution of the equilibrium partitioning sediment guideline toxic unit with 34 PAHs ($\Sigma ESGTU_{FCV,TOT}$) to the draft equilibrium partitioning sediment guideline toxic unit with 13 PAHs ($\Sigma ESGTU_{FCV,13}$) is presented in Table B-3.

Method for Determination of Log K_{ow}s. The determination of log K_{ow} values was based on EPA draft guidelines (USEPA 2000a; 2000b; 2000c; 2000d).

Table B-2. EPA Aquatic Life Final Acute/Chronic Values (FAV/FCV), and Effect Concentration of PAH in Sediment (C_{oc}), Log K_{ow}, and Log K_{oc} for PAH Mixtures.

CAS Number	Chemical Name	Log K_{ow}	FAV (µg/L)	FCV (µg/L)	Log K_{oc}	$C_{oc,PAHi,FAVi}$ (µg/g_{oc})	$C_{oc,PAHi,FCVi}$ (µg/g_{oc})	$C_{oc,PAHi,MAX}$[a] (µg/g_{oc})
83329	Acenaphthene	4.012	232.3	55.85	3.944	2043	491	33400
208968	Acenaphthylene	3.223	1277	306.9	3.168	1880	452	24000
120127	Anthracene	4.534	86.24	20.73	4.457	2471	594	1300
56553	Benzo(a)anthracene	5.673	9.264	2.227	5.577	3499	841	4153
50328	Benzo(a)pyrene	6.107	3.982	0.9573	6.003	4014	965	3840
205992	Benzo(b)fluoranthene	6.266	2.818	0.6774	6.160	4073	979	2169
207089	Benzo(k)fluoranthene	6.291	2.669	0.6415	6.184	4081	981	1220
218019	Chrysene	5.713	8.495	2.042	5.616	3511	844	826
206440	Fluoranthene	5.084	29.57	7.109	4.998	2941	707	23870
86737	Fluorene	4.208	163.5	39.3	4.137	2238	538	26000
91203	Naphthalene	3.356	805	193.5	3.299	1602	385	61700
85018	Phenanthrene	4.571	79.58	19.13	4.494	2479	596	34300
129000	Pyrene	4.922	42.06	10.11	4.839	2900	697	9090

[a] When the organic carbon-normalized sediment concentration ($C_{oc,PAHi}$) is greater than $C_{oc,PAH,MAX}$, use $C_{oc,PAH,MAX}$ in place of $C_{oc,PAHi}$.

Table B-3. Relative Distribution of $\Sigma ESGTU_{FCV,TOT}$ to $\Sigma ESGTU_{FCV,13}$ for the Combined EMAP Data Set (N = 488).

Percentile	$\Sigma ESGTU_{FCV,TOT}/\Sigma ESGTU_{FCV,13}$
50	2.75
80	6.78
90	8.45
95	11.5
99	16.9

Selection of Chronic Toxicity Values. EPA developed a hierarchy of sources for chronic toxicity values for the development of the draft ESGs (USEPA, 2000e). The following sources were identified and ranked from most to least confidence in the chronic values to be used:

1. Final chronic values from the Great Lakes Initiative (GLI, 1995).
2. Final chronic values from the National Ambient Water Quality Criteria documents.
3. Final chronic values from draft freshwater criteria documents.
4. Final chronic values developed from data in EPA's Aquatic Toxicity Information Retrieval database (AQUIRE) and other sources.
5. Secondary chronic values developed from data in AQUIRE and other sources.
6. Secondary chronic values from Suter and Mabrey (1994).

Twelve aquatic toxicity values were based on work conducted by Oak Ridge National Laboratories (Suter and Mabrey, 1994) using the GLI (1995) methodology for obtaining secondary chronic values

("Tier II"). This methodology was developed to obtain whole-effluent toxicity screening values based on all available data, but the methodology could also be used to calculate SCVs with less toxicity data than the amount required for the criteria methodology outlined in USEPA (1985). The SCVs are generally more conservative than those which can be produced by the FCV methodology, reflecting greater uncertainty in the absence of additional toxicity data. The minimum requirement for deriving an SCV is toxicity data from a single taxonomic family (Daphnidae), provided the data are acceptable. Only those values from Suter and Mabrey (1994) that included at least one daphnid test result in the calculation of the SCV were included for the *National Sediment Quality Survey*. SCVs from Suter and Mabrey (1994) were used to develop draft ESGs for the following chemicals:

benzene
chlorobenzene
delta-BHC
dibenzofuran
diethyl phthalate
di-n-butyl phthalate
ethylbenzene
1,1,2,2-tetrachloroethane
tetrachloroethene
toluene
1,1,1-trichloroethane
trichloroethene

A preliminary search of data records in EPA's AQUIRE database indicated that the following chemicals might have sufficient toxicity data for the development of FCVs or SCVs using the GLI (1995) methodology. Only diazinon had sufficient data for the development of an FCV. The other chemicals listed below had sufficient data for the development of SCVs.

biphenyl
4-bromophenyl phenyl ether
butyl benzyl phthalate
diazinon
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
endosulfan mixed isomers
alpha-endosulfan
beta-endosulfan
hexachlorethane
malathion
methoxychlor
pentachlorobenzene
tetrachloromethane
tribromomethane
1,2,4-trichlorobenzene
trichloromethane
xylene

In addition, EPA has developed FCVs for dieldrin and endrin (USEPA, 2000f, 2000g).

Calculation of Acute Toxicity Values. Acceptable freshwater acute test results were entered in taxonomic order. If the tests were conducted properly, acute values reported as "greater than" values and those that were above the solubility of the test material were entered because rejection of such acute values would unnecessarily lower the FAV by eliminating acute values for resistant species. Reported results were not rounded off to fewer than four significant digits. To derive freshwater FAVs (USEPA, 1985), it was necessary to have results of acceptable acute toxicity tests with at least one species of freshwater animal in eight different families, such that all of the following minimum data requirements (MDRs) were satisfied:

- The family Salmonidae in the class Osteichthyes.
- A second family in the class Osteichthyes, preferably a commercially or recreationally important warm-water species (e.g., bluegill, channel catfish).

- A third family in the phylum Chordata (may be in the class Osteichthyes or may be an amphibian, etc.).
- A planktonic crustacean (e.g., cladoceran, copepod).
- A benthic crustacean (e.g., ostracod, isopod, amphipod, crayfish).
- An insect (e.g., mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge).
- A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca).
- A family in any order of insect or any phylum not already represented.

In the case of a species for which at least one acceptable acute value was available, the species mean acute value (SMAV) was computed as the geometric mean of the results of all flow-through tests in which the concentrations of test material were measured. For each genus for which one or more SMAVs were available, the genus mean acute value (GMAV) was calculated as the geometric mean of the SMAVs available for the genus. The GMAVs were ranked from the highest to the lowest.

If all eight of the MDRs were satisfied, the FAV was calculated using the procedure outlined by USEPA (1985), which uses the total number of GMAVs and the four lowest. The calculated value of FAV was compared with the low SMAVs to determine whether the FAV should be lowered to protect a commercially or recreationally important species. When all eight of the acute freshwater MDRs were not satisfied, a freshwater SAV was calculated. It was essential to have at least one acceptable acute toxicity test with a species in one of the three genera (*Daphnia, Ceriodaphnia,* or *Simocephaus*) in the family Daphnidae.

Acid-Volatile Sulfide Concentration

EPA (USEPA, 2000c) has developed draft ESGs for metal mixtures based on their bioavailability in sediment. These guidelines are similar to the draft ESGs for nonionic organic chemicals. The draft ESGs consider cadmium, copper, lead, nickel, silver, and zinc and mixtures thereof. Solid-phase and interstitial water-phase draft ESGs have been developed. These draft guidelines are intended to protect benthic organisms from the direct effects of these six metals in sediments that are permanently inundated with water, are intertidal, or are inundated periodically for durations sufficient to permit development of benthic assemblages. Moreover, the draft guidelines do not consider the possibility of bioaccumulation and transfer to organisms at upper trophic levels.

The use of the total concentration of a trace metal in sediment as a measure of its toxicity and its ability to bioaccumulate is not supported by field and laboratory studies because different sediments exhibit different degrees of bioavailability for the same total quantity of metal (Di Toro et al., 1990; Luoma, 1983). These differences have been reconciled by relating organism toxic response (mortality) to the metal concentration in the sediment pore water (Adams et al., 1985; Di Toro et al., 1990). Some metals form insoluble complexes with the reactive pool of solid-phase sulfides in sediments (iron and manganese sulfides), restricting their bioavailability. AVS has been used for divalent cationic metals to predict their bioavailability in sediments. The metals that can bind to these sulfides have sulfide solubility parameters smaller than those of iron sulfide, and they include nickel, zinc, cadmium, copper, lead, and mercury. In addition, more recently Berry et al. (1999) used AVS to predict the toxicity of sediments spiked with silver. However, silver is different from divalent transition metals because it predominantly exists as monovalent and 2 moles of silver are required to bind to 1 mole of sulfide. In this NSI data evaluation, silver has been added to other metals (cadmium, copper, lead, nickel, and zinc) in sediment AVS assessment.

Acid-volatile sulfide (AVS) is one of the major chemical components that control the activities and availability of metals in the pore waters of anaerobic sediments (Meyer et al., 1994). Because binding factors other than AVS dominate the bioavailability, the SEM–AVS methodology for predicting the bioavailability and toxicity of selected metals is valid only in anaerobic sediments (Berry et al., 1996). AVS is operationally defined as the sulfide fraction consisting of solid metal sulfide, mainly in the form of iron monosulfide (Hansen et al., 1996a). The metal concentrations extracted during the same analysis are called the simultaneously extracted metals (SEM). SEM is operationally defined as those metals that form less soluble sulfides than do iron or manganese (i.e., the solubility products of these sulfides are lower than that of iron or manganese sulfide) and that are at least partially soluble under the same test conditions in which the AVS content of the sediment is determined (Allen et al., 1993; Di Toro et al., 1992; Meyer et al., 1994).

Laboratory studies using spiked sediments and field-collected metal-contaminated sediments demonstrated that when the molar ratio of SEM to AVS, [SEM]/[AVS], was less than 1 (excess AVS remained), no acute toxicity (mortality greater than 50 percent) was observed in any sediment for any benthic test organism. When [SEM]/[AVS] was greater than 1 (excess metal remained), the mortality of sensitive species (e.g., amphipods) increased in the range of 1.5 to 2.5 μmol of SEM per μmol AVS (Casas and Crecelius, 1994; Di Toro et al., 1992).

Experimental studies indicate that the lower limit of applicability for AVS is approximately 1 mmol AVS/g sediment and possibly lower; other sorption phases, such as organic carbon, probably become important for sediments with smaller AVS concentrations and for metals with large partition coefficients and large chronic water quality criteria (Di Toro et al., 1990). In addition, studies indicate that copper, as well as mercury, might be associated with another phase in sediments, such as organic carbon, and AVS alone might not be the appropriate partitioning phase for predicting its toxicity. Pore-water concentrations of metals should also be evaluated (Allen et al., 1993; Ankley et al., 1993; Casas and Crecelius, 1994). The AVS approach has been traditionally used to predict when a sediment contaminated with metals is not acutely toxic (Ankley et al., 1993; Di Toro et al., 1992). However, Hansen et al. (1996b) studied the chronic effect of cadmium in sediments and concluded that the equilibrium partitioning-based SEM–AVS analysis may be used for chronically exposed benthic organisms.

Logistic Regression Model Approach

The sediment chemistry screening values used to evaluate the NSI data for potential adverse effects of sediment contamination on aquatic life include both theoretically and empirically based values. The theoretically based values rely on physical/chemical properties of sediment and chemicals to derive concentrations of a substance (or substances in the case of metal mixtures and PAH mixtures) that are protective to benthic aquatic life. The theoretically based screening values include the draft equilibrium partitioning sediment guidelines for nonionic organics, metal mixtures, and PAH mixtures. The empirically based, or correlative, screening values rely on paired field and laboratory data to relate incidence of observed biological effects to the dry-weight sediment contamination of a specific chemical. The empirically based, correlative screening values include the effects range-median (ERM)/effects range-low (ERL) values, probable effects level (PEL)/threshold effects level (TEL), and apparent effects thresholds (AET). Field et al. (1999, 2002) have proposed an alternative empirical method for evaluating sediment quality by using logistic regression models using a marine and estuarine database. These models can be used to predict the probability of observing specific toxic effects.

The logistic model was originally developed for use in survival analysis, where the dependent variable of interest has only two outcomes—toxic or nontoxic—and hence can be represented by a binary indicator variable taking on values of 0 and 1.

For a single independent variable (x), the logistic regression model can be expressed in the following form:

$$p = \frac{\exp[\mathrm{B}_0 + \mathrm{B}_1(\mathrm{x})]}{1 + \exp[\mathrm{B}_0 + \mathrm{B}_1(\mathrm{x})]}$$

where p = probability of observing a toxic effect, B_0 = intercept parameter, B_1 = slope parameter, and x = chemical concentration in $\log_{10}$ units. Metal concentrations are expressed in parts per million (ppm) and concentrations of organics are in parts per billion (ppb) in the preceding equation.

Field et al. (1999) used matched sediment chemistry and toxicity data obtained from sources spanning many geographic areas and toxicity endpoints. From the database, separate tables were created for individual contaminants. The individualized tables contained chemical concentrations for each sample, with the toxicity results indicating whether the sample was toxic or nontoxic for each toxicity endpoint. Samples classified as toxic were screened to eliminate the possibility of a selected contaminant's not contributing to the reported toxic effect. Within the same study and geographical area, the concentration of a particular contaminant was compared to the mean concentration of the same contaminant identified as nontoxic. When the concentration in a toxic sample was less than or equal to the mean concentration in a nontoxic sample, the samples were excluded from the data set used to develop the logistic model for the particular chemical. These models were developed using 10-day amphipod survival toxicity tests with marine and estuarine data. Samples were considered toxic if they were significantly different from a negative control—as designated by the original investigator—and had less than 90 percent survival.

The screening procedure developed by the authors enabled the data to be transformed into a format consistent with logistic regression modeling. For preselected concentration intervals—based on the range of sample concentrations for each contaminant—the proportion of toxic samples was computed. Using the screened data, individual logistic regression models were developed for each contaminant, and the slope (B_1), intercept (B_0), and chi-square statistic values were calculated using the maximum likelihood approach. Similar to the correlation coefficient (r) in linear regression models, the chi-square statistic provides information on the slope parameter (B_1) of the logistic regression model and the goodness-of-fit of the model with the data. For data sets with comparable sample sizes,a larger chi-square indicates a goodness-of-fit between the logistic model and the data used to derive the model. Because the chi-square statistic increases with sample size, the normalized chi-square statistic value (i.e., chi-square divided by the sample size) is more applicable when data sets of different magnitude are considered.

Although the logistic model developed gives the probability of observing a toxic effect for a particular contaminant concentration, the model can also be inverted to determine the concentrations at which a certain percentage of the samples would be deemed toxic. When the model is used in the inverse form, it is also possible to calculate the confidence interval for the probability of finding a percentage of the samples toxic at a particular concentration. The confidence interval reflects the range of concentrations within which a certain percentage of toxic effect can be expected.

Table B-4 gives the intercept coefficients, the slope, the number of samples used to derive the individual chemical-specific logistic regression model, and the normalized chi-square value for a list of 37 chemicals representing metals, PAHs, and PCBs. The log chemical concentrations, normalized to either dry weight or total organic carbon, are in parts per million (ppm) for metals and are in parts per billion (ppb) for organics.

Table B-4. Logistic Regression Model Coefficients.

CAS Number	Chemical Name	Intercept (B_0)	Slope (B_1)	No. of Samples	Normalized χ-square Value
83329	Acenaphthene	-3.6165	1.7532	1424	0.334
208968	Acenaphthylene	-2.962	1.3797	1447	0.23
120127	Anthracene	-3.6574	1.4854	1823	0.289
7440360	Antimony	-0.9005	2.4111	1718	0.25
7440382	Arsenic	-4.1407	3.1674	2336	0.173
56553	Benzo(a)anthracene	-4.2013	1.5747	2099	0.298
50328	Benzo(a)pyrene	-4.3005	1.5832	2053	0.299
205992	Benzo(b)fluoranthene	-4.5409	1.4916	1348	0.266
191242	Benzo(g,h,i)perylene	-4.2811	1.5878	1818	0.25
207089	Benzo(k)fluoranthene	-4.2781	1.5669	1376	0.286
92524	Biphenyl	-4.1144	2.2085	1226	0.263
7440439	Cadmium	-0.34	2.5073	2413	0.313
7440473	Chromium, total	-6.4395	2.9952	2399	0.195
218019	Chrysene	-4.3241	1.5372	2126	0.286
7440508	Copper	-5.7878	2.9325	2580	0.383
72548	DDD, p,p'-	-1.8983	1.4913	1360	0.268
72559	DDE, p,p'-	-1.8392	0.9129	1552	0.162
50293	DDT, p,p'-	-1.7705	1.6786	931	0.335
53703	Dibenz(a,h)anthracene	-3.6308	1.7692	1546	0.326
60571	Dieldrin	-1.1728	2.558	633	0.354
581420	Dimethylnaphthalene, 2,6-	-4.0456	1.904	1249	0.201
206440	Fluoranthene	-4.4574	1.4787	2189	0.263
86737	Fluorene	-3.7146	1.8071	1668	0.323
193395	Indeno(1,2,3-c,d)pyrene	-4.3674	1.6245	1837	0.269
7439921	Lead	-5.4523	2.7662	2481	0.274
7439976	Mercury	0.8041	2.5461	2296	0.32
90120	Methylnaphthalene, 1-	-4.1405	2.0961	1368	0.239
91576	Methylnaphthalene, 2-	-3.7579	1.7833	1704	0.25
832699	Methylphenanthrene, 1-	-3.5884	1.7501	1401	0.284
91203	Naphthalene	-3.7753	1.6152	1816	0.235
7440020	Nickel	-4.6119	2.7658	2450	0.18
1336363	Polychlorinated biphenyls	-3.4613	1.3488	1617	0.241
198550	Perylene	-4.6827	1.7632	1823	0.218
85018	Phenanthrene	-4.4576	1.6768	2173	0.298
129000	Pyrene	-4.708	1.5854	2240	0.287
7440224	Silver	-0.1117	1.9684	2103	0.252
7440666	Zinc	-7.9834	3.342	2516	0.279

Source: Field et al., 2002.

Using the logistic model developed for each contaminant, the probability of observing a toxic effect is computed for various chemical concentrations (Field et al., 1999, 2002). The logistic regression models for individual chemicals were combined to estimate the probability of toxicity for the mixture of contaminants in a given sample using the maximum (P_{max} model) probabilities from the individual models. The multichemical model (P_{max}) was derived from the probability-interval plots, which summarize all the data in the database (Field et al., 2002). The parameter estimates shown in Table B-4 were used to develop the P_{max} model, except for PCBs. A correction in PCB units for 15 samples resulted in a minor change in the PCB model. However, because the effects of the correction on the P_{max} model was extremely small (the maximum difference in the predicted probability of toxicity was 0.0025 for the P_{max} model), the P_{max} model was not changed (Field et al., 2002).

For the unscreened data, the proportion of toxic samples—within different ranges of maximum probability of toxic effects computed above at discrete concentration intervals—is determined as the ratio of the number of toxic samples to the total number of samples in the unscreened data. This procedure can be repeated for different concentrations of the individual contaminants to obtain sufficient data to generate a regression equation with the proportion of toxic samples as the dependent variable and the maximum probability of observing toxic effects as the independent variable. The following regression equation (Field et al., 2002) was used in the NSI data evaluation:

$$y = 0.11 + 0.33\ p_{max} + 0.4\ p_{max}^2$$

where p_{max} = maximum probability of observing a toxic effect and y = predicted proportion toxic.

From multiple chemical measures of the 37 target chemicals, the predicted proportion toxic is computed for each sample using the preceding regression equation. When the maximum value of the predicted proportion toxic is greater than or equal to 50 percent (0.5), the station is classified as Tier 1. When the maximum value of the predicted proportion toxic is less than 50 percent but greater than or equal to 25 percent, the station is classified as Tier 2. All other stations with available data are grouped as Tier 3.

To evaluate the applicability of the marine amphipod models to freshwater data, matching sediment chemistry and toxicity data were compiled for three freshwater toxicity test endpoints: 10- to 14-day acute lethality tests with *Hyalella azteca* and *Chironomus* spp. and a long-term 28-day growth and survival test with *Hyalella azteca*. The predicted proportion toxic from the marine models was compared to the observed acute toxicity for each test endpoint within four probability quartiles. The results of the evaluations for all three endpoints showed that the increase in probability of toxicity based on the marine amphipod model was accompanied by an increase in the observed proportion toxic. For the acute freshwater tests with *Hyalella azteca* and *Chironomus* spp., only samples that the model predicted to have a high probability of toxicity ($p > 0.75$) showed substantial increase in the proportion of samples that were toxic (Figure B-1; *Chironomus* plot not shown). However, the results for the chronic *Hyalella azteca* test endpoint (28-day growth and survival) correspond very well to the model predictions (Figure B-2). In the 28-day database, 61 samples had a predicted proportion toxic greater than 0.5 (with a mean of 0.68) compared to 0.61 observed proportion toxic. These results indicate that the LRM P_Max model used in this analysis would tend to overestimate toxicity observed in *Hyalella azteca* and *Chironomus* spp. 10- to 14-day survival tests, but not the *Hyalella azteca* 28-day growth and survival test. Based on this evaluation, the difference between model predictions and the acute freshwater toxicity test results may be more related to differences in endpoint sensitivity than to differences between marine and freshwater geochemistry.

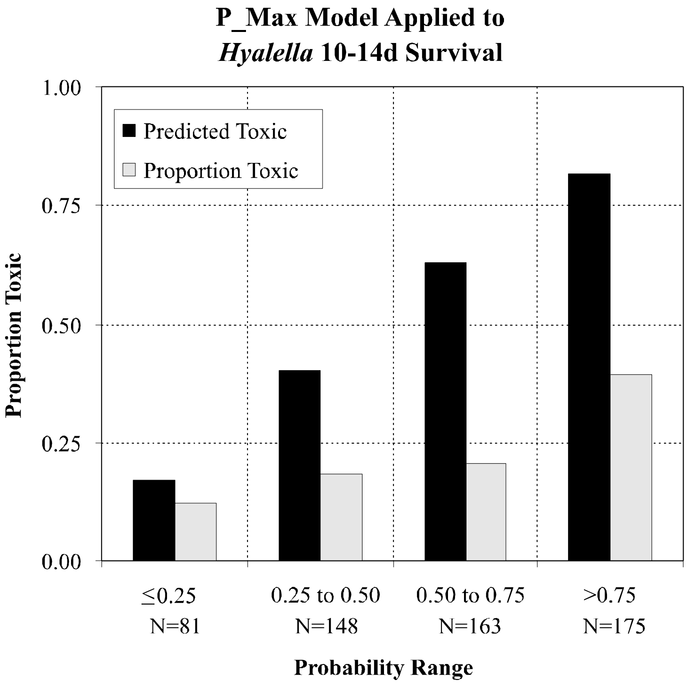

Figure B-1. Application of the Logistic Model to Freshwater Data for *Hyalella azteca* 10- to 14-day Survival Endpoint.

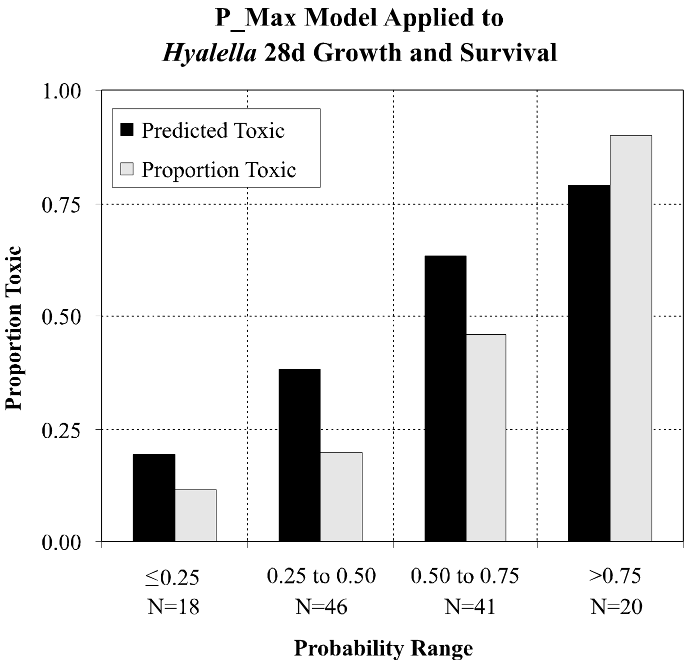

Figure B-2. Application of Logistic Model to Freshwater Data for *Hyalella azteca* 28-day Growth and Survival Endpoint.

Sediment Toxicity Approaches

Sediment toxicity tests provide important information on the effects of multiple chemical exposures to assist in the evaluation of sediment quality. Methods for testing the short- and long-term toxicity of sediment samples to benthic freshwater and marine organisms have been developed (see reviews in API, 1994; Burton et al., 1992; Lamberson et al., 1992; USEPA, 1994a, 1994b, 2000h) and used primarily for dredged material evaluation (USEPA and USACE, 1998). The NSI data contain short- and long-term sediment toxicity results from tests in which organisms were exposed to field-collected sediments and mortality or other endpoints were recorded.

Data in the NSI database were reviewed, and only bulk sediment nonmicrobial toxicity tests with test durations of 7 days or more were analyzed. Test results with survival (or mortality) as an endpoint were considered for all marine and freshwater species with valid control-adjusted results. In addition, for freshwater species growth-based endpoints—length and weight—were considered for long-term toxicity. Test results with the freshwater invertebrate *Hyalella azteca* were analyzed for variation in control-adjusted length. Variations in control-adjusted weight were considered for the freshwater invertebrates *Hyalella azteca* and *Chironomus* spp. Test results with either unknown test species or unknown test duration were not analyzed in this NSI data evaluation. Table B-5 presents a list of species used in toxicity tests whose results are included in the *National Sediment Quality Survey*.

Table B-5. Species Used in Bulk Sediment Toxicity Tests[a].

Survival (or Mortality) Endpoint: Marine and Freshwater Species		
Acanthomysis costata	*Eohaustorius estuarius*	*Neanthes* spp.
Ampelisca abdita	*Grandidierella japonica*	*Nebalia pugettensis*
Ampelisca verrilli	*Hexagenia limbata*	*Nephtys caecoides*
Ceriodaphnia dubia	*Hyalella azteca*	*Nereis virens*
Chironomus riparius	*Macoma nasuta*	*Panaeus duorarum*
Chironomus tentans	*Mysidopsis bahia*	*Rhepoxynius abronius*
Crassostrea virginica	*Neanthes arenaceodentata*	*Rhepoxynius hudsoni*
Growth-Based Endpoint (Length): Freshwater Species		
Hyalella azteca		
Growth-Based Endpoint (Weight): Freshwater Species		
Chironomus riparius	*Chironomus tentans*	*Hyalella azteca*

[a] With test durations ≥ 7 days.

Test Controls. Toxicity data were screened to determine whether control data were reported. Sediment toxicity test laboratory or performance controls are usually clean sand or sediment tested under the same conditions in which the test organisms are exposed at the same time as those exposed to the sediment samples tested. Controls are used to determine whether observed mortality might be the result of the quality of test organisms used or other factors, and not the result of exposure to possible toxics in the sediment samples.

The databases were screened to locate control test data for each sediment sample tested. Multiple control sample test results were reported in some of the databases. These were determined to be replicate test results. The percent survival (or mortality) for the reference replicates were averaged for each reference site to obtain the mean percent survival (or mortality).

Control-corrected survival (percent) was computed using the following formula:

$$\text{Control-corrected survival (\%)} = 100 \times \frac{\text{organism survival in test sample (\%)}}{\text{organism survival in control sample (\%)}}$$

Where necessary, data reported as “percent mortality” were converted to “percent survival” by the following formula:

$$\text{Survival (\%)} = 100 - \text{mortality (\%)}$$

Determination of Thresholds for Tier Classification. Minimum detectable differences (MDDs), based on sediment toxicity data from round robin tests, were used to determine the thresholds for tier classification of toxicity data (USEPA, 2000h). Although the quantitative relationship between statistical significance and expected ecological effects is not fully understood, EPA presumes that these values are related to expected ecological effects, as is the presumption of other EPA assessment approaches (USEPA, 1985). Table B-6 shows the MDDs calculated for the different species and test endpoints. MDD values from a control sediment are compared with contaminated sediments used in round robin 10-day and 28-day tests. The MDDs were calculated with a one-tailed *t*-test at a confidence level of 95 percent with four replicates. Based on the values of MDDs presented in Table B-6, samples with a percent reduction of mean MDD plus 2 standard deviations from control data (selected 25 percent mortality from a range of 25.0 to 29.8 percent mortality, i.e., < 75 percent control-adjusted survival) were classified as Tier 1 for survival endpoints. Similarly, when the percent reduction from the control data was mean MDD less 1 standard deviation (i.e., < 90 percent control-adjusted survival), the samples with survival endpoints were categorized as Tier 2.

Table B-6. Minimum Detectable Differences (MDDs) Calculated from Round Robin Test Data.

Species/Endpoint	Sediment Compared	Average MDD (% reduction from control)	Standard Deviation (as % of control)	Mean + 2 SD (% reduction from control)	Mean – 1 SD (% reduction from control)
Chironomus tentans 10-d survival	WBS[a] vs LS[b]	13.7	7.2	28.1	6.5
	WBS vs DC[c]	13.3	5.9	25	7.4
Hyalella azteca 10-d survival	WBS vs LS	15.8	5.1	26.1	10.7
	WBS vs DC	16.6	6.6	29.8	10
Hyalella azteca 28-d length	WBS vs LS	4.9	1.1	7.1	3.9
	WBS vs CC[d]	5.3	1.1	7.5	4.2
Chironomus tentans 10-d weight	WBS vs LS	12.3	5.1	22.5	7.2
	WBS vs DC	19.6	5.8	31.2	13.9
Hyalella azteca 28-d weight	WBS vs LS	17.6	7.1	31.8	10.5
	WBS vs CC	27.3	11.1	49.5	16.2

[a] WBS: control sediment from West Bearskin Lake, Minnesota

[b] LS: contaminated sediments from Little Scioto River, Ohio.

[c] DC: contaminated sediments from Defoe Creek site, Michigan.

[d] CC: contaminated sediments from Cole Creek, Michigan.

Using the threshold stated above, for growth-based measurements of length, samples with less than 90 percent control-adjusted length were classified as Tier 1 and samples with less than 70 percent control-adjusted weight were classified as Tier 1. Tier 2 classification for length was based on less than 95 percent control-adjusted length and less than 90 percent control-adjusted weight.

Human Health Assessments

In the evaluation of NSI data, two primary evaluation parameters were used to assess potential human health impacts from sediment contamination: (1) sediment chemistry theoretical bioaccumulation potential and (2) tissue levels of contaminants in demersal, nonmigratory, and edible species.

Theoretical Bioaccumulation Potential

The theoretical bioaccumulation potential (TBP) is an estimate of the equilibrium concentration of a contaminant in tissues if the sediment in question were the only source of contamination to the organism (USEPA and USACE, 1998). The TBP calculation is used as a screening mechanism to represent the magnitude of bioaccumulation likely to be associated with nonpolar organic contaminants in the sediment. At present, the TBP calculation can be performed only for nonpolar organic chemicals; however, methods for TBP calculations for metals and polar organic chemicals are under development (USEPA and USACE, 1998).

The environmental distribution of nonpolar organic chemicals is controlled largely by their solubility in various media. Therefore, in sediments they tend to occur primarily in association with organic matter (Karickhoff, 1981) and in organisms they are found primarily in the body fats or lipids (Bierman, 1990; Geyer et al., 1982; Konemann and van Leeuwen, 1980; Mackay, 1982). Bioaccumulation of nonpolar organic compounds from sediment can be estimated from the organic carbon content of the sediment, the lipid content of the organism, and the relative affinities of the chemical for sediment organic carbon and animal lipid content (USEPA and USACE, 1998). It is possible to relate the concentration of a chemical in one phase of a two-phase system to the concentration in the second phase when the system is in equilibrium. The TBP calculation focuses on the equilibrium distribution of a chemical between the sediment and the organism. By normalizing nonpolar organic chemical concentration data for lipid in organisms, and for organic carbon in sediment, it is possible to estimate the preference of a chemical for one phase or the other (USEPA and USACE, 1998).

The TBP can be calculated relative to the biota-sediment accumulation factor (BSAF), as in the following equation (USEPA and USACE, 1998):

$$\mathrm{TBP} = \mathrm{BSAF}\,(C_s/f_{oc})f_l$$

where TBP is expressed on a whole-body basis in the same units of concentration as C_s and

TBP = theoretical bioaccumulation potential (ppm);

C_s = concentration of nonpolar organic chemical in sediment (ppm);

BSAF = biota-sediment accumulation factor (ratio of the concentration of a chemical in tissue, normalized to lipid, to the concentration of the chemical in surface sediment, normalized to organic carbon (in kg sediment organic carbon/kg lipid));

f_{oc} = total organic carbon (TOC) content of sediment expressed as a decimal fraction (i.e., 1 percent = 0.01); and

f_l = organism lipid content expressed as a decimal fraction (e.g., 3 percent = 0.03) of fillet or whole-body dry weight.

BSAFs are transfer coefficients that relate concentrations in biota to concentrations in sediment. They are calculated as the ratio of the concentration of nonpolar organic chemical in fish tissue (normalized by lipid content) to the concentration of nonpolar organic chemical in sediment (normalized by organic carbon content). At equilibrium, BSAFs are in theory approximately 1.0. In practice, BSAFs can be greater than or less than 1.0 depending on the disequilibrium between fish and water, and that between water and sediment. Although based on a partitioning theory, field-measured BSAFs empirically account for factors such as metabolism and food chain magnification. BSAFs can vary depending on the biota, dynamics of chemical loadings to the waterbody, food chain effects, and rate of sediment-water exchange. Thus, measured BSAF values will depend on many site-specific variables, including hydraulic, biological, chemical, and ecological factors that affect bioavailability. The accuracy of a BSAF, measured at one location at a point in time, when applied to another location at another point in time depends on two factors. The first factor is the degree to which variation from a theoretical BSAF of 1.0 is controlled by inherent properties of the chemical as opposed to environmental conditions of the locale. The second is the degree of similarity between environmental conditions at the place of measurement and at the place of application.

The BSAFs used in the TBP evaluation were obtained from the EPA Office of Research and Development (EPA ORD) Environmental Research Laboratories at Duluth, Minnesota, and Narragansett, Rhode Island (USEPA, 1997). The BSAFs developed by EPA ORD-Narragansett were for benthic organisms and demersal (bottom-dwelling) fishes. The BSAFs developed by EPA ORD-Duluth, on the other hand, were for benthically coupled pelagic (open-water) fishes (USEPA, 1997). If TOC measurements were not available at a site, f_{oc} was assumed to be 0.01 (1 percent).

For the evaluation of NSI data, EPA selected a 3 percent lipid content in fish fillets for the TBP calculation for assessing human health effects from the consumption of contaminated fish. Lipid normalization is now part of the EPA guidance on bioaccumulation, and the current national methodology uses a 3 percent value for human health assessments. *The Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation Factors* (USEPA, 1995a) uses a 3.10 percent lipid value for trophic level 4 fish and 1.82 percent for trophic level 3 fish in its human health assessments.

As part of the NSI data TBP evaluation, EPA also evaluated percent lipid measurements included in the STORET database, the *National Study of Chemical Residues in Fish* (NSCRF; USEPA, 1992b), and other published sources and compared those values to the value selected for the NSI data evaluation (Appendix C of *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*; USEPA, 1997). The mean fillet percent lipid content for various groups of fish species in the STORET database ranged from 0.753 to 4.49 percent; in the NSCRF, mean fillet values ranged from 1.6 to 4.9 percent. The mean whole-body percent lipid content for various groups of fish species in the STORET database ranged from 3.757 to 6.33 percent; in the NSCRF, mean whole-body values ranged from 4.6 to 8.8 percent.

In the NSI data evaluation approach, TBP values were compared to U.S. Food and Drug Administration (FDA) tolerance/action/guidance levels and EPA risk levels. These parameters are discussed below.

FDA Tolerance/Action/Guidance Levels

FDA is responsible for the safety of the Nation's commercial food supply, including fish and shellfish for human consumption. Under the authority of the Federal Food, Drug and Cosmetic Act (FFDCA), FDA ensures that regulated products are safe for use by consumers. The FFDCA authorizes FDA to conduct assessments of the safety of ingredients in foods. The key element of the FFDCA, and the source of FDA's main tools for enforcement, is the prohibition of the "adulteration" of foods. FDA can prescribe the level of contaminant that will render a food adulterated and, therefore, can initiate enforcement action based on scientific data. The establishment of guidance and action levels (informal judgments about the level of a food contaminant to which consumers can be safely exposed) or tolerances (regulations having the force of law) is the regulatory procedure FDA uses to control environmental contaminants in the commercial food supply.

During the 1970s the available detection limits were considered to demonstrate elevated contamination and were used as action levels. Since that time FDA has focused on using risk-based standards derived by individually considering each chemical and the species of fish it is likely to contaminate. FDA also considered (1) the amount of potentially contaminated fish eaten and (2) the average concentrations of contaminants consumed. FDA has established action levels in fish for 10 pesticides and methylmercury, tolerance levels for polychlorinated biphenyls (PCBs), and guidance for 5 metals.

EPA Risk Levels

Potential impacts on humans are evaluated by estimating potential carcinogenic risks and noncarcinogenic hazards associated with the consumption of chemically contaminated fish tissue. In this assessment it was assumed that the only source of contamination to fish is contaminated sediment. The procedures for estimating human health risks due to the consumption of chemically contaminated fish tissue are based on *Risk Assessment Guidance for Superfund* (USEPA, 1989) and *Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories*, Volume I: *Fish Sampling and Analysis* (USEPA, 2000i).

EPA human health risk assessment methods were used in this assessment to determine the levels of contamination in fish that might result in a 10^{-5} cancer risk (1 in 100,000 extra chance of cancer over a lifetime) or a noncancer hazard in humans. A 10^{-5} risk level exceeds the lower bound (10^{-6}) but is lower than the upper bound (10^{-4}) of the risk range accepted by EPA (USEPA, 1990).

Human health cancer risks and noncancer hazards are based on the calculation of the chronic daily intake (CDI) of contaminants of concern:

$$\mathrm{CDI} = \frac{(\mathrm{EPC})(\mathrm{IR})(\mathrm{EF})(\mathrm{ED})}{(\mathrm{BW})(\mathrm{AT})}$$

where:

CDI = chronic daily intake (mg/kg/day);

EPC = exposure point concentration (contaminant concentration in fish);

IR = ingestion rate (17.5 g/day);

EF = exposure frequency (365 days/year);

ED = exposure duration (70 years);

BW = body weight (70 kg); and

AT = averaging time (70 years x 365 days/year).

These are the same parameter values EPA used to develop human health water quality criteria. A consumption rate of 17.5 g/d is chosen to be protective of the majority (i.e., 90 percent) of the population (USEPA, 2000i). Carcinogenic risks are then quantified using the following equation:

$$\text{Cancer risk}_i = (\text{CDI})\ (\text{SF}_i)$$

where:

Cancer risk_i = the potential carcinogenic risk associated with exposure to chemical *i* (unitless);

CDI_i = chronic daily intake for chemical *i* (mg/kg/day); and

SF_i = slope factor for chemical *i* $(\text{mg/kg/day})^{-1}$.

The hazard quotient, which is used to quantify the potential for an adverse noncarcinogenic effect to occur, is calculated using the following equation:

$$\text{HQ}_i = \frac{\text{CD}_i}{\text{RfD}_i}$$

where:

HQ_i = hazard quotient for chemical *i* (unitless);

CDI_i = chronic daily intake for chemical *i* (mg/kg/day); and

RfD_i = reference dose for chemical *i* (mg/kg/day).

If the hazard quotient exceeds unity (i.e., 1), an adverse health effect might occur. The higher the hazard quotient, the more likely that an adverse noncarcinogenic effect will occur as a result of exposure to the chemical. If the estimated hazard quotient is less than unity, noncarcinogenic effects are unlikely to occur.

Using these formulas, the fish tissue concentration (EPC) of a contaminant that equates to a cancer risk of 10^{-5} or a hazard quotient that exceeds unity can be back-calculated.

Cancer risk:

$$\text{EPC} = \frac{(10^{-5})(\text{BW})(\text{AT})(\text{C}_1)}{(\text{IR})(\text{EF})(\text{ED})(\text{SF}_1)}$$

Noncancer hazard:

$$\text{EPC} = \frac{(\text{BW})(\text{AT})(\text{RfD}_i)(\text{C}_1)}{(\text{IR})(\text{EF})(\text{ED})}$$

where:

C_1 = conversion factor (10^3 g/kg).

The cancer slope factors and noncancer reference doses reported in the *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA, 2000i) were used to calculate the EPA risk levels and hazard quotients in this NSI data evaluation. When the risk levels and hazard quotients were not reported in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA, 2000i), cancer slope factors and noncancer reference doses used in the 1997 *National Sediment Quality Survey* report to Congress (Appendix E, Table E-1, USEPA, 1997) were used. In such instances an average consumption of 17.5 grams per day of uncooked fish and shellfish from estuarine waters and freshwaters by recreational fishers was used in the computation of risk values and hazard quotients.

Tissue Levels of Contaminants

In addition to sediment chemistry TBP values, measured levels of contaminants in the tissues of resident aquatic species were used to assess potential human health risk. As was the case with the evaluation of TBP values, the NSI data evaluation approach compared contaminant tissue levels to FDA tolerance/action/guidance levels and EPA risk levels. Each of these parameters was discussed in the previous section. In such a comparison it is assumed that contaminant concentrations in tissue result from bioaccumulation of contaminants in the sediment.

The draft ESGs used for the NSI data evaluation for nonionic organics, PAH mixtures, and metal mixtures; model parameters used for the logistic regression models; EPA risk levels; and FDA tolerance/action/guidance levels are presented in Table C-1 of Appendix C.

Wildlife Assessments

In addition to the evaluation parameters described above for the assessment of potential aquatic life and human health impacts, EPA also conducted a separate analysis of potential wildlife impacts resulting from exposure to sediment contaminants.

First, wildlife criteria based on fish tissue concentrations were derived using methods similar to those employed for deriving EPA wildlife criteria, as presented in the *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife*: *DDT; mercury; 2,3,7,8-TCDD; PCBs* (USEPA, 1995b). EPA has developed Great Lakes Water Quality Wildlife Criteria for four chemicals: DDT; mercury; 2,3,7,8-TCDD; and PCBs. A Great Lakes Water Quality Wildlife Criterion (GLWC) is the concentration in the water of a substance that, if not exceeded, protects avian and mammalian wildlife populations from adverse effects resulting from the ingestion of surface waters and aquatic prey (USEPA, 1995b). Wildlife values are calculated using the following equation:

$$\mathrm{WV} = \frac{(\mathrm{NOAEL})(\mathrm{SSF})(\mathrm{Wt}_A)}{W_A + (F_A)(\mathrm{BAF})}$$

where:

WV = wildlife value (mg/L);

NOAEL = no-observed-adverse-effect level, as derived from mammalian or avian studies (mg/kg-d);

Wt_A = average weight for the representative species identified for protection (kg);

W_A = average daily volume of water consumed by the representative species identified for protection (L/d);

SSF = species sensitivity factor, an extrapolation factor to account for the difference in toxicity between species;

F_A = average daily amount of food consumed by the representative species identified for protection (kg/d); and

BAF = bioaccumulation factor (L/kg), the ratio of the concentration of a chemical in tissue, normalized to lipid, to the concentration in ambient water. Chosen using guidelines for wildlife presented in appendix B to part 132, Methodology for Development of Bioaccumulation Factors (*Federal Register*, Vol. 58, No. 72, April 16, 1993).

In the development of the four GLWCs, wildlife values for five representative Great Lakes basin wildlife species (bald eagle, herring gull, belted kingfisher, mink, and river otter) were calculated, and the geometric mean of these values within each taxonomic class (birds and mammals) was determined. The GLWC is the lower of two class-species means (USEPA, 1995b).

The wildlife values are considered to be generally protective of wildlife species. However, it should be noted that the approach is not based on the most sensitive wildlife species, but rather a typical class of either avian or mammalian piscivores. Despite this limitation, this approach is still considered appropriate and conservative because of the many conservative assumptions used to derive these wildlife values (e.g., species sensitivity factors, assumption that animals consume only contaminated fish).

Proposed EPA wildlife criteria are based on surface water contaminant levels protective of potential wildlife exposure. Thus, the proposed EPA wildlife criteria cannot be compared directly to the NSI fish tissue concentrations (either the calculated TBPs or fish tissue monitoring data). It was necessary, therefore, to develop an approach for estimating wildlife criteria for fish tissue based on the same toxicity and exposure parameter assumptions that were used to derive the surface water wildlife criteria. First, wildlife values (i.e., fish tissue concentrations protective of wildlife) were derived for the most sensitive mammalian species (i.e., otter and mink) and avian species (i.e., kingfisher, herring gull, and eagle)—the same species used to derive the proposed EPA wildlife criteria. The equation used to estimate wildlife values for fish tissue is presented below. (Exposure assumptions used for each species are presented in USEPA, 1995b.)

$$WV_{fish} = \frac{(NOAEL)(SSF)(Wt_A)}{F_A}$$

where:

WV_{fish} = wildlife value for fish tissue (mg/kg);

NOAEL = no-observed-adverse-effect level (mg/kg-day);

SSF = species sensitivity factor;

Wt_A = average weight of animal in kilograms (kg); and

F_A = average daily amount of food consumed (kg/day).

Second, the geometric mean of the wildlife values was calculated for the mammal group, as well as for the avian group. Finally, the lower of the two geometric mean values was considered the wildlife criterion for fish tissue for a given chemical.

It should be noted that direct ingestion of surface water was included when developing proposed EPA wildlife criteria for surface water. This exposure route, however, was not considered when evaluating NSI data, even though sediment contamination might result in contamination of surface water available for wildlife consumption. A sensitivity analysis was conducted to evaluate the impact of excluding the surface water ingestion exposure route. Based on this analysis, ingestion of surface water contributes less than 0.0001 percent of the total exposure (i.e., ingestion of fish and water). Therefore, excluding the water ingestion exposure route had no significant impact on the evaluation of NSI data with respect to potential wildlife impacts.

Wildlife criteria derived for DDT; mercury; 2,3,7,8-TCDD; and PCBs based on fish tissue concentration are presented below.

Chemical	Fish Tissue Criterion (mg/kg)
DDT	3.93E-2
Mercury	5.73E-2
2,3,7,8-TCDD	5.20E-7
PCBs	1.60E-1

The wildlife criteria were compared to measured fish tissue residue data contained in the NSI and to TBPs calculated for DDT; 2,3,7,8-TCDD; and PCBs. Mercury is not a nonpolar organic chemical, and thus a TBP for mercury was not calculated. A whole-body lipid value of 10.31 was assumed for the TBP evaluation of potential wildlife impacts, based on the *Great Lakes Water Quality Technical Support Document for the Procedure to Determine Bioaccumulation Factors* (USEPA, 1995a).

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APPENDIX C
VALUES USED FOR CHEMICALS EVALUATED

Sediment Values

Table C-1 (at the end of this appendix) presents the values used in the evaluation of NSI sediment chemistry data.

Fish Tissue Concentrations

Fish tissue concentrations are presented in Table C-1. EPA risk levels were calculated for a standard human health cancer risk of 10^{-5} and a noncancer hazard quotient of 1 and for an elevated cancer risk level of 10^{-4} and a noncancer hazard quotient of 10 (USEPA, 1995a; 1995b). Other available EPA sources were consulted as necessary to obtain risk-based concentrations for use in the screening analysis, including the Environmental Criteria and Assessment Office (as cited in USEPA, 1995c). FDA tolerance/action/guidance levels were obtained from the FDA Office of Seafood (Title 40 of the *Code of Federal Regulations*, Sections 180.213a and 180.142; DHHS, 1994; USFDA, 1993a, 1993b, 1993c, 1993d, 1993e).

Biota-Sediment Accumulation Factors

The final column in Table C-1 presents the biota-sediment accumulation factors (BSAFs) used in the analysis. The BSAFs were used in calculating the theoretical bioaccumulation potential (TBP), which represents the potential concentrations that might occur in tissues of fish exposed to contaminated sediments.

Methodology for Combining Chemical Data Using a Risk-Based Approach

Several screening values, as provided in the original source documents, refer to groups of chemicals. The majority of the data included in the NSI database are for specific chemicals. To perform a screening analysis that accommodates the way the data appear in the NSI database and provides a reasonably conservative risk-based approach, chemical data were combined in particular cases.

Four of the chemical groups affected by this approach are polychlorinated biphenyls (PCBs); DDT and its derivatives; polycyclic aromatic hydrocarbons; and dioxins, furans, and dioxin-like PCB compounds. The maximum value computed from the sum of detected PCB congeners, the sum of detected PCB homologs, or the maximum detected PCB aroclor was used for analyzing total PCBs in this report. If congener, homolog or aroclor data were not available, the total PCBs reported in the NSI database were used. If the above calculations did not result in a detected PCB result, then the largest non-detected result was used. This value enabled comparisons to the screening values available for total PCBs. DDT and its derivatives were summed to derive a total DDT value. In addition, the dioxins, furans, and dioxin-like PCB congeners and the polycyclic aromatic hydrocarbons were evaluated using the toxic equivalency factor (TEF) approach (Van den Berg et al., 1998; Nisbet and LaGoy, 1992; USEPA, 1989). For dioxins, furans, and dioxin-like PCB congeners this approach involves summing specific dioxin congeners and dioxin-like compounds based on their relative toxicity as compared to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), for which screening values are available. TEFs as recommended by the World Health Organization for risk assessments for humans and other mammals were used to derive a composite TEF (Van den Berg et al., 1998). The TEFs used for dioxins, furans, and dioxin-like PCBs in the NSI data evaluation are presented in Table C-2. Similarly TEF, factors used for PAHs in the NSI data evaluation are presented in Table C-3.

Because EPA typically performs risk-based screening by analyzing closely related chemicals with the same risk-based concentrations, this methodology was applied in the NSI data evaluation. If no screening values were available for a certain chemical but were available for a closely related chemical or group of chemicals, the lower or more conservative screening values of the closely related chemicals were used in analyzing the chemicals without screening values. The following chemicals and chemical groups were affected by this methodology: benzene hexachlorides (BHCs), chlordanes, cresols, DDT and its derivatives, dichlorobenzenes, endosulfans, methylmercury, nonachlor, anthracene and phenanthrene, benzo(a)anthracene/ chrysene, xylenes, and PCBs.

Frequency of Detection

The frequency at which a given chemical or chemical group is responsible for sites in the NSI being categorized as Tier 1 or Tier 2 is often a reflection of the number of times that chemical is measured and detected in sediment samples. Thus, chemicals that are measured and detected less frequently might be identified less frequently as posing a potential risk to aquatic life or human health, even though the chemicals are highly toxic. Table C-4 lists the number of stations at which each chemical included in the NSI data evaluation was measured and detected (i.e., a positive result) in sediment and fish tissue. Table C-5 presents the number of detected sediment observations in watersheds containing areas of probable concern (APCs).

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Table C-1. Screening Values for Chemicals Evaluated.

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS
May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions

CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG (μg/g_{oc})		Logistic Regression Model		C_{oc}, PAH (μg/g_{oc})			Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]						
83329	Acenaphthene	1			0.27	0.04	2,043	491	33,400						0.29[g]
208968	Acenaphthylene	1			0.42	0.04	1,880	452	24,000						
67641	Acetone	1									409		4,090		1[h]
98862	Acetophenone	1									409		4,090		
107028	Acrolein	1									81.7		817		
107131	Acrylonitrile	1								0.0743	4.09	0.743	40.9		1[h]
15972608	Alachlor/Lasso	1								0.483	40.9	4.83	409		
116063	Aldicarb/Temik										4.09		40.9		
309002	Aldrin[i]	1,3								0.00234	0.119	0.0234	1.19	0.3	1.8[g]
62533	Aniline									7.06		70.6			
120127	Anthracene	1			0.8	0.08	2,471	594	1,300						0.29[g]
	Anthracene and Phenanthrene	1									1,190		11,900		0.29[g]
7440360	Antimony				4.41	1.09					1.6		16		
7440382	Arsenic	2			32.61	11.29				0.026	1.2	0.26	12	68	
1912249	Atrazine									0.182	141	1.82	1,410		
7440393	Barium										279		2,790		
71432	Benzene	1	100	5.7						1.37		13.7			1[h]
92875	Benzidine									0.000175	11.9	0.00175	119		
56553	Benzo(a)anthracene[i]	1			1.21	0.14	3,499	841	4,153						0.29[g]
	Benzo(a)anthracene/Chrysene[i]	1								0.0557		0.557			0.29[g]
50328	Benzo(a)pyrene[i]	1			1.34	0.16	4,014	965	3,840						0.29[g]
205992	Benzo(b)fluoranthene[i]	1			3.03	0.32	4,073	979	2,169						0.29[g]
191242	Benzo(g,h,i)perylene[i]	1			1.28	0.15									
207089	Benzo(k)fluoranthene[i]	1			1.4	0.16	4,081	981	1,220						0.29[g]
65850	Benzoic acid										16,000		160,000		
	Benzoquinone-p	1													
98077	Benzotrichloride	1								0.00308		0.0308			
100516	Benzyl alcohol										1,190		11,900		
100447	Benzyl chloride	1								0.234		2.34			
7440417	Beryllium									0.00929	20.1	0.0929	201		
319846	BHC, alpha-	1,3								0.00631		0.0631		0.3	1.8[g]
319857	BHC, beta-	1,3								0.0223		0.223		0.3	1.8[g]
319868	BHC, delta-	1,3	230	13						0.0223		0.223		0.3	1.8[g]
58899	BHC, gamma- (Lindane)	1,3	8.8	0.37						0.0307	1.2	0.307	12	0.3	1.8[g]
608731	BHC, technical grade	1,3								0.0223	1.19	0.223	11.9	0.3	1.8[g]
92524	Biphenyl	1	850	110	0.14	0.03					201		2,010		0.29[g]
111444	Bis(2-chloroethyl)ether	1								0.0364		0.364			
108601	Bis(2-chloroisopropyl)ether	1								0.557	160	5.57	1,600		
117817	Bis(2-ethylhexyl)phthalate[i]	1								2.86	81.7	28.6	817		1[h]
542881	Bis(chloromethyl)ether									0.000182		0.00182			
7440428	Boron										360		3,600		

Table C-1. (Continued)

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions															
CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG (µg/g_{oc})		Logistic Regression Model		C_{oc}, PAH (µg/g_{oc})			Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]						
75274	Bromodichloromethane	1								0.631	81.7	6.31	817		
74839	Bromomethane	1									5.57		55.7		
101553	Bromophenyl phenyl ether, 4-	1	2,300	130							230		2,300		1[h]
1689845	Bromoxynil										81.7		817		
85687	Butyl benzyl phthalate	1	15,000	1,100							817		8,170		1[h]
7440439	Cadmium	2			2.49	0.65					4		40	3	
63252	Carbaryl/Sevin										409		4,090		
1563662	Carbofuran/furadan										20.1		201		
75150	Carbon disulfide										409		4,090		
133904	Chloramben										59.4		594		
57749	Chlordane[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
	Chlordane (Nonachlor)[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
	Chlordane (*cis*-Nonachlor)[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
3734494	Chlordane (*trans*-Nonachlor)[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
5103719	Chlordane, alpha (*cis*)-[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
5103742	Chlordane, beta (*trans*)-[i]	1,3								0.114	2	1.14	20	0.3	2[j]
	Chlordane, *cis*-[i]	1,3								0.114	2	1.14	20	0.3	4.77[j]
5566347	Chlordane, gamma (*trans*)-[i]	1,3								0.114	2	1.14	20	0.3	2.22[j]
	Chlordane, *trans*-[i]	1,3								0.114	2	1.14	20	0.3	2.22[j]
108907	Chlorobenzene	1	1,500	82							81.7		817		1[h]
510156	Chlorobenzilate									0.149	81.7	1.49	817		
75003	Chloroethane	1									1,600		16,000		
75014	Chloroethene	1								0.0212		0.212			
110758	Chloroethylvinyl ether, 2-	1									100		1,000		
74873	Chloromethane	1								3.08		30.8			
91587	Chloronaphthalene, 2-	1									319		3,190		
95578	Chlorophenol, 2-										20.1		201		
2921882	Chlorpyrifos/Dursban	1									1.2		12		1.8[g]
7440473	Chromium	2			233.27	76.00					20.1		201	11	
218019	Chrysene[i]	1			1.73	0.19	3,511	844	826						0.29[g]
7440508	Copper				157.13	49.98					149		1,490		
108394	Cresol, *m*-										201		2,010		
95487	Cresol, *o*-										201		2,010		
106445	Cresol, *p*-										20.1		201		
1319773	Cresols										20.1		201		
98828	Cumene	1									160		1,600		
21725462	Cyanazine									0.0483	8.17	0.483	81.7		
57125	Cyanide										81.7		817		
1861321	DCPA/Dacthal	1									40.9		409		1.8[g]
72548	DDD, p, p'-[i]	1,3			0.05	0.01								5	0.28[j]
72559	DDE, p, p'-[i]	1,3			0.54	0.01								5	7.7[j]
	DDT (Total)[i]	1,3								0.117	2	1.17	20	5	7.7[j]

Table C-1. (Continued)

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS
May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions

CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG (µg/g_{oc})		Logistic Regression Model		C_{oc}, PAH (µg/g_{oc})			Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]						
50293	DDT, p, p'-[i]	1,3			0.03	0.004								5	1.67[j]
1163195	Decabromodiphenyl oxide	1									40.9		409		
84742	Di-n-butyl phthalate	1	8,000	1,100							409		4,090		1[h]
117840	Di-n-octyl phthalate[i]	1									81.7		817		1[h]
333415	Diazinon/Spectracide	1	0.73	0.19							2.8		28		1.8[g]
53703	Dibenzo(a,h)anthracene[i]	1			0.26	0.04									0.29[g]
132649	Dibenzofuran	1	3,700	200							16		160		1[h]
96128	Dibromo-3-chloropropane, 1,2-	1								0.0286		0.286			
124481	Dibromochloromethane	1								0.483	81.7	4.83	817		1
1918009	Dicamba										119		1,190		
95501	Dichlorobenzene, 1,2-	1	610	34							360		3,600		1[h]
541731	Dichlorobenzene, 1,3-	1	1,500	170							357		3,570		1[h]
106467	Dichlorobenzene, 1,4-	1	420	35						1.67		16.7			1[h]
25321226	Dichlorobenzenes	1								1.67	357	16.7	3,570		1
91941	Dichlorobenzidine, 3,3'-									0.0891		0.891			
75718	Dichlorodifluoromethane	1									817		8,170		
75343	Dichloroethane, 1,1-	1									409		4,090		1[h]
107062	Dichloroethane, 1,2-	1								0.446		4.46			1[h]
75354	Dichloroethene, 1,1-	1								0.0669	36	0.669	360		
156605	Dichloroethene, *trans*-1,2-	1									81.7		817		1[h]
156592	Dichloroethylene, *cis*-1,2-	1									40.9		409		
75092	Dichloromethane	1								5.2	241	52	2,410		1[h]
120832	Dichlorophenol, 2,4-										11.9		119		
94757	Dichlorophenoxyacetic acid, 2,4-	5									40.9		409	1	
94826	Dichlorophenoxybutanoic acid, 2,4-										31.9		319		
78875	Dichloropropane, 1,2-	1								0.594		5.94			1[h]
542756	Dichloropropene, 1,3-	1								0.23	1.19	2.3	11.9		
62737	Dichlorvos	1								0.137	2.01	1.37	20.1		
115322	Dicofol/Kelthane[i]									2.5	1.6	25	16		
60571	Dieldrin	1,3	55	13	0.01	0.001				0.0025	0.2	0.025	2	0.3	1.8[g]
84662	Diethyl phthalate	1	1,100	63							3,190		31,900		1[h]
119904	Dimethoxybenzidine, 3,3'-									2.86		28.6			
131113	Dimethyl phthalate	1									40,900		409,000		1
581420	Dimethylnaphthalene, 2,6-				0.29	0.05									
105679	Dimethylphenol, 2,4-										81.7		817		
528290	Dinitrobenzene, 1,2-										1.6		16		
99650	Dinitrobenzene, 1,3-										0.409		4.09		
100254	Dinitrobenzene, 1,4-										1.6		16		
51285	Dinitrophenol, 2,4-										8.17		81.7		
121142	Dinitrotoluene, 2,4-										8.17		81.7		
606202	Dinitrotoluene, 2,6-										4.09		40.9		
88857	Dinoseb/DNBP										4.09		40.9		

Table C-1. (Continued)

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS
May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions

CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG (µg/g_{oc})		Logistic Regression Model		C_{oc}, PAH (µg/g_{oc})			Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]						
122667	Diphenylhydrazine, 1,2-									0.0483		0.483			
298044	Disulfoton	1									0.16		1.6		
115297	Endosulfan mixed isomers	1	1.4	0.54							24		240		1.8[g]
959988	Endosulfan, alpha-	1	0.74	0.29							24.1		241		1.8[g]
33213659	Endosulfan, beta-	1	3.5	1.4							24.1		241		1.8[g]
72208	Endrin	1	17	5.5							1.2		12		1.8[g]
563122	Ethion/Bladen	1									2		20		1.8[g]
141786	Ethyl acetate	1									3,600		36,000		
100414	Ethylbenzene	1	8,500	480							409		4,090		1[h]
106934	Ethylene dibromide	1								0.000483		0.00483			
206440	Fluoranthene	1			2.86	0.29	2,941	707	23,870						0.29[g]
86737	Fluorene	1			0.26	0.04	2,238	538	26,000						0.29[g]
944229	Fonofos	1									8.17		81.7		
76448	Heptachlor[i]	1,3								0.00891	2.01	0.0891	20.1	0.3	1.8[g]
1024573	Heptachlor epoxide	1,3								0.00439	0.052	0.0439	0.52	0.3	1.8[g]
118741	Hexachlorobenzene[i]	1								0.025	3.2	0.25	32		0.09[j]
87683	Hexachlorobutadiene	1								0.52	0.817	5.2	8.17		1[h]
74474	Hexachlorocyclopentadiene	1									27.9		279		
67721	Hexachloroethane	1	1,800	100						2.86	4.09	28.6	40.9		1[h]
51235042	Hexazinone	1									134		1,340		
123319	Hydroquinone										160		1,600		
193395	Indeno(1,2,3-cd)pyrene[i]	1			1.23	0.16									0.29[g]
78591	Isophorone	1								40.9	817	409	8,170		1[h]
33820530	Isopropalin[i]										59.4		594		
7439921	Lead	2			161.06	47.82								1.3	
121755	Malathion	1	0.62	0.067							81.7		817		1.8[g]
108316	Maleic anhydride										409		4,090		
7439965	Manganese										20.1		201		
7439976	Mercury				0.87	0.23					0.4		4	1	
72435	Methoxychlor	1	9.5	1.9							20.1		201		1.8[g]
78933	Methyl ethyl ketone	1									2,410		24,100		1[h]
108101	Methyl isobutyl ketone	1									319		3,190		
22967926	Methyl mercury	3									0.4		4	1	
90120	Methylnaphthalene, 1-				0.19	0.04									
91576	Methylnaphthalene, 2-	1			0.30	0.05									
832699	Methylphenanthrene, 1-				0.27	0.04									
21087649	Metribuzin										100		1,000		
2385855	Mirex/Dechlorane[i]	1,3									0.8		8	0.1	1.31[j]
7439987	Molybdenum										20.1		201		
91203	Naphthalene	1			0.55	0.07	1,602	385	61,700		160		1,600		0.29[g]
91598	Naphthylamine, 2-									0.000308		0.00308			
7440020	Nickel	2			80.07	23.77					81.7		817	70	

Table C-1. (Continued)

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS
May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions

CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG ($\mu g/g_{oc}$)		Logistic Regression Model		C_{oc}, PAH ($\mu g/g_{oc}$)								
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]	Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
98953	Nitrobenzene										2.01		20.1		
100027	Nitrophenol, 4-										249		2,490		
55185	Nitrosodiethylamine, N-									0.00078		0.0078			
924163	Nitrosodi-n-butylamine, N-									0.00743		0.0743			
621647	Nitrosodi-n-propylamine, N-									0.00557		0.0557			
86306	Nitrosodiphenylamine, N-									8.17		81.7			
42874033	Oxyfluorfen									0.546	12	5.46	120		
56382	Parathion, ethyl-										24.1		241		
608935	Pentachlorobenzene	1	1,200	69							3.19		31.9		0.04[j]
82688	Pentachloronitrobenzene/Quintozene									0.152	11.9	1.52	119		
87865	Pentachlorophenol									0.334	119	3.34	1,190		
198550	Perylene				1.06	0.16									
85018	Phenanthrene	1			1.12	0.15	2,479	596	34,300						
108952	Phenol										2,410		24,100		
298022	Phorate/Famophos/Thimet	1									0.817		8.17		
85449	Phthalic anhydride										8,170		81,700		
1336363	Polychlorinated biphenyls[i]	1,4			1.12	0.09				0.02	0.08	0.2	0.8	2	1.85[j]
1610180	Prometon/Pramitol										59.4		594		
7287196	Prometym/Caparol										16		160		
23950585	Pronamide										301		3,010		
1918167	Propachlor										52		520		
129000	Pyrene	1			2.41	0.29	2,900	697	9,090						0.29[g]
91225	Quinoline	1								0.00334		0.0334			
7782492	Selenium										20		200		
7440224	Silver				2.45	0.44					20.1		201		
122349	Simazine	5								0.334	20.1	3.34	201	12	
7440246	Strontium										2,410		24,100		
100425	Styrene	1									817		8,170		
	TEF Dioxins, Furans, and Dioxin-like PCBs[i]	1								2.56E-07		2.56E-06			0.025[j]
	TEF PAHs									0.00547		0.0547			0.29[g]
13071799	Terbufos/Counter	1									0.08		0.8		
886500	Terbutryn										4.09		40.9		
95943	Tetrachlorobenzene, 1,2,4,5-	1									1.19		11.9		1[h]
79345	Tetrachloroethane, 1,1,2,2-	1	830	160						0.201		2.01			1[h]
127184	Tetrachloroethene	1	420	53						0.78	40.9	7.8	409		1[h]
56235	Tetrachloromethane	1	2,100	120						0.308	2.79	3.08	27.9		1[h]
58902	Tetrachlorophenol, 2,3,4,6-										119		1,190		
961115	Tetrachlorvinphos/Gardona/Stirofos	1								1.67	119	16.7	1,190		
7440315	Tin										2,410		24,100		
108883	Toluene	1	1,600	89							817		8,170		1[h]
8001352	Toxaphene[i]	1	490	10						0.0363	1	0.363	10		1.8[g]

Table C-1. (Continued)

GUIDANCE VALUES INTENDED ONLY FOR SCREENING-LEVEL HAZARD COMPARISON AMONG CHEMICALS
May Be Over- or Under-protective of Sediment at a Given Location Depending on Site-specific Conditions

CAS Number	Chemical Name	Code	Sediment Value							Fish Tissue Concentration (ppm)					BSAF (Unitless)
			ESG ($\mu g/g_{oc}$)		Logistic Regression Model		C_{oc}, PAH ($\mu g/g_{oc}$)			Concen. = EPA Risk 10^{-5}	EPA Noncancer Hazard Quotient = 1	Concen. = EPA Risk 10^{-4}	EPA Noncancer Hazard Quotient = 10	FDA Tolerance/Action/ Guidance Level	
			Tier 1[a]	Tier 2[b]	T50[c] (ppm)	T25[c] (ppm)	Tier 1[d]	Tier 2[e]	Max[f]						
75252	Tribromomethane/Bromoform	1	460	65						5.2	81.7	52	817		1[h]
688733	Tributyltin										1.2		12		
120821	Trichlorobenzene, 1,2,4-	1	6,100	920							40.9		409		1[h]
71556	Trichloroethane, 1,1,1-	1	170	17							360		3,600		1[h]
79005	Trichloroethane, 1,1,2-	1								0.706	16	7.06	160		1[h]
79016	Trichloroethene	1	2,000	210						3.64	24.1	36.4	241		1[h]
75694	Trichlorofluoromethane	1									1,190		11,900		1[h]
67663	Trichloromethane/Chloroform	1								6.69	40.9	66.9	409		1[h]
95954	Trichlorophenol, 2,4,5-										409		4,090		
88062	Trichlorophenol, 2,4,6-									3.64		36.4			
93765	Trichlorophenoxyacetic acid, 2,4,5-										40.9		409		
93721	Trichlorophenoxypropionic acid, 2,4,5-										31.9		319		
1582098	Trifluralin/Treflan[i]									5.2	30.1	52	301		
95636	Trimethylbenzene, 1,2,4-	1									2.01		20.1		
118967	Trinitrotoluene									1.34	2.01	13.4	20.1		
7440622	Vanadium										27.9		279		
108054	Vinyl acetate	1									4,090		40,900		
108383	Xylene, *m*-	1	45	2.5							8,170		81,700		1[h]
95476	Xylene, *o*-	1									8,170		81,700		1[h]
106423	Xylene, *p*-	1													1
1330207	Xylenes (Total)	1									8,170		81,700		1[h]
7440666	Zinc				383.81	140.48					1,190		11,900		

Codes:
1. Chemical is a nonpolar organic.
2. FDA criterion is a guideline.
3. FDA criterion is an action level.
4. FDA criterion is a tolerance level, with the force of law.
5. Fish tissue action level set by USEPA, 40 CFR Part 180.
6. Preliminary ESG developed for this chemical is under technical review.

[a] Derived from chemical-specific log K_{ow}, log K_{oc}, and FAV or SAV as indicated in Table B-1.
[b] Derived from chemical-specific log K_{ow}, log K_{oc}, and FCV or SCV as indicated in Table B-1.
[c] Tp = Effect concentration that would give a response of "p" percent according to the logistic regression model.
[d] Derived from chemical-specific log K_{ow}, log K_{oc} and PAH-specific FAV as indicated in Table B-2.
[e] Derived from chemical-specific log K_{ow}, log K_{oc} and PAH-specific FCV as indicated in Table B-2.
[f] When the organic carbon normalized sediment concentration (C_{oc},$_{PAHi}$) is greater than $C_{oc,PAH,MAX}$, use $C_{oc,PAH,MAX}$ in place of C_{oc}, PAH_i.
[g] Hansen, 1995 (BSAF source).
[h] Default value of 1.
[i] Chemicals with log $K_{ow} \geq 5.5$.
[j] Cook, 1995 (BSAF source).

Table C-2. Toxic Equivalency Factors for Dioxins, Furans and Dioxin-Like PCBs.[a]

Chemical Name	TEF
1,2,3,4,7,8-HexaCDD	0.1
1,2,3,6,7,8-HexaCDD	0.1
1,2,3,7,8,9-HexaCDD	0.1
1,2,3,4,7,8-HexaCDF	0.1
1,2,3,6,7,8-HexaCDF	0.1
1,2,3,7,8,9-HexaCDF	0.1
2,3,4,6,7,8-HexaCDF	0.1
1,2,3,4,6,7,8-HeptaCDD	0.01
1,2,3,4,6,7,8-HeptaCDF	0.01
1,2,3,4,7,8,9-HeptaCDF	0.01
1,2,3,4,6,7,8,9-OctaCDD	0.0001
1,2,3,4,6,7,8,9-OctaCDF	0.0001
1,2,3,7,8-PentaCDD	1
1,2,3,7,8-PentaCDF	0.05
2,3,4,7,8-PentaCDF	0.5
2,3,7,8-TetraCDD (dioxin)	1
2,3,7,8-TetraCDF	0.1
3,3',4,4'-TetraCB (77)	0.0001
3,4,4',5-TetraCB (81)	0.0001
2,3,3',4,4'-PentaCB (105)	0.0001
2,3,4,4',5-PentaCB (114)	0.0005
2,3',4,4',5-PentaCB (118)	0.0001
2',3,4,4',5-PentaCB (123)	0.0001
3,3',4,4',5-PentaCB (126)	0.1
2,3,3',4,4',5-HexaCB (156)	0.0005
2,3,3',4,4',5'-HexaCB (157)	0.0005
2,3',4,4',5,5'-HexaCB (167)	0.00001
3,3',4,4',5,5'-HexaCB (169)	0.01
2,3,3',4,4',5,5'-HeptaCB (189)	0.0001

[a] Source: Van den Berg et al., 1998.

Table C-3. Toxicity Equivalency Factors for Various PAHs.[a]

Compound	TEF
Acenaphthene	0.001
Acenaphthylene	0.001
Anthracene	0.01
Benzo(a)anthracene	0.1
Benzo(a)pyrene	1
Benzo(b)fluoranthene	0.1
Benzo(g,h,i)perylene	0.01
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenz(a,h)anthracene	5
Fluoranthene	0.001
Fluorene	0.001
Indeno(1,2,3-cd)pyrene	0.1
Phenanthrene	0.001
Pyrene	0.001

[a] Source: Nisbet and LaGoy, 1992.

Table C-4. Frequency of Detection of Chemicals in Sediment and Tissue Residue.[a]

CAS Number	Chemical Name	Number of Stations Where Chemical Was Measured in Sediment	Number of Stations Where Chemical Was Detected in Sediment	Number of Stations Where Chemical Was Measured in Tissue Residue	Number of Stations Where Chemical Was Detected in Tissue Residue
83329	Acenaphthene	8,259	2,864		
208968	Acenaphthylene	7,879	2,298		
67641	Acetone	545	197		
107028	Acrolein			5	
107131	Acrylonitrile	333		37	
15972608	Alachlor/Lasso			3	
309002	Aldrin	9,624	612	1,324	30
120127	Anthracene	8,062	4,332		
	Anthracene and Phenanthrene	44		16	
7440360	Antimony	5,784	3,746	436	17
7440382	Arsenic	12,526	10,922	804	515
1912249	Atrazine			16	
7440393	Barium			464	353
71432	Benzene	1,110	16	63	2
92875	Benzidine			45	
56553	Benzo(a)anthracene	7,892	5,347		
	Benzo(a)anthracene/Chrysene	290	238	4	
50328	Benzo(a)pyrene	7,115	4,943		
205992	Benzo(b)fluoranthene	6,192	4,273		
191242	Benzo(g,h,i)perylene	8,098	4,849		
207089	Benzo(k)fluoranthene	6,179	3,981		
65850	Benzoic acid			24	
100516	Benzyl alcohol			27	
7440417	Beryllium			465	4
319846	BHC, alpha-	6,234	309	1,197	24
319857	BHC, beta-	5,070	255	799	14
319868	BHC, delta-	3,394	217	710	2
58899	BHC, gamma- (Lindane)	8,419	684	1,255	57
608731	BHC, technical grade	1,530	707		
92524	Biphenyl	2,382	1,656	30	21
111444	Bis(2-chloroethyl)ether			94	
108601	Bis(2-chloroisopropyl)ether			93	
117817	Bis(2-ethylhexyl)phthalate	4,339	2,609	97	7
7440428	Boron			375	364
75274	Bromodichloromethane			58	
74839	Bromomethane			24	
101553	Bromophenyl phenyl ether, 4-	3,458	16	104	
85687	Butyl benzyl phthalate	4,814	1,280	99	
7440439	Cadmium	13,621	8,948	940	592
57749	Chlordane	6,619	1,688	728	332
	Chlordane (Nonachlor)	42		150	4
	Chlordane (*cis*-Nonachlor)	2,781	554	864	159
3734494	Chlordane (*trans*-Nonachlor)	3,628	1,153	923	327
5103719	Chlordane, alpha (*cis*)-	3,244	862	42	33
	Chlordane, *cis*-	2,789	650	856	247
5566347	Chlordane, gamma (*trans*)-	2,330	483	19	14
	Chlordane, *trans*-	2,886	645	857	168
108907	Chlorobenzene	1,037	29	60	

Table C-4. (Continued)

CAS Number	Chemical Name	Number of Stations Where Chemical Was Measured in Sediment	Number of Stations Where Chemical Was Detected in Sediment	Number of Stations Where Chemical Was Measured in Tissue Residue	Number of Stations Where Chemical Was Detected in Tissue Residue
75003	Chloroethane			54	1
75014	Chloroethene			60	
110758	Chloroethylvinyl ether, 2-			47	
74873	Chloromethane			24	
91587	Chloronaphthalene, 2-			111	
95578	Chlorophenol, 2-			91	
2921882	Chlorpyrifos/Dursban	1,072	248	128	8
7440473	Chromium	12,509	12,246	889	596
218019	Chrysene	8,165	5,921		
7440508	Copper	13,896	13,464	842	800
95487	Cresol, *o*-			10	
106445	Cresol, *p*-			10	
57125	Cyanide			21	1
1861321	DCPA/Dacthal	1,175	81	492	31
72548	DDD, p, p'-	7,685	2,479	907	279
72559	DDE, p, p'-	7,907	2,837	949	597
	DDT (Total)	11,000	5,099	1,529	1,018
50293	DDT, p, p'-	7,757	1,838	948	204
84742	Di-n-butyl phthalate	4,576	1,218	105	5
117840	Di-n-octyl phthalate	5,014	424	86	1
333415	Diazinon/Spectracide	1,156	95	130	2
53703	Dibenzo(a,h)anthracene	8,149	3,121		
132649	Dibenzofuran	3,584	1,174	46	12
96128	Dibromo-3-chloropropane, 1,2-			16	
124481	Dibromochloromethane	899		57	
95501	Dichlorobenzene, 1,2-	4,972	127	171	7
541731	Dichlorobenzene, 1,3-	4,871	134	171	1
106467	Dichlorobenzene, 1,4-	4,931	249	95	1
91941	Dichlorobenzidine, 3,3'-			82	
75718	Dichlorodifluoromethane			16	
75343	Dichloroethane, 1,1-	1,082	1	57	
107062	Dichloroethane, 1,2-	1,076	3	60	
156605	Dichloroethene, *trans*-1,2-	667		58	
75354	Dichloroethene, 1,1-			60	2
75092	Dichloromethane	936	120	55	25
120832	Dichlorophenol, 2,4-			95	
78875	Dichloropropane, 1,2-	1,082		58	
542756	Dichloropropene, 1,3-			8	
115322	Dicofol/Kelthane			7	
60571	Dieldrin	9,600	2,158	1,380	486
84662	Diethyl phthalate	4,734	310	101	
131113	Dimethyl phthalate	5,201	554	115	11
581420	Dimethylnaphthalene, 2,6-	3,083	1,992		
105679	Dimethylphenol, 2,4-			96	
51285	Dinitrophenol, 2,4-			70	
121142	Dinitrotoluene, 2,4-			95	
606202	Dinitrotoluene, 2,6-			95	
122667	Diphenylhydrazine, 1,2-			55	
298044	Disulfoton			5	
115297	Endosulfan mixed isomers	993	27	35	1

Table C-4. (Continued)

CAS Number	Chemical Name	Number of Stations Where Chemical Was Measured in Sediment	Number of Stations Where Chemical Was Detected in Sediment	Number of Stations Where Chemical Was Measured in Tissue Residue	Number of Stations Where Chemical Was Detected in Tissue Residue
959988	Endosulfan, alpha-	3,889	82	168	7
33213659	Endosulfan, beta-	3,315	368	167	6
72208	Endrin	8,406	370	1,293	33
563122	Ethion/Bladen	805	25	9	
100414	Ethylbenzene	2,118	45	60	
206440	Fluoranthene	8,354	6,474		
86737	Fluorene	7,262	3,364		
76448	Heptachlor	9,444	566	1,328	18
1024573	Heptachlor epoxide	8,579	518	1,247	166
118741	Hexachlorobenzene	8,377	1,068	750	94
87683	Hexachlorobutadiene	4,033	150	176	73
74474	Hexachlorocyclopentadiene			91	
67721	Hexachloroethane	3,472	32	169	17
193395	Indeno(1,2,3-cd)pyrene	8,058	4,788		
78591	Isophorone	3,676	19	92	
7439921	Lead	13,623	12,802	944	456
121755	Malathion	1,018	22	48	
7439965	Manganese			443	435
7439976	Mercury	13,236	9,316	1,545	1,299
72435	Methoxychlor	4,265	191	532	2
78933	Methyl ethyl ketone	614	85		
90120	Methylnaphthalene, 1-	2,613	1,673		
91576	Methylnaphthalene, 2-	6,249	2,704		
832699	Methylphenanthrene, 1-	3,353	1,998		
2385855	Mirex/Dechlorane	4,224	320	1,052	29
7439987	Molybdenum			378	368
91203	Naphthalene	7,873	3,441	161	24
7440020	Nickel	12,404	11,680	598	340
98953	Nitrobenzene			9	
100027	Nitrophenol, 4-			92	
621647	Nitrosodi-n-propylamine, N-			94	
86306	Nitrosodiphenylamine, N-			102	
56382	Parathion, ethyl-			48	1
608935	Pentachlorobenzene	90	2	79	57
87865	Pentachlorophenol			103	
198550	Perylene	2,966	2,348		
85018	Phenanthrene	8,263	5,889		
108952	Phenol			95	1
1336363	Polychlorinated biphenyls	12,305	5,590	1,962	1,020
129000	Pyrene	8,272	6,303		
7782492	Selenium			625	555
	SEM est	739	739		
7440224	Silver	10,504	5,844	488	217
122349	Simazine			16	
7440246	Strontium			375	370
100425	Styrene			18	
	TEF Dioxins, Furans, and Dioxin-like PCBs	3,814	2,662	93	80
	TEF PAHs	9,422	7,244	165	31
95943	Tetrachlorobenzene, 1,2,4,5-	108	5	76	13
79345	Tetrachloroethane, 1,1,2,2-	1,059	3	60	

Table C-4. (Continued)

CAS Number	Chemical Name	Number of Stations Where Chemical Was Measured in Sediment	Number of Stations Where Chemical Was Detected in Sediment	Number of Stations Where Chemical Was Measured in Tissue Residue	Number of Stations Where Chemical Was Detected in Tissue Residue
127184	Tetrachloroethene	1,130	29		
56235	Tetrachloromethane	1,083	1	59	
58902	Tetrachlorophenol, 2,3,4,6-			6	
7440315	Tin			59	28
108883	Toluene	1,078	96	58	1
8001352	Toxaphene	5,894	99	1,200	24
75252	Tribromomethane/Bromoform	1,080	1	58	
688733	Tributyltin			16	15
120821	Trichlorobenzene, 1,2,4-	4,904	94	178	21
71556	Trichloroethane, 1,1,1-	1,073	2	58	1
79005	Trichloroethane, 1,1,2-	1,022	1	60	
79016	Trichloroethene	1,480	35	3	
75694	Trichlorofluoromethane	444	1	37	
67663	Trichloromethane/Chloroform	1,091	23	60	1
95954	Trichlorophenol, 2,4,5-			16	
88062	Trichlorophenol, 2,4,6-			98	
93721	Trichlorophenoxypropionic acid, 2,4,5-			1	
1582098	Trifluralin/Treflan			4	2
7440622	Vanadium			401	254
108383	Xylene, *m*-	20	1		
95476	Xylene, *o*-	198	10		
1330207	Xylenes (Total)	1,826	84	36	
7440666	Zinc	13,210	13,034	718	718

[a] Only stations with data included in NSI evaluation were included in this assessment.

Table C-5. Number of Detected Sediment Observations in Watersheds Containing APCs.

Chemical	Lower Connecticut (01080205)	Charles (01090001)	Narragansett (01090004)	Quinnipiac (01100004)	Housatonic (01100005)	Saugatuck (01100006)	Long Island Sound (01100007)	Hudson-Hoosic (02020003)	Mohawk (02020004)	Middle Hudson (02020006)	Hudson-Wappinger (02020008)	Lower Hudson (02030101)	Bronx (02030102)	Hackensack-Passaic (02030103)	Sandy Hook-Staten Island (02030104)	Raritan (02030105)
Acenaphthene	10	2	6	8	8	17	18	4	8	7	18	28	25	43	85	2
Acenaphthylene	16	4	3	9	15	18	16	8	12	10	12	25	25	44	86	4
Acetone														42	1	
Aldrin			1				3				2	2		26	11	2
Anthracene	15	16	10	11	14	19	23	12	23	11	17	30	25	86	97	7
Antimony	13	6	4	8	9	17	25	16	22	18	22	31	25	22	104	5
Arsenic	19	35	5	9	21	18	25	22	38	18	22	31	25	140	132	54
Benzene														2		
Benzo(a)anthracene	14	4	10	10	14	20	27	22	32	14	20	30	25	102	102	9
Benzo(a)anthracene/Chrysene		12														
Benzo(a)pyrene	10	12	6	9	9	16	22	8	16	3	6	15	25	97	105	1
Benzo(b)fluoranthene	15	4	3	9	15	17	7	19	32	10	10	15	14	94	45	8
Benzo(g,h,i)perylene	11	15	8	10	15	20	28	5	28	9	16	26	25	88	93	4
Benzo(k)fluoranthene	19	4	8	10	16	18	12	19	32	12	14	20	15	92	47	9
BHC, alpha-														12	7	
BHC, beta-														9	4	
BHC, delta-														17	7	
BHC, gamma- (Lindane)			2	1		2	13					9	12	7	46	
BHC, technical grade				1		2	13					9	12	2	42	
Biphenyl	3		6	6	3	14	15			3	10	18	25	16	82	1
Bis(2-ethylhexyl)phthalate	6	3	1	2	8	4		14	14	10	6	2		84	21	4
Bromophenyl phenyl ether, 4-																
Butyl benzyl phthalate	4	4	2		4	3		14	14	8	10	10		29	1	
Cadmium	15	56	6	11	17	18	33	31	40	29	29	34	26	124	132	13
Chlordane	3	6	16	5	4	14	21			2	5	29	25	43	98	41
Chlordane (*cis*-Nonachlor)	2	3	1		1	2						4		16	8	1
Chlordane (*trans*-Nonachlor)	8	4	3	7	2	15	16	2	2	2	4	20	23	25	94	1
Chlordane, alpha (*cis*)-	3		1	5	4	13	16				1	10	24	57	71	
Chlordane, *cis*-	5	4	1	2	1	3			2	2		11	1	18	29	1
Chlordane, gamma (*trans*)-														54	6	
Chlordane, *trans*-	5	4	4	3	1	4	1		4	1	6	13	1	19	12	2
Chlorobenzene														23		
Chlorpyrifos/Dursban																
Chromium	19	62	3	10	24	19	19	36	41	29	19	28	26	146	132	54
Chrysene	17	16	5	10	16	20	15	18	30	10	11	24	25	104	105	8
Copper	20	64	7	13	24	20	33	36	53	41	29	34	26	160	139	60
DCPA/Dacthal														13	7	
DDD, p, p'-	9	4	4	6	7	15	15		6	5	10	15	24	84	114	2
DDE, p, p'-	11	3	5	9	7	18	16	6	12	13	14	25	26	90	117	2
DDT (Total)	13	16	22	10	7	18	28	6	12	17	23	46	26	145	133	52

Table C-5. (Continued)

Chemical	Lower Connecticut (01080205)	Charles (01090001)	Narragansett (01090004)	Quinnipiac (01100004)	Housatonic (01100005)	Saugatuck (01100006)	Long Island Sound (01100007)	Hudson-Hoosic (02020003)	Mohawk (02020004)	Middle Hudson (02020006)	Hudson-Wappinger (02020008)	Lower Hudson (02030101)	Bronx (02030102)	Hackensack-Passaic (02030103)	Sandy Hook-Staten Island (02030104)	Raritan (02030105)
DDT, p, p'-	8	15	2	4	2	13	16		4	7	12	23	17	68	92	1
Di-n-butyl phthalate	7	3		2	5	3		12	14	10	10	12		17	1	
Di-n-octyl phthalate	2	3	1		2	2		2	2	2	2	2		37	4	1
Diazinon/Spectracide														4		1
Dibenzo(a,h)anthracene	11	16	7	9	8	17	20	6	16	6	15	25	23	65	70	4
Dibenzofuran	2		4	1	1	1	4				2	3	1	15	3	1
Dichlorobenzene, 1,2-												2		1		
Dichlorobenzene, 1,3-																
Dichlorobenzene, 1,4-	2				1				2		2	2		16		
Dichloroethane, 1,1-																
Dichloroethane, 1,2-																
Dichloromethane														7	10	
Dieldrin	5	3	9	6	4	14	16			4	4	17	23	73	100	24
Diethyl phthalate	2			2		1			2	2		4		2		
Dimethyl phthalate	1			2		3	5			2		8	11	9	51	
Dimethylnapthalene, 2,6-	10	4	9	9	8	15	13	14	12	13	16	22	14	2	29	1
Endosulfan mixed isomers																
Endosulfan, alpha-	1							2							2	
Endosulfan, beta-														32	1	
Endrin				1		2	3						2	21	16	
Ethion/Bladen																
Ethylbenzene														3	1	
Fluoranthene	20	16	10	13	17	21	28	20	30	14	18	28	25	118	114	9
Fluorene	5	12	7	6	5	15	22		2	3	10	18	25	41	88	1
Heptachlor			1	4		3	9			1	1	3	9	3	19	
Heptachlor epoxide		1	2			3	1				1	6	9	26	36	4
Hexachlorobenzene			1	6	1	5	11					10	16	18	89	
Hexachlorobutadiene																
Hexachloroethane																
Indeno(1,2,3-cd)pyrene	13	16	8	12	17	20	27	14	28	13	19	28	25	90	97	6
Isophorone																
Lead	17	65	6	13	23	20	31	36	55	40	26	32	26	155	136	45
Malathion																
Mercury	20	33	8	13	22	20	32	23	49	20	28	34	26	152	137	31
Methoxychlor			1											3	5	
Methyl ethyl ketone														13	2	
Methylnaphthalene, 1-	3		4	6	3	13	17			3	10	18	25	19	81	1
Methylnaphthalene, 2-	4		7	7	3	14	21			3	10	17	25	32	85	1
Methylphenanthrene, 1-	8	4	4	7	8	16	12	6	12	8	13	21	20	13	48	3
Mirex/Dechlorane	1				1	2	4					3	11	28	24	
Naphthalene	10	2	6	9	8	17	18	4	8	6	11	20	25	32	90	

Table C-5. (Continued)

Chemical	Lower Connecticut (01080205)	Charles (01090001)	Narragansett (01090004)	Quinnipiac (01100004)	Housatonic (01100005)	Saugatuck (01100006)	Long Island Sound (01100007)	Hudson-Hoosic (02020003)	Mohawk (02020004)	Middle Hudson (02020006)	Hudson-Wappinger (02020008)	Lower Hudson (02030101)	Bronx (02030102)	Hackensack-Passaic (02030103)	Sandy Hook-Staten Island (02030104)	Raritan (02030105)
Nickel	18	62	8	12	21	19	33	36	56	41	28	34	26	125	137	42
Perylene	4	12	7	8	3	14	26			4	9	18	25	20	93	1
Phenanthrene	18	16	10	13	17	20	29	18	30	14	18	29	25	103	107	9
Polychlorinated biphenyls	6	16	24	9	7	17	29	158	26	58	43	65	26	148	138	45
Pyrene	20	16	10	13	15	21	29	20	32	14	18	28	25	118	115	9
SEM est	3		2	7	3	12	12			2	4	1	12	14	11	
Silver	13		7	11	11	18	30	14	22	19	27	33	25	80	121	5
TEF Dioxins, Furans, and Dioxin-like PCBs	4	12	6	6	4	15	22	127	1	45	30	43	25	126	153	1
TEF PAHs	20	16	11	13	20	21	33	22	32	15	22	32	26	120	119	9
Tetrachloroethene																
Toluene														14	2	
Toxaphene			2											1		
Trichlorobenzene, 1,2,4-					1									1		
Trichloroethane, 1,1,1-																
Trichloroethene																
Trichlorofluoromethane																
Trichloromethane/Chloroform																
Xylene, *o*-																
Xylenes (Total)														7	1	
Zinc	20	63	8	12	24	20	33	36	56	41	29	34	26	160	138	61

Table C-5. (Continued)

Chemical	Northern Long Island (02030201)	Southern Long Island (02030202)	Lower Delaware (02040202)	Brandywine-Christina (02040205)	Gunpowder-Patapsco (02060003)	Severn (02060004)	York (02080107)	Cooper (03050201)	South Carolina Coastal (03050202)	Lower Savannah (03060109)	Cumberland-St_ Simons (03070203)	Tampa Bay (03100206)	Middle Chattahoochee-Lake Harding (03130002)	Pensacola Bay (03140105)	Mobile Bay (03160205)	Menominee (04030108)
Acenaphthene	56	17	4	10	16	56	6	31	25	32	10	7		10		5
Acenaphthylene	52	20	2	4	11	53	6	38	29	38	17	5		11		2
Acetone				6				7								
Aldrin	6	6	4	4	3	15		8	7	3	2	19		7		
Anthracene	64	29	6	15	22	65	17	54	31	46	17	14	2	17	1	9
Antimony	62	47	4	16	14	60	5	12	17	10	2	4	12	13	8	5
Arsenic	61	55	29	106	23	68	40	47	38	65	28	59	51	53	31	20
Benzene																
Benzo(a)anthracene	68	38	7	15	24	66	39	57	35	47	22	22	5	29	7	1
Benzo(a)anthracene/Chrysene																
Benzo(a)pyrene	60	36	4	14	20	58	35	55	35	44	20	25		24	7	
Benzo(b)fluoranthene	28		2	9	3	54	7	55	38	52	24	40	6	13	7	11
Benzo(g,h,i)perylene	70	34	6	15	20	60	39	48	33	39	17	38	3	29	7	10
Benzo(k)fluoranthene	38	6	5	15	10	56	6	47	35	48	22	1	5	13	7	11
BHC, alpha-				5	2	36	3	3	4		1			1		
BHC, beta-				4	2	9	4	6	8		1			1		
BHC, delta-				4	2	15	3	6	8		1			1		
BHC, gamma- (Lindane)	9	30	2	4	4	11		11	10	21	3	44		8	1	
BHC, technical grade	12	30	1	2				13	19	20	8	44		5	7	
Biphenyl	54	19	2	5	16	63	6	32	22	50	18			9	1	
Bis(2-ethylhexyl)phthalate			1					3				3	11			1
Bromophenyl phenyl ether, 4-																
Butyl benzyl phthalate								1	1			1	3			
Cadmium	78	57	8	106	23	69	23	49	42	65	19	66	18	52	31	14
Chlordane	57	50	26	15	7	4	3	14	22	8	9	54	22	6	7	
Chlordane (*cis*-Nonachlor)								7	12			2	1	1		
Chlordane (*trans*-Nonachlor)	45	43	1		7	36	3	6	15	12	2	49	3	10		
Chlordane, alpha (*cis*)-	37	45		3	11	31	5	13	14	9	4	51		15		
Chlordane, *cis*-	10				1							3	3	7		
Chlordane, gamma (*trans*)-				1		1		6	6					1		
Chlordane, *trans*-	7	3	2	3	5	1						2	3			
Chlorobenzene																
Chlorpyrifos/Dursban														4	2	
Chromium	54	53	30	122	22	65	48	156	106	78	28	73	123	57	31	14
Chrysene	47	32	3	17	16	63	40	60	37	52	24	30	5	29	7	14
Copper	78	63	35	134	25	70	50	137	97	74	27	72	123	56	31	23
DCPA/Dacthal																
DDD, p, p'-	46	45	2	3	14	49	4	15	19	8	6	46	2	19	3	
DDE, p, p'-	45	47	2	5	15	59	10	30	22	7	4	37	4	9	7	2
DDT (Total)	70	53	32	31	23	65	13	35	38	16	10	57	23	28	8	2

Table C-5. (Continued)

Chemical	Northern Long Island (02030201)	Southern Long Island (02030202)	Lower Delaware (02040202)	Brandywine-Christina (02040205)	Gunpowder-Patapsco (02060003)	Severn (02060004)	York (02080107)	Cooper (03050201)	South Carolina Coastal (03050202)	Lower Savannah (03060109)	Cumberland-St_ Simons (03070203)	Tampa Bay (03100206)	Middle Chattahoochee-Lake Harding (03130002)	Pensacola Bay (03140105)	Mobile Bay (03160205)	Menominee (04030108)
DDT, p, p'-	36	28	1	5	12	30	2	15	21	9	3	37	1	17		
Di-n-butyl phthalate								3	1			3	3			2
Di-n-octyl phthalate												1	1			
Diazinon/Spectracide												3				
Dibenzo(a,h)anthracene	59	15	3	7	19	56	10	35	30	18	6		2	20	1	2
Dibenzofuran	8	4	3	4	4	1	1	3						6		
Dichlorobenzene, 1,2-																1
Dichlorobenzene, 1,3-																
Dichlorobenzene, 1,4-																1
Dichloroethane, 1,1-																
Dichloroethane, 1,2-																
Dichloromethane																
Dieldrin	42	37	22	12	11	30		12	9	5	2	2	10	18		
Diethyl phthalate								3				1				1
Dimethyl phthalate	15	32						1								
Dimethylnapthalene, 2,6-	48	3	5	4	16	54	1	42	25	49	18	2	1	11	3	1
Endosulfan mixed isomers																
Endosulfan, alpha-				4								2				
Endosulfan, beta-				4		13		5	12	1	1					
Endrin	1	7		4	2	6	2	5	3		1	30		10		
Ethion/Bladen												3				
Ethylbenzene				2				1								
Fluoranthene	69	47	8	33	24	70	43	67	40	56	27	36	7	32	7	15
Fluorene	64	21	4	14	21	62	6	42	27	50	17	10		17	1	5
Heptachlor	9	4	3	4	4	15	1	4	1	10	3	21	3	6		
Heptachlor epoxide	12	18	8	3	5	9		7	5		1	21	1	7		
Hexachlorobenzene	30	41			8	30	2	11	13	28	10	30	1	6		
Hexachlorobutadiene																
Hexachloroethane																
Indeno(1,2,3-cd)pyrene	64	30	5	15	20	63	34	51	34	28	14	38	6	26	7	12
Isophorone								1								
Lead	73	61	28	144	25	70	51	123	79	72	28	72	124	57	31	22
Malathion									1							
Mercury	77	58	30	85	24	60	32	44	33	63	26	71	16	58	31	20
Methoxychlor			2	4	1			1	1							
Methyl ethyl ketone				11				1								
Methylnaphthalene, 1-	59	12	5	3	17	53	6	48	25	47	21			13	7	
Methylnaphthalene, 2-	62	24	5	5	18	55	6	50	29	46	23			13	7	
Methylphenanthrene, 1-	40	7	1	2	14	56	5	30	25	31	7	1		12	7	1
Mirex/Dechlorane	10	11		1	4	31	1	8	6	6		2		9		

Table C-5. (Continued)

Chemical	Northern Long Island (02030201)	Southern Long Island (02030202)	Lower Delaware (02040202)	Brandywine-Christina (02040205)	Gunpowder-Patapsco (02060003)	Severn (02060004)	York (02080107)	Cooper (03050201)	South Carolina Coastal (03050202)	Lower Savannah (03060109)	Cumberland-St_ Simons (03070203)	Tampa Bay (03100206)	Middle Chattahoochee-Lake Harding (03130002)	Pensacola Bay (03140105)	Mobile Bay (03160205)	Menominee (04030108)
Naphthalene	56	31	2	6	20	60	15	49	31	40	24	5		15	7	1
Nickel	78	61	8	124	24	70	45	117	85	68	25	66	123	56	8	5
Perylene	66	35	5	5	16	54	23	47	36	56	17	35		24	7	13
Phenanthrene	70	42	6	28	24	63	39	55	36	58	27	24	4	27	7	14
Polychlorinated biphenyls	73	54	27	54	29	66	15	45	36	52	25	55	34	17	7	1
Pyrene	70	45	8	32	24	67	43	63	35	55	26	41	7	13	7	14
SEM est	27	3	2	1	4	57	8	32	16	44	18			7		
Silver	70	58	5	18	13	62	15	19	29	34	21	64	14	54	8	4
TEF Dioxins, Furans, and Dioxin-like PCBs	62	53	4	21	15	41	1	9	14	25	10	44		15		
TEF PAHs	72	50	8	38	31	71	44	71	45	58	29	50	7	32	7	15
Tetrachloroethene				2												
Toluene				1												
Toxaphene				4												
Trichlorobenzene, 1,2,4-																
Trichloroethane, 1,1,1-																
Trichloroethene																
Trichlorofluoromethane																
Trichloromethane/Chloroform																
Xylene, *o*-																
Xylenes (Total)				4				1								
Zinc	78	64	37	149	25	70	52	165	103	77	28	70	124	57	31	5

Table C-5. (Continued)

Chemical	Lower Fox (04030204)	Little Calumet-Galien (04040001)	Pike-Root (04040002)	Chautauqua-Conneaut (04120101)	Seneca (04140201)	Upper Scioto (05060001)	Tippecanoe (05120106)	Upper White (05120201)	Lower East Fork White (05120208)	Watts Bar Lake (06010201)	Upper Clinch (06010205)	Middle Tennessee-Chickamauga (06020001)	Rush-Vermillion (07040001)	Copperas-Duck (07080101)	Lower Rock (07090005)	Green (07090007)
Acenaphthene	1	8	1					5	3					50		
Acenaphthylene	1							7	1					7		
Acetone		4						3						6		
Aldrin		5	1					1	3		4				2	
Anthracene	3	18	1	2	10			20	9					47		
Antimony	2	6					7	9	3	1	7	1	5			
Arsenic	21	56	48	6	12	57	26	45	5	3	57	5	5	50	52	33
Benzene		4														
Benzo(a)anthracene	1	21		4	12		2	28	20	1	5	1	4	135		
Benzo(a)anthracene/Chrysene																
Benzo(a)pyrene		20		4	12		2	24	18					165		
Benzo(b)fluoranthene	2	22	1	4	12		2	29	14	1	5	1	7	164		
Benzo(g,h,i)perylene	6	20	1	3	12		2	26	17	1	5	1		142		
Benzo(k)fluoranthene	1	20	1	4	12		2	27	18	1	7	1	5	153		
BHC, alpha-		2					1						4			
BHC, beta-		5						2	2							
BHC, delta-																
BHC, gamma- (Lindane)							1	4	1				4			
BHC, technical grade																
Biphenyl														6		
Bis(2-ethylhexyl)phthalate	4	1	3				1	20	3		1	1	1			
Bromophenyl phenyl ether, 4-																
Butyl benzyl phthalate	1							8			3		6	3		
Cadmium	6	39	47	4	15	56	11	36	9	2	13	2	28	26	5	
Chlordane		2						38		7	4	4				
Chlordane (*cis*-Nonachlor)		2						4	1				4			
Chlordane (*trans*-Nonachlor)		1						6	2		2		4			
Chlordane, alpha (*cis*)-		5					1	6	2				4			
Chlordane, *cis*-		2	2					5								1
Chlordane, gamma (*trans*)-													4			
Chlordane, *trans*-		14	4					13	4							2
Chlorobenzene																
Chlorpyrifos/Dursban																
Chromium	22	58	56	6	12	55	24	62	15	22	108	39	28	99	52	33
Chrysene	6	22	1	4	12		2	30	20	1	5		6	120		
Copper	18	57	56	6	29	57	26	62	15	22	112	39	40	101	52	33
DCPA/Dacthal																
DDD, p, p'-	2	30	13				4	1					8		6	
DDE, p, p'-		35	12				3	4	4				4		3	1
DDT (Total)	2	41	15				5	49	5		5	3	8		6	3
DDT, p, p'-	2	16	13					3	4		1	3	3		2	3

Table C-5. (Continued)

Chemical	Lower Fox (04030204)	Little Calumet-Galien (04040001)	Pike-Root (04040002)	Chautauqua-Conneaut (04120101)	Seneca (04140201)	Upper Scioto (05060001)	Tippecanoe (05120106)	Upper White (05120201)	Lower East Fork White (05120208)	Watts Bar Lake (06010201)	Upper Clinch (06010205)	Middle Tennessee-Chickamauga (06020001)	Rush-Vermillion (07040001)	Copperas-Duck (07080101)	Lower Rock (07090005)	Green (07090007)
Di-n-butyl phthalate	1							8	3	1	7	1	7			
Di-n-octyl phthalate								2								
Diazinon/Spectracide								37								
Dibenzo(a,h)anthracene	1	20		2	8		2	17	8		2		2	76		
Dibenzofuran		1														
Dichlorobenzene, 1,2-								1								
Dichlorobenzene, 1,3-																
Dichlorobenzene, 1,4-								3								
Dichloroethane, 1,1-																
Dichloroethane, 1,2-																
Dichloromethane							1									
Dieldrin		14			3		2	51	2		4		4	5	12	21
Diethyl phthalate	1															
Dimethyl phthalate								1								
Dimethylnapthalene, 2,6-	1							7	3		7	1	4			
Endosulfan mixed isomers								3								
Endosulfan, alpha-		1					1		1							
Endosulfan, beta-		1														
Endrin		2						2	1		4		2			
Ethion/Bladen																
Ethylbenzene																
Fluoranthene	6	23	3	4	12		5	38	20	1	7	1	8	167		
Fluorene	3	17	1	2				5	7					36		
Heptachlor		2						1	2		4					1
Heptachlor epoxide		6					1	16			4					5
Hexachlorobenzene		3	2					1					4		1	
Hexachlorobutadiene																
Hexachloroethane																
Indeno(1,2,3-cd)pyrene	4	20	1	3	12		2	25	18	1	5	1	4	126		
Isophorone																
Lead	22	56	56	6	29	43	23	60	15	22	111	39	43	90	48	8
Malathion								9								
Mercury	22	38	35	2	22	9	26	55	13	21	15	30	44	5	6	
Methoxychlor		2													2	
Methyl ethyl ketone																
Methylnaphthalene, 1-		1							1							
Methylnaphthalene, 2-		9					1		1							
Methylphenanthrene, 1-								6	1		5					
Mirex/Dechlorane																
Naphthalene	1	2						6	1		5			61		
Nickel	6	56	54	6	29	44	26	49	13	20	111	39	5	51	52	33

Table C-5. (Continued)

Chemical	Lower Fox (04030204)	Little Calumet-Galien (04040001)	Pike-Root (04040002)	Chautauqua-Conneaut (04120101)	Seneca (04140201)	Upper Scioto (05060001)	Tippecanoe (05120106)	Upper White (05120201)	Lower East Fork White (05120208)	Watts Bar Lake (06010201)	Upper Clinch (06010205)	Middle Tennessee-Chickamauga (06020001)	Rush-Vermillion (07040001)	Copperas-Duck (07080101)	Lower Rock (07090005)	Green (07090007)
Perylene	4		1										1	16		
Phenanthrene	6	22	1	5	12		2	31	17	1	5	1	4	67		
Polychlorinated biphenyls	10	51	31	1	9			32	7	2	8	1	20	82	2	
Pyrene	6	22	4	3	12		2	41	21	1	7	1	8	153		
SEM est		15					2	10	19							
Silver	2	10	3			3	1	8	3	1	7	1	5	4	1	
TEF Dioxins, Furans, and Dioxin-like PCBs																
TEF PAHs	6	23	4	5	12		5	42	22	1	7	1	8	170		
Tetrachloroethene																
Toluene																
Toxaphene											4					
Trichlorobenzene, 1,2,4-																
Trichloroethane, 1,1,1-																
Trichloroethene																
Trichlorofluoromethane																
Trichloromethane/Chloroform																
Xylene, *o*-																
Xylenes (Total)																
Zinc	2	57	47	6	29	56	26	50	15	22	110	39	22	98	52	33

Table C-5. (Continued)

Chemical	Kankakee (07120001)	Iroquois (07120002)	Chicago (07120003)	Des Plaines (07120004)	Upper Illinois (07120005)	Upper Fox (07120006)	Lower Fox (07120007)	Lower Illinois-Senachwine Lake (07130001)	Lower Illinois-Lake Chautauqua (07130003)	South Fork Sangamon (07130007)	Lower Illinois (07130011)	Macoupin (07130012)	Big Sunflower (08030207)	Deer-Steele (08030209)	Lower Mississippi-New Orleans (08090100)	Lower Neosho (11070209)
Acenaphthene	1			2											13	
Acenaphthylene				1	2			1							9	
Acetone	1		2													
Aldrin	5		3	3	2	3	2		2	3	4	3	3	1		
Anthracene	3		3	2	2			1							26	
Antimony	4	1	3		1	2		1	2	1	2		3	5	33	
Arsenic	28	27	27	70	21	67	28	8	31	20	44	27	28	12	37	3
Benzene																
Benzo(a)anthracene	5		4	2	2	1		1	1						29	
Benzo(a)anthracene/Chrysene																
Benzo(a)pyrene	4		4												29	
Benzo(b)fluoranthene	5		4	2	2	7			1		1				29	
Benzo(g,h,i)perylene	4		4	2	2	3		1	1						30	
Benzo(k)fluoranthene	5		4	2	2	5		1	1						29	
BHC, alpha-			9	6	2	9								1	12	
BHC, beta-			1										6		1	
BHC, delta-													6	1		
BHC, gamma- (Lindane)				1		5							7	2	8	
BHC, technical grade															23	
Biphenyl															26	
Bis(2-ethylhexyl)phthalate	1	1		2	2	4			2		2					
Bromophenyl phenyl ether, 4-																
Butyl benzyl phthalate				1					1		1					
Cadmium	13	7	14	22	10	27	7	8	17	3	11	4	27	4	32	4
Chlordane	1		7	8	1	1			1	5			1		28	
Chlordane (*cis*-Nonachlor)			2	1											7	
Chlordane (*trans*-Nonachlor)	3	1	1	1						1					24	
Chlordane, alpha (*cis*)-	3		1												12	
Chlordane, *cis*-	2		5	6	2	6	2		1	8	1	1				
Chlordane, gamma (*trans*)-															20	
Chlordane, *trans*-	4	2	11	12	2	1	1		3	8	2	3				
Chlorobenzene																
Chlorpyrifos/Dursban															2	
Chromium	32	27	27	70	23	79	28	8	32	20	44	27	28	12	38	8
Chrysene	5		4	2	2	6		1	1				1		31	
Copper	32	27	27	70	23	68	28	8	32	20	44	27	28	12	38	8
DCPA/Dacthal																
DDD, p, p'-	8	9	27	48	6	33	9	1	3	2	4	2	33	18	22	
DDE, p, p'-	18	7	30	49	9	34	13	1	4	1	8	1	34	18	13	
DDT (Total)	23	10	32	53	10	41	16	1	4	2	8	3	35	26	35	
DDT, p, p'-	20	8	14	31	1	4	6			2	2	1	35	13	16	

Table C-5. (Continued)

Chemical	Kankakee (07120001)	Iroquois (07120002)	Chicago (07120003)	Des Plaines (07120004)	Upper Illinois (07120005)	Upper Fox (07120006)	Lower Fox (07120007)	Lower Illinois-Senachwine Lake (07130001)	Lower Illinois-Lake Chautauqua (07130003)	South Fork Sangamon (07130007)	Lower Illinois (07130011)	Macoupin (07130012)	Big Sunflower (08030207)	Deer-Steele (08030209)	Lower Mississippi-New Orleans (08090100)	Lower Neosho (11070209)
Di-n-butyl phthalate	1				1	2							1			
Di-n-octyl phthalate						1										
Diazinon/Spectracide																
Dibenzo(a,h)anthracene	2		4	2	2			1							25	
Dibenzofuran																
Dichlorobenzene, 1,2-																
Dichlorobenzene, 1,3-																
Dichlorobenzene, 1,4-																
Dichloroethane, 1,1-																
Dichloroethane, 1,2-																
Dichloromethane																
Dieldrin	27	24	17	33	11	16	21	1	9	23	20	19	22	1	1	
Diethyl phthalate	1															
Dimethyl phthalate																
Dimethylnapthalene, 2,6-				1		2		1							29	
Endosulfan mixed isomers														2		
Endosulfan, alpha-													6	5		
Endosulfan, beta-													4	2		
Endrin	3		3	5		4				1	6	3	19	4	4	
Ethion/Bladen																
Ethylbenzene																
Fluoranthene	5	1	4	2	2	17		1	2		1		1		32	
Fluorene	1		2												27	
Heptachlor	1		1	3	1	9	1						27	8		1
Heptachlor epoxide	2		3		2	3	1			8	1	6	5	1	3	
Hexachlorobenzene			5	12		8				1					12	
Hexachlorobutadiene																
Hexachloroethane																
Indeno(1,2,3-cd)pyrene	5		4	2	2	3			1						29	
Isophorone																
Lead	29	27	27	70	19	80	21	8	22	20	43	27	26	11	33	8
Malathion																
Mercury	10	27	17	30	4	45	8	7	14	5	12	5	3	7	30	3
Methoxychlor			5	12		6	3		3	2	3		1			
Methyl ethyl ketone			1													
Methylnaphthalene, 1-	1														32	
Methylnaphthalene, 2-	1														32	
Methylphenanthrene, 1-				2	2			1							29	
Mirex/Dechlorane																
Naphthalene				1	2			1							32	
Nickel	29	27	27	70	23	66	28	8	32	20	44	27	28	12	33	3

Table C-5. (Continued)

Chemical	Kankakee (07120001)	Iroquois (07120002)	Chicago (07120003)	Des Plaines (07120004)	Upper Illinois (07120005)	Upper Fox (07120006)	Lower Fox (07120007)	Lower Illinois-Senachwine Lake (07130001)	Lower Illinois-Lake Chautauqua (07130003)	South Fork Sangamon (07130007)	Lower Illinois (07130011)	Macoupin (07130012)	Big Sunflower (08030207)	Deer-Steele (08030209)	Lower Mississippi-New Orleans (08090100)	Lower Neosho (11070209)
Perylene						1									32	
Phenanthrene	5		4	2	2	6		1	1						32	
Polychlorinated biphenyls	5		11	19	2	18		1			3				34	1
Pyrene	5	1	4	2	2	15		1	2		2		1		29	
SEM est	4		3													
Silver			3	17	1	19	2	5	4	1	3		2	1	32	
TEF Dioxins, Furans, and Dioxin-like PCBs															20	
TEF PAHs	5	1	4	2	2	17		1	2		2		1		32	
Tetrachloroethene																
Toluene			2													
Toxaphene																
Trichlorobenzene, 1,2,4-																
Trichloroethane, 1,1,1-																
Trichloroethene																
Trichlorofluoromethane																
Trichloromethane/Chloroform																
Xylene, *o*-																
Xylenes (Total)																
Zinc	30	27	27	70	23	57	28	8	32	20	44	27	28	12	38	3

Table C-5. (Continued)

Chemical	Lower West Fork Trinity (12030102)	Austin-Travis Lakes (12090205)	Blue (14010002)	Lower Salt (15060106)	Carson Desert (16050203)	Franklin D_ Roosevelt Lake (17020001)	Lower Columbia-Sandy (17080001)	Lower Willamette (17090012)	Queets-Quinault (17100102)	Grays Harbor (17100105)	Strait Of Georgia (17110002)	Lake Washington (17110012)	Duwamish (17110013)	Puget Sound (17110019)	Mad-Redwood (18010102)	Sacramento-Upper Clear (18020112)
Acenaphthene	14						7	194	30	37	132	120	251	729	17	
Acenaphthylene	14			1			5	114	27	69	103	90	75	438	9	
Acetone							13	5				8	5	31		
Aldrin		1		16						14	31	12	22	96		
Anthracene	26	1	1	1			8	214	44	106	187	116	325	1,110	19	
Antimony	15	4	18	2	19	46	4	28	16	66	93	38	87	389	20	
Arsenic	94	76	18	58	18	46	67	213	57	144	330	213	589	1,529	10	
Benzene											1	6	2	1		
Benzo(a)anthracene	36	2	1	1			15	271	48	112	225	151	396	1,139	20	
Benzo(a)anthracene/Chrysene											3	1	33	209		
Benzo(a)pyrene		2					12	270	47	108	215	149	382	1,327	20	
Benzo(b)fluoranthene	35	1	2	1			1	137	11	104	141	128	450	706	10	
Benzo(g,h,i)perylene	32	1	1	1			10	252	44	108	148	136	346	1,052	8	
Benzo(k)fluoranthene	33	1	1	2			3	194	11	110	141	92	366	651	8	
BHC, alpha-								1								
BHC, beta-		1						2					3			
BHC, delta-		1					1						3			
BHC, gamma- (Lindane)		3		9						7		7	6	132	7	
BHC, technical grade											2			7		
Biphenyl											59			24	20	
Bis(2-ethylhexyl)phthalate	30		2	3	1		16	153		93	81	107	396	970		
Bromophenyl phenyl ether, 4-														4		
Butyl benzyl phthalate	26		2	2			1	75		42	23	33	299	379		
Cadmium	49	75	18	26	18	52	58	258	5	142	250	164	549	1,385	20	62
Chlordane	14	43		49							6	15	9	112		
Chlordane (*cis*-Nonachlor)	4			1			2								1	
Chlordane (*trans*-Nonachlor)	7			2			2	2				1				
Chlordane, alpha (*cis*)-										20	6		1	114		
Chlordane, *cis*-	8			2			2	2				1				
Chlordane, gamma (*trans*)-								4		2			22	245		
Chlordane, *trans*-	8			1			2	2				1			1	
Chlorobenzene								1								
Chlorpyrifos/Dursban															2	
Chromium	98	72	18	56	19	46	69	337	10	51	243	166	590	1,570	20	
Chrysene	39	1	1	1			17	288	49	114	248	181	511	1,495	20	
Copper	95	67	18	63	19	58	28	334	81	128	357	251	659	2,066	20	62
DCPA/Dacthal															3	
DDD, p, p'-	6			1			5	48		50	11	35	70	231	4	
DDE, p, p'-	12			2			10	48		8	8	17	19	165		
DDT (Total)	38	47		51			12	77		53	98	37	102	578	4	
DDT, p, p'-	4			1			4	54		4	32	9	10	117		
Di-n-butyl phthalate	30		2	2	1		3	69		8	21	25	108	203		

Table C-5. (Continued)

Chemical	Lower West Fork Trinity (12030102)	Austin-Travis Lakes (12090205)	Blue (14010002)	Lower Salt (15060106)	Carson Desert (16050203)	Franklin D_ Roosevelt Lake (17020001)	Lower Columbia-Sandy (17080001)	Lower Willamette (17090012)	Queets-Quinault (17100102)	Grays Harbor (17100105)	Strait Of Georgia (17110002)	Lake Washington (17110012)	Duwamish (17110013)	Puget Sound (17110019)	Mad-Redwood (18010102)	Sacramento-Upper Clear (18020112)
Di-n-octyl phthalate	5		1		1			54			11	5	33	133		
Diazinon/Spectracide				16												
Dibenzo(a,h)anthracene	21			1			6	137	37	52	83	72	267	641	9	
Dibenzofuran							4	86		21	144	81	182	545		
Dichlorobenzene, 1,2-								1		4	11	4	10	89		
Dichlorobenzene, 1,3-	1			1								4	8	103		
Dichlorobenzene, 1,4-	1			2			1	4		1	11	7	18	125		
Dichloroethane, 1,1-													1			
Dichloroethane, 1,2-												2				
Dichloromethane	1						7	2			5		1	8		
Dieldrin	16	38		45			2	7		3	26	8	15	111	2	
Diethyl phthalate	23			1	1		2	4		3	11	8	6	86		
Dimethyl phthalate	21							17		4	11	28	120	163		
Dimethylnapthalene, 2,6-	32		1	1	1		1	3			64	2	1	38	20	
Endosulfan mixed isomers				1										7		
Endosulfan, alpha-		1														
Endosulfan, beta-								1								
Endrin				1				1						1		
Ethion/Bladen																
Ethylbenzene							1				1		2	25		
Fluoranthene	37	2	2	6			17	300	53	126	267	165	450	1,495	20	
Fluorene							8	197	36	71	172	104	286	795	20	
Heptachlor		5		9						4	11	7	3	97		
Heptachlor epoxide	1	23		27			1						6	7	1	
Hexachlorobenzene							1			9	53	7	4	249	2	
Hexachlorobutadiene								1		2	7	5		136		
Hexachloroethane								1						29		
Indeno(1,2,3-cd)pyrene	30	1	1				9	232	44	107	150	119	402	1,108	6	
Isophorone	2															
Lead	96	79	18	59	19	56	68	272	70	123	332	232	629	1,922	20	
Malathion				4												
Mercury	10	65	18	57	18	44	50	247	139	120	372	184	562	1,473	20	
Methoxychlor				3							2		6		9	
Methyl ethyl ketone							2				2	14	15	15		
Methylnaphthalene, 1-											61	24		30	20	
Methylnaphthalene, 2-							8	99	20	40	152	93	85	490	20	
Methylphenanthrene, 1-	20			2				3			63	2	1	31	16	
Mirex/Dechlorane																
Naphthalene	4						8	201	30	79	168	110	95	706	10	
Nickel	98	20	18	7	19		28	251		100	230	225	637	1,944	10	
Perylene								2			49			47	19	
Phenanthrene	25	1	1	1			12	287	52	119	265	154	411	1,405	20	

Table C-5. (Continued)

Chemical	Lower West Fork Trinity (12030102)	Austin-Travis Lakes (12090205)	Blue (14010002)	Lower Salt (15060106)	Carson Desert (16050203)	Franklin D_ Roosevelt Lake (17020001)	Lower Columbia-Sandy (17080001)	Lower Willamette (17090012)	Queets-Quinault (17100102)	Grays Harbor (17100105)	Strait Of Georgia (17110002)	Lake Washington (17110012)	Duwamish (17110013)	Puget Sound (17110019)	Mad-Redwood (18010102)	Sacramento-Upper Clear (18020112)
Polychlorinated biphenyls	38	39		40			8	62		80	42	61	901	979	8	
Pyrene	36	2	2	6			18	299	53	120	253	166	422	1,471	20	
SEM est							2	54								
Silver	43	5	18	2	16		11	235	2	102	170	69	472	1,092	20	
TEF Dioxins, Furans, and Dioxin-like PCBs							2	22				4	536	127	5	
TEF PAHs	42	4	2	7			18	337	55	126	364	203	566	1,836	20	
Tetrachloroethene													4	23		
Toluene							6	3				3	7	8		
Toxaphene	1			38				1								
Trichlorobenzene, 1,2,4-											8	4	3	66		
Trichloroethane, 1,1,1-													1			
Trichloroethene													2	38		
Trichlorofluoromethane													1			
Trichloromethane/Chloroform							1						1	1		
Xylene, *o*-							1					6	2			
Xylenes (Total)							1	2			5	4	5	45		
Zinc	97	83	18	64	19	58	28	284	79	135	379	251	642	1,738	20	62

Table C-5. (Continued)

Chemical	Lower Cosumnes-Lower Mokelumne (18040005)	Suisun Bay (18050001)	San Pablo Bay (18050002)	Coyote (18050003)	San Francisco Bay (18050004)	Central Coastal (18060006)	Alisal-Elkhorn Sloughs (18060011)	Calleguas (18070103)	Santa Monica Bay (18070104)	San Gabriel (18070106)	Seal Beach (18070201)	Santa Ana (18070203)	Newport Bay (18070204)	Aliso-San Onofre (18070301)	San Diego (18070304)	Eastern Prince William Sound (19020201)
Acenaphthene		19	73	11	70	1	9	4	79	4	8		3	1	110	8
Acenaphthylene		19	81	11	73		5	4	64	3	1		4	1	133	
Acetone																
Aldrin		1	6	1	5		7	1	5	1	6	11	2		1	
Anthracene	1	25	102	13	76	1	11	7	115	18	23	2	7	1	176	16
Antimony	1	5	29	3	42	24	10	14	127	23	37		20	4	217	
Arsenic	1	25	108	32	143	52	10	9	109	24	56	180	55	4	209	
Benzene																
Benzo(a)anthracene	1	26	106	13	76	3	18	11	126	23	31	4	20	5	219	14
Benzo(a)anthracene/Chrysene																
Benzo(a)pyrene		25	105	13	76	3	17	12	130	23	34	3	20	5	225	14
Benzo(b)fluoranthene	1	25	106	13	76		8	11	76	12	24	3	21	7	194	
Benzo(g,h,i)perylene		27	104	13	76		8	10	80	12	18	2	20	5	192	
Benzo(k)fluoranthene	1	25	104	13	76		8	10	76	12	18	4	19	4	191	
BHC, alpha-		4	18	2	7			2	12	1	4	32	2		2	
BHC, beta-		1	10	2	9		1	1	4		3	36	6	1	1	
BHC, delta-			2		2			1	7			15	5		3	
BHC, gamma- (Lindane)		5	18	3	8	1	4	3	9	2		1	2	1	17	
BHC, technical grade																
Biphenyl		22	88	11	70		9	4	61	7	5		2		83	1
Bis(2-ethylhexyl)phthalate	1					5					2	38	1		1	
Bromophenyl phenyl ether, 4-																
Butyl benzyl phthalate	1										1	17	4			
Cadmium	59	25	103	25	78	10	10	14	127	24	74	206	133	60	217	
Chlordane											1	35	6			
Chlordane (*cis*-Nonachlor)	1	7	21	9	36		1	9	49	12	12	1	15	2	117	
Chlordane (*trans*-Nonachlor)	1	8	17	8	29	1	10	11	76	23	26	3	19	4	136	
Chlordane, alpha (*cis*)-		4	10	7	4											
Chlordane, *cis*-	1	3	9	1	26		10	11	80	23	25	1	19	4	142	
Chlordane, gamma (*trans*)-		3	13	3	5											
Chlordane, *trans*-	1	2	9	1	23		8	11	59	12	15	2	20	4	140	
Chlorobenzene																
Chlorpyrifos/Dursban		4	14	2	27		8	9	38	6	10		3		22	
Chromium	1	25	109	41	216	52	10	14	127	24	107	212	253	117	218	
Chrysene	1	26	106	13	76	3	18	13	125	23	37	5	21	6	224	34
Copper	60	25	109	41	216	52	10	14	127	24	107	212	235	107	222	
DCPA/Dacthal			2		2		8	9	13		11	1	2	1	7	
DDD, p, p'-		26	100	13	75	5	18	14	127	23	54	4	75	7	182	
DDE, p, p'-	1	25	102	13	72	6	18	14	130	23	69	7	148	26	216	
DDT (Total)	1	26	102	13	75	6	202	14	130	23	86	139	192	26	218	

Table C-5. (Continued)

Chemical	Lower Cosumnes-Lower Mokelumne (18040005)	Suisun Bay (18050001)	San Pablo Bay (18050002)	Coyote (18050003)	San Francisco Bay (18050004)	Central Coastal (18060006)	Alisal-Elkhorn Sloughs (18060011)	Calleguas (18070103)	Santa Monica Bay (18070104)	San Gabriel (18070106)	Seal Beach (18070201)	Santa Ana (18070203)	Newport Bay (18070204)	Aliso-San Onofre (18070301)	San Diego (18070304)	Eastern Prince William Sound (19020201)
DDT, p, p'-		13	42	6	33	4	15	13	89	17	34	5	71	2	87	
Di-n-butyl phthalate	1					2					1	14	3		1	
Di-n-octyl phthalate												19			1	
Diazinon/Spectracide														1		
Dibenzo(a,h)anthracene		23	87	12	67	2	12	9	123	22	23		14	3	185	10
Dibenzofuran			5		6											
Dichlorobenzene, 1,2-																
Dichlorobenzene, 1,3-																
Dichlorobenzene, 1,4-																
Dichloroethane, 1,1-																
Dichloroethane, 1,2-																
Dichloromethane												6				
Dieldrin		12	40	10	48	1	14	12	50	9	15	24	12		60	
Diethyl phthalate																
Dimethyl phthalate			1		5							4				
Dimethylnapthalene, 2,6-	1	22	68	11	58		9	4	82	11	7	4	3		76	
Endosulfan mixed isomers																
Endosulfan, alpha-			1				31	1	6	1		4		2		
Endosulfan, beta-		2	4		13	1	41	9	19	4	1	14	4		12	
Endrin		4	7	1	5	1	8	2	6	1	1	4	2			
Ethion/Bladen					1		2		1							
Ethylbenzene																
Fluoranthene	1	27	107	13	76	3	18	13	126	23	37	14	20	6	226	45
Fluorene		23	87	11	71	1	10	6	96	9	14		4	1	126	19
Heptachlor		1	2		14		2	2	32	5			2		10	
Heptachlor epoxide			4	1	6		2	2	18	4			1		7	
Hexachlorobenzene		15	34	2	30	1	10	9	62	7	11		3	2	35	
Hexachlorobutadiene																
Hexachloroethane																
Indeno(1,2,3-cd)pyrene		27	106	13	76		8	11	80	12	14	1	19	4	191	
Isophorone																
Lead	9	25	109	41	216	48	10	14	127	24	107	208	167	74	222	
Malathion																
Mercury	6	34	141	49	241	3	10	14	127	23	48	196	60	4	217	
Methoxychlor			4		4	1	1	6	16	1				1	22	
Methyl ethyl ketone																
Methylnaphthalene, 1-		17	76	11	68		13	5	98	12	6		3	1	92	3
Methylnaphthalene, 2-		21	81	11	70	1	16	7	117	22	20		6	1	131	15
Methylphenanthrene, 1-		23	94	12	74	1	11	9	111	20	18		7	2	154	76
Mirex/Dechlorane		1	1		18		2		14	1					4	

Table C-5. (Continued)

Chemical	Lower Cosumnes-Lower Mokelumne (18040005)	Suisun Bay (18050001)	San Pablo Bay (18050002)	Coyote (18050003)	San Francisco Bay (18050004)	Central Coastal (18060006)	Alisal-Elkhorn Sloughs (18060011)	Calleguas (18070103)	Santa Monica Bay (18070104)	San Gabriel (18070106)	Seal Beach (18070201)	Santa Ana (18070203)	Newport Bay (18070204)	Aliso-San Onofre (18070301)	San Diego (18070304)	Eastern Prince William Sound (19020201)
Naphthalene		23	91	11	71		8	11	76	12	16		6	2	162	4
Nickel	1	22	108	41	203	52	10	9	111	24	101	210	208	97	218	
Perylene		22	88	11	70	3	17	13	130	23	28		19	4	211	16
Phenanthrene	1	26	105	13	76	3	17	13	125	23	30	6	20	5	214	64
Polychlorinated biphenyls		34	132	21	100		14	14	133	23	41	108	39	6	221	
Pyrene	1	27	107	13	76	3	18	13	126	23	37	18	23	10	227	65
SEM est		3	1		12		8	12	26	3			1		8	
Silver	1	25	100	25	72	14	10	14	127	22	57	196	48	8	217	
TEF Dioxins, Furans, and Dioxin-like PCBs		12	87	17	91		11	11	132	23	24		17	3	205	
TEF PAHs	1	27	107	13	76	3	18	13	130	23	37	22	25	10	227	76
Tetrachloroethene																
Toluene																
Toxaphene			1			1		2	4							
Trichlorobenzene, 1,2,4-																
Trichloroethane, 1,1,1-																
Trichloroethene																
Trichlorofluoromethane																
Trichloromethane/Chloroform																
Xylene, *o*-																
Xylenes (Total)																
Zinc	60	25	109	41	220	52	10	14	127	24	107	212	264	119	222	

APPENDIX D
SPECIES CHARACTERISTICS RELATED TO NSI BIOACCUMULATION DATA

Table D-1 presents the species for which tissue residue analyses are included in the NSI database. For each species listed, Table D-1 identifies the species as resident or migratory (or either) and demersal or pelagic (or either) and specifies whether the species might be consumed by humans (i.e., recreational or subsistence anglers). A species is considered either resident or migratory if it stays predominately in one location as long as food and habitat are available but is capable of traveling long distances to find food and suitable habitat. A species is considered either demersal or pelagic if it spends much of its time in the water column but is likely to feed off the bottom. If a species is identified as either resident or migratory, it is considered resident for the purpose of this analysis. If a species is identified as either demersal or pelagic, it is considered demersal.

Table D-1. Species Characteristics Related to Tissue Residue Data.

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Acanthomysis macropsis	Mysid shrimp	E	E	N
Acartia spp.	Copepod (unknown species)	M	P	N
Acipenser brevirostrum	Shortnose sturgeon	M	D	Y
Acipenser fulvescens	Lake sturgeon	R	D	Y
Acipenser oxyrhynchus	Atlantic sturgeon	M	D	Y
Acipenser spp.	Sturgeon (unknown species)	M	D	Y
Acipenser transmontanus	White sturgeon	M	D	Y
Acrocheilus alutaceus	Chiselmouth	R	P	N
Agrionidae	Broad-winged damselflies	R	E	N
Acroneuria spp.	Stonefly (unknown species)	R	D	N
Allosmerus elongatus	Whitebait smelt	M	P	Y
Alosa aestivalis	Blueback herring	M	P	Y
Alosa alabamae	Alabama shad	M	P	Y
Alosa chrysochloris	Skipjack herring	M	P	Y
Alosa mediocris	Hickory shad	M	P	Y
Alosa pseudoharengus	Alewife	M	P	Y
Alosa sapidissima	American shad	M	P	Y
Amblema plicata	Three-ridge mussel	R	D	Y
Ambloplites cavifrons	Roanoke bass	R	P	Y
Ambloplites constellatus	Ozark bass	R	P	Y
Ambloplites rupestris	Rock bass	R	P	Y
Amia calva	Bowfin	R	E	Y
Amphipoda	Amphipod (order)	R	E	N
Amphistichus rhodoterus	Redtail surfperch	R	P	Y
Anarhichas denticulatus	Northern wolffish	R	D	Y
Anchoa mitchilli	Bay anchovy	R	P	Y
Anguilla rostrata	American eel	M	P	Y
Anoplopoma fimbria	Sablefish	M	E	Y
Apeltes quadracus	Fourspine stickleback	R	E	N
Aplodinotus grunniens	Freshwater drum	M	E	Y
Archoplites interruptus	Sacramento perch	R	P	Y
Archosargus probatocephalus	Sheepshead	M	P	Y
Arctica islandica	Ocean quahog	R	D	Y
Arctopsyche spp.	Caddisfly (unknown species)	R	D	N
Arius felis	Hardhead catfish	M	D	Y
Artedius notospilotus	Bonehead sculpin	R	D	N
Asellus militaris	Aquatic sow bug	R	D	N
Asellus militaris	Aquatic sow egg	R	D	N
Astacidae	Crayfish (family)	R	D	Y
Astarte spp.	Astarte clam (unknown species)	R	D	N
Astarte undata	Waved astarte	R	D	N
Astronotus ocellatus	Oscar	R	P	Y
Astropecten verrilli	Margined seastar	R	D	N
Atherinidae	Silversides (family)	R	P	N
Bagre marinus	Gafftopsail catfish	M	E	Y
Bairdiella chrysoura	Silver perch	M	P	Y
Belostomatidae	Giant waterbug	R	E	N
Bidessinae	Dytiscid beetle (subfamily)	R	E	N
Bivalvia	Bivalvia (class)	R	D	Y
Brachiodontes recurvus	Hooked mussel	R	D	Y

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Brachycentrus spp.	Four-sided case maker caddisfly (unknown species)	R	D	N
Brevoortia patronus	Gulf menhaden	M	P	Y
Brevoortia spp.	Menhaden (unknown species)	M	P	Y
Brevoortia tyrannus	Atlantic menhaden	M	P	Y
Callinectes sapidus	Blue crab	M	D	Y
Cambarus bartoni	Appalachian brook crayfish	R	D	Y
Cambarus spp.	Crayfish (unknown species)	R	D	Y
Campostoma anomalum	Central stoneroller	R	E	N
Cancer gracilis	Graceful rock crab	R	D	Y
Cancer magister	Dungeness crab	M	D	Y
Cancer productus	Red rock crab	R	D	Y
Caranx hippos	Crevalle jack	M	P	Y
Carassius auratus	Goldfish	R	E	N
Carcharhinus obscurus	Dusky shark	M	E	Y
Carcharhinus plumbeus	Brown shark (sandbar)	M	E	Y
Carpiodes carpio	River carpsucker	R	D	Y
Carpiodes cyprinus	Quillback	R	D	Y
Carpiodes spp.	Carpsucker (unknown species)	R	D	Y
Carpiodes velifer	Highfin carpsucker	R	D	Y
Catostomus ardens	Utah sucker	R	D	Y
Catostomus catostomus	Longnose sucker	R	D	Y
Catostomus columbianus	Bridgelip sucker	R	D	Y
Catostomus commersoni	White sucker	R	D	Y
Catostomus discobolus	Bluehead sucker	R	D	Y
Catostomus latipinnis	Flannelmouth sucker	R	D	Y
Catostomus macrocheilus	Largescale sucker	R	D	Y
Catostomus occidentalis	Sacramento sucker	R	D	Y
Catostomus platyrhynchus	Mountain sucker	R	D	Y
Catostomus snyderi	Klamath largescale sucker	R	D	Y
Catostomus spp.	Sucker (unknown species)	R	D	Y
Catostomus tahoensis	Tahoe sucker	R	D	Y
Centrarchidae	Sunfish (family)	R	P	Y
Centrarchus macropterus	Flier	R	P	Y
Centropomus undecimalis	Common snook	M	P	Y
Centropristis striata	Black sea bass	M	P	Y
Ceratopsyche spp.	Caddisfly (unknown species)	R	D	N
Chaetodipterus spp.	Spade fish	E	E	Y
Chelydra serpentina	Snapping turtle	R	E	Y
Cheumatopsyche spp.	Net-spinning caddisfly (unknown species)	R	D	N
Chironomidae	Midge (family)	R	D	N
Chironomus riparius	Midge	R	D	N
Cichla ocellaris	Peacock cichlid	R	P	Y
Cichlasoma uropthalmus	Mayan cichlid	R	P	Y
Citharichthys sordidus	Pacific sanddab	E	D	N
Citharichthys xanthostigma	Longfin sanddab	E	D	N
Clarius fuscus	Chinese catfish	R	E	Y
Clinocardium nuttalli	Nuttall cockle	R	D	Y
Clinostomus funduloides	Rosyside dace	R	P	N
Clupea harengus harengus	Atlantic herring	M	P	Y
Compsomyax subdiaphana	Milky venus	R	D	Y
Corbicula spp.	Asiatic clam (unknown species)	R	D	Y

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Corbicula manilensis	Asiatic clam	R	D	Y
Coregonus artedii	Cisco (lake herring)	M	P	Y
Coregonus clupeaformis	Lake whitefish	M	P	Y
Coregonus hoyi	Bloater	M	P	Y
Coregonus spp.	Whitefish	M	P	Y
Cottidae	Sculpin (family)	R	D	Y
Cottus aleuticus	Coastrange sculpin	R	D	N
Cottus bairdi	Mottled sculpin	R	D	N
Cottus beldingi	Paiute sculpin	R	D	N
Cottus carolinae	Banded sculpin	R	D	N
Cottus cognatus	Slimy sculpin	R	D	N
Cottus gulosus	Riffle sculpin	R	D	N
Cottus leiopomus	Wood river sculpin	R	D	N
Cottus spp.	Sculpin (unknown species)	R	D	N
Crassostrea gigas	Pacific oyster	R	D	Y
Crassostrea spp.	Oysters (unknown species)	R	D	Y
Crassostrea virginica	Eastern oyster	R	D	Y
Ctenopharyngodon idella	Grass carp	R	E	Y
Cycleptus elongatus	Blue sucker	M	D	Y
Cynoscion arenarius	Sand sea trout	R	P	Y
Cynoscion nebulosus	Spotted sea trout	R	P	Y
Cynoscion nothus	Silver sea trout	M	P	Y
Cynoscion regalis	Weakfish	M	P	Y
Cyprinella lutrensis	Red shiner	R	P	N
Cyprinella spiloptera	Spotfin shiner	R	P	N
Cyprinid spp.	Minnows	R	E	Y
Cyprinidae	Carp/goldfish (hybrid)	R	E	Y
Cyprinidae (Family)	Minnows (family)	R	E	Y
Cyprinus carpio	Common carp	R	D	Y
Dasyatis sabina	Atlantic stingray	M	D	Y
Decapoda	Lobsters (order)	E	D	Y
Dicentrarchus labrax	Bass	M	P	Y
Diptera larva	True fly larva	R	D	N
Dorosoma cepedianum	Gizzard shad	M	P	N
Dorosoma petenense	Threadfin shad	M	P	N
Elliptio complanata	Freshwater clam	R	D	Y
Eopsetta exilis	Slender sole	E	D	Y
Equetus punctatus	Spotted drum	R	D	N
Erimyzon oblongus	Creek chubsucker	R	E	N
Erimyzon spp.	Chubsucker (unknown species)	R	E	N
Erimyzon sucetta	Lake chubsucker	R	E	N
Esocidae	Pike (family)	R	P	Y
Esox americanus americanus	Redfin pickerel	R	P	Y
Esox americanus vermiculatus	Grass pickerel	R	P	Y
Esox lucius	Northern pike	R	P	Y
Esox lucius × *Esox masquinongy*	Tiger muskellunge	R	P	Y
Esox masquinongy	Muskellunge	R	P	Y
Esox niger	Chain pickerel	R	P	Y
Etheostoma olmstedi	Tesselated darter	R	D	N
Etheostoma radiosum	Orangebelly darter	R	D	N
Etheostoma spectabile	Orangethroat darter	R	D	N

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Etheostoma stigmaeum	Speckled darter	R	D	N
Etheostoma whipplei	Redfin darter	R	D	N
Etheostoma zonale	Banded darter	R	D	N
Exoglossum maxillingua	Cutlips minnow	R	P	N
Fundulus diaphanus	Banded killifish	R	P	N
Fundulus heteroclitus	Mummichog/killifish	R	P	N
Fundulus olivaceus	Blackspotted topminnow	R	P	N
Fundulus spp.	Killifish species	R	P	N
Fundulus zebrinus	Plains killifish	R	P	N
Gadus macrocephalus	Pacific cod	M	E	Y
Galeocerdo cuvier	Tiger shark	M	E	Y
Gambusia holbrooki	Eastern mosquito fish	R	P	N
Gambusio affinis	Mosquito fish	R	P	N
Gastropoda	Gastropods (class)	R	D	N
Genyonemus lineatus	White croaker	R	E	Y
Gila robusta	Roundtail chub	R	E	N
Gila spp.	Chub (unknown species)	R	E	N
Girella nigricans	Opaleye	M	P	N
Glupeidae	Herring family	M	P	Y
Glyptocephalus zachi	Rex sole	E	D	N
Gonidea angulata	Freshwater mussel	R	D	Y
Haemulon spp.	Grunt	R	P	Y
Hexagenia limbata	Mayfly	R	D	N
Hexagenia spp.	Burrowing mayfly (unknown species)	R	D	N
Hiodon alosoides	Goldeye	M	P	Y
Hiodon tergisus	Mooneye	M	P	Y
Hippoglossina stomata	Bigmouth sole	M	D	Y
Hippoglossoides elas	Flathead sole	M	D	Y
Hippoglossoides platessoides	American plaice	M	D	Y
Homarus americanus	American lobster	E	D	Y
Hyalella azteca	Freshwater amphipod	R	E	N
Hybognathus placitus	Plains minnow	R	P	N
Hydrolagus colliei	Spotted rat fish	M	D	N
Hydropsyche spp.	Caddisfly (unknown species)	R	D	N
Hydropsychidae	Caddisfly (family)	R	D	N
Hypentelium nigricans	Northern hog sucker	R	D	Y
Hypomesus pretiosus	Surf smelt	M	P	Y
Hypsopsetta guttulata	Diamond turbot	M	D	Y
Ictaluridae	Bullhead catfish (family)	R	D	Y
Ictalurus brunneus	Snail bullhead	R	D	Y
Ictalurus catus	White catfish	R	D	Y
Ictalurus furcatus	Blue catfish	R	D	Y
Ictalurus melas	Black bullhead	R	D	Y
Ictalurus natalis	Yellow bullhead	R	D	Y
Ictalurus nebulosus	Brown bullhead	R	D	Y
Ictalurus platycephalus	Flat bullhead	R	D	Y
Ictalurus punctatus	Channel catfish	R	D	Y
Ictalurus serracanthus	Spotted bullhead	R	D	Y
Ictalurus spp.	Catfish (unknown species)	R	D	Y
Ictiobus bubalus	Smallmouth buffalo	R	E	Y
Ictiobus cyprinellus	Bigmouth buffalo	R	E	Y

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Ictiobus niger	Black buffalo	R	E	Y
Isopoda	Isopod (order)	R	D	N
Labidesthes sicculus	Brook silverside	R	P	N
Lagodon rhomboides	Pinfish	E	P	N
Lamniformes	Mackerel shark (order)	M	P	Y
Lampetra spp.	Lamprey (unknown species)	M	E	N
Lavinia exilicauda	Hitch	R	P	N
Leiostomus xanthurus	Spot	M	P	Y
Lepidogobius lepidus	Bay goby	R	P	N
Lepidopsetta bilineata	Rock sole	E	D	Y
Lepisosteidae	Garfish (family)	E	P	Y
Lepisosteus oculatus	Spotted gar	E	P	Y
Lepisosteus osseus	Longnose gar	E	P	Y
Lepisosteus platostomus	Shortnose gar	E	P	Y
Lepisosteus platyrhincus	Florida gar	E	P	Y
Lepisosteus spatula	Alligator gar	E	P	Y
Lepisosteus spp.	Gar (unknown species)	E	P	Y
Lepomis auritus	Redbreast sunfish	R	P	Y
Lepomis cyanellus	Green sunfish	R	P	Y
Lepomis gibbosus	Pumpkinseed	R	P	Y
Lepomis gulosus	Warmouth	R	P	Y
Lepomis humilis	Orangespotted sunfish	R	P	Y
Lepomis macrochirus	Bluegill	R	P	Y
Lepomis marginatus	Dollar sunfish	R	P	Y
Lepomis megalotis	Longear sunfish	R	P	Y
Lepomis microlophus	Redear sunfish	R	P	Y
Lepomis punctatus	Spotted sunfish	R	P	Y
Lepomis spp.	Common sunfishes	R	P	Y
Loligo opalescens	California market squid	M	P	Y
Loligo pealei	Longfin squid	M	P	Y
Lota lota	Burbot	M	E	Y
Loxorhynchus grandis	Sheep crab	R	D	N
Lumbriculus variegatus	Aqauatic worm	R	D	N
Lumbricus terrestris	Earthworm	R	D	N
Lutjanus campechanus	Red snapper	M	D	Y
Lutjanus griseuses	Gray snapper	M	D	Y
Luxilus chrysocephalus	Striped shiner	R	P	N
Luxilus cornutus	Common shiner	R	P	N
Lytechinus anamesus	Little gray sea urchin	R	D	N
Macoma inquinata	Stained macoma	R	D	Y
Macoma irus	Clam (macoma)	R	D	Y
Macoma nasuta	Bent-nosed macoma	R	D	N
Macrhybopsis gelida	Sturgeon chub	R	E	N
Macromia magnifica	Dragon fly	R	D	N
Megalonaias gigantea	Washboard mussel	R	D	Y
Menidia menidia	Atlantic silverside	R	P	N
Mercenaria mercenaria	Quahog	R	D	Y
Mercenaria spp.	Hard clam (unknown species)	R	D	Y
Merluccius bilinearis	Silver hake	M	E	Y
Merluccius productus	Pacific hake	M	E	Y
Microgadus proximus	Pacific tomcod	M	E	Y

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Microgadus tomcod	Atlantic tomcod	M	E	Y
Micropogonias undulats	Atlantic croaker	M	P	Y
Micropterus coosae	Redeye bass	R	P	Y
Micropterus dolomieu	Smallmouth bass	R	P	Y
Micropterus notius	Swannee bass	R	P	Y
Micropterus punctulatus	Spotted bass	R	P	Y
Micropterus salmoides	Largemouth bass	R	P	Y
Micropterus spp.	Bass (unknown species)	R	P	Y
Minytrema melanops	Spotted sucker	E	D	Y
Modiolus demissus	Ribbed mussel	R	D	Y
Modiolus modiolus	Northern horse mussel	R	D	Y
Molpadia intermedia	Sea cucumber	R	D	Y
Morone americana	White perch	M	P	Y
Morone chrysops	White bass	M	P	Y
Morone chrysops x saxatilis	Hybrid striped bass (white/striped)	E	P	Y
Morone mississippiensis	Yellow bass	M	P	Y
Morone saxatilis	Striped bass	M	P	Y
Morone spp.	Temperate bass (unknown species)	E	P	Y
Moxostoma anisurum	Silver redhorse	R	D	Y
Moxostoma carinatum	River redhorse	R	D	Y
Moxostoma congestum	Gray redhorse	R	D	Y
Moxostoma duquesnei	Black redhorse	R	D	Y
Moxostoma erythrurum	Golden redhorse	R	D	Y
Moxostoma macrolepidotum	Shorthead redhorse	R	D	Y
Moxostoma pappillosum	V-lip redhorse	R	D	Y
Moxostoma poecilurum	Blacktail redhorse	R	D	Y
Moxostoma rupiscartes	Striped jumprock	R	D	Y
Moxostoma spp.	Redhorse (unknown species)	R	D	Y
Mugil cephalus	Striped mullet	M	E	Y
Mugil curema	White mullet	M	E	Y
Mugilidae	Mullet (family)	M	E	Y
Mustelus canis	Smooth dogfish	M	E	Y
Mya arenaria	Soft shell clam	R	D	Y
Mylocheilus caurinus	Peamouth	R	E	N
Mylopharodon conocephalus	Hardhead	R	E	N
Mytilus californianus	California mussel	R	D	Y
Mytilus edulis	Blue mussel	R	D	Y
Mytilus spp.	Mussel (unknown species)	R	D	Y
Neanthes arenaceodentata	Sand worm	R	D	N
Neoamphitrite robusta	Terrebellid worm	R	D	N
Nephtys caecoides	Sand worm	R	D	N
Nephtys incisa	Red-lined worm	R	D	N
Nigronia serricornis	Hellgrammite	R	D	N
Nocomis asper	Redspot chub	R	E	N
Nocomis biguttatus	Hornyhead chub	R	E	N
Nocomis leptocephalus	Bluehead chub	R	E	N
Nocomis micropogon	River chub	R	E	N
Notemigonus crysoleucas	Golden shiner	M	P	N
Notonectidae	Backswimmer (family)	R	P	N
Notropis amblops	Bigeye chub	R	E	N
Notropis boops	Bigeye shiner	R	P	N

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Notropis buchanani	Ghost shiner	R	P	N
Notropis chrysocephalus	Striped shiner	R	P	N
Notropis cornutus	Common shiner	R	P	N
Notropis emiliae	Pugnose minnow	R	P	N
Notropis hudsonius	Spottail shiner	R	P	N
Notropis nubilus	Ozark minnow	R	E	N
Notropis spp.	Shiner (composite)	R	E	N
Notropis stramineus	Sand shiner	R	P	N
Noturus flavus	Stone cat	R	D	N
Noturus insignis	Margined madtrom	R	D	N
Noturus miurus	Brindled madtom	R	D	N
Noturus phaeus	Brown madtom	R	D	N
Odonata	Dragonfly (order)	R	E	N
Odontaspis taurus	Sand tiger	M	E	Y
Oligochaetes	Aquatic worms	R	D	N
Oncorhynchus clarkii	Cutthroat trout	E	P	Y
Oncorhynchus gorbuscha	Pink salmon	M	P	Y
Oncorhynchus kisutch	Coho salmon	M	P	Y
Oncorhynchus mykiss	Rainbow trout	E	P	Y
Oncorhynchus nerka	Sockeye salmon	M	E	Y
Oncorhynchus tshawytscha	Chinook salmon	M	E	Y
Ondatra zibethicus	Muskrat	R	E	Y
Opsanus spp.	Toadfish	R	D	N
Opsanus spp.	Toadfish (unknown species)	R	D	N
Orthodon microlepidotus	Sacramento blackfish	R	P	N
Orthopristis chrysoptera	Pigfish	R	P	Y
Osmeridae	Smelt (family)	M	P	Y
Osmerus mordax	Rainbow smelt	M	P	Y
Palaemontes pugio	Grass shrimp	R	E	N
Pandalus borealis	Northern longbeak	R	D	N
Paralabrax nebulifer	Barred sand bass	E	D	Y
Paralichthys spp.	Flounder (unknown species)	M	D	Y
Paralichthys californicus	California halibut	M	D	Y
Paralichthys dentatus	Summer flounder (fluke)	M	D	Y
Paralichthys lethostigma	Southern flounder	M	D	Y
Parastichopus californicus	California sea cucumber	R	D	N
Pectinaria californiensis	Sandworm	R	D	N
Penaeus aztecus	Brown shrimp	R	E	Y
Penaeus setiferus	White shrimp	R	E	Y
Penaeus spp.	Shrimp (unknown species)	R	D	Y
Peprilus triacanthus	Butterfish	M	P	Y
Perca flavescens	Yellow perch	R	P	Y
Percina copelandi	Channel darter	R	D	N
Perlidae	Common stonefly (family)	R	D	N
Phanerodon furcatus	White seaperch	R	P	Y
Phoca vitulinae	Harbor seal	R	P	Y
Phoxinus erythrogaster	Southern redbelly dace	R	P	N
Pimephales notatus	Bluntnose minnow	R	P	N
Pimephales promelas	Fathead minnow	R	P	N
Pisaster brevispinus	Starfish	R	D	N
Placopecten magellanicus	Sea scallop	R	D	N

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Platichthys stellatus	Starry flounder	M	D	Y
Platygobio gracilis	Flathead chub	R	E	N
Plecoptera	Stonefly (order)	R	D	N
Pleuronectes americanus	Winter flounder	M	D	Y
Pleuronectes bilineatus	Rock sole	E	D	Y
Pleuronectes vetulus	English sole	M	D	Y
Pleuronectidae	Righteye flounder (family)	M	D	Y
Pleuronichthys coenosus	C-O sole	M	D	Y
Pleuronichthys decurrens	Curlfin sole	M	D	Y
Pleuronichthys verticalis	Hornyhead turbot	M	D	Y
Poecilia vittata	Cuban limia	E	P	N
Pogonias cromis	Black drum	M	P	Y
Polyodon spathula	Paddlefish	M	P	Y
Pomatomus saltatrix	Bluefish	M	P	Y
Pomoxis annularis	White crappie	R	P	Y
Pomoxis nigromaculatus	Black crappie	R	P	Y
Pomoxis spp.	Crappie (unknown species)	R	P	Y
Potamogeton pectinatus	Sago pondweed	R	D	N
Prionotus carolinus	Northern searobin	R	D	Y
Prionotus evolans	Stripped searobin	R	D	Y
Decapoda	Crayfish (order)	R	D	Y
Procambarus clarkii	Red crayfish	R	D	Y
Prosopium cylindraceum	Round whitefish	M	P	Y
Prosopium williamsoni	Mountain whitefish	M	P	Y
Protothaca staminea	Clam (Pacific littleneck)	R	D	Y
Psettichthys melanostictus	Sand sole	M	D	Y
Psilotreta/Cheumatopsyche	Caddisfly (unknown species)	R	D	N
Ptychocheilus oregonensis	Northern squawfish	R	E	Y
Ptychocheilus spp.	Squawfish	R	E	Y
Pylodictis olivaris	Flathead catfish	R	E	Y
Raja binoculata	Winter skate	M	D	Y
Rana spp.	Common frog (unknown species)	R	P	Y
Rana catesbeiana	Bullfrog	R	P	Y
Rana clamitans	Green frog	R	P	Y
Rangia cuneata	Brackish water clam	R	D	Y
Remora spp.	Sucker (unknown species)	E	P	N
Rhinichthys atratulus	Blacknose dace	R	D	N
Rhinichthys cataractae	Longnose dace	R	D	N
Rhinichthys spp.	Dace (unknown species)	R	D	N
Rhithropanopeus harrisii	Mud crab	R	D	N
Richardsonius balteatus	Redside shiner	R	P	N
Salmo gairdneri	Rainbow trout	E	P	Y
Salmo salar	Atlantic salmon	M	P	Y
Salmo spp.	Trout (unknown species)	E	P	Y
Salmo trutta	Brown trout	E	P	Y
Salmonidae	Trout (family)	E	P	Y
Salvelinus fontinalis	Brook trout	E	P	Y
Salvelinus hybrid	Splake (hybrid)	E	P	Y
Salvelinus malma	Dolly varden	E	P	Y
Salvelinus namaycush	Lake trout	E	P	Y
Saxidomus giganteus	Clam (smooth Washington)	R	D	Y

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Scaphirhynchus platorynchus	Shovelnose sturgeon	M	D	Y
Sciaenidae	Drum (family)	M	E	Y
Sciaenops ocellatus	Red drum	M	E	Y
Scomber japonicus	Chub mackerel	M	P	Y
Scomberomorus cavalla	King mackerel	M	P	Y
Scomberomorus maculatus	Spanish mackerel	M	P	Y
Scophthalmus aquosus	Windowpane	M	D	Y
Scorpaena guttata	California scorpionfish	R	D	Y
Scorpaenichthys marmoratus	Cabezon	R	D	N
Sebastes auriculatus	Brown rockfish	M	P	Y
Sebastes caurinus	Copper rockfish	M	P	Y
Sebastes maliger	Quillback rockfish	M	P	Y
Sebastes marinus	Ocean perch	M	P	Y
Sebastes melanops	Black rockfish	M	P	Y
Sebastes norvegicus	Golden redfish	M	P	Y
Sebastes paucispinis	Bocaccio	M	P	Y
Sebastes proriger	Redstripe rockfish	M	P	Y
Sebastes sp.	Rockfish (unknown species)	M	P	Y
Semotilus atromaculatus	Creek chub	R	E	N
Semotilus corporalis	Fallfish	R	E	N
Semotilus lumbee	Sandhills crab	R	E	N
Serranidae	Sea bass (family)	E	E	Y
Sicyonia ingentis	Pacific rock shrimp	R	D	N
Solen sicarius	Razor clam	R	D	N
Spisula spp.	Surf clam	R	D	Y
Squalus acanthias	Spiny dogfish	M	E	Y
Stizostedion canadense	Sauger	R	P	Y
Stizostedion vitreum	Walleye	R	P	Y
Strongylura marina	Atlantic needlefish	M	P	N
Syacium papillosum	Dusky flounder	M	D	Y
Symphurus atricauda	California tonguefish	M	D	N
Synodus foetens	Inshore lizardfish	R	D	N
Tapes philippinarum	Japanese littleneck	R	D	Y
Tautoga onitis	Tautog	R	E	Y
Tautogolabrus adspersus	Cunner (bergall)	R	E	Y
Thalamita crenata	Blue pincher crab	R	D	Y
Theragra chalcogramma	Walleye pollock	M	E	Y
Thunnus atlanticus	Blackfin tuna	M	P	Y
Thymallus arcticus	Arctic grayling	E	P	Y
Tilapia mossambica	Mozambique tilapia	R	E	Y
Tilapia zillii	Redbelly tilapia	R	E	Y
Tipula spp.	Cranefly (unknown species)	R	D	N
Trachinotus carolinus	Pompano	M	P	Y
Tresus capax	Horse clam	R	D	Y
Triakis semifasciata	Leopard shark	M	E	Y
Tridentiger trigonocephalus	Chameleon goby	R	D	N
Trinectes maculatus	Hogchoker	M	D	N
Tylosurus crocodilus	Houndfish	M	E	Y
Uca minax	Redjointed fiddler	R	D	N
Uca pugnax	Atlantic marsh fiddler	R	D	N
Umbra limi	Central mudminnow	R	E	N

Table D-1. (Continued)

Scientific Name	Common Name	Resident/ Migratory[a]	Demersal/ Pelagic[b]	Potentially Edible
Urophycis chuss	Red (squirrel) hake	M	E	Y
Urophycis regia	Spotted hake	M	E	Y
Vaucheria	Macroalgae	R	E	N
	Sorted benthic sample	R	D	N
	Unsorted benthic sample	R	D	N

[a] Fish species is considered R-resident, M-migratory, E-either resident or migratory.

[b] Fish species is considered D-demersal, P-pelagic, E-either.

APPENDIX E
TREND ANALYSIS CASE STUDIES

Introduction

This appendix discusses temporal trends in sediment contamination by using three case studies reported in literature. These studies are Lake Pepin (downstream of Minneapolis, Minnesota, on the Mississippi River), four lakes in the Chattahoochee and Flint River Basin (Georgia), and Puget Sound (Washington).

Case Studies
Mercury Loading to Lake Pepin from the Upper Mississippi River

Introduction

Lake Pepin is a natural lake located on the Mississippi River, 80 km downstream of Minneapolis and St. Paul, Minnesota. Upstream of Lake Pepin, the St. Croix and Minnesota Rivers join the Mississippi River, creating a catchment of 122,000 km^2 (Figure E-1). The major land use in the Minnesota River Basin is agriculture. Forests and wetlands make up much of the headwater Mississippi (despite the twin cities) and St. Croix River Basins. Because of the diverse nature of the three watersheds—Mississippi, Minnesota, and St. Croix—the flows from these watersheds are different. The nutrient content, suspended sediment, and mercury (Hg) concentrations are substantially higher in the Minnesota River than in the headwater Mississippi and St. Croix Rivers. Lake Pepin has a typical hydraulic residence time of more than 5 days, sufficient to enable settling of suspended matter. Eighty-five to ninety percent of the sediment load to Lake Pepin originates from the Minnesota River Basin and consists of fine silt and clays. The location, the hydraulic residence time, and the waters that flow into Lake Pepin make it a repository for sediment and the attached heavy metals. The Mississippi River and Lake Pepin received significant inputs of Hg during the 1960s when the other lakes in the region received no point source loads (Balogh et al., 1997). Balogh et al. (1999) collected sediment cores from Lake Pepin to reconstruct the history of Hg loading in the Upper Mississippi River over the past 200 years. Sediment cores were dated and stratigraphically correlated by using ^{210}Pb, ^{137}Cs, ^{14}C, magnetic susceptibility, pollen analysis, and loss-on-ignition. The authors reported that the Hg stratigraphy in Lake Pepin was undisturbed by postdepositional processes.

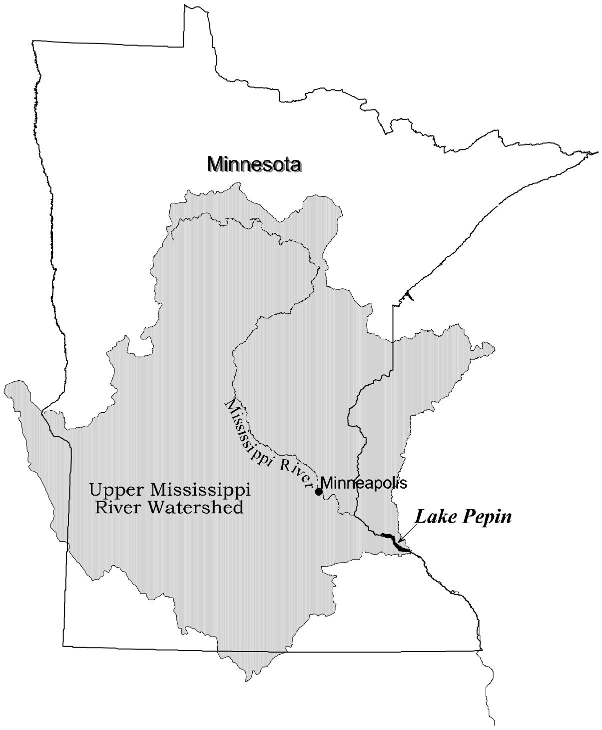

Figure E-1. Lake Pepin Location Map.

Total Hg Concentrations in Lake Pepin

Balogh et al. (1999) reported that Hg concentrations in deep presettlement core samples in Lake Pepin varied between 33 and 40 nanograms per gram (ng/g). These levels of Hg are similar to those in other lakes in the region and are comparable to the surface soil Hg concentrations of 18 to 44 ng/g in the

Minnesota River Basin. Results from sediment cores indicate increased Hg concentrations after 1800, when the European settlers established their continuous presence along the Minnesota and Mississippi Rivers. By 1900 the Hg concentration in sediments was above 200 ng/g, and most cores indicated a steady or decreasing Hg concentration between 1920 and 1950. However, between 1949 and 1968, Hg concentrations began to increase, reaching peak values ranging from 452 to 669 ng/g. The concentration of Hg in sediment cores declined substantially from the late 1960s and continued to decrease to concentrations between 106 and 161 ng/g, as presented in Table E-1.

Table E-1. Total Hg Concentrations in Lake Pepin Sediment Cores.

Core Number	Pre-settlement (ng/g)	Peak (ng/g)	Modern (ng/g)
1	33	662	106
2	34	669	120
3	34	528	120
4	33	561	128
5	40	519	121
6	36	503	135
7	38	570	123
8	34	499	128
9	37	452	137
10	39	492	161

Source: Balogh et al., 1999.

Averaging the sediment core data by 10-year intervals, Balogh et al. (1999) estimated a loading rate of 3 kilograms per year (kg/yr) to characterize naturally occurring deposition of Hg under pristine conditions before European settlement began around 1830. Hg deposition progressively increased during the 19th and 20th centuries; about one-half of the total Hg load was deposited from 1940 to 1970, and the peak accumulation rate of 357 kg/yr was identified during the 1960s. As a result of decreasing the discharges of Hg from municipal and industrial wastewater plants, the Hg deposition rate in Lake Pepin has declined by almost 70 percent from the maximum loading during the 1960s to 110 kg/yr in 1990 through 1996 as shown in Figure E-2. However, the current Hg loading rate of 110 kg/yr for Lake Pepin is substantially higher than the estimated pre-settlement loading rate of 3 kg/yr. The average Hg loading rate in the Mississippi River immediately upstream of Lake Pepin was reported as 102 kg/yr by Balogh et al. (1999). This indicates that much of the Hg loading from the Upper Mississippi River is deposited with the sediment into Lake Pepin.

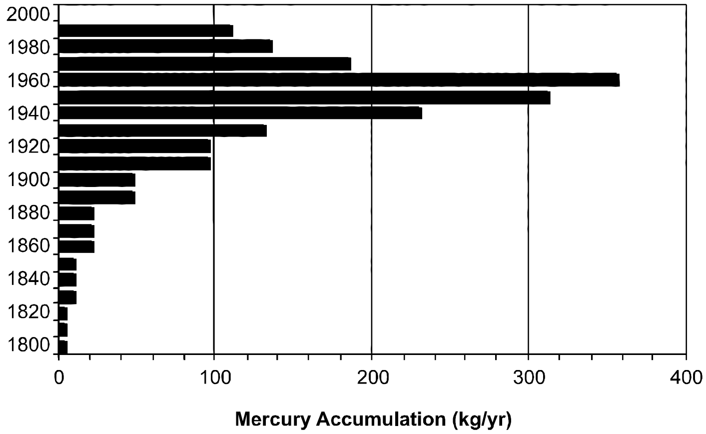

Figure E-2. Historical Hg Loading Rates in the Upper Mississippi River Reconstructed from Sediments of Lake Pepin. Source: Balogh et al, 1999.

Summary and Conclusions

The accumulation of Hg to Lake Pepin can be attributed to urban runoff and industrial/domestic users. In addition to the Hg loading due to atmospheric deposition from coal combustion and industrial emissions, Balogh et al. (1999) have identified other possible sources of Hg that might have contributed to the accumulation in Lake Pepin. During the period of initial European settlement, Hg was used extensively for medicinal purposes, in photography, in dentistry, in the tanning/dyeing industries, and in thermometers. In the 1900s the medicinal use of Hg decreased, but its industrial use continued to escalate.

Balogh et al. (1999) have suggested that the inability of Metropolitan Wastewater Treatment Plant, located along the Mississippi River at St. Paul, Minnesota, to cope with the increased population might have contributed to the increased Hg loading. The capacity of the treatment plant was increased and a secondary treatment unit was added during the years 1966 through 1968. The enhanced treatment capacity and the diminished use of Hg after the 1960s are reflected in the substantial decline of Hg loadings to Lake Pepin, as shown in Figure E-2. Although the investment in water pollution control has been very successful in reducing Hg in the Upper Mississippi River, ambient levels are still 30 times greater than the pristine conditions of the early 1800s (MCES, 2000).

Historical Trends in Organochlorine Compounds from Four Georgia Lakes

Introduction

One of the major objectives of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey is to study and define historical trends of water quality in the waters of United States. As a part of the NAWQA program, Van Metre et al. (1997) studied temporal trends of PCBs, total DDT, and chlordane concentrations using sediment cores in four lakes in Georgia (Figure E-3). The study used radiochemical dating of sediment cores and measurement of chlorinated organic compounds by standard extraction techniques. Other results for a lake in Texas and a reservoir in Iowa can be found in Van Metre et al. (1997).

Lake Harding is located along the Chattahoochee River 184 km downstream of Atlanta and receives drainage from metropolitan Atlanta. The Chattahoochee River flows from northeast Georgia through metropolitan Atlanta and is a major water supply source and receptacle for wastewater disposal for Atlanta. The drainage to Lake Harding was reduced when West Point Lake, 25 km upstream of Lake Harding was constructed in 1974. Lake Walter F. George is located on the Chattahoochee River, 290 miles downstream of Atlanta and is separated from metropolitan Atlanta by Lake Harding and West Point Lake. Lake Blackshear is located 314 km downstream from Atlanta along the Flint River. Land use in the drainage area for Lake Blackshear consists of agriculture and forestry. Lake Seminole is located at the confluence of the Flint and Chattahoochee Rivers, forming the Apalachicola River. The drainage area for Lake Seminole is mainly agricultural.

Figure E-3. Location Map of Upper Chattahoochee Basin.

In all four locations (i.e., Lakes Harding, Walter F. George, Blackshear and Seminole), Van Metre et al. (1997) reported uniform, fine-textured sediments with no evidence of bioturbation, i.e., no major displacements within the unconsolidated sediments by benthic organisms. In addition, the authors reported no postdepositional mixing of the sediment by current or waves in the lakes. This conclusion was feasible by virtue of pronounced ^{137}Cs peaks with exponential decreases in ^{137}Cs to the sediment surfaces at the lakes.

Trends in PCBs

Results of the findings by Van Metre et al. (1997) for sediment concentrations of PCBs are presented in Table E-2. The peak PCB concentrations from 1950 through 1969 in Lakes Harding and Walter F. George near Atlanta, Georgia, are higher than those in Lakes Blackshear and Seminole in rural Georgia. Lakes Harding and Walter F. George receive effluent from metropolitan Atlanta, whereas the drainage areas for Lakes Blackshear and Seminole are mainly agricultural and forested areas.

Table E-2. PCB Concentrations in Lake Sediments.

Period	Lake Harding (µg/kg)	Lake Walter F. George (µg/kg)	Lake Blackshear (µg/kg)	Lake Seminole (µg/kg)
Before 1950	~50	NA	NA	NA
1950–1969	280–380[a]	220[b]	8	3–10
1990s	42–46	<14	1	10
% Decrease	85–88	94	88	(70)–0

NA: not available.
[a] Between 1950 and 1966.
[b] In 1968.
Source: Data extracted from Van Metre et al., 1997.

Drainage and effluent from metropolitan Atlanta was directed to Lake Harding until 1974, when West Point Lake, upstream of Lake Harding, was constructed to intercept a portion of the flow. Van Metre et al. (1997) have reported that PCB concentrations in seven sediment core samples at West Point Lake ranged from 110 mg/kg to 32 mg/kg for the period from 1974 through the 1990s. The concentrations of PCB during the corresponding time period at Lake Harding are similar (Table E-2). This led them to conclude that the substantial decrease in PCB concentrations in sediments in Lake Harding between the 1970s and the 1990s is not due to West Point Lake's intercepting a significant PCB load from upstream. The decreases are due to reduced manufacture and use of PCB, and its regulation in the United States. The authors have attributed the spatial trend of PCB concentrations in the sediments of Lake Seminole partly to the location of the coring site.

Trends in Total DDT

Sediment concentrations of DDT and its derivatives (DDD and DDE) found in core samples in the four lakes are shown in Table E-3. Like the temporal variation of PCBs in the lake sediments, total DDT concentrations showed steep decline in all lake sediments presented here. This decline is consistent with the use of DDT in the United States, with peak usage in the early 1960s until the use of DDT was prohibited nationally in 1973. DDT concentrations in West Point Lake sediments follow a pattern similar to that of the two downstream lakes, Lakes Harding and Walter F. George, after the early 1970s. As in the case of PCBs, the decline in DDT concentrations in Lake Harding is not due to West Point Lake's intercepting a portion of the DDT load before it reaches Lake Harding. Actual reduction in usage and the banning of DDT resulted in reduced concentrations of total DDT in lake sediments.

Table E-3. DDT Concentrations in Lake Sediments.

Period	Lake Harding (µg/kg)	Lake Walter F. George (µg/kg)	Lake Blackshear (µg/kg)	Lake Seminole (µg/kg)
1940s–1965	35	74[a]	57	30
1990s	5.9	5.5	6.5	7.5
% Decrease	83	93	89	75

[a] In 1968

Source: Data extracted from Van Metre et al., 1997.

Trends in Chlordane

Used as a pesticide in agricultural and residential areas, chlordane was introduced for agricultural use in the United States in the early 1970s and was used extensively until 1974, when its agricultural use was banned. It continued to be used in termite control, however, until 1988 (Van Metre and Callender, 1997). The only permitted uses of chlordane after 1988 were in power transformers, for fire ant control, and the use of existing stocks by homeowners. Sediment concentrations of chlordane from the study by Van Metre et al. (1997) are presented in Table E-4. Like PCB concentrations, chlordane concentrations are higher in urban lakes by virtue of their use in such surroundings. Unlike PCBs and total DDT, which reached peak values during the 1960s, chlordane concentrations peaked during the late 1980s or the 1990s. Chlordane showed a minor decline during sampling in 1994/95. This might be the result of the more stringent control of the use of chlordane even in urban areas, as permitted under current regulations.

Table E-4. Chlordane Concentrations in Lake Sediments.

Period	Lake Harding (µg/kg)	Lake Walter F. George (µg/kg)	Lake Blackshear (µg/kg)	Lake Seminole (µg/kg)
1960s	46–84[a]	6[c]	ND	ND
1990s	6–8[b]	NA	ND	ND
% Decrease	87–90	NA	NA	NA

ND: not detected.
NA: not available.
[a] 1950–1970.
[b] Early 1970s.
[c] In 1973.
Source: Data extracted from Van Metre et al., 1997.

Van Metre et al. (1997) have reported that chlordane concentrations in West Point Lake ranged between 20 to 55 mg/kg. These concentrations are higher than the chlordane concentrations in Lake Harding prior to 1974. Hence the substantial decrease in chlordane concentration in Lake Harding is due to West Point Lake's serving as a sink for chlordane from urban Atlanta and other enhanced sources of chlordane.

Summary and Conclusions

The temporal decline of PCB and DDT and its derivatives, DDD and DDE, in the lake sediments parallels the usage and regulation of these chemicals in the United States. Eisenreich et al. (1989) have reported similar results on sediment cores from the Rochester Basin of eastern Lake Ontario. Steep increases in PCB concentrations in sediments occurred between the 1940s and 1960s, with peak values between 1966 and 1969. These concentrations decreased substantially by 1980. Sanders et al. (1992) studied sediment cores from a lake in rural England. Their study found similar declines in PCB and total DDT concentrations from peak values during the respective peak production and usage periods. However, Eisenreich et al. (1989) and Sanders et al. (1992) have alluded to the possibility of sediment mixing by various processes, distorting the historical records of contaminant deposition. In addition, Sanders et al. (1992) have reported that PCB and DDT in sediment cores were recorded prior to their use in the United Kingdom. The authors have suggested long-range atmospheric transport from the United States and mainland Europe as possible sources of such contamination.

Accumulation of Chemicals in Puget Sound Introduction

Puget Sound, an estuary in northwestern Washington State (Figure E-4), was one of the first areas in the United States to be studied extensively for sediment contamination. Early studies from the 1980s demonstrated fairly extensive sediment contamination, especially near major industrial embayments (Dexter et al., 1981; Long, 1982; Malins et al., 1980; Riley et al., 1981). These early assessments demonstrated that Puget Sound sediments were contaminated by many organic and inorganic chemicals, including PCBs, polycyclic aromatic hydrocarbons (PAHs), and metals. Although contaminant concentrations in sediments tended to decrease rapidly with distance from the nearshore sources, researchers also documented widespread low-level contamination in the deepwater sediments of the main basin of Puget Sound (Ginn and Pastorok, 1982). Also in the 1980s, several kinds of biological effects, including cancerous tumors, were reported in organisms from contaminated areas of Puget Sound (Becker at al., 1987).

Although contaminant levels in some surface sediments have started to decrease since pollution controls were established in the past few decades, contamination in the deep central Puget Sound Basin are still significantly higher than estimated preindustrial levels. In urban areas, present levels of contaminants are up to 100 times the levels in the cleanest rural bays. Sediment samples collected from many locations in Puget Sound, such as Bellingham Bay, Commencement Bay, Port Gardner Bay, Elliot Bay, and Eagle Harbor, were observed to be toxic to test organisms. In 1985 the Washington State legislature established the Puget Sound Water Quality Authority (PSWQA). The PSWQA has exercised greater control of point source discharges to the sound by mandating industries to reduce the chemical concentrations of their discharges.

Scientists from the Battelle/Marine Sciences Laboratory (MSL) in Sequim, Washington, collected sediment cores from six locations in the main basin of Puget Sound during 1991. The location of these sites was based on minimal disturbances reported due to natural or anthropogenic activity in these areas. The study analyzed PAHs, PCBs, metals, and pesticides using sediment cores. The field sampling techniques, the different analytical methods, and the data analysis used for the various classes of chemicals listed above are described in the National Oceanic and Atmospheric Administration Technical Memorandum NOS ORCA 111 (Lefkovitz et al., 1997). Recovery rates for the various contaminants were computed based on the decline from a peak concentration to the background level over a certain time period. Sediment ages were calculated by ignoring the sediment density. The study used both ^{210}Pb and ^{137}Cs dating. By virtue of a distinct subsurface maximum of ^{137}Cs, the authors have ruled out the possibility of sediment disturbance by mixing and migration. A trend analysis was also carried out for metals, PCBs, and DDT at three core locations to evaluate the statistical significance of

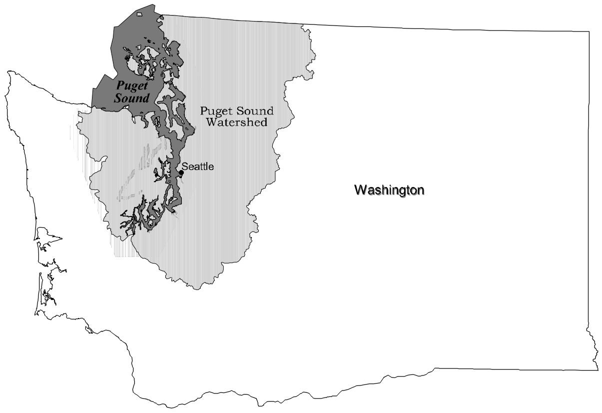

Figure E-4. Location Map of Puget Sound.

the relationship between the concentrations of the various contaminants and the time period from 1970 to 1991. A decrease in concentration of the contaminants during this 20-year period—at a predetermined confidence level (95 percent, i.e., $\alpha = 0.05$)—served as empirical evidence of the effectiveness of the environmental legislation enacted during this period.

Of the 16 metals analyzed, 8 showed reproducible temporal trends of increasing concentrations to a peak followed by a decline through the present time. The peak and surface (background) concentrations of metals showing a temporal trend from three locations and the year associated with these concentrations are listed in Table E-5. The concentrations listed in Table E-5 were extracted from profiles of concentration versus year at the various core sites.

Table E-5. Maximum and Surface Concentrations of Selected Metals for Three Core Locations Collected During 1991.

Metal	Silver (µg/g)	Arsenic (µg/g)	Copper (µg/g)	Mercury (µg/g)	Lead (µg/g)	Antimony (µg/g)	Tin (µg/g)	Zinc (µg/g)
Location 1								
Max Year	1965	1965	1960	1949	1965	1960	1965	1965
Max	0.91	19.5	54.6	0.479	48.9	2.05	4.9	134.6
Surface	0.68	12.5	42.7	0.179	30.3	1.28	3.94	114.7
% Decrease	25.3	35.9	21.8	62.6	38.0	37.6	19.6	14.8
Recovery Rate	0.009	0.280	0.397	0.007	0.744	0.026	0.038	0.796
Location 2								
Max Year	1982	1964	1947	1947	1922	1952	1962	1962
Max	0.84	28.3	70	0.505	69.4	3.9	4.85	167.7
Surface	0.69	13.1	49.3	0.213	36.7	1.6	3.96	119.2
% Decrease	17.9	53.7	29.6	57.8	47.1	59	18.4	28.9
Recovery Rate	0.017	0.563	0.470	0.007	0.474	0.059	0.031	1.672
Location 3								
Max Year	1965	1950	1963	1950	1954	1963	1963	1954
Max	0.65	23.5	64.7	0.403	62.3	2.43	4.25	128.8
Surface	0.59	17.3	52.7	0.28	44.7	1.52	2.78	115.5
% Decrease	9.2	26.4	18.5	31.3	28.3	37.4	34.6	10.3
Recovery Rate	0.002	0.155	0.444	0.003	0.489	0.034	0.054	0.369
Average Recovery Rate	0.009	0.333	0.437	0.006	0.569	0.039	0.041	0.946
95% CL ±	0.014	0.424	0.076	0.005	0.308	0.035	0.025	1.348

Source: Lefkovitz et al., 1997.

The concentration of lead in all sites peaked during the period from 1920 to 1960, followed by a declining trend from 1960 to the present. In addition to the recovery rate, lead also showed a decreasing trend with time for the period from 1970 to 1991. The authors of this study have attributed the effectiveness of the current environmental regulations for this declining trend. The concentration of arsenic peaked between the early 1950s and the 1960s. The maximum concentration of arsenic was found on two locations close to a copper smelter operated from 1889 to the 1980s in Tacoma, Washington. Crecelius et al. (1975) reported the smelter as the major anthropogenic source of arsenic and antimony, both by-products of the smelting operation. Concentrations of antimony showed an increasing trend between 1900 and the 1950s followed by a decline in concentration to the time of sampling. Though both metals showed percentage decreases greater than 25 percent, only antimony had a statistically significant recovery rate of 0.039 at the 95 percent confidence level. Moreover, antimony had a decreasing trend with time, whereas concentrations of arsenic remained unchanged during this period. Levels of Hg in all three locations decreased by an average of 50 percent from peak concentrations during late 1940s, and mercury had a sediment recovery of 0.006 at a 95 percent confidence level. However, from the trend analysis for the period from 1970 to 1991, the level of Hg remained the same with no statistically significant decrease with time.

Silver showed an average recovery of 17 percent from peak values in the three locations. The trend analysis did not show a significant correlation between time period and concentration for silver except at location 3. Copper and zinc produced a statistically significant decreasing trend with time. The sediment recovery rate for copper, was significant at a 95 percent confidence level, whereas zinc did not show a significant recovery rate. Tin showed an average decrease of 24 percent in all three locations and an average recovery rate of 0.041 (±0.025) µg/g per annum. However, concentrations have not shown a declining trend since wide fluctuations are still reflected in surface sediments. For most metals the highest reductions in concentrations were detected at location 2, which is in the vicinity of many sewage treatment plant outfalls. Because secondary treatment of sewage discharge to Puget Sound was initiated after the late 1950s, the decrease in metal concentrations can be attributed to these treatment techniques.

In addition to metal concentrations in sediment cores, the study included concentrations of PAHs, PCBs, and DDT. Details of the levels of the various contaminants are shown in Table E-6. Concentrations of total PAH varied from 100 (±21.6) µg/g at the lower levels of the sediment to a maximum of 6,788 µg/g during the early 1940s, subsequently declining to an average of 1,300 µg/g at the time of sampling in 1991. Neither the sediment recovery rate nor the correlation between time period and the concentration of total PAHs were statistically significant at the preselected 95 percent confidence level. The temporal trend in PAHs in the sediment is consistent with the use of fossil fuel in two cities, Seattle and Tacoma in Washington State, during the time period. Barrick (1982) has reported that combined sewage and storm water effluent and atmospheric deposition are the major sources of PAH contamination of the sediments of Puget Sound. Combustible PAHs derived from combustion of fossil fuels and other organic-rich materials such as wood have a high molecular weight and consist of four to six aromatic ring compounds. Like the total PAHs, the combustible PAHs had neither the sediment recovery rate nor the decreasing trend between time period and concentration.

Both PCBs and DDT showed trends similar to those of metals and PAHs. PCB concentrations in Puget Sound sediments appeared from the 1930s to peak values until the mid-1970s when the use of PCBs was restricted in the United States. In spite of an average reduction of 68 percent from peak values of PCB in all three locations, in only one location was a statistically significant decrease with time recorded for sediments deposited after 1970 to the present. Moreover, the estimated sediment recovery rate of 0.649 (±0.653) µg/g was not statistically significant at the 95 percent confidence level. DDT concentrations were reduced by an average of 42 percent in the three locations. In only one location was there a decreasing trend in DDT concentrations for sediments deposited after 1970. The average recovery rate for DDT in all three core locations was 0.103 (± 0.096) µg/g per year.

Table E-6. Maximum and Surface Concentrations of Selected Organic Contaminants for Three Core Locations Collected During 1991.

Organic Contaminant	PCB (µg/g)	DDT (µg/g)	Total PAH (µg/g)	Combustible PAH (µg/g)
Location 1				
Max Year	1960	1960	1943	1943
Max	34.5	4.71	6,788	5,917
Surface	9.00	1.19	1,434	1,162
% Decrease	73.9	74.8	78.9	80.4
Recovery Rate	0.851	0.117	114	101
Location 2				
Max Year	1966	1984	1942	1942
Max	25.8	5.76	3,430	2,898
Surface	5.33	4.77	1,303	1,050
% Decrease	79.3	17.2	62	63.8
Recovery Rate	0.819	0.142	43.412	37.878
Location 3				
Max Year	1961	1961	1935	1935
Max	15.5	4.25	1,883	1,516
Surface	7.39	2.8	1,212	977
% Decrease	52.2	34.2	35.6	35.5
Recovery Rate	0.278	0.050	12.198	9.793
Average Recovery Rate	0.649	0.103	56.5	49.6
95% CL ±	0.653	0.096	106	95

Source: Lefkovitz et al., 1997.

Summary and Conclusions

The concentrations of copper, lead, antimony, and zinc declined in Puget Sound at statistically significant levels from 1970 to the time of sampling in 1991. Silver, mercury, arsenic, and tin did not exhibit a similar declining trend in sediment contamination. Moreover, the average recovery rates (i.e., decrease in sediment contamination levels) for arsenic, silver, and zinc were not significant between the peak period and time of sampling. Among the organic chemicals studied, only DDT showed a statistically significant recovery rate, whereas the recovery rates for PCBs, total PAH, and combustible PAH had wider margins of variation. The authors of this study have not given significance to the recovery rates reported for Hg because the analytical error could be greater than the actual concentrations of Hg observed in this study. Though the declining trend in sediment contamination for certain chemicals is an encouraging sign, it is essential to note that there are some areas of concern with certain classes of chemicals. These may be attributed to either previous use and disposal practices or to chemicals discharged currently to Puget Sound from direct or indirect sources. Puget Sound is surrounded by Seattle and Tacoma, two rapidly developing and heavily industrialized regions. Hence it is essential to control future discharges to the area, as well as to implement the best available technology and to monitor the water quality.

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APPENDIX F

COMPARISON OF WATERSHEDS CONTAINING APCS

The 1997 *National Sediment Quality Survey* identified 96 watersheds with areas of probable concern (APCs) based on data collected from 1980 through 1993. Using the updated methodology described in Chapter 2 and the same APC definition, this second report identified 96 watersheds containing an APC based on data collected from 1990 through 1999. Table F-1 compares the watersheds identified in the reports. Thirty-seven watersheds were identified in *both* reports as containing an APC because data were available on these watersheds from both time periods, 1980 through 1993 and 1990 through 1999. Of the remaining 59 watersheds with an APC in the previous report to Congress, 26 watersheds had fewer than 10 total monitoring stations with data evaluated, 26 had fewer than 10 Tier 1 stations, and 7 had less than 75 percent of the analyzed stations classified as Tier 1 or Tier 2 in the current report. Of the remaining 59 watersheds with an APC in the current analysis, 19 watersheds had fewer than 10 total monitoring stations with data evaluated, 36 had fewer than 10 Tier 1 stations, and 4 watersheds had less than 75 percent of the analyzed stations classified as Tier 1 or Tier 2 in the previous report to Congress. Table F-2 and Figure F-1 present a detailed listing and geographical location, respectively, of the watersheds summarized in Table F-1. As indicated above, this disparity could be due to a lack of data collected in those watersheds identified as containing an APC in the first report but not containing an APC in this report. This difference could also be due to different stations being evaluated in those watersheds that resulted in the APC designation in the first report than were evaluated in the same watersheds in the current report and not designated as containing an APC in this report. Therefore, it should not be inferred that there are no ecological or human health impacts due to contaminated sediments for the stations located in watersheds that were designated as containing APCs in the first report but are not designated as such in this first update. Additional analysis should be conducted to determine the degree of impact due to contaminated sediments.

Table F-1. Watersheds Containing APCs: Comparison of Previous Report to Congress and Current Report.

Characteristics	Watershed Contained an APC Based on Data Evaluated in the Previous Report to Congress	Watershed Contains an APC Based on Data Evaluated in the Current Report to Congress
Identified as APC	37	37
Had fewer than 10 total monitoring stations	26	19
Had 10 or more total stations, but fewer than 10 stations were classified as Tier 1	26	36
Had 10 or more stations classified as Tier 1, but less than 75 percent of all stations were classified as Tier 1 or Tier 2	7	4
Total Watersheds Containing an APC	**96**	**96**

Table F-2. Detailed Comparison of Watersheds Containing APCs: Previous Report to Congress and Current Analysis.

		First Report to Congress Results						Current Report to Congress Results					
			Number of Sampling Stations						Number of Sampling Stations				
Cataloging Unit Number	Cataloging Unit Name	APC Status	Total	Tier 1	Tier 2	Tier 3	Percent of Sampling Stations in Tier 1 or Tier 2	APC Status	Total	Tier 1	Tier 2	Tier 3	Percent of Sampling Stations in Tier 1 or Tier 2
Watersheds that contain areas of probable concern in both reports													
01090001	Charles	APC	708	195	402	111	84	APC	69	38	20	11	84
01090004	Narragansett	APC	48	28	20	0	100	APC	14	12	1	1	93
02030103	Hackensack-Passaic	APC	103	43	58	2	98	APC	172	149	20	3	98
02030104	Sandy Hook-Staten Island	APC	100	60	21	19	81	APC	194	155	31	8	96
02030105	Raritan	APC	65	13	37	15	77	APC	30	15	9	6	80
02030202	Southern Long Island	APC	43	11	24	8	81	APC	85	47	21	17	80
02040202	Lower Delaware	APC	57	18	29	10	83	APC	26	11	15	0	100
02060003	Gunpowder-Patapsco	APC	29	17	7	5	83	APC	32	22	8	2	94
03130002	Middle Chattahoochee-Lake Harding	APC	27	21	4	2	93	APC	26	21	4	1	96
03160205	Mobile Bay	APC	81	31	43	7	91	APC	31	17	14	0	100
04030108	Menominee	APC	21	12	6	3	86	APC	21	18	2	1	95
04030204	Lower Fox	APC	51	49	2	0	100	APC	26	16	5	5	81
04040001	Little Calumet-Galien	APC	89	45	26	18	80	APC	24	22	1	1	96
04040002	Pike-Root	APC	72	34	30	8	89	APC	60	39	13	8	87
04120101	Chautauqua-Conneaut	APC	110	21	86	3	97	APC	16	13	2	1	94
06010201	Watts Bar Lake	APC	89	63	7	19	79	APC	19	16	3	0	100
06020001	Middle Tennessee-Chickamauga	APC	94	47	29	18	81	APC	33	15	12	6	82
07040001	Rush-Vermillion	APC	14	13	1	0	100	APC	19	10	5	4	79
07080101	Copperas-Duck	APC	27	17	5	5	82	APC	136	99	22	15	89
07120003	Chicago	APC	103	64	36	3	97	APC	49	34	14	1	98
07120004	Des Plaines	APC	110	61	43	6	95	APC	81	40	37	4	95
07120006	Upper Fox	APC	60	15	40	5	92	APC	81	31	37	13	84
07130001	Lower Illinois-Senachwine Lake	APC	21	11	10	0	100	APC	12	11	1	0	100
08030209	Deer-Steele	APC	21	11	10	0	100	APC	24	23	1	0	100

Table F-2. (Continued).

		First Report to Congress Results						Current Report to Congress Results					
			Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2		Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
Cataloging Unit Number	**Cataloging Unit Name**	**APC Status**	**Total**	**Tier 1**	**Tier 2**	**Tier 3**		**APC Status**	**Total**	**Tier 1**	**Tier 2**	**Tier 3**	
Watersheds that contain areas of probable concern in both reports (continued)													
08090100	Lower Mississippi-New Orleans	APC	51	16	34	1	98	APC	34	28	6	0	100
11070209	Lower Neosho	APC	20	13	3	4	80	APC	20	11	5	4	80
17090012	Lower Willamette	APC	76	21	51	4	95	APC	382	243	96	43	89
17110002	Strait Of Georgia	APC	263	32	168	63	76	APC	443	184	179	80	82
17110013	Duwamish	APC	127	48	69	10	92	APC	930	599	267	64	93
17110019	Puget Sound	APC	1,383	418	851	114	92	APC	2,135	1,246	552	337	84
18050003	Coyote	APC	24	18	6	0	100	APC	32	25	7	0	100
18050004	San Francisco Bay	APC	64	19	37	8	88	APC	130	113	16	1	99
18070104	Santa Monica Bay	APC	132	79	31	22	83	APC	132	109	21	2	98
18070201	Seal Beach	APC	442	63	339	40	91	APC	59	38	18	3	95
18070204	Newport Bay	APC	108	24	68	16	85	APC	74	36	20	18	76
18070301	Aliso-San Onofre	APC	32	10	22	0	100	APC	19	17	1	1	95
18070304	San Diego	APC	107	53	51	3	97	APC	278	208	47	23	92
Watersheds that contain areas of probable concern in the first report but have fewer than 10 total monitoring stations in the current report													
04060103	Manistee	APC	14	11	3	0	100		0	0	0	0	0
04090002	Lake St. Clair	APC	19	13	5	1	95		0	0	0	0	0
04090004	Detroit	APC	115	85	29	1	99		0	0	0	0	0
04100002	Raisin	APC	38	18	19	1	97		1	0	1	0	100
04100012	Huron-Vermilion	APC	45	10	35	0	100		2	0	2	0	100
04110003	Ashtabula-Chagrin	APC	31	10	18	3	90		8	0	4	4	50
04120103	Buffalo-Eighteenmile	APC	101	59	33	9	91		4	4	0	0	100
04120104	Niagara	APC	41	24	16	1	98		3	2	0	1	67
04130001	Oak Orchard-Twelvemile	APC	86	39	46	1	99		5	3	0	2	60
04150301	Upper St. Lawrence	APC	31	21	5	5	84		2	0	0	2	0
05030101	Upper Ohio	APC	53	12	29	12	77		6	6	0	0	100

Table F-2. (Continued).

		First Report to Congress Results						Current Report to Congress Results					
			Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2		Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
Cataloging Unit Number	Cataloging Unit Name	APC Status	Total	Tier 1	Tier 2	Tier 3		APC Status	Total	Tier 1	Tier 2	Tier 3	
Watersheds that contain areas of probable concern in the first report but have fewer than 10 total monitoring stations in the current report (continued)													
05030102	Shenango	APC	15	11	1	3	80		5	5	0	0	100
06010104	Holston	APC	15	12	2	1	93		5	3	1	1	80
06010207	Lower Clinch	APC	79	61	14	4	95		6	5	1	0	100
06030001	Guntersville Lake	APC	92	25	46	21	77		4	1	1	2	50
06040001	Lower Tennessee-Beech	APC	25	15	6	4	84		3	0	1	2	33
08010100	Lower Mississippi-Memphis	APC	20	14	3	3	85		5	0	2	3	40
08040207	Lower Ouachita	APC	12	12	0	0	100		0	0	0	0	0
10270104	Lower Kansas	APC	29	12	15	2	93		8	1	1	6	25
11070207	Spring	APC	41	10	25	6	85		9	9	0	0	100
17010303	Coeur D'Alene Lake	APC	23	10	13	0	100		2	2	0	0	100
17030003	Lower Yakima	APC	47	23	19	5	89		4	0	0	4	0
17110014	Puyallup	APC	19	12	6	1	95		9	8	1	0	100
18030012	Tulare-Buena Vista Lakes	APC	20	10	5	5	75		3	1	2	0	100
18070105	Los Angeles	APC	37	14	19	4	89		6	6	0	0	100
18070107	San Pedro Channel Islands	APC	25	14	10	1	96		4	2	1	1	75
Watersheds that contain areas of probable concern in the first report but have fewer than 10 stations classified as Tier 1 in the current report													
01090002	Cape Cod	APC	108	15	73	20	82		34	6	15	13	62
02040105	Middle Delaware-Musconetcong	APC	48	11	26	11	77		18	6	5	7	61
02040301	Mullica-Toms	APC	42	10	22	10	76		20	6	7	7	65
02070004	Conococheague-Opequon	APC	29	11	12	6	79		13	2	7	4	69
03040201	Lower Pee Dee	APC	34	11	20	3	91		29	6	15	8	72
03060101	Seneca	APC	16	10	3	3	81		12	8	1	3	75
03060106	Middle Savannah	APC	36	20	11	5	86		21	6	5	10	52
03080103	Lower St. Johns	APC	188	32	111	45	76		33	9	15	9	73
03140102	Choctawhatchee Bay	APC	51	19	23	9	82		44	9	14	21	52

Table F-2. (Continued).

Cataloging Unit Number	Cataloging Unit Name	First Report to Congress Results						Current Report to Congress Results					
		APC Status	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2	APC Status	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3			Total	Tier 1	Tier 2	Tier 3	
Watersheds that contain areas of probable concern in the first report but have fewer than 10 stations classified as Tier 1 in the current report (continued)													
03140107	Perdido Bay	APC	38	10	24	4	90		19	8	9	2	89
04030102	Door-Kewaunee	APC	20	12	5	3	85		12	6	1	5	58
04050001	St. Joseph	APC	32	17	9	6	81		11	6	5	0	100
04100001	Ottawa-Stony	APC	29	13	15	1	97		19	4	10	5	74
04100010	Cedar-Portage	APC	56	13	39	4	93		32	6	20	6	81
04110001	Black-Rocky	APC	59	24	31	4	93		22	4	10	8	64
05040001	Tuscarawas	APC	78	10	53	15	81		16	8	4	4	75
05120109	Vermilion	APC	28	12	16	0	100		34	6	24	4	88
05120111	Middle Wabash-Busseron	APC	33	15	17	1	97		18	8	7	3	83
06020002	Hiwassee	APC	33	13	17	3	91		17	7	9	1	94
06030005	Pickwick Lake	APC	69	49	9	11	84		20	9	7	4	80
06040005	Kentucky Lake	APC	30	15	14	1	97		11	1	6	4	64
07040003	Buffalo-Whitewater	APC	26	17	3	6	77		10	1	5	4	60
07070003	Castle Rock	APC	22	20	0	2	91		19	5	7	7	63
07090006	Kishwaukee	APC	34	10	24	0	100		15	6	8	1	93
07140201	Upper Kaskaskia	APC	55	31	24	0	100		26	9	16	1	96
07140202	Middle Kaskaskia	APC	38	13	22	3	92		20	5	10	5	75
Watersheds that contain areas of probable concern in the first report but have less than 75 percent of all stations classified as Tier 1 or Tier 2 in the current report													
02040203	Schuylkill	APC	44	12	23	9	80		56	26	15	15	73
04040003	Milwaukee	APC	90	60	16	14	84		67	32	10	25	63
07010206	Twin Cities	APC	35	26	2	7	80		44	25	6	13	70
07140101	Cahokia-Joachim	APC	56	18	34	4	93		37	10	14	13	65
07140106	Big Muddy	APC	94	23	65	6	94		100	20	29	51	49
08080206	Lower Calcasieu	APC	100	26	52	22	78		153	73	11	69	55
12040104	Buffalo-San Jacinto	APC	36	10	23	3	92		57	21	20	16	72

Table F-2. (Continued).

Cataloging Unit Number	Cataloging Unit Name	First Report to Congress Results						Current Report to Congress Results					
		APC Status	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2	APC Status	Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
			Total	Tier 1	Tier 2	Tier 3			Total	Tier 1	Tier 2	Tier 3	
Watersheds that contain areas of probable concern in the current report but have fewer than 10 total monitoring stations in the first report													
01100007	Long Island Sound		0	0	0	0	0	APC	31	23	7	1	97
02030101	Lower Hudson		8	4	3	1	88	APC	68	60	2	6	91
02030102	Bronx		8	4	3	1	88	APC	27	26	0	1	96
05120106	Tippecanoe		0	0	0	0	0	APC	25	17	3	5	80
05120208	Lower East Fork White		1	1	0	0	100	APC	19	10	8	1	95
08030207	Big Sunflower		7	4	3	0	100	APC	38	38	0	0	100
12030102	Lower West Fork Trinity		7	5	2	0	100	APC	31	19	10	2	94
12090205	Austin-Travis Lakes		8	5	3	0	100	APC	22	16	4	2	91
14010002	Blue		1	0	0	1	0	APC	15	15	0	0	100
17080001	Lower Columbia-Sandy		5	3	2	0	100	APC	72	20	39	13	82
17100102	Queets-Quinault		0	0	0	0	0	APC	108	77	23	8	93
17110012	Lake Washington		1	0	1	0	100	APC	216	179	30	7	97
18010102	Mad-Redwood		9	4	4	1	89	APC	26	20	4	2	92
18020112	Sacramento-Upper Clear		1	0	1	0	100	APC	25	23	2	0	100
18040005	Lower Cosumnes-Lower Mokelumne		1	1	0	0	100	APC	60	23	23	14	77
18050001	Suisun Bay		3	3	0	0	100	APC	27	16	8	3	89
18070103	Calleguas		2	0	0	2	0	APC	26	26	0	0	100
18070203	Santa Ana		5	1	4	0	100	APC	98	30	53	15	85
19020201	Eastern Prince William Sound		0	0	0	0	0	APC	31	10	15	6	81

Table F-2. (Continued).

		First Report to Congress Results						Current Report to Congress Results					
			Number of Sampling Stations						Number of Sampling Stations				
Cataloging Unit Number	Cataloging Unit Name	APC Status	Total	Tier 1	Tier 2	Tier 3	Percent of Sampling Stations in Tier 1 or Tier 2	APC Status	Total	Tier 1	Tier 2	Tier 3	Percent of Sampling Stations in Tier 1 or Tier 2
Watersheds that contain areas of probable concern in the current report but have fewer than 10 stations classified as Tier 1 in the first report													
01080205	Lower Connecticut		16	2	8	6	63	APC	19	17	2	0	100
01100004	Quinnipiac		21	3	18	0	100	APC	13	12	1	0	100
01100005	Housatonic		36	7	26	3	92	APC	24	22	0	2	92
01100006	Saugatuck		14	4	10	0	100	APC	19	18	1	0	100
02020003	Hudson-Hoosic		23	3	10	10	57	APC	163	155	8	0	100
02020004	Mohawk		27	0	23	4	85	APC	43	32	7	4	91
02020006	Middle Hudson		14	1	13	0	100	APC	76	55	13	8	89
02020008	Hudson-Wappinger		19	3	9	7	63	APC	40	34	6	0	100
02030201	Northern Long Island		31	8	20	3	90	APC	75	62	9	4	95
02060004	Severn		18	1	14	3	83	APC	72	48	20	4	94
02080107	York		22	3	17	2	91	APC	67	16	35	16	76
03050201	Cooper		25	9	10	6	76	APC	105	52	30	23	78
03060109	Lower Savannah		27	8	12	7	74	APC	68	20	45	3	96
03070203	Cumberland-St. Simons		39	9	13	17	56	APC	30	19	8	3	90
04140201	Seneca		14	1	11	2	86	APC	20	11	4	5	75
05060001	Upper Scioto		57	8	48	1	98	APC	50	10	32	8	84
05120201	Upper White		13	7	6	0	100	APC	42	23	14	5	88
06010205	Upper Clinch		67	8	30	29	57	APC	27	10	11	6	78
07090005	Lower Rock		54	7	33	14	74	APC	37	11	20	6	84
07090007	Green		37	6	28	3	92	APC	47	17	24	6	87
07120001	Kankakee		16	8	8	0	100	APC	34	20	10	4	88
07120002	Iroquois		25	0	25	0	100	APC	29	10	18	1	97
07120005	Upper Illinois		14	6	6	2	86	APC	24	11	12	1	96
07120007	Lower Fox		49	6	42	1	98	APC	26	10	13	3	88
07130003	Lower Illinois-Lake Chautauqua		27	6	21	0	100	APC	36	16	15	5	86

Table F-2. (Continued).

		First Report to Congress Results						Current Report to Congress Results					
			Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2		Number of Sampling Stations				Percent of Sampling Stations in Tier 1 or Tier 2
Cataloging Unit Number	Cataloging Unit Name	APC Status	Total	Tier 1	Tier 2	Tier 3		APC Status	Total	Tier 1	Tier 2	Tier 3	
Watersheds that contain areas of probable concern in the current report but have fewer than 10 stations classified as Tier 1 in the first report (continued)													
07130007	South Fork Sangamon		48	8	37	3	94	APC	16	12	4	0	100
07130011	Lower Illinois		44	5	38	1	98	APC	36	17	14	5	86
07130012	Macoupin		16	0	15	1	94	APC	19	10	9	0	100
15060106	Lower Salt		13	7	4	2	85	APC	52	39	13	0	100
16050203	Carson Desert		33	7	10	16	52	APC	19	14	5	0	100
17020001	Franklin D. Roosevelt Lake		32	4	24	4	88	APC	66	52	9	5	92
17100105	Grays Harbor		20	1	18	1	95	APC	139	102	33	4	97
18050002	San Pablo Bay		36	8	21	7	81	APC	101	69	28	4	96
18060006	Central Coastal		71	8	62	1	99	APC	54	25	22	7	87
18060011	Alisal-Elkhorn Sloughs		18	1	15	2	89	APC	34	25	9	0	100
18070106	San Gabriel		15	5	6	4	73	APC	34	21	11	2	94
Watersheds that contain areas of probable concern in the current report but have less than 75 percent of all stations classified as Tier 1 or Tier 2 in the first report													
02040205	Brandywine-Christina		101	22	21	58	43	APC	220	109	67	44	80
03050202	South Carolina Coastal		64	14	29	21	67	APC	60	33	18	9	85
03100206	Tampa Bay		196	11	54	131	33	APC	70	41	18	11	84
03140105	Pensacola Bay		96	12	47	37	62	APC	59	20	25	14	76

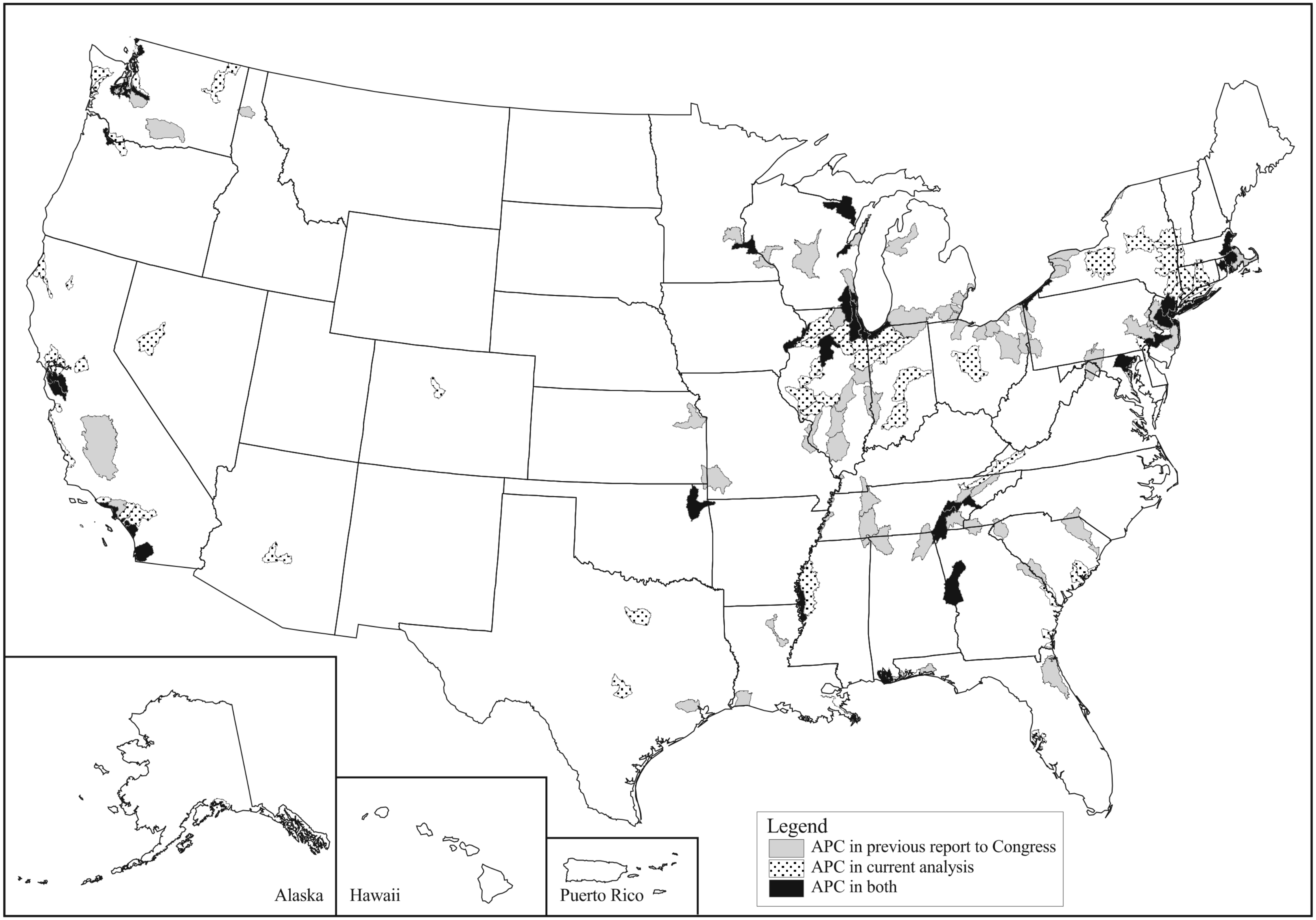

Figure F-1. Comparison of Watersheds Containing APCs: Previous Report to Congress and Current Analysis.