United States
Environmental Protection
Agency

Office of Water, Office of Water
Regulations and Standards
Washington, D.C. 20460 and
Region 5
Chicago, Illinois 60604

EPA-905/9-88-002
June 1987

EPA

An Overview of Sediment Quality in the United States

AN OVERVIEW OF SEDIMENT QUALITY IN THE UNITED STATES

Final Report

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Contract No. 68-01-6951, Task 20

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WASHINGTON, DC

June, 1987

ACKNOWLEDGEMENTS

We gratefully acknowledge helpful conversations with individuals in over fifty State and Federal offices with responsibilities for environmental protection (see Appendix C). Many of these individuals helped us identify and obtain the reports listed in Appendix B.

The STORET maps in Section IV were prepared by Mike Paquette (Versar, Inc., Springfield, VA). Alec Naugle (Arthur D. Little, Inc.) compiled the site latitudes and longitudes needed for the preparation of these maps.

ABSTRACT

This report provides an overview of sediment quality in waters of the United States. The focus is on describing qualitatively the nature and extent of contaminated sediments, i.e., bottom deposits in rivers, lakes, harbors and oceans that have been polluted with heavy metals, organic chemicals and other materials from anthropogenic sources. Such materials, also called "in-place pollutants," may be significantly impacting aquatic ecosystems in some areas, and may be degrading the quality of the overlying water to the extent that water quality criteria are exceeded and that uses of the water - by both aquatic life and humans - are impaired.

Information for this report was obtained from a review of the published literature (identified via computerized bibliographic data bases and via personal contacts) and from interviews with knowledgeable individuals in approximately fifty federal and state agencies that deal with contaminated sediments. Although a considerable amount of personal experience was drawn upon and a large volume of literature assessed, the data collection effort was not statistically designed or geographically complete. It was also not within the scope of the study to include any major compilation of sediment quality data or to screen such data to determine the degree of contamination. For these reasons the conclusions drawn may reflect a somewhat impressionistic view of overall sediment quality issues.*

Major sections of the report provide information on: (1) the nature of sediment contamination problems (e.g., types of locations, pollutants and ecological impacts); (2) sources of contaminated sediments (including a discussion of current vs. old sources); (3) available responses to sediment contamination; and (4) an overview of sediment quality criteria (or evaluation processes) that are, or have been, used to classify sediments as polluted or not. Appendix A provides summary information on over 180 sites with "in-place pollutants." Appendix B contains a coded bibliography of literature on this subject. Appendix C identifies the specific agencies and individuals contacted for information on polluted sediments.

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I. INTRODUCTION

A. BACKGROUND[1]

Sediment contamination problems have been documented in an increasing number of areas over the last few years. Contaminated sediments can have direct effects on aquatic life by making areas uninhabitable for benthic organisms or by contaminating the food chain and adversely affecting fish. An example of the latter is the development of cancerous tumors in fish from streams where the sediments are contaminated with polycyclic aromatic hydrocarbons (PAHs). Food chain contamination can also pose a threat to human health as pollutants in sediments bioaccumulate in fish tissue. There are numerous examples of cases where fish consumption warnings or bans have been issued for pollutants such as PCBs, mercury, dioxin, kepone, and others due to contaminated sediments affecting the food chain. Sediment contamination can also affect commerce, most prominently by raising the price of navigational dredging to levels that can not be borne by the Corps of Engineers or shipping interests.

While sediment contamination has been recognized as a serious problem for some time, there has been relatively little success in mitigating these situations for a number of reasons. One factor is the lack of national guidelines and well developed scientific basis for determining what levels of various pollutants in sediments constitute a problem. To date, problems have been defined primarily on the basis of observed effects on aquatic life, such as a lack of benthic organisms or diseased or contaminated fish. In some instances, however, pollutant loadings to another body of water, sediment oxygen demand, and regional or state guidelines have been effectively used for problem definition.

Another factor which makes sediment contamination problems difficult to solve is the handling of contaminated sediments. Both dredging and disposal can raise additional problems. Although there are control techniques available, dredging can result in resuspension of contaminated material which can then become more available to aquatic life or possibly affect water supplies. Disposal requires locating a secure site where large amounts of difficult-to-handle aqueous material can be safely transported and contained.

Contaminated sediments can also be expensive to control. Not only are specialized dredging techniques and disposal sites sometimes needed but the sediments may need to be dewatered or otherwise treated before disposal can occur. Other complicating factors are the higher concentrations of contamination that sometimes underlie the surface

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1. This Background discussion was excerpted from an internal EPA document on Sediment Strategy, dated July 1985.

sediments and the difficulty in establishing a responsible party, especially when older sediments or multiple dischargers are involved. Frequently, sediment contamination is the result of discharges of some years past, prior to NPDES regulation.

A further reason that EPA has had limited success in mitigating sediment contamination problems is the administrative limitation in the authorities EPA and the Corps of Engineers (COE) have for dealing with contaminated sediments. First, while Congress has authorized $15 million under Section 115 of the Clean Water Act to clean up contaminated sediments, little money has been appropriated under that authority, and then only for investigation. Second, the scoring system under which potential Superfund sites are rated to determine their priority tends to focus on immediate human health hazards as opposed to the long term type of problems caused by contaminated sediments. Finally, the COE is limited to dredging only where necessary for navigation and must justify added environmental control costs on the basis of the benefits of the project involved.

While a large number of sediment contamination problems have been identified, no systematic effort has been made to compile a comprehensive national assessment of the extent of sediment contamination problems. As a first step, it would be helpful to have an extensive survey of all the regional offices, a detailed review of relevant literature, a review of COE and State information, and an evaluation of data available through STORET and other water quality data bases to define the extent of the problem.

Once a comprehensive listing of known contamination problems and apparent sources has been developed, it should be possible to correlate the problems with respect to source category such as particular type of industrial discharge, type of hazardous waste spill, etc. The purpose of this exercise would be to establish relationships between various types of industrial activities and sediment contamination problems. (Aside from source category, factors such as land use, sediment type and flow regime are also relevant.) This would allow EPA to predict where currently undetected problems may exist, to determine to what extent field studies are necessary to further investigate various source categories, and to suggest regulatory followup approaches that might be taken.

B. STUDY OBJECTIVES

This study was undertaken as an initial step towards the goal of compiling a comprehensive national assessment of the nature and extent of sediment contamination problems. Specific objectives were to:

- Document the extent to which various sources have been associated with sediment contamination problems;
- Document approaches to, and effectiveness of, remediation of sediment contamination;
- Provide documentation of Regional and State approaches to sediment contamination problem identification and response; and

Provide support and perspective to the development and eventual implementation of sediment quality criteria through an inventory and description of known contaminated sediment problem areas.

The major purpose of this study was thus to provide a "picture" of the sediment contamination problem in the United States in the most efficient and objective way possible. It is hoped that this "picture" can act as a framework or plateau on which future discussions of sediment contamination problems can take place. We realized that the data base of information being collected lacked the numeric rigor and statistical base that is often needed in other studies, and that some of the information may be called subjective or anecdotal. This approach was taken purposely in the hopes that it will provide an alternative view, a balance, to other approaches in which sediment quality data are, in a mechanistic way, compared with concentration limits that are akin to criteria values. Studies of this latter type can be very helpful, however. Two good examples (described briefly in Sections III and IV) are reports by Johanson and Johnson (1976) and Bolton et al. (1985). The existence of these studies, which included extensive analysis of numeric data on pollutant concentrations in sediments, provides a valuable supplement to the current work.

C. REPORT OVERVIEW

A number of summary observations and conclusions are presented in Section II. As explained above, the statements may be somewhat impressionistic due to the nature of the study approach.

Section III describes the study methodology used in this project. It also provides a brief summary of four other reports that contain, at least in part, surveys of sites with in-place pollutants. (Some summary data from these other reports are presented in Section IV.)

The main findings of the report are presented in Section IV. The first two subsections focus on: (a) descriptions of the types of sites and pollutants involved; and (b) descriptions of the pollutant sources responsible. To a large extent, the information provided has been based upon a review of over 180 sites with in-place pollutants. (Summary information on these sites is provided in Appendix A.) The final subsection of Section IV provides an overview of available responses to sediment contamination, focusing more on management issues and generic approaches than on engineering details.

Section V provides a discussion of several approaches to deriving sediment quality criteria. The discussion focuses on approaches that have been developed by federal and state offices for current use in sediment contamination problems. Less information is provided on ongoing research efforts to derive new sediment quality criteria.

Full references to the literature cited in the main body of the report are given in Section VI.

Appendix A provides summary information on over 180 sites with in-place pollutants. Information is given on the following: water body/location; contaminants and their concentration ranges; perceived or noted impacts; sources of pollutants; code for remedial actions undertaken; additional comments; and a literature reference. The list of sites is subdivided into ten tables by EPA region.

Appendix B provides a coded bibliography of literature (on in-place pollutants) obtained during this study. The coding relates to eight different criteria including EPA region, type of water body, types of contaminants, suspected sources, remedial actions taken, and ecological effects noted.

Appendix C identifies the specific individuals and agencies contacted for information on sediment quality. The purpose is to make it easier for future projects to identify and obtain needed information.

II. CONCLUSIONS AND OBSERVATIONS

As described in Section I, the objective of this project was to provide a "picture" of the sediment contamination problem in the United States. The conclusions and observations given below are thus a series of summary statements which represent collective wisdom; they are generally supported by the data in Sections IV and V, but may also contain a subjective or impressionistic flavor and may be skewed by the nature of the data collection effort.

A. THE SEDIMENT CONTAMINATION PROBLEM: SINKS AND SOURCES

1. There are hundreds of sites in the U.S. with in-place pollutants at concentration levels that are of concern to environmental scientists and managers. These sites include all types of water bodies (streams, lakes, harbors, near-shore ocean, etc.) and are found in all regions of the country.

2. It is probably safe to conclude that all surface waters receiving significant waste water discharges, runoff or infiltration from anthropogenic sources contain some in-place pollutants, and that the amounts present are related, in part, to the historic record of waste loads received by the water body. Only the smallest and most remote water bodies are likely to have pristine sediments although even these may be affected by wind-borne pollutants which reach the water body via wet or dry fallout.

3. The overall magnitude of the problem in terms of areal extent and severity has not been assessed. The potential, however, is staggering given the historic use of our waterways as a disposal area and the fact that the U.S. has 39.4 million acres of lakes, 1.8 million miles of rivers, 32 thousand square miles of estuaries,* 23 thousand ocean coastline miles,* and hundreds of thousands of square miles of near-shore, continental shelf (marine) habitat. Even if only a small percentage were affected with polluted sediments, it would represent a very significant problem.

4. Municipal and industrial point source discharges, urban and agricultural runoff, combined sewer overflows, spills, mine drainage, and atmospheric deposition are frequently cited sources. It is presumed that illegal (intentional) discharges have contributed significantly, but perhaps less so in recent years.

5. There is a general feeling that the worst sources of pollution (leading to contaminated sediments) have been stopped or brought under control. However, no evidence was found that documented the extent to which the problem of in-place pollutants has been mitigated by the Clean Water Act, the National Pollutant

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* Excluding Alaska

Discharge Elimination System (NPDES), and other federal and state acts and regulations. It is clear that many of the worst cases of sediment contamination are associated with sources that have ceased discharge. However, it is known that in many locations the older polluted sediments are still in place but have been covered by recent deposits of cleaner material. Such natural burial may diminish current impact, but it complicates future removal strategies as may be associated with navigational dredging.

6. In addition to pollutant source strength, patterns of sediment contamination are strongly affected by hydrologic factors (specifically sedimentation patterns), and the physical and chemical characteristics of the sediments. Fine-grained sediments with high surface area-to-volume ratios and/or high organic carbon contents, for example, are good sorbents for many pollutants. In areas where sediment-laden streams enter quiescent waters (e.g., discharge into a reservoir, harbor or other large body of water), or in other places where sediments tend to accumulate, large masses of contaminated sediments may accumulate.

7. The combined effect of varied source locations, and variable hydrology and sediment characteristics, has led to large variability in the concentrations of in-place pollutants within a water course or water body. The more contaminated sites are often referred to as "hot spots."

8. Harbor areas, both freshwater and marine, have clearly been impacted most severely. This is understandable given that they usually receive waste loads: (1) from the local urban and industrial sources (including point and non-point); (2) from commercial and recreational boat traffic; (3) from dredging operations; and (4) from any rivers entering the harbor and dropping their (possibly contaminated) sediments in the harbor.

9. Our understanding of the nature and extent of the problem of in-place pollutants is hampered by the fact that sediment quality data are not easy to collect and review. There have been no national surveys of sediment quality (a limited one is currently being sponsored by NOAA); the existing data, although extensive in some regards, are associated with varying sampling and analytical methods, and are widely scattered in many state and federal offices, often in uncompiled formats (some has been entered into STORET); and only a few states (e.g., Texas, Oregon and Washington) have regular programs to check for in-place pollutants.

10. Our understanding of the environmental impacts associated with in-place pollutants is limited by gaps in knowledge relating to sediment-pollutant chemistry (especially the bioavailability of

pollutants associated with sediments) and the direct and indirect ecological impacts on the aquatic biota.

B. PROBLEM CHEMICALS

1. One would only expect significant sediment accumulation of non-volatile, persistent chemicals. Both terms are relative, but "non-volatile" might be appropriate for chemicals with a Henry's law constant less than 10^{-3} atm m^3/mol. By "persistent" it is meant resistant to degradation by microbiological or chemical pathways (e.g., hydrolysis, photolysis, reduction); chemicals with a half-life (in sediments) of at least a year would certainly be considered persistent. Heavy metals (which do not "degrade" at all) and highly chlorinated organics are examples of persistent chemicals.

2. The available data do cite heavy metals and metalloids most frequently as in-place pollutants. Polychlorinated biphenyls (PCBs), "pesticides", and polycyclic aromatic hydrocarbons (PAHs) are also frequently cited. Radionuclides and microbiological pollution are rarely cited.

3. In addition to toxic metals and organics, other sediment quality problems involve nutrients, pathogens, acidity, oxygen demand, salinity, physical habitat alteration and sedimentation.

4. Although the use of scans may be increasing, it is very uncommon to find analyses where an attempt was made to identify all pollutants in the sediments. More commonly, sediments are analyzed for a screening list of chemicals. In some instances it appears that a few chemicals or parameters are being used as indicator pollutants for contaminated sediments; examples include PCBs, dioxins, total organic carbon (or oil and grease), selected heavy metals (e.g., mercury), and selected pesticides.

5. Because of the very selective nature of most of the analyses done, it is possible that certain classes of in-place pollutants have not yet been recognized as such, or that their relative importance is underestimated. Petroleum- and coal-derived hydrocarbons may be one such class of chemicals. Stable metabolites of some pesticides may be another.

6. Sediment quality data are obtained using a variety of analytical techniques, with the largest differences being in the initial digestion or extraction step. Comparison of data sets is thus made difficult, as is drawing any conclusions regarding the bioavailability of the pollutants.

7. Although some sediments have been found with extremely high pollutant concentrations, it is unusual to find samples that fail the extraction procedure (EP) test used to define hazardous wastes under RCRA. Easily extracted pollutants are presumably

also easily leached by the natural water flow from contaminated sediments.

C. RESPONSES TO SEDIMENT CONTAMINATION

1. The most common responses to recognized sediment contamination problems have been the issuance of fishing bans, fish consumption advisories, and bans on swimming, and the closing of water supplies.

2. If one neglects the Corps of Engineers' experience with the removal of (contaminated) sediments -- which is almost exclusively connected with the maintenance dredging of harbors and channels -- there has been very little experience with removing (or mitigating the effects of) in-place pollutants.

3. The initial consideration in every case must include a careful study of the extent to which the sources of the in-place pollutants have been controlled. If they have not been controlled, then any response that involves removal of the contaminated sediments may have only limited, short-term value.

4. Fueled primarily by CERCLA ("Superfund") money, there is now more serious consideration of technological solutions to contaminated sediments. Such solutions might involve, for example, temporary stream diversions, stabilization of the contaminated sediments, dredging, open water burial (and subsequent capping) of the contaminated sediments, on-land treatment and disposal, or in situ treatment of the contaminated sediments. One or more such technological solutions have been tried in at least 8 cases (see Section IV-C).

5. Most cases have considered (and properly should) the "no action" alternative in which the in-place pollutants are not disturbed. At a minimum, this provides a baseline for a comparison of relative risks and costs for alternate responses. It is quite possible that the "no action" alternative may be, by choice or by default, a very common one in the future given the technological complexity, costs, and institutional and political constraints associated with other actions. The "no action" case would also receive support in instances where in situ degradation or natural burial (by cleaner sediments) is expected to mitigate the problem within a reasonable time span.

6. An attractive variation on (and improvement over) the strict "no action" alternative is the use of broadcast material or caps to enhance the effects of natural burial. In more sophisticated projects, the contaminated sediments may be relocated to a prepared pit in the waterbody sediments before a cap is added. The use of caps for in situ or in-water disposal is gaining wider attention.

7. There is a general consensus that consideration of responses is, and must be, very site specific. This is presumably due mostly to physical and ecological differences at each site, but local public involvement, and other institutional considerations may play a significant role too.

8. The process of deciding just what remedial action is "best" for a site with contaminated sediments is complex, lengthy, and fraught with many uncertainties. The complexity is due, in part, to the numerous alternatives that can (or must) be considered. The uncertainties may be associated with: (1) unknown effectiveness of various technologies (under the local conditions); (2) possible long term "failure" of a solution (e.g., disintegration of a cap over buried contaminants); (3) crude methodologies to carry out exposure and risk assessments associated with different solutions; (4) equipment availability (especially dredging equipment); (5) uncertain or unknown costs; (6) availability of funding; (7) the uncertain basis and utility of various sediment quality criteria that have recently been proposed; and (8) extent of cleanup required.

9. Responses that involve removal of the contaminated sediments will usually be on a much higher plane of complexity, cost, and controversy than non-removal options since it must then be decided where else to place the polluted material.

D. DEVELOPMENT OF SEDIMENT QUALITY CRITERIA

1. Criteria that are currently in use for evaluating levels of pollutants in sediments, or for making regulatory decisions regarding the disposal of dredged material, are primarily based on comparison to background levels of pollutants, rather than on biological effects data.

2. In addition to the background concentration method, other methods being developed for the derivation of sediment quality criteria include approaches based: (1) on the toxicity of pollutants in water in situations where equilibrium sorption conditions can be assumed; (2) on laboratory measures of the biological effects of contaminated sediments; and (3) on field data indicating the impact of in-place pollutants on the distribution or abundance of benthic organisms. Approach (1) makes use of existing water quality criteria for aquatic life.

3. The factors affecting the toxicity of contaminated sediments are still poorly understood. Uncertainties include the variation of effects with sediment particle size and organic carbon content, and the relative importance of various methods of contaminant uptake by biota (e.g, ingestion or absorption of overlying water; ingestion of sediment particles, or biomagnification).

4. Efforts to develop new toxicological data to support sediment quality criteria are highly resource-intensive. As a result, most recent sediment criteria development efforts have focused on making optimal use of existing data.

5. Sediment criteria derived by the different methods developed to date, although they may be quite similar, sometimes vary by orders of magnitude for a given pollutant.

III. STUDY METHODOLOGY

A. OVERVIEW

The approach to gathering information for this study consisted of two separate efforts: (1) a search of the recent published literature on sediment contamination, and (2) a series of interviews, both by telephone and in person, with representatives of various federal and state agencies that deal with contaminated sediments. Each of these segments of the study is described in more detail below. Two general types of information were gathered: (1) data on specific cases of sediment contamination, their causes and effects, and (2) descriptions of federal and state agency approaches to identifying, studying and cleaning up contaminated sediments.

B. LITERATURE SEARCH AND REVIEW

The literature search consisted of both in-house searching of computerized literature databases and review of bibliographies and publications listings obtained from various federal agencies.

Two databases were searched in-house: NTIS and Pollution Abstracts. The NTIS database, produced by the National Technical Information Service of the U.S. Department of Commerce, consists of references to reports of U.S. government-sponsored research. The Pollution Abstracts database includes references from approximately 2,500 primary sources (including books, conference papers or proceedings, periodicals, research papers, and technical reports) dealing with pollution, its sources, and its control. Both of these databases were searched for citations for which the word "sediment" or "sediments" and some form of either "pollution" or "contaminants" (i.e., words beginning with "pollut" or "contamin") were listed as descriptor terms. In Pollution Abstracts, the search strategy specified that "sediment" or "sediments" must be a word in the title as well as being a descriptor term. (Some additional citations, which did not contain these words in their titles, were obtained from Pollution Abstracts for the years 1978 to 1980.) Citations obtained from Pollution Abstracts were limited to the English language. In NTIS, the search strategy specified that the term "sediment" or "sediments" must either be both a descriptor term and a word in the title of each document or be listed as a major descriptor term.

In addition to the in-house searches, a literature search on the topic of sediment contamination was ordered from the Defense Technical Information Center (DTIC). This search covered reports published by the U.S. Department of Defense.

The DTIC search covered the years 1976 to 1986, the Pollution Abstracts search covered 1978 to 1986, and the NTIS search covered 1980 to 1986. Complete bibliographic citations with abstracts were obtained from all three databases: a total of about 220 citations from DTIC, 450 from Pollution Abstracts, and 390 from NTIS.

Additional bibliographic listings were obtained from several sources:

- A bibliography of literature on "Lake and River Bottom Sampling" (dated 1977 to July, 1985) compiled by NTIS
- A list of publications of the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi
- A list of publications of the U. S. Geological Survey
- A literature search conducted by the information specialist at the U.S. Fish and Wildlife Service (USFWS), Columbia National Fisheries Research Laboratory. (In addition, a search of literature published by the USFWS was requested from the Fish and Wildlife Reference Service in Rockville, Maryland. However, no references specifically to sediment contamination were found).

From the above-mentioned citations and abstracts, reports and articles were selected for inclusion in this study. All of the literature gathered in this search process, together with reports and articles received from the various agencies contacted (as described below), were listed in a bibliography. Each citation in the bibliography was coded to indicate the major subject areas touched upon by the report or article. In addition, the literature was cross-indexed according to geographical location, in order to facilitate review of all literature on hand dealing with a given location. The bibliography and cross-index, which are included in this report as Appendix B, were used in preparing the table of sediment contamination problem areas (Appendix A) and writing the remainder of this report.

C. TELEPHONE INTERVIEWS AND VISITS

The second major approach to gathering information for this study was speaking to representatives of various federal and state agencies that deal with sediment contamination. The majority of these interviews were conducted by telephone, but a few agencies were visited in order to have in-person discussions of the subject. The agencies/offices contacted are listed in Table III-1. The specific individuals contacted are identified in Appendix C. Prior to our contacting the EPA regional offices, the EPA Office of Water, Monitoring and Data Support Division, sent a "letter of introduction" to all of the regional offices, explaining the purpose of this study and requesting that they identify individuals for us to contact in their offices. Names of contacts in state environmental agencies were provided by the individuals we spoke to in the EPA regional offices.

TABLE III-1. AGENCIES CONTACTED

NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
- National Ocean Service, Ocean Assessment Div. (Rockville, MD)
- National Marine Fisheries Service (Sandy Hook, NJ)

U.S. ARMY CORPS OF ENGINEERS
- *New England Division (Waltham, MA)
- *North Central Division (Chicago, IL)
- New York District Office
- Norfolk, VA, District Office
- Jacksonville, FL, District Office
- Galveston, TX, District Office
- Omaha, NE, District Office
- Memphis, TN, District Office
- Portland, OR, District Office

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY (USATHAMA)
- Installation Restoration Program Division

U.S. FISH AND WILDLIFE SERVICE (USFWS)
- Resource Contaminant Assessment Division
- Biological Services Division
- Western Energy and Land Use Division
- National Fisheries Research Laboratory (Columbia, MO)
- Great Lakes Fishery Laboratory (Ann Arbor, MI)

U.S. GEOLOGICAL SURVEY (USGS)
- Office of Surface Water
- Northeast Region
- Central Region (Denver, CO)
- Harrisburg, PA, District
- Baton Rouge, LA, District
- Rapid City, SD, District
- Lakewood CO, District
- Salt Lake City, UT District
- Oregon District

U.S. EPA ENVIRONMENTAL RESEARCH LABORATORY, NARRAGANSETT, RI

U.S. EPA REGION I
- Water Quality Branch
- State Agencies:
  - Connecticut Department of Environmental Protection
  - Massachusetts Department of Environmental Quality Engineering

U.S. EPA REGION II
- Water Management Division

(continued)

* Indicates offices visited

TABLE III-1. AGENCIES CONTACTED (continued)

U.S. EPA REGION III
- Water Quality Control Division
- Environmental Services Division

U.S. EPA REGION IV
- Environmental Services Division (Atlanta, GA)
- Ocean Disposal Division (Atlanta, GA)
- Superfund Division (Atlanta, GA)
- State and Local Agencies:
  - Florida Department of Environmental Regulation
  - Metro-Dade County, FL, Planning Department
  - Miami River Coordinating Committee

U.S. EPA REGION V
- *Water Division
- *Great Lakes National Program Office
- *Environmental Review Branch
- Dredge and Fill Section
- *Waste Managment Division
- State Agencies:
  - Michigan Department of Natural Resources
  - *Wisconsin Department of Natural Resources

U.S. EPA REGION VI
- Water Management Division
- Hazardous Waste Management Division
- State Agencies:
  - Texas Water Commission
  - Louisiana Department of Environmental Quality

U.S. EPA REGION VII
- Water Management Division
- Superfund Section
- State Agencies:
  - Iowa Department of Water, Air and Waste Management
  - Kansas Department of Health and Environment
  - Missouri Department of Natural Resources
  - Nebraska Department of Environmental Control

U.S. EPA REGION VIII
- Water Division
- State Agencies:
  - Colorado Department of Health
  - Montana Department of Health and Environmental Sciences
  - North Dakota Department of Health
  - South Dakota Department of Water and Natural Resources
  - Utah Department of Water Pollution Control
  - Wyoming Department of Environmental Quality

(continued)

* Indicates offices visited

TABLE III-1. AGENCIES CONTACTED (continued)

U.S. EPA REGION IX
Water Management Division
Environmental Services Branch (Policy Division)
State Agency:
California Water Resources Control Board

U.S. EPA REGION X
Environmental Services Division
Water Resources Assessment Section
Office of Water Planning
Puget Sound Office
State Agencies:
Alaska Department of Environmental Conservation
Oregon Department of Environmental Quality
Washington Department of Ecology

In speaking to these personal contacts, we asked for: (1) information that individuals could provide from personal knowledge; and (2) sediment quality reports and data summaries that they could send us or to which they could provide references. The type of information requested included the following:

- Statewide or regional surveys of sediment quality;
- Data on specific locations considered to be "problem areas" with regard to sediment contamination, including the nature and extent of contamination, known or suspected sources of pollutants, and remedial actions considered or implemented;
- Information about approaches identifying sediment contamination problems, deciding what level of contamination constitutes a "problem", determining the need for remedial action, and evaluating remedial action alternatives.

D. INFORMATION REVIEW AND SYNTHESIS

Among the first steps in the review of the information collected was the preparation of a large table listing specific sediment contamination problem areas. This table, presented in Appendix A, is not intended to be a comprehensive listing of sites that have contaminated sediments, nor is it a list of the "worst" sites. Rather, it provides a sampling of sediment contamination problems throughout the nation, with the most attention given to sites for which documentation is readily available. This listing was used as a starting point for the preparation of an overview of sediment contamination in the United States, discussing the types of contaminants most frequently found, and the known and suspected sources of contaminants (Sections IV-A and IV-B). Another section of this report (IV-C) discusses approaches to detecting, characterizing and responding to instances of sediment contamination. This section was based on conversations with agencies that deal with sediment contamination, together with the literature collected.

E. OTHER STUDIES

Several previous studies have reviewed sediment contamination on a nationwide scale. They include Johanson and Johnson (1976), Bolton et al. (1985), Science Applications International Corporation (1985), U.S. Fish and Wildlife (1986) and NOAA (1987). Each of these studies has a different focus and provides information on different sets of sites although there may be some overlap. Brief descriptions of these studies are given below. (Some additional details are given in Section IV-A.)

- Johanson and Johnson (1976), Identifying and Prioritizing Locations for the Removal of In-Place Pollutants.

This study was prepared for the U.S. Environmental Protection Agency, Office of Water Planning and Standards. The purpose of this study was to assist in the selection of locations for consideration under Section 115 of the Federal Water Pollution Control Act (PL-500), which requires EPA to identify the location of in-place pollutants, with emphasis on toxics. Under Section 115, EPA was also authorized to make contracts through the Secretary of the Army for removal and disposal of these in-place pollutants. Section 115 and the study covered harbors and navigable waterways. Data was obtained from U.S. Corps of Engineers, EPA regional and field offices, federal and state agencies, port authorities, academia, and other institutes. A semifinal list of 23 locations was developed based on a pollution index which was a measure of contamination relative to national median concentrations. These 23 locations were prioritized based on considerations such as availability of disposal sites for contaminated dredged spoils, chemicals present, population and shipping traffic. The prioritized list is shown in Table IV-6 (Section IV-A), with Priority 1 sites as those deserving the most consideration for Section 115 funds. Among a list of other conclusions, the authors concluded that the data available at that time were not adequate to set final priorities for removal or inactivation of in-place pollutions in response to Section 115. Also, the authors perceived that the magnitude of sediment pollution was such that the available funds could not begin to have a significant impact. There was also concern on the bias of inadequate intensity and geographically non-uniform availability of data.

- Bolton, et al. (1985), National Perspective on Sediment Quality

This study was prepared for the U.S. Environmental Protection Agency, Criteria and Standards Division of the Office of Water Regulations and Standards. The purpose of this study was to provide a nationwide overview of the quality of freshwater and marine/estuarine sediments and to provide assistance in the development of sediment criteria. Data from the EPA Storage and Retrieval (STORET) system computer file, the open literature, and reports from state and federal agencies were included. Preliminary threshold concentrations, shown in Table IV-9 (Sect. IV), primarily based on sediment-water-equilibrium partitioning were used to compare sediment contamination monitoring data for different pollutants. These threshold concentrations had been developed in earlier reports (Pavlou and Weston, 1983; JRB Associates, 1984). In their methodology, the assumption is made that the distribution of a chemical between the organic carbon phase of the sediment and the soluble phase in interstitial water in equilibrium with the solid phase is described by the organic carbon-water partition coefficient (K_{oc}) for the chemical. If the water quality criterion value for the chemical is taken to be the maximum acceptable concentration of the chemical in solution in the interstitial water, then the threshold concentration of the chemical in the bulk sediment is calculated based on the sediment organic-normalized K_{oc} for the chemical. Water bodies with sediment contamination monitoring data were categorized into those having contaminant(s) at Level 4 (greater than 10 times the threshold value),

Level 3 (3 to 10 times the threshold value), Level 2 (1 to 3 times the threshold value), and Level 1 (sediment concentrations less than the threshold value). The highest contamination levels were usually found in "hot spots" rather than over broad areas. For marine/estuarine sites, only a limited number of areas contained contaminants at higher concentrations. Details on the results of this study are given in Section IV-A.

- Science Applications International Corporation, 1985, Removal and Mitigation of Contaminated Sediments.

This study was prepared for the U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory in the Office of Research and Development. This report described 11 case studies of sediment contamination selected out of 33 cases based on remedial actions considered and implemented at these sites. These case studies provided information on state-of-the-art contaminated sediments management. A list of chemicals was also provided on sediment contaminants based on their physical and chemical characteristics. Equipment and techniques for sediments removal, dredged material management, and in-situ treatment and isolation techniques are described in the report.

- U.S. Fish and Wildlife, April 1986, Preliminary Survey of Contaminant Issues of Concern on National Wildlife Refuges.

This is an effort to inventory the presence of potentially harmful contaminants on national wildlife refuges. Sediment contamination was one of the issues considered but was not the primary focus. Information for the report was compiled from a questionnaire survey of refuge field stations. The report identified 78 contaminant issues of concern on 85 refuges. We noted eight national wildlife refuges that had sediment contamination problems as shown in Table IV-8 (Section IV-A).

- National Oceanic and Atmospheric Administration (NOAA), 1987, "National Status and Trends Program. Progress Report and Preliminary Assessment of Findings of the Benthic Surveillance Project - 1984."

The report summarizes the results of the first year (1984) of a national program to monitor toxic chemicals in bottom feeding fish and sediments at 50 coastal and estuarine sites in the U.S. Chemical contaminants surveyed included PCBs, aromatic hydrocarbons, selected chlorinated pesticides, metals, and sewage materials. The incidence of fish disorders (gross and histopathological lesions) was also surveyed, as a potential measure of biological response to contaminants. Areas with high concentrations of several pollutants included Boston Harbor and Salem Harbor, Massachusetts, Raritan Bay, New Jersey, Western Long Island Sound, New York, San Diego Harbor, California, and Elliott Bay, Washington. (The full NOAA report was not available at the time this report was being prepared and thus no data or site information are included herein.)

IV. STUDY FINDINGS

A. SEDIMENT CONTAMINATION PROBLEMS

1. Overview

This section presents the results of the data-gathering on sites which, based upon the information sources used, probably contain some in-place pollutants in the sediments. The term "in-place pollutants" is used to describe those contaminants found in sediments. The use of this term precludes some of the value judgment that may accompany the term "contaminated sediments". It was not within the scope of this study to provide a detailed and complete analysis of in-place pollutants in sediment; thus, the overview of the status of sediment contamination in the U.S. presented is somewhat subjective. We also did not attempt to include an independent judgment on the accuracy, adequacy, or rigor of the data as provided us from various sources.

In total, our study included 184 separate sites. Most of these were in the Northeast, along the Atlantic and Gulf Coasts, and in the Great Lakes region. This is not to say that these are also where the problem is most severe, but where most of our data is concentrated. Many water bodies serving major urban and industrial areas in the U.S. contain sediments with elevated levels of pollutants. Affected water bodies include ocean waters, estuaries, rivers/streams, lakes, and reservoirs. Heavy metals and metalloids, PCBs, pesticides, and PAHs were the most frequently mentioned contaminants in sediments. Ecological impacts from these contaminants, including biological impacts (e.g., impacts on reproduction, structure and health of the community, and fish kills), were frequently noted. Accumulation in edible fish has been severe enough to warrant fishing bans or fish consumption advisories in many cases. In one case, an alternative water supply was brought into a community because the water supply was contaminated by arsenic in the sediments. There are also numerous examples where contaminated sediments have stymied navigational dredging efforts; this, in turn, has had impacts on shipping.

This section provides:

- a brief discussion on the extent of the problem of in-place pollutants;
- a description of the sites involved;
- a discussion of the types of pollutants in sediments; and
- a brief discussion on the types of impacts that have occurred from in-place pollutants.

From the literature survey, U.S. EPA Offices, various state and federal agencies and other sources that were contacted, data regarding in-place pollutants were summarized in tables shown in

Appendix A. These tables show the site (water body and location), contaminants, any impacts that were noted or perceived, the source(s) of the contamination, whether remedial actions were considered or implemented, the reference or agency that the data were obtained from, and other comments regarding the site. The inclusion of sites was not based on ADL's judgment on contamination or non-contamination as measured by concentrations, impacts, or other criteria. Rather, there was no discrimination and sites were included as given by the literature and other sources. In addition, the tables do not provide an exhaustive list of all sites in the United States with in-place pollutants. The information in the tables in Appendix A is the primary basis of our conclusions. We also relied on results from other studies similar to this one, which were described in Section III.

The terms "contaminated" and "non-contaminated", or other such terms used in conjunction with sediments are somewhat arbitrary. Different sources and agencies have different approaches to making these designations. Section V describes the current criteria and approaches that are used by various Federal agencies, EPA regions or states. As a result of these varied approaches, the sites across a region and the country listed in the tables in Appendix A vary greatly in terms of contaminants monitored, procedures of testing and analyses, and concentrations.

An important consideration is the current database that exists on sediment monitoring data. The effort that was made to compile the data in Appendix A was not uniform throughout the EPA regions in the U.S. As a result, certain regions are better represented than others. However, the bias of such non-uniform effort is also partially a function of the non-uniformity of the available data. There are certain regions of the country that have received more intensive study than others, e.g., the Northeastern coast and Great Lakes region. The data available are not statistically rigorous. In some sites, intensive monitoring has occurred over a long period and many samples have been collected. In others, very few data points are available. All these and other issues of concern should be kept in mind when approaching a study of this type. The results and conclusions of this report are qualified by these concerns.

2. How Widespread is the Problem of In-Place Pollutants?

Although it is reasonable to say that there is significant in-place contamination in U.S. waters, it is not possible with the current level of knowledge to quantify the problem. We do not know and cannot even begin to estimate, for example, the river miles affected or the cubic yards of sediment involved. Part of this has to do with limitations on the quality and quantity of the available data, but a larger part is probably associated with not knowing how to define and apply criteria that distinguish between contaminated and uncontaminated sediments. However, from the information we have, it

is possible to attempt some general statements regarding the problem.

In regions of the country where there has been industrialization, the sediments in rivers, estuaries, and harbors serving these regions generally contain elevated concentrations of metals, organic compounds, or other man-made contaminants when compared to levels in "pristine" areas (e.g., open ocean sediments). Every major harbor in the U.S. may be considered to be contaminated from sources upstream and from ship traffic. Similarly, estuaries in industrial areas appear to be contaminated by industrialization and urbanization in these areas. Rivers flowing through major cities are also impacted. Increased industrialization and urbanization in the coastal areas and Great Lakes harbor areas have historically contributed to these areas being more affected than other areas, e.g., upstream portions of rivers. However, some rivers in non-urbanized areas show elevated levels of agricultural chemicals because they receive drainage from agricultural areas. An important qualification in all these generalized statements is that in each location, the actual areas of high contamination may be extremely localized. These localized areas with high levels are often related to the location of the sources of contamination, e.g., at the end of a sewage or industrial outfall. In general, however, they are difficult to identify and pinpoint. Their locations appear to vary due to the movements of currents and other disturbances, e.g., ship traffic or dredging.

The high mobility of sediments in some waterbodies is a complicating issue. Pollutants discharged in the upper reaches of a watershed may travel tens or hundreds of miles before finding a relatively permanent 'home' in an open harbor, lake or bay. Even here, however, permanent or episodic (e.g., storm generated) currents can result in significant sediment redistribution. In some areas, older contaminated sediments may become buried by cleaner material as part of the natural sedimentation process.

Another perspective to describing the extent of in-place contamination is through the impacts of such contamination. By and large, known impacts due directly to in-place pollutants are difficult to identify. Impacts are frequently indirectly observed from effects related to contaminants in the overlying water. In many of the areas where in-place contamination has been noted, there have also been noted or perceived impacts on the aquatic biota and/or water contaminated by the sediments, e.g., the detection of contaminant(s) in biota and one recorded case where an alternative water supply had to be provided for a community because arsenic in sediments in a reservoir affected the water supply. Other cases of potential human health impacts have led to such actions as fishing bans, fish consumption advisories, and swimming bans. In terms of impacts, therefore, the problem of in-place contamination is significant. In instances where all other polluting sources have been regulated, in-place contaminants may be the primary source contributing to the impacts.

The historical record of concentrations of pollutants in sediments shows that in-place contamination has increased rapidly through this century. Figures IV-1a and -1b show, for example, the historical concentration of aliphatic hydrocarbons in Lake Washington sediments, and the historical concentration of mercury in Lake Ontario sediments. The accumulation of pollutants with industrialization is clear from these figures. (Reductions in point source loadings over the last decade may have reduced surface pollutant concentrations from the values shown in the Figures.) The concentration profiles show that the contamination decreases rapidly with depth. The volume of sediments affected in many cases is concentrated only in the surface sediments. This profile, however, may be disturbed by currents, dredging operations, or other disturbances. In some cases, reverse concentration profiles (i.e., showing higher concentrations at depth) are found; this is frequently seen with PCBs in Great Lakes Harbors. In these cases, burial of older contaminated sediments by cleaner material is probably involved.

3. Types of Sites Involved

Figures IV-2a to -2h and Tables IV-1a to -1h indicate the locations of the sites listed in Tables 1-10 in Appendix A. In many cases, several sites were incorporated as one map site because they were close together. It was often difficult to differentiate the sites by type (marine, estuary, etc.) because the water systems are connected. For example, many of the sites in the Great Lakes Region were located at the mouths of rivers that drain into the lake. These were arbitrarily designated as lake sites. There were other similar cases of arbitrary designations.

In all, 184 sites were included in this study: 48 marine, 15 estuaries, 78 river/stream, and 43 lake/reservoir. Table IV-2 shows the locations of these sites by region. From these data, it appears that in-place pollutants occur in all types of water bodies.

The types of water bodies affected tend to be related to the types of activities that are often associated with these areas. Figure IV-3 shows a generalized picture of how sources and water bodies are related. Bays and harbors are associated with sources from shipping, among others. Major cities are usually also located in these areas. Similarly, upper reaches of rivers and streams are polluted by sources that are located in these areas, e.g., mines. Section IV-B discusses the sources of in-place pollutants in greater detail.

In addition to nearby sources, the extent of in-place contamination is also dependent on the characteristics of the sediments. Fine sediments tend to sorb pollutants to a greater degree than coarse sediments because of their higher surface areas. For organics, the organic matter content of the sediments is a very important factor; the higher the organic matter content, the greater the sorption of

(Text continues on p.42)

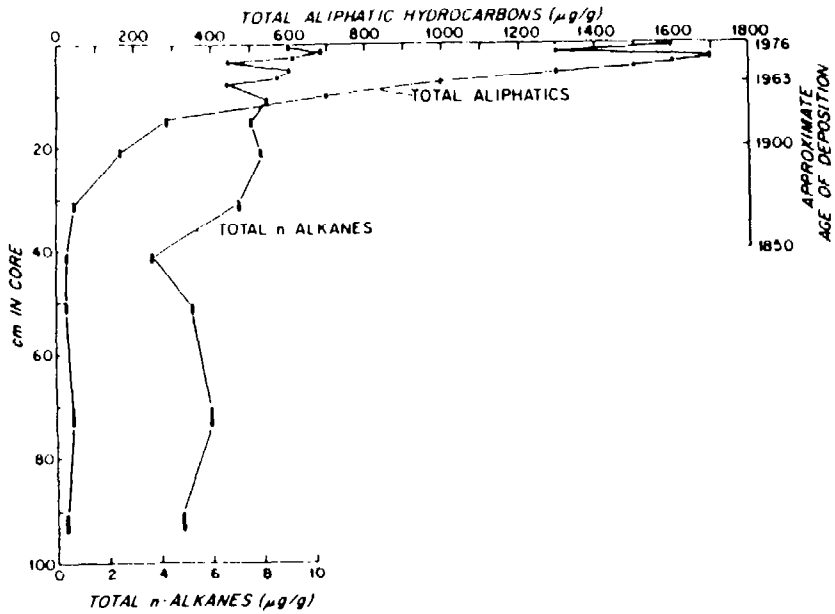


Figure IV-1a Total Aliphatic and n-Alkanes in Sediment Core from Lake Washington, WA

Source: Wakeham and Farrington (1980)

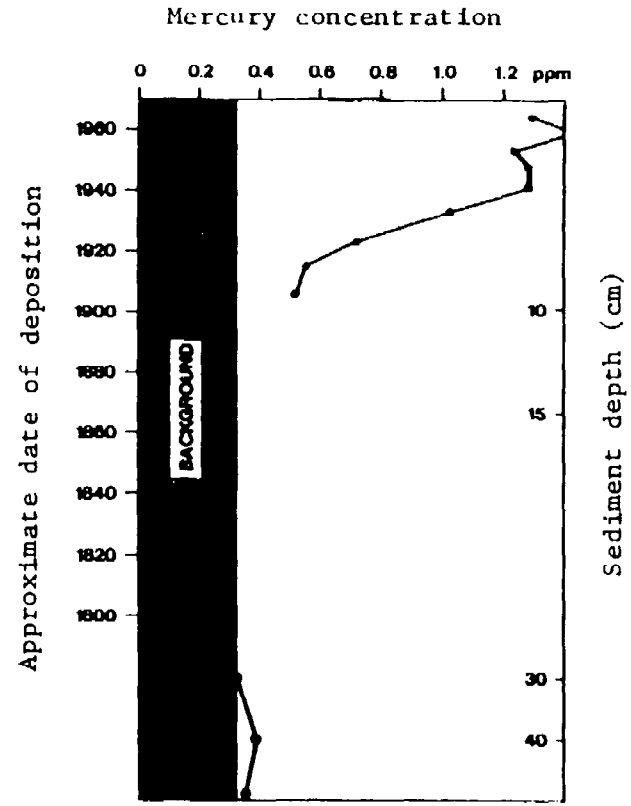


Figure IV-1b Mercury in Sediment Core from Lake Ontario

Source: Forstner and Wittman (1983)

TABLE IV-1a LISTING OF REVIEWED SITES IN EPA REGION I

SITE NUMBER	NAME	TYPE
1	Gulf of Maine, Casco Bay Region	Marine
2	Gulf of Maine, Penobscot Bay Region	Marine
3	Gulf of Maine/Wilkinson Basin, Murray Basin, Franklin Basin	Marine
4	Saco River Estuary, ME	Estuary
5	Kennebec River Estuary, ME	Estuary
6	Sebasticook River, ME	River
7	Pawtucket River, Providence River, RI	River
8	Narragansett Bay, RI	Marine
9	Fishing Rip Shoals, MA	Marine
10	Buzzards Bay, MA	Marine
11	New Bedford Harbor, MA	Marine
12	Falmouth Marsh, MA	Marine
13	Charles River, MA	River
14	French River, MA	River
15	Blackstone River, MA and RI	River
16	Bass River, MA	River
17	Neponset River, MA	River
18	Winthrop Harbor, Dorchester Bay, Boston Harbor, etc.	Marine
19	Silver Lake, MA	Lake
20	Coopers Pond, MA	Lake
21	Mill River, Mill Pond, CT	River
22	Housatonic River, CT	River
23	Eastern Long Island Sound, CT	Marine
24	Branford, Bridgeport, Stamford, New Haven Harbors, CT	Marine
25	Quinhipiac River, CT	River
26	Ten Mile River, MA and RI	River

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

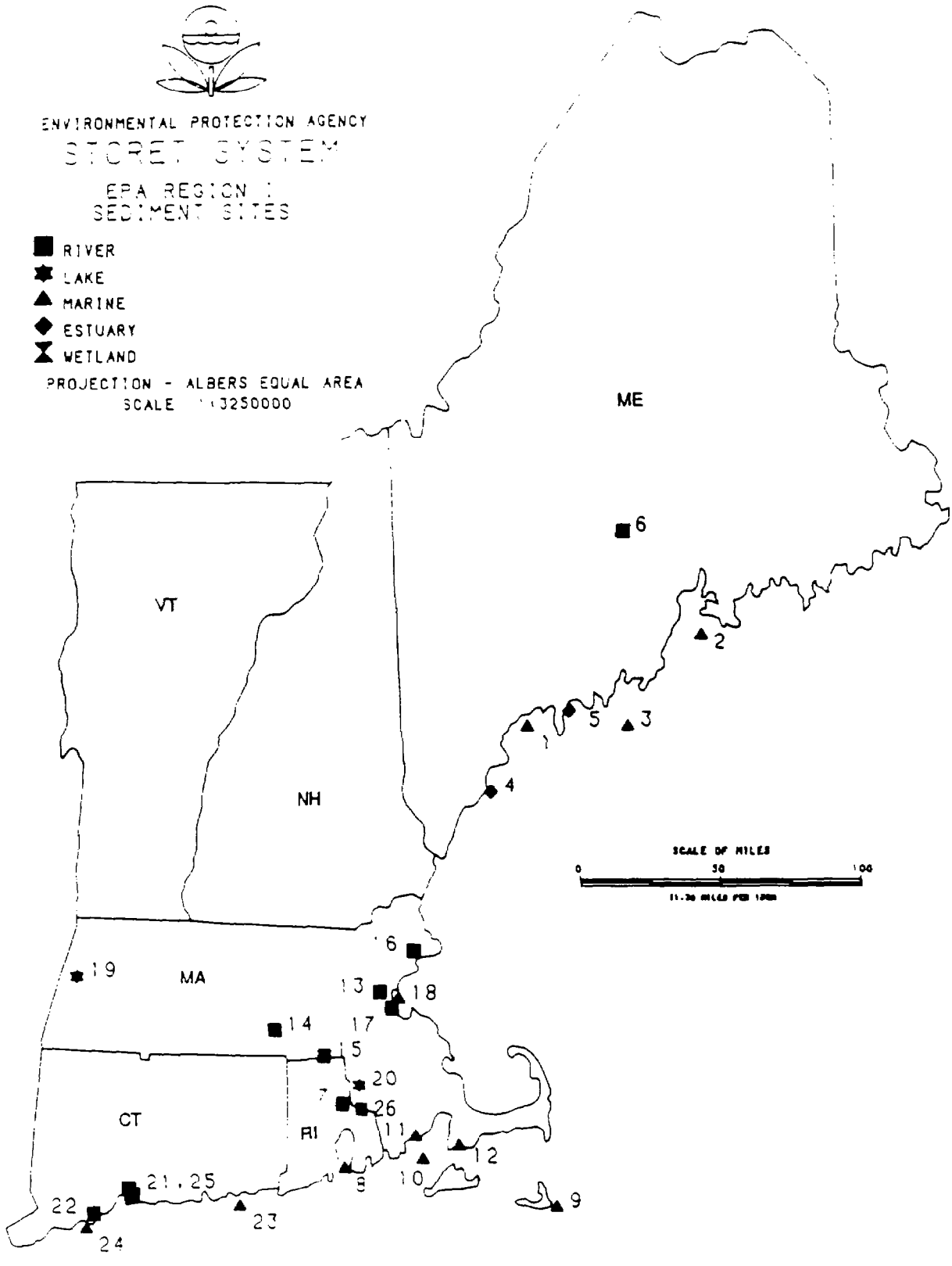


Figure IV-2a. Location of Reviewed Sites in EPA Region I

TABLE IV-1b LISTING OF REVIEWED SITES IN EPA REGIONS II AND III

SITE NUMBER	NAME	TYPE
Region II		
1	Upper Hudson River/Fort Edward, NY	River
2	Hudson River, NY/Tidal Portion	Estuary
3	New York Bight	Marine
4	Long Island Sound	Marine
5	Eastchester Creek (Hutchinson River), NY	River
6	Saw Mill River, Westchester, NY	River
7	Foundry Cove, Cold Spring, NY	River
8	The Saddle River/Near Lodi, NJ	River
9	Lake Ontario/Whole Lake	Lake
10	Lake Ontario/Oswego River and Harbor	River
11	Lake Ontario/Buffalo River, Niagara River	River
12	Lake Ontario/Eighteen Mile Creek, NY	River
13	Lake Ontario/Rochester Embayment, NY	Lake
14	Wine Creek and White Creek, Oswego, NY	River
15	St. Lawrence River, Messena, NY	River
16	Wetlands, Moira, NY	Wetlands
17	Black Creek, Bergholtz Creek, Niagara River, Niagara Falls, NY	River
18	Elizabeth River, Arthur Kill, Elizabeth, NJ	Estuary
19	Cannon Run, North Branch Rancocas Creek, NJ	River
20	Burnt Fly Bog, Marlboro Township, NJ	Wetlands
21	Edwards Run, Delaware River, Gloucester County, NJ	River
22	Maurice River drainage basin, Vineland, NJ	Estuary
Region III		
1	Tinicum National Environmental Center, PA	River
2	Monongahela River, Pittsburgh, PA	River
3	Schuylkill River, PA	Estuary
4	Chesapeake Bay	Marine
5	Baltimore Harbor, MD	Marine
6	James River, Hopewell, VA	Estuary
7	North Fork, Holston River, VA and TN	River
8	South River and South Fork, Shenandoah River, Waynesboro, VA	River
9	Elizabeth River Estuary, VA	Estuary
10	Lynnhaven Estuary, VA	Estuary

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

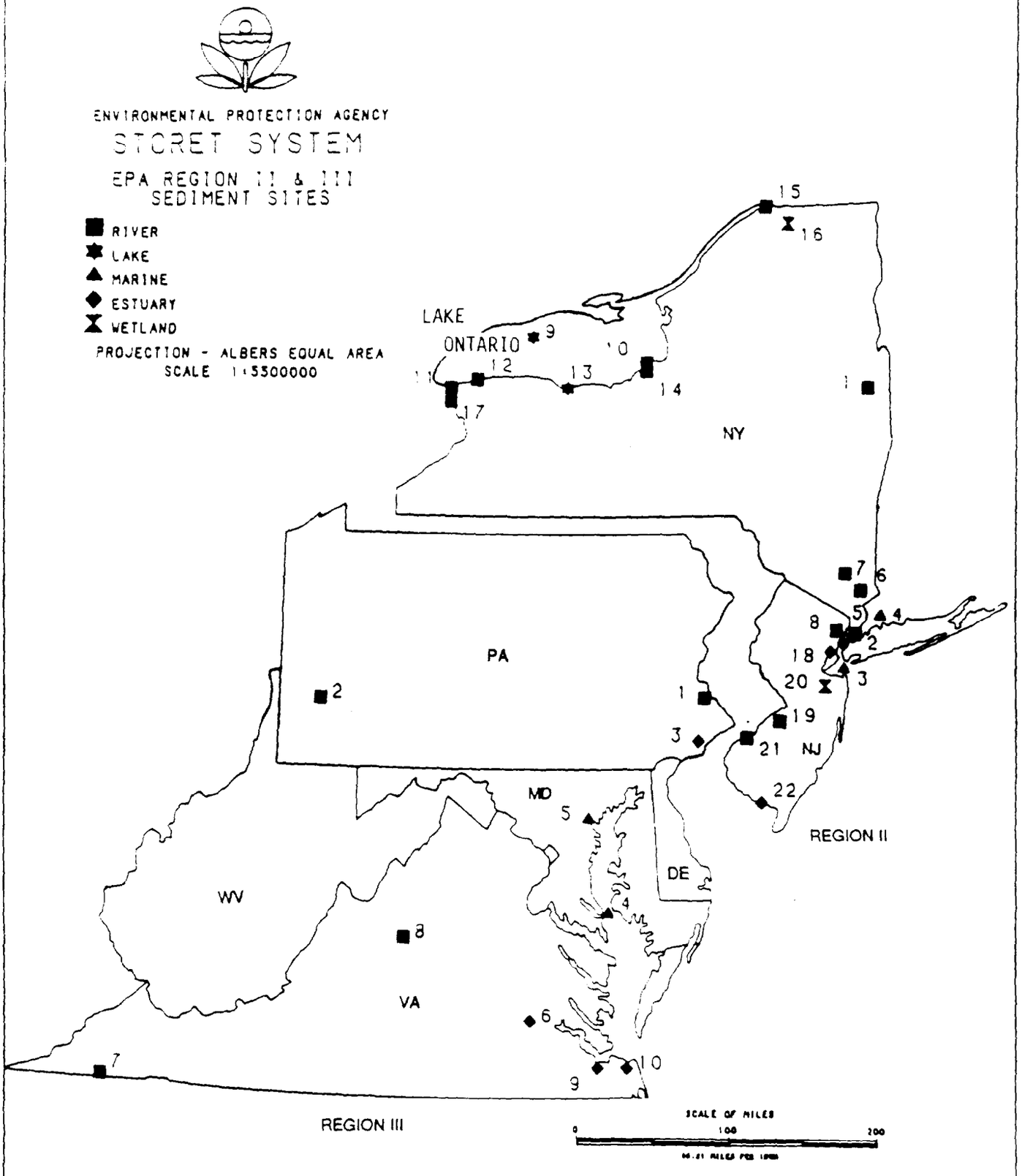


Figure IV-2b. Location of Reviewed Sites in EPA Regions II and III

TABLE IV-1c LISTING OF REVIEWED SITES IN EPA REGION IV

SITE NUMBER	NAME	TYPE
1	Sampit River, Georgetown, SC	Estuary
2	Savannah River Estuary, GA	Estuary
3	Latham Bayou and Loosahatchie River, TN	River
4	Wheeler National Wildlife Refuge, AL	River
5	Redstone Arsenal, Huntsville, AL	River
6	Mobile Harbor, AL	Marine
7	Mississippi Sound, Escatawpa River, Bayou Casotte, Pascagoula River, Biloxi Bay, MS	Marine
8	Escambia Bay, FL	Marine
9	Bayou Chico, Estuary, FL	Estuary
10	Canaveral Port, FL	Marine
11	Ft. Pierce Port, FL	Marine
12	Jacksonville Port, FL	Marine
13	Manatee Port, FL	Marine
14	Miami Port and River, FL	Marine
15	Pensacola Port, FL	Marine
16	Port St. Joe, FL	Marine
17	Tampa Port, FL	Marine
18	West Palm Beach, FL	Marine
19	Hillsborough River, FL	River

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

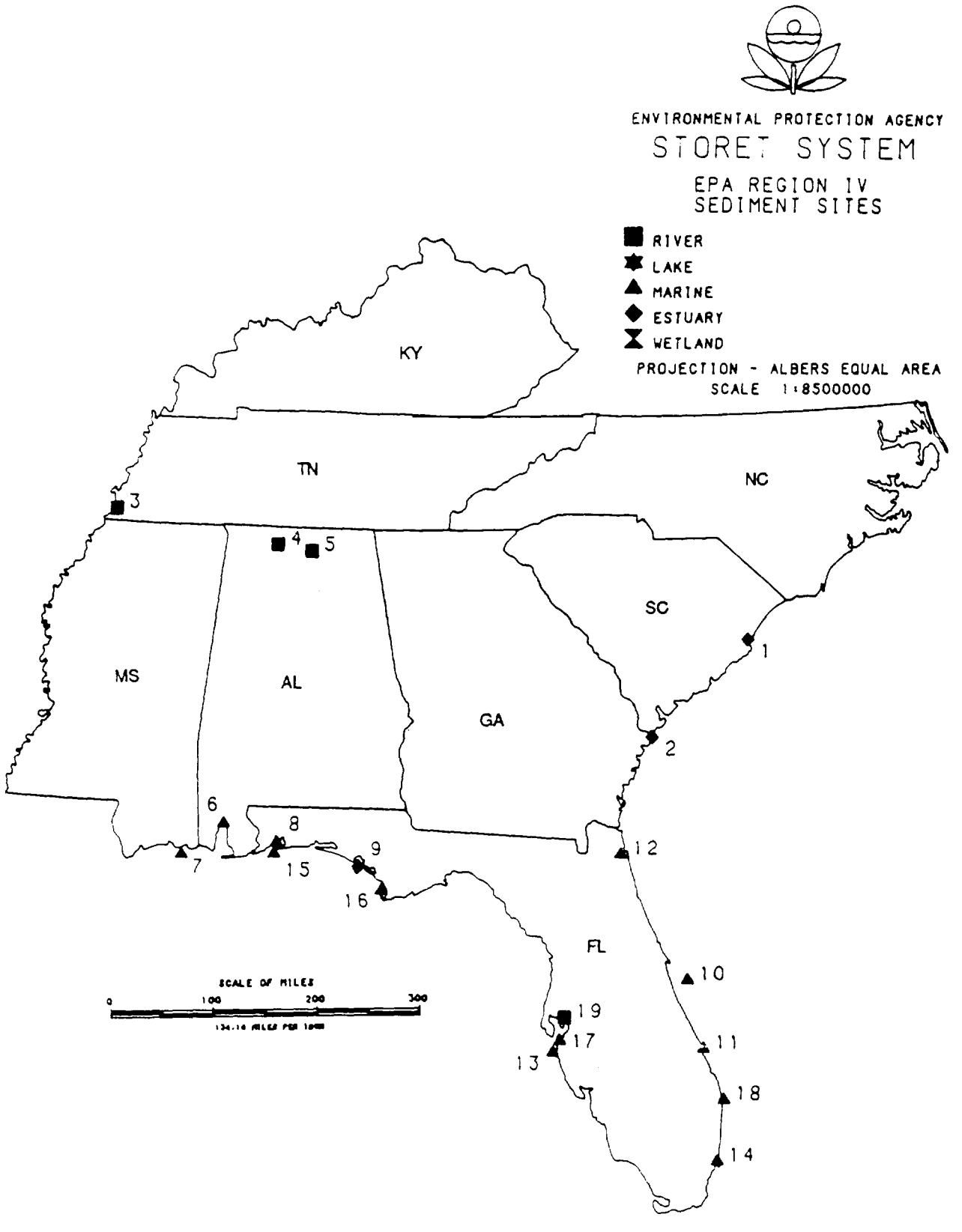


Figure IV-2c. Location of Reviewed Sites in EPA Region IV

TABLE IV-1d LISTING OF REVIEWED SITES IN EPA REGION V

SITE NUMBER	NAME	TYPE
1	Cleveland Harbor, Cuyahoga River, OH	River
2	Lake Erie, Western	Lake
3	Lake Erie, Central	Lake
4	Lake Erie, Eastern	Lake
5	Lake Erie/Maumee River, OH	River
6	Lake Erie/Black River, OH	River
7a	Lake Erie/Ashtabula River and Harbor, OH	River
7b	Detroit River, MI	River
8	Shiawassee River, Howell, MI, South Branch	River
9	Lake Erie/Clinton River, Rouge River, Raisin River, MI	River
10	Lake Huron, Southern	Lake
11	Lake Huron, Saginaw Bay	Lake
12	Lake Huron	Lake
13	Georgian Bay	Lake
14	Lake Michigan, Green Bay	Lake
15	Lake Michigan, Algoma Basin	Lake
16	Lake Michigan, Fox Basin	Lake
17	Lake Michigan, Grand Haven Basin	Lake
18	Lake Michigan, Sarian Basin	Lake
19	Lake Michigan, Southern Basin	Lake
20	Lake Michigan, Traverse Basin	Lake
21	Lake Michigan, Waukegan Basin	Lake
22	Lake Michigan, Manistique River, MI	River
23	Lake Michigan, Menominee River, WI and MI	River
24	Lake Michigan, Sheboygan Harbor	Lake
25	Lake Michigan, Milwaukee Estuary and Basin	Lake
26	Lake Michigan, Kalamazoo River, MI	River
27	Indiana Harbor, Grand Calumet River, East Chicago, IL	River
28	Michigan City Harbor, IN	Lake
29	Lake St. Clair	Lake
30	Lake Superior	Lake
31	Lake Superior, Keweenaw Peninsula	Lake
32	Lake Superior, St. Louis River, MN	River
33	Lake Superior, Torch Lake, MI	Lake
34	Lake Superior, Deer Lake, Carp Creek, Carp River	River

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

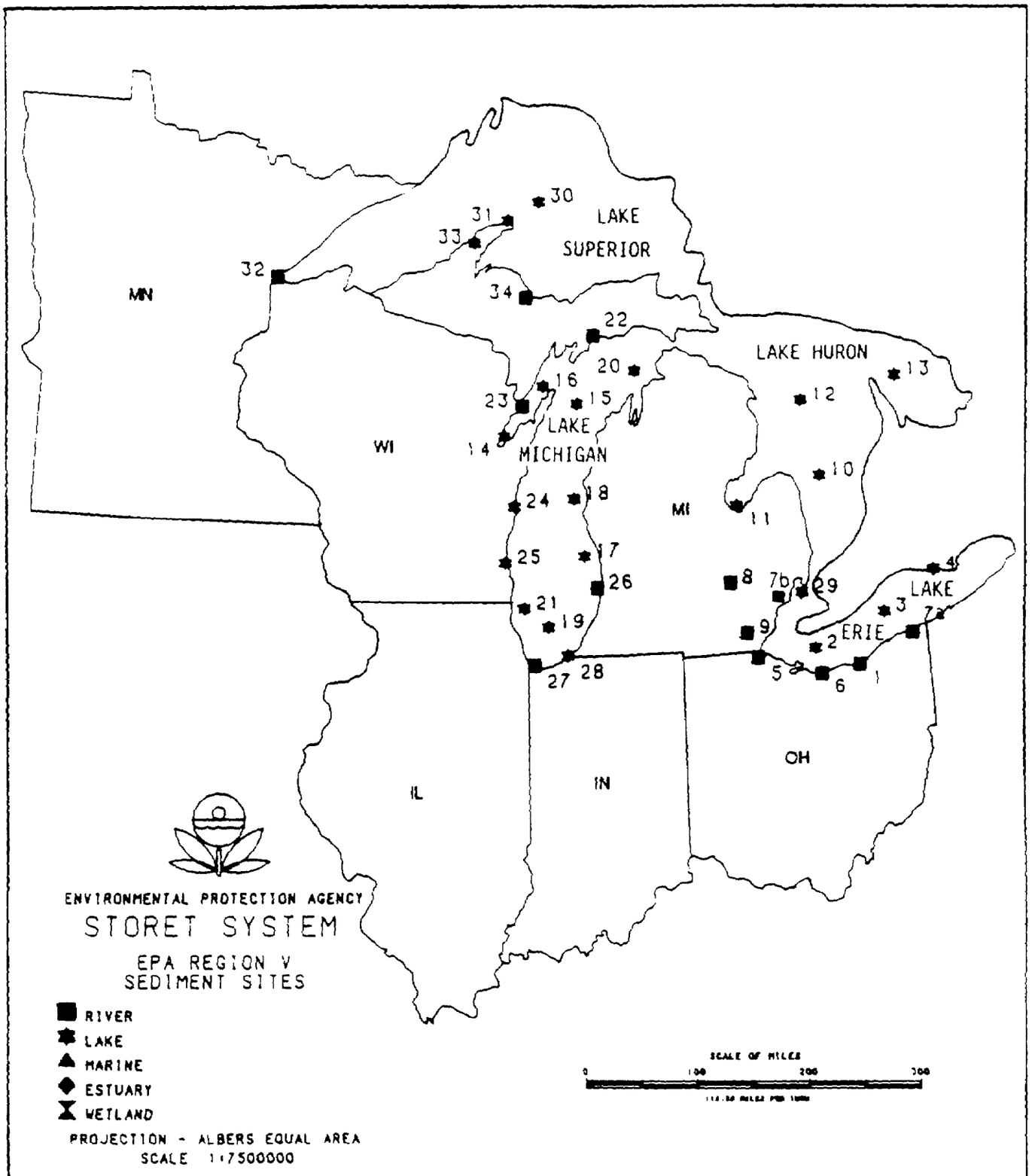


Figure IV-2d. Location of Reviewed Sites in EPA Region V

TABLE IV-1e LISTING OF REVIEWED SITES IN EPA REGION VI

SITE NUMBER	NAME	TYPE
1	Aransas National Wildlife Refuge, TX	Marine
2	Laguna Atascosa National Wildlife Refuge, TX	Marine
3	Corpus Christi Harbor and Ship Channel, TX	Marine
4	Gulf Intracoastal Waterway, Tx/San Antonio Bay to Aransas Bay	Marine
5	Sabine Neches Waterway and Neches River, TX	Marine
6	Houston Ship Channel	Marine
7	Lavaca Bay, TX	Marine
8	Petronila Creek, TX	Marine
9	Rio Grande, Presidio, TX	River
10	Double Mountain Fork of Brazos River, North Fork, Lubbock, TX	River
11	Finfeather and Municipal Country Club Lakes, Bryan, TX	Lake
12	Mountain Creek Lake, Dallas, TX	Lake
13	Trinity River, TX	River
14	Crutcho and Soldier Creeks, Oklahoma City, OK	River
15	Mississippi River, Shell Beach, LA, Gulf Outlet	River
16	Lake Pontchartrain, LA	Marine
17	Capitol Lake, Baton Rouge, LA	Lake
18	Lake St. John, Northeastern LA	Lake
19	Lake Bruin, Northeastern LA	Lake
20	Lake Providence, Northeastern LA	Lake
21	Middle Rio Grande, NM/Elephant Butte Reservoir and Caballo Reservoir	Lake

Site numbers are used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

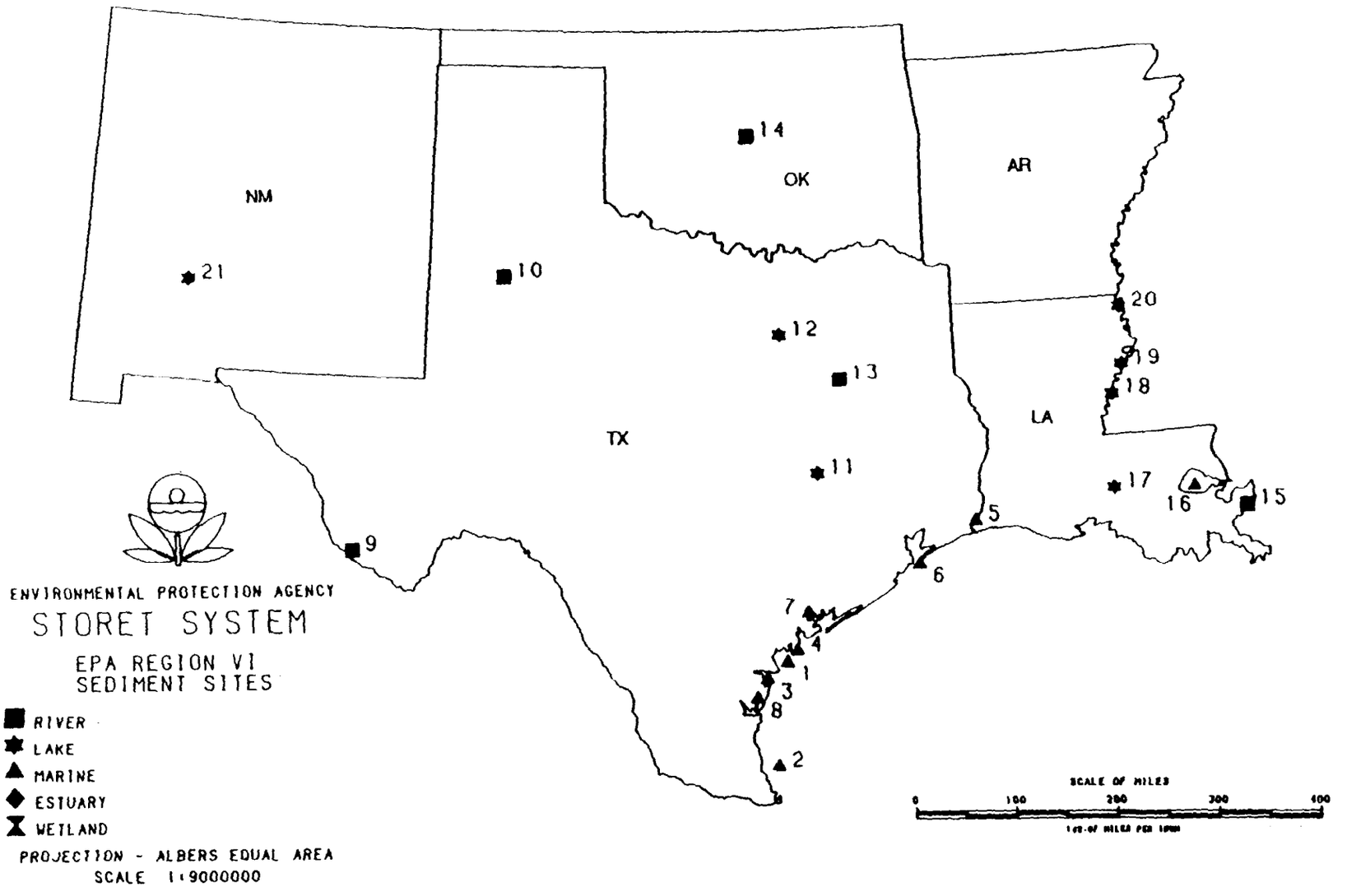


Figure IV-2e. Location of Reviewed Sites in EPA Region VI

TABLE IV-1f LISTING OF REVIEWED SITES IN EPA REGIONS VII AND VIII

SITE NUMBER	NAME	TYPE
Region VII		
1	Cedar Lake, Cedar Rapids, Iowa	Lake
2	Mississippi River and Romaine Creek, St. Louis, MO	River
3	Swope Park Lakes, Kansas City, MO	Lake
4	Squaw Creek National Wildlife Refuge, MO	River
5	Gum Spring Creek, Wolf Creek, Granby, MO	River
6	Shoal Creek, Joplin West, Center Creek, MO-KS	River
7	Missouri River, Omaha, NE	River
8	Spring River, MO	River
9	Big River near Desloge, MO, Irondale-Brown's Foprd, MO	River
10	St. Francis River Basin, near Farmington and Fredericktown, MO	River
11	Tebo Creek, Henry County, MO	River
12	North Claybank Creek, Macon County, MO	River
13	Blue River, near Kansas City, MO	River
14	Local surface waters, St.Louis, MO	River
15	Pin Oak Creek, Johnson County, MO	River
16	Mississippi River Side Channel, Clinton, IA	River
17	Mississippi River Side Channel, Davenport, IA	River
18	Cedar River near Charles City, IA	River
Region VIII		
1	Benton Lake National Wildlife Refuge, MT	Lake
2	Freezout Lake, MT	Lake
3	Lake Bowdoin, MT	Lake
4	Silverbow Creek/Upper Clark Fork, Butte, MT	River
5	Milltown Reservoir, MT	Lake
6	Clark Fork River near Frenchtown, MT	River
7	Prickly Pear Creek/Spring Creek, Jefferson City, MT	River
8	Columbus, MT	River
9	Whitewood Creek, Belle Fourche River, Cheyenne River, South Dakota	River
10	Laramie River, WY, Wheatland Res. No. 2 - Laramie	River
11	Little Popo Agie River, WY	River
12	Jordan River near Salt Lake City, UT	River
13	Upper Arkansas River, California Gulch, Yak Tunnel, Leadville, CO	River
14	Missouri River, near Williston, ND	River
15	James River, ND and SD	River

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

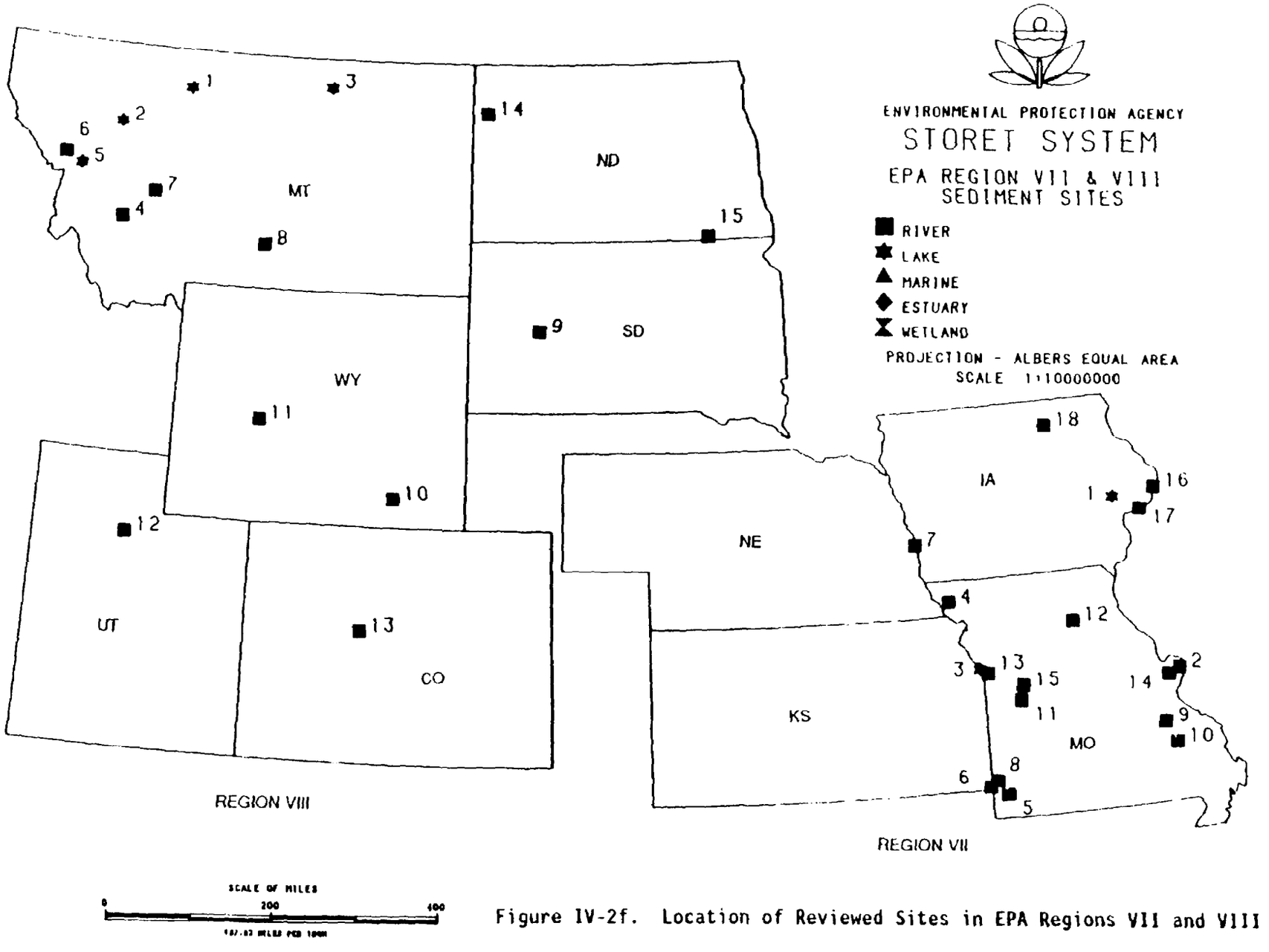


Figure IV-2f. Location of Reviewed Sites in EPA Regions VII and VIII

TABLE IV-1g LISTING OF REVIEWED SITES IN EPA REGION IX

SITE NUMBER	NAME	TYPE
1	Kesterson National Wildlife Refuge, CA	Lake
2	Stillwater Wildlife Management Area, NV	River/Lake
3	San Francisco Bay, CA	Marine
4	Southern Coastal California*	Marine
5	San Diego Harbor, CA	Marine
6	Blanco Drain, Salinas/Monterey Bay area, CA	River
7	Elkhorn Slough, tributary to Monterey Bay, CA	River
8	Monterey Harbor, CA	Marine
9	Urban Lakes, LA, CA	Lake
10	Los Angeles/Long Beach Harbor, CA	Marine
11	Santa Monica Bay, CA	Marine
12	Newport Bay, CA	Marine

Site numbers used to show locations on following map. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

* The Southern California Bight encompasses a very large area. Although it is shown here, for convenience, as a single site, it is actually comprised of several "sites" related to municipal and industrial outfalls, river discharges, off-shore oil development, and other sources. Additional details on available data are contained in a report by Tetra Tech (1986).

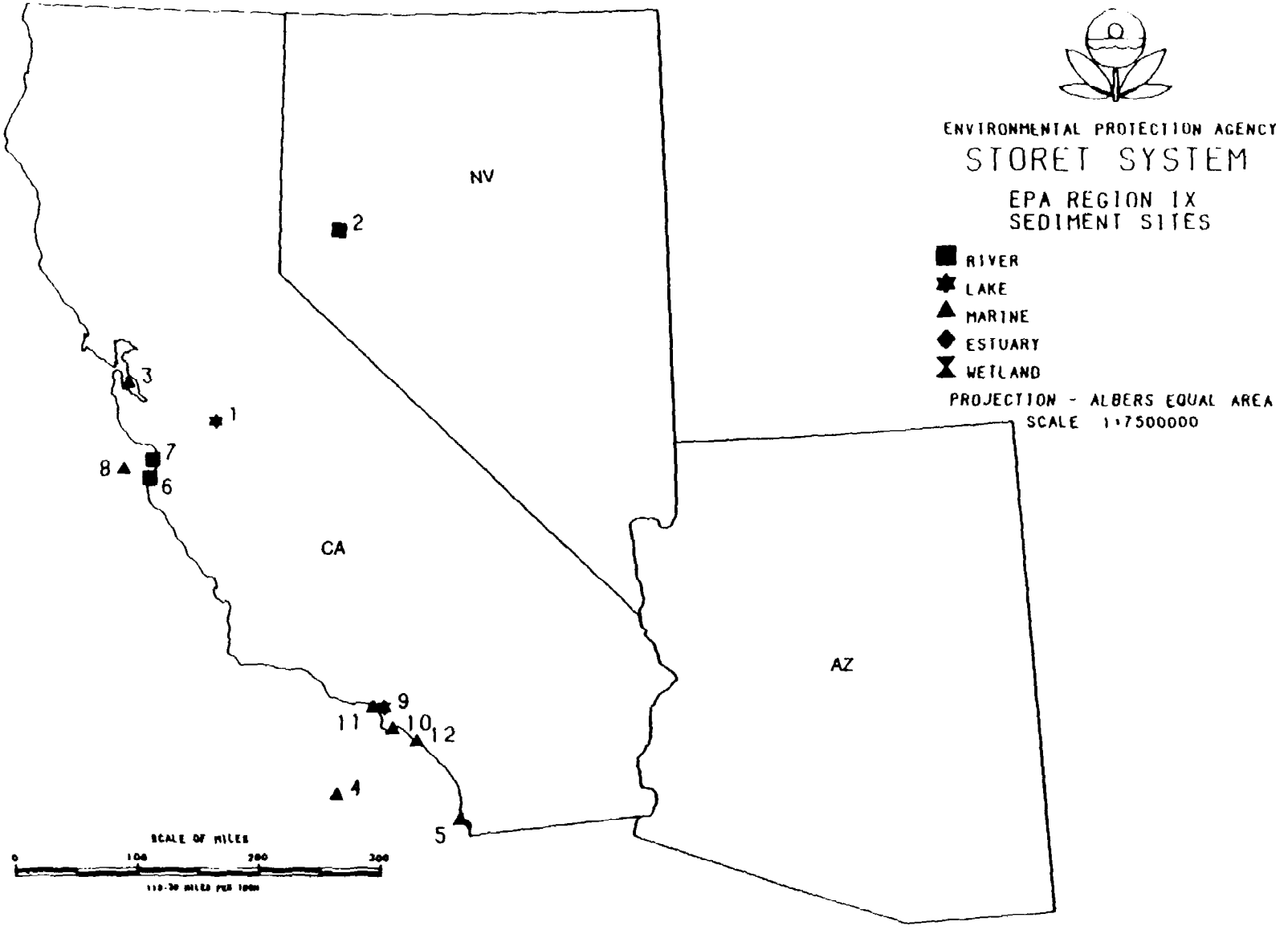


Figure IV-2g. Location of Reviewed Sites in EPA Region IX

TABLE IV-1h LISTING OF REVIEWED SITES IN EPA REGION X

SITE NUMBER	NAME	TYPE
1	Duwamish Waterway, Seattle, WA	Marine
2	Commencement Bay, Tacoma, WA	Marine
3	Everett Harbor, WA	Marine
4	Puget Sound, WA/Colvos Passage and Southern Puget Sound	Marine
5	Alaska Maritime Nat. Wildlife Refuse, AK, Woman's Bay	Marine
6	Alaska Maritime Nat. Wildlife Refuse, AK, Anchitka and Atka Is.	Marine

Site numbers used to show locations on following map. Alaskan sites not mapped. The same numbers are also used in Tables 1-10 of Appendix A where detailed information on the sites are given.

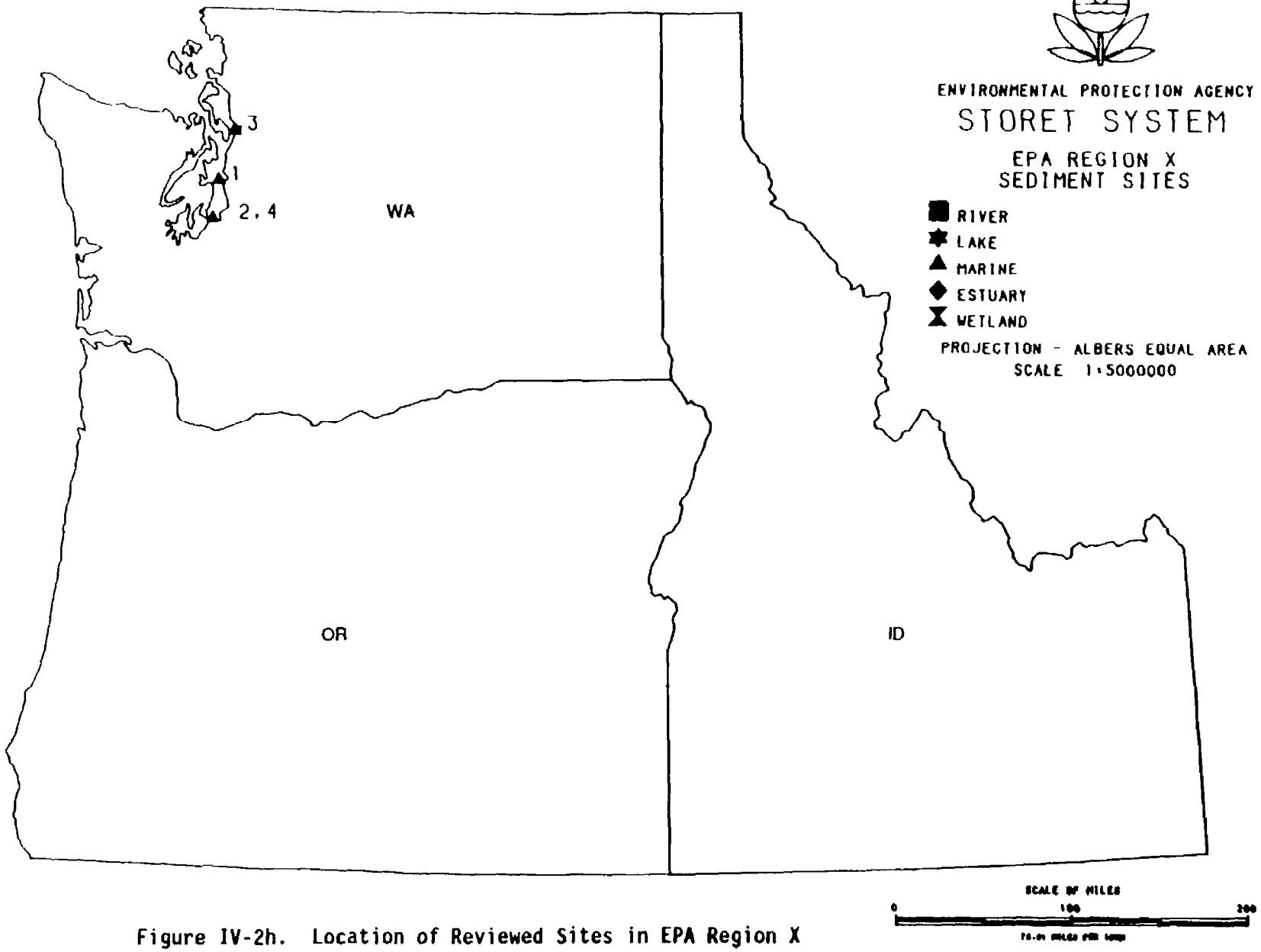


Figure IV-2h. Location of Reviewed Sites in EPA Region X

TABLE IV-2. NUMBER OF REVIEWED SITES BY TYPE AND REGION

Region	Marine	Estuarine	River/Stream	Lake/Reservoir	Total
I	11	3	10	2	26
II	2	3	13	4*	22
III	2	4	4	0	10
IV	12	3	4	0	19
V	0	0	13	22	35
VI	8	2	4	7	21
VII	0	0	16	2	18
VIII	0	0	11	4	15
IX	7	0	3	2	12
X	6	0	0	0	16
TOTAL	48	15	78	43	184

* Including 2 classified as wetlands.

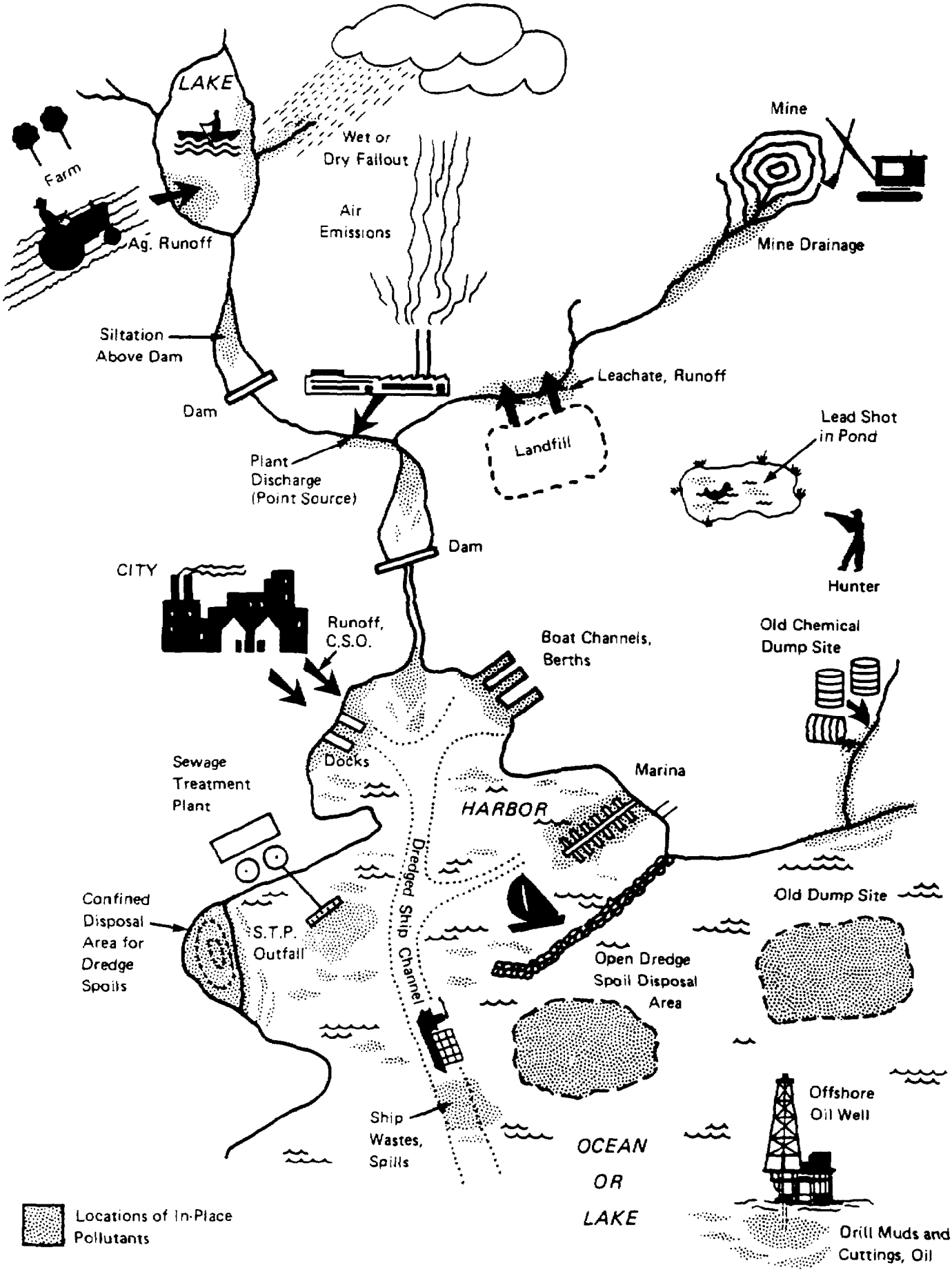


FIGURE IV-3 SOURCES AND SINKS OF CONTAMINATED SEDIMENTS

organics would be. However, this enhanced sorption may reduce the bioavailability of the pollutants to aquatic life.

Areas where sediments tend to settle are also prime locations for sediment contamination. These areas include reservoirs, other impoundments, and lakes where the flow of a river is appreciably slowed. Sediments that are contaminated by upstream sources are carried to the reservoir, impoundment, or lake and deposited there. As rivers flow toward the ocean, the rate of flow becomes slower and sediments are deposited. Also, the interaction with salt water can cause the flocculation and sedimentation of pollutant-laden suspended sediments, and the precipitation and/or increased sediment sorption of other pollutants due to oxidation (e.g., of metals) or the "salting out" effect. Because of these effects, estuaries and deltas become depositories of pollutants from upstream.

4. Types of Pollutants Involved

From the pollutants mentioned in each of the sites shown in Tables 1-10 in Appendix A, a summary table of contaminants and their frequency of occurrence is shown in Table IV-3. Heavy metals and metalloids (e.g., arsenic) are the most frequently mentioned contaminants; 69 percent of the sites showed the presence of at least one heavy metal or metalloid. PCBs were mentioned in 34 percent of the sites; PAHs, 19 percent; pesticides, 26 percent; and other organics, 25 percent. The pesticides most frequently found are DDT and its derivatives, dieldrin, and chlordane. Some classes of contaminants were rarely mentioned, e.g., biological and radiological pollutants.

The above observations regarding pollutants and their frequency of occurrence seem to be similar to those from other studies. Table IV-4, taken from the study of Bolton et al. (1985), shows the number of sites that were contaminated with various pollutants. Metals again appear in many sites. PCBs and PAHs were also found in many sites. Table IV-5, adapted from the same study, shows the sites containing the highest levels of at least one pollutant. This table shows that heavy metals, PAHs, PCBs, and DDT are found at high levels. Johanson and Johnson (1976) studied the harbors and navigable waterways in the country. Table IV-6 shows heavy metals, PCBs, oil and grease, and DDT to be the most frequent contaminants in these sites. Tables IV-7 and IV-8, from two other studies (Science Applications Corp. 1985 and U.S. Fish and Wildlife Service 1986), show similar contaminants. Pentachlorophenol, creosote, cyanide and a few other chemicals occur in a few sites.

The ranges of concentrations of contaminants found in all the sites from Tables 1-10 in Appendix A are very wide. It was not the purpose of this study to provide a statistical analysis of the concentrations found. Table IV-9 and Figures IV-4a to -4h, adapted from Bolton et al. (1985), show the concentrations that were obtained from the data in their study. Since that study was based

(Text continues on p 54)

TABLE IV-3. TYPES OF POLLUTANTS IN CONTAMINATED SEDIMENTS AT REVIEWED SITES

	Heavy Metals & Metalloids		PCBs		PAHs		Pesticides		Other Organics[a]		Biological	
Region	Frequency[b]	%[c]	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
I	19	73	9	35	9	35	1	4	8	31	0	0
II	16	73	8	36	3	14	4	18	6	22	0	0
III	6	60	4	40	3	30	4	40	1	10	1	10
IV	14	74	1	5	4	21	3	16	2	10	0	0
V	21	60	15	43	4	11	14	40	12	34	0	0
VI	14	67	7	33	4	19	9	43	6	29	0	0
VII	11	61	3	17	1	6	2	11	3	17	0	0
VIII	12	80	4	27	0	0	3	20	3	20	0	0
IX	8	67	6	50	0	0	8	67	2	17	0	0
X	4	100	4	100	4	100	0	0	2	50	0	0
TOTAL	125	69	61	34	34	19	48	26	45	25	1	0.5

a. Includes oil and grease, hydrocarbons, volatile organics, phenols, base/neutrals, dioxin.
b. "Frequency" is the number of sites where the pollutant(s) was mentioned.
c. Percentage of sites with these pollutants.

TABLE IV-4. NUMBER OF SITES IN THE U.S. SHOWING SEDIMENT CONTAMINANTS AT DIFFERENT LEVELS*

	Level 4	Level 3	Level 2	Level 1	No Value Available
AROMATIC HYDROCARBONS					
Acenaphthalene	0	0	0	1	44
Acenaphthene	0	0	0	1	44
Anthracene	0	0	0	9	36
Benzene	0	0	0	1	44
Benzo(a)anthracene	0	0	0	11	34
Benzo(a)pyrene	0	0	0	4	41
Benzo(k)fluoranthene	0	0	0	3	42
Chrysene	0	0	0	4	41
Dinitrotoluene	0	0	0	0	45
Ethylbenzene	0	0	0	4	41
Fluorene	0	0	0	4	41
Indeno(1,2,3)pyrene	0	0	0	2	43
Napthalene	0	0	1	10	34
Nitrobenzene	0	0	0	1	44
Phenanthrene	0	0	0	14	31
Pyrene	0	0	0	8	37
Toluene	0	0	0	5	40
PAH	14	6	6	12	7
TOTAL AROMATIC HYDROCARBONS	14	6	7	94	689
PESTICIDES					
Aldrin	0	0	0	44	93
Chlordane	0	0	0	2	135
DDD	0	0	0	32	105
DDE	0	0	0	27	110
DDT	4	1	2	6	124
Heptachlor	0	0	0	0	137
Isophorone	0	0	0	14	123
Lindane	0	0	0	1	136
Toxaphene	0	0	0	0	137
TOTAL PESTICIDES	4	1	2	126	1100

(continued)

TABLE IV-4. NUMBER OF SITES IN THE U.S. SHOWING SEDIMENT CONTAMINANTS AT DIFFERENT LEVELS* (continued)

	Level 4	Level 3	Level 2	Level 1	No Value Available
OTHER CHLORINATED HYDROCARBONS					
Dichlorobenzene	0	0	0	1	136
Hexachlorobutadiene	0	0	0	1	136
Hexachlorethane	0	0	0	0	137
Methylchloride	0	0	0	0	137
Methylenechloride	0	0	0	3	134
Tetrachloroethylene	0	0	0	2	135
Trichloroethylene	0	0	0	4	133
PCBs	1	8	15	106	7
TOTAL OTHER CHLORINATED HYDROCARBONS	1	8	15	117	955
METALS					
Arsenic	1	0	4	30	68
Cadmium	1	0	2	79	21
Chromium	5	7	16	8	67
Copper	2	3	8	39	51
Lead	0	7	14	69	13
Mercury	2	7	19	28	47
Nickel	0	2	23	14	64
Zinc	0	2	5	69	27
TOTAL METALS	11	28	91	336	358
PHTHALATES					
Butylbenzyl phthalate	0	0	0	0	103
Diethylphthalate	0	0	0	4	99
Dimethylphthalate	0	0	0	1	102
Di-N-butylphthalate	0	0	0	7	96
TOTAL PHTHALATES	0	0	0	12	400

* Level 1 - Sediment concentrations less than threshold value.
Level 2 - 1 to 3 times threshold value.
Level 3 - 3 to 10 times threshold value.
Level 4 - Greater than 10 times threshold value.
Threshold values are primarily based on EPA water quality criteria and assumed sediment-water equilibrium partitioning. Please see III-E for further details.

Source: Bolton et al. (1985)

TABLE IV-5. COASTAL U.S. REGIONS CONTAINING AT LEAST ONE POLLUTANT IN SEDIMENTS AT CONCENTRATIONS EXCEEDING PROVISIONSAL THRESHOLD VALUES BY MORE THAN TEN-FOLD (LEVEL 4)*

Water Body Location	Contaminant(s) At Level 4	Other Contaminant(s) At Site
LA County Wastewater Treat. Plant Outfall,CA	DDT	PCBs
Palos Verdes Whites Point Outfall, CA	DDT	
Palos Verdes Penn. JWPCP Outfall System, CA	DDT	Cr,Cu,Hg,Ni
San Francisco Bay, Beemar Point, CA	Cd	
LA City, Hyperion Outfall, CA	Cr	Cu,Hg,Ni
Joint Water Poll. Cont. Monitoring Zone, CA	Cr	Ni,Cu,Pb,Hg
Palos Verdes Shelf, CA	Cr	Cu,Pb,Ni,Cd,Zn
Quinhipiac River, CT	Hg	
Charles River, Boston, MA	PAH	
Boston Harbor, MA	PAH	Hg
Achushnet River/New Bedford Harbor, MA	PCBs,Cu	
Patapso Estuary, Baltimore Harbor, MA	Cr	Cu,Pb,Ni,Zn
Arthur Kill, NJ	PAH	Pb,Hg,PCBs,Zn,As
Newark Bay, NJ	PAH, PCBs	Hg,Pb
New York Bight, NY	PAH	PCBs
East River, NY	PAH	
Newton Creek, NY	PAH (total)	Napthalene,PCBs
Gowanus Canal, NY	PAH (total)	PCBs
Lower Bay, NY	PAH (total)	DDT,PCBs
Sewage Sludge Dumpside, NY	DDT	PCBs,Cr,PAH,Pb,Hg,Ni
Hudson River, NY	PCBs	Pb,DDT,Cu
Providence River, RI	Cr	Cu
Corpus Christi Channel, TX	Hg	Cr,Pb,Zn
Puget Sound: Commencement Waterways, WA	PAH,As	Cr,Ni
Puget Sound: Duwamish Waterway	PAH	PCBs,Cr,Ni
Puget Sound: West Point	PAH	PCBs
Puget Sound: Seattle Waterfront	PAH	PCBs
Puget Sound: Hylebos Waterway	PAH	PCBs

*Level 4 indicates concentrations greater than 10 times threshold value. Threshold values are primarily based on sediment-water equilibrium partitioning. Please see Section III-E for further details.

Source: Bolton et al. (1985)

TABLE IV-6. LIST OF LOCATIONS WITH CONTAMINATED SEDIMENTS - 1976

Water Body	Contaminant(s)
Priority 1*	
Detroit River, MI	heavy metals, oil & grease
Baltimore Harbor, MD	heavy metals
Indiana Harbor, IN	heavy metals, cyanide, oil & grease
Duwamish Waterway, Seattle, WA	heavy metals, PCB, oil & grease
Michigan City Harbor, IN	heavy metals, oil & grease
San Francisco Harbor, CA	heavy metals, PCB, oil & grease
Priority 2*	
Bridgeport Harbor, CT	heavy metals, DDT, PCB, oil & grease
New Bedford Harbor, MA	heavy metals, DDT, PCB, oil & grease
Corpus Christi Harbor, TX	heavy metals, oil & grease
Priority 3*	
Providence River and Harbor, RI	heavy metals
New Haven Harbor, CT	heavy metals
Eastchester Creek, NY	heavy metals
Newark Bay, NJ	heavy metals
Sampit River, Georgetown, SC	Pb
Monongahela River above Pittsburg, PA	Pb
Mississippi River below St. Louis, MO	heavy metals
Cleveland Harbor and Cuyahoga River, OH	heavy metals, cyanide
Milwaukee Harbor, WI	heavy metals
Neches Waterway, Beaumont, TX	Pb
Richmond Harbor CA	Hg
Oakland Harbor, CA	heavy metals, oil & grease
Los Angeles Harbor, CA	heavy metals
San Diego Harbor, CA	heavy metals

*Priority 1 sites are those regarded as deserving the most consideration for clean-up funds under Section 115 of the Federal Water Pollution Control Act. Priority 2 and Priority 3 sites are those deserving less consideration. The findings and recommendations of this report, now over 10 years old, might not be considered very pertinent for any current policy decisions on clean-up, but they do add weight to the conclusion that harbors are amongst the most impacted areas, and that a variety of inorganic and organic pollutants are involved. Please see Section III-E for further details on the study.

Source: Johanson and Johnson (1976)

TABLE IV-7. WATER BODIES AND LOCATIONS WITH CONTAMINATED SEDIMENTS

Water Body	Location	Contaminant(s)
Duwamish Waterway	Seattle, WA	PCB
Gulf outlet of Mississippi River	Shell Beach, LA	PCP
James River	Hopewell, VA	Kepone
Mill River	Fairfield, CT	Lead
North Fork Holston River	Saltville, VA	Mercury
South Branch of the Shiwassee River	Howell, MI	PCB
South and South Fork Shenandoah Rivers	Waynesboro, VA	Mercury
Stamford and New Haven Harbors	Stamford and New Haven, CT	Heavy Metals
Commencement Bay	Tacoma, WA	Various
Fox River	Wisconsin	PCB
Sheboygan Harbor	Sheboygan, WI	PCB
Milwaukee Harbor	Milwaukee, WI	PCB
Elizabeth River	Portsmouth, VA	PAHs
Upper Hudson River	Fort Edward, NY	PCB
Waukegan Harbor	Waukegan, IL	PCB
Little Menomonee River	Milwaukee, WI	Creosote
New York Bight	New York, NY	Heavy metals, PCB

(continued)

TABLE IV-7. WATER BODIES AND LOCATIONS WITH CONTAMINATED SEDIMENTS (Continued)

Water Body	Location	Contaminant(s)
Whitewood Creek	Deadwood, SD	Arsenic-contaminated tailings
Housatonic River	MA and CT	PCB
Lake Dupree	Jacksonville, AR	Agent Orange
Bayou Bonfouca	Slidell, LA	Creosote
Puerco River	Churchrock, NM	Uranium tailings
Cottonwood Creek	Edgewood, SD	Uranium tailings
Baltimore Harbor	Baltimore, MD	Heavy metals
Fields Brook, Ashtabula River, and Ashtabula Harbor	Ashtabula, OH	PCB, Heavy metals
Black River and Lorain Harbor	Lorain, OH	Coal tars, Napthalene
Kalamazoo River	Kalamazoo, MI	PCB
Tittabawasee River	Midland, MI	PCB, PBB
Indian Creek and Wheeler Reservoir	Alabama	DDT
Grand Calumet River and Indiana Harbor Canal	Indiana	PCB
Raisin River	Adrian, MI	Curene 442, Anilines
Pine River and Reservoir	St. Louis, MI	PBB

Please see Section III-E for a brief description of this study by Science Applications International Corp.

Source: Science Applications International Corp. (1985)

TABLE IV-8. SUMMARY OF SEDIMENT CONTAMINATION IN NATIONAL WILDLIFE REFUGES IN THE UNITED STATES

EPA Region	Name of Site	Contaminants in Sediments
III	Tinicum National Env. Center, PA/ Creeks and Marsh	heavy metals, pesticides, cyanide, PCBs, chlordane, PAHs
IV	Wheeler National Wildlife Refuge, AL/ Huntville Spring Branch of Indian Creek	DDT & metabolites
VI	Aransas National Wildlife Refuge, TX/ Bay areas adjacent to refuge	heavy metals (Hg,As,Cd,Zn), PAHs
	Aransas National Wildlife Refuge, TX/ Burgentine Lake	oil & grease, pesticides
	Laguna Atascosa Nat. Wildlife Refuge, TX	Agricultural chemicals (incl. DDE, toxaphene), heavy metals (incl. Se)
VIII	Benton Lake National Wildlife Refuge, MT/Benton Lake	Se
IX	Kesterson National Wildlife Refuge, CA/Kesterson Ponds	Se, other trace metals
	Stillwater Wildlife Mgt. Area, NV/ Paiute Drain, Carson River, Lahontan Reservoir	Se,As,Hg

Please see Section III-E for a brief description of this study by the U.S. Fish and Wildlife Service.

Source: U.S. Fish and Wildlife Service (1986)

TABLE IV-9. CONCENTRATIONS (PPM) OF POLLUTANTS FOUND IN FRESHWATER SEDIMENT

Pollutant	"Threshold Value"*	Sediment Concentration	
		Median	95th Percentile
Metals			
Copper	136	4.0	32
Lead	132	16	199
Mercury	0.8	< 1.0	1.0
Zinc	760	41	379
Nickel	20	13	99
Arsenic	33	4.0	39
Cadmium	31	1.0	12
Polynuclear Aromatic Hydrocarbons			
Acenaphthalene	24	0.6	4.3
Anthracene	44	0.5	4.5
Benzo(a)anthracene	220	0.01	0.014
Fluorene	28	0.6	4.5
Phenanthrene	56	0.6	5.6
Phthalate Esters			
Diethylphthalate	1.28	0.4	5.62
Dimethylphthalate	1.96	0.5	4.47
Pesticides			
Aldrin	0.021	0.0001	0.03
Chlordane	0.020	0.001	0.097
DDT	0.006	0.0004	0.015
Heptachlor	0.020	----	0.006
Lindane	0.0124	0.0006	0.012
Toxaphene	0.020	----	0.044

*Threshold values are primarily based on EPA water quality criteria and assumed equilibrium sediment-water partitioning. Please see Section III-E for further details.

Source: Bolton et al. (1985)

FIGURE IV-4 Cumulative Frequency Plots

(Note: See Tables IV-4 and -9, and Section III-E for information on threshold values.)

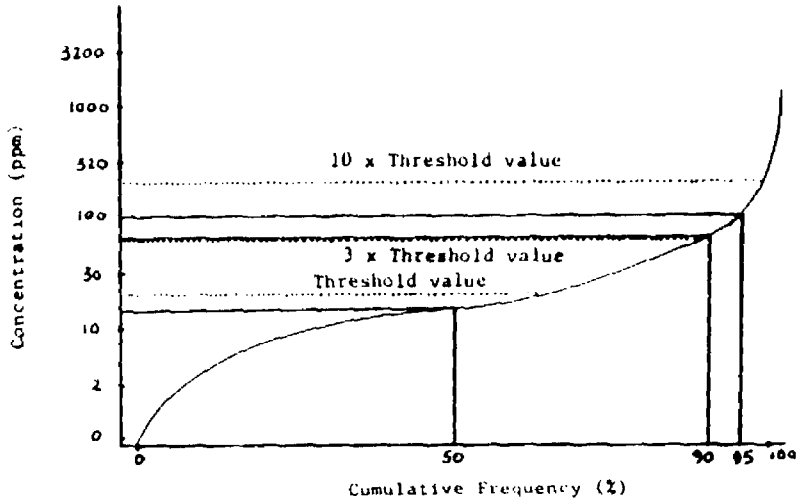


FIGURE 4a. CUMULATIVE FREQUENCY PLOT FOR NICKEL

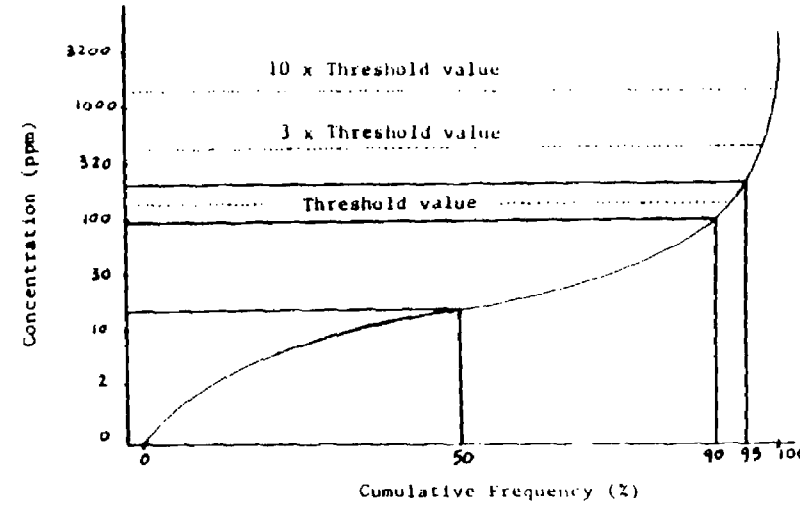


FIGURE 4b. CUMULATIVE FREQUENCY PLOT FOR LEAD

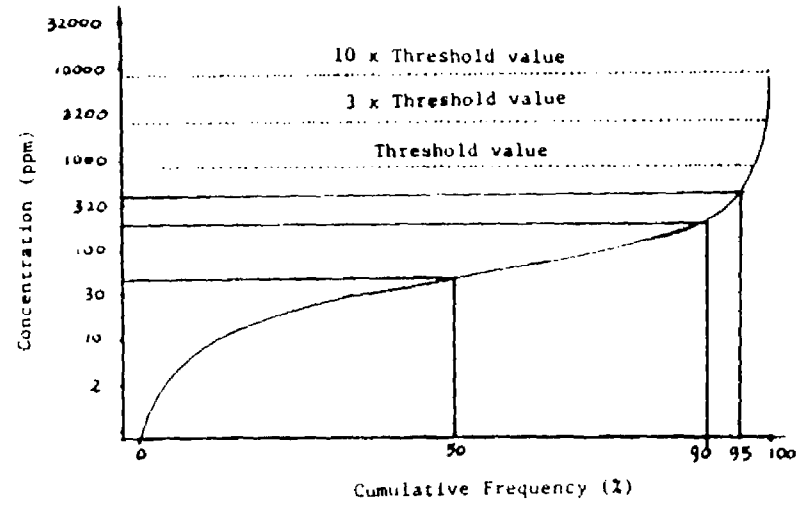


FIGURE 4c. CUMULATIVE FREQUENCY PLOT FOR ZINC

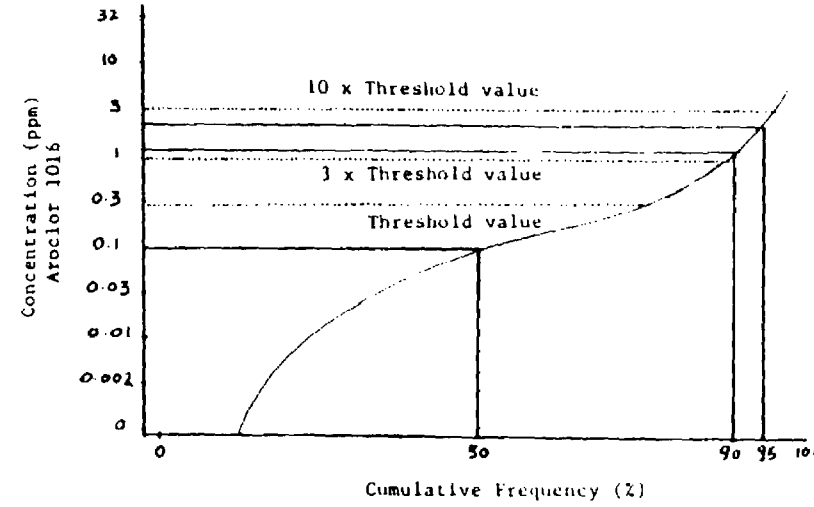


FIGURE 4d. CUMULATIVE FREQUENCY PLOT FOR PCB

FIGURE IV-4 (continued)

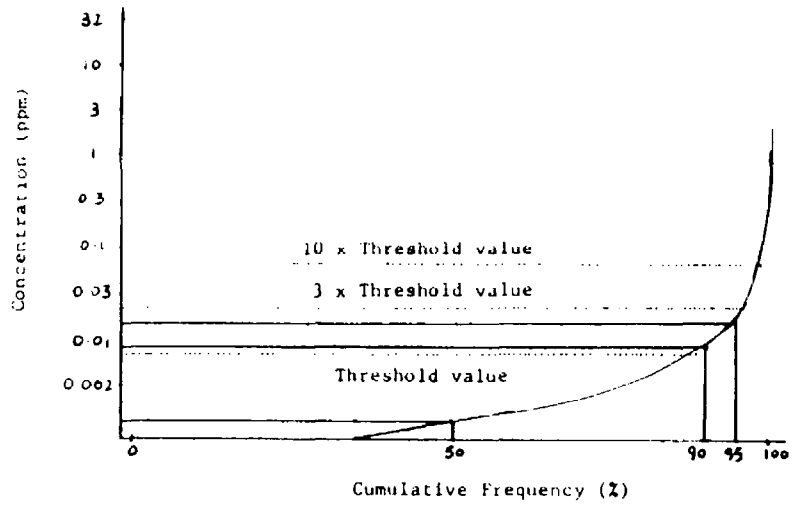


FIGURE 4e. CUMULATIVE FREQUENCY PLOT FOR DDT

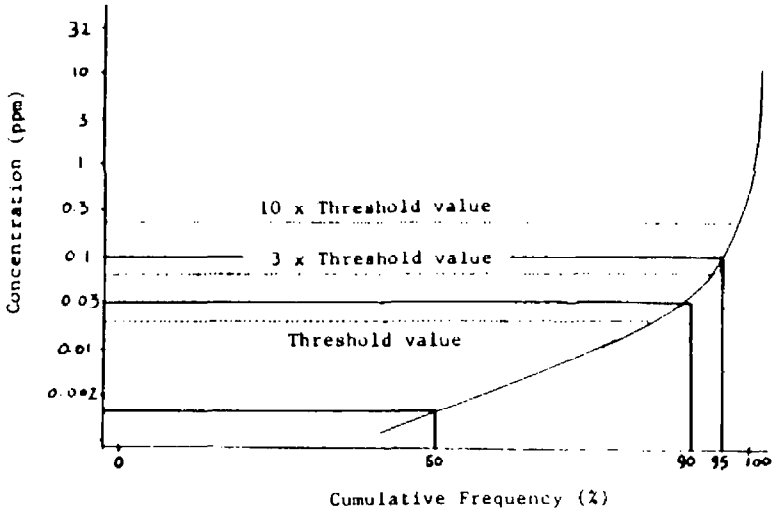


FIGURE 4f. CUMULATIVE FREQUENCY PLOT FOR CHLORDANE

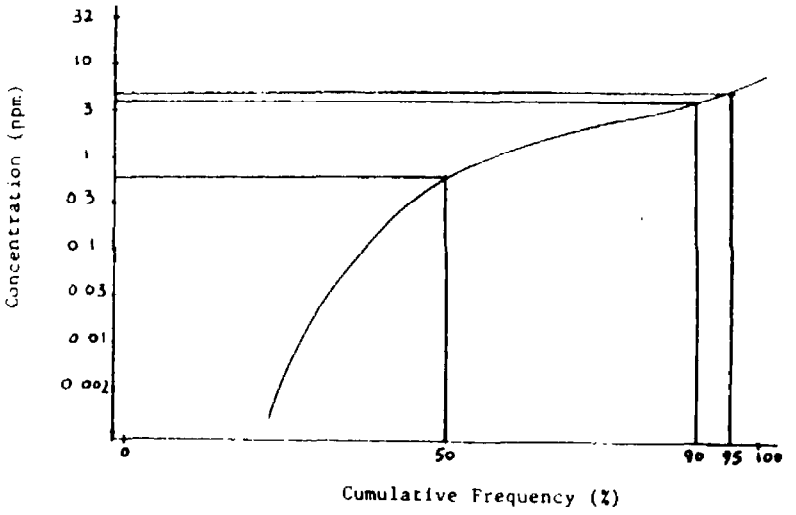


FIGURE 4g. CUMULATIVE FREQUENCY PLOT FOR FLUORENE

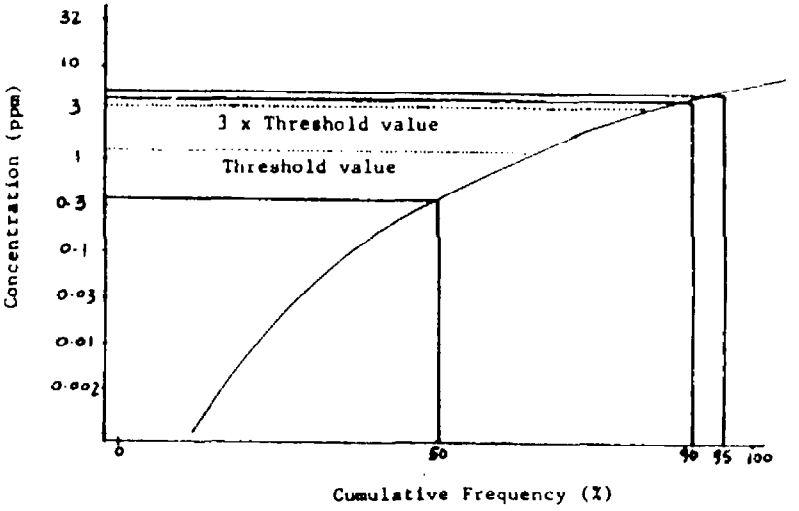


FIGURE 4h. CUMULATIVE FREQUENCY PLOT FOR DIETHYLPHTHALATE

on data from stations, regardless of whether they were "contaminated" or "non-contaminated", their data do not provide a picture of the range of concentrations found in "contaminated" sites. However, the high levels shown are indications of the levels of contamination in "contaminated" sites.

Although the specific pollutants and classes of pollutants mentioned above clealy demonstrate the existence of in-place pollutant problems, it would be misleading to assume that they are the only contaminants of concern, or that they present a complete picture of in-place pollution. It is important to remember that what is found depends on what is looked for. In many studies, the investigators looked only for metals. Certain agencies, e.g. the Corps of Engineers, have a list of standard parameters which are to be tested for. A list of parameters for the bulk sediment test from the New England District of the Corps of Engineers is shown in Table IV-10. Additional parameters may be included at many sites, but the standard list is rather limited. Section V of this report describes other screening lists used by other state and federal Agencies, and their use as sediment quality criteria.

In some cases, a small list of pollutants is used because these specific pollutants are being used as indicators of contamination. Such a list, therefore, is not intended to provide a complete picture of all the pollutants at the site.

TABLE IV-10. PARAMETERS FOR BULK SEDIMENT TEST

(NEW ENGLAND DIVISION, CORPS OF ENGINEERS)

	volatile solids
	water
	oil and grease
Metals	Mercury
	Lead
	Zinc
	Arsenic
	Cadmium
	Chromium
	Copper
	Nickel
PCB	Total PCBs

Source: Information obtained from U.S. Army Corps of Engineers, New England Division (1986)

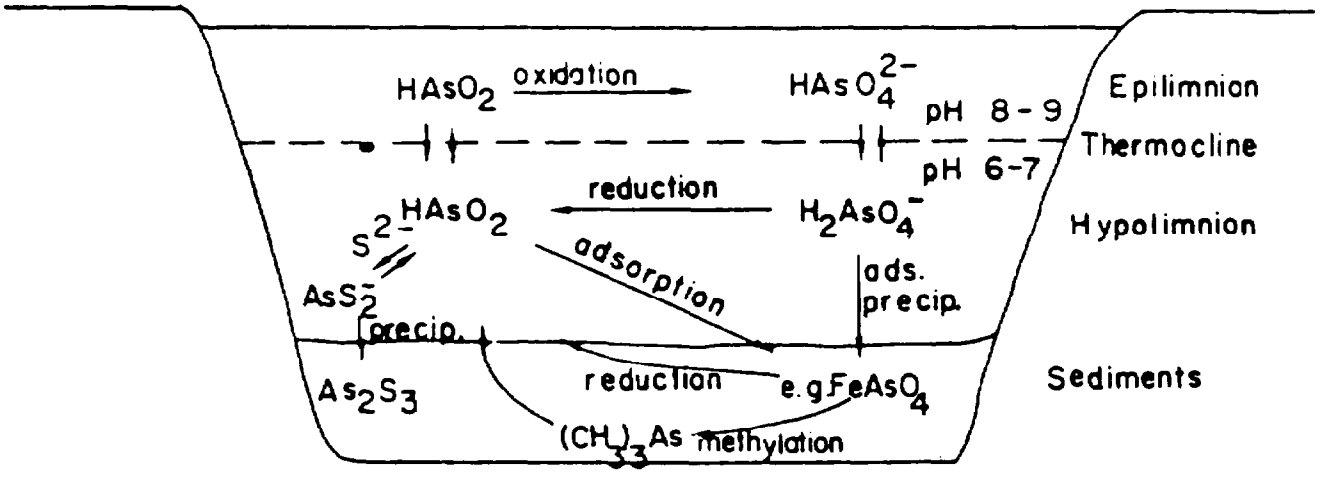
Another related issue of concern is that once a site is considered "contaminated" based on a particular pollutant (e.g. PCBs), investigators may not be on the look-out for other pollutants which may have important ecological impacts.

The sediment analysis data that are available are primarily in the form of bulk sediment analyses. Elutriate and bioassay data are also available on occasion but tests for these are rarely based on consistent procedures from investigator to investigator, and are therefore not easily comparable. Although the methods for bulk sediment analyses are not uniform, the data have more in common in terms of bases for comparison. However, bulk sediment concentrations do not necessarily correlate with the availability of the contaminants to biota. It is therefore impossible, on the basis of bulk concentrations alone, to predict the toxicity or other impacts of these sediments to the biota in the water body.

The issue of bioavailability is a major quetion for all contaminants in sediments. Contaminants are sorbed onto sediments, become partially immobilized, and therefore are not "available" to biota in the overlying water. However, benthic organisms or bottom feeders could still be exposed to the sorbed contaminant. For metals, speciation in water also influences the bioavailability and toxicity of the metal to biota. Bioavailability is a complex issue, and a thorough discussion of it is not within the scope of this study.

These and other factors determine the impact of contamination in sediments. To illustrate the complexities involved in metal contamination, Figure IV-5 shows the speciation of arsenic in a stratified lake. Arsenate and arsenite may coprecipitate with or sorb onto hydrous iron oxides in the sediments. Under reduced conditions in the presence of sulfide, orpiment (AS_2S_3) may be formed in the sediments. Arsenic species also sorb onto aluminum oxides and clays.

Except for PCBs and PAHs, and some agricultural chemicals (e.g. DDT), organics are not as frequently monitored in sediments as metals. Other organics that may be present (and, perhaps, should be analyzed for) include other chlorinated hydrocarbons (besides PCBs and pesticides), polymers, and metabolites of anthropogenic compounds. Degradation or reactions of compounds in the environment will produce new products. These products may be as important or even more important than the parent compounds in terms of biological or human health impacts. An example of reaction products that may be significant but which are currently not monitored are sulfides formed by abiotic reactions of organics with sulfide. Compounds which are persistent and have high adsorption coefficients should be emphasized in sediment monitoring efforts. Radionuclides are another class of contaminants not frequently reported. It is conceivable that these may be more frequently detected if they are analyzed for in sediments. An important point to emphasize, however, is that contaminant analyses do not always provide information on the speciation or bioavailability of the pollutant.



Source: Ferguson and Gavis (1972).

FIGURE IV-5 Local Cycle of Arsenic in a Stratified Lake

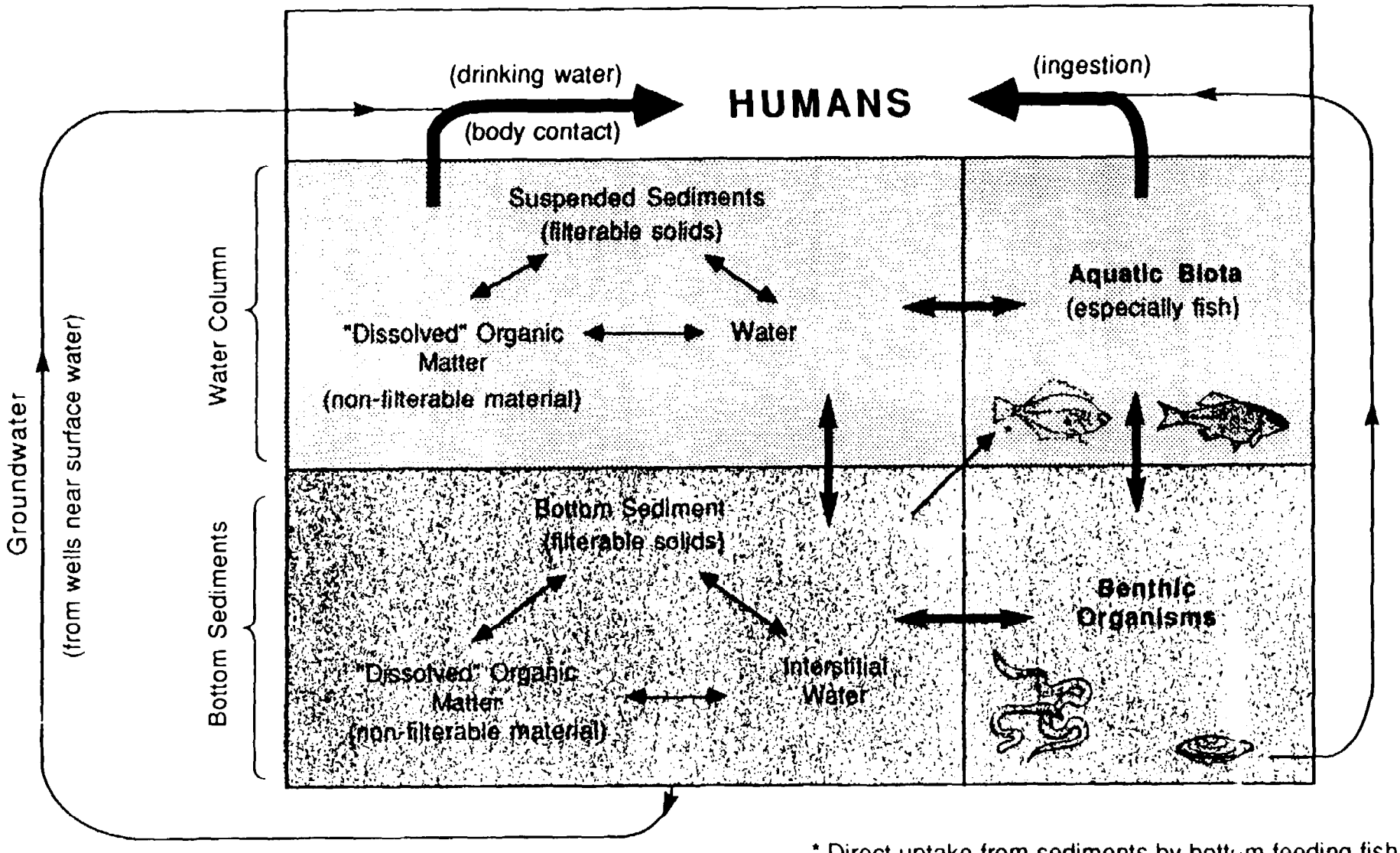
5. Types of Ecological Impacts

An examination of the ecological and human health impacts from sediment contamination was not the primary objective of this study. Thus, this section provides only a brief discussion of exposure pathways and a brief summary of the impacts noted or perceived.

The primary exposure pathways which may be followed by chemicals in contaminated sediments, and which could lead to adverse effects on aquatic life and humans, are shown in Figure IV-6. There are two significant features of this Figure. First, it points out that, within both the 'bottom sediments' and 'water column' compartments, pollutant chemicals are partitioned between three subcompartments: (1) sorbed to filterable sediments; (2) sorbed to non-filterable dissolved organic matter (DOM) (primarily humic and fulvic acids); and (3) dissolved in water. The bioavailability (to benthic organisms and other aquatic life) of pollutant chemicals may differ significantly depending on which subcompartment the pollutant is primarily associated with. For example, strongly sorbed chemicals (e.g., DDT, dioxin, benzo[a]pyrene) will be primarily associated with sediment particles and DOM; only the small residual portion in true solution is probably immediately bioavailable to most biota as the other two are not in a form that can pass through gill membranes or other cell membranes of the organisms.

Second, the routes leading to human exposure are mostly indirect, involving, first, transport of the pollutants out of the bottom sediments into the water column and/or biota. Direct contact of humans (such as swimmers, divers, and workmen cleaning boat hulls) with sediments is also possible, but occurs much less frequently than exposure via indirect pathways. No exposure pathway involving volatilization from the water column and subsequent human inhalation is shown since few volatile chemicals accumulate to any significant extent in sediments. (While volatilization may not be important from a human health [exposure] standpoint, it may be important from a mass balance standpoint, especially if other degradation and loss mechanisms are negligible.) Other more convoluted exposure routes, including the use of contaminated water as irrigation water on food crops, are also not shown. The human exposure route involving drinking water may start with a surface water withdrawal, or with a groundwater withdrawal where the well is near the surface water.

It is not difficult to conceptualize a range of possible impacts on aquatic biota deriving from polluted sediments. These would include specific toxic effects on individual organisms, both lethal and sublethal. The latter include, for example, skin lesions ("fin rot"), tumors, excess fatty vacuoles in the liver, altered metabolism and strength, and altered behavior and reproductive habits. Population-scale impacts could include decreased population size, decreased reproduction potential, shorter average life span, and loss of habitat. While laboratory studies can show the extent of effects on



* Direct uptake from sediments by bottom feeding fish.

FIGURE IV-6 PATHWAYS OF HUMAN EXPOSURE TO CHEMICALS ORIGINATING IN CONTAMINATED SEDIMENTS

individual organisms, extrapolating to whole species/population effects can be difficult. The use of field studies to determine the impacts of contaminated sediments is also difficult since it must be demonstrated that the identified sediment pollutants were taken up by the studied organisms and caused the perceived impacts.

In the last several years there have been significant advances in sediment (contamination) assessment by toxicity testing, including monitoring: (1) for a variety of non-lethal effects on individual organisms; (2) for changes at the cellular and molecular level (e.g., detection of histopathological abnormalities and chromosome damage); (3) for changes in life cycle and whole population effects; and (4) for effects on community structure. As noted above, studies focusing on the nature and extent of such impacts, and the types of test protocols used, are beyond the scope of this report.

Some information on reported "impacts" is included in Tables 1-10 in Appendix A. This information is summarized in Table IV-11. Some of these "impacts" are clearly not direct manifestations of adverse health impacts, but merely suggestions (e.g., by the finding of excess levels in fish) that such impacts might be expected. It is difficult to directly associate the impacts shown in Table IV-11 to the contamination in sediments. They are mainly indirectly experienced through the contamination in the overlying water. Also, a number of the impacts are indirectly implied through the institutional controls that were instituted to reduce the exposure of humans to the contaminants.

From the information in Table IV-11, brief statements may be made regarding the impacts of in-place pollutants. Impacts on biota, most notably impacts on reproduction, structure and health of the ecological community (e.g., tumors, lesions, deformities, shorter lifespan and therefore a skewing of the population toward smaller, younger fish), and fish kills were frequently mentioned by investigators. Contaminants were also detected or bioaccumulated in biota to levels unacceptable for human consumption. Fishing bans or fish consumption advisories were common institutional controls to reduce exposure. In several cases, investigators specifically mentioned that levels in fish exceeded limits for human consumption set by the Food and Drug Administration (FDA). Swimming bans or beach closings were also noted in several cases. Livestock toxicity was noted once. In a case in Milltown, Montana, a groundwater supply was contaminated with arsenic that originated from mine tailings deposited in a reservoir (Site No. 5, Region VIII). An alternative water supply was provided for this community.

TABLE IV-11. IMPACTS ASSOCIATED WITH CONTAMINATED SEDIMENT

Impact or Institutional Action	Number of Mentions
Detected or accumulated in biota	23
Impact on biota (e.g., community structure and health, fish kill)	35
Fishing ban or fish consumption advisories	32
Levels in fish exceed FDA limits	11
Swimming ban/beach closings	4
Alternative water supply	1
Lifestock toxicity	1
Alteration, postponement or elimination of navigational dredging	-*

Information summarized from Tables 1-10 in Appendix A.

* Not mentioned directly, but many examples are known to exist. Impacts would be socio-economic in nature.

B. SEDIMENT CONTAMINATION SOURCES

1. Overview

This section presents a description of sources contributing to the contamination of sediments in U.S. waters. There are basically two ways in which sources affect sediment quality in a water body. Sources can directly contribute sediments that are contaminated in the form of solids, e.g., mine tailings. Sources can also discharge pollutants in the aqueous phase which are then sorbed into the sediments.

There are numerous difficulties associated with the task of identifying the responsible sources for a particular site. For any one contaminated site, investigators normally listed many associated sources. These often consisted of a list of suspected sources rather than proof of actual sources. This is a function of the location of many contaminated sites in urban and industrial areas where there are many possible contributing sources in one location. The main source or sources are frequently not identifiable. Unless a pollutant is unique to a particular facility, it is difficult to separate out the individual contributors. To identify the main sources, one would have to know, at a minimum, the pollutants and loadings into the water body, from each individual source.

A very important characteristic of in-place pollutants in sediment is that the problem could exist long after the sources are gone. There may be sources that are discontinued and other sources that are continuing to contribute to the contamination. An example of this is the existence of DDT and its derivatives in sediments. Although agricultural uses of DDT have been discontinued, some residues may still be carried (via erosion) from formerly-treated fields to surface waters for several years or decades. Because of this characteristic, sources cannot be easily identified from the current activities around the water body.

There appear to be numerous types of point, non-point and other sources (e.g. spills) that were mentioned as sources of in-place pollutants. Sewage treatment plants are important contributors to in-place pollutants in virtually all regions of the country. Other point sources include chemical, steel, metal working, and electroplating plants. In many cases, unspecified industrial sources were cited as responsible sources. Important non-point sources include urban and agricultural runoff. Mining is a very important source in regions where it is an economic activity. Spills are also significant contributors to in-place pollutants.

This section provides:

- a review of the categories of sources of in-place pollutants;
- a discussion of the major point sources and the pollutants associated with these sources;

- a discussion of significant non-point sources and the pollutants associated with these sources; and

- a review of other sources, e.g. spills and the types of chemicals involved.

The information obtained from published literature, U.S. EPA offices and various state and federal agencies was the primary basis for the results discussed in this section. This information is summarized in Tables 1-10 in Appendix A; additional information on sources is shown in Tables IV-12 and -13. As in the case of determining the status of contaminated sites in the U.S., the amount of information on sources was not uniform from site to site. In many cases, no information on the sources of contamination was available, while in others, numerous suspected sources were cited. In some cases, the source or sources responsible for the in-place pollutants were clearly identifiable because of the relative locations of the source and contamination site, or because of the particular pollutant involved. As was pointed out in Section IV-A, the database from which our results and conclusions are drawn is non-statistical. Our objective is to present a picture of the situation, not a statistical analysis.

2. Categories of Sources

There are essentially three types of sources that can be identified: point sources, non-point sources, and other sources which include spills and purposeful addition. Each one of these categories will be described in detail in the sections below.

In point sources, effluents are usually from an identifiable source and usually from the end of a pipe that is in a fixed location. Point sources include industrial and municipal wastewater discharges which are regulated under the National Pollution Discharge Elimination System (NPDES) by authority of the Clean Water Act. Non-point sources are usually characterized by effluents from an area and not from a pipe. The types of pollutants associated with non-point sources are determined primarily by land-use characteristics. Examples of non-point sources are urban runoff and agricultural runoff. The category of other sources includes accidental (unintentional) releases and purposeful addition of chemicals into a water body. Examples are spills, dumping, and the addition of herbicides into reservoirs or lakes.

Although the definitions above provide reasonably clear distinctions among the categories, there are a number of sources that are difficult to categorize. Combined sewer overflows, which result from the overwhelming of sewage systems due to runoff from storms, were classified as point sources, even though overflow outlets may be located at several points upstream of the sewage treatment facility. Discharges from shipping, such as the washing of decks and cleaning of containers, were classified as non-point sources, as was atmospheric deposition.

TABLE IV-12 SOURCES OF IN-PLACE POLLUTANTS - POINT SOURCES*

Location	Region	Point Source (Status)**	Pollutants Found	Reference (see Appendix B)
Providence River	I	Sewage (C)	hydrocarbons	Hurtt & Quinn, 1979
Cattaraugus & Buttermilk Creeks, NY	II	Nuclear fuel services facility (U)	radionuclides	Walters et al., 1982
Murderkill River, Delaware	III	Sewage treatment plants (C)	heavy metals	Hoffman & Biggs, 1983
Miami Beach, FL	IV	Sewage outfall (U)	enteroviruses, coliforms, fecal coli and streptococcus	Schaiberger et al., 1982
Ashtabula River & Harbor, OH	V	Chemical plants & landfills (C)	PCBs,*** other synthetic organics	U.S. EPA Region V, 1984
Fields Brook, Ashtabula, OH	V	Industrial point sources, abandoned landfills, lagoons, chemical storage sites (all C)	organics, heavy metals	U.S. EPA Region V, 1984
Fox River & Green Bay Harbor, WI	V	Industrial point sources (C)	PCBs,*** PCDD,*** PCDF, resin acids, chlorinated resin acids, chlorophenols, ammonia	U.S. EPA Region V, 1984
Grand River, Grand Rapids, MI	V	POTWs,*** automotive, chemicals, metals, other industrial (all C)	heavy metals	U.S. EPA Region V, 1984
Indiana Harbor, Grand Calumet River	V	Steel mills, refineries, foundries, chemicals, municipal, sewer overflows, landfills & dumps (all C)	PCBs, PAHs,*** heavy metals	U.S. EPA Region V, 1984
Menominee River, WI & MI	V	Chemical company (C)	As	U.S. EPA Region V, 1984

(Continued)

TABLE IV-12 SOURCES OF IN-PLACE POLLUTANTS - POINT SOURCES* (Continued)

Location	Region	Point Source (Status)	Pollutants Found	Reference (see Appendix B)
Sheboygan River & Harbor, WI	V	Techumseh Engine (C)	PCBs	U.S. EPA Region V, 1984
St. Louis River, MN	V	Steel Company (C)	PAHs, heavy metals	U.S. EPA Region V, 1984
Waukegan Harbor, Waukegan, IL	V	Outboard Marine Corp. (C)	PCBs	U.S. EPA Region V, 1984
Lower Waukegan Harbor	V	Outboard Marine Corp. (C)	PCBs, heavy metals	U.S. EPA Region V, 1984
Southern California Bight	IX	Sewage outfall (C)	petroleum hydrocarbons	Eganhouse et al., 1984
Los Angeles, Palos Verdes, Shelf, CA	IX	Sewage outfall (C)	oil & grease, heavy metals, phenols, PAHs, phthalates, DDT & deriv., dieldrin	Swartz et al., 1985
Columbia River, WA	X	U.S. Atomic Energy Commission, Hanford Reservation (C)	Radionuclides	Haushild, 1980
Willamette River, OR	X	Zinc hydrosulfide used in ground wood pulp & paper mills (C)	Zn	Ricket et al., 1977

* See Tables 1-10 in Appendix A for compilations of more sources.

** Status of sources indicate whether they were currently continuing at the time of the cited report (C), discontinued (D), or their status was unknown (U).

*** POTWs - Publicly-Owned Treatment Works; PCBs - Polychlorinated Biphenyls; PCDD - Polychlorinated Dibenzodioxins; PCDF - Polychlorinated Dibenzofurans; PAHs - Polynuclear Aromatic Hydrocarbons.

TABLE IV-13 SOURCES OF IN-PLACE POLLUTANTS - NON-POINT SOURCES AND OTHER SOURCES*

Location	Region	Non-Point Source (Status)**	Pollutants Found	Reference (see Appendix B)
Georges Bank	I	Exploratory drilling (D)	Aromatic hydrocarbons	Payne et al., 1983
Lake Whitney, Lake Saltonstall, New Haven, CT	I	Deposition from leaded gasolines (C), $CuSO_4$ biocide in reservoirs (C)	heavy metals	Bertine & Mendeck, 1978
New York Bight	II	contaminated dredge spoil (C), sewage sludge in ocean dump site (C)	hydrocarbons	Farrington & Tripp, 1977
Adirondack Lake	II	atm. deposition from fossil fuels combustion (C)	heavy metals	Galloway & Likens, 1979
Murderkill River, DE	III	agri. runoff, runoff from pastures & woodlands, urban runoff (all C)	heavy metals	Hoffman & Biggs, 1983
Delaware River	III	urban stormwater runoff (C)	aromatic hydrocarbons	MacKenzie & Hunter, 1979
Wisconsin Lakes	V	sodium arsenite used as aquatic herbicide (C)	As	Kobayashi and Lee, 1978
Standley Lake, CO	VIII	runoff into creek before discharge into Lake (C)	heavy metals	Heit et al., 1980
Southern California Bight	IX	surface runoff (C)	petroleum hydrocarbons	Eganhouse et al., 1982
Hansen Lake Los Angeles, CA	IX	vehicular emissions (C)	PAHs***	Heit, 1979
Grays Harbor, WA	X	oil spills, sewage effluents (C), urban storm runoff (C)	aliphatic hydrocarbons	Rapp et al., undated

* See Table 1-10 in Appendix A for compilations of more sources.
** Status of Sources indicate whether they were currently continuing at the time of the cited report (C), discontinued (D), or their status was unknown (U).
*** PAHs - Polynuclear Aromatic Hydrocarbons.

Another way to categorize sources is to differentiate on the basis of whether they are continuing sources or old (discontinued) sources. This distinction is an important element in the choice of remedial actions for a site. Cleaning up a site without reducing the loadings from the sources causing the problem would have no lasting benefit. Unfortunately, it is very difficult to determine the current status of a particular source from the information available. Most of the literature reviewed did not include this piece of information. In many cases, the references were not current enough for any conclusions on the status of the sources.

Choices for remediation or mitigation of sediment contamination problems also differ depending on whether the contamination is due to "point", non-point", or "other" sources. For example, reducing loadings from a point source may be more straightforward than reducing loadings from non-point sources. Considerations of remedial actions for large areas that are non-point sources (e.g. mining areas) may involve more complex factors.

Table IV-14 shows in-place pollutant sources cited by EPA region. This table does not provide information on the size of loading contributions from various sources. We were not able to evaluate sources on the basis of their contribution but only on the number of times they were mentioned by investigators. To provide information on pollutants associated with particular types of sources, cases in which the sources of contamination were known were used to generate Table IV-15. This table presents the pollutants discharged by different sources. Some types of sources, e.g. urban runoff tended to be cited together with numerous other sources; in such cases it is impossible to figure out what pollutants were released by each type of source. Tables IV-14 and -15 summarize the information contained in Tables 1-10 in Appendix A and Tables IV-12 and -13. The discussions in the following sections are primarily based on the information summaries in Tables IV-14 and -15.

3. Point Sources

Point sources were mentioned frequently as sources of in-place pollutants. Both industrial and municipal point sources are significant contributors to in-place pollutants.

As shown in Table IV-14, many types of point sources contribute to sediment contamination. There were a large number of sites in which industrial sources were cited as a group and not specified. Municipal sewage treatment plants are important contributors in virtually all the regions of the country. Chemical, steel, metal working and electroplating are commonly cited sources.

Other important industrial sectors include: engines and automotive; nuclear energy production; paper mills; tanneries; refineries and other petroleum industries; electrical component and capacitor manufacture; wood preserving, wharfs and pilings. Although combined sewer overflows

TABLE IV-14 SUMMARY OF SEDIMENT CONTAMINATION SOURCES BY REGION

Source	Frequency of Citation, by EPA Region										
	I	II	III	IV	V	VI	VII	VIII	IX	X	TOTAL
Point											
Municipal sewage treatment	9	9	3	1	15	2	0	1	3	1	44
Combined sewer overflows	1	7	0	0	8	0	0	0	0	0	16
Industrial (other or not specified)	9	10	2	1	9	4	3	0	2	3	43
Chemical	1	3	3	2	8	1	1	1	0	0	20
Steel, metal working, electroplating	5	3	1	0	7	0	0	0	0	0	16
Engines, automotive	0	2	0	0	5	0	0	0	0	0	7
Energy production (nuclear)	0	2	0	1	0	0	0	0	0	1	4
Paper mills	1	0	0	0	1	0	0	0	0	1	3
Tanneries	3	0	0	0	1	0	0	0	0	0	4
Refineries, other petroleum	1	1	0	1	1	2	0	1	0	0	7
Electrical component, capacitor manuf.	1	2	0	0	0	0	0	0	0	0	3
Wood preserving, wharf and pilings	2	1	1	0	0	0	0	0	0	0	4
Non-Point											
Urban surface runoff	3	8	2	1	9	2	3	1	3	3	35
Rural, agricultural runoff	0	0	1	0	15	2	0	4	6	0	28
Ocean dumpsite (sewage sludge, dredged spoil)	1	2	0	0	0	0	0	0	0	0	3
Atmospheric, combustion (fossil fuels and vehicles)	2	1	0	0	2	0	0	0	2	1	8
Waste disposal seepage and runoff (landfills, etc.)	1	10	1	0	2	0	3	1	3	1	22
Mining	0	0	0	0	1	0	10	7	0	2	20
Shipping	1	1	0	0	0	2	0	0	1	0	5
Other											
Spills	3	1	3	1	0	3	1	0	1	2	15
Purposeful addition (herbicide, etc.)	1	0	0	0	1	0	0	0	0	0	2

TABLE IV-15 SOURCES AND ASSOCIATED POLLUTANTS IN CONTAMINATED SEDIMENTS

Source Type	Heavy Metals and Metalloids	PCBs	PAHs	Oil and Grease	Pesticides	Hydrocarbons	Organics	Transuranics and Radionuclides
Point								
Sewage	x	x	x	x		x		
Chemical	Hg, As				Mirex, kepone, DDT		x	
Steel, metal working, electroplating	x	x	x	x				
Engines, automotive		x						
Nuclear energy production	x							x
Pulp and Paper	x, Zn	x					Phenols	
Tanneries	x							
Refineries	x			x		x		
Electrical component, capacitor	x	x						
Non-Point								
Agricultural runoff	Se, As, Hg	x			DDT and derivatives, heptachlor epoxide, dieldrin, chlordane, toxaphene			
Ocean dumpsite	x							
Atmospheric, combustion			x					
Mining	x							
Other								
Spills	Hg	x			DDT, chlordane, endosulfan	x	penta-chlorophenol	
Purposeful addition	As, Cu							

An x indicates that the pollutant is associated with the source in the first column.

are not strictly point sources, they are included in here because the discharges from these are associated with sewage treatment plants.

It is difficult to find any geographical trends in the information on point sources. Overall they seem to be located more in the Northeast and Great Lakes regions. However, this is probably a function of the greater data availability for these areas.

Heavy metals and metalloids are associated with virtually all types of point sources as shown in Table IV-15. Particular metals and metalloids are pointed out when they appeared uniquely associated with some sources. Sewage treatment plants were sources for many pollutants, including PCBs, PAHs, oil and grease, and hydrocarbons. Some of these may originate with industry as many sewage treatment plants have substantial industrial contributions. Because the chemical plants noted in our study were mainly pesticide facilities, a number of pesticides (Mirex, Kepone, DDT) were released by them. Mercury and arsenic, two commonly used metalloids in pesticides, were also discharged by chemical plants. PCBs were found associated with many types of sources. The origin of the PCBs is frequently not clear. As expected, nuclear energy production was related to transuranics and radionuclides found in sediments. Metals, oil and grease, and hydrocarbons were pollutants from refineries.

4. Non-Point Sources

Important non-point sources of sediment contamination include: urban surface runoff, rural and agricultural runoff, atmospheric deposition, seepage from waste disposal facilities, mining, shipping, and ocean dump sites.

Urban surface runoff is a significant source of sediment contamination in virtually all urbanized areas. In all regions of the country, urban runoff was mentioned as a contributor to the problem of sediment contamination. Rural and agricultural runoff was also cited frequently. The sources of air pollutants that are subsequently deposited include sources burning fossil fuels, and vehicles. The disposal of waste in landfills, surface impoundments, and other waste disposal facilities can lead to seepage and runoff from these facilities to water bodies. In some Superfund sites (e.g., Love Canal, NY and Holbrook, MA) the sediments of nearby streams were severely contaminated by pollutants in the infiltrating groundwater. Similarly, sewage sludge, garbage and dredged spoil have been disposed in ocean sites. Currents and other disturbances cause the dispersal of contaminants from these areas to their surroundings. Mining sites are very important sources of pollutants into water bodies, particularly of metals. Mining sites with identified sediment contamination are primarily located in Regions VII and VIII.

The pollutants associated with non-point sources are primarily related to the land-use characteristics of the area. Urban runoff is normally mentioned with a number of point sources. Because of this, it is

difficult to separate out the contribution of urban runoff to the contamination in sediments. Table IV-15 (mentioned earlier) shows the pollutants associated with various sources. Certain metals (selenium, arsenic and mercury) and pesticides (DDT and derivatives, heptachlor epoxide, dieldrin, chlordane, and toxaphene) have been found where agricultural runoff is a non-point source. Strangely enough, PCBs have also been found in sites receiving agricultural runoff. As would be expected, a large number of metals have been found associated with mining sources. Metals were also found in sediments contaminated disposed sewage sludge and dredged spoil disposed of in ocean dumpsites. Atmospheric deposition of polynuclear aromatic hydrocarbons (PAHs) is an important source of PAHs in lake sediments. On certain industrialized rivers, coke ovens and creosoting operations have been significant sources of PAH discharges. Some PAHs may also be derived from the natural degradation of humic material.

5. Other Sources

This category includes spills (unintentional releases of pollutants) and the purposeful addition of chemicals to a water body. Spills are frequently mentioned as sources. These include spills of chemicals into inland waters and spills into harbor and other marine areas. According to data compiled by the U.S. Coast Guard (1983), the majority of spills, both in terms of number of incidents and quantities spilled, are into inland waters. Materials spilled include petroleum substances, hazardous chemicals, and other types of materials as shown in Table IV-16. Purposeful addition was only mentioned twice from the information we obtained. In both cases, chemicals were added to reservoirs/lakes as biocides (Bertine and Mendeck; 1978; Kobayashi and Lee, 1978).

Some pollutants in sediments associated with spills were shown in Table IV-15. A number of classes of contaminants are included: metals (mercury), PCBs, pesticides (DDT, chlordane, endosulfan), hydrocarbons, and organics (pentachlorophenol). The use of sodium arsenite and copper sulfate as aquatic herbicides have contributed to arsenic and copper contamination in sediments.

TABLE IV-16. MATERIALS SPILLED IN U.S. WATERS

Material	Percent by Volume 1982 %	1983 %
Crude Oil	34.8	12.3
Gasoline	5.4	2.8
Other Distillate	2.0	1.7
Solvents	0.4	0.1
Diesel Oil	6.7	9.9
Fuel Oil	11.8	1.8
Asphalt/Tar/Pitch	0.3	0.4
Animal/Vegetable Oil	1.3	0.0
Waste Oil	0.6	5.1
Other Oil	5.3	4.8
Chemical	4.1	8.5
Other Pollutant	25.1	50.4
Natural Substance	0.0	1.4
Other Material	2.0	0.7
Unknown	0.2	0.0
TOTAL	100.0	100.0

Source: U.S. Coast Guard (1983)

C. RESPONSES TO SEDIMENT CONTAMINATION

1. Overview

The process of responding to a sediment contamination problem begins with the initial determination that a problem exists at a particular location. Once a problem has been identified, the next step is characterizing the nature of the contamination and assessing its extent and severity. Based on such an assessment, together with considerations of cost and technical feasibility, a decision must be made as to what type of remedial action (if any) to implement. A variety of remedial action options are available. Some have been repeatedly demonstrated, while others are still in experimental phases. No one option is best in all situations, as the decision process must consider many site-specific factors.

The following section describes the steps which may be taken to identify and assess a sediment contamination problem and the general decision logic that can be used in developing a remedial action plan. Individual response alternatives are briefly described, and their applicability, advantages and disadvantages are summarized.

2. Problem Identification and Assessment

Environmental agencies may become aware of sediment contamination problems by several means. Few agencies currently conduct routine sediment quality monitoring, although several one-time surveys of sediment quality throughout a given area have been undertaken.

Investigations of sediment quality may be initiated for several reasons:

- in response to a particular polluting incident, such as a chemical spill;
- as part of a follow-up study of other pollution problems, such as fish contamination, fish kills, or surface water contamination;
- to monitor pollutant levels in areas subject to major impacts from urgan and industrial discharges (e.g., the New York and Los Angeles bights, and major bays and harbors);
- to determine the extent of a sediment contamination problem detected in one location and suspected to be widespread (e.g., selenium contamination caused by agricultural runoff in California);
- as baseline studies for environmental impact assessments or environmental impact statements;
- to establish background levels of pollutants in sediments (e.g., for the purpose of sediment quality criteria development); or
- to determine whether material that is to be dredged is acceptable for open water disposal.

This last is among the most common reasons for sampling sediments; the regulation of dredged material disposal has provided the motivation for many studies on the effects of contaminated sediments and on new dredging and disposal methods.

The initial determination that sediments at a given site are contaminated may be based on a variety of indications. Historical data on the occurrence of spills or discharges of pollutants may suggest a potential problem. Ecological stress indicators, such as reduced diversity or abundance of benthic organisms, tumors found in bottom-dwelling fish, or, in more severe cases, fish kills, provide additional evidence of sediment contamination. Areas with severe contamination may be recognizable because of odors or the appearance of surface slicks when sediments are disturbed. High concentrations of contaminants in biota also point toward sediment contamination. Finally, data from analyses of sediment samples can be used to compare contaminant concentrations to background levels or to criteria values. No single method for deciding what level of contamination constitutes a problem has yet been firmly established; see Section V for a discussion of the development of sediment quality criteria.

Once preliminary investigations have identified a sediment contamination problem, further study is needed to characterize the problem, assess its severity, and determine the most appropriate response. Such assessments are likely to include consideration of the sources of pollutants, the hydrologic conditions and uses of the water body, and data from bioassays and bulk analysis of sediments.

The investigation of sediment contamination may proceed quite differently depending on the reason for the investigation. If sediment contamination is detected in the course of planning a routine dredging operation, an assessment of the problem is likely to be narrowly focused. It might be aimed at producing just enough information to determine what kind of precautions are needed to avoid releasing contaminants into the water column during dredging, and what type of disposal is appropriate for the dredged material.

For purposes of regulating dredged material disposal, more or less standard procedures for evaluating sediment contamination have been devised. Such procedures, which have been developed by the U.S. Army Corps of Engineers, the EPA, and state environmental agencies, typically involve a series of tests to be performed on sediments to determine whether or not they can be disposed of in open water. For disposal of dredged material in inland waters, actions are controlled by Section 404 of the Clean Water Act, and by regulations issued under the authority of the Act.

The disposal of dredged material in the ocean is governed by the Marine Protection, Research, and Sanctuaries Act (MPRSA), which requires permits for the dumping of materials into ocean waters. Federal regulations specify criteria for evaluating the environmental impact of materials (40 CFR 227). These criteria require that dredged material to be disposed of in ocean waters must either meet one of several exclusions (based on the physical characteristics of the material and on historical data that indicate whether it is likely to be polluted), or

be evaluated by specified tests. The evaluation procedure, developed by the EPA together with the Corps of Engineers (U.S. EPA/CE, 1977), calls for chemical analysis of the liquid phase, and bioassays of the solid phase and suspended particulate phase, of the dredged material. The results of the chemical analysis of the liquid phase are to be compared to the applicable marine water quality criteria, after allowance for initial mixing. If the liquid phase contains contaminants for which marine water quality criteria are not established, it is to be evaluated by bioassays. The bioassays compare mortality of test organisms exposed to the dredged material to mortality in a control sediment, and measure bioaccumulation in surviving organisms.

In practice, the various Corps of Engineers regional divisions follow somewhat variable procedures for evaluating proposed dredging projects in accordance with the federal regulatory requirements. In general, the Corps first requires a bulk chemical analysis and an elutriate test on the material to be dredged. (The elutriate test, which involves mixing a sediment sample with a measured amount of water, then measuring contaminant concentrations in the extracted water, is designed to estimate the potential release of contaminants into the water column during dredging operations.) If the results of these two tests indicate that contaminants may be present at levels of concern, then bioassays are conducted. The test results are usually interpreted on a site-specific basis, as numerical criteria for allowable contaminant levels in dredged material have not been widely established. However, a number of state, federal, and regional environmental regulatory agencies have established (or are in the process of developing) more formalized testing procedures and requirements, including numerical criteria applicable to dredged material disposal in particular locations. (See Section V for a summary of criteria levels.)

Recent attempts to standardize procedures for dredged material evaluation have focused on establishing tiered testing schemes. For example, at a workshop on bioassessment methodologies for dredged material, a group of researchers and representatives of regulatory agencies arrived at a consensus tiered testing program for sediment scheduled for open-water disposal in freshwater environments (Dillon and Gibson, 1986). This program is outlined in Figure IV-7. Following such a testing scheme, the tests included in a given tier would be required only if the results of the previous tier indicated that sediments are likely to be contaminated. Thus, for example, laboratory bioaccumulation tests would be run only if bulk chemical analysis of sediments and/or acute toxicity tests give reason for concern.

In addition to following dredged material disposal guidelines, in some instances involving heavily contaminated sediments, regulatory agencies may find it appropriate to apply criteria for classifying materials as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) or as toxic materials subject to regulation under the Toxic Substances Control Act (TSCA). In such cases, disposal of dredged materials must conform to the applicable RCRA or TSCA regulations.

FIGURE IV-7. CONSENSUS TIERED TESTING PROGRAM FOR EVALUATION OF SEDIMENTS SCHEDULED FOR OPEN-WATER DISPOSAL IN FRESHWATER ENVIRONMENTS

Tier	Activity
I	- Initial assessment: Historical inputs, siting, identification of existing data, etc.
II	- Bulk chemistry - Predictive calculation of bioaccumulation potential (rapid) *- Acute lethality - Ames test (rapid)
III	*- Life cycle test (growth and reproduction) *- Laboratory determination of bioaccumulation potential
IV	- Other bioassessment techniques Bioenergetics, histopathology, aryl hydrocarbon hydroxylase induction, sister chromatid exchange, adenylate energy charge, microcosms - Trophic transfer potential *- Laboratory determination of steady-state concentrations and important factors affecting bioaccumulation

*These tests could conceivably be combined into a single test.

Source: Dillon and Gibson, 1986

If sediment contamination is being investigated as a known pollution problem posing a potential risk to human health and the environment (for example, at a toxic waste site or at the site of a chemical spill), a much more thorough investigation than that required for routine dredging operations might be undertaken. Such an investigation is likely to include sediment sampling to determine what contaminants are present at what range of concentrations, and to establish the depth and areal extent of contamination. Fish and benthic organisms might be sampled to determine whether contaminants are being bioaccumulated, and an inventory of flora and fauna might be conducted to note the impact of contamination on the distribution and abundance of biota. Another important question to be answered is what the source or sources of the pollution are, whether they are point or non-point sources, and whether or not the discharge of pollutants is continuing. The depth and frequency of mixing of the water body are also important considerations. Finally, in order to provide an overall exposure and risk assessment for a site, the uses of the water body by humans and by biota must be considered.

3. Available Responses

A variety of options are available for responding to sediment contamination. The first option to be considered in any instance of sediment contamination resulting from a continuing pollutant discharge is the possibility of controlling the source of pollutants. If it is impossible to eliminate or substantially reduce the flow of contaminants to a water body (for example, in some cases of agricultural or municipal runoff), there may be little benefit to cleaning up the sediments, as they will become contaminated again. Possible source control measures include improved sewage treatment, implementation of more stringent effluent limitations, and stricter enforcement of existing effluent limitations. Once the source of pollutants is under control, response options include the following:

- No action.
- Removal of contaminated sediments by dredging.
- Capping of sediments in place with clean sediments, with chemically active materials, with a synthetic membrane, or with a grout or sealant.
- Stabilization of contaminated sediments by injection of a grout or sealant.
- In situ chemical or biological treatment.

Each of these options is described briefly below. Table IV-17 summarizes advantages and disadvantages of each option.

TABLE IV-17. ADVANTAGES AND DISADVANTAGES OF VARIOUS REMEDIAL ACTION TECHNIQUES

Response Option	Advantages/Applications	Disadvantages/Limitations
Dredging Methods		
Mechanical dredging	-Sediments removed without added water, minimizing needs for transportation, treatment and disposal of dredged material.	-Low production rates. -May generate high turbity in fine-grained sediments. -Does not remove free/unabsorbed liquid contaminants.
Hydraulic dredging	-Higher production rates than mechanical dredges. -Lower resuspension/turbidity than mechanical dredges.	-Pumping at low solids concentrations necessitating large settling dewatering areas for dredged material.
Dredged Material Disposal Methods		
Open-water disposal with capping	-Anoxic water-saturated environment favors contaminant retention (especially metals). -Calm, deep-water sites less likely to be disturbed than near-shore sites. -Any contaminants released would be diluted by overlying water, decreasing adverse impacts. -Little risk of human exposure to contaminants.	-Possibility for contaminant release especially soluble organics) via water exchange through cap. -Only available control of contaminant release is increasing cap thickness or or impermeability. -Potential adverse effects or bioaccumulation in benthic organisms.
Upland confined disposal	-Many site control and treatment options available for handling heavily contaminated material. -Less potential for release of soluble contaminants than in aquatic environment.	-Exposure to air and drying of sediments may cause increased mobility of contaminants. -Proximity to human habitation results in increased human health risk.

(Continued)

TABLE IV-17. ADVANTAGES AND DISADVANTAGES OF VARIOUS REMEDIAL ACTION TECHNIQUES (continued)

Response Option	Advantages/Applications	Disadvantages/Limitations
Upland confined disposal (continued)		Potential routes for contaminant release: - in effluent - in surface runoff produced by rainwater - by leaching into groundwater - by plant or animal uptake - by gaseous or volatile emissions
Shoreline confined disposal	-Ease of transportation of dredged material from nearby dredging sites.	-Potential routes for contaminant release include both those found at upland sites (from dry, upper layer) and those found at open-water sites (from water-saturated lower layer). -High risk of human and environmental exposure to contaminants.
Capping Methods		
Cover and capping of contaminated sediments in situ or of dredged material disposal mounds	-Potentially applicable as (1) a temporary remedial measure to retard the spread of contaminated material until recovery or treatment can be implemented; (2) as a final step in the remedial process, to isolate any residual material following recovery; or (3) as a primary remedial measure.	-Limited to protected open waters where bottom currents and flow velocity are not sufficient to erode the cap. Possible problems include: - turbidity and dispersion generated during capping. - scouring and resuspension of cover material. - leaching of pollutants through cover material. - impact on benethic organisms, e.g. through bioaccumulation of contaminants by organisms that colonize the cap, or through disruption of habitat. - erosion of cap by burrowing organisms.

(Continued)

TABLE IV-17. ADVANTAGES AND DISADVANTAGES OF VARIOUS REMEDIAL ACTION TECHNIQUES (continued)

Response Option	Advantages/Applications	Disadvantages/Limitations
Burial in subaqueous pits	-Cap can restore ambient sediment type and topography. -Reduced potential for erosion (compared to capping a disposal mound).	-Possible loss of habitat for fish inhabiting subaqueous pits. -Other possible problems as listed above for capping.
Capping with active materials	-Potential to neutralize or detoxify contaminants.	-Limited field application to date. -Requires accurate placement of cover materials. -Requires resistance to scouring (in order to have time to react with contaminants); coarse materials may need to be mixed with more stable inert material.
Covering with synthetic membranes	-Impermeability potentially prevents leaching from highly contaminated sediments.	-Liner must be compatible with contaminants to be contained. -Possible problems include: - puncture of membranes by jagged objects. - need to vent gases released from sediments. - need to bond adjacent liner strips. - tearing or displacement of liner by bottom currents (need to weight down with clay, sand, or sediments). - difficulty of placing membrane.
Capping with sealant	-Less potential for resuspension of contaminated sediments than with injection of sealant. -Potentially applicable in less accessible areas.	-Grout or sealant may impact water column during application. -Application may be slow. -Difficult to obtain complete coverage.

(Continued)

TABLE IV-17. ADVANTAGES AND DISADVANTAGES OF VARIOUS REMEDIAL ACTION TECHNIQUES (continued)

Response Option	Advantages/Applications	Disadvantages/Limitations
Other In Situ Treatment Methods		
Sealing and grouting (by injection)	-Isolates contaminants, eliminating need for sediment removal. -Potentially creates stable base for construction.	-Limited information available on impacts and effectiveness. - Limited to protected open waters or to low flow streams where the flow can be diverted while grouting takes place.
Chemical and biological in situ treatment	-Eliminates need to remove contaminated sediments.	-Potential for secondary contamination by treatment reagents or by contaminant degradation products; therefore limited to areas that can be contained during treatment or where stream flow can be diverted during treatment. -Need to ensure that treatment reagents are completely mixed with the contaminated material. -Biological treatment involving aerbobic degradation requires that sediments contain sufficient oxygen. -Method not yet demonstrated.

Source: Summarized from Science Applications International Corp., 1985, and Phillips et al., 1985.

The following descriptions of contaminated sediment cleanup technologies are based on the more detailed discussions given by Science Applications International Corp. (1985). Descriptions of dredged material disposal methods are based on the discussion by Phillips et al. (1985).

No Action Alternative

Taking no direct action to clean up contaminated sediments may be appropriate in situations where the contamination poses little immediate threat to human health and the environment, and where natural processes are expected to result in rapid burial of the contaminated sediments by clean material with little risk of scour by storms at a later date. In such cases, the short-term impacts of cleanup operations (e.g., sediment resuspension and increased bioavailability of contaminants) and/or the long-term impacts of the disposal of contaminated material may be found to outweigh the benefits. In other cases, the "no action" alternative may be selected even though it is not deemed the most beneficial to the environment, because of a lack of sufficient funds for cleanup.

In situations where taking no action is clearly unacceptable, the expected consequences of this alternative may be evaluated as a baseline against which to compare other alternatives.

Dredging

Removal of contaminated sediments by dredging, perhaps the most obvious solution to sediment contamination problems, has both advantages and drawbacks. Complete removal of all contaminated material would ensure that pollutants will not impact local biota or human uses of the water body. However, complete removal may not be possible in areas with extensive contamination. In addition, the process of dredging may resuspend contaminated material, thus increasing its availability to biota. Another concern is the need to dredge below the contaminated layers (which may lie under a relatively clean surface layer) so that dredging does not make the situation worse by just exposing the contaminated material.

Numerous types and design of dredging equipment are available. Typical applications and capabilities of dredge equipment are compared in Table IV-18. Mechanical dredges remove bottom sediment by the direct application of mechanical force. Hydraulic dredges use centrifugal pumps to create suction, removing and transporting material in liquid slurry form. Pneumatic dredges, a type of hydraulic dredge, use compressed air and/or hydrostatic pressure to dislodge and collect sediments. Most types of dredging equipment are mounted on barges, but some are land- or dock-based. Specialized dredging equipment includes both smaller, hand-held dredges, and large, self-propelled equipment that may operate on land, in shallow water, and/or underwater.

A variety of support activities may be required in conjunction with dredging operations. These include pre-dredging activities such as stream diversion or removal of weeds or debris from bottom sediments, the use of barriers to control turbidity during dredging, and treatment and disposal of the dredged material.

TABLE IV-18. COMPARISON OF DREDGE EQUIPMENT

	Type of Dredge											
	Mechanical			Hydraulic						Pneumatic		
	Clamshell	Dragline	Backhoe	Plain Suction	Cutterhead	Dustpan	Hopper	Portable	Clean Up	Air Lift	Pneuma	Oozer
Typical Application												
Volume	A, B	A, B	A	B, C	B, C	B, C	B, C	A, B	B, C	A, B	B, C	B, C
Setting	D, E, F, G, H	D, E, F	D, E		G, H	G, H	H	E, F, G	G, H	E, F, G, H	E, F, G, H	E, F, G, H
Auxiliary Facilities	I, J, M	I, J, M	I	J, K, L	J, K, L	J, K, L	None	K, L, M	J, K, L	J, K, L, M	J, K, L, M	J, K, L, M
Depth Limitations												
Minimum (Ft.)	None[1]	None[1]	None	5 6[4]	3 5[4]	5[4]	12 30[4]	1½ 6[4]	(3)	None	(1)	(1)
Maximum (Ft.)	None[2]	None[2]	40	60	12 50[4]	60[4]	36 65[4]	15 58[4]	(3)	None	None[2]	None[2]
Precision Obtainable												
Horizontal (Ft.)	1[4]	2	1	2 3[4]	2 3[4]	2 3[4]	10[4]	1[4]	2 3	1	2 3	2 3
Vertical (Ft.)	1	2	1	1	1	1	1	1	1	1	1[4]	1
Rate of Production (C.Y./Hr.)	30 600[4]	60 700	60 700	25 10,000[4]	25 2,600[4]	3,500[4]	500 2,000[4]	50 1,850[4]	(3)	(3)	60 390[4]	(3)
Turbidity/Resuspension	High[4]	High	High	Low[4]	Avg[4]	Avg[4]	Avg[4]	Low[4]	Low	Low	Low[4]	Low
Availability	T	T	T	X[4]	R[4]	Q[4], X[4]	Q[4], S[4]	U	W	Y	V	W
Transportability	4	4	1	5	5	5	6	1 3[4]	5	4	4	4

Volume
- A - Small scale, less than 1,000 cubic yards (4)
- B - Medium scale, 1,000 to 200,000 cubic yards (4)
- C - Large scale, greater than 200,000 cubic yards (4)

Setting
- D - Narrow and/or very shallow (less than 5 feet) streams
- E - Shallow (less than 20 feet) streams and rivers, navigable by small vessels
- F - Inland lakes and ponds
- G - Inland navigable channels and lake and coastal harbors
- H - Great lakes and coastal harbors

Auxiliary Facilities
- I - Dump trucks
- J - Barges
- K - Transport piping
- L - Settling impoundments
- M - Crane

Availability
- Q - All or most owned by Corps of Engineers
- R - Based in most major harbors and commercial waterways.
- S - Based in some coastal and great lakes harbors
- T - Widely available in general earthwork applications
- U - Widely available from contractors and vendors.
- V - Limited availability through U.S. distributors.
- W - Not generally available in U.S.
- X - Generally available on inland commercial waterways.
- Y - Can be fabricated

Transportability
- 1 - Dredge can be moved over existing roads "as is" or with slight modification (5)
- 2 - Dredge can be moved over existing roads after disassembling to 3 or fewer pieces. (5)
- 3 - Dredge can be moved over existing roads after disassembling to more than 3 pieces. (5)
- 4 - Dredge head can be moved over existing roads "as is" or with slight modification and mounted on conventional vessel or crane.
- 5 - Transport restricted to navigation channels (greater than 5 foot depth) due to draft.
- 6 - Transport restricted to deep (greater than 12 feet) navigation channels due to draft.

Footnotes
(1) Determined by draft of vessel; if not vessel mounted, there is not limiting minimum depth

(2) Limited only by availability of support equipment (e.g., cables, winches, etc.)

(3) Information not available

References
(4) Hand et al., 1978

(5) Clark, 1983

Source: Science Applications International Corp., 1985

In the process of dredging contaminated sediments, treatment and disposal of the dredged material are frequently more costly and of greater environmental concern than the actual dredging. Three general dredged material disposal alternatives are discussed here: open-water, shoreline, and upland. Within each of these alternatives, various restrictions or controls may be implemented to contain contaminants. Advantages and disadvantages of these disposal methods are summarized in Table IV-17.

Open-water disposal involves depositing dredged material at an aquatic site. Material may be placed at an open-water site by dumping from barges or hopper dredges or by discharging directly from a pipeline. A submerged diffuser system, which radially discharges slurry just above the bottom at a low velocity, has been developed as a means of more accurately placing dredged material and minimizing turbidity during discharge. Other methods for reducing the impacts of open-water disposal include containment in subaqueous depressions or in areas confined by underwater dikes, and capping with clean sediments. Treatment of dredged material by chemical, physical, or biological means either prior to or during discharge is also possible.

Upland disposal involves placing dredged material in a diked containment area on dry land. Upland disposal sites usually are designed to contain the solids from a dredged material slurry, allowing the supernatant water to flow out over a weir as the solids settle. Upland sites may also be used for disposal of hydraulically dredged material that has been dewatered elsewhere, or mechanically dredged material transported directly to the site. Control options that may be implemented to reduce the impacts resulting from disposal of contaminated sediments include the following:

- effluent quality controls--techniques for removal of suspended solids and/or soluble contaminants from the effluents
- runoff water quality controls--measures to prevent the erosion of dried dredged material and the dissolution of contaminants from its oxidized surface
- leachate controls--measures to minimize leaching of soluble contaminants into groundwater
- control of contaminant uptake by plants and animals
- control of gaseous or volatile emissions
- control of wind erosion

Control measures may involve chemical treatment, capping or covering the surface, lining the bottom, physical, chemical or vegetative stabilization of the surface, or other techniques. Upland disposal facilities can be used either for long-term containment of dredged material, or for temporary storage and/or treatment of dredged material prior to long-term disposal or beneficial use. For particularly contaminated sediments, RCRA or TSCA designs for land disposal facilities may be appropriate (or required).

Shoreline disposal, like upland disposal, involves placing dredged material in a diked containment area. In the case of shoreline disposal, the containment area is in the water, at a location such that the final surface of the dredged material after the facility is filled is above water. Control measures similar to those used at upland disposal sites may be implemented to reduce contaminant release.

In other instances these confined disposal areas may have specialized designs including dikes specially constructed (with slurry walls, clay, and/or impermeable plastic liners) to prevent leakage of contaminated leachate into the waterbody. Where impermeable materials are not used, filtering layers (e.g., of sand) may be employed. Other design features may provide for water level control, and for the collection and treatment of runoff and/or leachate.

Capping

Several techniques have been proposed or developed for capping or covering contaminated sediments. These include capping with inert materials (e.g., sand, silt, clay, or clean dredge spoils), capping with active materials that neutralize or detoxify contaminants (e.g., limestone, gypsum, or alumina), covering with synthetic membranes, and covering with sealants or grouts (e.g., cement). Such techniques may be used to cover a dredged material disposal mound, to cover materials deposited in an underwater pit, or to cover contaminated sediments in place. Advantages and disadvantages of these general capping methods are summarized in Table IV-17.

Capping could be supplemented by additional confinement on the sides of a contaminated area by the installation of slurry walls and/or grouting (see below).

Sealing and Grouting

Stabilization of sediments by injection of grouts or sealants is a technique that has been used extensively to facilitate marine construction, but has had relatively little application as a control measure for contaminated sediments. Sealing materials used include cement, quicklime, silicates, bentonite, and combinations of these materials. The applicability of particular types of grouts is determined by their viscosity, particle size, permeability, and compatibility with the contaminants to be contained. The viscosity of chemical grouts and the particle size of particulate grouts limit the type of sediment that the grout will penetrate. The grout chosen must be chemically compatible with the contaminants and sufficiently impermeable to contain them. Potential applications of several grouts and sealants are summarized in Table IV-19. Grouting and sealing of contaminated sediments may be accomplished *in situ* by injection of grouting materials or by stream diversion followed by sealing, as well as by capping with sealant, as mentioned above.

TABLE IV-19. POTENTIAL APPLICATIONS OF GROUTS AND SEALANTS FOR STABILIZATION OF CONTAMINATED SEDIMENTS

Grout/Sealant Material	Grout Type	Solidification Methods	Suitable Sediment Types	Incompatible Waste Types	Comments
Portland Cement	unstable, particulate	Solidification of Portland Cement	• Penetrability limits are a function of grain size--generally limited to coarse sands and gravel	• Acids & bases, organic solvents and sulfurous compounds, unless sulfur resistant type Portland Cement is used	• Durability and strength is high but so is permeability • Cement grouts are more permeable than other types of grouts mentioned
Bentonite Portland Cement	stable, particulate	Solidification of Portland Cement; swelling and gellation of expanding clay that stabilizes the cement	• Penetrability limits are a function of grain size--coarse sands and and gravel	• Strong organic and inorganic acids and bases; organic solvents, sulfurous compounds unless Type V Portland Cement is used	• Addition of clay lowers permeability and improves rheological properties • Watertightness increases with increase in clay content
Bentonite	stable, particulate	Swelling and gellation of expanding clay	• Penetrability limits are a function of grain size--fine to medium sands and coarser	• Strong organic and inorganic acids & bases • In the long term shrink/swell may be affected by wide variety of organics and metal salts	• Bentonite has a lower permeability than cement but has lower structural strength also
Silica Gel	chemical	Polymerization to form silica gel (SiO_2 lattice) upon mixing with gelling agents such as acids, polyvalent cations, or acid forming compounds	• Sand and silty sand	• Basic solutions • There are such a wide variety of gelling agents and additives being investigated, that it is difficult to generalize about incompatibility	• Silicate grout chemistry is a developing field, new additives for improving strength & watertightness and reducing syneresis. Gelling agents such as those produced by Dynamit Nobel should be further investigated. • Syneresis is the major concern in using silica gels
Quicklime	stable, particulate	Pozzolanic reaction	• Clay soil to silty sand soil in which a pozzolanic reaction is fully expected and concentration of organic matter is less than about 3%	• Organics	

Source: Science Applications International Corp., 1985

In Situ Chemical and Biological Treatment

Several chemical and biological treatment methods that have been developed, although primarily designed for treating contaminated soils and groundwater, are potentially applicable to contaminated sediments and sinking chemical spills. Applicable in situ treatment methods include neutralization, precipitation, oxidation, chemical dechlorination, and biological treatment. The applications and limitations of these methods are summarized in Table IV-20.

Demonstrated Application of Cleanup Technologies

A recent survey of eleven case studies involving the cleanup of contaminated sediments illustrates the number and variety of remedial action technologies available (SAIC, 1985). Case studies were selected to illustrate a variety of cleanup technologies, especially innovative technologies, in situations involving a range of contaminants, water body types, and sediment characteristics. Ten of the cases involved U.S. locations, and one involved a harbor in Japan. Cases where sediment cleanup was actually implemented and/or where several alternative cleanup technologies were considered and evaluated were preferentially selected for inclusion.

The cleanup technologies considered and implemented in these case studies are summarized in Table IV-21. A total of 53 separate technologies (excluding "no action") were identified. From 3 to 29 of these technologies were considered or implemented at each site. The most commonly implemented cleanup actions consisted of sediment removal, sediment and water separation, water treatment, and sediment disposal. However, in one case sediment removal was followed by riverbed capping with concrete to isolate remaining contaminants. In another case, the "no action" alternative, accompanied by long-term monitoring, was selected. (Two of the case studies describe sites where cleanup is planned, but has not yet been implemented.) A variety of in situ treatment methods were evaluated, but none (other than capping) were implemented in the case studies.

4. Evaluation and Selection of Remedial Alternatives

When a decision has been made to clean up contaminated sediments, the available remedial alternatives must be carefully evaluated. Evaluation of alternatives may proceed via one or a series of screening processes, in which the number of alternatives under consideration is reduced by the application of technical, environmental, economic and other criteria.

The process of evaluating and selecting remedial alternatives is illustrated by several site-specific studies, such as those by CH_2M Hill and Ecology & Environment (1983 and 1986), McGinn (1981), NUS Corp. (1984), and Phillips et al. (1985). A typical decision-making process is described below.

TABLE IV-20. SUMMARY OF IN SITU CHEMICAL AND BIOLOGICAL TREATMENT

Treatment Method	Waste Types Amenable	Treatment Reagents	Potential Problems	Comments
Neutralization	Acids & bases	• Weak acids and bases • To neutralize acids: calcium carbonate, sodium carbonate or sodium bicarbonate; limestone or greenstone may be applied as active cover material	• Toxicity to pH-sensitive benthos if not properly placed on the spill • Use of ferric sulfate under aerobic conditions may result in the formation of hydrous iron oxides which can scavenge heavy metals from water and may coat the gills of bottom feeders	• Containment of the spill or contaminated sediments is required before neutralization in situ • Remote pH meter should be used to locate pH imbalances • Materials can be applied in situ as solids either by broadcast spreading or use of hand shovels within the contained area • Materials can be applied in situ as slurries using such methods as sand spreader, open pipe discharge or the diffuser head • Materials can also be applied by diverting stream flow and then spreading and mixing the neutralizing agents; limited to streams with relatively low flow velocity
Precipitation	Inorganic cations and anions	• Sulfide precipitation is most promising since metal sulfides are the least soluble metal compounds likely to form over a broad pH range. Calcium sulfate, iron sulfate, or gypsum may be used	• Potential for formation of H_2S gas; likelihood increases as the reactivity of sulfide and metals decrease • Effective only under reduced conditions, oxidation to more soluble sulfide species could occur under aerobic conditions	• Containment of the spill or contaminated sediments is required in order to allow adequate time for reaction to proceed to completion • Solutions or slurries could be applied together with capping material (e.g., sand or clay) using methods such as pump down, open pipe discharge or the diffuser head • Solutions and slurries can be applied directly in calm waters using pumps and hoses • Mixing will generally be required so that formation of the precipitant will not prevent further reaction • Materials can also be applied by diverting stream flow and then spreading and mixing precipitating agents; reduced conditions should be maintained
Oxidation	Wide range of organics; highly chlorinated compounds and nitro aromatics are not well suited	• Oxygen and/or ozone and hydrogen peroxide	• Oxidation can result in more mobile degradation products • Both ozone and hydrogen peroxide may react with organics in the water column or sediments which are not target compounds, thereby reducing effectiveness • Compounds which are sorbed to sediments may be difficult to oxidize	• Containment of spills or contaminated sediments is required prior to oxidation in order to prevent loss of oxidant and oxidation of non-target compounds outside the contaminated area

(continued)

TABLE IV-20. SUMMARY OF IN SITU CHEMICAL AND BIOLOGICAL TREATMENT (Continued)

Treatment Method	Waste Types Amenable	Treatment Reagents	Potential Problems	Comments
Oxidation (continued)			• Ozone will decompose back to oxygen rapidly in the presence of organics; stability of hydrogen peroxide is not well known	
Chemical dechlorination (KUMPEG process)	Highly chlorinated organics (e.g. PCB, dioxins)	Polythylene glycol and potassium hydroxide	• Treatment system can tolerate some water but limits have not been established • Degradation is temperature dependent and may proceed slowly at ambient temperatures	• Due to a limited tolerance of water, stream diversion and/or dewatering would be required prior to treatment
Biological treatment	Most organics are amenable to biodegration to some degree; groups that tend to be most resistant to aerobic decomposition include chlorinated and nitro organics and polynuclear aromatic hydrocarbons with three or more rings; however, removal of nitro and chlorine groups may occur under reduced conditions	Microorganisms, oxygen source (for aerobic degradation) and nutrients	• Organics sorbed to sediments may be refractory • Degradation rates proceed very slowly at low temperatures • Partial degradation products may be more soluble or more toxic • Microorganisms used for treatment may be pathogenic	• Containment is required to confine microorganisms to contaminated areas when treating in situ • Acclimated, mutant and genetically engineered microorganisms have or are being developed for degradation of a broad range of waste types • Considerable research is needed to find suitable means of maintaining adequate oxygen supply; research needs to concentrate on oxygen delivery systems as well as on the use of ozone and hydrogen peroxide as an oxygen source

Source: Science Applications International Corp., 1985

TABLE IV-21. CLEANUP TECHNOLOGIES CONSIDERED (C) AND IMPLEMENTED(I) IN ELEVEN CASE STUDIES

Technology	No. Sites C	No. Sites I
NO ACTION	2	1
SEDIMENT REMOVAL	3	8
• Predredging Activities		
- Stream Diversion	4	1
- Coffer Dams	4	1
- Snagging	-	1
- Diver Assistance	-	3
• Mechanical Dredges		
- Clamshell	2	1
- Dragline	2	2
- Backhoe	2	1
- Scraper	2	-
- Loader	2	1
• Hydraulic Dredges		
- Plain Suction	-	-
- Cutterhead	2	1
- Dustpan	1	1
- Hopper	1	-
- Clean Up	-	1
- Portable	1	1
- Special Head	-	1
• Pneumatic Dredges		
- Airlift	1	1
- Pneuma	1	1
- Oozer	2	1
• Specialized Dredges		
- Hand-Held (Above- or Under-Water)	-	2
- Amphibious	-	1
- Underwater	-	-
• Turbidity Control Measures		
- Silt Curtain	1	1
- Air Curtain	-	1
- In-Stream Filter	-	1
- In-Stream Detention	-	1
DREDGED MATERIAL MANAGEMENT		
• Dewatering:	3	5
- Settling Tanks	-	2
- Settling Impoundments	3	2
- Settling Barges	1	2
- Filter Press	2	1
- Solidification	2	2
• Sediment Separation by Grain Size:	-	2
- Settling	-	1
- Screens	-	1
• Disposal:	3	7
- Special Landfill	3	4
- Sanitary Landfill	-	3
- Water Column	1	1
- Special On-Site Facility	2	2
- On-Land Nearby	1	-
• Supernatant Treatment	3	5
- Sand Filtration	1	2
- Coagulation	2	3
- Carbon Adsorption	2	4
- Chlorination	-	1
- Photochemical Degrad.	1	-
- Ozonation	1	
- Direct Discharge	1	1
- Radiation	1	-
IN SITU TREATMENT	4	2
- Sorbents	2	-
- Capping with Sealant	3	1
- Capping with Clean Sediments	1	1
- Fixation	2	-
- Chemical Treatment	2	-
- Biological Treatment	2	-
- Stabilization/ Containment	1	-

Source: Science Applications International Corp., 1985

A first step in choosing appropriate remedial actions is specifying objectives and key criteria. For example, the goal may be to restore the site to near-pristine conditions, to improve sediment quality to a level that is equal to adjacent areas, or to mitigate or contain the worst pollution so that it does not pose an immediate threat to human health and the local environment. Depending on the site, greater or lesser importance may be placed on particular factors, such as completing the cleanup as quickly as possible, making the solution agreeable to the local community, or minimizing costs.

The next step in a comprehensive approach to planning remedial activities is to identify potentially applicable technologies or "unit processes". Such technologies might include methods of capping or of chemical or biological treatment, dredging techniques and equipment, dredge spoils disposal methods, and support activities such as stream diversion, dredged material dewatering, or turbidity control. These technologies must then be screened to eliminate inappropriate ones. For example, a first screening would eliminate technologies that:

- do not meet objectives for environmental quality;
- have excessive costs (e.g., exceeding costs of other methods by a factor of ten or more);
- require unacceptable time delays (e.g., because equipment is not readily available, or because of permit requirements);
- have not been previously demonstrated (unless the resources are available to develop and test technologies that are in conceptual or experimental stages);
- cannot be easily monitored; or
- do not meet institutional or regulatory requirements.

Additional criteria may be applied to further limit the number of technologies under consideration.

Following this preliminary screening, the remaining technologies may be assembled into "remedial alternatives" that combine individual technologies into a complete cleanup plan. For example, one alternative may combine a stream flow diversion plan with an in-place capping method, while another alternative combines a selected dredging technique and sediment dewatering technique with a particular confined disposal design. Once such remedial alternatives have been defined, further screening and evaluation can compare the impacts and benefits of the complete alternatives. If many alternatives have been identified, a more cursory screening that narrows consideration to a few options may be followed by a detailed evaluation of the remaining few. This evaluation should include consideration of technical, environmental,

public health, socioeconomic, institutional, and cost factors, such as those listed in Table IV-22. As becomes clear upon reviewing these factors, the choice of the most appropriate alternative is highly site-specific, depending on the nature of the contamination, the water body, the local biota, and the local human community, among other factors.

Procedures for selecting appropriate dredged material disposal methods have received considerable research attention. Choice of a disposal method and site is influenced by several considerations (Phillips et al., 1985):

- the class of contaminants of concern;
- the physicochemical environment at the disposal site;
- the properties of the dredged material;
- accessibility of the disposal site from the dredging site; and
- the risk of adverse impacts from contaminants released to the surrounding environment.

Dredged material properties and the physicochemical conditions at a disposal site influence the mobility of contaminants in dredged material. Important parameters are clay and organic matter content, pH, and oxidation-reduction conditions. Sediments rich in organic matter and clay tend to retain many contaminants to a greater extent than sandy sediments with low organic content. Thus, although sandy sediments are less likely to accumulate contaminants, once contaminated, they are more likely to release contaminants to the water column during dredging operations or to groundwater by leaching from a disposal facility (Phillips et al., 1985).

In general, disposing of contaminated sediments in a chemical environment similar to their in situ condition favors contaminant retention. Many contaminated sediments are initially in a reduced state and at near neutral pH. If such sediments are exposed to air and allowed to dry, they may become acidic, increasing the solubility and potential release of heavy metals. Exposure to air and oxygen can also dissolve, degrade, or volatilize sediment organic matter, increasing the mobility of organic contaminants. Thus, many contaminants would be better retained by sediments in a capped, open-water disposal site than in an upland or nearshore site. However, organic contaminants, because they tend to remain partly soluble whether in a wet or dry environment, are more subject to release by water exchange than are metals; thus, upland disposal may be preferable to open-water or nearshore disposal in some cases (Phillips et al., 1985; Francingues et al., 1985). Other concerns related to open water disposal sites are: (1) monitoring requirements; (2) disturbance and failure of the cap; and (3) the possible need to consider the applicability of TSCA and RCRA regulations.

TABLE IV-22. CONSIDERATIONS FOR EVALUATION OF REMEDIAL ALTERNATIVES

Technical/Engineering Considerations

- efficiency of contaminant removal or effectiveness of contaminant confinement (depends on contaminant type).
- demonstrated reliability of techniques.
- safety of operations.
- ease of implementation (at the particular site in question).
- availability of equipment.
- availability and accessibility of suitable disposal sites.

Environmental Considerations

- short-term impact of cleanup operations on biota at the contaminant site, in adjacent areas, and at the disposal site.
- long-term impact on biota.

Public Health Considerations

- impact on health of cleanup workers.
- short-term and long-term impact on health of the surrounding community.

Socioeconomic Considerations

- impact on recreational and commercial uses of the water.
- impact on desirability of land surrounding the contaminated water body and the disposal site.

Institutional/Regulatory Considerations

- compliance with environmental standards.
- compliance with land use/zoning regulations.
- requirements for obtaining permits.

Cost Considerations

- total cost of cleanup operations.
- maintenance costs.
- cost per mass of contaminants contained or removed.

The issue of monitoring at completed remediation sites is a growing concern for many. Some sites (e.g., open water disposal areas, underwater capped areas, and even some shoreline confined disposal areas) clearly would involve difficult and costly monitoring programs if thorough checks on the integrity of the confinement (or actual measurements of the contaminant leakage rates) were required. The results of this uncertainty in monitoring capability are often more stringent requirements to design for complete containment, requirements for point source treatment (e.g., of runoff or leachate collected from shoreline disposal areas), or a requirement to use upland sites.

The U.S. Army Corps of Engineers (Francingues et al., 1985) have developed a "Management Strategy for Disposal of Dredged Material", specifying tests to be performed on dredged material to determine the need for restrictions and controls on its disposal. A flowchart outlining this strategy is shown in Figure IV-8. (In this flowchart, the term "confined disposal" refers to any disposal option in which fine-grained sediments are taken out of the water and allowed to dry, i.e., shoreline, intertidal, or upland disposal). The strategy calls for proceeding via the following steps to select a disposal method:

a. Conduct an initial evaluation to assess contamination potential.

b. Select a potential disposal alternative.

c. Identify potential problems associated with that alternative.

d. Apply appropriate testing protocols.

e. Assess the need for disposal restrictions.

f. Select an implementation plan.

g. Identify available control options.

h. Evaluate design considerations for technical and economic feasibility.

i. Select appropriate control measures.

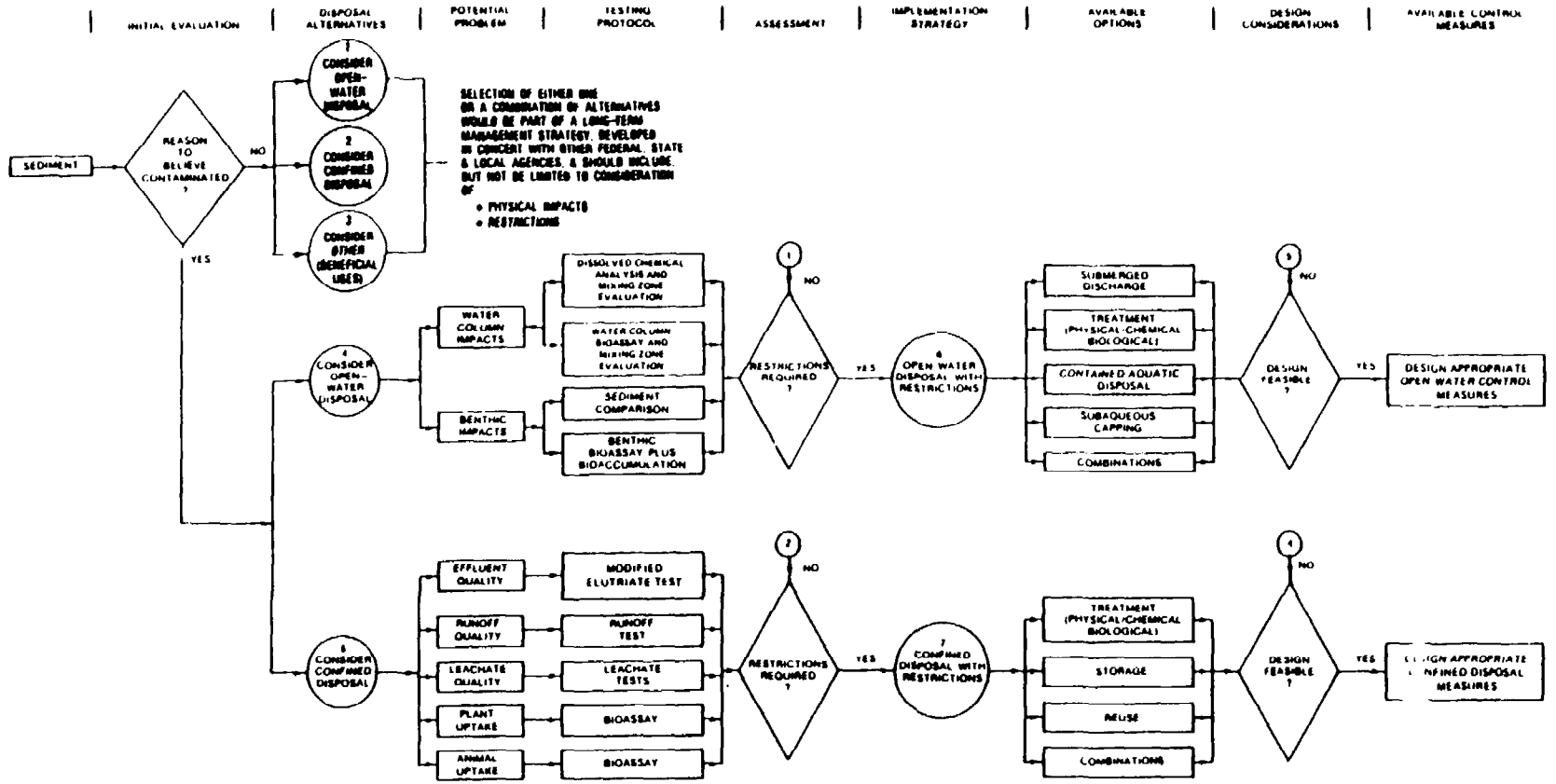


FIGURE IV-8. MANAGEMENT STRATEGY FLOWCHART

Source: Francingues et al., 1985

V. DEVELOPMENT OF SEDIMENT QUALITY CRITERIA

A. OVERVIEW

A question of great importance to environmental managers is how to decide when in-place pollutants constitute a sediment contamination problem. There are currently no nationwide standards for sediment quality, although efforts to develop such criteria are underway under the direction of EPA's Criteria and Standards Division in the Office of Water Regulations and Standards. Most agencies that must make decisions regarding sediment contamination (e.g., EPA regional offices, state environmental agencies, and Corps of Engineers district offices) evaluate instances of sediment contamination on a case-by-case basis.

Ideally, judgments of the seriousness of sediment contamination should be based on the potential for adverse ecological (and human health) effects. Such effects are not always correlated with the total concentration of pollutants in sediments. It has been found that bulk sediment analyses do not adequately predict water quality effects, release of contaminants from sediment, or bioaccumulation of contaminants (Engler, 1980). However, because pollutant concentrations are easily measurable by standard analytical methods, bulk analyses of sediments are often used as an indication of the level of pollution. Most commonly, in areas that have no formal sediment quality criteria, judgments of the severity of pollution are made by comparing contaminant levels to background levels, i.e., contaminant levels measured at locations considered unpolluted. In addition, evaluation of dredged material being considered for in-water disposal usually includes consideration of bioassays and of the physical characteristics of the material.

In the past two decades, a number of regional and state agencies have developed numerical criteria for evaluating pollutant levels in sediments or dredged material. Most of the earlier sets of sediment quality criteria were based primarily on background levels of pollutants. More recently, efforts to develop sediment quality criteria have had the goal of deriving numerical values for maximum pollutant levels that do not cause unacceptable biological effects.

The majority of the criteria developed have been based on total pollutant concentrations in sediments. Other proposed criteria have been based on pollutant concentrations in sediment interstitial water, on the ratio of a metal concentration to the concentration of aluminum in sediment, or on the concentration of an organic pollutant divided by the total organic carbon concentration in sediment.* The coverage and applicability of several sets of sediment criteria (including regulatory criteria, non-regulatory guidelines, and preliminary values intended to demonstrate new methods for deriving criteria) are summarized in Table V-1.

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* This may be referred to as the organic carbon-normalized concentration.

TABLE V-1. COMPARISON OF COVERAGE OF EXISTING SEDIMENT QUALITY CRITERIA

Criteria [Ref.]	Number of elements or chemicals for which numerical criteria are given: Metals & Metalloids	Conventional Pollutants*	Pesticides	Other Organics	Area of Applicability	Comments
Puget Sound Interim Sediment Criteria, 1984-86 [1]	6	-	1	3	Puget Sound	• Includes 3 sets of criteria, for different dredged material disposal sites. • Bioassays and physical parameters are also considered.
Wisconsin DNR Interim Criteria for In-Water Disposal, 1985 [2]	10	1	8	3	Great Lakes harbors	• Analyses for particle size, TOC, and N-containing pollutants are also required.
Long Island Sound Interim Dredged Material Disposal Plan, 1980 [3]	9	(see comment)	2	1	Long Island Sound	• Primary classification of dredged material is based on percentages of oil & grease, volatile solids, water, and silt & clay; levels of chemicals are used to confirm classifications.
Maine DEP Dredged Material Disposal Guidelines [4]	8	(see comment)	1	1	Gulf of Maine	• Primary classification of dredged material is based on percentages of oil & grease, volatile solids, water, and silt & clay; levels of chemicals are used to confirm classifications.

(Continued)

TABLE V-1. COMPARISON OF COVERAGE OF EXISTING SEDIMENT QUALITY CRITERIA (Continued)

Criteria [Ref.]	Number of elements or chemicals for which numerical criteria are given: Metals & Metalloids	Conventional Pollutants*	Pesticides	Other Organics	Area of Applicability	Comments
Massachusetts Dredged Material Disposal Guidelines [4]	9	(see comment)	-	1	marine water	• Combination of chemical parameters and physical parameters (% oil & grease, volatile solids, water, and silt & clay) determines disposal options.
EPA Region V Guidelines for Pollutional Classification of Sediments, 1977 [5]	11	7	-	1	Great Lakes harbors	• Interim guidelines, classifying sediments as non-, moderately, or heavily polluted.
Florida DER Guide to Interpretation of Metal Concentrations, 1986 [6]	7	-	-	-	Florida estuaries	• Non-regulatory guide for assessing pollution. • Based on the ratio of metal concentration to aluminum concentration, not total metal concentration.
USGS Sediment Alert Levels [7]	8	3	15	1	nationwide	• Screening levels, used to flag high contaminant levels (detected in monitoring program) for further investigation.

(Continued)

TABLE V-1. COMPARISON OF COVERAGE OF EXISTING SEDIMENT QUALITY CRITERIA (Continued)

Criteria [Ref.]	Number of elements or chemicals for which numerical criteria are given: Metals & Metalloids	Conventional Pollutants*	Pesticides	Other Organics	Area of Applicability	Comments
JRB Equilibrium Partitioning-Based Criteria, 1984 [8]	6	-	6	41	marine waters	• Preliminary values, demonstrating method. • Derived using sediment-water partitioning coefficients and water quality criteria.
Screening Level Concentrations (SLC), 1986 [9]	- -	- -	4 1	1 8	freshwater saltwater	• Preliminary values, demonstrating method.
Apparent Effects Threshold (AET), 1986 [10]	14	-	3	17	Puget Sound	• Preliminary values, demonstrating method. • Several AET values were derived for each contaminant, based on different measures of biological effects.
Oklahoma Numerical Criteria Goals for Sediment [11]	6	-	2	1	Oklahoma freshwater	• Non-regulatory screening levels.
Sediment Quality Triad [12]	1	-	-	2	Puget Sound	• Preliminary values, demonstrating method.

(Continued)

TABLE V-1. COMPARISON OF COVERAGE OF EXISTING SEDIMENT QUALITY CRITERIA (Continued)

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*"Conventional pollutants" include: ammonia, nitrate, nitrite, Kjeldahl nitrogen, cyanide, phosphorus, COD, volatile solids, oil and grease.

REFERENCES:

1. U.S. EPA Region X, 1986

2. Sullivan et al., 1985

3. New England River Basins Commission, 1980

4. New England Governor's Conference, 1982

5. U.S. EPA Region V, April, 1977, as cited in Great Lakes Water Quality Board, 1982

6. Florida Department of Environmental Regulation, 1986

7. Pavlou and Weston, 1983

8. JRB Associates, 1984

9. Neff et al., 1986

10. Tetra Tech, 1986, as cited in Puget Sound Water Quality Authority, 1986

11. Personal communication from P. Crocker, EPA Region VI.

12. Chapman, 1986.

A variety of approaches have been used to derive sediment criteria, including approaches based on background levels, biological effects, or equilibrium partitioning. Several of these approaches are described briefly below. Some of the advantages and disadvantages of each method are summarized in Table V-2. Table V-3 compares, for a few pollutants, criteria values derived by various methods. As illustrated by this comparison, criteria for a given pollutant may vary widely depending on the method of derivation.

B. CHEMICAL ANALYSIS OF INTERSTITIAL WATER

This approach, which was originally proposed by EPA Region VI, calls for evaluating sediments by comparing contaminant levels in the interstitial water to EPA water quality criteria. This approach is based on the assumption that the toxic effects of contaminated sediments are primarily due to contaminants absorbed from overlying and interstitial water, rather than direct absorption from sediments or ingestion of sediment particles. A disadvantage is the difficulty of extracting sufficient interstitial water for analysis from certain types of sediment. However, this method has the advantage of being based on the extensive toxicological database incorporated into the water quality criteria (Pavlou and Weston, 1983). The remainder of the approaches described below are based on measuring contaminant concentrations in the sediments directly.

C. BACKGROUND LEVEL APPROACH

Following this approach, criteria are established by reference to measured contaminant concentrations in sediments of a relatively unpolluted reference area. This has been the most widely used method of setting sediment quality criteria to date, principally because the necessary background concentration data are readily available, while sediment toxicity data are not generally available. Some advantages and disadvantages of this approach are listed in Table V-2.

One source of background concentration data that is used by several EPA regions, as well as by the Monitoring and Data Support Division at EPA Headquarters, is the STORET water quality monitoring database. Several of the EPA regions, whether or not they conduct routine sediment quality monitoring, collect some sediment samples in conjunction with water quality sampling, and input the results into the STORET system. The 85th percentile of the sediment pollutant concentrations recorded in STORET is used as a screening level against which to compare contaminant levels at potential sediment problem areas. The 85th percentile level (i.e., the level that is higher than 85 percent of the values recorded) may be calculated on either a regional or national basis. The accessibility and nationwide coverage of the STORET system make it a useful source of data. However, because much sediment sampling is conducted in areas with suspected pollution problems, the database may be skewed toward higher pollutant concentrations. Thus, the 85th percentile level may be an inappropriately high screening level (Personal communication, J. Lazorchak, EPA Region VIII).

TABLE V-2. COMPARISON OF APPROACHES TO DERIVING SEDIMENT CRITERIA

Approach [Ref.]	Advantages	Disadvantages
Background Level [1]	• Background concentration data are readily available.	• Criteria are site-specific, depending on the region from which background samples were taken. • Criteria based on contaminant levels in unpolluted sediments may be overly restrictive. • Setting a permissible level of contaminant enrichment above background levels is somewhat arbitrary and does not represent a maximum biologically safe level.
Bioassay [1]	• Represents a direct measure of contaminated sediment toxicity, accounting for all possible routes of contaminant uptake.	• Requires development of standard bioassay methodologies. • Requires a large number of lab tests for each contaminant.
Apparent Effects Threshold [2,3]	• Uses existing data and can be refined as more data are obtained.	• Results in several possible criteria values, depending on what biological effects indicator is used.
Screening Level Concentration (SLC) [3,4]	• Based on actual field data indicating effects of contaminated sediments.	• Distribution of organisms may be affected by many factors other than sediment contaminant levels; thus not a direct measure of contaminant effects. • Range and distribution of data points affects calculated value.

(continued)

TABLE V-2. COMPARISON OF APPROACHES TO DERIVING SEDIMENT CRITERIA (Continued)

Approach [Ref.]	Advantages	Disadvantages
Sediment Quality Triad [6]	• Based on a combination of laboratory and field data indicating effects of actual contaminated sediments; can be refined as more data are obtained.	• Available data may be of variable quality, from studies conducted at different times and using different techniques.
Equilibrium Sediment- Water Partitioning [5]	• Utilizes large toxicological database incorporated in water quality criteria. • Relies on well-developed theory of partitioning.	• Limited to contaminants for which both water quality criteria and sediment-water partitioning coefficients are available. • Sediment and water may not be at equilibrium with respect to contaminant concentration. • Does not account for contaminant uptake by ingestion of particles or by direct absorption from sediments.
Equilibrium Sediment-Biota Partitioning. [1]	• Criteria would account for all possible routes of contaminant uptake. • The only chemical-specific information required is an acceptable body burden limit.	• Limited to hydrophobic neutral organic compounds. • Assumption of constant bioaccumulation factor for various contaminants and organisms is questionable. • Some compounds may accumulate in animal tissues in a non-equilibrium fashion. • Few data are available on acceptable body burden limits.

REFERENCES:
1. Sullivan et al., 1985
2. Barrick et al., 1986
3. Puget Sound Water Quality Authority, 1986
4. Neff et al., 1986
5. JRB Associates, 1984
6. Chapman, 1986

TABLE V-3. COMPARISON OF SELECTED MARINE SEDIMENT CRITERIA VALUES DERIVED BY VARIOUS METHODS

Chemical	Equilibrium Partitioning Based Criteria (for sediment with 4% organic carbon)[a]		Apparent Effects Threshold (AET)[b]	Screening Level Concentration (SLC) (for sediment with 4% organic carbon)[c]	Puget Sound Open-Water Disposal Criteria[d]
	Acute	Chronic			
Metals	Concentrations in parts per million (ppm)				
Arsenic	64	32.8	700-85		12.5
Cadmium	96	30.8	9.6-5.8		0.7
Copper	216	136	800-310		68.0
Lead	3360	132	700-300		33.0
Mercury	[c]0.6	0.032	2.1-0.41		0.15
Zinc	2240	760	1600-260		105.0
Organics	Concentrations in parts per billion (ppb)				
DDE	28,000		15-9		
DDD	13,000		43-2		
DDT	840	6.4	11-3.9	1712	5.0 (sum of DDD, DDE, & DDT)
PCBs (total)			2500-130	170.4	380
2-PCB		2.56			
3-PCB		40			
4-PCB		56			
5-PCB		208			
6-PCB		280			

(continued)

TABLE V-3. COMPARISON OF SELECTED MARINE SEDIMENT CRITERIA VALUES DERIVED BY VARIOUS METHODS (continued)

Chemical	Equilibrium Partitioning Based Criteria (for sediment with 4% organic carbon)[a]		Apparent Effects Threshold (AET)[b]	Screening Level Concentration (SLC) (for sediment with 4% organic carbon)[c]	Puget Sound Open-Water Disposal Criteria[d]
	Acute	Chronic			
Organics	Concentrations in parts per billion (ppb)				
Low Molecular Wt. PAHs[e]			6100-5200		680
Naphthalene	42,000		21,000-21,000	1468	
Phenanthrene	56,000		3200-1500	1036	
High Molecular Wt. PAHs[f]			>51,000-12,000		2690
Benzo(a)anthracene	220,000		4,500-1300	1044	
Benzo(a)pyrene	1,800,000		6800-1600	1584	
Chrysene	460,000		6700-1400	1536	
Fluoranthene	36,000	14,400	6300-1700	1728	
Pyrene	198,000		>7300-2600	1736	

(Continued)

TABLE V-3. COMPARISON OF SELECTED MARINE SEDIMENT CRITERIA VALUES DERIVED BY VARIOUS METHODS (continued)

FOOTNOTES:

a. Values calculated from organic carbon-normalized criteria given by JRB Associates, 1984. These criteria are based on EPA water quality criteria, or, for contaminants for which no water quality criteria have been established, on one-half the lowest concentration at which toxic effects have been noted. Note that several of the water quality criteria have been updated since the time of publication of these values, so sediment criteria derived from the current water quality criteria may differ from them.

b. Values cited by Puget Sound Water Quality Authority, 1986, from Tetra Tech, 1986. Highest and lowest of four values, derived based on various biological tests, are presented.

c. Values calculated from organic carbon-normalized criteria given by Neff et al., 1986.

d. Values from U.S. EPA, Region X, 1986 (Unpublished information). These are interim criteria, administered by EPA and the Washington Dept. of Ecology. Sediments must meet specified bioassay criteria, as well as these chemical criteria, in order to be approved for unconfined open water disposal.

e. Sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

f. Sum of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, and pyrene.

A variation on the background level approach has been used by the Florida Department of Environmental Regulation (1986) to develop guidelines for interpreting reported metal concentrations in estuarine sediments. This approach is based on the principle that, although metal concentrations in unpolluted estuarine sediments may vary widely, the ratio of the concentration of a given heavy metal to the concentration of aluminum is fairly constant. Thus, polluted sediments can be identified by comparing measured metal-to-aluminum ratios to "natural" ratios calculated from data for uncontaminated sediments. Using data collected from presumably uncontaminated estuarine sediments in Florida, graphs like the one in Figure V-1 were prepared for seven metals, showing the mean metal-to-aluminum ratio, as well as the mean plus one and two standard deviations.

Metal concentrations data for estuarine sediments can be interpreted by comparison to the mean metal-to-aluminum ratios; sediments with metal-to-aluminum ratios more than two standard deviations above the mean are probably polluted, while those with ratios below the mean or within one standard deviation of the mean are probably unpolluted. Each graph also includes a line indicating the maximum metal concentration observed in the unpolluted sediments analyzed; it is assumed that any sample having a metal concentration above this value is contaminated regardless of its aluminum concentration.

D. BIOLOGICAL EFFECTS APPROACHES

A few possible approaches establish criteria by relating sediment contaminant concentrations to observed adverse biological effects. Effects may be quantified based on either laboratory bioassays or field observations.

Biassay. An approach that theoretically could result in very accurate criteria is to conduct a series of bioassay tests for each contaminant of concern, comparing effects on test organisms held in sediments with known contaminant concentrations to effects in controls. Mortality, sublethal effects, or bioconcentration may be measured. However, such an approach would require an extensive series of tests for each contaminant, using a variety of organisms and sediment types (Sullivan et al., 1985).

Apparent Effects Threshold. An alternative approach is to compile existing data on biological effects noted for natural sediments with known chemical composition. Although bioassay results for a single sediment sample containing several contaminants cannot be used to quantify the effects of any one contaminant, results from many such samples can be used to derive an apparent effects threshold (AET) for each contaminant. The AET is the contaminant concentration above which adverse effects are always expected to occur. An AET can be established using any measure of biological effects, including both laboratory bioassays and field observations (e.g., abundance of benthic infauna). Several different AET values can be derived, depending on the biological effects indicator used. In addition, AETs

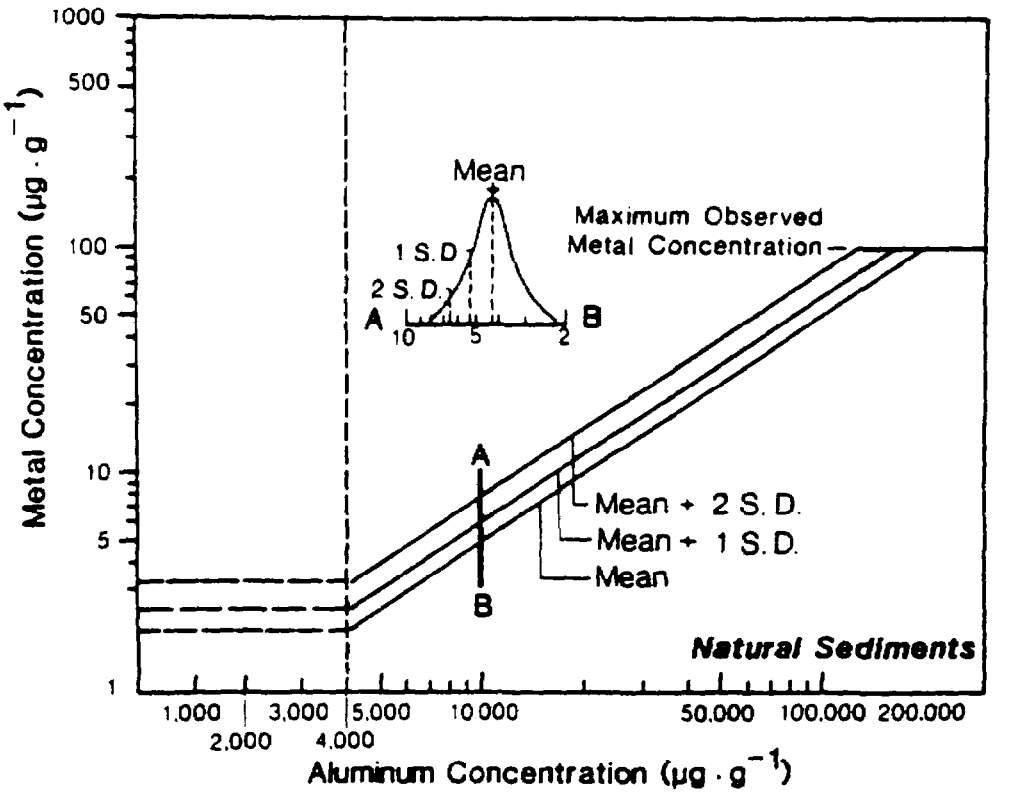

FIGURE V-1. HYPOTHETICAL METAL VERSUS ALUMINUM DIAGRAM FOR INTERPRETATION OF REPORTED METAL CONCENTRATIONS IN ESTUARINE SEDIMENTS.

Source: Florida Department of Environmental Regulation, 1986

may be based either on total contaminant concentrations or on concentrations normalized for organic carbon (or any other desired parameter). This approach has been applied to data from Puget Sound sediments to derive AETs for over 50 inorganic and organic pollutants (Barrick et al., 1986; Puget Sound Water Quality Authority, 1986).

Screening Level Concentration. A third method for relating sediment contaminant levels to biological effects has been termed the screening level concentration (SLC) approach. This approach uses field data on the occurrence of benthic infaunal invertebrates in sediments with varying concentrations of organic contaminants. The SLC is a calculated estimate of the highest concentration of a given contaminant that can be tolerated by 95 percent of the benthic infauna. The method for calculating an SLC involves two steps. First, the 90th percentile concentration of a given contaminant at all stations where a given species occurs is calculated. This value is called the species screening level concentration (SSLC). Next, after SSLCs have been derived for many species, the concentration that is below 95 percent of the SSLCs is designated the SLC. This method was used by Neff et al. (1986) to calculate SLCs for five contaminants in freshwater sediments and nine contaminants in saltwater sediments. The method was applied to nonpolar organic contaminants only, and the SLCs were calculated using organic carbon-normalized concentrations. The method has also been applied to Puget Sound sediments by Tetra Tech (Puget Sound Water Quality Authority, 1986).

Sediment Quality Triad. Another criteria-development approach is referred to as the sediment quality triad, because it combines the three elements of sediment chemistry, bioassays, and in situ studies. Criteria are developed by analyzing data on the spatial distribution of selected chemicals in sediments of a given area, the results of laboratory bioassays of sediments collected from that area, and the results of in situ studies such as measures of resident organism histopathology, benthic community structure, or bioaccumulation. In a demonstration of this approach by Chapman (1986), three chemical groups were studied: high molecular weight combustion polycyclic aromatic hydrocarbons (PAHs), total PCBs, and lead. These chemicals were selected because sufficient data were available to determine their spatial distributions, and their distribution appeared representative of other chemical contaminants. Three types of bioassays (amphipod acute lethality, oligochaete respiration effects, and fish cell anaphase aberration tests) were considered, and the in situ measure used was fish histopathology (i.e., the frequency of selected liver lesions in English sole). Based on an analysis of data from these studies for the Puget Sound area, a general trend of increasing biological effects with increasing sediment chemical concentrations was found. Three ranges of concentrations, for which biological effects levels were low, hign, or intermediate, were determined for each chemical group. The contaminant concentrations at or below which biological effects were minimal are: 50 ppm lead, 3.8 ppm combustion PAHs, and 0.1 ppm total PCBs. The contaminant concentrations at or above which biological effects were always high are: 130 ppm lead, 6.8 ppm combustion PAHs, and 0.8 ppm total PCBs. The range between these low- and high-effects levels is considered an area of uncertainty.

E. EQUILIBRIUM SEDIMENT-WATER PARTITIONING APPROACH

This approach uses sediment-water partitioning coefficients to set criteria at a level that ensures that contaminant concentrations in interstitial water will not exceed the EPA water quality criteria. Criteria are calculated by multiplying the sediment-water partitioning coefficient for a given contaminant by the water quality criterion for that contaminant. Since partitioning coefficients are usually normalized for organic carbon, this method results in criteria for organic carbon-normalized concentrations of contaminants. This approach is based on two major assumptions: (1) that the toxic effects of contaminated sediments are caused primarily by ingestion or absorption of contaminated water in contact with the sediments and are not significantly increased by ingestion of contaminated particles, and (2) that contaminants are at equilibrium between sediments and water. Criteria based on the equilibrium partitioning approach have been derived by JRB Associates (1984) for 6 metals and 47 organic pollutants.

F. EQUILIBRIUM SEDIMENT-BIOTA PARTITIONING APPROACH

In this approach, criteria are established at levels such that organisms at thermodynamic equilibrium with the sediment cannot accumulate tissue concentrations of contaminants in excess of established permissible limits. This approach has been suggested for use only for hydrophobic or neutral organic compounds. It relies on the assumptions that all such compounds have essentially the same bioaccumulation potential (sediment-to-biota partition coefficient), and that when the bioaccumulation potential is expressed on a lipid basis, it is the same for all organisms. Thus, the only data needed for the development of sediment quality criteria by this method are (1) an acceptable body burden limit for each contaminant and (2) a partition coefficient indicating the relative concentration of hydrophobic/neutral compounds in sediment organic carbon and in lipids. To date, however, permissible body burden levels have not been established for many compounds (Sullivan et al., 1985).

VI. LITERATURE CITED

Barrick, R.C., H.R. Beller, T.C. Ginn, and D.S. Becker (1986), "Apparent Effects Thresholds: Evaluation as a Tool for Sediment Quality Management," in Environmental Data: Significance in Decision Making, abstracts of presentations at the 7th Annual Meeting of the Society of Environmental Toxicology and Chemistry, November 2-5, 1986, Alexandria, Virginia.

Bertine, K.K. and M.F. Mendeck (1978), "Industrialization of New Haven, Conn., as Recorded in Reservoir Sediments," Environ. Sci. Technol., 12:201-207.

Bolton, H.S., R.J. Breteler, B.W. Vigon, J.A. Scanlon, and S.L. Clark (May, 1985), "National Perspective on Sediment Quality," U.S. Environmental Protection Agency, Criteria and Standards Division, Office of Water Regulations and Standards, Washington, DC, EPA Contract No. 68-01-6986.

Chapman, P.M. (1986), "Sediment Quality Criteria from the Sediment Quality Triad: An Example," Environ. Toxicol. Chem., 5:957-964.

CH2M Hill and Ecology & Environment (July, 1983), "Source Control Feasibility Study, OMC Hazardous Waste Site, Waukegan, Illinois," U.S. EPA Hazardous Site Control Div., EPA 13-5M28.0.

CH2M Hill and Ecology & Environment (July, 1986), "Feasibility Study: Fields Brook Site, Sediment Operable Unit, Ashtabula, Ohio," Public Comment Draft, U.S. EPA Hazardous Site Control Div., EPA 19.4L46.0.

Dillon, T.M., and A.B. Gibson (June, 1986), "Bioassessment Methodologies for the Regulatory Testing of Freshwater Dredged Material," Proceedings of a Workshop, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper EL-86-6.

Engler, R.M. (1980), "Prediction of Pollution Potential through Geochemical and Biological Procedures: Development of Regulation Guidelines and Criteria for the Discharge of Dredged and Fill Material," in Contaminants and Sediments, Vol. 1, R.A. Baker, ed., Ann Arbor Science Publishers, Ann Arbor, MI.

Ferguson, J. and J. Gavis (1972), "A Review of the Arsenic Cycle in Natural Waters," Water Research, 6:1259-1274.

Florida Department of Environmental Regulation (March, 1986), "Guide for Interpreting Reported Metal Concentrations in Estuarine Sediments," Draft Version.

Forstner, U. and G.T.W. Wittmann (1983), Metal Pollution in the Aquatic Environment, Second Revised Edition, Springer-Verlag, Berlin, Germany.

Francingues, N.R., Jr., M.R. Palermo, C.R. Lee and R.K. Peddicord (August, 1985), "Management Strategy for Disposal of Dredged Material: Contaminant Testing and Controls," Dredging Operations Technical Support Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Misc. Paper D-85-1.

Great Lakes Water Quality Board (January, 1982), "Guidelines and Register for the Evaluation of Great Lakes Dredging Projects," Report of the Dredging Subcommittee to the Water Quality Programs Committee of the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario.

JRB Associates (April, 1984), "Initial Evaluation of Alternatives for Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase II: Development and Testing of the Sediment-Water Equilibrium Partitioning Approach," U.S. EPA, Washington, D.C., EPA 910/9-82-117.

Johanson, E.E. and J.C. Johnson (May, 1976), "Identifying and Prioritizing Locations for the Removal of In-Place Pollutants," U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, DC, Contract No. 68-01-2920.

Kobayashi, S. and G.F. Lee (1978), "Accumulation of Arsenic in Sediments of Lakes treated with Sodium Arsenite," Environ. Sci. Technol., 12:1195-1200.

McGinn, J.M. (July, 1981), "A Sediment Control Plan for the Blackstone River," Massachusetts Department of Environmental Quality Engineering. NTIS PB 84-22963-2.

National Oceanic and Atmospheric Administration (NOAA) (1987), "National Status and Trends Program: Progress Report and Preliminary Assessment of Findings of the Benthic Surveillance Project-1984," NOAA Rockville, MD.

Neff, J.M., D.J. Bean, B.W. Cornaby, R.M. Vaga, T.C. Gulbransen, and J.A. Scanlon (July, 1986), "Sediment Quality Criteria Methodology Validation: Calculation of Screening Level Concentrations from Field Data," U.S. Environmental Protection Agency, Criteria and Standards Division, Washington, D.C.

New England Governor's Conference (September, 1982), "New England/New York Long Range Dredge Management Study: Final Report," prepared for the U.S. Water Resources Council.

New England River Basins Commission (August, 1980), "Interim Plan for the Disposal of Dredged Material from Long Island Sound."

NUS Corporation (July, 1984), "Feasibility Study of Remedial Action Alternatives: Acushnet River Estuary Above Coggeshall Street Bridge, New Bedford site, Bristol County, Massachusetts," EPA Work Assignment #28-1L43, Contract #68-01-6699 (Draft).

Pavlou, S.P. and D.P. Weston (October, 1983), "Initial Evaluation of Alternatives for Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase I: Development of Conceptual Framework," U.S. EPA Region X, Seattle, WA.

Phillips, K.E., J.F. Malek, and W.B. Hamner (June, 1985), "Commencement Bay Nearshore Tideflats Superfund Site, Tacoma, Washington; Remedial Investigations. Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments," U.S. Army Corps of Engineers, Seattle District. NTIS AD-A162 732.

Puget Sound Water Quality Authority (May, 1986), "Issue Paper: Contaminated Sediments and Dredging."

Science Applications International Corp. (September, 1985), "Removal and Mitigation of Contaminated Sediments," Draft report, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Sullivan, J., J. Ball, E. Brick, S. Hausmann, G. Pilarski and D. Sopcich (November, 1985), "Report on the Technical Subcommittee on Determination of Dredge Material Suitability for In-Water Disposal," Wisconsin Department of Natural Resources, Madison, WI.

Tetra Tech, Inc. (1986), "Compilation of Historical Data on Selected Pollutants in the Southern California Bight;" Final Report to the U.S. Environmental Protection Agency, Office of Marine and Estuarine Protection, Washington, D.C.

U.S. Army Corps of Engineers, New England Division (1986), Unpublished information.

U. S. Coast Guard (1983), "Polluting Incidents in and around U.S. Waters," Calendar Year 1982 and 1983, COMDTINST M16450.2F.

U.S. Environmental Protection Agency Region X (1986), Unpublished information.

U.S. Environmental Protection Agency/Corps of Engineers (U.S. EPA/CE) Technical Committee on Criteria for Dredged and Fill Material (1977), "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters: Implementation Manual for Section 103 of Public Law 92-532 (Mrine Protection, Research and Sanctuaries Act of 1972)," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Fish and Wildlife Service (April, 1986), "Preliminary Survey of Contaminant Issues of Concern on National Wildlife Refuges".

Wakeham, S.G. and J.W. Farrington (1980), "Hydrocarbons in Contemporary Aquatic Sediments," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, MI.

APPENDIX A

DATA ON SITES WITH IN-PLACE POLLUTANTS

Table of Contents

APPENDIX A

DATA ON SITES WITH IN-PLACE POLLUTANTS

I. Introduction

Information on sites with in-place pollutants was obtained from various sources, as discussed in Section III of this report. In general, detailed information on individual sites has not been provided in the main body of this report. Rather, the information in this Appendix was used to generate the summary tables shown in the main report.

There are a total of 10 tables in Appendix A, organized by EPA regions; Table 1 lists sites from Region 1, and so on. Sites were chosen for inclusion in these tables based on the sources of information available. No independent judgment was made to include or exclude sites on the basis of contaminant concentrations or other criteria. However, the list provided in the following tables is by no means an exhaustive compilation of all sites in the U.S. with in-place pollutants.

The numbers in the left-most column of each table correspond to the site numbers used in Section IV-A to indicate the locations of the sites, as shown on the maps in Figures IV-2a to -2h. Please refer to these maps for the approximate geographical locations of the sites. Note that more than one entry in a table may pertain to a single site, and may therefore be assigned the same site number. Separate entries in the tables represent data obtained from different sources.

For each site, information is provided under each of these headings:

- Water body/Location
- Contaminants (concentration)
- Perceived/Noted impacts
- Source
- Remedial actions
- Comments
- Reference (References are listed in Appendix B.)

The concentrations of contaminants are given in ppm, unless otherwise stated, and are provided within parentheses next to the contaminant name. In most cases, ranges of concentrations are given. In other cases, an average concentration is given or in cases where only one measured concentration is available, a single value is given. For certain classes of contaminants, e.g., polynuclear aromatic hydrocarbons (PAHs), a total concentration of the whole class is given, rather than individual concentrations for each contaminant in the class. Where impacts were perceived or noted, these are also briefly described.

The suspected source or sources of the in-place pollutants are also briefly described. Where sources were not mentioned in the reference, or were unknown, the column is left blank. Where it was known that the source was a current (continuing) source, the letter "C" is shown in parentheses next to the source. The letter "D" is shown when it was known that the source was a discontinued source. In the majority of cases, the status of the source was unknown.

Codes are used to indicate whether remedial actions have been implemented (I) or considered (C) at the site. The reader should refer to the literature source cited for a description of the remedial actions implemented or considered. Descriptions of possible remedial action techniques are provided in Section IV-C.

Additional relevant information on the site is given under the "Comments" column. The source for information on the site is given under "Reference." A bibliography of these references is provided in Appendix B.

II. Data on Sites with In-Place Pollutants

Tables 1-10 which follow provide data on sites with in-place pollutants.

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region I						
1	Gulf of Maine/Casco Bay Region	Cd(0.2-0.9); Cr(6-60); Cu(2-40); Ni(5-30); Pb(10-60); Zn(20-100)					Larsen, Zdanowicz, et al., 1983
1	Gulf of Maine/Casco Bay Region	PAHs(0.2-14 total); numerous PAHs highest indiv.: benzo-b-fluoranthene (ND-5)					Larsen, Gadbois, et al., 1983
1	Gulf of Maine/Casco Bay Region	PCBs(0.04-0.2)					Larsen et al., 1984
1	Gulf of Maine/Casco Bay	Cd(0.2-0.9), Cr(6-55), Cu(2-45), Ni(5-32), Pb(9-61), Zn(21-100), PCBs(0.04-0.3), PAHs(0.2-14), highest individual benzo-b-fluoranthene(4)		Industrial sources, sewage treatment, petroleum, air pollution fallout, storm drainoff, creosote wharfs and pilings		High values in Portland Harbor	Larsen, 1985
2	Gulf of Maine/Penobscot Bay Region	PAHs(0.3-9 total)		Combustion sources			Johnson and Larsen, 1985
2	Gulf of Maine/Penobscot Bay	Ag(0.05-0.7), Cd(0.2-0.8), Cr(18-65), Cu(6-32), Ni(8-35), Pb(14-33), Zn(43-100), PCBs(ND-0.2), PAHs(<1-6)		Tannery operations, combustion sources			Larsen, 1985
3	Gulf of Maine/Wilkinson Basin, Murray Basin, Franklin Basin	PCBs(0.004-0.01), PAHs(<0.01-0.4)		Sewage			Boehm, 1984
4	Saco River Estuary, Maine	Cr(ave. 274), Pb(ave. 36), Zn(ave. 47)		Tannery operations			Reported in Larsen, 1985
5	Kennebec R., Estuary, ME	Cr(ave. 29), Cu(ave. 33), Pb(ave. 33), Zn(ave. 64)					As reported in Larsen, 1985

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
6	Sebasticook R., Maine/Great Moose Lake and Pittsfield	Cr(13-24,000); Ag(ND-1); Cd(ND-6); Cu(7-55); Pb(7-890); Zn(33-360)	Metals detected in invertebrates	Tannery		Secondary treatment installed in 1977	Duval et al., 1980
7	Pawtucket River, RI	Numerous organics(ND-670 indiv.)		Specialty chem. plant			Jungclaus et al., 1978
	Pawtucket R., Cove, Providence R., Narragansett Bay R I	Numerous organics(ND-1600 indiv.)		Specialty chem. plant			Lopez-Avila & Hites, 1980
	Providence R., RI	Cr(428)					As reported in Bolton et al., 1985
	Providence R. and Harbor, CT	Cu(1400), Pb(840), As(64)		Metal working, plating			Johanson and Johnson, 1976
	Pettaquamscutt R., RI	PAHs(10)					As reported in Larsen, 1975
8	Narrangansett Bay, RI	PAHs		Coal tar (coating of pilings), sewage outfall, combustion			Lake et al., 1979
	Narrangansett Bay, RI	Radionuclides(Th, Pb, Pu), Cu(0.02-0.3), Pb(0.05-0.3), hydrocarbons(0.05-10)		Sewage(Cu), atm dep. & urban runoff(Pb)			Santschi et al., 1984
9	Nantucket Shoals, MA/Fishing Rip Shoals	Oil droplets(hydrocarbons <0.1-0.6)(36-120)	Mortality of fish eggs	Oil tanker spill (D)		Hydrocarbons in samples did not resemble tanker cargo; this may not be source; concentrations in 1977	Hoffman and Quinn, 1979; Hoffman and Quinn, 1980
10	Buzzards Bay/West Falmouth, MA	Hydrocarbons(1-4310)	Acc. in birds & fish	Spill (D)		Spill in 1969	Burns and Teal, 1979
	Buzzards Bay, MA	PCBs	Impacts on aquatic organisms	Spills, New Bedford Harbor problem			Boehm, 1983

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
10	Buzzards Bay, MA	PCBs(0.01-0.5)					SMU 1980 unpubl., Boehm, 1983, as reported in Boehm, 1984
	Buzzards Bay, MA	PCBs(up to 0.06)					Energy Resources Co., Inc., 1983
	Buzzards Bay, MA	PAHs(1-5)					As reported in Larsen, 1985
11	New Bedford area, MA/Acushet R. Estuary to harbor	PCBs(up to 190,000)	Fish(area closed to fishing)	Point sources, landfills, comb-sewer overflows, urban runoff			Weaver, 1982
	New Bedford Harbor/Upper Acushnet R.	PCBs(up to 1000)					Farrington unpubl. as reported in Boehm, 1984
	New Bedford Harbor/Inner Harbor	PCBs(3-100)					Mass DEQE 1980 unpubl. as reported in Boehm, 1984,
	New Bedford Harbor/Outer Harbor	PCBs(0.3-78)					U.S. EPA 1980, unpubl. as reported in Boehm 1984 reported in Boehm, 1984
	New Bedford Harbor, MA	PAHs(63)					As reported in Larsen, 1985
	New Bedford Harbor, MA	Hg(0.2-8), Cd(0.1-76), Pb(3-560), As(0-50), Cu(5-7250), Zn(6-2300), Cr(5-3200), Ni(2-550), DDT(0.1), PCBs(125), oil and grease(0-2%)		Copper and brass produ., plating, municipal sewer			Johanson and Johnson, 1976

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
11	New Bedford Site, MA/Acushnet R., estuary	PCBs(>100,000), Cu(>1000), As(>50), Pb(300-500), Zn(>600), Hg(>2.5), Cr(400-500), Ni(>150), Cd(>20)	Closure of estuary to all fishing	Electrical component manufacturing	C		NUS, 1984
	Acushnet R/New Bedford Harbor	PCBs(5-900), Cu(3000-7500)					As reported in Bolton et al., 1985
18	Boston Harbor, Mass Bay, Cape Cod Bay System	PAHs(0.3-880), PCBs(0.002-0.3), coprostanol(0.03-16)	Impact on structure and health of benthic community	Stormwater run-off, municipal wastewater, sewage sludge, cont. sediments disposal, industrial sources, ship traffic	C	Area considered more contaminated than NY Bight	Boehm, 1984
12	Falmouth Marsh, MA	PAHs(8)					As reported in Larsen, 1985
18	Massachusetts Bay, MA	PAHs(0.2-3)					As reported in Larsen, 1985
	Boston Harbor	PAHs(8.5)					As reported in Larsen, 1985
	Boston Harbor, MA	PAHs(87)					As reported in Bolton et al., 1985
13	Charles R., MA	PAHs(87-120)					As reported in Larsen, 1985
	Charles R., MA	PAHs(12-120)					As reported in Bolton et al., 1985
14	French River, MA/4 impoundment sites along river	As(4-50); Be(ND-0.6); Cd(1-24); Cr(220-2560); Cu(70-1980); Hg(0.8-5); Ni(8-550); Pb(80-630); Zn(140-1680); CN total (4-7); Tot. phenols (ND-0.3); Base/Neuts(highest indiv.1-23); VOCs(highest inidv. 0.03-0.2)ppm	Metals and PAHs in fish, pop. skewed toward smaller, young fish	Numerous pt sources (muni. and industrial) (C)	C		Metcalf & Eddy, 1985

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
14	French River, MA	Metals, CN, PAHs, VOCs		Oil spills, coke-oven effluents, road runoff			Info. from EPA Region I
15	Blackstone River Basin, MA & RI/8 sites in basin	Cd(ND-410); Cr(6-3300); Cu(5-10900); Pb(10-3500); Ni(9-2900); Zn(20-13200); As(0.5-130)		Numerous pt. sources (muni. and industrial) (C)	C	Separate remedial alternatives considered for different points in basin	McGinn, 1981
16	Bass R., Beverly, MA/Bass Yacht Club	PCBs(3-10); Hg(2-3); Cd(7-9); Pb(340-430); Cr(1200-1700); Cu(< 200); As(12.0-12.5); Ni(47-52); Zn(390-420)					Info. from COE, New England
17	Neponset R., MA/around Granite Ave. Bridge	PCBs(<1-68)					Info. from COE, New England
	Neponset R., MA/around Granite Ave. Bridge	As(19-20); Cd(3-4); Cr(130-180); Cu(84-150); Pb(170-250); Hg(0.75-1.5); Ni(20-30); V(60-80); Zn(180-300); PCBs(0.3-12)					Info. from COE, New England
18	Winthrop Harbor, MA	As(10-25); Cr(50-190); Cu(40-160); Ni(10-30); Pb(40-130); V(25-70); Zn(72-300); oil and grease(2-5%)					Info. from COE, New England
	Dorchester Bay, MA/Dorchester Yacht Club	As(23); Cd(6); Cr(310); Cu(210); Hg(3); Ni(30); Pb(290); V(77); Zn(380); oil and grease(1.5%); PCBs(2.2)					Info. from COE, New England

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
18	Savin Hill Yacht Club, U. Mass Pier, MA	As(18-25); Cr(2.7-3); Cr(140-190); Cu(120-150); Hg(1-2); Ni(18-23); Pb(150-170); V(42-46); Zn(230-240); PCBs(ND-1.17); oil and grease (1.1-5.8%)					Info. from COE, New England
	South Boston Yacht Club, Boston, MA	As(5-23); Cd(3.3-3.9); Cr(250-280); Cu(190-200); Hg(2); Ni(30-31); Pb(190-220); V(58-68); Zn(420-700); PCB(0.07-0.84); oil and grease(3.1-5.1%)					Info. from COE, New England
19	Silver Lake/Pittsfield, MA	PCBs(0.1-6350)		Industrial			Info. from EPA Region I
20	Coopers Pond/Attleboro, MA	Al(3510-26700); Cd(< 50-260); Cr(< 50-660); Cu(400-16500); Pb(<50-400); Ni(190-6120); Pt(<50-334); Ag(<50-210); Zn(70-2390)		Metal finishing plant (C)			Info. from EPA Region I
21	Mill R., Mill Pond, vicinity/Fairfield, CT	Pb		Manuf. facility	I		Info. from CT DEP
	Mill River, Fairfield, CT	Pb(up to 147,000), Al		Manufacturing facility	I	Facility produced aluminum products from 1930s-51, Pb-acid batteries 1951-1981, remedial plan completed in 1983	Science Applications Int'l Corp., 1985
	Versailles Pond, CT	Pb(20-808); Zn(66-650); Hg(0.22-0.55); Cu(50-60); Phenols(0.2-10); PCBs(0-27)		Paper mill			Info. from CT DEP

TABLE 1. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION I (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
22	Housatonic R., CT	PCBs(0-76)	PCBs in fish exceed FDA levels	Industrial (D) municipal (D)	C		Info. from CT DEP
	Housatonic R., CT	PCBs (< 1-210)					Info. from EPA Region I
24	Branford Harbor, Ct	Cd(ave. 1), Cu(ave. 35), Pb(ave. 265), Zn(ave. 55)					As reported in Larsen, 1985
23	Eastern Long Island Sound	Cd(ave. 3), Cr(ave. 60), Cu(ave. 20), Ni(ave. 8), Pb(ave. 16), Zn(ave. 50)					As rpeorted in Larsen, 1985
	Bridgeport Harbor, CT	Hg(0.01-10), Cd(2-140), Pb(50-1640), As(5-9300), Zn(50-3000), Cr(20-3500), Cu(40-9300), Ni(<10-400), DDT(0.05-1), PCB(0.1-2), oiland grease(0.1-4%)		Steel mill, brass mill, metal plating facilities			Johanson and Johnson, 1976
24	New Haven Harbor, CT	Cu(2500), Zn(1000)		Brass mills, metal plating, primary waste-water treatment			Johanson and Johnson, 1976
	Stamford and New Haven Harbors, CT	Heavy metals					Science Applications Int'l Corp., 1985
25	Quinhipiac R., CT	Hg(320)					As reported in Bolton et al., 1985
	Great Bay Estuary, NH	Cr(10-590), Cu(3-130), Pb(1-150), Zn(13-210)					As reported in Larsen, 1985
26	Ten Mile River, MA and RI	Cr, Cu, Ni, Pb, Zn; may be organics too		Metal plating			Atkinson et al., 1985; and conversations with EPA Region I, Mass. DEQE.

TABLE 2. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION II

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region II						
1	Upper Hudson R., NY/Fort Edward & miles downstream	PCBs	PCB levels in fish exceed FDA limits	Point sources	C		Weaver, 1982; Brown et al., 1985
1	Upper Hudson R./Fort Edward, NY	PCBs(5-250)	Some fish species severely contaminated	Capacitor manufacturing plants	C	40 mile stretch of river contaminated; certain sections--Superfund	Science Applications International Corp., 1985
1	Upper Hudson R. Basin, NY	PCBs(4-200)	Fishing ban	Capacitor manufacturing plants (D)	C		Turk, 1980
2	Hudson R., NY/Tidal portion	PCBs(0.5-140)		Capacitor manufacturing plants upstream (D)			Bopp et al. 1981
3	NY Bight/Various Sites	PCBs(0.5-7)					From various sources as reported in Boehm, 1984
3	New York Bight	PCBs (1-6)		Sewage sludge			West and Hatcher, 1980
3	NY Bight/Hudson Valley Transect	PCBs(0.002-0.2); PAHs(< 0.01-46)		Combustion, sewage sludge, dredge material			Boehm, 1984
3	NY Bight/Christiaensen Basin	PCBs(up to 0.7)					Energy Resources Co., Inc., 1983
3	NY Bight/near dumpsite	PAHs(0-30)		Sewage sludge			Energy Resources Co., Inc., 1983
3	Ocean dump sites off NY City	Cr(2-370), Cu(1-330), Ni(2-40), Pb(5-270), Zn(7-480)					As reported in Greig and McGrath, 1977
3	NY Bight/Raritan Bay	PAHs(0.2-3)					Energy Resources Co., Inc., 1983

TABLE 2. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION II (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
3	New York Bight/Raritan Bay	Cd(up to 15), Cr(up to 1260), Cu(up to 1230), Ni(up to 50), PCB(up to 990), Zn(up to 820)	Area closed to shellfish harvesting, water quality not suited for bathing, yield of commercial fishery declined; decrease in benthic diversity and crop.	Municipal and industrial		Concs. similar to Corpus Christi Harbor, dump sites of NY city, basins off S. Calif., Long Island Sound	Greig and McGrath, 1977
	Newark Bay, Passaic R., NJ	Hg(up to 20), Cd(up to 40), Cu(up to 1100), Pb(up to 1000); TCDD	Very few desirable aquatic organisms found				Johanson and Johnson, 1976; NUS, 1986
	Newark Bay, NJ	Pb(70-3200), Zn(80-2280), Cd(0-20), Hg(0.3-30)		Many sources: industrial, municipal, non-point, shipping			Meyerson et al., 1981
4	Long Island Sound	Cr(5-280), Cu(<2-280), Ni(<2-40), Pb(<6-210), Zn(5-350)					As reported in Greig and McGrath, 1977
	New York Bight and Long Island Sound	Cd(<0.25-4), Cr(2-100), Hg(<0.04-0.7), Cu(0.2-150), Ni(0.8-30), Pb(2-130), Zn(3-330), PAHs(0-60)	Elevated levels in aquatic species				Reid et al., 1982
3	Jamaica Bay, NY City	Pb(up to 500), Cr(up to 500), Ni(up to 100), Zn(up to 1930), Cu(up to 760), Co(up to 20), Cd(up to 10), V(up to 130)	Sediment feeder enriched in Cu and Zn, bottom life nearly gone in areas of heavy metal concentration	Sewer treatment plants			Ramondetta, 1978
5	Eastchester Creek (Hutchinson R.), NY	Pb(up to 900), Cu(290), Zn(650)					Johanson and Johnson, 1976
6	Saw Mill R., Westchester NY/lower 3 miles of river	Cu(6-200), Pb(12 570), ZN(7-520)					Rogers, 1983
7	Foundry Cove, Cold Spring, NY	Cd 171,000) Ni(156,000) Co(6,000)	Elevated Cd levels in biota (plants and fish)	Discharge from Ni-Cd battery mfg. facility (D)		Has been dredged before (1972-73) but concs. similar to before dredging. Not succesful. Superfund site	Kneip and Nazen, 1979; EPA Reg.II

TABLE 2. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION II (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
8	The Saddle R./near Lodi, NJ	Pb(10-200), Zn(70-280), Cu(20-100), Ni(7-20), Cr(4-40), Cd(0.4-3)		Pptn., storm-water runoff			Wilber and Hunter, 1979
9	Lake Ontario/whole lake	PCBs(ave. 0.057), DDT(ave. 0.04), chlordane, endosulfan		Endosulfan spill			Frank et al., 1979
10	Lake Ontario/Oswego R. and Harbor	Mirex(ND-0.07)		Chemical company, cork co.			Scrudato and Del Prete, 1982
	Lake Ontario/Oswego R., NY	Heavy metals	Fish consumption advisories, fish contaminated with PCB and mirex	Municipal and industrial point sources, urban non-point, sewer overflows, waste disposal sites	C	Remedial action plan being developed by NY DEC	Great Lakes Water Quality Board, 1985
11	Lake Ontario/Buffalo R., NY	Organics, metals	Fish consumption advisories, biota impacted	Municipal, industrial point sources, urban non-point, sewer overflows, waste disposal sites	C	USEPA, State of NY developing Remedial Action plans	Great Lakes Water Quality Board, 1985
	Niagara R., NY	Heavy metals, organics-PCB, mirex	Fish consumption advisories; Biota impacted	Aluminum, automotive, chemical, other industrial, urban non-point, sewer overflows, waste disposal sites	C		Great Lakes Water Quality Board, 1985
	Buffalo, NY/Niagara R., Tonawanda Channel, Buffalo R., Lake Erie	Volatile organics, PAHs, other organics, PCBs, pesticides, heavy metals, phenols, CN					Rockwell et al., 1984
12	Lake Ontario/Eighteen Mile Creek, NY	Heavy metals		Industrial point sources, urban non-point, sewer overflows	C		Great Lakes Water Quality Board, 1985
13	Lake Ontario/Rochester Embayment, NY	Heavy metals	Fish consumption advisories	Municipal and industrial point sources, urban non-point, sewer overflows	C		Great Lakes Water Quality Board, 1985

TABLE 2. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION II (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
14	Wine Creek and White Creek, Oswego, NY	Be(3-6), Cd(1-22), Cr(7-137), Cu(13-38), Pb(25-277), Hg(0.01-0.07), Ni(9-49), Zn(36-258), VOCs(highest indiv. 1200), Base/Neutrals (highest indiv. 0.9)		Landfill and industrial point source		Superfund site	Information from EPA Region II.
15	St.Lawrence River, Massena, NY	PCBs	PCBs detected in fish	Indusrial (foundry): direct discharge and from disposal sites via groundwater		Superfund site	Information from EPA Region II.
16	Wetlands, Moira, NY	PCBs(up to 210), Pb (640)		Oil recycling facility (D)		Superfund site	Information from EPA Region II.
17	Black Creek, Bergholtz Creek, Niagara River, Niagara Falls,NY	2,3,7,8-TCDD (3.3-46 ppb), other chlorinated organics	Dioxin detected in fish	Sewer outfalls, landfill	C	Superfund site (Love Canal)	Information from EPA Region II.
18	Elizabeth River, Arthur Kill, Elizabeth, NJ	Numerous organics (Highest indiv. 61)		Waste treatment facility, urban and industrial runoff (C)	C	Superfund site	Information from EPA Region II
19	Cannon run, North Branch Rancocas Creek, NJ	Organics (highest indiv. 2.6), Metals		Landfill		Superfund site	Information from EPA Region II

TABLE 2. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION II (CONTINUED)

Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
Burnt Fly Bog, Marlboro Township, NJ	PCBs(up to 254), Pb (up to 13,000)	lagoons	Waste		Superfund site EPA Region II	Information from
Edwards Run, Delaware River, Gloucester County, NJ	Metals (40-2443), VOCs(ND-3100), Semi-volatiles (ND-21), Pesticides (ND-50)		Landfill		Superfund site	Information from EPA Region II
Maurice River, Black-water Branch and Union Lake, Vineland, NJ	As (1-21,160)		Chemical company		Superfund site	Information from EPA Region II

TABLE 3. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION III

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region III						
1	Tinicum Nat. Env. Center, PA/Creeks and Marsh	Heavy metals, pesticides, cyanide, PCBs, chlordane, PAHs		Landfills			U.S. Fish & Wildlife Service, 1986
2	Monongahela R./Pittsburgh, PA	Pb(up to 1300)					Johanson and Johnson, 1976
3	Schuylkill R., PA/lower basin	Cd, Cr, Cu, Pb, Ni, Zn, DDT(0.01), PCBs(<0.1-0.2)		Spills, discharges			Yorke et al., 1985
	Schuylkill R., PA	As(<1-4), Cu(10-3000), Pb(20-19000), Be(<1-55), Ni(10-930), Hg(<0.01-0.9), Zn(30-1400), Cr(10-880), Chlordane(0-0.07), DDD, DDE & DDT(0-0.1), PCBs(0-2.4)					Stamer et al., 1985
4	Chesapeake Bay	PCBs(0.004-0.4)					Sayler et al., 1978 as reported in Boehm, 1984
	Chesapeake Bay	PAHs(ND->100), DDT, PCBs	Elevated levels in oysters				Bieri et al., 1983
5	Baltimore Harbor, MD	Hg(0.1-10), Cd(<1-650), Pb(130-13890), Cu(60-2930), Zn(350-6040), Cr(60-5750), Ni(20-90)	Absence of many aquatic species	Industrial sources, spills (creosote, paint, dye-stuffs, plating solutions, pickle liquors)		Worst conditions in northern shore of the harbor; all hot spots adjacent to heavily industrial areas	Johanson and Johnson, 1976
	Baltimore Harbor, MD	PCBs(0.05-80)		Sewage treatment plants, many potential industrial sources, spills			Morgan and Sommer, 1979
	Baltimore Harbor/Patapsco Es.	Cr(490)					As reported in Bolton et al., 1985

TABLE 3. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION III (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
6	James River, Hopewell, VA	Kepone(0.02-30)	Fish contamination; kepone concentration in crab above FDA action level	Chemical company (D)	C	Between 1966-75, 65,000 lbs. of kepone discharged into river	Science Applications Int'l Corp., 1985
	James River, VA/estuary	Kepone		Kepone plant (D)		Kepone being covered by sediment; disturbance could return contamination to surface	Cutshall et al., 1981
	James River, VA/estuary	Kepone(<0.02-4.5)	Elevated kepone levels in fish, crabs, oysters	Kepone plant (D)		Source discontinued in 1975	Huggett et al., 1980
7	Holston R., Saltville, VA/North Fork	Hg(300-1000)	River closed to fishing	Chemical plant including electrolytic chlorine (D)	I	Plant from 1895-1972; elevated levels of Hg at least 10 miles upstream of plant and downstream to Cherokee Reservoir; remedial action declared complete	Science Applications Int'l Corp., 1985
	North Fork Holston R., VA and TN	Hg(0.3-20)	Hg conc. in fish above FDA action level	Chloralkali plant			Hildebrand et al., 1980
8	South River and South Fork Shenandoah River, Waynesboro, VA	Hg(50 ppm)	Hg in fish exceed FDA action level	Spill at plant	C	"No active" alternative recommendation	Science Applications Int'l Corp., 1985
9	Elizabeth R., VA/estuary	Hydrocarbons(100-2900), PNAs		Wood preserving facilities, other industrial sources		Three facilities, two discontinued by 1981	Merrill and Wade, 1985
10	Lynnhaven Estuary, VA	Bacteria	Oyster beds closed at intervals	Sewage treatment plant, non-point sources, septic tanks			Erkenbrecher, 1980

TABLE 4. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IV

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region IV						
1	Sampit R., Georgetown, SC	Pb(1000)					Johanson and Johnson, 1976
2	Savannah R. estuary, GA	Transuranics(Pu), Pb(14-60), Zn(20-110), Cr(30-320), Cu(6-60), Co(3-20), Ni(6-30), V(40-460)	Savannah R. Plant - Department of Energy				Goldberg et al., 1979
3	Latham Bayou, TN	Sb, Hg, Cd, Pb, PAHs, DDT and derivatives, heptachlor, chlordane					Information from EPA Region IV
	Loosahatchie R., TN	Pb, dieldrin, chlordane					Information from EPA Region IV
4	Wheeler National Wildlife Refuge, AL/Huntsville Spring Branch of Indian Creek	DDT and associated metabolites	Bioacc. in fish; levels hazardous to human health	Olin Chem. Corp. - DDT manufacturer (D)	C	Remedial action scheduled to begin 1986	U.S. Fish & Wildlife Service, 1986
5	Redstone Arsenal, Huntsville, AL	DDT, DDE, DDD & other degradation products		DDT plant (D)	I	DDT plant closed in 1970	Sullivan and Thiess, 1983
6	Mobile Harbor, AL	Hg(0.1-2), As(0.3-10), Cu(1-50), Zn(1-250), Ni(4-40), Cr(3-100)					Information from EPA Region IV
7	Mississippi Sound/ Escatawpa R.	Aliphatic hydrocarbons(up to 5860)					Lytle & Lytle, 1980
	Bayou Casotte, Mississippi	Petroleum hydrocarbons(up to 12300)		Industrial (C); spills and leaks from refinery (C)			Lytle and Lytle, 1983
	Pascagoula R., Mississippi Sound	Aliphatic hydrocarbons(up to 830), Arom. hydrocarbons(up to 100)					Lytle & Lytle, 1985
	Mississippi Sound/Biloxi Bay	Aliphatic hydrocarbons(up to 130), Arom. hydrocarbons(up to 210)					Lytle & Lytle, 1985
8	Escambia Bay, FL	PCBs(ND-8)					U.S. EPA 1976 as reported in Bochm, 1984

TABLE 4. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IV (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Deep Sea and Florida Lakes, FL	Cd(0.1-0.4), Cu(2-250), Ni(<2-230), Pb(<0.2-80), Zn(4-170)					As reported in Greig and McGrath, 1977
9	Bayou Chico, estuary, FL	Ni(<2-80), Pb(U<6-1480), Cu(<5-190), Rb(2-210), Ti(220-10300), Cr(<20-170), Zr(30-1840)					Pilotte et al., 1978
10	Canaveral Port, FL	As(5-8), Cd(0.2-4), Cr(5-100), Cu(4-100), Pb(8-500), Mn(30-330), Hg(0.1-1), Ni(1-20), Ag(0.02-0.1), Zn(8-220)					Ryan et al., 1985
11	Ft. Pierce Port, FL	As(1-9), Cd(0.01-0.2), Cr(2-60), Cu(1-40), Pb(4-40), Mn(30-190), Hg(0.1-0.7), Ni(1-12), Ag(0.01-0.06), Zn(1-80)					Ryan et al., 1985
12	Jacksonville Port, FL	As(0.5-10), Cd(0.03-1), Cr(3-60), Cu(1-30), Pb(0.6-60), Hg(0.1-1), Ni(1-30), Ag(0.01-1), Zn(3-270)					Ryan et al., 1985
13	Manatee Port, FL	As(0.1-5), Cd(0.2-0.8), Cr(10-60), Cu(2-20), Pb(4-10), Hg(0.1-0.3), Ni(3-20), Ag(0.01-0.3), Zn(5-80)					Ryan et al, 1985
14	Miami Port & River, FL	As(1-10), Cd(0.8-3), Cr(6-80), Cu(5-310), Pb(9-980), Mn(10-60), Hg(0.2-4), Ni(0.4-10), Ag(0.04-3), Zn(14-480)			C	Remedial actions considered in Florida legislature	Ryan et al, 1985; Metro-Dade County Planning Department, personal comms., Miami River Management Committee 1984, 1985
15	Pensacola Port, FL	As(0.1-10), Cd(0.2-0.5), Cr(5-80), Cu(1-20), Pb(9-40), Hg(0.04-0.8), Ni(3-20), Ag(0.1-0.3), Zn(10-100)					Ryan et al., 1985

TABLE 4. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IV (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
16	Port St. Joe, FL	As(12-20), Cd(0.1-0.8), Cr(15-80), Cu(5-50), Pb(8-40), Mn(90-600), Hg(0.1-1), Ni(4-20), Ag(0.03-0.2), Zn(20-90)					Ryan et al., 1985
17	Tampa Port, FL	As(0.1-10), Cd(0.6-4), Cr(60-100), Cu(4-130), Pb(9-180), Hg(0.12-1.2), Ni(9-50), Ag(0.2-1), Zn(31-390)					Ryan et al, 1985
18	West Palm Beach, FL	As(0.6-2), Cd(0.04-0.9), Cr(4-20), Cu(1-10), Pb(4-60), Hg(0.1-1.5), Ni(1.4-2.4), Ag(0.01-0.04), Zn(6-80)					Ryan et al., 1985
19	Hillsborough River, FL	Aliphatic hydrocarbons(60-400), Arom. hydrocarbons(15-90)		Urban stormwater runoff(C)			Brown et al., 1985

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region V						
1	Cleveland Harbor, Cuyahoga R., OH	Cd(70), Pb(560), Zn(2390), Cr(540), CN(35)		Steel, chemical, paint dischargers			Johanson and Johnson, 1976
2	Lake Erie/Western	Chlorobenzenes(highest individual hexachloro 0.02), -chlordane(0.001-0.004), DDT & derivatives(highest individual 0.017), PCBs(0.1-0.7)					Oliver & Bourbonniere, 1985
	Lake Erie/Westerm	Cd(7), Cu(150), Pb(140), Zn(370)		Sewage			Nriagu et al., 1979
	Lake Erie/S. Western	PAHs(0.5-0.8)		Coal-fired power plant			Eadie et al., 1979
3	Lake Erie/Central	Chlorobenzenes(highest individual hexachloro 0.004), -chlordane (0.0006-0.002), DDT & derivatives(highest individual 0.015), PCBs(0.04-0.2)					Oliver & Bourbonniere, 1985
	Lake Erie/Central	Cd(3), Cu(100), P(100), Zn(300)		Sewage			Nriagu et al., 1979
4	Lake Erie/Eastern	Chlorobenzenes(highest individual hexachloro 0.005), -chlordane (0.0008-0.002), DDT & derivatives(highest individual 0.012), PCBs(0.04-0.1)					Oliver & Bourbonniere, 1985
	Lake Erie/Eastern	Cd(4), Cu(100), Pb(100), Zn(330)	Sewage				Nriagu et al., 1979

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
1	Lake Erie/Cuyahoga R., OH	Organics, heavy metals	Biota impacted, aesthetics	Steel, chemical, other industrial, municipal, urban non-point, sewer overflows	C		Great Lakes Water Quality Board, 1985
5	Lake Erie/Maumee R., OH	Organics, heavy metals	Biota impacted, aesthetics	Municipal and industrial point sources, urban and rural non-point, sewer overflows	C		Great Lakes Water Quality Board, 1985
6	Lake Erie/Black R., OH	Organics, PAHs, heavy metals	Fish consumption advisories, biota impacted, aesthetics	Steel industry, other industrial, municipal, urban and rural non-point, sewer overflows, waste disposal sites	C	Remedial action plan to be drafted November 1986	Great Lakes Water Quality Board, 1985
7a	Lake Erie/Ashtabula R. & Harbor, OH	Chlorinated organics, PCBs, heavy metals	Fish consumption advisories, biota impacted	Industrial point sources, urban non-point	C	Sediments in Fields Brook qualify for Superfund; draft remedial action plan September 1985	Great Lakes Water Quality Board, 1985
7b	Detroit River, Detroit, MI	Hg(<1-90), Cd(<30), Ni(10-230), Pb(22-900), Cr(9-540), Cu(9-290), Zn(35-1300), oil & grease (7%)	High Hg levels in fish	9 muni. wwater trtment plants, over 40 indust. outfalls--Hg cell operations, steel mills, chemical cos, brass mills			Johanson and Johnson, 1976

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc, range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
7b	Detroit R.	Organochlorine contaminants in ducks: PCBs (ave. 8-11), hexachlorobenzene(1.7), transnonachlor(0.33), DDE(1.3)	PCB levels in duck and carp exceed FDA guidelines				Smith et al., 1985
8	Shiawassee R., Howell, MI/South Branch	PCBs	PCBs level in fish exceeded FDA safe level	Manufacture of Al castings (D)	I	Cleanup completed	Science Applications Int'l Corp., 1985
9	Lake Erie/Clinton R., MI	Oil and grease, heavy metals	Biota impacted	Muni. and ind. point sources, urban and rural non-point, sewer overflows	C	Water Quality	Great Lakes Water Quality Board, 1985
9	Lake Erie/Rouge R., MI	Heavy metals, organics	Fish consumption advisories, biota severely impacted, aesthetics	Muni. and ind. point sources, urban and rural non-point, sewer overflows	C		Great Lakes Water Quality Board, 1985
9	Lake Erie/Raisin R., MI	Organics, oil & grease, heavy metals	Fish consumption advisories, fish contaminated with PCBs, other organics; biota impacted, aesthetics	Muni. and ind. point sources, urban and rural non-point, sewer overflows	C	Water Quality	Great Lakes Water Quality Board, 1985
10	Lake Huron/Southern	Chlorobenzenes(highest individual 1,2,4-trichloro 0.007), -chlordane(0.0002-0.0008), DDT & derivatives(highest individual 0.02), PCBs(0.01-0.05)					Oliver & Bourbonniere, 1985
11	Lake Huron/Saginaw Bay	PCBs(1-1.3)		Landfills, road pavements, atm. deposition			Richardson et al., 1983
11	Lake Huron/Saginaw R., and Bay	Organics, heavy metals	Fish consumption advisories, biota impacted	Automotive plant, municipal point source, rural non-point sources	C	Remedial action plan in 1985	Great Lakes Water Quality Board, 1985

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
12	Lake Huron	Hg(0.04-0.3), Pb(14-150), Zn(60-230), Cu(25-80), Ni(30-95), Co(13-50), Cd(1-3), Cr(30-50), Be(1-1.5), V(50-110), As(3-30)					Kemp et al., 1978
13	Georgian Bay	Hg(0.03-0.2), Pb(16-160), Zn(90-230), Cu(50-90), Ni(50-130), Co(20-30), Cd(1-5), Cr(30-44), Be(1-1.5), V(50-80), As(6-30)					Kemp et al., 1978
14	Lake Michigan/Green Bay	As(7-40), Hg(0.1), Co(10-20), Cr(40-65), Ba(350-750), La(20-30), Sc(7-14), Th(5-10), U(1-4)		Pulp and paper (D), chemical co., shipbuilding, muni. sewage, urban, agri. runoff			Christensen and Chien, 1979
15	Lake Michigan/Algoma Basin	Total DDT (ave. 0.02)		Agricultural runoff			Frank et al., 1981
16	Lake Michigan/Fox Basin	Total DDT(ave. 0.01), heptachlor epoxide(0.003), PCBs(0.07)		Agricultural runoff			Frank et al., 1981
17	Lake Michigan/Grand Haven Basin	Total DDT(ave. 0.03), dieldrin(0.0005), chlordane(0.001)		Agricultural runoff			Frank et al., 1981
25	Lake Michigan/Milwaukee Basin	Total DDT(0.04), heptachlor epoxide(0.003), PCBs(0.03)		Agricultural runoff			Frank et al., 1981
18	Lake Michigan/Sarian Basin	Total DDT(0.03)		Agricultural runoff			[illegible] et al., 1981

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
19	Lake Michigan/Southern Basin	Total DDT(0.03)		Agricultural runoff			Frank et al., 1981
20	Lake Michigan/Traverse Basin	Total DDT(0.02)		Agricultural runoff			Frank et al., 1981
21	Lake Michigan/Waukegan Basin	Total DDT(0.02), dieldrin(0.0008), chlordane(0.001)		Agricultural runoff			Frank et al., 1981
22	Lake Michigan/Manistique R., MI	PCBs	Fish consumption advisories, biota impacted	Municipal and ind. point sources (paper mill (D))		Proposed studies to identify sources	Great Lakes Water Quality Board, 1985
23	Lake Michigan/Menominee R., WI, MI	As			C	Remedial action plan under development	Great Lakes Water Quality Board, 1985
16	Lake Michigan/Fox R., Southern Green Bay, WI	PCBs, furans	Fish consumption advisories, biota impacted	Pulp and paper, muni. wewater discharges	C	In-place contamination not to be addressed in remedial action	Great Lakes Water Quality Board, 1985
24	Lake Michigan/Sheboygan Harbor	PCBs	Fish consumption advisories	PCB source (D)	C	Remedial action plans developed by 1986; Superfund site	Great Lakes Water Quality Board, 1985
25	Lake Michigan/Milwaukee Es.	Heavy metals, PCBs, DDT, PAHs	Fish consumption advisories, biota impacted, beach closings, aesthetics	Sewer overflows, agricultural runoff, runoff from industrial sites, waste disposal sites seepage	C	Construction of large deep tunnel to control sewer overflows already started	Great Lakes Water Quality Board, 1985
26	Lake Michigan/Kalamazoo R., MI	PCBs	Fish consumption advisories	PCB sources (D)	C	Sediment cleanup feasibility study being conducted	Great Lakes Water Quality Board, 1985
27	Indiana Harbor, E. Chicago, IN	Cd(230-7490), Pb(250-1370), Cu(24-180), Zn(620-10580), Ni(40-170), Cr(10-170), CN(ND-0.7), oil and grease(4-17%)		Industrial (petroleum, steel), stormwater runoff		Data from 1967; discharges probably significantly reduced since then	Johanson and Johnson, 1976

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
28	Michigan City Harbor, IN	Hg(0.02-2), As(350-9660), Pb(10-240), Zn(20-10900), oil and grease(0.02-2%)		Sewage plant		Arsenic concentrations very high	Johanson and Johnson, 1976
25	Milwaukee Harbor, WI	Cu(1380), Pb(50), Cd(77)		Sewage plant, foundries, tanneries, incinerator			Johanson and Johnson, 1976
21	Waukegan Harbor, Waukegan, IL	PCBs(up to >300,000)		Aluminum die-casting	C		Science Applications Int'l Corp., 1985
	Lake Michigan/Waukegan Harbor, IL	PCBs(up to 50,000), heavy metals	Fish consumption advisories, biota impacted	Outboard marine corp. (D)	C	Superfund site	Great Lakes Water Quality Board, 1985
27	Lake Michigan/Grand Calumet R., and Indiana Harbor Canal, IN	Heavy metals, PCBs	Fish consumption advisories, biota impacted, aesthetics	Muni. and ind. point sources, waste disposal sites, sewer overflows	C	Remedial action plan scheduled to be completed by late 1986	Great Lakes Water Quality Board, 1985
29	Lake St. Clair	Chlorobenzenes(highest ind. hexachloro 0.07), -chlordane (0.0004), DDT and derivatives(highest ind. 0.002), PCBs(0.03)					Oliver & Bourbonniere, 1985

TABLE 5. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION V (CONTINUED)

	Water Body/Location	Contaminants (conc, range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
29	Lake St. Clair	PCBs(ave. 0.004)					Pugsley et al., 1985
30	Lake Superior	Hg(0.06-0.4), Pb(16-140), Zn(50-200), Cu(30-260), Ni(24-65), Co(10-30), Cd(0.4-2.5), Cr(26-60), Be(0.6-2), V(70-120), As(5-8)					Kemp et al., 1978
	Lake Superior	DDT(ND-0.02), dieldrin(ND-0.002), PCBs(ND-0.06)					Frank et al., 1980
	Lake Superior	PCBs(0.005-0.4), DDE(0.001-0.2)					Eisenreich et al., 1980, 1979
31	Lake Superior/Keweenaw Peninsula	Cu(14-930)		Mine tailings			Kraft, 1979
32	Lake Superior/St. Louis, R., MN	PCBs, PAHs	Fish consumption advisories	Unknown	C	Remedial action plans under preparation for Superfund cleanup	Great Lakes Water Quality Board, 1985
33	Lake Superior/Torch Lake, MI	Cu	Fish consumption advisories, biota impacted	Copper concentration oeprations	C	Current studies	Great Lakes Water Quality Board, 1985
34	Lake Superior/Deer Lake, Carp Creek, Carp River	Hg	Fish consumption advisories	Unknown		Rish being restocked; no remaining Hg source	Great Lakes Water Quality Board, 1985

TABLE 6. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VI

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region VI						
1	Aransas Nat. Wildlife Refuge, TX/Bay Areas Adj. to Wildlife Refuge	Heavy metals - Hg; As(> 40); Cd; Zn; PAHs; oil and grease(>9000)		Petrochemical, metal refining, oil and gas prod., pipeline transp., oil tanker traffic			U.S. Fish and Wildlife Service, 1986
	Aransas NWR, TX/Burgentine Lake	Pesticides		Agricultural drainwater			U.S. Fish and Wildlife Service, 1986
2	Laguna Atascosa Nat. Wildlife Refuge, TX	Agri. chems.--incl. DDE, toxaphene, trace metals--incl. Se	Elev. concs. DDE, toxaphene in fish, birds	Agricultural drainwater			U.S. Fish and Wildlife Service, 1986
3	Corpus Christi Inner Harbor, TX	Hg(0.5-40), Cd(2-130), Pb(40-670), As(3->25), Cu(12-280), Zn(73-11000), Cr(20-160), Ni(8-20), oil and grease(0.1%)					Johanson and Johnson, 1976
	Corpus Christi Harbor, TX	Cd(0.1-130), Zn(6-11000)					As reported in Greig and McGrath, 1977
	Corpus Christi Channel	Hg(18)					As reported in Bolton et al., 1985
	Corpus Christi Ship Channel	As(3-4), Cd(<0.5-7), Cr(7-15), Cu(6-13), Pb(9-18), Zn(50-165)					Information from U.S. Corps of Engineers, Galveston, TX
4	Gulf Intracoastal Waterway, TX/San Antonio Bay to Aransas Bay	As(1-41), Cr(<5-9), Pb(<5-6), Zn(<5-20)					Information from U.S. Corps of Engineers, Galveston, TX
5	Sabine Neches Waterway, TX/ Port Arthur turning basins and junction area	As(8-11), Cd(1-2), Cr(18-30), Cu(5-12), Pb(22-32), Ni(22-28), Zn(70-110)					Information from U.S. Corps of Engineers, Galveston, TX

TABLE 6. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VI (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
5	Neches R., Beaumont, TX	Pb(3000)		Industrial			Johanson and Johnson, 1976
6	Houston Ship Channel, TX/Carpenter Bayou to Greens Bayou	As(2-3), Cd(0.2-1), Cr(22-43), Cu(25-60), Pb(34-52), Hg(ND-0.5), Ni(4-12), Zn(56-170), PAHs(3-16), DDT and derivatives(0.004-0.05)					Information from U.S. Corps of Engineers, Galveston, TX
7	Lavaca Bay, TX	Hg(0.5-11)					Information from Texas Department of Water Resources
8	Petronila Creek, TX	As, Ba(430-1900), Cr(4-10), Zn(20-150), oil and grease(90-10500)	Fish kill	Petroleum operations brine water			Information from Texas Department of Water Resources
9	Rio Grande, Presidio, TX	DDT and derivatives(up to 0.03), PCB(0.04)	DDT biomag in fish				Information from Texas Department of Water Resources
10	Double Mountain Fork of Brazos River, Lubbock, TX/North Fork	PCBs(ND-9)					Information from Texas Department of Water Resources
11	Finfeather and Municipal Country Club Lakes, Bryan, TX	As(<1-12000)	Biota impacted, As levels in fish objectionable for human consumption	Industrial			Information from Texas Department of Water Resources
12	Mountain Creek Lake, Dallas, TX	Hg(22)					Information from EPA Region VI
13	Trinity R., TX	As(1-5), Cd(1-20), Cr(1-120), Cu(5-160), Pb(20-80), Mn(10-500), Hg(0.2-2.2), Ni(7-75), Zn(10-240), chlordane(<0.0003-0.06), DDT(<0.0005-0.05), dieldrin(0.0003-0.2), endrin(0.0003-0.02), heptachlor(0.0007-0.009), lindane(0.0002-0.0007), PCBs(<0.00001), oil and grease(400-8300)	Impact on biota	Municipal and industrial outfalls			Qasim et al., 1980

TABLE 6. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VI (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
14	Crutcho & Soldier Creeks, Oklahoma City, OK	Dichlorobenzenes(highest indiv. 0.3), toluene(0.04), PAHs(highest indiv. 0.8), phthalate esters(0.05-7), phenolics(up to 7), chlorinated alip.(up to 0.07), As(2-4), Cd(20-70), Cr(20-730), Cu(7-30), Pb(13-35), Ni(10-170), Se(1-2), Ag(7-10), Zn(20-70), Ba(240-890)		Air Force Base			Crocker, 1985 information from EPA Region VI
15	Mississippi R., Shell Beach, LA/Gulf Outlet	Pentachlorophenol(PCP), probably other pollutants	Bioacc. of PCP in oysters	Spill of hydrobromic acid, ethylmercaptan, lubrication oil, PCP		Spill in 1980; spill cleanup declared complete	Science Applications Int'l Corp., 1985
16	Lake Pontchartrain, LA	PAHs, phthalate esters(up to 0.9), PCBs(up to 0.1), Pb(up to 270), Cd(up to 4), Zn(up to 250), Cu(up to 83), Hg(up to 0.5), As(up to 1.5), Cr(up to 90), Ni(up to 45)	Metals found in biota	Urban stormwater, domestic sewage, discharges and spills from marine facilities and vessels			Schurtz & St. Pe, 1984
	Lake Pontchartrain, LA	PAHs, DDT, PCBs, heavy metals		Urban runoff, spills			Overton et al., 1986

TABLE 6. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VI (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
17	Capitol Lake, Baton Rouge, LA	PCBs(4-11)	Biota impacted; bioacc. of chlorinated hydrocarbons, low diversity, absence of reproduction, absence of tertiary predator species	Industrial point, spills, urban stormwater runoff	C		Schurtz & Albritton, 1986
18-20	Oxbow Lakes/NEastern LA	DDT and metabolites(0.1), PCBs(0.03), toxaphene	Biomagnification in biota				Niethammer et al., 1984
21	Middle Rio Grande, NM/Elephant Butte Reservoir, Caballo Reservoir	As(3-10), Cd(1-4), Cr(30-50), Cu(20-40), Hg(1-10), Pb(30-60), Mo(1-3), Se(0.04-0.3), U(180-280), V(40-110), Mn(230-1070)	Hg, Pb, V in fish; Hg levels in fish warrant public health concern				Popp et al., 1983

TABLE 7. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VII

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region VII						
1	Cedar Lake, Cedar Rapids, Iowa	Chlordane(0.0005-0.5)	Fish tissue levels exceeded FDA action levels;	Urban runoff	Fishing restricted		Information from EPA Region VII
2	Mississippi R., St. Louis, MO	As(up to 100), Pb(up to 440)		Industrial			Johanson and Johnson, 1976
3	Swope Park Lakes, Kansas City, MO	Chlordane(0.5)	Fish tissue levels exceeded FDA action levels	Urban runoff	Fishing restricted		Information from EPA Region VII
2	Romaine Creek, St. Louis, MO	Dioxin(ND-0.04)		Urban runoff			Information from EPA Region VII
4	Squaw Creek National Wildlife Refuge, Holt County, MO	Pb(0.1-940)		Secondary lead smelting/recovery			Information from EPA Region VII
5	Gum Spring Creek, Wolf Creek, Granby, MO	Heavy metals as below		Mining			Information from EPA Region VII and Missouri Dept.Nat.Res.
6	Shoal Creek, Joplin West, MO-KS	Al(3400-5400), Sb(40-60), As(7-10), Ba(35-60), Ca(18-90), Cr(9-16), Cd(4-16), Cu(17-40), Pb(150-4300), Ni(27-40), Se(3-5), Ag(7-10), Th(7-10), Sn(27-40), V(12-30), Zn(3700-26000)		Mining		More info.on #6 below	Information from EPA Region VII
	Center Creek, Oronogo-Duenweg	Heavy metals as above		Mining			Information from EPA Region VII
7	Missouri R., Omaha, NE	Al(3000-7000), As(5-6), Cd(0.1-0.2), Cr(5-10), Cu(3-10), Ni(10-20), Pb(4-10), Zn(20-40)					Information from EPA Region VII

TABLE 7. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VII

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
8	Spring R., MO	Dioxin		Discharge from herbicide mfgr.			Information from from KS officials
9	Big River, Desloge, MO	Pb(1000-49,000), Cd(11-30),Zn(700-1660), Cu(60-130)		Mining			Information from MO Dept. of Natur. Resources
6	Center Creek, Oronogo, MO	Pb(73-7300) Zn(750-16,000) Fe(10,000-28,000)		Mining			Information from MO Dept. of Natur. Resources
	Shoal Creek, Joplin, MO	Pb(66 4300) Zn(750-26,000) Fe(6200-14,000)		Mining			Information from MO Dept. of Natur. Resources
	Turkey Creek, Joplin, MO	Pb (230) Zn(2300)		Mining			Information from MO Dept. of Natur. Resources
10	Doe Run Creek & Little St. Francis River, Fredericktown, MO	Cu(3-6280) Co(12-1744) Ni(5-2815) Pb(65-29,420) Zn(36-2330)		Mining			Information from MO Dept. of Natur. Resources
11	Tebo Creek, Henry County, MO	Fe, sulfate		Coal mining			Information from MO Dept. of Natur. Resources
12	North Claybank Creek, Macon County, MO	Fe, sulfate		Coal mining			Information from MO Dept. of Natur. Resources
13	Blue River, Kansas City, MO	PCBs		Chemical dumping			Information from MO Dept. of Natur. Resources

TABLE 7. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VII (continued)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
14	local surface waters, St.Louis, MO	PCBs		Chemical Dumping			Information from MO Dept. of Natur. Resources
15	Pin Oak Creek, Johnson County, MO	PCBs		Discharges and spill from waste treatment facility (D)			Information from MO Dept. of Natur. Resources
16	Mississippi River side channel, Clinton, IA	PAHs, aliphatic hydrocarbons					Information from IA Dept. of Water Air & Waste Mgmt.
17	Mississippi River side channel, Davenport, IA	Metals, organics					Information from IA Dept. of Water Air & Waste Mgmt.
18	Cedar River, Charles City, IA	Hg compounds		Leaching from landfill, wastes originally from a pharmaceutical company			Information from IA Dept. of Water Air & Waste Mgmt.

TABLE 8. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VIII

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region VIII						
1	Benton Lake National Wildlife Refuge, MT	Se	Concentrations exceed EPA drinking water criterion	Agricultural drainwater			US Fish & Wildlife Service, 1986
1	Benton Lake National Wildlife Refuge, MT	Salinity, Se	Salinity associated with increased botulism in waterfowl	Agricultural drainage			MT Dept. of Health & Environmental Sciences, 1986
2	Freezeout Lake, MT	Salinity, Se		Agricultural drainage			MT Dept. of Healt & Environmental Sciences, 1986
3	Lake Bowdoin National Wildlife Refuge, MT	Se		Agricultural drainage			MT Dept. of Health & Environmental Sciences, 1986
4	Silver Bow Creek & upper Clark Fork River, near Butte, MT	Metals(Cu, Fe, Pb, Zn)	Occasional fish kills	Mining, mill tailings		Superfund site	MT Dept. of Health & Environmental Sciences, 1986
5	Milltown, Montana/Milltown Reservoir Sediments site	As	Alternative water supply recommended	Mining, milling, smelting	C	Superfund site	U.S. EPA, 1984
6	Clark Fork River, Frenchtown, MT	Pulp wastes		Pulp & paper mill discharge			Information from EPA Region VIII
7	Spring Creek & Prickly Pear Creek, south of Helena, MT	Metals		Mining			MT Dept. of Health Environmental Ser 1986
8	Surface waters near Columbus, MT	Cr(VI)		Chromium ore processings wastes		Superfund site	Information from EPA Region VIII

TABLE 8. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VIII

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
9	Cheyenne River at Lake Oahe, SD	Hg(0.03-0.62)		Mining, mill tailings			Walter et al., 1973
9	Cheyenne River at Lake Oahe, SD	Hg(3-16) As(2-65) Se(ND-4)	Concentration of contaminants, especially Se, noted in fish and aquatic birds.	Mining (source of Hg)			Information from SD Dept. of Water & Natural Resources.
9	Whitewood Creek, Belle Fourche R., Cheyenne R., S. Dakota	As, Cu, Ni, Cr	Groundwater contamination, biota impacted	Mining			Information from USGS, Rapid City, South Dakota,
9	Whitewood Creek, Belle Fourche R., Cheyenne R., S. Dakota	As(up to 4), Hg(up to 1.1)	Hg in fish often exceed FDA guidelines; biota impacted	Mining			U.S. EPA, 1971
9	Whitewood Creek, Belle Fourche R., Cheyenne R., S. Dakota	Hg(<0.1-4), Zn(40-230), Cu(3-150), As(4-11800)		Mining			U.S. EPA, 1973
10	Laramie River, Laramie, WY	PCBs, DDT, DDE, DDD, lindane, dieldrin, endrin, creosote		Railroad tie treatment plant waste discharge (source of creosote)			WY Dept. of Environmental Quality, 1986
11	Little Popo Agie R., WY	Total oil residue(ND-2520)	Sediment microbial activity stimulated	Effluent from oil field			Heitkamp & Johnson, 1984
11	Little Popo Agie R., WY	Total hydrocarbons(980-2520), Zn(20-60)	Species diversity reduced	Effluent from oil field			Woodward & Riley, 1983
12	Jordan River & tributaries, Salt Lake City, UT	PCBs(ND-0.32), 2,4-D(ND-0.32), DDD(ND-0.005), DDE(ND-0.002), dieldrin(ND-0.002), methoxychlor(ND-0.08), Cu(7-120), Pb(10-480), Zn(23-400), As(6-20), Cr(2-20)		Urban runoff, WWTP discharges			Information from USGS, Salt Lake City, UT

TABLE 8. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION VIII

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
13	Upper Arkansas R., California Gulch, Yak Tunnel, Leadville, CO	As, Be, Cd, Cr, Cu, CN, Pb, Hg, Ni, Se, Ag, Th, Zn	Stream biota severely impacted, periodic fish kills, metals toxicity in area livestock, groundwater potentially contaminated	Acid mine drainage	C	Superfund site--Yak Tunnel/California Gulch	Information received from USGS Colorado District
14	Missouri River, Williston, ND	PCBs					Information from Omaha district Corps of Engineers
15	James River, ND/SD	pesticides, PCBs					Information from Omaha district Corps of Engineers

TABLE 9. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IX

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
	Region IX						
1	Kesterson Nat. Wildlife Refuge, CA/Kesterson Ponds	Se, other trace metals	Bioacc.; poor reproduction, deformities, deaths in birds	Agri. drainwater (being phased out)	C	Plans being developed	U.S. Fish and Wildlife Service, 1986
2	Stillwater Wildlife Mgt. Area, NV/Paiute Drain, Carson River, Lahontan Reservoir	Se, As, Hg	Hg in fish one to four times maxi. sugg. for human consump.	Agricultural drainwater(C)			U.S. Fish and Wildlife Service 1986
3	San Francisco Harbor, CA/Islais Creek	Hg(0.1-8), As(0.1-7), Cd(0.4-500), Pb(3-100), Cu(23-700), Cr(93-100), Zn(60-200), PCBs(0.1-0.3), oil and grease(0.02-0.8%)		Industries, storm sewers			Johanson and Johnson, 1976
	San Francisco Bay	Pb(16-60), Zn(55-190), Hg(0.2-1), Cd(1-3), Cu(20-85)		Municipal and industrial point sources, storm drains, surface runoff, atmospheric fallout, overboard discharge, agricultural drainage, upland erosion, waste disposal sites			Sustar & Wakeman, 1977
	San Francisco Bay	Ag(0.1-12), As(1-12), Cd(0.2-22), Cr(2-300), Cu(4-100), Hg(0.1-16), Ni(4-200), Pb(3-80), Se(0.3-12), Zn(3-200)	Elevated metal concentrations in shellfish	Municipal point sources, other sources			Bradford & Luoma, 1980
3	San Francisco Bay/ Richmond Inner Harbor, CA	DDT, dieldrin	All test organisms exposed to sediment/water mixture died.	Agricultural runoff			Information from California Water Resources Control Board
3	Oakland Harbor, CA	Pb(up to 1800), Cd(up to 33), oil and grease(up to 3.3%)		Industrial			Johanson and Johnson, 1976

TABLE 9. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IX (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
3	San Francisco Bay/Beemar Point	Cd(1000)					As reported in Bolton et al., 1985
4	Palos Verdes, CA	Hg(2-90)		Sewage outfall			Eganhouse et al., 1978
	Palos Verdes, CA	Ag(2-30), Cd(1-70), Cr(50-1500), Cu(10-940), Ni(20-130), Pb(20-580), Zn(50-2880)		Municipal sewage treatment			Herchelman et al., 1981
	Palos Verdes, CA	DDT(0.2-280), Cr(1000-13000)					As reported in Bolton et al., 1985
	Coastal Calif./depending on distance from Los Angeles discharges	PCBs(0.5-7)					Young et al., 1977, as reported in Boehm, 1984
	Various basins off Southern California	Cr(8-360), Cu(1-300), Ni(6-65), Pb(<0.1-360), Zn(7-1530)					As reported in Greig and McGrath, 1977
	California Coast/Southern California	Cu(up to 550), Cd Cr, Zn, Pb, Ag, Ni, Co		Municipal sewage treatment			Galloway, 1978
	Los Angeles Harbor, CA	Hg(10), Cu(1800), Ni(570)		Food processing			Johanson and Johnson, 1976
5	San Diego Harbor, CA	As(135), Hg(9)		Sandblasting of ships, marine paints			Johanson and Johnson, 1976
5	San Diego Bay, CA (north Bay)	PCBs		Aircraft mfg. plants, via storm drains (probable)			Information from California Water Resources Control Board
5	San Diego Bay, CA (24th St. Marine Terminal)	Cu,Zn (25%)		Spillage from ore shipment			Information from California Water Resources Control Board

TABLE 9. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION IX (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
6	Blanco Drain, east of Monterey, CA	DDT,DDE, toxaphene		Agricultural runoff			Information from California Water Resources Control Board
7	Elkhorn Slough, north of Monterey, CA	pesticides (toxaphene, endosulfan,dacthal, dieldrin, DDT)		Agricultural runoff			Information from California Water Resources Control Board
8	Monterey Harbor, CA (Cannery Row area)	Pb		Railroad (lead dumped as ballast for tracks) (D)	C	Highest concentration of Pb ever found in marine environment	Information from California Water Resources Control Board
9	Urban lakes, Los Angeles metropolitan area, CA	Pb, sometimes PCBs DDT,toxaphene, other pesticides			C,I		Information from California Water Resources Control Board
10	Los Angeles/ Long Beach Harbor, CA	PCBs, DDT, and others					Information from California Water Resources Control Board
11	Santa Monica Bay, CA	DDT	Health warnings issued against eating shellfish	Sewage outfalls			Information from California Water Resources Control Board
12	Newport Bay, CA	DDT, toxaphene, PCBs, other pesticides, metals (Pb,Cd,Zn)		Non-point sources			Information from California Water Resources Control Board

TABLE 10. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION X

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
1	Puget Sound/Seattle Waterfront	PAHs(0.3-50)					As reported in Bolton et al., 1985
	Region X						
1	Duwamish Waterway, Seattle, WA	PCBs(0.2-6), Hg(0.1-70), Cd(0-10), Pb(35-340), Cu(30-160), Zn(70-6700), Cr(20-70), Ni(25-60), oil & grease(0-2%)		PCB spill (D), municipal and industrial outfalls (C), stormwater runoff (C), sanitary landfill/ garbage dump (C)		265 gallons PCB spill in 1974; PCB levels among highest in country	Johanson and Johnson, 1976
	Duwamish Waterway, Seattle, WA	PCBs		PCB oil coolant spill (D)	I	260 gallons spill in 1974; spread over 3 acres; spill cleanup complete	Science Applications Int'l Corp., 1985
	Duwamish Waterway, Seattle, WA	PCBs(<0.01-140), As, Cd, Cu, Mn, Hg, Ni, Zn		PCB spill (D)	I	Concs. average post-dredge, 5/4/76	Blazevich et al., 1977
	Puget Sound/Duwamish Waterway	PAHs(2-30)					As reported in Bolton et al., 1985
	Commencement Bay, WA/Hylebos & Blair Waterways	PCBs(0.4-7), chlorinated butadienes(2-80), PAHs(0.2-110), halogenated organics, As, Pb	Acc. of contaminants in demersal and benthic organisms, tumors and lesions in fish and invertebrates			Superfund site	Riley et al., 1981
	Puget Sound/Hylebos Waterway	PAHs(0.1-50)					As reported in Bolton et al., 1985
2	Commencement Bay Nearshore/Tideflats, Tacoma, WA				C	Superfund site	Phillips et al., 1985
	Commencement Bay Nearshore/Tideflats, Tacoma, WA	As(1-30000), Cu(10-36000), Pb(2-10000), Hg(0.01-50), numerous other metals, PCBs(0.004-20), Alip. hydrocarbons, phenols(ND-100), PAHs(ND-600), dichlorobenzenes(ND-14), dibenzofuran, phthalates	Acc. in biota, abnormalities in indigenous biota; advisory on fish consumption in 1982	Numerous industrial sources, TSDFs, smelter, runoff, spills	C	Superfund site; levels of contamination and biological effects vary widely	Tera-Tech 1985, see also Gahler et al., 1982

TABLE 10. DATA ON REVIEWED SITES WITH IN-PLACE POLLUTANTS IN EPA REGION X (CONTINUED)

	Water Body/Location	Contaminants (conc. range)	Perceived/ Noted Impacts	Source (status)	Remedial Actions	Comments	Reference
2	Puget Sound/Commencement Waterways	PAHs(0.3-50)					As reported in Bolton et al., 1985
	Puget Sound/Commencement Bay	As(470)					As reported in Bolton et al., 1985
3	Everett Harbor, WA/East Waterway	Cr(40-80), Ni(20-50), Cu(30-100), Zn(140-170), Pb(20-70), As(3-10), Hg(0.1-0.4), Cd(1-1.1), Ag(0.1-0.2), Be(0.2-0.4), Tl(1.6-2.4), PAHS(0.2-16), PCBs					Anderson & Crecelius, 1985
4	Puget Sound, WA/Colvos Passage and Southern Puget Sound	Co(6-20), V(30-110), Cr(70-150), Ni(20-50), Cu(10-80), Zn(30-130), As(3-30), Se(<0.5-3), Pb(10-50), PAHs(0.03-2), PCBs(0.03)	Biomag. of PCBs in fish	Runoff, sewage, industrial point sources, auto exhaust, smelter			Riley et al., 1983
	Puget Sound/West Point	PAHs(50)					As reported in Bolton et al., 1985
5	Alaska Maritime Nat. Wildlife Refuge, AK/Woman's Bay		Biological desert	Solid waste disposal(C); seafood processor(D); ship repair(D)		Follow-up to define type and source of contaminants	U.S. Fish and Wildlife Service, 1986
6	Alaska Maritime Nat. Wildlife Refuge, AK/Amchitka and Atka Islands			Military installations (D)	C	Plans are underway; sampling conducted in 1985	U.S. Fish and Wildlife Service 1986

APPENDIX B

BIBLIOGRAPHY OF LITERATURE ON IN-PLACE POLLUTANTS

Table of Contents

I. INTRODUCTION

This appendix contains a complete listing of the literature obtained for this study. Included are reports and articles collected by means of a literature search supplemented by inquiries to environmental agencies, as described in Section III. (References for literature cited in the body of this report are listed in Section VI. Some of the citations listed in Section VI also appear in this bibliography.) The bibliography is divided into two parts: The first section includes literature reviews, nationwide surveys dealing with in-place pollutants, and a few general works describing in-place pollutants. The second section includes reports and articles dealing with in-place pollutants at particular locations, as well as works dealing in general with techniques for cleaning up contaminated sediments or with the ecological effects of in-place pollutants.

The second section of the bibliography is coded to indicate the subject areas touched upon by each report or article. Each citation is marked with a set of code letters and numbers indicating:

- What EPA region it refers to (Roman numerals I through X)
- What type of water body it discusses:

  M = Marine
  E = Estuarine
  R = River/Stream
  L = Lake/Reservoir

- What types of contaminants were analyzed for or detected:

  1 = Metals
  2 = PAHs
  3 = Petroleum Hydrocarbons
  4 = PCBs
  5 = Pesticides
  6 = Radionuclides
  7 = Bacteria/Viruses
  0 = Other

In addition, code letters are added for any of the following specific subjects that are discussed:

S Sources or suspected sources of contaminants (e.g., specific industries, agricultural runoff, chemical or oil spills, atmospheric deposition).

P Remedial actions considered or undertaken.

E Ecological/biological effects noted (e.g., disease, mortality, community structure changes, pollutant uptake/bioaccumulation/biomagnification).

J Judgements or methods of judging what constitutes a sediment contamination "problem"; sediment quality criteria or classification systems.

P "Problem Area" -- This code was used when an article discussed a site that we felt should be included in our Appendix A "inventory" of sediment contamination problem areas.

For example, the article "Polycyclic Aromatic Hydrocarbons in Sediments and Associated Benthos in Lake Erie", which discusses the results of sampling near a large coal fired power plant, would be coded as follows: V, W-L, C-2, S, E, P (where W-refers to type of water body and C-refers to type of contaminants).

Following the bibliography is an index to the reports and articles by location, organized according to EPA regions.

II. GENERAL REPORTS, LITERATURE REVIEWS, AND NATIONWIDE SURVEYS

Alderton, D.H.M. (1985), "Sediments," in: Historical Monitoring, Monitoring and Assessment Research Centre (MARC Report #31), University of London.

Bolton, H.S., R.J. Breteler, B.W. Vigon, J.A. Scanlon, and S.L. Clark (May, 1985), "National Perspective on Sediment Quality," U.S. Environmental Protection Agency, Criteria and Standards Division, Office of Water Regulations and Standards, Washington, DC, EPA Contract No. 68-01-6986.

Forstner, U. and G.T.W. Wittmann (1983), Metal Pollution in the Aquatic Environment, Second Revised Edition, Springer-Verlag, Berlin, Germany.

Johanson, E.E. and J.C. Johnson (May, 1976), "Identifying and Prioritizing Locations for the Removal of In-Place Pollutants," U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, DC, Contract No. 68-01-2920.

Judy, R.D., P.N. Seeley, T.M. Murray, S.C. Svirsky, M.R. Whitworth, and L.S. Ischinger (June, 1984), "1982 National Fisheries Survey Volume I Technical Report: Initial Findings," U.S. Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC, FWS/OBS-84/06.

Khalid, R.A., R.P. Gambrell, B.A. Taylor, and W.H. Patrick, Jr. (May, 1983), "Literature Survey of Reservoir Contaminant Problems," Environmental & Water Quality Operational Studies, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Technical Report E-83-13

Lathrop, Joyce E., and W.S. Davis (1986), "Aquatic Sediments," J. Water Pollution Control Fed., 58:684-699.

National Oceanographic and Atmospheric Administration (NOAA) (1987), "National Status and Trends Program: Progress Report and Preliminary Assessment of Findings of the Benthic Surveillance Project-1984," NOAA, Rockville, MD.

Olsen, L.A. (April, 1984), "Effects of Contaminated Sediment on Fish and Wildlife: Review and Annotated Bibliography," U.S. Fish and Wildlife Service, U.S. Department of the Interior, FWS/OBS-82/66.

Patin, T.R., ed. (July, 1984), "Management of Bottom Sediments Containing Toxic Substances," Proceedings of the 8th U.S./Japan Experts Meeting, 8 - 10 November, 1982, Tokyo, Japan, U.S. Army Corps of Engineers, NTIS AD-A149 291.

Patin, T.R., ed. (March, 1985), "Management of Bottom Sediments Containing Toxic Substances," Proceedings of the 9th U.S./Japan Experts Meeting, 17 - 19 October, 1983, Jacksonville, Florida, U.S. Army Corps of Engineers, NTIS AD-A157 863.

Patin, T.R., Ed., (October, 1985), "Management of Bottom Sediments Containing Toxic Substances," Proceedings of the 10th U.S./Japan Experts Meeting, 30-31 October 1984, Kyoto, Japan, U.S. Army Corps of Engineers, Water Resources Support Center, DTIC AD-A163 709.

Seelye, J.G. and M.J. Mac (February, 1984), "Bioaccumulation of Toxic Substances Associated with Dredging and Dredged Material Disposal: A Literature Review," Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL, EPA-905/3-84-005.

U.S. Army Corps of Engineers, Water Resources Support Center (March 1982), "Management of Bottom Sediments Containing Toxic Substances," Proceedings of the 6th U.S./Japan Experts Meeting, 16-18 February 1981, Tokyo, Japan, DTIC AD-A116 778.

U.S. Environmental Protection Agency, Office of Water Regulations and Standards (August, 1985), "National Water Quality Inventory, EPA 440/4-85-029.

U.S. Fish and Wildlife Service (April, 1986), "Preliminary Survey of Contaminant Issues of Concern on National Wildlife Refuges".

Vinopal, J. Howard, and J.F. Suprock, "Pesticide Monitoring Special Study, No. 44-0100-77d, Dept. of the Army Pesticide Monitoring Program, Interim Evaluation of Soil and Sediment Samples Collected in CY 1975 from Fourteen Installations, January - December 1976," U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD.

III. LOCATION- AND SUBJECT-SPECIFIC REPORTS

X,W-M,C-1,2,4,P — Anderson, J.W. and E.A. Crecelius (March, 1985), "Analysis of Sediments and Soils for Chemical Contamination for the Design of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington," Prepared for U.S. Army Corps of Engineers, Seattle District, under a Related Services Agreement with the U.S. Department of Energy, Contract DE-AC06-76RLO 1830,Pacific Northwest Laboratory, Richland, Washington, PNL-5383.

I,W-R,C-1,S,E — Atkinson, D.S., N.M. Ram and M.S. Switzenbaum (March, 1985), "Evaluation of the Microtox™ Analyzer for Assessment of Sediment Toxicity," University of Massachusetts, Env. Eng. Report No. 86-85-3, Prepared for Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control.

III,W-R,C-5,S,R,E,P — Battelle Memorial Institute (June, 1978), "The Feasibility of Mitigating Kepone Contamination in the James River Basin," Pacific Northwest Laboratory, Richland, WA.

I/II,W-M/E,C-1 — Bender, M.L. (August, 1981), "Nearshore Marine Trace Metal Geochemistry," U.S. EPA Environmental Research Laboratory, Narragansett, RI, EPA 600/3-81-050. NTIS PB 82-109372.

I,W-L,C-1,S — Bertine, K.K. and M.F. Mendeck (1978), "Industrialization of New Haven, Conn., as Recorded in Reservoir Sediments," Environ. Sci. Technol., 12:201-207.

III,W-M,C-O,E,P — Bieri, R.H., P.DeFur, R.J. Huggett, W. MacIntyre, P. Shou, C.L. Smith, and C.W. Su (April, 1983), "Organic Compounds in Surface Sediments and Oyster Tissues from the Chesapeake Bay," U.S. EPA Chesapeake Bay Program, Annapolis, MD EPA-600/3-83-018a. NTIS PB 83-187443.

V,W-R/L,C-1,4,R,P — Blasland & Bouck Engineers, P.C. (November, 1985, Revised January and March, 1986), "Sheboygan River and Harbor Remedial Investigation/Feasibility Study Work Plan." EPA Contract No. 68-61-6939.

X,W-E,C-4,S,R,P — Blazevich, J.N., A.R. Gahler, G.J. Vasconcelos, R.H. Rieck, and S.V.W. Pope (August, 1977), "Monitoring of Trace Constituents During PCB Recovery Dredging Operations Duwamish Waterway," U.S. Environmental Protection Agency, Region X, Seattle, WA, EPA 910/9-77-039.

I/II/III,W-M,C-2,4,0 Boehm, P. (January, 1983), "Chemical Contaminants in Northeast United States Marine Sediments," National Ocean Service, Rockville, MD, NOAA Technical Report NOS99. NTIS PB 83-192237.

I,W-M,C-3,4,S,E Boehm, P.D. and J.G. Quinn (1978), "Benthic Hydrocarbons of Rhode Island Sound," Estuarine and Coastal Marine Science, 6:471-494.

II,W-E/R,C-4,S,P Bopp, R.F., H.J. Simpson, C.R. Olsen, and N. Kostyk (1981), "Polychlorinated Biphenyls in Sediments of the Tidal Hudson River, New York," Environ. Sci. & Technol., 15:210-216.

I,W-M,C-1,S Bothner, M.H., R.R. Rendigs, E.Y. Campbell, M.W. Doughton, C.M. Parmenter, C.H. O'Dell, G.P. DeLisio, R.G. Johnson, J.R. Gillison, and N. Rait (February, 1985), "The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Third Year of Monitoring", Minerals Management Service, Vienna, Virginia, MMS/AT/ES-85/04. NTIS PB 85-231967.

IX,W-E,C-1,S,E,P Bradford, W.L. and S.N. Luoma (1980), "Some Perspectives on Heay Metal Concentrations in Shellfish and Sediment in San Francisco Bay, California," in Contaminants and Sediments, Vol. 2, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, Michigan.

E,R Brannon, James M., R.E. Hoeppel, T.C. Sturgis, I. Smith, Jr., and D. Gunnison (November, 1985), "Effectiveness of Capping in Isolating Contaminated Dredged Material from Biota and the Overlying Water," (Long-Term Effects of Dredging Operations Program), Technical Report D-85-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, DTIC AD-A165 251.

VI,W-M,C-2,O Brooks, J.M., E.L. Estes, D.A. Wiesenburg, C.R. Schwab and H.A. Abdel-Reheim (1980), "Investigations of Surficial Sdiments, Suspended Particulates and Volatile Hydrocarbons at Buccaneer Gas and Oil Field." Vol. 1, in: Jackson, W.B. and E.P. Wilkens (eds.) Environmental Assessment of Buccaneer Gas and Oil Field in the Northwestern Gulf of Mexico, 1975-1980. NOAA Technical Memorandum NMFS-SEFC-47. NTIS PB 81-157778

II,W-R,C-4,P Brown, M.P. et al. (1985), "Polychlorinated biphenyls in the Hudson River, "Environ. Sci. Technol., 19:656-661.

IV,W-R/M,C-3,S,P Brown, R.C., R.H. Pierce, and S.A. Rice (1985), "Hydrocarbon Contamination in Sediments from Urban Stormwater Runoff," Marine Pollution Bulletin, 16:236-240.

I,W-M/E,C-3,S,E,P Burns, K.A. and J.M. Teal (1979), "The West Falmouth Oil Spill: Hydrocarbons in the Salt March Ecosystem," Estuarine and Coastal Marine Science, 8:349-360.

IX,W-R/L/M	California Water Resources Control Board (1984), "Toxic Substances Monitoring Program 1984," State of California, Water Resources Control Board, Water Quality Monitoring Report #86-4-WQ.
V,W-L,C-4,S,R,E,P	CH2M Hill and Ecology & Environment (July, 1983), "Source Control Feasibility Study, OMC Hazardous Waste Site, Waukegan, Illinois," U.S. EPA Hazardous Site Control Div., EPA 13-5M28.0. [Note: See also appended record of decision, technical documentation, and public comments.]
V,W-R,C-1,4,0,S,R,E,P	CH2M Hill and Ecology & Environment (July, 1986), "Feasibility Study: Fields Brook Site, Sediment Operable Unit, Ashtabula, Ohio," Public Comment Draft, U.S. EPA Hazardous Site Control Div., EPA 19.5L46.0.
V,W-L,C-1,S,P	Christensen, E.R. and N.K. Chien (1979), "INAA and AAS Determination of Arsenic, Mercury, and Other Elements in Dated Green Bay Sediments," American Nuclear Society, Transactions, 32:178-179.
III,W-E,C-5,S,P	Cutshall, N.H., I.L. Larsen, and M.M. Nichols (1981), "Man-Made Radionuclides Confirm Rapid Burial of Kepone in James River Sediments," Science, 213:440-442.
V,W-R,L,C-O	Davenport, T.E. and M.H. Kelly (December, 1984), "Water Resource Data and Preliminary Trend Analysis for the Highland Silver Lake Monitoring and Evaluation Project," Madison County, Illinois," Illinois Environmental Protection Agency, Springfield, Illinois, IEPA/WPC/84-030. NTIS PB 85-163665.
X,W-M,C-4,R,E	Dexter, R.N., D.E. Anderson, and E.A. Quinlan (September, 1984), "Long-Term Impacts Induced by Disposal of Contaminated River Sediments in Elliott Bay, Seattle, Washington," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Technical Report D-84-4. NTIS AD-A148815.
VI,W-R/L/E,C-4,5,S,E	Dick, M. (January, 1982), "Pesticide and PCB Concentrations in Texas-Water, Sediment, and Fish Tissue," Texas Department of Water Resources, Austin, TX, Report 264.
E,R	Dillon, T. M., and A.B. Gibson (June, 1986), "Bioassessment Methodologies for the Regulatory Testing of Freshwater Dredged Material," Proceedings of a Workshop, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper EL-86-6.
W-M/E,C-2,3,0,E	DiSalvo, L.H., H.E. Guard, N.D. Hirsch, and J. Ng (November, 1977), "Assessment and Significance of Sediment-Associated Oil and Grease in Aquatic Environments," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Technical Report D-77-26. NTIS AD A050044.

W-R/L,C-5,S — Duda, A.M. (1985), "Environmental and Economic Damage Caused by Sediment from Agricultural Nonpoint Sources" Water Resources Bulletin, 21:225-234.

I,W-R,C-1,S,E,P — Duval, R.L., C.R. Ferris, R.B. Owen, Jr., K.E. G: s, ".K. Fink, Jr., and F.E. Woodard (1980), "Effects of a tl kin Tannery on Stream Quality and Benthic Macroinver' a' in Central Maine," Bull. Environm. Contam. oxicol., 25:269-276.

V,W-L,C-2,S,E,P — Eadie, B.J., W. Faust, W.S. Gardner, and T. N pa (1982), "Polycyclic Aromatic Hydrocarbons in Sediments id Associated Benthos in Lake Erie," Chemosphere, 11:185-191.

X,W-M,C-1,E — Ecological Analysts, Inc., Concord, CA, (September, 1981) "A Technical Evaluation of Potential Environmental Impacts of Proposed Ocean Disposal of Dredged Material at Winchester Bay, Oregon," U.S. Army Corps of Engineers Portland District, Portland, OR.

IX,W-M,C-1,S,P — Eganhouse, R.P., D.R. Young, and J.N. Johnson (1978), "Geochemistry of Mercury in Palos Verdes Sediments," Environ. Sci. & Technol., 12:1151-1157.

IX,W-M,C-3,S — Eganhouse, R.P., D.L. Blumfield, and I.R. Kaplan, "Petroleum Hydrocarbons in Stormwater Runoff and Municipal Wastes: Input to Coastal Waters and Fate in Marine Sediments," VIIth International Symposium "Chemistry of the Mediterranean," -- Transport and Reactivity of Pollutants in the Estuary, May 6-12, 1982, Primosten, Croatia, Yugoslavia. CONF-8205127--1. NTIS DE 83 001318.

V,W-L,C-4,S,P — Eisenreich, S.J. and G.J. Hollod (1979), "Accumulation of Polychlorinated Biphenyls (PCBs) in Surficial Lake Superior Sediments. Atmospheric Deposition," Environ. Sci. & Technol., 13:569-573.

V,W-L,C-4,S,P — Eisenreich, S.J., G.J. Hollod, and T.C. Johnson (1980), "Polychlorinated Biphenyls and Other Microcontaminant-Sediment Interactions in Lake Superior," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, Michigan.

III,W-E,C-7,S,P — Erkenbrecher, C.W. Jr. (June, 1980), "Sediment Bacteria as a Water Quality Indicator in the Lynnhaven Estuary," Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University Blacksburg, VA, Bulletin 126. NTIS PB 80-192354.

II,W-M,C-3,S — Farrington, J.W. and B.W. Tripp (1977), "Hydrocarbons in Western North Atlantic Surface Sediments," Geochimica et Cosmochimica Acta, 41:1627-1641.

IV,W-E,C-1,J	Florida Department of Environmental Regulation (March, 1986), "Guide for Interpreting Reported Metal Concentrations in Estuarine Sediments," Draft Version.
IV,W-E,C-1,J	Florida Department of Environmental Regulation (February, 1986), "Geochemical and Statistical Bases for Assessing Metals Pollution in Estuarine Sediments," Draft Version.
R	Francingues, N.R., Jr., M.R. Palermo, C.R. Lee, and R.K. Peddicord (August, 1985), "Management Strategy for Disposal of Dredged Material: Contaminant Testing and Controls," Dredging Operations Technical Support Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Misc. Paper D-85-1.
II,W-L,C-4,5,S,P	Frank, R., R.L. Thomas, M. Holdrinet, A.L.W. Kemp and H.E. Brown (1979), "Organochlorine Insecticides and PCB in Surficial Sediments (1968) and Sediment Cores (1976) from Lake Ontario, J. Great Lakes Res., 5:18-27.
V,W-L,C-4,5,P	Frank, R., R.L. Thomas, H.E. Braun, J. Rasper, and R. Dawson (1980), "Organochlorine Insecticides and PCB in the Surifical Sediments of Lake Superior (1973)," J. Great Lakes Res., 6:113-120.
V,W-L,C-4,5,S,P	Frank, R., R.L. Thomas, H.E. Braun, D.L. Gross, and T.T. Davies (1981), "Organochlorine Insecticides and PCB in Surficial Sediments of Lake Michigan (1975)," J. Great Lakes Res., 7:42-50.
X,W-R,C-1,5,O	Fuhrer, G.J. (1984), "Chemical Analyses of Elutriates, Native Water, and Bottom Material from the Chetco, Rogue, and Columbia Rivers in Western Oregon," U.S. Geological Survey Open File Report 84-133.
X,W-R/E,C-1,4	Fuhrer, G.J. and F.A. Rinella (1983), "Analyses of Elutriates, Native Water, and Bottom Material in Selected Rivers and Estuaries in Western Oregon and Washington," U.S. Geological Survey Open File Report 82-922.
X,W-M,C-1,4,5,O,E,P	Gahler, A.R., J.M. Cummins, J.N. Blazevich, R.H. Rieck, R.L. Arp, C.E. Gangmark, S.V.W. Pope, and S. Filip (December, 1982), "Chemical Contaminants in Edible, Non-Salmonid Fish and Crabs from Commencement Bay, Washington," Environmental Services Division Laboratory, U.S. Environmental Protection Agency, Region 10, Seattle, Washington, EPA-910/9-82-093. NTIS PB 83-172163.
IX,W-M,C-1,S,P	Galloway, J.N. (1979), "Alteration of Trace Metal Geochemical Cycles Due to the Marine Discharge of Wastewater," Geochimica et Cosmochimica Acta, 43:207-218.

II,W-L,C-1,S — Galloway, J.N. and G.E. Likens (1979), "Atmospheric Enhancement of Metal Deposition in Adirondack Lake Sediments," Limnol. Oceanogr., 24:427-433.

VI,W-L,C-1 — Garcia, J.D. and D.E. Kidd (1979), "Mercury Levels in Water and Sediment of Elephant Butte Reservoir, New Mexico," Bull. Environm. Contam. Toxicol., 21:624-630.

IV,W-E,C-1,6,S,P — Goldberg, E.D., J.J. Griffin, V. Hodge, and M. Koide (1979), "Pollution History of the Savannah River Estuary," Environ. Sci. & Technol., 13:588-594.

VI,W-E/R,C-7,S,P — Goyal, Sagar M., C.P. Gerba and J.L. Melnick (1977), "Occurrence and Distribution of Bacterial Indicators and Pathogens in Canal Communities Along the Texas Coast," Applied and Environmental Microbiology, 34:139-149.

II/V,W-L,J — Great Lakes Water Quality Board (January, 1982), "Guidelines and Register for the Evaluation of Great Lakes Dredging Projects," Report of the Dredging Subcommittee to the Water Quality Programs Committee of the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario.

II,V,W-L,R,P — Great Lakes Water Quality Board (June, 1985), "1985 Report on Great Lakes Water Quality," Report to the International Joint Commission, Kingston, Ontario.

II,W-E,C-1,P — Greig, R.A. and R.A. McGrath (1977), "Trace Metals in Sediments of Raritan Bay," Marine Pollution Bulletin, 8:188-192.

II,W-M,C-1 — Greig, R.A., R.N. Reids, and D.R. Wenzloff (1977), "Trace Metal Concentrations in Sediments from Long Island Sound," Marine Pollution Bulletin, 8:183-188.

V,W-R,C-7,S,P — Grimes, D.J. (1980), "Bacteriological Water Quality Effects of Hydraulically Dredging Contaminated Upper Mississippi River Bottom Sediment," Applied and Environmental Microbiology, 39:782-789.

IV/V/VI/VII,W-L,C-1,O — Gunkel, R.C., Jr., R.F. Gaugush, R.H. Kennedy, G.E. Saul, J.H. Carroll, and J.E. Gauthey (February, 1984), "A Comparative Study of Sediment Quality in Four Reservoirs," U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Technical Report E-84-2. NTIS AD-A140750.

X,W-E,C-1,4,5,P — Hancock, D.R., P.O. Nelson, C.K. Sollitt, and K. J. Williamson (December, 1984), "Coos Bay Offshore Disposal Site Investigation," Interim Report Phase I, February, 1979 - March, 1980, Portland District Corps of Engineers, Portland, OR, Contract #DACW57-79-C00040

III,W-E,C-1,E — Harrison, G. (1984), "A Survey of the Trace-Metal Content of Corbicula fluminea and Associated Sediments in the Tidal Potomac River," U.S. Geological Survey Open-File Report #84-558.

X,W-R,C-6,S — Haushild, W.L. (1980), "Transport, Accumulation and Distribution Interrelationships Between Hanford-Reactors' Radionuclides and Columbia River Sediment," in Contaminants and Sediments, Vol 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, Michigan.

VIII/IX,W-L,C-2,S — Heit, M. (1979), "Concentrations of Benzo(a)Pyrene in the Sediments of Six Western United States Lakes," Water, Air, and Soil Pollution, 11:447-454.

II,W-L,C-1,2,6,E — Heit, M., C.S. Klusek, and K.M. Miller (1980), "Trace Element, Radionuclide, and Polynuclear Aromatic Hydrocarbon Concentrations in Unionidae Mussels from Northern Lake George," Environ. Sci. & Technol., 14:465-468.

VIII,W-L,C-1,2,S — Heit, M., C.S. Klusek, and H.L. Volchok (1980), "Time History of Trace Elements in Sediments from Standley Lake, Colorado," Environ. International, 4:229-237.

VIII,W-R,C-3,S,E,P — Heitkamp, M.A. and B.T. Johnson (1984), "Impact of an Oil Field Effluent on Microbial Activities in a Wyoming River," Can. J. Microbiol., 30:786-792.

IX,W-M,C-1,S,P — Hershelman, G.P., H.A. Schafer, T.K. Jan, and D.R. Young (1981), "Metals in Marine Sediments Near a Large California Municipal Outfall," Marine Pollution Bulletin, 12:131-134.

II,W-R/E,C-4,S,E,R,P — Hetling, L., E. Horn and J. Tofflemire (April, 1978), "Summary of Hudson River PCB Study Results," New York State Department of Environmental Conservation, Technical Paper #51.

III/IV,W-R,C-1,S,E,P — Hildebrand, S.G., R.H. Strand, and J.W. Huckabee (1980), "Mercury Accumulation in Fish and Invertebrates of the North Fork Holston River, Virginia and Tennessee," J. Environ. Qual., 9:393-400.

IX,W-M,C-6,S — Hisamatsu, S. and M. Sakanoue (1978), "Determination of Transuranium Elements in a So-Called "Bikini Ash" Sample and in Marine Sediment Samples Collected Near Bikini Atoll," Health Physics, 35:301-307.

II,W-R/E,C-1,2,4,5,O,P — Hochreiter, J. (June, 1982), "Chemical-Quality Reconnaissance of the Water and Surficial Bed Material in the Delaware River Estuary and Adjacent New Jersey Tributaries, 1980-81," U.S. Geological Survey, Trenton, NJ, Water-Resources Investigations 82-36. NTIS PB83 151852.

I,W-M,C-3,S,P — Hoffman, E.J. and J.G. Quinn (1979), "Gas Chromatographic Analyses of Argo Merchant Oil and Sediment Hydrocarbons at the Wreck Site," Marine Pollution Bulletin, 10:20-24.

I,W-M,C-3,S,E,P — Hoffman, E.J. and J.G. Quinn (1980), "The Argo Merchant Oil Spill and the Sediments of Nantucket Shoals: Research Litigation and Legislation," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers Ann Arbor, Michigan.

III,W-R,C-1,S — Hoffman, D. and R. Biggs (September, 1983), "Trace Metals in Sediments of the St. Jones and Murderkill Rivers, Delaware," OWP Project A-055-DEL, Agreement No. 14-34-0001-2108. NTIS PB 84-111897.

II,W-L,C-5,S,P — Holdrinet, M.V.H., R. Frank, R.L. Thomas and L.J. Hetling (1978), "Mirex in the Sediments of Lake Ontario," J. Great Lakes Res., 4:69-74.

X,W-R/L,C-1,2,5,O — Hopkins, B.S., D.K. Clark, M. Schlender, and M. Stinson (November, 1985), "Basic Water Monitoring Program Fish Tissue and Sediment Sampling for 1984," Washington State Department of Ecology, Olympia, WA.

III,W-E,C-5,S,E,P — Huggett, R.J., M.M. Nichols, and M.E. Bender (1980), "Kepone Contamination of the James River Estuary," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, Michigan.

I,W-M,C-3,S — Hurtt, A.C. and J.G. Quinn (1979), "Distribution of Hydrocarbons in Narragansett Bay Sediment Cores," Environ. Sci. & Technol., 13:829-836.

I,W-M,C-2,S,P — Johnson, A.C., P.F. Larsen, D.F. Gadbois, and A.W. Humason (1985), "The Distribution of Polycyclic Aromatic Hydrocarbons in the Surficial Sediments of Penobscot Bay (Maine, USA) in Relation to Possible Sources and to Other Sites Worldwide," Marine Environmental Research, 15:1-16.

X,W-M-C-A,2,4,5,O,J — JRB Associates (April, 1984), "Initial Evaluation of Alternatives for Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase II: Development and Testing of the Sediment-Water Equilibrium Partitioning Approach," U.S. EPA, Washington, D.C., EPA 910/9-82-117.

I,W-R/M,C-O,S,P — Jungclaus, G.A., V. Lopez-Avila, and R.A. Hites (1978), "Organic Compounds in an Industrial Wastewater: A Case Study of Their Environmental Impact," Environ. Sci. & Technol. 12:88-96.

V,W-L,C-1,4,5,S,J — Kelly, M.H. and R.L. Hite (1981), "Chemical Analysis of Surficial Sediments from 63 Illinois Lakes, Summer, 1979," Illinois Environmental Protection Agency, Division of Water Pollution Control, Springfield, Illinois. NTIS PB 84-180876.

V,W-R,C-1,4,5,S,J — Kelly, M.H. and R.L. Hite (January, 1984), "Evaluation of Illinois Stream Sediment Data: 1974 - 1980," Illinois Environmental Protection Agency, Division of Water Pollution Control, Springfield, Illinois, IEPA/WPC/84-004. NTIS PB 84-161785.

V,W-L,C-1,S,P — Kemp, A.L.W., J.D.H. Williams, R.L. Thomas, and M.L. Gregory (1978), "Impact of Man's Activities on the Chemical Composition of the Sediments of Lakes Superior and Huron," Water, Air, and Soil Pollution, 10:381-402.

V,W-R/L,C-1,2,4,5,O,S,P — Kizlauskas, A.G. (October, 1982), "Report on an Investigation of Sediment Contamination, The Milwaukee Estuary, Wisconsin, Sampled July 29-31, 1980," Great Lakes National Program Office, U.S. Environmental Protection Agency, Region V, Chicago, IL, EPA-905/4-85-006.

V,W-L,C-1,5,J,P — Kizlauskas, A.G. and D. Homer (1984), "RCRA EP Toxicity Test Applied to Dredged Material," U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, Reprinted from Proceedings of the Conference Dredging '84, ASCE, Clearwater Beach, FL, November 1984.

II,W-R/L,C-1,2,4,5,O — Kizlauskas, A.G., D.C. Rockwell, and R.E. Claff (April, 1984), "Great Lakes Naitonal Program Office Harbor Sediment Program Lake Onatario 1981: Rochester, New York, Oswego, New York, Olcott, New York," U.S. Environmental Protection Agency Great Lakes National Program Office, Chicago, IL, EPA-905/4-84-002.

V,W-R/L,C-1,2,4,5,O — Kizlauskas, A.G., D.C. Rockwell, and R.E. Claff (April, 1984), "Great Lakes National Program Office Harbor Sediment Program Lake Superior 1981: Ashland, Wisconsin, Black River, Michigan, L'Anse, Michigan," U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, EPA 905/4-84-0003.

S — Klemetson, S.L. (1985), "Factors Affecting Stream Transport of Combined Sewer Overflow Sediments," Journal of the Water Pollution Control Fed., 57:390-397.

II,W-R/L,C-1,S,R,E,P — Kneip, T.J. and R.E. Hazen (1979), "Deposit and Mobility of Cadmium in a Marsh-Cove Ecosystem and the Relation to Cadmium Concentration in Biota," Environmental Health Prospectives, 28:67-73.

V,W-L,C-1,S — Kobayashi, S. and G.F. Lee (1978), "Accumulation of Arsenic in Sediments of Lakes treated with Sodium Arsenite," Environ. Sci. Technol., 12:1195-1200.

V,W-L,C-1,S,E,P — Kraft, K.J. (1979), "Pontoporeia Distribution Along the Keweenaw Shore of Lake Superior Affected by Copper Tailings," J. Great Lakes Res., 5:28-35.

II,W-M,C-1,S,P — Krom, M.D., K.K. Turekian, and N.H. Cutshall (:ober, 1982), "The Fate of Trace Metals in the Sediments of e New York Bight," CONF-8110104--5, Environmental Scienc Div., ORNL, Publication No. 2035. NTIS DE83 001896.

II,W-R,C-O,S — Kuehl, D.W., E. Durhan, B.C. Butterworth, and J. Linn (1984), "Tetrachloro-9H-Carbazole, A Previously U- ecognized Contaminant in Sediments of the Buffalo River," J. Great Lakes Res., 10:210-214.

I,W-M,C-2,S,P — Lake, J., C. Norwood, C. Dimock, and R. Bowen (1979), "Origins of Polycyclic Aromatic Hydrocarbons in Estuarine Sediments," Geochim. Cosmochim. Acta, 43:1847-1854.

I,W-M,C-2 — Larsen, P.F., D.F. Gadbois, and A.C. Johnson (1986), "Polycyclic Aromatic Hydrocarbons in Gulf of Maine Sediments: Distributions and Mode of Transport," Marine Environ. Res. 18, in press.

I,W-M,C-4 — Larsen, P.F., D.F. Gadbois, and A.C. Johnson (1985), "Observations on the Distribution of PCBs in the Deepwater Sediments of the Gulf of Maine," Marine Pollution Bulletin, 16:439-442.

I,W-M,C-2 — Larsen, P.F., D.F. Gadbois, A.C. Johnson, and L.F. Doggett (1983), "Distribution of Polycyclic Aromatic Hydrocarbons in the Surficial Sediments of Casco Bay, Maine," Bull. Environ. Contam. Toxicol., 30:530-535.

I,W-M,C-4,P — Larsen, P.F., D.F. Gadbois, A.C. Johnson, and R.F. Maney (1984), "On the Appearance of PCBs in the Surficial Sediments of Casco Bay, Maine," Marine Pollution Bulletin, 15:452-453.

I,W-M,C-1,P — Larsen, P.F., V. Zdanowicz, A.C. Johnson, and L.F. Doggett (1983), "Trace Metals in New England Marine Sediments: Casco Bay, Maine, in Relation to Other Sites," Chemistry in Ecology, 1:191-200.

X,W-M,R,J,P — Lee, C.R., R.K. Peddicord, M.R. Palermo, and N.R. Francingues, Jr. (February 1985), "Decisionmaking Framework for Management of Dredged Material: Application to Commencement Bay, Washington," U.S. Army Engineer District, Seattle, WA, NTIS AD-A162731.

I,W-R/M,C-O,S,P — Lopez-Avila, V. and R.A. Hites (1980), "Organic Compounds in an Industrial Wastewater. Their Transport into Sediments," Environ. Sci. & Technol., 14:1382-1390.

IV,W-E,C-2,3,O,E,J	Lytle, T.F. and J.S. Lytle (July, 1985), "Pollutant Transport in Mississippi Sound," Mississippi-Alabama Sea Grant Consortium, MASGP-82-038. NTIS PB 86-123809.
IV,W-R/E,C-1,3,S,P	Lytle, T.F. and J.S. Lytle (1980), "Pollution Impact in Mississippi Coastal Waters," Mississippi-Alabama Sea Grant Consortium, MASGP-80-020. NTIS PB 82-153891.
IV,W-E,C-3,S,E,R,J,P	Lytle, J.S. and T.F. Lytle (June, 1983), "Potential Damage of Oil Wastes in Coastal Estuary Sediments," Mississippi-Alabama Sea Grant Consortium, MASGP-82-024. NTIS PB 83-22865-0.
E	Mac, M.J., C.C. Edsall, R.J. Hesselberg, and R.E. Sayers, Jr. (November, 1984), "Flow-Through Bioassay for Measuring Bioaccumulation of Toxic Substances from Sediment," Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL, EPA-905/3-84-007.
III,W-R,C-3,S	MacKenzie, M.J. and J.V. Hunter (1979), "Sources and Fates of Aromatic Compounds in Urban Stormwater Runoff," Environ. Sci. & Technol., 13:179-183.
II,W-R,C-4,R,P	Malcolm Pirnie, Inc. (January, 1978), "Feasibility Report: Dredging of PCB-Contaminated River Bed Materials Upper Hudson River, New York," New York State Department of Environmental Conservation, Albany, NY.
VII/VIII,W-R/L,C-1	Martin, D.B. and W.A. Hartman (1984), "Arsenic, Cadmium, Lead, Mercury, and Selenium in Sediments of Riverine and Pothole Wetlands of the North Central United States," J. Assoc. Off. Anal. Chem., 67:1141-1146.
VII/VIII,W-R/L,C-4,5,E	Martin, D.B. and W.A. Hartman (1985), "Organochlorine Pesticides and Polychlorinated Biphenyls in Sediment and Fish from Wetlands in the North Central United States," J. Assoc. Off. Anal. Chem., 68:712-717.
I,W-R,C-7,S,J	Matson, E.A., S.G. Hornor, and J.D. Buck (1978), "Pollution Indicators and Other Microorganisms in River Sediment," Water Poll. Control Fed. Journal, 50:13-19.
I,W-R,C-1,R,E,J,P	McGinn, J.M. (July, 1981), "A Sediment Control Plan for the Blackstone River," Massachusetts Department of Environmental Quality Engineering. NTIS PB 84-22963-2.
III,W-E,C-2,S,P	Merrill, E.G. and T.L. Wade (1985), "Carbonized Coal Products as a Source of Aromatic Hydrocarbons to Sediments from a Highly Industrialized Estuary," Environ. Sci. & Technol., 19:597-603.

I,W-R,C-1,2,0,S,R,E,P — Metcalf & Eddy, Inc., (September, 1985), "Draft Supplemental Environmental Impact Statement for the French River Cleanup Program in Massachusetts and Connecticut," U.S. Environmental Protection Agency, Region 1, Boston, MA.

II,W-E,C-1,S,P — Meyerson, A.L., G.W. Luther III, T Krajewski, and R.I. Hires (1981), "Heavy Metal Distribution in Newark Bay Sediments," Marine Pollution Bulletin, 12:244-250.

IV,W-L,C-1,0 — Miller, H.D. and J. Boyd (January, 1983), "Large-Scale Operations Management Test of Use of the White Amur for Control of Proglem Aquatic Plants; Report 4, Third Year Poststocking Results; Volume VI: The Water and Sediment Quality of Lake Conway, Florida," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Technical Report A-78-2. NTIS AD-A124443.

VIII,W-R/L,P — Montana Department of Health and Environmental Sciences (May, 1986), "Montana Water Quality 1986," Water Quality Bureau, Environmental Sciences Division, Department of Health and Environmental Sciences, Helena, MT.

III,W-E/M,C-4,P — Morgan, R.P. II and S.E. Sommer (1979), "Polychlorinated Biphenyls in Baltimore Harbor Sediments," Bull. Environm. Contam. Toxicol., 22:413-419.

W-R/L/M,C-2,4,5,E,J — Neff, J.M., D.J. Bean, B.W. Cornaby, R.M. Vaga, T.C. Gulbransen, and J.A. Scanlon (July, 1986), "Sediment Quality Criteria Methodology Validation: Calculation of Screening Level Concentrations from Field Data," U.S. Environmental Protection Agency, Criteria and Standards Division, Washington, D.C.

X,W-E,C-1,4,5,R,E,P — Nelson, P.O., C.K. Sollitt, K.J. Williamson, and D.R. Hancock (December, 1984), "Coos Bay Offshore Disposal Site Investigation," Interim Report Phase II, III, April, 1980 - June, 1981, Portland District Corps of Engineers, Portland, OR, Contract # DACW57-79-C0040.

I/II,W-M,R,J — New England Governors' Conference (September, 1982), "New England/New York Long Range Dredge Management Study: Final Report," prepared for the U.S. Water Resources Council.

I/II,W-M,J — New England River Basins Commission (August, 1980), "Interim Plan for the Disposal of Dredged Material from Long Island Sound."

I/II,W-M,C-1,4,5,E,J — New England River Basins Commission (September, 1981), "Dredging Management: Data and Analysis for the New England/Long Island Sound Region," Technical Assistance Report, Dredging Management Program, Long Range Dredging Study.

III,W-M,C-1 Nichols, M., R. Harris, G. Thompson, and B. Nelson (October, 1982), "Fate, Transport and Transformation of Toxic Substances: Significance of Suspended Sediment and Fluid Mud," U.S. EPA Chesapeake Bay Program, Annapolis, MD, EPA-600/3-82-089. NTIS PB 83-116426.

VI,W-L,C-4,5,S,E,P Niethammer, K.R., D.H. White, T.S. Baskett and M.W. Sayre (1984), "Presence and Biomagnification of Organochlorine Chemical Residues in Oxbow Lakes of Northeastern Louisiana," Arch. Environ. Contam. Toxicol., 13:63-74.

V,W-L,C-1,S,P Nriagu, J.O., A.L.W. Kemp, H.K.T. Wong, and N. Harper (1979), "Sedimentary Record of Heavy Metal Pollution in Lake Erie," Geochimica et Cosmochimica Acta, 43:247-258.

I,W-M,C-4,R,P NUS Corporation (July, 1984), "Feasibility Study of Remedial Action Alternatives: Acushnet River Estuary Above Coggeshall Street Bridge, New Bedford site, Bristol County, Massachusetts," EPA Work Assignment #28-1L43, Contract #68-01-6699 (Draft).

II,W-R, C-O,P NUS Corporation (1986), "Sampling Results for 2,3,7,8-Tetrachlorodibenzo-p-dioxin in the Passaic River in the Vicinity of 80 Lister Avenue, Newark, NJ, "EPA Contract #68-01-6699.

II,W-M,C-1,3,4,5,R,E,P O'Connor, J.M. and S.G. O'Connor (1980), "Evaluation of Capping Operations at the Experimental Mud Dump Site, New York Bight, 1980," U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MI, Contract DACW39-82-2544.

V,W-L,C-4,5,O,S,P Oliver, B.G. and R.A. Bourbonniere (1985), "Chlorinated Contaminants in Surficial Sediments of Lakes Huron, St. Clair, and Erie: Implications Regarding Sources Along the St. Clair and Detroit Rivers," J. Great Lakes Res., 11:366-372.

X,W-R/L,C-1,2,3,4,5,0,E Oregon Department of Environmental Quality (November, 1984), "Oregon Ambient Water Quality Toxics Data Summary -- 1979 to 1983" (Draft).

VI,W-L,C-1,2,S,E,P Overton, E.B, M.H. Schurtz, K.M. St. Pe and C. Byrne (1986), "Distribution of Trace Organics, Heavy Metals, and Conventional Pollutants in Lake Pontchartrain Louisiana," Organic Marine Geochemistry, 247-270.

X,W-M,C-1,2,4,5,0,J Pavlou, S.P. and D.P. Weston October, 1983), "Initial Evaluation of Alternatives for Development of Sediment Related Criteria for Toxic Contaminants in Marine Waters (Puget Sound). Phase I: Development of Conceptual Frame-Framework," U.S. EPA Region X, Seattle, WA.

I,W-M,C-1,2,3,S,E — Payne, J.R., J.L. Lambach, R.E. Jordan, C.R. Phillips, G.D. McNabb, Jr., M.K. Beckel, G.H. Farmer, R.R. Sims, Jr., J.G. Sutton, and A. Abasumara (November, 1983), "Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna During the Second Year of Monitoring," U.S. Department of Interior, Minerals Management Service, Reston, VA, MMS/AT/ES-83/08. NTIS PB 84-141449.

I/II/III,W-M,C-1,2,4,7,0,E — Pearce, J.B., C.R. Berman, Jr., and M.R. Rosen (eds.) (January, 1985), "Annual NEMP Report on the Health of the Northeast Coastal Waters, 1982," NOAA Technical Memorandum NMFS-F/NEC-35. NTIS PB 85-219129.

V,W-R,C-1,4,E — Peddicord, R., H. Tatem, A. Gibson, and S. Pedron (December, 1980), "Biological Assessment of Upper Mississippi River Sediments," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper EL-80-5. NTIS AD-A094248

III,W-R/M,C-0,S — Pellenbarg, R. (1979), "Environmental Poly(Organosiloxanes) (Silicones)," Environ. Sci. & Technol., 13:565-569.

R — Peterson, S.A. (1982), "Lake Restoration by Sediment Removal," Water Resources Bulletin, 3:423-435.

R — Peterson, S.A. (August, 1984), "Sediment Removal," U.S.EPA Environmental Research Laboratory, Corvallis, Oregon EPA-600/D-84-207. NTIS PB 84-236397.

IV,W-E,C-1,P — Pilotte, J.O., J.W. Winchester, and R.C. Glassen (1978), "Detection of Heavy Metal Pollution in Estuarine Sediments," in: Water, Air & Soil Pollution (1978), 363-368.

X,W-M,R,P — Phillips, K.E., J.F. Malek, and W.B. Hamner (June, 1985), "Commencement Bay Nearshore Tideflats Superfund site, Tacoma, Washington; Remedial Investigations. Evaluation of Alternative Dredging Methods and Equipment, Disposal Methods and Sites, and Site Control and Treatment Practices for Contaminated Sediments," U.S. Army Corps of Engineers, Seattle District. NTIS AD-A162 732.

VI,W-L,C-1,5,E,P — Popp, C.J., D.K. Brandvold, T.R. Lynch, and L.A. Brandvold (March, 1983), "Evaluation of Sediments in the Middle Rio Grande, Elephant Butte Reservoir, and Caballo Reservoir as Potential Sources for Toxic Materials," New Mexico Water Resources Research Inst. Las Cruces, NM, Report No. 161. NTIS PB 83-221754.

IV,W-L,C-1,E — Price, R.E. and L.A. Knight, Jr. (1978), "Mercury, Cadmium, Lead, and Arsenic in Sediments, Plankton, and Clams from Lake Washington and Sardis Reservoir, Mississippi, October 1975 - May, 1976," Pesticides Monitoring Journal, 11:182-189.

X,W-M,C-1,2,4, O,S,E,J,P	Puget Sound Water Quality Authority (May,1986), "Issue Paper Paper: Contaminated Sediments and Dredging."
V,W-R/L,C-4,O,E,	Pugsley, C.W., P.D.N. Hebert, G.W. Wood, G. Brotea, and T.W. Obal (1985), "Distribution of Contaminants in Clams and Sediments from the Huron-Erie Corridor. I - PCBs and Octachlorostyrene," J. Great Lakes Res., 11:275-289.
VI,W-R,C-1,4,5,S,E,P	Qasim, S.R., A.T. Armstrong, J. Corn, and B.L. Jordan (1980), "Quality of Water and Bottom Sediments in the Trinity River," Water Resources Bulletin, 16:522-531.
II,W-M,C-1,S,E,P	Ramondetta, P.J. and W.H. Harris (1978), "Heavy Metals Distribution in Jamaica Bay Sediments," Environ. Geology, 2:145-149.
X,W-E,C-3,S	Rapp, J.B., K.A. Kvenvolden, and H.E. Clifton "Aliphatic Hydrocarbons in Surface Sediments of Willapa Bay and Grays Harbor, Washington," U.S. Geological Survey Open File Report 82-609.
II,W-M,C-1,2,4,7,O,E,P	Reid, R.N., J.E. O'Reilly, and V.S. Zdanowicz, eds. (September, 1982), "Contaminants in New York Bight and Long Island Sound: Sediments and Demersal Species, and Contaminant Effects on Benthos, Summer, 1980," Northeast Monitoring Program, NOAA Technical Memorandum NMFS-F/NEC-16, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, MA.
V,W-L,C-4,P	Richardson, W.L., R. Wethington, and V.E. Smith (August, 1983), "Dynamic Mass Balance of PCB and Suspended Solids in Saginaw Bay -- A Case Study," U.S. EPA Environmental Research Lab., Duluth, MN, EPA-600/D-83-092. NTIS PB 83-250308.
X,W-R,C-1,S	Rickert, D.A., V.C. Kennedy, S.W. McKenzie, and W.G. Hines (1977) "A Synoptic Survey of Trace Metals in Bottom Sediments of the Willamette River, Oregon," U.S. Geological Survey Circular 715-F.
X,W-M,C-1,2,4,O,E,P	Riley, R.G., E.A. Crecelius, R.E. Fitzner, B.L. Thomas, J.M. Gurtisen, and N.S. Bloom (June, 1983), "Organic and Inorganic Toxicants in Sediment and Marine Birds From Puget Sound," Pacific Northwest Laboratories, Richland, Washington, NOAA Technical Memorandum NOS OMS 1. NTIS PB 84-16023-3.
X,W-M,C-2,4,O,S,P	Riley, R.G., E.A. Crecelius, M.L. O'Malley, K.H. Abel, and D.C. Mann (November, 1981), "Organic Pollutants in Waterways Adjacent to Commencement Bay (Puget Sound)," National Oceanic and Atmospheric Administration, Boulder, CO, NOAA Technical Memorandum OMPA-12. NTIS PB 82-174947.

II,W-R/L,C-1,2,4,5,O,J,P Rockwell, D.C., R.E. Claff, and D.W. Kuehl (April, 1984), "1981 Buffalo, New York, Area Sediment Survey (BASS)," U.S. EPA Great Lakes National Program Office, EPA 905/3-84-001. NTIS PB 84-19967-8.

II,W-R,C-1,P Rogers, R.J. (1983), "Heavy Metals in Bottom Sediments from the Saw Mill River, Westchester County, New York, 1981," Northeastern Environmental Science, 2:188-197.

IV,W-R/E,C-1,2,4,5,J,P Ryan, J.D., F.D. Calder, L.C. Burney, and H.L. Windom (1985), "The Environmental Chemistry of Florida Estuaries: Deepwater Ports Maintenance Dredging Study," Technical Report: Port of Miami and the Miami River, Florida Dept. of Environmental Regulation.

I,W-M,C-1,3,S,P Santschi, P.H., S. Nixon, M. Pilson, and C. Hunt (1984), "Accumulation of Sediments, Trace Metals (Pb,Cu) and Total Hydrocarbons in Narragansett Bay, Rhode Island," Estuarine, Coastal and Shelf Science, 19:427-449.

IV,W-M,C-7,S Schaiberger, G.E., T.D. Edmond, and C.P. Gerba (1982), "Distribution of Enteroviruses in Sediments Contiguous with a Deep Marine Sewage Outfall," Water Res., 16:1425-1428.

V/VII,W-R,C-1,4,R,J Schnoor, J.L., A.R. Giaquinta, C. Sato, C.P. Robison and D.B. McDonald (July, 1982), "Refinement and Verification of Predictive Models of Suspended Sediment Dispersion and Desorption of Toxics from Dredged Sediments," U.S. Army Corps of Engineers, St. Louis District, Iowa Institute of Hydraulic Research Report No. 249, DTIC AD A120725.

VI,W-L,C-4,S,E,P Schurtz, M.H. and R. Albritton (March, 1986), "An Evaluation of Polychlorinated Biphenyls in Capitol Lake, Baton Rouge, Louisiana," Louisiana Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division.

VI,W-L,C-1,2,4,5,O,E,P Schurtz, M. and K.M. St. Pe (April, 1984), "Report on Interim Findings: Water Quality Investigation of Environmental Conditions in Lake Pontchartrain," Louisiana Department of Environmental Quality Water, Pollution Control Division.

R Science Applications International Corp. (September, 1985), "Removal and Mitigation of Contaminated Sediments," Draft report, U.S. Environmental Protection Agency, Cincinnati, Ohio.

V,W-R/L,C-2,S,J Science Applications International Corporation (May, 1986), "Sediment PAH Concentrations and Associated Sampling Site Rankings in the Great Lakes Region," U.S. Environmental Protection Agency, Chicago, IL, Draft Report, EPA contract No. 68-04-5035,D.O. 012.

II,W-L,C-5,S,P	Scrudato, R.J. and A. DelPrete (1982), "Lake Ontario Sediment - Mirex Relationships," J. Great Lakes Res., 8:695-699
X,W-M,C-2,3,S	Shaw, D.G., D.J. McIntosh, and E.R. Smith (1979), "Arene and Alkane Hydrocarbons in Nearshore Beaufort Sea Sediments," Estuarine and Coastal Marine Science, 9:435-449.
V,W-L,C-4	Simmons, M.S., D.I. Bialosky, and R.Rossmann (1980), "Polychlorinated Biphenyl Contamination in Surficial Sediments of Northeastern Lake Michigan," J. Great Lakes Res., 6:167-171.
II,W-E,C-6,S	Simpson, H.J. and R.M. Trier, "Plutonium and Cesium Radionuclides in the Hudson River Estuary and Other Environments," Annual Technical Progress Report, December 1, 1978 - November 30, 1979, Prepared for the U.S. Department of Energy Under Contract EY-76-S-02-2529. NTIS COO 2529-12.
V,W-R,C-4,5,E,P	Smith, V.E., J.M. Spurr, J.C. Filkins, and J.J. Jones (1985), "Organochlorine Contaminants of Wintering Ducks Foraging on Detroit River Sediments," J. Great Lakes Res., 11:231-246.
X,W-E,C-1,4,5,R,E,P	Sollitt, C.K., D.R. Hancock, and P.O. Nelson (December, 1984), "Coos Bay Offshore Disposal Site Investigation," Final Report Phase IV, V, July 1981 - September, 1983, Portland District, Corps of Engineers, Portland, Oregon, Contract #DACW57-79-C-0040.
III,W-R,C-1,4,5,P	Stamer, J.K., T.H. Yorke, and G.L. Pederson (1985), "Distribution and Transport of Trace Substances in the Schuylkill River Basin from Berne to Philadelphia, Pennsylvania," United States Geological Survey Water-Supply Paper 2256-A.
IV,W-R,C-1,4,5,O,S,R,E,P	Sullivan, J. and W. Thiess (March 1983), "Redstone Arsenal (RSA) Installation Restoration Summary -- Volumes 1-3," U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland, Report DRXTH-AS-CR-83198. DTIC AD-B072965.
V,W-R/L,C-1,4,5,O,J	Sullivan, J., J. Ball, E. Brick. S. Hausmann, G. Pilarski and D. Sopcich (November, 1985), "Report of the Technical Subcommittee on Determination of Dredge Material Suitability for In-Water Disposal," Wisconsin Department of Natural Resources, Madison, WI.
IX,W-M/E,C-1,R,E,P	Sustar, J. and T. Wakeman (February, 1977), "Dredge Disposal Study, San Francisco Bay and Estuary, Main Report," U.S. Army Engineer District San Francisco, San Francisco, CA, NTIS #AD A037727.

IX,W-M,C-1,2,3,5,O,S,E — Swartz, R.C., D.W. Schults, G.R. Ditsworth, W.A. DeBen, and F.A. Cole (September, 1985), "Sediment Toxicity, Contamination, and Macrobenthic Communities Near a Large Sewage Outfall," U.S. EPA Corvallis Environmental Research Laboratory, Newport, OR, EPA/600/D-85/202. NTIS PB 86-102142.

V/X,W-L/M,C-1,4,R — Tatem, H.E. (November, 1984), "Long-Term Impact of Dredged Material at Two Open-Water Sites: Lake Erie and Elliott Bay; Evaluative Summary," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS Technical Report D-84-5. NTIS AD-A152029.

IV,W-R,C-1,2,4,6,O — Tennessee Valley Authority (April, 1985), "Sediment Characterization: Task 2, Instream Contaminant Study," U.S. Department of Energy, Oak Ridge, Tennessee, DOE/OR/21444--T2-Vol. 1. NTIS DE85 013502.

X,W-M,C-1,2,4,5 O,S,R,P — Tetra-Tech, Inc.(August, 1985), "Commencement Bay Nearshore/ Tideflats Remedial Investigation," Vols. 1 & 2, Washington State Department of Ecology and U.S. Environmental Protection Agency Region 10, EPA-910/9-85-134b. NTIS PB 86-104569 & PB 86-104577.

IX,W-M,P — Tetra-Tech, Inc. (November, 1986), "Compilation of Historical Data on Selected Pollutants in the Southern California Bight," Report to U.S. EPA Office of Marine and Estuarine Protection.

II,W-R,C-4,S,P — Turk, J.T. (1980), "Applications of Hudson River Basin PCB - Transport Studies," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor, Michigan.

R — U.S. Army Corps of Engineers, New York, and U.S. EPA Region II (December, 1984), "Guidance for Performing Tests on Dredged Material to be Disposed of in Ocean Waters."

VI/VIII/IX,W-R/L, C-O,E,P — U.S. Department of Interior Task Group on Irrigation Drainage (December, 1985), "Preliminary Evaluation of Selenium Selenium Concentrations in Ground and Surface Water, Soils, Sediment, and Biota from Selected Areas in the Western United States," Draft report.

VIII,W-R,C-1,S,E,P — U.S. Environmental Protection Agency Office of Enforcement (September, 1971), "Pollution Affecting Water Quality of the Cheyenne River System Western South Dakota," Division of Field Investigations -- Denver Center, Denver, CO, NTIS PB 216 948.

VIII,W-R,C-1,P — U.S. Environmental Protection Agency, Region VIII, Denver CO (April, 1973), "Mercury, Zinc, Copper, Arsenic, Selenium, and Cyanide Content of Selected Waters and Sediment Collected Along Whitewood Creek, the Belle Fourche River, and the Cheyenne River in Western South Dakota. December 1971 October, 1972." NTIS PB-244 950.

V,W-R/L,C-1,S,R,E,J,P — U.S. Environmental Protection Agency (February, 1978), "In-Place Pollutants in Trail Creek and Michigan City Harbor, Indiana," Office of Water Planning and Standards, Washington, DC, EPA-440/5-78-012.

III,W-M/E,C-1,2,5,S,E,P — U.S. Environmental Protection Agency (September, 1982), "Chesapeake Bay Program Technical Studies: A Synthesis," Chesapeake Bay Program, Annapolis, MD. NTIS PB-84-111202.

V,W-R/L,C-1,2,4,O, S,R,E,J — U.S. Environmental Protection Agency, Region V (April, 1984), "Preliminary Report on In-Place Pollutants in Region V," U.S. EPA Region V In-Place Pollutant Task Force, Chicago, IL.

VIII,W-L,C-1,S,R,P — U.S. Environmental Protection Agency, (April, 1984), "Superfund Record of Decision: Milltown Site, MT" EPA/ROD/R08-84/001. NTIS PB 85-214070.

VI,W-E,C-1,2,O,E — Voyksner, R.D. (March, 1985), "Final Report: Analysis of Metals and Organics in Sediment and Biota. Period Covered: March, 1984 to February, 1985," Department of Environmental Quality, Baton Rouge, LA, Report #RTI/2830/00-01Q.

I/X,W-M/L,C-3,S — Wakeham, S.G. and J.W. Farrington (1980), "Hydrocarbons in Contemporary Aquatic Sediments," in Contaminants and Sediments, Vol. 1, R.A. Baker (ed.), Ann Arbor Science Publishers, Ann Arbor Michigan.

VIII,W-L,C-1,E,P — Walter, C.M., F.C. June and H.G. Brown (1973), "Mercury in Fish, Sediments, and Water in Lake Oahe, South Dakota," J. Water Poll. Cont. Fed., 45:2203-2210.

II,W-R,C-6,S — Walters, W.H., R.M. Ecker, and Y. Onishi (November, 1982), "Sediment and Radionuclide Transport in Rivers: Summary Report: Field Sampling Program for Cattaraugus and Buttermilk Creeks, New York," Battelle Pacific Northwest Laboratories, Richland, WA, PNL-3117, U.S. Nuclear Regulatory Commission, Washington, DC, NUREG/CR-1020-Vol. 4.

IV,W-E,C-4,5 — Wang, T.C., J.P. Krivan, Jr. and R.S. Johnson (1979), "Residues of Polychlorinated Biphenyls and DDT in Water and Sediment of the St. Lucie Estuary, Florida, 1977," Pesticides Monitoring Journal, 13:69-71.

VI,W-R/L/E/M,C-1,J — Warshaw, S. (May, 1976), "Metals Concentrations in Water and Sediment of Texas," Texas Department of Water Resources, Special Report No. SR-4.

I,W-M/E,C-4,S,E,P — Weaver, G. (June, 1982), "PCB Pollution in the New Bedford, Massachusetts Area: A Status Report," Massachusetts Office of Coastal Zone Management. [Note: Also contains other PCB case studies.]

II,W-M,C-4,S,P — West, R.H. and P.G. Hatcher (1980), "Polychlorinated Biphenyls in Sewage Sludge and Sediments of the New York Bight," Marine Pollution Bulletin, 11:126-129.

V/VII,W-R,C-1,E — Wiener, J.G., G.A. Jackson, T.W. May, and B.P. Cole (1984), "Longitudinal Distribution of Trace Elements (As, Cd, Cr, Hg, Pb, and Se) in Fishes and Sediments in the Upper Mississippi River," Chapter 7, pp. 139-169, in J. G. Wiener, R.V. Anderson, and D.R. McConville, eds. Contaminants in the Upper Mississippi River, Butterworth Pub., Stoneham, MA.

II,W-R,C-1,P — Wilber, W.G. and J.V. Hunter (1979), "The Impact of Urbanization on the Distribution of Heavy Metals in Bottom Sediments of the Saddle River," Water Resources Bulletin, 15:790-800.

I,W-M,C-2 — Windsor, J.G. Jr. and R.A. Hites (1979), "Polycyclic Aromatic Hydrocarbons in Gulf of Maine Sediments and Nova Scotia Soils," Geochimica et Cosmochimica Acta, 43:27-33.

VI,W-L,C-1,4,5,E — Winger, P.V. and J.K. Andreasen (1985), "Contaminant Residues in Fish and Sediments from Lakes in the Atchafalaya River Basin (Louisiana)," Arch. Environ. Contam. Toxicol., 14:579-586.

VIII,W-R,C-1,3,S,E,P — Woodward, D.F. and R.G. Riley (1983), "Petroleum Hydrocarbon Concentrations in a Salmonid Stream Contaminated by Oil Field Discharge Water and Effects on Macrobenthos," Arch. Environ. Contam. Toxicol., 12:327-334.

VIII,W-R/L,P — Wyoming Department of Environmentl Quality (1986), "Wyoming 1986 305(b) Summary Report" and "Wyoming 1986 Water Quality Assessment," Water Quality Division, Department of Environmental Quality, Cheyenne, WY.

III,W-R,C-1,4,5,P — Yorke, T.H., J.K. Stamer, and G.L. Pederson (1985), "Effects of Low-Level Dams on the Distribution of Sediment, Trace Metals, and Organic Substances in the Lower Schuylkill River Basin, Pennsylvania," United States Geological Survey Water Supply Paper 2256-B.

IV. INDEX TO REPORTS AND ARTICLES BY LOCATION

Location	References
Region I	
Northeast Coast	Boehm, 1983 Pearce et al., 1985 New England River Basins Commission, 1981
Western North Atlantic	Wakeham & Farrington, 1980 Farrington & Tripp, 1977
Georges Bank	Bothner et al., 1985 Payne et al., 1983
Penobscot Bay, ME	Johnson et al., 1985
Casco Bay, ME	Larsen et al., 1983 a & b Larsen et al., 1984
Gulf of Maine	Larsen et al., 1986 Larsen et al., 1985 Windsor & Hites, 1979
West Falmouth, MA	Burns & Teal, 1979
Buzzards Bay, MA	Wakeham & Farrington, 1980
Nantucket Shoals, MA	Hoffman & Quinn, 1979 Hoffman & Quinn, 1980
New Bedford Harbor, MA	NUS Corp., 1984 Weaver, 1982
Narragansett Bay, RI	Bender, 1981 Lake et al., 1979 Jungclaus et al., 1978 Lopez-Avila & Hites, 1980 Hurtt & Quinn, 1979 Wakeham & Farrington, 1980 Santschi et al., 1984
Rhode Island Sound, MA/RI	Boehm & Quinn, 1978
Sebasticook R., ME	Duval et al., 1980
Blackstone R., MA	McGinn, 1981

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French R., MA	Metcalf & Eddy, Inc., 1985 Connecticut DEP (Misc. file) U.S. EPA Region I (Misc. file)
Ten Mile R., MA/RI	Atkinson et al., 1985
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Newark Bay, NJ	Meyerson et al., 1981
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Delaware R. estuary & tributaries, NJ	Hochreiter, 1982
Hudson R. estuary	Bender, 1981 Bopp et al., 1981 Simpson & Trier, 1979
Upper Hudson R. Basin, NY	Brown et al. 1985 Turk, 1980 Hetling et al., 1978 Malcolm Pirnie, Inc., 1978 U.S. EPA Region VI (Misc.File)

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Lake Ontario	Scrudato & Del Prete, 1982 Frank et al., 1979 Great Lakes Water Quality Board, 1982 Great Lakes Water Quality Board, 1985 Holdrinet et al., 1978 Kizlauskas et al., 1984a
Oswego R. & Harbor	Scrudato & Del Prete, 1982
Buffalo R., NY	Kuehl et al., 1984
Buffalo, NY area	Rockwell et al., 1984
Cattaraugus & Buttermilk Creeks, NY	Walters et al., 1982
Lake George, NY	Heit et al., 1980
Adirondack Lakes, NY	Galloway & Likens, 1979
Marsh near Cold Spring, NY	Kneip & Hazen, 1979
Sawmill R., NY	Rogers, 1983
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Chesapeake Bay	Bieri et al., 1983 Nichols et al., 1982 U.S. EPA, 1982
Baltimore Harbor	Morgan & Sommer, 1979
Lynnhaven Estuary, VA	Erkenbrecher, 1980
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Elizabeth R. Estuary, VA	Merrill & Wade, 1985
St. Jones R. & Murderkill R., DE	Hoffman & Biggs, 1983
Potomac R., Washington, DC	Pellenbarg, 1979 Harrison, 1984
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St. Lucie Estuary, FL	Wang et al., 1979
Mississippi coastal waters	Lytle & Lytle 1980, 1983 & 1985
Streams near Oak Ridge, TN	Tennessee Valley Authority
L. Washington & Sardis Res., MS	Price & Knight, 1979
Lake Conway, FL	Miller & Boyd, 1983
Florida estuaries	Fla. Dept. of Environ. Regulation 1986 a & b Ryan et al., 1985 Pilotte et al., 1978
Savannah R., Estuary	Goldberg et al., 1979
West Point Lake, GA/AL	Gunkel et al., 1984
Redstone Arsenal, Huntsville, AL	Sullivan & Thiess, 1983

Location	References
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Region V (general)	U.S. EPA Region V, 1984 Great Lakes Water Quality Board, 1982 Great Lakes WaterQuality Board, 1985 Kizlauskas & Homer, 1984 Science Applications Int'l. Corp., 1986 Sullivan et al., 1985
Lake Superior	Eisenreich et al., 1979 Eisenreich et al., 1980 Frank et al., 1980 Kemp et al., 1978 Kizlauskas et al., 1984b Kraft, 1979
Lake Michigan	Christensen & Chien, 1979 Frank et al., 1981 Simmons et al., 1980 Blasland & Bouck Eng., 1985 CH2M Hill, 1983 Kizlauskas, 1982 U.S. EPA, 1978
Lake Huron	Kemp et al., 1978 Oliver & Bourbonniere, 1985 Richardson et al., 1983
Lake St. Clair	Oliver & Bourbonniere, 1985 Pugsley et al., 1985
Detroit River	Pugsley et al., 1985 Smith et al., 1985
Lake Erie	Eadie et al., 1982 Nriagu et al., 1979 Oliver & Bourbonniere, 1985 Tatem, 1984
Fields Brook, Ohio (trib to L.Erie)	CH2M Hill, 1986
Mississippi R. (upper)	Grimes, 1980 Peddicord et al., 1980 Schnoor et al., 1982 Wiener et al., 1984
Highland Silver Lake watershed, IL	Davenport & Kelly, 1984
Illinois Lakes	Kelly & Hite, 1981
Illinois Streams	Kelly & Hite, 1984

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Wisconsin Lakes	Kobayashi & Lee, 1978
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Coastal canals, TX	Goyal et al, 1977
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Elephant Butte Reservoir, NM	Garcia & Kidd, 1979 Popp et al., 1983
Middle Rio Grande R. & Caballo Res., NM	Popp et al., 1983
DeGray Lake, AR	Gunkel et al., 1984
Lakes in Atchafalaya R. Basin, LA	Winger & Andreason, 1985
Oxbow Lakes, LA	Niethammer et al., 1984
Capitol Lake, LA	Schurtz & Albritton, 1986
Lake Pontchartrain, LA	Schurtz & St. Pe, 1984 Overton et al., 1986

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Montana (geneal)	Montana Dept. of Health & Environmental Sciences, 1986
Wyoming (general)	Wyoming Dept. of Environmental Quality, 1986
Milltown Superfund Site, MT	U.S. EPA, 1984
Standley Lake, CO	Heit et al., 1980 Heit, 1979
Cheyenne River Basin, SD	U.S. EPA, 1971 & 1973
Lake Oahe, SD	Walter et al., 1973
Great Salt Lake, UT	Heit, 1979
Lake Mead, NV	Heit, 1979
Navajo Reservoir, CO	Heit, 1979
Utah Lake, UT	Heit, 1979
Little Popo Agie R., WY	Heitkamp & Johnson, 1984 Woodward & Riley, 1983
Wetlands in MT, ND & SD	Martin & Hartman, 1984 Martin & Hartman, 1985
Several sites in MT, SD & UT	U.S. Dept. of Interior, 1985
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California (general)	California State Water Resources Control Board, 1984
Near Bikini Atoll	Hisamatsu & Sakanoue, 1978
San Francisco Bay, CA	Bradford & Luoma, 1980 Sustar & Wakeman, 1977

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Southern California coast/ Palos Verdes Shelf	Eganhouse et al., 1978 Eganhouse et al., 1980 Galloway, 1979 Hershelman et al., 1981 Swartz et al., 1985 Tetra-Tech, 1986
Hansen Lake, Los Angeles, CA	Heit, 1979
Several sites in AZ, CA & NV	U.S. Dept. of Interior, 1985
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Commencement Bay, WA	Phillips et al., 1985 Riley et al., 1981 Tetra-Tech, 1985 Gahler et al., 1982 Lee et al., 1985
Duwamish Waterway, WA	Blazevich et al., 1977
Everett Harbor, WA	Anderson & Crecelius, 1985
Willapa Bay & Grays Harbor, WA	Rapp et al.
Elliott Bay, WA	Dexter et al., 1984 Tatem, 1984
Puget Sound, WA	JRB Associates, 1984 Pavlou & Weston, 1983 Puget Sound Water Quality Authority, 1986 Riley et al., 1983
Coos Bay, OR	Hancock et al., 1984 Nelson et al., 1984 Sollitt et al., 1984
Winchester Bay, OR	Ecological Analysts, 1981
Beaufort Sea, AK	Shaw et al., 1979
Columbia R., WA/OR	Haushild, 1980
Lake Washington, WA	Wakeham & Farrington, 1980
Chetco, Rogue, & Columbia R., OR	Fuhrer, 1984
Western OR & WA rivers & estuaries	Fuhrer & Rinella, 1983

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Washington rivers	Hopkins et al., 1985
Willamette R., OR	Rickert et al., 1977
Portland Area, OR	Oregon Department of Environmental Qual., 1984

APPENDIX C

LIST OF AGENCIES AND INDIVIDUALS CONTACTED

This appendix identifies the specific individuals contacted for information during the course of this project. It should be noted that the list is certainly not exhaustive (there was no attempt to contact all knowledgable individuals), and that the individuals that are listed may not be (today or in the future) the best individuals to contact in any future study. However, it is hoped that the listing will help some future efforts by identifying at least a fraction of the individuals in State and Federal agencies who have information or expertise related to chemical contamination of sediments.

LIST OF AGENCIES AND INDIVIDUALS CONTACTED

Agency/Office	Name	Telephone No.
National Oceanographic and Atmospheric Administration (NOAA)		
Ocean Assessment Division, National Ocean Service (Rockville, MD)	Dr. John Calder	(301) 443-8655
National Marine Fisheries Service (Sandy Hook, NJ)	Mr. Robert Reid Mr. Vincent Zdanowicz	(201) 872-0200 (201) 282-0200
U.S. Army Corps of Engineers		
Headquarters Library	Ms. Jackie Patterson (Librarian)	(202) 272-0455
Waterways Experiment Station	Ms. Jimmie Perry (Librarian)	(601) 634-2543
New England Division (Waltham, MA)	Mr. James Bajek	(617) 647-8307
Jacksonville, FL District	Ms. Nancy Schwall	
Galveston, TX District	Mr. Rick Medina	(409) 766-3962
Portland, OR District	Mr. Jim Reese	(503) 221-6021
New York District	Mr. Mario Paula	
Norfolk, VA District	Mr. Eugene Whitehurst Mr. Terry Getchell	(804) 441-3243 (804) 441-3617
North Central Division (Chicago, IL)	Mr. Dale Raven	(312) 353-7762
Omaha, NE District	Dr. John Anderson	(402) 221-4620
Memphis, TN District	Mr. Dick Mochow	(901) 521-3618
U.S. Army Toxic and Hazardous Materials Agency (USATHAMA)		
USATHAMA, U.S. Army IRP Division	Mr. Andy Anderson	(301) 671-3618

Agency/Office	Name	Telephone No.
U.S. Fish and Wildlife Service		
Resource Contaminant Assessment	Ms. Lynn Lewis	(202) 343-4767
Biological Services Division	Dr. Edward LaRoe	(202) 653-8723
Western Energy & Land Use Division	Mr. Lee Ischinger	(303) 226-9390
National Fisheries Research Lab (Columbia, MO)	Ms. Ell-Piret Multer (Information Specialist)	(314) 875-5399
Great Lakes Fishery Lab (Ann Arbor, MI)	Dr. Wayne Willford	(313) 994-3331
U.S. Geological Survey		
Northeast Region	Mr. Waite Osterkamp	(703) 860-6083
Central Region (Denver, CO)	Mr. Ned Andrews	(303) 236-5004
Oregon District	Mr. Stuart McKenzie	(503) 231-2016
Rapid City, SD District	Mr. Kim Goddard	(605) 342-6812
Baton Rouge, LA District	Mr. Charlie Demas	(504) 389-0391
Lakewood, CO District	Mr. Briant Kimball	(303) 236-4886
Office of Surface Water (USGS Headquarters, VA)	Mr. Douglas Glysson	(703) 648-5317
Harrisburg, PA District	Mr. Bob Helm	(717) 782-4514
Salt Lake City, UT District	Mr. Doyle Stephens	(801) 524-4249
EPA Environmental Research Labs		
Narragansett, RI	Mr. Richard Lattimer Mr. David Hanson	(401) 789-1071

Agency/Office	Name	Telephone No.
EPA Region I		
Water Quality Branch, Planning & Standards Section	Ms. Corrine Paul	(617) 223-0893
Water Quality Branch, Environmental Evaluation Section	Ms. Dorothy Allen	(617) 223-0838
Massachusetts Department of Environmental Quality Engineering	Mr. Paul Hogan	(617) 366-9181
Connecticut Department of Environmental Protection	Mr. Art Mauger Mr. Charlie Fredette	(203) 566-2588
EPA Region II		
Water Management Division	Ms. Rosella O'Connor	(212) 264-8479
EPA Region III		
Water Quality Control Division	Ms. Susan Insetta	(215) 597-3927
Environmental Services Division	Mr. John Ruggero	(215) 597-1196
EPA Region IV		
Environmental Services Division (Athens, GA)	Mr. Doug Lair Mr. Mike Carter Mr. Dave Hill Mr. Del Hicks	(404) 546-3351 (404) 546-3117 (404) 546-2207 (404) 546-2294
Ocean Disposal Division (Atlanta, GA)	Mr. Reginald Rogers	(404) 347-2156
Waste Management Division (Atlanta, GA)	Mr. Russ Wright	(404) 347-2643
Florida Department of Environmental Regulation	Mr. Mark Latch Mr. Joseph Ryan	(904) 488-8614
Metro-Dade County, FL Planning Department	Ms. Ricky Schechtman	(305) 375-2835
Miami River Coordinating Committee	Ms. Sandra Howard	(305) 358-2800

Agency/Office	Name	Telephone No.
EPA Region V		
Great Lakes National Program Office	Mr. Anthony Kizlauskas	(312) 353-3576
Water Division	Mr. Howard Zar Mr. Marc Tuchman	(302) 886-1491 (312) 886-1505
Environmental Review Branch	Ms. Kay Brennan	(312) 886-6873
Dredge & Fill Section	Mr. Elmer Shannon	(312) 353-2307
Waste Management Division	Mr. Tony Rutter Mr. Greg Kulma Mr. Dan Caplice	(312) 886-3009
Michigan Department of Natural Resources	Dr. Elwin Evans	(517) 373-2867
Wisconsin Department of Natural Resources	Dr. John Sullivan Mr. Joe Ball Mr. Scott Hausmann	(608) 267-9753
EPA Region VI		
Water Quality Division	Mr. Philip Crocker	(214) 767-8987
Waste Management Division	Mr. Barry Nash	(214) 767-5233
Texas Water Commission	Mr. Dave Buzan	(512) 463-7919
Louisiana Department of Environmental Quality	Mr. Mike Schurtz	(504) 342-8930
EPA Region VII		
Water Management Division	Mr. John Houlihan	(913) 236-2817
Waste Management Division	Ms. Kerry Herndon (section chief) Ms. Kathy Barrett	(913)236-2856
Iowa Department of Water, Air & Waste Management	Mr. Ralph Turkle	(515) 281-8779
Kansas Department of Health & Environment	Mr. Mike Butler Mr. Jerry Stoltenberg	(913) 862-9360, X258 (913) 862-9360, X236
Missouri Department of Natural Resources	Mr. John Ford	(314) 751-1300
Nebraska Department of Environmental Control	Mr. John Bender	(402) 471-4201

Agency/Office	Name	Telephone No.
EPA Region VIII		
Water Division	Mr. Jim Lazorchak	(303) 293-1581
Colorado Department of Health	Mr. John Scherschligt	(303) 331-4757
Montana Department of Health & Environmental Sciences	Mr. Loren Bahls	(406) 444-2406
North Dakota Department of Health	Mr. Francis Schwindt	(701) 224-2354
South Dakota Department of Water & Natural Resources	Mr. Rich Hanson	(605) 773-3351
Utah Department of Water Pollution Control	Mr. Mike Reichert	(801) 538-6146
Wyoming Department of Environmental Quality	Mr. Dave Hogan	(307) 777-7098
EPA Region IX		
Water Management Division	Mr. Phil Woods	(415) 974-8505
Policy Division, Environmental Services Branch	Mr. Milton Tunzi	(415) 974-8594
California Water Resources Control Board	Mr. John Youngerman	(916) 322-0214
EPA Region X		
Environmental Services Division	Mr. Evan Horning	(206) 442-1685
Puget Sound Office	Mr. John Armstrong	(206) 442-1368
Water Resources Assessment Section	Mr. Carl Kassebaum	(206) 442-1286
Office of Water Planning	Mr. Tom Wilson Ms. Sally Marquis	(206) 442-1354 (206) 442-8293
Alaska Department of Environmental Conservation	Mr. Jeffrey Hock Mr. Randy Bayliss	(907) 465-2681 (907) 465-2640
Oregon Department of Environmental Quality	Mr. Larry Patterson Mr. Andy Schaedel	(503) 229-5374 (503) 229-5983
Washington Department of Ecology	Mr. Dale Norton Mr. Dave Bradley	(206) 753-2812 (206) 459-6355

*U.S. GOVERNMENT PRINTING OFFICE:1988-516-202:80184