NEWARK BAY STUDY AREA
REMEDIAL INVESTIGATION WORK PLAN

SEDIMENT SAMPLING
AND SOURCE IDENTIFICATION PROGRAM
NEWARK BAY, NEW JERSEY

Volume 1a of 3

Inventory and Overview Report of Historical Data

Text and Appendices

Revision 0
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Submitted by

Tierra Solutions, Inc.
East Brunswick, NJ

Document Distribution List

Individual	Organization
Elizabeth Butler	USEPA Region 2
Diamond Alkali Site Attorney – Newark Bay Study Area	USEPA Region 2
Jeri Weigard	NJDEP
Richard McNutt	Tierra Solutions, Inc.
Clifford Firstenberg	Firstenberg Consulting, LLC
Jay Keough	Blasland, Bouck & Lee, Inc.
Robert Romagnoli	Blasland, Bouck & Lee, Inc.
Diane Waldschmidt	Environmental Data Services, Inc.
Dennis Farley	The Intelligence Group

Foreword

The Newark Bay Study Area Remedial Investigation Work Plan (RIWP) has been developed in accordance with Paragraph 39 of the Administrative Order on Consent Index No. CERCLA 02-2004-2010 (AOC), and is segregated into three main volumes, including:

- ***Volume 1: Inventory and Overview Report of Historical Data (herein referred to as the Inventory Report)*** (three binders total)
  - 1a: Text/Appendices
  - 1b: Tables
  - 1c: Figures

- ***Volume 2: Investigation Work Plan (IWP)/Sampling and Analysis Plan (SAP)/Site Management Plan (SMP)/Quality Assurance Project Plan (QAPP) (herein referred to as the IWP)*** (two binders total)
  - 2a: Text/Tables/Figures
  - 2b: Appendices

- ***Volume 3: Health and Safety/Contingency Plan (herein referred to as the HASCP)*** (one binder total)

As noted above, multiple binders were required to document the pertinent information associated with Volumes 1 and 2. Therefore, the binders associated with these two volumes have been identified with both a number (e.g., 1) and a letter (e.g., a). More specific information regarding the various documents is provided in each volume and/or associated binder.

Table of Contents

Appendices (provided on CD)

List of Tables

List of Figures

Acronyms and Abbreviations

3D	3-dimensional
ADCP	acoustic Doppler current profiler
AFs	accumulation factors
Ag	silver
As	arsenic
AOC	Administrative Order on Consent
AVS	acid volatile sulfides
BBL	Blasland, Bouck & Lee, Inc.
Be	beryllium
BHC	beta hexachlorocyclohexane
BOD	biological oxygen demand
CARP	Contamination Assessment and Reduction Program
Cd	cadmium
CDF	Confined Disposal Facility
Cr	chromium
CRP	Community Relations Plan
Cs	cesium
CSO	combined sewer overflow
CTD	conductivity, temperature, depth
Cu	copper
DO	dissolved oxygen
DOC	dissolved organic carbon
EFH	essential fish habitat
GIS	geographic information system
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
HDP	Harbor Deepening Project
HEP	Harbor Estuary Program
Hg	mercury
HMDC	Hackensack Meadowlands Development Commission
IEC	Interstate Environment Commission
Inventory Report	*Inventory and Overview Report of Historical Data*
ISC	Interstate Sanitation Commission
Lower Passaic River	lower 6 miles of the Passaic River
MERI	Meadowlands Environmental Research Institute
Ni	nickel
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollutant Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
NY/NJ	New York/New Jersey
NYCDEP	New York City Department of Environmental Protection
NYOFS	Port of NY/NJ Operational Forecast System
NYSDEC	New York State Department of Environmental Conservation
PA NY/NJ	Port Authority of New York/New Jersey
PAHs	polycyclic aromatic hydrocarbons

Pb	lead
PCA	principal components analysis
PCBs	polychlorinated biphenyls
PCDD/Fs	polychlorinated dibenzo-*p*-dioxins and dibenzofurans
PCDT	polychlorinated dibenzothiophene
POTW	publicly owned treatment work
PVA	polytopic vector analysis
QA/QC	quality assurance/quality control
R-EMAP	Regional Environmental Monitoring and Assessment Program
RI/FS	Remedial Investigation and Feasibility Study
RIWP	Remedial Investigation Work Plan
Sb	antimony
SD	standard deviation
Se	selenium
SEM	simultaneously extractable metals
SOW	Statement of Work
SVOCs	semivolatile organic compounds
TCDT	tetrachlorinated dibenzothiophene
TCDD/Fs	tetrachlorinated dibenzo-*p*-dioxin and dibenzofurans
TEPH	total extractable petroleum hydrocarbons
TEQs	toxic equivalency quotients
TIE	toxicity identification and evaluation
Tierra	Tierra Solutions, Inc.
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish & Wildlife Service
USCG	U.S Coast Guard
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
YOY	young-of-the-year
Zn	zinc

Executive Summary

The Remedial Investigation Work Plan (RIWP) for the Newark Bay Study Area has three primary components: the Inventory and Overview Report of Historical Data (Volume 1), the Investigation Work Plan (Volume 2), and the Health and Safety Contingency Plan (Volume 3). This RIWP has been developed in accordance with the requirements outlined in Section VII, Paragraph 39 of the Administrative Order on Consent (AOC), Index No. CERCLA 02-2004-2010 of February 2004 for the Newark Bay Study Area. Tierra Solutions, Inc. (Tierra), on behalf of Occidental Chemical Corporation, is undertaking the Remedial Investigation/Feasibility Study (RI/FS) for the Newark Bay Study Area in accordance with the provisions of the AOC.

Introduction

This report is Volume 1 of the Newark Bay Remedial Investigation Work Plan (RIWP) and is entitled *Inventory and Overview Report of Historical Data* (herein referred to as the "Inventory Report"). It presents the results of a data and information inventory that was conducted for Newark Bay and its tributaries in accordance with Paragraph 39 and Section B.3.a of Appendix I (Statement of Work [SOW]) of the Administrative Order on Consent (AOC), dated February 13, 2004, between the U.S. Environmental Protection Agency (USEPA) and Occidental Chemical Corporation.

The objectives of the Inventory Report are as follows:

- Create an inventory of historical environmental data, publications, and sources of information that are potentially relevant to environmental conditions in Newark Bay and its tributaries;
- Prepare an overview that summarizes the content of the inventory;
- Provide a searchable bibliography of the relevant publications, databases, internet sites, and other information sources; and
- Provide raw and summary data from environmental studies conducted in Newark Bay and its tributaries from 1990 to the present.

This Inventory Report contains 6 sections and 14 appendices. The Newark Bay Inventory Area Bibliography is provided in Appendix A. Appropriate data files for select studies (as described in subsequent sections of the Report) are provided in Appendices B through N.

This Inventory Report was developed as thoroughly as possible using the data and information search methods described in Section 2. The data and information contained in this Report include what was obtainable through April 30, 2004.

Definition of Inventory Area

Paragraph II.2.r of the AOC defines the Newark Bay Study Area as "Newark Bay and portions of the, Hackensack River, Arthur Kill and the Kill Van Kull." These waterways, in conjunction with the lower portion of the Passaic River, form an estuarine system consisting of Newark Bay and its tributaries (Figure 1-1). In order for this Inventory Report to provide as much data and information as possible on the environmental conditions in Newark Bay and its tributaries, data and information that were collected for the lower Passaic River have been included in the Report. As such, the "Inventory Area" includes the following waterways:

- Arthur Kill;
- Hackensack River (tidal portion only);
- Kill Van Kull;
- Newark Bay; and
- Passaic River (tidal portion only).

Each of these waterways has major and/or minor tributaries for which data or information may be available. Available data for these additional tributaries are presented in this Inventory Report.

Background on Inventory Area and Key Objectives of Historical Data Collection

Newark Bay, part of the New York/New Jersey (NY/NJ) Harbor Estuary, is located at the confluence of the Passaic and Hackensack Rivers, between the shores of Newark and Elizabeth to the West, Jersey City and Bayonne to the East, and Staten Island to the South. Newark Bay is linked to Upper New York Bay by the Kill Van Kull and to Lower New York Bay by the Arthur Kill (Figure 1-1). Newark Bay is approximately 6 miles long and 1 mile wide.

This estuarine system (including the entire Inventory Area) is at the center of one of the most urbanized and industrialized areas in the U.S. The urbanization of the area began with the arrival of early European explorers, followed by settlers. Throughout the 18th century, Newark was primarily a farming community. The population of Newark increased dramatically during the industrial revolution (Iannuzzi et al., 2002). Much of this growth was due to the construction of several bridges across the Hackensack and Passaic Rivers during this period, as well as development of a network of roads and railroad lines in the region. Between 1790 and 1850, Newark established its reputation for manufacturing – primarily leather goods, carriages, and iron and brass products (Urquhart, 1913). Industrialization and urbanization in the Newark Bay area increased at a rapid pace until the Great Depression of the 1930s, which limited industrial activity and stabilized population growth (Brydon, 1974; Cunningham, 1988). Industrial activities picked up again during World War II and, today, Newark – the largest city in New Jersey – is a trade and transportation center. One of Newark's important functions as a transportation center is the transfer of goods from cargo vessels in Newark Bay ports to the many railroad and truck lines that serve the region and beyond. The Newark International Airport, constructed in the 1960s, is another key component of the area's commerce. Newark is also home to one of the largest truck terminals in the country, which serves as a trans-shipment point between long-distance and short-distance trucking operations.

On the western shore of Newark Bay lies Port Newark with deepwater terminals connected to dredged channels in the Bay. Port Newark is among the nation's largest ports for containerized cargo and is a primary part of the NY/NJ port system managed by the Port Authority of NY/NJ (PA NY/NJ) (Mysak and Schiffer, 1997). To maintain Newark Bay's and its tributaries' status as one of the premier commercial ports in the nation, the U.S. Army Corps of Engineers (USACE) has conducted extensive dredging operations since the 1930s to accommodate the expanding draft of cargo vessels. Dredging operations have been carried out in Newark Bay (Federal navigation channel and Port Newark and Elizabeth Marine Terminals), Arthur Kill, Kill Van Kull, and the Passaic and Hackensack Rivers. Dredging is ongoing in Newark Bay, Arthur Kill, and Kill Van Kull (PA NY/NJ, 2004; USACE, 1997f; USACE, 2004a). The most recent dredging of the Passaic and Hackensack Rivers occurred during the 1980s (PA NY/NJ, 2004; USACE, 1997f; USACE, 2004a).

With the industrial growth of the Newark Region beginning in the mid-19th century, came a series of added environmental impacts to the waterways and ecological resources of the area. Most notable of these incremental impacts are habitat loss and pollution. Most of the environmental studies that have been conducted in the Inventory Area to date have focused on two key issues: 1) assessing the potential impacts of sustained dredging and dredged material management activities relative to maintaining and expanding the Newark Port commerce; and 2) assessing the effects of historical and current industrial and municipal pollution in the region on fish, wildlife, and human use of the Inventory Area waterways. This Inventory Report lists and summarizes these various environmental studies that have been conducted in the Inventory Area. While it does not provide an interpretation of the data from these studies, it does provide the reader with a summary of the objectives of each study (as available), maps of the spatial coverage of each study (as available), and a presentation of the data quantity and quality with respect to the data use objectives.

Approach to Data Inventory/Search

A systematic approach was used to search for historical data and information from environmental investigations conducted in the Inventory Area. This included the following steps/activities:

1. Accessed existing databases and technical libraries that were developed as part of a Remedial Investigation for the lower 6 miles of the Passaic River being conducted pursuant to an Administrative Order on Consent (AOC) between USEPA and Occidental Chemical Corporation (USEPA 1994);
2. Conducted a series of internet-based library and other database searches;
3. Searched the internet sites of regulatory agencies and other institutions (both governmental and non-governmental) that have been involved in the NY/NJ Harbor Estuary Program (HEP);
4. Contacted key regulatory agencies, universities, and other institutions that have conducted or are currently conducting, studies or investigations on the environmental conditions in the Inventory Area; and
5. Conducted a thorough search of and document retrieval from the Meadowlands Environmental Research Institute (MERI) library for the Hackensack River and other Inventory Area waterways.

These specific steps/activities are described in detail in the following sections.

Approach to Compilation and Primary Categorization of Data/Information

Data and information obtained from the search and assessment process described in Section 2.1 were entered into the Newark Bay Inventory Area Bibliography (hereinafter referred to as "the bibliography). This bibliography was developed in Microsoft® Access, and includes the full citation for each study/reference obtained, as well as a summary of key information regarding the study, including data/information categories that are provided in the study, types of data collected, sampling locations within the Inventory Area, and numbers of samples for each data type (as provided by the study's author[s]). The bibliography is provided in electronic format in Appendix A.

Each entry into the bibliographic database was evaluated and placed into one or more technical categories for subsequent evaluation. The names assigned to data/information categories for the Inventory Report were selected to provide a logical breakdown for reporting the data and information that are available for the Inventory Area. The specific categories used in this report are based on an assessment of the types of studies that have been and/or are currently being conducted for the purposes of characterizing the environmental conditions of the Inventory Area as necessary to complete the RI Report. These include:

Chemical, Toxicity, and Pathogen Data

- Water;
- Sediment;
- Toxicity and Pathogenicity; and
- Bioaccumulation.

Physical, Biological, and Other Data and Information

- Habitat;
- Biological communities;
- Hydrodynamics;
- Dredging;
- Bathymetry;
- Pollutant or Contaminant sources;
- Human use; and
- Miscellaneous.

Additional data and information that are pertinent to the Feasibility Study process for the Newark Bay Study Area will be compiled and evaluated under a separate work plan to be prepared at a later date.

Most of the available and obtainable sediment and bioaccumulation data that have been collected to date for the Inventory Area, have been collected under major government programs/initiatives and by studies sponsored by Tierra. The majority of these data (i.e., sediment chemistry and biota tissues chemistry) have been entered into a Microsoft® Access database entitled Newark Bay Study Area Analytical Database Version 1.0. This database is provided in Appendix B to this report. The format of this database has been developed by Tierra and approved by USEPA.

Approach to Presentation/Summarization of Inventory Data

Once the available studies were compiled, entered into the bibliography, and categorized as described above, each study was reviewed to determine the method by which the study would be presented in the Inventory Report.

For those studies conducted between 1990 and the present, both the raw data and a summary of the study (in abstract form) are provided in this Inventory Report. In addition, much of the data were summarized using selected tables and/or figures. While an attempt was made to provide a similar level of detail for each study, the descriptions are somewhat limited in many cases due to the fact that the authors of a number of studies did not provide substantial detail on the design, conduct, and/or data results for a specific study.

For data collected or studies conducted prior to 1990, the study is included in the bibliography, and briefly characterized in tables. However, pre-1990 data are not provided or summarized in this Report. The reasons for selecting the 1990 cut-off for data presentation are as follows:

- Pre-1990 data are not likely to be used for any current characterization of environmental conditions in the Inventory Area; and
- Presentation of raw and summary data collected from 1990 to present is consistent with the approach used by Tierra and USEPA for the lower Passaic River database and related reports/activities.

The studies from 1990–present are summarized in each section of the Results (Section 3) in alphabetical order by first author of the cited publication or dataset. Summary tables and figures are provided as appropriate. The units reported for the various datasets are those reports by the authors of the related publication or dataset. The data from the publications or datasets were not manipulated for this Inventory Report. As a result, many of the data summaries are limited to ranges of results (i.e., minimum – maximum), with the exception of those studies for which more detailed summary statistics were provided.

Results and Conclusions

The data and information obtained for the Inventory Area are presented in Section 3 (Results) of this report. The following is a breakdown of the number of studies obtained within each of the technical categories described above.

Category	Total Number of Documents	Number of Pre-1990 Documents	Number of 1990 – Present Documents
Chemical and Toxicity Data			
Water	103	46	57
Sediment	102	26	76
Toxicity and Pathogenicity	40	12	28
Bioaccumulation	72	37	35
Physical, Biological, and Other Data and Information			
Habitats	74	40	34
Biological Communities	116	70	46
Hydrodynamics	32	5	27
Dredging	21	10	11
Bathymetry	8	3	5
Pollutant or Contaminant Sources	61	27	34
Human Use	51	22	29
Miscellaneous	28	12	16

Note:
A number of documents contain data in more than one category.

During the data compilation process, a number of studies were identified for which data and/or information could not be obtained in time for inclusion in this Report. Most notable are data from two of the ongoing government investigations in the Inventory Area, including the NY/NJ HEP Contamination Assessment and Reduction Program (CARP) and the U.S. Army Corps of Engineers' (USACE's) NY/NJ Harbor Deepening Project (HDP). Additional data and information also exist, but were not obtainable, for several smaller studies conducted in various parts of the Inventory Area. Many of these are noted in the following sections. The data from these studies will be important to obtain and evaluate as part of the implementation of the RI/FS for the Newark Bay Study Area.

A substantial amount of data and information are provided for the inventory area in this Inventory Report. The studies and data summarized in Section 3 and provided in tables, figures, and appendices to this Report can be used to identify data gaps and help design studies to be conducted under the RI/FS for the Newark Bay Study Area pursuant to the AOC.

1. Introduction

This report represents Volume 1 of 3 of the Newark Bay Study Area Remedial Investigation Work Plan (RIWP) and is entitled *Inventory and Overview Report of Historical Data* (herein referred to as the "Inventory Report"). It presents the results of a data and information inventory that was conducted for Newark Bay and its tributaries in accordance with Paragraph 39 of the Administrative Order on Consent Index No. CERCLA 02-2004-2010 (AOC) for Tierra Solutions, Inc., on behalf of Occidental Chemical Corporation (the successor to Diamond Shamrock Chemicals Company [formerly known as Diamond Alkali Company]). Tierra is undertaking a Remedial Investigation/Feasibility Study (RI/FS) for the Newark Bay Study Are in accordance with the provisions of the AOC.

The objectives of the Inventory Report are as follows:

- Create an inventory of historical environmental data, publications, and sources of information that are potentially relevant to environmental conditions in Newark Bay and its tributaries;
- Prepare an overview that summarizes the content of the inventory;
- Provide a searchable bibliography of the relevant publications, databases, internet sites, and other information sources; and
- Provide raw and summary data from environmental studies conducted in Newark Bay and its tributaries from 1990 to the present.

This Inventory Report contains 6 sections and 14 appendices. This section provides the background and objectives of the Inventory Report. Section 2 presents the methods used to research and develop the inventory of environmental data and information. Section 3 provides the inventory results and discussion. Conclusions are provided in Section 4. References are provided in Section 5. The Inventory Report bibliography is provided in Section 6. The Newark Bay Inventory Area Bibliography is provided in Appendix A. Appropriate data files for select studies (as described in subsequent sections of the Report) are provided in Appendices B through N.

This Inventory Report was developed as thoroughly as possible using the data and information search methods described in Section 2. The data and information contained in this Report include what was obtainable through

April 30, 2004. A discussion of data and information that are believed to exist but were not obtainable for this Report is provided in Section 3.1.

1.1 Definition of Inventory Area

Paragraph 2.r of the AOC defines the Newark Bay Study Area as "Newark Bay and portions of the Hackensack River, Arthur Kill and the Kill Van Kull." These waterways, in conjunction with the lower portion of the Passaic River, form an estuarine system consisting of Newark Bay and its tributaries (Figure 1-1). In order for this Inventory Report to provide as much data and information as possible on the environmental conditions in Newark Bay and its tributaries, data and information that were collected for the lower Passaic River have been included in the Report. As such, the "Inventory Area" includes the following waterways:

- Arthur Kill;
- Hackensack River (tidal portion only);
- Kill Van Kull;
- Newark Bay; and
- Passaic River (tidal portion only).

Each of these waterways has major and/or minor tributaries for which data or information may be available. Available data for these additional tributaries are presented in this Inventory Report. The major additional tributaries are the Elizabeth and Rahway Rivers, tributaries to the Arthur Kill. Because these two waterways are substantial tributaries within the Inventory Area, specific data searches were performed for the lower portions of these rivers in the areas adjacent to the Arthur Kill. Data and information for other tributaries to the Inventory Area were included as discovered during searches related to the main waterways of interest. Section 2 contains additional detail regarding the methods by which geographic limits were placed on data searches for each waterway and specific category of data (e.g., surface water, sediment, biota, etc.).

1.2 Brief Background and History of Inventory Area

Newark Bay, part of the New York/New Jersey (NY/NJ) Harbor Estuary, is located at the confluence of the Passaic and Hackensack Rivers, between the shores of Newark and Elizabeth to the West, Jersey City and Bayonne to the East, and Staten Island to the South. Newark Bay is linked to Upper New York Bay by the Kill

Van Kull and to Lower New York Bay by the Arthur Kill (Figure 1-1). Newark Bay is approximately 6 miles long and 1 mile wide.

This estuarine system (including the entire Inventory Area) is at the center of one of the most urbanized and industrialized areas in the U.S. The urbanization of the area began with the arrival of early European explorers, followed by settlers. Throughout the 18th century, Newark was primarily a farming community. The population of Newark increased dramatically during the industrial revolution (Iannuzzi et al., 2002). Much of this growth was due to the construction of several bridges across the Hackensack and Passaic Rivers during this period, as well as development of a network of roads and railroad lines in the region. Between 1790 and 1850, Newark established its reputation for manufacturing – primarily leather goods, carriages, and iron and brass products (Urquhart, 1913). Industrialization and urbanization in the Newark Bay area increased at a rapid pace until the Great Depression of the 1930s, which limited industrial activity and stabilized population growth (Brydon, 1974; Cunningham, 1988). Industrial activities picked up again during World War II and, today, Newark – the largest city in New Jersey – is a trade and transportation center. One of Newark's important functions as a transportation center is the transfer of goods from cargo vessels in Newark Bay ports to the many railroad and truck lines that serve the region and beyond. The Newark Liberty International Airport, constructed in the 1960s, is another key component of the area's commerce. Newark is also home to one of the largest truck terminals in the country, which serves as a trans-shipment point between long-distance and short-distance trucking operations.

On the western shore of Newark Bay lies Port Newark with deepwater terminals connected to dredged channels in the Bay. Port Newark is among the nation's largest ports for containerized cargo and is a primary part of the NY/NJ port system managed by the Port Authority of NY/NJ (PA NY/NJ) (Mysak and Schiffer, 1997). To maintain Newark Bay's and its tributaries' status as one of the premier commercial ports in the nation, the U.S. Army Corps of Engineers (USACE) has conducted extensive dredging operations since the 1930s to accommodate the expanding draft of cargo vessels. Dredging operations have been carried out in Newark Bay (Federal navigation channel and Port Newark and Elizabeth Channels), Arthur Kill, Kill Van Kull, and the Passaic and Hackensack Rivers. Dredging is ongoing in Newark Bay, Arthur Kill, and Kill Van Kull (PA NY/NJ, 2004; USACE, 1997f; USACE, 2004a). The most recent dredging of the Passaic and Hackensack Rivers occurred during the 1980s (PA NY/NJ, 2004; USACE, 1997f; USACE, 2004a).

Along with the industrial growth of the Newark Region beginning in the mid-19th century, came a series of added environmental impacts to the waterways and ecological resources of the area. Most notable of these incremental impacts are habitat loss and pollution. Most of the environmental studies that have been conducted in the Inventory Area to date have focused on two key issues: 1) assessing the potential impacts of sustained dredging and dredged material management activities relative to maintaining and expanding the Newark Port commerce; and 2) assessing the effects of historical and current industrial and municipal pollution in the region on fish, wildlife, and human use of the Inventory Area waterways. This Inventory Report lists and summarizes these various environmental studies that have been conducted in the Inventory Area. While it does not provide an interpretation of the data from these studies, it does provide the reader with a summary of the objectives of each study (as available), maps of the spatial coverage of each study (as available), and a presentation of the data quantity and quality with respect to the data use objectives.

2. Methods

2.1 Approach to Data Inventory/Search

A systematic approach was used to search for historical data and information from environmental investigations conducted in the Inventory Area. This included the following steps/activities:

1. Accessed existing databases and technical libraries that were developed as part of an RI for the lower 6 miles of the Passaic River being conducted pursuant to an AOC between the U.S. Environmental Protection Agency (USEPA) and Occidental Chemical Corporation (USEPA, 1994);
2. Conducted a series of internet-based library and other database searches;
3. Searched the internet sites of regulatory agencies and other institutions (both governmental and non-governmental) that have been involved in the NY/NJ Harbor Estuary Program (HEP);
4. Contacted key regulatory agencies, universities, and other institutions that have conducted or are currently conducting, studies or investigations on the environmental conditions in the Inventory Area; and
5. Conducted a thorough search of and document retrieval from the Meadowlands Environmental Research Institute (MERI) library for the Hackensack River and other Inventory Area waterways.

These specific steps/activities are described in detail in the following sections.

2.1.1 Lower Passaic River Data, Technical Information, and Libraries

As a first step in the process of developing the Inventory Report, Tierra Solutions, Inc. (herein referred to as "Tierra," which is performing pursuant to private contract, Occidental Chemical Corporation's obligations under the 1994 AOC) and its consultants compiled their existing databases and bibliographies of data and information that had been collected as part of the RI activities for the lower 6 miles of the Passaic River. A bibliography was created from these data and information using Microsoft® Access. This bibliography was then used as the starting point to characterize the extent and categories of data that might be available for the Inventory Area, and subsequently to develop the parameters and approach for follow-up data searches. A key document identified in this step was the *Newark Bay Watershed Data Catalog* (NOAA, 1995a), which provides a summary and bibliographic information on studies/data collected in the vicinity of the Passaic and Hackensack Rivers and Newark Bay involving sediment chemistry, tissue chemistry, and bioeffects research. This document was used as a starting point for a chain-of-citation search for additional documents relevant to this Inventory Report.

Because Passaic River RI/FS activities are ongoing (for the lower 17 miles from the Dundee Dam to the River's confluence with Newark Bay), and there have been a number of up-to-date data and information searches conducted for the lower Passaic River under this program over the past several years, no additional search activities were conducted for the Passaic River beyond those described above. The data and information search activities described in the following sections were focused on waterways in the Inventory Area other than the Passaic River.

A substantial amount of the available data and information that were obtained for the Inventory Area for this Report were developed as part of RI and pre-RI sampling and analysis activities for the lower 6 miles of the Passaic River. As such, there is a substantially larger amount of data and information presented in this Report for the Passaic River than for the other Inventory Area waterways. It is anticipated that the data gaps for the Inventory Area waterways other than the Passaic River will be filled during the implementation of the RI/FS for the Newark Bay Study Area.

2.1.2 Dialog Databases

Literature searches were conducted using Dialog (www.dialog.com), an information service accessed through the internet with over 900 databases. The Dialog searches were restricted to 61 databases that include environmental data and information. Table 2-1 lists the collective databases that were accessed as part of the Dialog search. The following search terms and conditions were used in the Inventory Area search:

- "Newark Bay" combined with "New Jersey" anywhere in the record;
- "Arthur Kill" in the title or subject heading;
- "Hackensack River" in the title or subject heading;
- "Kill Van Kull" in the title or subject heading;
- "Elizabeth River" combined with "New Jersey" in the title or subject heading; and
- "Rahway River" in the title or subject heading.

The results of the Dialog search returned a list of study or report titles and abstracts or brief descriptions that related to one or more of the search terms/conditions. This list was reviewed and screened to determine which studies may provide relevant environmental data or information related to the Inventory Area. The studies that were identified as being relevant were then ordered from various sources or otherwise obtained through library visits and interlibrary loans.

2.1.3 Internet Data Searches

A list of regulatory agencies, universities, and research institutions that are currently conducting or have previously conducted environmental investigations in the Inventory Area was compiled. The internet sites for these organizations were then accessed, and a list of the relevant sites containing data or information for the Inventory Area was developed. This list is provided in Table 2-2. The relevant data and information from each of these internet sites was compiled and evaluated.

2.1.4 Regulatory Agency, University, and Other Institution Contacts

In addition to internet-based searches for data and information, a number of telephone contacts were made with regulatory agencies, university researchers, and other institution contacts. These contacts were focused on individuals or departments of such agencies/institutions that may have additional data and information beyond that which is currently available in the public domain (i.e., internet sites or publications).

2.1.5 MERI Library

A focused search and retrieval effort was undertaken for the MERI library because this particular library consists almost entirely of documents/files containing environmental data and information on the Inventory Area (and the Hackensack Meadowlands in particular). While other internet sites listed in Table 2-2 are also focused to some extent on the Inventory Area, none of these sites provide data and information repositories similar to that of the MERI library.

The MERI library was searched through two separate internet-based catalogs, first at the Digital Meadowlands internet site:

http://cimic.rutgers.edu/digitalmeadowlands/

and then, second, through the other catalog at the MERI library search engine:

http://cimic.rutgers.edu/meri/lib/Gateway.html

A print-out of the entire library catalog was obtained from the Digital Meadowlands internet site.

Focused searches for each waterway in the Inventory Area were conducted using the MERI library catalog search engine. Duplicates from these listings were removed and the search narrowed by subject matter. Documents containing environmental data and/or information for the Inventory Area were reviewed individually at the MERI Library in Lyndhurst, NJ, and pertinent data were extracted and/or the document was photocopied.

2.2 Approach to Compilation and Primary Categorization of Data/Information

Data and information obtained from the search and assessment process described in Section 2.1 were entered into the Newark Bay Inventory Area Bibliography (hereinafter referred to as "the bibliography"). This bibliography was developed in Microsoft® Access, and includes the full citation for each study/reference obtained, as well as a summary of key information regarding the study, including data/information categories that are provided in the study, types of data collected, sampling locations within the Inventory Area, and numbers of samples for each data type (as provided by the study's author[s]). The bibliography is provided in electronic format in Appendix A.

Each entry into the bibliography was evaluated and placed into one or more technical categories for subsequent evaluation. The names assigned to data/information categories for the Inventory Report were selected to provide a logical breakdown for reporting the data and information that are available for the Inventory Area. The specific categories used in this report are based on an assessment of the types of studies that have been and/or are currently being conducted for the purposes of characterizing the environmental conditions of the Inventory Area as necessary to complete the Newark Bay RI Report. These include:

Chemical, Toxicity, and Pathogen Data

- Water;
- Sediment;
- Toxicity and Pathogenicity; and
- Bioaccumulation.

Physical, Biological, and Other Data and Information

- Habitat;
- Biological communities;
- Hydrodynamics;
- Dredging;
- Bathymetry;
- Pollutant or Contaminant sources;
- Human use; and
- Miscellaneous.

Additional data and information that are pertinent to the FS process for the Newark Bay Study Area will be compiled and evaluated under a separate work plan to be prepared at a later date.

A brief description of the types of data that fall into each category, as well as any caveats for the search parameters or methods used for individual categories is provided below.

2.2.1 Chemical, Toxicity, and Pathogen Data

Chemical, toxicity, and pathogen data consist primarily of two key types of data:

- Water, sediment, and biological tissue chemistry studies; and
- Water, sediment, and porewater toxicity studies (laboratory and field investigations).

Pathogen or pathogenicity data are typically collected in conjunction with either chemical or toxicity studies. As such, these data (as discovered) are reported within the water, sediment, and biological tissue chemistry and toxicity sections of this Report. These categories are typically considered the key types of data required to assess the extent of contamination in a waterway, and the potential (i.e., risk-based) effects of the contamination to human and ecological receptors. As such, these are typically considered by USEPA to be the most important data categories for CERCLA investigations at aquatic sites, such as the Newark Bay Study Area. For this reason, and pursuant to the AOC, these data were a focus of this Inventory Report.

The following is a brief summary of the types of data and information included in each category.

2.2.1.1 Water

Water data include chemical measurements of water samples collected from the Inventory Area and monitoring data of physicochemical parameters in the water column.

2.2.1.2 Sediment

Sediment data include chemical, radiological, and geotechnical measurements of sediment samples collected from the Inventory Area.

2.2.1.3 Toxicity

Toxicity data include the results of *in situ* or laboratory toxicological studies performed using sediment, pore water, or surface water samples collected from the Inventory Area. These include tests performed using a variety of invertebrate and vertebrate animals, as well as algae and bacteria. In addition, these studies assess a variety of toxicological and other measurements including both lethal (i.e., survival) and sub-lethal (e.g., growth, histology, enzyme induction) endpoints.

2.2.1.4 Bioaccumulation

Bioaccumulation is a broad category that includes data on measured concentrations of chemical contaminants in tissue samples of plants and animals collected from the Inventory Area. The organisms and tissue types that were analyzed in bioaccumulation studies varied widely.

2.2.2 Physical, Biological, and Other Data and Information

The physical, biological, and other studies included in this Inventory Report include a broad base of data and information, both quantitative and qualitative, from a variety of investigations performed in the Inventory Area. Many of the categories (e.g., habitats and biological communities) contain data/information from some of the same sets of studies. The following is a brief summary of the types of data and information included in each category.

2.2.2.1 Habitats

Data and information on habitats is quite varied. This category includes studies that both describe and/or quantify existing or historical habitats in the Inventory Area. The habitat characterizations may be by either general habitat types or by specific habitats for select organisms. In addition, studies are included in this category that compare or characterize the value of habitat types within the Inventory Area to support select plant or animal communities.

2.2.2.2 Biological Communities

Data and information on biological communities includes the results of surveys that have been conducted to characterize and/or quantify populations and communities of plants and/or animals in the Inventory Area. Data on species diversity and abundance are presented as available. The available data are presented in the following categories:

- Plankton (phytoplankton, zooplankton, ichthyoplankton);
- Invertebrates;
- Fish;
- Birds;
- Mammals; and
- Other wildlife.

2.2.2.3 Hydrodynamics

Hydrodynamics data and information focus on physical measures of the water column that are used to determine circulation, flow, and sediment transport patterns in the Inventory Area.

2.2.2.4 Dredging

Data and information on dredging include reports of ongoing and historical dredging activities that have altered the sediment bed to create channels or berths for shipping/commerce. These include both authorized and requested dredging activities. This category also includes a history, description, and characterization of the Newark Bay Confined Disposal Facility (CDF).

2.2.2.5 Bathymetry

Data and information on bathymetry include the results of investigations performed to characterize the current and historical depth of the sediment bed in the Inventory Area.

2.2.2.6 Pollutant and Contaminant Sources

Maps of combined sewer overflows (CSOs), publicly owned treatment works (POTWs), storm water outfall locations; and publicly available documentation on primary sources of pollutants and contaminants to the water and sediment of the Inventory Area were collected and are presented in this Inventory Report.

There are thousands of potential industrial, non-industrial, and municipal sources of pollutants and contaminants to the Inventory Area, and most of the documentation for these sources is contained in regulatory files, letters, memoranda, notifications, or other publicly or privately held documents. A search for such documents could not be conducted within the timeframe allowed for development of the RIWP. Therefore, a characterization of specific sources to the Inventory Area will be performed as part of the Source Characterization Program that will be conducted under the RIWP pursuant to Paragraph 44 of the AOC, and Section B.3.iii.(2) of the Statement of Work (SOW). It also is anticipated that data and information on pollutant and contaminant sources to the Inventory Area will be collected under a work plan to be developed by USEPA (pursuant to Section B.3.iii.(1) of the SOW) focused upon contaminant fate and bioaccumulation modeling for the Inventory Area. A thorough source inventory and characterization of sources will be compiled through the implementation of these work plans.

2.2.2.7 Human Use

Data and information regarding human use of the Inventory Area includes historical and current characterization and/or quantification of industrial, commercial, and recreational uses of the various waterways. Much of this information is qualitative, with the exception of quantitative surveys of angling and recreational use of selected portions of the Inventory Area. This category also includes information on existing fishing bans/advisories for the Inventory Area.

2.2.2.8 Miscellaneous

The miscellaneous category includes data and information on the meteorology, air quality, and geology of the Inventory Area.

2.3 Approach to Presentation/Summarization of Inventory Data

Once the available studies were compiled, entered into the bibliography, and categorized as described above, each study was reviewed to determine the method by which the study would be presented in the Inventory Report.

For those studies conducted between 1990 and the present, both the raw data and a summary of the study (in abstract form) are provided in this Inventory Report. In addition, much of the data were summarized using selected tables and/or figures. While an attempt was made to provide a similar level of detail for each study, the descriptions are somewhat limited in many cases due to the fact that the authors of a number of studies did not provide substantial detail on the design, conduct, and/or data results for a specific study.

For data collected or studies conducted prior to 1990, the study is included in the bibliography, and briefly characterized in tables. However, pre-1990 data are not provided or summarized in this Report. The reasons for selecting the 1990 cut-off for data presentation are as follows:

- Pre-1990 data are not likely to be used for any current characterization of environmental conditions in the Inventory Area; and
- Presentation of raw and summary data collected from 1990 to present is consistent with the approach used by Tierra and USEPA for the lower Passaic River database and related reports/activities.

The studies from 1990–present are summarized in each section of the Results (Section 3) in alphabetical order by first author of the cited publication or dataset. Summary tables and figures are provided as appropriate. The units reported for the various datasets are those reports by the authors of the related publication or dataset. The data from the publications or datasets were not manipulated for this Inventory Report. As a result, many of the data summaries are limited to ranges of results (i.e., minimum – maximum), with the exception of those studies for which more detailed summary statistics were provided.

2.4 Newark Bay Study Area Analytical Database Version 1.0

Most of the available and obtainable sediment and bioaccumulation data that have been collected to date for the Inventory Area, have been collected under major government programs/initiatives and by studies sponsored by Tierra. The majority of these data (i.e., sediment chemistry and biota tissues chemistry) have been entered into a Microsoft® Access database entitled Newark Bay Study Area Analytical Database Version 1.0. This database is provided in Appendix B to this report.

The format of this database has been developed by Tierra and approved by USEPA. A summary of the contents of this Database is provided in Table 2-3.

2.5 Approach to Raw Data Presentations (1990 to Present)

Data that were obtainable for each of the environmental investigations conducted between 1990 and the present are made available in raw form in this Inventory Report. These data are provided for each of the technical data/information categories described in Section 2.2 above, in one of the five following formats.

1. Newark Bay Study Area Analytical Database Version 1.0 (April 2004). This is a Microsoft® Access database created by Tierra in a format acceptable to USEPA that contains water, sediment, and biological tissue chemistry data from a number of investigations.
2. Electronic data spreadsheets or databases. These include electronic copies of data from individual studies. They may be provided in either a spreadsheet or database format.
3. References to internet sites. For studies where the data are made available on an internet site, the reader is referred to this site in the appropriate section of the Report (i.e., in the text summary of the particular study)
4. Data tables. For some studies, where the data that were not available in an existing electronic database or on an internet site, data tables have been created in the text of this Report.
5. Electronic copies of individual reports/studies. For selected studies where either data entry was not feasible due either to the large size of the dataset or significant information was lacking (e.g., missing key study parameters, lack of obtainable quality assurance/quality control [QA/QC] documentation, etc.) to appropriately create data tables, electronic copies of the study are provided in Adobe Acrobat® (PDF file) format.

The specific form in which the data are presented in for each study/investigation is identified in the results and discussion section for that category of data. As such, a clear road-map of where to find each dataset is presented by data category. The electronic databases and copies of individual reports/studies are provided on a series of compact discs that are included as Appendices B through N to this Inventory Report. The references to appropriate internet sites and data tables that contain raw data are included in each relevant section of the Report.

2.6 Approach to Graphical Representation of Select Datasets

To the extent practicable, the data for the Inventory Area have been summarized in graphical format in this Inventory Report. This was useful for data types that are comparable across studies such as contaminant chemistry in sediments, sediment toxicity, and bioaccumulation. Graphical presentation was not practical for other data types such as biological communities, human use, and miscellaneous data. The specific types of graphical presentations used are specific to each of the categories of data and information that are presented in Section 3.

Pursuant to Section B.3.a of the AOC SOW, the contaminant chemistry (i.e., water, sediment, and biological tissue) data collected in this Inventory Report were examined to determine the efficacy of developing contour maps of the data. As is common scientific practice, interpolating between or extrapolating from existing datasets should only be undertaken where data density and comparability is sufficient to reasonably justify such exercises. In the case of the existing data for the Inventory Area, such densities and data comparability do not currently exist.

3. Results and Discussion

This section of the Inventory Report presents the results and discussion of the data and information collected for each of the categories described in Section 2.2. In addition, a discussion of major historical and ongoing government investigations in the Inventory Area is provided.

3.1 Inventory Report Completeness

As stated in Section 1, one of the goals in developing this Inventory Report was to be as thorough as possible in data and information search methods, and to make the resulting bibliography as complete as reasonably possible. During the data compilation process, a number of studies were identified for which data and/or information could not be obtained in time for inclusion in this Report. Most notable are data from two of the ongoing government investigations in the Inventory Area, including the NY/NJ HEP Contamination Assessment and Reduction Program (CARP) and the USACE's NY/NJ Harbor Deepening Project (HDP). A summary of some key datasets that are known to exist, but were not obtainable for this Inventory Report, is provided in Table 3-1. Additional data and information also exist, but were not obtainable, for several smaller studies conducted in various parts of the Inventory Area. Many of these are noted in the following sections. The data from these studies will be important to obtain and evaluate as part of the implementation of the RI/FS for the Newark Bay Study Area.

3.2 Chemical, Toxicity, and Pathogen Data for the Inventory Area

3.2.1 Water

This section presents surface water and groundwater studies that were identified and obtained for this Inventory Report.

3.2.1.1 Surface Water

A variety of surface water studies have been performed in the Inventory Area to assess water quality through physical and chemical analyses. One hundred three identified surface water studies are summarized in Table 3-2. Fifty-seven identified surface water studies that have been conducted since 1990 are discussed in greater detail below. Figures 3-1a through 3-1c present the sampling locations of the surface water sampling events from 1990–present. Raw data from several of these studies are presented in tables or electronic format in

Appendix C – Water Data. Forty-six identified surface water studies that were conducted prior to 1990 are briefly summarized in Table 3-2.

Surface water samples were collected by Battelle Ocean Sciences (Battelle, 1992a) and analyzed for inorganic chemicals for a metals waste load allocation modeling effort of the NY/NJ HEP. Samples were collected throughout the NY/NJ Harbor Estuary in 1991. Two locations were sampled in the Inventory Area including one each in Newark Bay and Arthur Kill (Figure 3-1a). Samples were analyzed for metals (silver [Ag], arsenic [As], cadmium [Cd], copper [Cu], mercury [Hg], nickel [Ni], lead [Pb], and zinc [Zn]) as total recoverable and dissolved, total suspended solids (TSS), particulate organic carbon, dissolved organic carbon (DOC), and salinity. In addition, Hg was analyzed in the particulate phase of samples. Analytical results are summarized in Table 3-3. Raw data are provided in electronic format in Appendix C – Water Data.

ChemRisk (1995) conducted a finfish and benthic invertebrate survey in August 1994 to characterize the ecological communities present in the lower Passaic River (Tierra, 1994a). Sampling was performed at six locations on August 10 and 11, 1994 (Figure 3-1c). Water quality data were collected at three depths at each of the six sampling locations. Temperature ranged from 23–25°C, dissolved oxygen (DO) ranged from 2.2 to 5.8 mg/L, salinity ranged from 6 to 23 ppth, and conductivity ranged from 8 to 305 μmho/cm^2 $\times$ 100. Raw data results are presented in Table 3-4.

Coastal & Environmental Studies, Inc. (2004) compiled existing data to characterize phytoplankton conditions and to determine the location and extent of and factors contributing to algal blooms in portions of the NY/NJ Harbor Estuary. The authors provide their data compilation in an electronic format. Data were obtained from four major monitoring programs: the New York City Department of Environmental Protection's (NYCDEP) New York City Harbor Survey; the Interstate Sanitation Commission (ISC); the New Jersey Department of Environmental Protection (NJDEP) in conjunction with the USEPA; and the National Park Service. This database includes chlorophyll-*a*, phytoplankton species and biomass, bloom conditions versus environmental and water quality variables, and algal bloom indices for 1957–1992. The Kill Van Kull is the only Inventory Area waterway included in this study. The database contains five locations and 276 samples within the Kill Van Kull from 1986–1992. The specific sampling locations are not provided. The raw data are presented at the following internet site:

http://www.hudsonriver.org/hep/depot/depot_5.htm

The chlorophyll-*a* data are summarized below as monthly averages.

Chlorophyll-*a* Concentrations (µg/L)					
January	**February**	**March**	**April**	**May**	**June**
7.1	no data	40	52	26	8.8
July	**August**	**September**	**October**	**November**	**December**
12	9.5	9.8	5.0	5.0	2.8

Eckenfelder (1993) performed surface water sampling at six locations in the Hackensack Meadowlands and two locations in Hackensack River. The sampling was conducted in August–November 1991. Figure 3-1b depicts the Hackensack River and four of the six Hackensack Meadowlands sampling locations; two of the Hackensack Meadowlands sampling locations were not specified in sufficient detail in the original document to permit their mapping. Water samples were collected at depths of approximately two-thirds of the depth of the water column. Samples were analyzed for seven water quality parameters (total organic carbon [TOC], biological oxygen demand [BOD], sulfides, total Kjeldahl nitrogen [TKN], fecal coliforms, hardness, and TSS). These results are summarized in Table 3-5. Additionally, select water quality parameters (conductivity, salinity, pH, temperature, and DO) were measured *in situ* at each sampling location and are summarized in Table 3-5. Raw data are provided in electronic format in Appendix C – Water Data.

Environmental Connection, Inc. (1997) collected a monthly surface water sample at each of seven sampling locations in the Hackensack Meadowlands from September through November 1996. Six of the seven sampling locations are depicted on Figure 3-1b; the position of the seventh sampling location was not provided in the report. The samples were analyzed for pesticides/polychlorinated biphenyls (PCBs), Cd, and Pb. Pesticides, PCBs, and Cd were not detected in any of the samples. Pb was detected at concentrations ranging from 11 to 147 µg/L; the raw data from this study is presented below.

Author's Sampling Location	Sampling Date	Pb (µg/L)	Sampling Date	Pb (µg/L)	Sampling Date	Pb (µg/L)
EC1	9/27/1996	ND	10/24/1996	17	11/21/1996	147
EC2	9/27/1996	ND	10/24/1996	12	11/21/1996	11
EC3	9/27/1996	ND	10/24/1996	48	11/21/1996	ND

Author's Sampling Location	Sampling Date	Pb (µg/L)	Sampling Date	Pb (µg/L)	Sampling Date	Pb (µg/L)
EC4	9/27/1996	69	10/24/1996	40	11/21/1996	62
EC5	9/27/1996	ND	10/24/1996	ND	11/21/1996	ND
EC6	9/27/1996	ND	10/24/1996	ND	11/21/1996	12
EC7	9/27/1996	ND	10/24/1996	ND	11/21/1996	ND

A study was performed by the Hackensack Meadowlands Commission (formerly the Hackensack Meadowlands Development Commission [HMDC]) to determine the extent that the Atlantic tomcod (*Microgadus tomcod*) utilizes the Hackensack River (HMDC, 1990c). In conjunction with the tomcod sampling, water quality monitoring was conducted, and surface water samples were collected at five locations in the Hackensack River and analyzed for Cu and chromium (Cr) in August 1990 (Figure 3-1b). Raw data from this study are presented below.

Parameter	Author's Sampling Location Number				
	1	2	3	4	5
Physicochemical					
DO (ppm)	6.5	6.1	5.2	3.3	5.8
Salinity (0/00)	10	8.5	5.0	3.8	7.0
pH	7.3	7.2	7.7	7.0	7.2
Temperature (^{o}C)	23	23	24	23	24
Secchi depth (cm)	50	50	50	41	50
Inorganic Chemicals					
Cu (mg/L)	0.024	0.0020	0.0020	0.0020	0.0020
Cr (mg/L)	0.014	0.036	0.014	0.014	ND

Note:
ND = not detected

The Interstate Environmental Commission (IEC), formerly the Interstate Sanitation Commission (ISC), is a joint agency from New York, New Jersey, and Connecticut created in 1936, that strives to abate and control water pollution. Since 1937, the IEC has been publishing annual reports that review the water quality issues within the NY/NJ Harbor Estuary (ISC, 1937–1999). Recent reports are found on IEC's internet site:

http://www.iec-nynjct.org/reports.htm

These annual reports typically include an update on water pollution control plants, and overview of effluent and ambient water quality monitoring, and details of any special, intensive surveys. The following discussion includes summaries of surveys conducted in the Inventory Area from 2000 through 2003:

- Water samples were collected from 42 sampling locations, including eight locations within the Inventory Area (Figure 3-1a) over a 17-week period in 2001 (August through November) to support the NY/NJ HEP's Pathogens Workgroup. Samples were analyzed for fecal and total coliforms, fecal streptococcus and enterococcus (IEC, 2000–2002; 2004). No data were provided for these sampling events.
- As a continuation of the 2001 program, water samples were collected from 42 sampling locations, including eight locations within the Inventory Area (Figure 3-1a) over a 10-week period in 2002 (February to August). Samples were analyzed for fecal and total coliforms, fecal streptococcus and enterococcus (IEC, 2000–2002; 2004). No data were provided for these sampling events.
- From October 2002 through June 2003, water samples were collected at 46 locations, including eight locations within the Inventory Area (Figure 3-1a) to support the NY/NJ HEP's Pathogens Workgroup. Samples were analyzed for fecal and total coliforms, fecal streptococcus and enterococcus (IEC, 2000–2002; 2004). No data were provided for these sampling events.

Additionally, the IEC (2003) conducted ambient water quality sampling for pathogens at 15 locations in Newark Bay, Hackensack River, and the Passaic River in 2003 (Figures 3-1a through 3-1c). The results are summarized below and the raw data are provided in electronic format in Appendix C – Water Data.

Sampling Location	Fecal Coliforms (MPN/100 ml)	Total Coliforms (MPN/100 ml)	Fecal Streptococci (MPN/100 ml)	Enterococci (MPN/100 ml)
Passaic River	1,200 – 46,000	4,300 – 110,000	210 – 4,600	210 – 46,000
Hackensack River	230 – 24,000	1,500 – 24,000	43 – 11,000	43 – 11,000
Newark Bay	430 – 15,000	9,300 – 46,000	9 – 430	4 – 430

Note:
MPN/100 ml = most probable number per 100 milliliters

Robert Kimball and Associates, Inc. (Kimball, 2000) conducted surface water sampling at seven locations in tributaries to the Hackensack River: three locations in Bucks Creek, one seep discharging to the mid-point of Bucks Creek, and three locations in Van Winkle Ditch (Figure 3-1b). In addition to sample collection, water quality parameters (pH, specific conductivity, DO, and oxidation-reduction potential) were measured *in situ* at each location. Surface water samples were analyzed for priority pollutant volatile organic compounds (VOCs) and base neutral organic compounds, inorganic chemicals, BOD, chemical oxygen demand, chlorides, pH, nitrate nitrogen, total solids, and TSS. Results of these analyses are summarized in Table 3-6. Raw data are provided in electronic format in Appendix C – Water Data.

Langan Engineering and Environmental Services, Inc. (Langan, 1999) collected surface water samples at 22 locations in the Kearny Marsh on April 7 and 8, 1999. Figure 3-1b depicts 18 of the 22 sampling locations; four sampling locations could not be mapped due to the poor quality of the original document.. Samples were collected by boat with a grab sampler and were analyzed for priority pollutants including VOCs, semivolatile organic compounds (SVOCs), pesticides, and inorganic chemicals, as well as several water quality parameters. In addition, select water quality parameters (pH, DO, temperature, specific conductance, oxidation-reduction potential, and salinity) were measured *in situ* at each sampling location. Priority pollutant and water quality monitoring results are summarized in Table 3-7. Raw data are provided in electronic format in Appendix C – Water Data.

From June through October 1999, McIntyre (2000) assessed the feasibility of using the diamondback terrapin (*Malaclemys terrapin*) as a bioindicator for a polluted estuarine environment at two sites. One of the sampling areas was within the Hackensack Meadowlands near Saw Mill Creek (Figure 3-1b). The specific locations were not provided. Ten surface water samples were collected in the creeks where turtles had been captured. At each sampling location, pH, conductivity, temperature, and DO were measured *in situ*. No water quality data were provided in the report.

Since 1993, the Hackensack Meadowlands Commission (formerly the HMDC) has been monitoring water quality within the Meadowlands District by sampling four times per year (spring, summer, fall, and winter) at 14 sites in the Hackensack River and its tributaries (MERI, 2004a). These water quality data have been published in Konsevick et al. (1994) and HMDC (1994; 1997). Each of these three documents summarize the initial sampling event in 1994. The program is currently under the direction of the MERI. The sampling locations are presented in Figure 3-1b. The 14 sampling locations include five in the Hackensack River, seven in major tributaries to the Hackensack, and two Kearny locations. Sampling is conducted at low tide and analyzed for 25 parameters (inorganic chemicals [Cd, Cr, Cu, Pb, Ni, iron, Zn], temperature, fecal coliforms, DO, BOD, chemical oxygen demand, TSS, turbidity, conductivity, salinity, total dissolved solids, pH, alkalinity, ammonium, nitrate, oil and grease, chloride, sulfate, and hardness). Results from the May 1993 through July 1999 sampling events are summarized in Tables 3-8a through 3-8c. Raw data are available at the following MERI internet site:

http://cimic.rutgers.edu/hmdc_public/wq/

In addition to the chemistry data, MERI is in the process of installing a network of 15 continuous, automated environmental monitoring stations for water quality (MERI, 2004b). Currently three stations are installed at Kingsland Impoundment, and on the Hackensack River at Meadowlands Marina and at Fairleigh Dickinson University (Figure 3-1b) to collect the following data:

Kingsland Impoundment	Hackensack River at Meadowlands Marina	Hackensack River at Fairleigh Dickinson University
Date, time, battery voltage, air temperature, relative humidity, rainfall, solar radiation, wind speed and direction, water temperature, conductivity, pH, depth, turbidity, DO, and salinity	Date, time, battery voltage, water temperature, conductivity, pH, depth, turbidity, DO, and salinity	Date, time, battery voltage, water temperature, conductivity, pH, depth, turbidity, DO, and salinity

Table 3-9 summarizes the water quality data (water temperature, conductivity, pH, turbidity, DO, and salinity) from each location for 2001, 2002, and 2003. Raw data are available at the following MERI internet site:

http://cimic.rutgers.edu/hmdc_public/statons/stationsbody.html

Metcalf & Eddy (1995) conducted surface water quality monitoring in Cromakill Creek and the Hackensack River to determine the level of treatment (above secondary) that was necessary for North Bergen Central Sewage Treatment Plant to meet water quality standards. Four monitoring events were conducted (July 1992, August 1992, October 1992, and November 1992) at 10 sampling locations (five locations per creek/river)

(Figure 3-1b). *In situ* measurements of conductivity, temperature, pH, and DO were collected using a calibrated field test monitor. Surface water samples were analyzed for 30-day carbonaceous BOD, 5-day carbonaceous BOD, total dissolved solids, TSS, total phosphorous, organic phosphorous, alkalinity, chlorophyll-*a*, TKN, ammonia nitrogen, nitrite plus nitrate. Results of the monitoring and analytical data are summarized in Table 3-10,. Raw data are provided in electronic format in Appendix C – Water Data.

Mohan et al. (1999) collected surface water samples as part of RI and corrective measures activities at the confluence of the Rahway River and Arthur Kill. One surface water sample was collected at each of seven locations and analyzed for inorganic chemicals (As, Cu, Pb, Zn) and select pesticides (DDD, DDE, DDT). The sampling results are presented below and sample locations are presented in Figure 3-1a. Raw data are provided in electronic format in Appendix C – Water Data.

Inorganic Chemicals Concentration Range (mg/kg)				**Pesticides Concentration Range (µg/kg)**		
As	**Cu**	**Pb**	**Zn**	**DDD**	**DDE**	**DDT**
105 – 160	654 – 11,500	520 – 878	1,580 – 6,360	3.8 – 7,200	ND	3.3 – 5,900

Every 2 years the NJDEP (NJDEP 1996; 1998; 2000) prepares an Integrated Water Quality and Monitoring Assessment Report (formerly Water Quality Inventory Report), which describes the status of the water quality within New Jersey's water bodies. The Integrated Water Quality and Monitoring Assessment Reports are available at the following NJDEP internet site:

http://www.state.nj.us/dep/wmm/sgwqt/wat/index.html

These reports include the following data and information:

- Chemical assessment for coastal waters and tidal and non-tidal rivers;
- River, stream, lake, and estuary designated use assessment; and
- Fish advisories and monitoring schedules.

Additionally, the data summarized in these reports can be found in the USEPA's electronic database STORET at the following internet site:

http://www.epa.gov/storet/

From May 1993 through April 1994, the National Oceanic and Atmospheric Administration (NOAA) (1994) conducted a biological characterization of Newark Bay. *In situ* water quality data for DO, salinity, and temperature were collected during each survey event. No raw data are provided in NOAA (1994). Water quality ranges for DO (4–12 mg/L), temperature (0–30 °C) and salinity (0–25 ppth) are provided at the NOAA Fisheries Northeast Fisheries Science Center internet site:

http://sh.nefsc.noaa.gov/NEWRKbay.htm

Sampling locations are presented in Figure 3-1a.

Since 1909, NYCDEP has been monitoring the water quality of New York Harbor (NYCDEP, 1993; 1998; 1999; 2000; 2001; 2003), including portions of the Inventory Area. The NYCDEP documents its water quality surveys in annual reports, which are available on its internet site:

http://www.ci.nyc.ny.us/html/dep/html/news/depnewshwqs.html

In general, samples are collected from surface waters (1 m below water surface) and bottom waters (1 m above the sediment surface). Typical parameters analyzed include total and fecal coliforms, temperature, salinity, density (with a CTD), DO, BOD, nutrients (total phosphorus, orthophosphate, ammonium, and nitrate-nitrite), chlorophyll-*a*, TSS, Secchi transparency, pH, and VOCs. In 2003, NYCDEP presented the results of their 93rd water quality survey in *2002 New York Water Quality Report* (NYCDEP, 2003). The report divided the New York Harbor system into four regions: Upper East River (including the Harlem River) and Western Long Island; the Inner Harbor (the Hudson River, Lower East River, Upper New York Bay, Arthur Kill and Kill Van Kull); Jamaica Bay; and the Lower Bay (including Raritan Bay) and presents ranges in data for each respective region. The Arthur Kill and Kill Van Kull sampling locations are presented in Figure 3-1a. For the purposes of this summary, data from Arthur Kill and Kill Van Kull sampling locations are presented if available. However, in the event site-specific data are not presented, data ranges for the Inner Harbor region are presented. Four parameters (DO, fecal coliform, chlorophyll-*a*, and Secchi disk depth) were monitored as part of the 2002 water quality study. The four site-specific locations in the Inventory Area (one location in Kill Van Kull and three locations in Arthur Kill) had mean surface and bottom concentrations of DO ranging from 5.9 to 7.0 mg/L and 5.1 to 6.1 mg/L, respectively. Fecal coliform results from sites in the Arthur Kill resulted in average concentrations from 26 to 77 cells/100 mL and maximum concentrations from 204 to >4,000 cells/100 mL. Chlorophyll-*a* concentrations within the entire Inner Harbor had mean concentrations <10 µg/L. Chlorophyll-*a* concentrations were highest at the southern end of Arthur Kill with a mean concentration of 21 µg/L and a maximum concentration of 38 µg/L. Finally, Arthur Kill and Kill Van Kull had Secchi depths ranging from 4.2±1.1 ft to 4.9±1.4 ft.

The NY/NJ HEP CARP is a collaboration of federal, state, and non-governmental partners with a common goal of understanding and reducing contamination within NY/NJ Harbor (New York State Department of Environmental Conservation [NYSDEC], 2003). CARP collects surface water, sediment, and biota samples, and investigates hydrodynamic aspects of the NY/NJ Harbor Estuary. A description of CARP is available at:

http://www.carpweb.org/main.html (NY/NJ HEP, 2004a)

New Jersey's component of CARP is the New Jersey Toxics Reduction Plan which includes hydrodynamic, water, and suspended sediment quality studies in Newark Bay, the Arthur Kill, and Kill Van Kull (NJDEP, 2001; NJDEP/SIT, 2004). This work is coordinated with water and sediment quality sampling studies undertaken at the head-of-tide and within the tidal reaches of the major New Jersey tributaries that discharge to NJ/NJ Harbor Estuary. From September 1998 to October 2000, surface water samples were collected from 20 ambient sampling stations, including five sampling stations located within the Inventory Area (Figures 3-1a through 3-1c). Surface water sampling was conducted with a trace organics platform sampler due to the low concentrations of several of the contaminants of concern (Litten and Fowler, 1999; Litten et al., 1999; NYSDEC, 2003). Large volumes of ambient water were continuously pumped through the trace organics platform sampler for 4 to 6 hours to obtain the sample sizes needed to detect the target organic analytes. The suspended sediment fraction was collected using a series of glass fiber cartridges and flat filters, while the dissolved fraction was collected on a series 2 XAD-resin columns. Surface water samples were analyzed for polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), PCBs, pesticides, polycyclic aromatic hydrocarbons (PAHs), inorganic chemicals, as well as particulate organic carbon, DOC, and suspended sediments. The results from these sampling events are summarized in Tables 3-11a through 3-11f. No raw data are presented in NYSDEC (2003). This document is provided in electronic format in Appendix C – Water Data. Some CARP data have been presented in Creed et al. (2001) and Rankin et al. (2001). Additionally, Rankin (2001) summarizes the acoustic Doppler current profiler (ADCP); conductivity, temperature, depth (CTD); optical backscatter sensor; and laser *in-situ* scattering and transmissometer collection activities at the following internet site:

http://marine.rutgers.edu/mrs/newark/pubs.html

No CTD data were provided.

Surface water sampling was performed by Science Applications International Corporation (SAIC) in June and July 1991 and January 1992 (SAIC, 1993) as part of the NY/NJ HEP to document the nature and severity of environmental water quality problems in the NY/NJ Harbor Estuary. Fourteen water sampling stations were located within the Inventory Area (four locations in Newark Bay, four locations in Kill Van Kull, and six locations in Arthur Kill). Sampling locations are presented in Figure 3-1a. Grab samples were collected from three depths (1 m below the surface, mid-depth below the pycnocline, and 1 m above the bottom). Samples were analyzed for total recoverable inorganic chemicals (Ag, As, beryllium [Be], Cd, Cr, Cu, Hg, Ni, Pb, antimony [Sb], selenium [Se], titanium, and Zn), TOC, and total ammonia by USEPA's Environmental Services Division in Edison, NJ. TOC results in the Inventory Area were 5 mg/L, while total ammonia ranged from 0.28 to 0.92 µg/L. Results of the surface water samples for inorganic chemicals are summarized below. Raw data are provided in electronic format in Appendix C – Water Data.

Location	Inorganic Chemicals Concentration Range (µg/L)												
	Ag	As	Be	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Se	Ti	Zn
Newark Bay	7 to 11	ND to 1.3	ND to 3.0	ND to 4.8	ND	ND to 4.5	ND to 0.61	ND	ND	ND	ND	ND	ND to 16
Kill Van Kull	ND to 14	ND to 5	ND	ND	ND	ND to 3.7	ND	ND	ND	ND	ND	ND	ND to 10
Arthur Kill	ND to 8.8	ND to 5	ND	ND	ND	ND to 4.3	ND	ND	ND	ND	ND	ND	ND to 19.2

Note:
ND = not detected

In April 1999, the USACE removed five derelict barges from the Passaic River. From April 9 through April 11, 1999, sampling and monitoring activities were performed by Blasland, Bouck & Lee, Inc. (BBL), during the removal of four of the five barges (Su et al., 2002; Tierra, 1999e). The sampling areas are presented in Figure 3-1c. Under this program, nine water column samples and three filterable solids samples were collected from the Passaic River to characterize the chemical nature (including TSS) of the water column during removal operations. Unfiltered water column samples were collected at approximately 80% of the water depth and analyzed for inorganic chemicals, total cyanide, total extractable petroleum hydrocarbons (TEPH), ammonia-nitrogen, TKN, TOC, DOC, TSS, PCB congeners, 2,3,7,8-substituted PCDD/Fs, herbicides, pesticides, PCB Aroclors, PAHs, and VOCs. Water-column samples were composites of two samples collected approximately 20 to 40 ft apart. Results of the unfiltered surface water samples are summarized in Table 3-12a. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Filterable solids samples were collected at approximately 80% of the water depth. At each location, water was collected in 5-gallon carboys and filtered at an on-shore location. Results of the filtered solids are presented in Table 3-12b. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. In addition, BBL monitored temperature, pH, DO, and turbidity *in situ* in the water column during this sampling event. Measurements were obtained for every 2 ft of water depth. Table 3-12c summarizes these water quality measurements. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

ChemRisk conducted a biological and surface water sampling program in the lower1 Passaic River (Tierra, 1995a). Surface water samples were collected from two locations (Figure 3-1c). Samples were analyzed for PCDD/Fs and the results of these analyses are presented below. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Author's Sampling Location	Concentration Range (ppt)	
	Total PCDDs	Total PCDFs
Passaic River - WAT1	0.175	0.108
Passaic River - WAT2	0.366	0.175

EA, Engineering, Science, and Technology (EA) collected physicochemical data as part of the RI activities for the lower 6 miles of the Passaic River in 1995 and 1996 (Tierra, 1996b; 2004a,b,c,d). The objective of this study was to obtain data for use in calibrating a sediment transport model (Tierra, 2004a,b,c,d). This study included the collection of 1,318 TSS samples and performing CTD casts over the course of a complete tidal cycle during each of three sampling rounds:

- Round 1 – July 6, 1995 through August 2, 1995;
- Round 2A – April 1, 1996 through April 23, 1996; and
- Round 3 – May 6, 1996 through May 31, 1996.

1,318 TSS samples were collected at five locations laterally across the channel of the River at each of eight cross-sections from the mouth to a location 6 miles upriver. The eight cross-sections are depicted in Figure 3-1c. For Round 1, a depth-integrated sample and a discrete near-bottom sample (total of two samples) were collected at each location for TSS analysis, while individual discrete samples were collected over a range of depths (up to five discrete depths based on water column depth) at each location during Round 2A and 3. In addition to the transect sampling, 28 TSS samples were collected at current meter mooring locations. The results of the TSS samples are summarized below. Raw data are provided in Appendix C – Water Data.

Parameter	Round 1	Round 2A	Round 3
TSS (mg/L)	5.0 to 1,600	5.0 to 642	5.0 to 4,540

Similarly, CTD casts were conducted at mid-channel stations along the eight cross-sections as well as at opportunistic times at current meter mooring locations. Temperature, pH, and conductivity data were collected continuously (approximately every 0.5 seconds) from the water surface to above the river bed. Salinity was calculated using conductivity and temperature data. The results of the salinity, pH, and temperature measurements are summarized below. Raw data are provided in Appendix C – Water Data.

Parameter	Round 1	Round 2A	Round 3
Salinity (0/00)	0.22 to 24	0.020 to 16	0.14 to 15
Temperature (^{o}C)	24 to 29	7.0 to 16	12 to 22
pH	6.0 to 7.9	5.3 to 7.9	6.1 to 8.0

ChemRisk conducted a CSO sampling program in 1997 in the lower Passaic River (Tierra, 1997b). Sampling was conducted on September 18, 1997 (dry-weather conditions) and November 1, 1997 (wet-weather conditions). Surface water samples were collected from three CSOs during dry-weather conditions and six CSOs during wet-weather conditions (Figure 3-1c). Samples were analyzed for organic, inorganic, and water quality parameters. The results are summarized in Table 3-13 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

The PA NY/NJ periodically dredges Newark Bay Reaches A, B, C, and D to maintain sufficient channel and berth depths for commercial shipping. In May and June 1999, BBL conducted two dredge monitoring programs: one in May 1999 to obtain baseline surface water data in Reaches A, B, C, and D for future comparisons (Tierra, 1999a); and the other in June 1999 to monitor dredging activities in Reach A (Tierra, 1999c). In May 1999, surface water samples were collected from six locations – two within Reach A, two within Reach C, and one each within Reaches B and D (Figure 3-1a). One unfiltered sample was collected at each location by compositing discrete grab samples collected at 10-ft depth intervals and analyzing for TSS. Results of the TSS samples ranged from 8 to 14.8 mg/L. Raw data for TSS are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. In addition, *in situ* measurements of temperature, salinity, alkalinity, pH, DO, and turbidity were obtained for every 10 ft of water depth extending to the sediment/water interface (generally 40 to 45 ft below the water surface) at each location. Raw data for the water quality measurements are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0, and are summarized below.

Location	Turbidity (NTU)	Conductivity (mS/cm)	pH	Salinity (0/00)	DO (mg/L)	Temperature (°C)
Reach A	5.0 – 9.3	22.6 – 23.9	7.49 – 7.66	18.07 – 19.7	8.41 – 9.42	12.15 – 13.10
Reach B	7.8 – 10.7	22.6 – 24.4	7.58 – 7.62	18.12 – 19.97	8.47 – 8.87	12.57 – 13.06
Reach C	8.5 – 14.0	22.8 – 24.5	7.53 – 7.69	18.11 – 20.04	9.3 – 10.68	12.4 – 13.52
Reach D	5.4 – 7.0	23.0 – 24.4	7.59 – 7.71	18.16 – 19.95	10.27 – 11.81	12.69 – 13.62

In June 1999, water quality monitoring (temperature, salinity, pH, DO, and turbidity) was conducted for every 10 ft of water depth to a maximum depth of 40 ft at locations corresponding to dredging activities (Figure 3-1a). At least one measurement was taken each day at the mouth of Reach A in an effort to measure sediment flux into Newark Bay. Measurements were taken at additional locations depending on the location of dredging activities. Results of the water quality measurements are summarized in Table 3-14a. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Three surface water samples were collected in Reach A during dredging operations. Water samples were collected at a discrete depth (20 to 30 ft) based on the interval exhibiting the highest turbidity measurement during the water quality monitoring and analyzed for TSS, PCDD/Fs, PCBs (congeners and Aroclors), inorganic chemicals, pesticides, herbicides, SVOCs, and total petroleum hydrocarbons (TPH). Results are summarized in Table 3-14b. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. In addition to collecting water samples, approximately 35 L of water were filtered to obtain a filterable solids sample. This sample was analyzed for PCDD/Fs and PCBs. Results of the total PCDD/Fs were 3.7 and 1.7 µg/kg, respectively, while total PCBs were 430 µg/kg. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

As part of the evaluation for the construction of a CDF location, the USACE (1997a) presents the results of NYCDEP's and Battelle's (1992a) waste load allocation study performed in 1991, as well as water quality data collected near Shooter's Island from 1991 through 1994 previously reported in NYCDEP's annual report (NYCDEP, 1993). The results of the NYCDEP/Battelle study were previously discussed. A summary of water quality concentrations at Shooter's Island are presented below, as provided in USACE (1997a). No specific sampling locations or raw data were provided.

Parameter	1991	1992	1993	1994
DO (mg/L)	5.0	5.9	8.5	7.0
TSS (mg/L)	15	NA	20	13
Secchi disk (ft)	4.4	4.8	5.0	4.3
Dissolved ammonia (mg/L)	0.54	0.49	0.49	0.50
Nitrate & nitrite nitrogen (mg/L)	0.49	0.57	0.68	0.55
Total phosphorous (mg/L)	0.23	0.17	0.18	0.20
Ortho-phosphate (mg/L)	0.16	0.16	0.12	0.15
BOD 5-day (mg/L)	1.3	1.4	1.5	1.2

Note:
NA = not analyzed

As part of the NY/NJ HDP environmental impact assessment (USACE, 1999a), water quality data (salinity, temperature, DO, and several other parameters) were collected in 1991 and 1994–1995 to aid in calibration of a hydrodynamic model (USACE, 1999a). These water quality data results were not provided by USACE.

Additional water quality data were collected during the USACE 2001–2002 Aquatic Biological Sampling Program and the 2002–2003 Aquatic Biological Sampling Program (USACE, 2003a,b,c). The Aquatic Biological Sampling Programs measured water quality parameters (DO, temperature, conductivity, and salinity) in three study areas: Arthur Kill/Newark Bay, Upper Bay, and Lower Bay. The Arthur Kill/Newark Bay area is included in the Inventory Area and includes nine sampling locations: two locations in Arthur Kill shallow/shoal areas, two locations in Arthur Kill/Kill Van Kull confluence area, three locations in Newark Bay shallow/shoal areas, and two locations in the Newark Bay navigational channel (Figure 3-1a). The water quality data are summarized in Table 3-15 for each of the sampling programs. Raw data are provided in electronic format in Appendix C – Water Data.

In 1993 and 1994, the USEPA Regional Environmental Monitoring and Assessment Program (R-EMAP) conducted environmental sampling in the NY/NJ Harbor Estuary (USEPA, 1998). For the purposes of this study, USEPA separated the NY/NJ Harbor into six geographic areas: Upper Harbor, Newark Bay, Lower Harbor (includes Raritan and Sandy Hook Bays), Jamaica Bay, western Long Island Sound, and the New York Bight Apex. Of these six areas, the Newark Bay area, which includes Newark Bay, Arthur Kill, Kill Van Kull, and the lower Passaic and Hackensack Rivers, includes most of the Inventory Area (Figure 3-1a). *In situ* water quality measurements, including DO, pH, temperature, and salinity, were collected from each of the sampling areas. Water quality measurements were taken from within 1 m of the water surface to approximately 1 m above the sediment/water interface. Water clarity was measured using a 20 cm Secchi disk. The USEPA (1998) presented the Newark Bay area water quality measurements as surface and bottom area-weighted means (±90% confidence interval) as summarized below. Raw data for water quality measurements are available at the following USEPA internet site:

http://www.epa.gov/emap/remap/html/two/data/nynj.html

Parameter	Values
Temperature (°C) – surface	20 – 28
Temperature (°C) – bottom	20 – 28
Salinity (ppth) – surface	1.3 – 25
Salinity (ppth) – bottom	1.3 – 26
DO (mg/L) – surface	3.1 – 12
DO (mg/L) – bottom	3.0 – 12
pH – surface	7.1 – 7.6
pH – bottom	7.1 – 7.7

The U.S. Geological Survey (USGS) collects continuous river flow measurements and water quality data from a variety of waterways. In 2001, USGS (2001) documented streamflow data as well as a discussion of inputs for Passaic River and Hackensack River basins from 1993–1996. Additionally, USGS provides historical and real-time flow measurements and water quality data (at select gaging stations), including DO, conductivity, temperature, pH, and turbidity, on the following internet site:

http://waterdata.usgs.gov/nj/nwis/sw

The observed streamflows for August through September and March through April from 1993–1996 for streamflow gaging stations on the Passaic River are summarized below:

USGS Streamflow-Gaging-Station Number	Observed Streamflow			
	August – September		March – April	
	Ft^3/second	Ft^3/second/mi^2	Ft^3/second	Ft^3/second/mi^2
01378690	6.7	0.8	35.4	4.0
01379000	22.6	0.4	215	3.9
01379500	52.5	0.5	376	3.8
01379580	71.3	0.5	468	3.5
01381900	192	0.6	1,370	3.9
01382000	199	0.6	1,420	3.9
01389005	321	0.4	2,290	3.1
01389500	260	0.3	2,340	3.1
01389880	282	0.4	2,420	3.0

3.2.1.2 Ground Water

There were two studies identified that contain information linking groundwater data to the environmental conditions of the Inventory Area (Table 3-2). Both were conducted since 1990, and are summarized below.

2B Environmental, Inc. (2B, 1997) presented a petition to reclassify groundwater in the Ironbound section of Newark, NJ, from a potable Class II-A Area to a non-potable Class II-B Area on behalf of 20 companies located in this area. This document provides an overview of historical industrial activity in the area, land use, hydrologic conditions, groundwater quality, and an assessment of the impact of groundwater on local receptors. A list of facilities in the petition area is provided along with well locations, ownership, and well characteristics. Out of 57 sites with groundwater data in the petition area, there were 22 chemicals in groundwater detected above New Jersey Ground Water Quality Standards at 10 or more sites; this information is summarized below. Summary tables and raw data presenting historic groundwater data from select monitoring wells are provided in electronic format in Appendix C – Water Data.

Groundwater Chemicals Detected at 10 or More Sites Above NJ Groundwater Quality Standards	Number of Sites Exceeding NJ Groundwater Quality Standards out of 57 Sites with Groundwater Data
BTEX	
Benzene	38
Toluene	22
Ethylbenzene	17
Xylene	24
VOCs	
1,1 Dichloroethane	11
1,1,1-Trichloroethane	13
1,2-Dichloroethane	13
Chlorobenzene	26
Tetrachloroethene	20
Trichloroethene	27
Methylene Chloride	28
Vinyl Chloride	17
Chloroform	11
SVOCs	
Bis(2-ehtylhexyl)phthalate	10
Inorganic Chemicals	
Sb	10
As	28
Cd	13
Cr	12
Pb	29
Hg	14
Ni	11
Zn	11

On behalf of the PA NY/NJ, Weston (1998) presented a petition to reclassify shallow groundwater beneath the area occupied by Newark International Airport and the Port Newark/Elizabeth Port Authority Marine Terminal, New Jersey. This petition sought to amend and designate the shallow groundwater beneath the proposed reclassification area from a potable Class II-A Area to a non-potable Class II-B Area. Additionally, this document provides an overview of historical industrial activity in the area, land use, hydrologic conditions, groundwater quality, and an assessment of the impact of groundwater on local receptors. A listing of facilities in the petition area is provided along with well locations, ownership, and well characteristics. A summary of groundwater concentration ranges from multiple studies are presented in the following table. Monitoring well logs, summary tables, and raw data presenting historic groundwater data from select monitoring wells are provided. The entire document has been provided in electronic format in Appendix C – Water Data.

Groundwater Chemistry	Concentration Range (µg/L)
Inorganic Chemicals	
As	2 – 5,100
Ba	57 – 3,140
Cd	0.79 – 228
Cr	12.1 – 1,280
Cu	3.6 – 3,390
Pb	2 – 22,500
Hg	0.30 – 432
Ni	18 – 670
Sb	23 – 41
Se	1.4 – 510
Tl	5.0 – 36
Zn	4.2 – 10,900
BTEX	
Benzene	0.071 – 11,000
Toluene	0.12 – 100,000
Ethylbenzene	60 – 3,000
Xylene	0.12 – 10,000
SVOCs	
Bis(2-ethylhexyl)phthalate	75
Other	
TEPH	1.4 – 324
Styrene	8 – 30
trichloroethylene	4 – 5
Acenapthene	1 – 1,400
Fluorene	1 – 880
Anthracene	29,000

3.2.1.3 Dredging Permit Applications

Twelve dredging permit applications filed since 1990 were identified that include surface water and (sediment) elutriate data. It is likely that a substantial number of additional dredging permit applications exist for this time period for the Inventory Area; however, these were not obtainable for this Report. The obtained permit applications are summarized below by waterway and test type (i.e., surface water or elutriate) and data contained within these permit applications are summarized in Tables 3-16a and 3-16b. Locations of the sites described in the dredging permit applications are depicted in Figure 3-2. A copy of each of the dredging permit applications from 1990 to the present that contain water or elutriate data is provided in electronic format in Appendix C – Water Data.

Waterway	Surface Water Data	Elutriate Data
Newark Bay	PA NY/NJ (USACE, 1991b); USACE (1997b)	PA NY/NJ (USACE, 1991b); USACE (1997b)
Arthur Kill	Northville Linden Terminal Corporation (USACE, 1992c); CITGO Petroleum Corporation (USACE, 1997e); Consolidated Edison of New York (USACE, 1992d); PA NY/NJ (USACE, 1992b); Bayway Refining Company (USACE, 1993b); Mobil Oil Corporation (USACE, 1997i)	Northville Linden Terminal Corporation (USACE, 1992c); CITGO Petroleum Corporation (USACE, 1997e); Consolidated Edison of New York (USACE, 1992d); PA NY/NJ (USACE, 1992b); Bayway Refining Company (USACE, 1993b); Mobil Oil Corporation (USACE, 1997i)
Kill Van Kull	Federal Navigation Project (USACE, 1999k); EXXON Company, USA (USACE, 1997g)	Federal Navigation Project (USACE, 1999k); EXXON Company, USA (USACE, 1997g)
Passaic River	Celanese Chemical Company, Inc. (USACE, 1991a)	Celanese Chemical Company, Inc. (USACE, 1991a)
Hackensack River	None identified	None identified

The locations represented by these dredging permit applications are presented in Figure 3-2. Summaries of the surface water and elutriate chemistry data from these 12 permit applications are provided in Tables 3-16a and 3-16b.

3.2.1.4 Summary of Available QA/QC for Water Studies

The water studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. Available QA/QC information for each water study from 1990–present is presented in Table 3-17.

3.2.2 Sediment

A variety of sediment studies have been performed in the Inventory Area to evaluate the concentrations of various organic and inorganic chemicals. One hundred two identified sediment studies are summarized in Table 3-18. Seventy-six identified sediment studies that have been conducted since 1990 are discussed in greater detail below. Figures 3-3a through 3-4b present the sampling locations of the sediment sampling events from 1990–present. Raw data from several of these studies are presented in tables or electronic format in Appendix

B – Newark Bay Study Area Analytical Database Version 1.0 or Appendix C – Water Data. Twenty-six identified surface water studies that were conducted prior to 1990 are briefly summarized in Table 3-18.

The majority of the sediment investigations in the Inventory Area to date have been conducted under major government programs/initiatives and by studies sponsored by Tierra. The data from these studies, referred to as the primary sediment investigations in this section of the Report, are included in the Newark Bay Study Area Analytical Database Version 1.0 (Appendix B). A graphical presentation of select data from these studies is provided in Figures 3-5 through 3-7p. This graphical presentation includes the following chemicals or groups of chemicals that are typically considered to be the primary contaminants of concern in the NY/NJ Harbor Estuary (NY/NJ HEP, 2004a):

- PCDD/Fs (represented by the key congeners 2,3,7,8-PCDD and 2,3,7,8-PCDF) (Figures 3-5a through 3-5p);
- Total PAHs (Figures 3-6a through 3-6p);
- Total PCBs (as the sum of Aroclors) (Figures 3-6a through 3-6p);
- Total DDT (Figures 3-6a through 3-6p);and
- Select inorganic chemicals (As, Cd, Cu, Pb, Hg, Ni, and Zn) (Figures 3-7a through 3-7p).

The additional sediment studies described in this section were generally smaller in scope than the primary sediment investigations. The raw data for many of these studies are provided in Appendix D – Sediment Data.

3.2.2.1 Primary Sediment Investigations

ChemRisk (1995) conducted surface sediment sampling was conducted at six locations on August 10 and 11, 1994 (Figures 3-3a through 3-3i) (Tierra, 1994a). At each location, four replicate grab samples were collected. Three of the four replicate samples from each location were used to characterize the benthic invertebrate communities within the sediment sample. Grain size analyses were conducted on the fourth replicate sample. The grain size data are summarized in Table 3-19 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

On July 30, 1999, Hart Crowser (1999) conducted sediment sampling in Newark Bay, the Passaic River, Plum Creek, and Arthur Kill at five sampling locations (Tierra, 1999b). A total of 12 sediment samples were collected from depth intervals of 0 to 1 ft, 1 to 3 ft, and 3 to 5 ft. The sediment samples were analyzed for acid volatile sulfides (AVS), simultaneously extractable metals (SEM), ammonia nitrogen, pH, percent moisture, PAHs, PCDD/Fs, inorganic chemicals, total cyanide, PCBs, pesticides, SVOCs, and TOC. Sampling locations are depicted in Figures 3-3a through 3-3i. Concentrations of select chemicals are presented in Figures 3-3a through 3-3i. The results are summarized in Table 3-20 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Beginning in 1991, a survey of the toxicity of sediments in the NY/NJ Harbor was performed by NOAA's National Status and Trends Program (NOAA, 1995b). Phase I of this study included sediment sampling in Newark Bay, Arthur Kill, and other areas within the NY/NJ Harbor Estuary area. Phase II of this study included sampling 20 locations in the lower Passaic River. Sampling locations are depicted in Figures 3-3a through 3-3i. At each sampling location, approximately 2 gallons of sediment from the upper 1 in. of sediment bed were collected. Samples were analyzed for inorganic chemicals, AVS/SEM, PAHs, chlorinated pesticides, PCB congeners, and PCDD/Fs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results of this investigation are presented in NOAA (1995b) and Wolfe et al. (1996) and are summarized in Tables 3-21a and 3-21b. Raw data from these studies are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Under the NY/NJ HEP CARP the NYSDEC collected 91 surface sediment grab samples and 43 sediment cores (NYSDEC, 2003) (Figures 3-3a through 3-3i). NYSDEC (2003) presents only limited sediment data from these samples, including pesticide results for surface sediments. These are presented below. The data type for the pesticide results (e.g., average, median, individual result) and the sampling locations are not provided by NYSDEC (2003).

Location	Concentration Range (µg/kg)					
	Aldrin/Dieldrin	HCB	Heptachlor	Total HCH	Total Chlordane	Total DDT
Passaic River	40	36	6	5.4	370	840
Arthur Kill	18	62	0.4	2.7	88	3,900
Hackensack River	27	20	1.5	2	99	320

Location	Concentration Range (µg/kg)					
	Aldrin/Dieldrin	HCB	Heptachlor	Total HCH	Total Chlordane	Total DDT
Newark Bay	10	8.7	0.14	1.1	47	350

Notes:
HCB = hexachlorobenzene
HCH = hexachlorocyclohexane
Total HCH = sum of HCH, alpha; HCH, beta; HCH, delta;, HCH, gamma
Total DDT = sum of 2,4'-DDD, 2,4'-DDE, 2,4'-DDT,4,4'-DDD, 4,4'-DDE, 4,4'-DDT
Total chlordane = chlordane, alpha (cis); chlordane, gamma (trans); chlordane, oxy-; nonachlor, cis-; nonachlor, trans-.

In February 1990, ChemRisk collected 19 surface sediment samples within the Inventory Area (Tierra, 1990). Sampling locations in the lower Passaic River and Newark Bay were selected based on historical information concerning industrial and municipal disposal practices in the area. Sampling locations are depicted in Figures 3-3a through 3-3i. Surface sediment grab samples (0 to 0.5 ft) were collected and analyzed for total cyanide, PCDD/Fs, inorganic chemicals, PCBs, pesticides, percent moisture, SVOCs, and PAHs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Select results from this sampling are presented in Bonnevie et al. (1992), Finley et al. (1990), Gillis et al. (1993), and Iannuzzi et al. (1995). The chemicals of interest and major findings of these documents (as they pertain to the 1990 dataset) are summarized in the table below. Table 3-22 summarizes the results of the 1990 surface sediment investigation, while the raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Reference	Chemicals of Interest	Major Findings (as reported by authors)
Bonnevie et al. (1992)	Pb	Presence of Pb in surface sediments in the Newark Bay Estuary may pose a threat to aquatic organisms.
Finley et al. (1990)	PCDD/Fs	Principal components analysis (PCA) and cluster analysis of PCDD/Fs data indicate that surficial sediments from lower Passaic River and Newark Bay contain elevated distributions of PCDD/Fs from a number of likely sources.
Gillis et al. (1993)	Hg	Sediments in the Newark Bay Estuary contain Hg at concentrations that exceed background levels and benchmark sediment quality guidelines.
Iannuzzi et al. (1995)	PCBs	Data from the lower Passaic River suggest that PCB contamination in sediment is due to the relatively high depositional environment and accumulation of PCB contamination from local and upstream sources.

ChemRisk conducted a core sediment investigation from November through December 1991 to collect data to characterize the distribution, sources, and depositional history of chemical contaminants in sediments (Tierra, 1991). A total of 511 samples were collected from 33 core locations in the lower Passaic River. Sampling locations are depicted in Figures 3-3a through 3-3i. Surface sediment grab samples (0 to 0.5 ft) and cores, which had a target depth of either 10 or 20 ft, were collected. Core lengths varied from 3.0 ft to 20.0 ft. Sediment samples were collected for analysis from 1-in (radiochemical analyses) or 2-in (chemical analyses) segments at pre-determined sampling intervals for each core. Samples were analyzed for total cyanide, PCDD/Fs, ^{137}Cs, ^{210}Pb, inorganic chemicals, organotins, PCBs, pesticides, SVOCs, PAHs, TOC, and TPH. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Select results from this investigation are presented in Bonnevie et al. (1993), Ehrlich et al. (1994), Gillis et al. (1995), Huntley et al. (1993; 1995a,b; 1998), Iannuzzi et al. (1995), Scott et al. (2000), Wallin et al. (2002), and Wenning et al. (1994). The chemicals of interest and major findings of these documents (as they pertain to the 1991 dataset) are summarized in the table below. The results of the 1991 core sediment investigation are summarized in Table 3-23 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Bonnevie et al. (1993)	inorganic chemicals	Inorganic chemicals concentrations were generally higher at depth than at the surface, which suggests a decline in recent inputs as compared to historical discharges.
Ehrlich et al. (1994)	PCDD/Fs	Polytopic vector analysis (PVA) was used to develop a five end-member mix model using data from the 1991 and other investigations.
Gillis et al. (1995)	DDT, DDD, & DDE	DDT, DDE, and DDD are found at levels that may be hazardous to aquatic organisms and birds.
Huntley et al. (1993)	PAHs & TEPH	Elevated PAH concentrations often occurred in sediments with high TEPH concentrations. High PAH concentrations were generally higher at depth, which suggests a decline in recent inputs as compared to historical discharges.
Huntley et al. (1995a)	PAH & TEPH	PAH and TEPH contamination is widespread in sediments of the Passaic River above Dundee Dam and in the lower Passaic River. Chemical “hot spots” are proximate to suspected point sources and CSOs.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Huntley et al. (1995b)	sedimentation rates with ^{137}Cs & ^{210}Pb	Profiles of ^{137}Cs and ^{210}Pb in sediment cores collected in the lower Passaic River provide evidence of continual sediment deposition and high rates of sediment accretion.
Huntley et al. (1998)	PCDD/Fs	PVA was used to analyze PCDD/F from several sites. Results suggest that sources associated with PCB contamination, sewage sludge, and combustion have been the primary contributors to PCDD/F contamination of subsurface sediments in the lower Passaic River.
Iannuzzi et al. (1995)	PCBs	Elevated concentrations of PCB Aroclors and several non-ortho and mono-ortho coplanar PCBs in the Passaic River suggest the presence of ongoing sources. Data from the lower Passaic River suggest that Aroclors and coplanar PCB contamination in sediment is due to the relatively high depositional environment and accumulation of PCB contamination from local and upstream sources.
Scott et al. (2000)	2,3,7,8-TCDD & coplanar PCBs	Several datasets were used to evaluate three methods of determining exposure concentrations: 95% upper confidence limits (UCLs) of the arithmetic mean for normal distribution, 95% UCLs of the arithmetic mean for lognormal distribution, and area-weighted mean using Thiessen polygons. Area-weighted mean is the most appropriate method for developing representative site concentrations with very heterogeneous site data.
Wallin et al. (2002)	inorganic chemicals & several organics	The presence of inorganic chemicals, DDT, and PAHs in surface and buried sediments in the lower Passaic River has historically adversely impacted the benthic community.
Wenning et al. (1994)	inorganic chemicals, PCBs, & PAHs	Comparisons to benchmark toxicity values suggest that the average concentrations of Pb, Hg, Ni, Zn, several PAHs, and total PCBs in the lower Passaic River may pose a threat to aquatic organisms.

ChemRisk conducted a core sediment investigation in December 1992 to supplement the 1991 investigation (Tierra, 1992). A total of 101 samples (including three duplicates) were collected from 16 cores in the lower Passaic River. Sampling locations are depicted in Figures 3-3a through 3-3i. Sediment samples were collected for analysis from 1-in (radiochemical analyses) or 2-in (chemical analyses) segments from pre-determined sampling intervals for each core. Samples were analyzed for total cyanide, PCDD/Fs, ^{137}Cs, ^{210}Pb, inorganic chemicals, organotins, PCBs, pesticides, SVOCs, PAHs, TOC, TPH, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Core lengths varied from 4.2 ft to 9.2 ft. Select results from this investigation are presented in Ehrlich et al. (1994), Gillis et al. (1995), Huntley et al. (1995a; 1998), Iannuzzi and Wenning (1995), Iannuzzi et al. (1995), Scott et al. (2000), Wallin et al. (2002), and Wenning et al. (1994). The chemicals of interest and major findings of these documents (as they pertain to the 1992 and earlier datasets) are summarized in the table below. The results of the 1992 core sediment investigation are summarized in Table 3-24 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Ehrlich et al. (1994)	PCDD/Fs	PVA was used to develop a five end-member mix model using data from the 1992 and other investigations
Gillis et al. (1995)	DDT, DDD, & DDE	DDT, DDE, and DDD are found at levels in surface sediments that may be hazardous to aquatic organisms and birds.
Huntley et al. (1995a)	PAH & TEPH	PAH and TEPH contamination is widespread in the Passaic River above Dundee Dam and in lower Passaic River. Chemical "hot spots" are proximate to suspected point sources and CSOs.
Huntley et al. (1995b)	sedimentation rates with ^{137}Cs & ^{210}Pb	Profiles of ^{137}Cs and ^{210}Pb in sediment cores collected in the lower Passaic River provide evidence of continuing sediment deposition and high rates of sediment accretion.
Huntley et al. (1998)	PCDD/Fs	PVA was used to analyze PCDD/F from several sites. Results suggest that sources associated with PCB contamination, sewage sludge, and combustion have been the primary contributors to PCDD/F contamination of subsurface sediments throughout the lower Passaic River.
Iannuzzi and Wenning (1995)	Hg	Total Hg concentrations at depth were generally higher than at the surface. Hg concentrations throughout Newark Bay Estuary were detected at concentrations exceeding effects-range low and median benchmark toxicity values (0.15 and 0.71 mg/kg, respectively).
Iannuzzi et al. (1995)	PCBs	Elevated concentrations of PCB Aroclors and several non-ortho and mono-ortho coplanar PCBs in the Passaic River indicate the presence of ongoing sources. Data from the lower Passaic River suggest that Aroclors and coplanar PCB contamination in sediment is due to the relatively high depositional environment and accumulation of PCB contamination from local and upstream sources.
Scott et al. (2000)	2,3,7,8-TCDD & coplanar PCBs	Several datasets were used to evaluate three methods of determining exposure concentrations: 95% UCLs of the arithmetic mean for normal distribution, 95% UCLs of the arithmetic mean for lognormal distribution, and area-weighted mean using Thiessen polygons. Area-weighted mean is the most appropriate method for developing representative site concentrations with very heterogeneous site data.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Wallin et al. (2002)	inorganic chemicals & several organics	The presence of inorganic chemicals, DDT, and PAHs in surface and buried sediments in the lower Passaic River has historically adversely impacted the benthic community.
Wenning et al. (1994)	inorganic chemicals, PCBs, & PAHs	Comparisons to benchmark toxicity values suggest that the average concentrations of Pb, Hg, Ni, Zn, several PAHs, and total PCBs in the lower Passaic River may pose a threat to aquatic organisms.

ChemRisk conducted a core sediment investigation in March 1993, to supplement the previous sediment investigations (i.e., 1990 surface sediment investigation, 1991 core sediment investigation, and 1992 core sediment investigation) (Tierra, 1993). A total of 124 samples were collected in March 1993 from 17 sediment core locations in the lower Passaic River. Sampling locations are depicted in Figures 3-3a through 3-3i. Core lengths varied from 0.17 ft to 9.0 ft. Samples were analyzed for PCDD/Fs, ^{137}Cs, ^{210}Pb, inorganic chemicals, organotins, PCBs, pesticides, SVOCs, PAHs, TOC, and TPH, as well as radiochemistry. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Cores were collected to a depth of 6 ft or to refusal at each location. Select results from this investigation are presented in Ehrlich et al. (1994), Gillis et al. (1995), Huntley et al. (1995a; 1998), Iannuzzi and Wenning (1995), Iannuzzi et al. (1995), and Scott et al. (2000). The chemicals of interest and major findings of these documents (as they pertain to the 1993 and earlier datasets) are summarized in the table below. The results of the 1993 (March) core sediment investigation are summarized in Table 3-25 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Ehrlich et al. (1994)	PCDD/Fs	PVA was used to develop a five end-member mix model using data from the 1992 and other investigations
Gillis et al. (1995)	DDT, DDD, & DDE	DDT, DDE, and DDD are found at levels in surface sediments that may be hazardous to aquatic organisms and birds.
Huntley et al. (1995a)	PAH & TEPH	Profiles of ^{137}Cs and ^{210}Pb in sediment cores collected in the lower Passaic River provide evidence of continuing sediment deposition and high rates of sediment accretion.
Huntley et al. (1998)	PCDD/Fs	PVA was used to analyze PCDD/F from several sites. Results suggest that sources associated with PCB contamination, sewage sludge, and combustion have been the primary contributors to PCDD/F contamination of subsurface sediments throughout the lower Passaic River.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Iannuzzi and Wenning (1995)	sedimentation rates with ^{137}Cs & ^{210}Pb	Total Hg concentrations at depth were generally higher than at the surface. Hg concentrations throughout Newark Bay Estuary were detected at concentrations above both effects-range low and median benchmark toxicity values (0.15 and 0.71 mg/kg, respectively).
Iannuzzi et al. (1995)	Hg	Elevated concentrations of PCB Aroclors and several non-ortho and mono-ortho coplanar PCBs in the Passaic River indicate the presence of ongoing sources. Data from the lower Passaic River suggest that Aroclors and coplanar PCB contamination in sediment are due to the relatively high depositional environment and accumulation of PCB contamination from local and upstream sources.
Scott et al. (2000)	2,3,7,8-TCDD & coplanar PCBs	Several datasets were used to evaluate three methods of determining exposure concentrations: 95% UCLs of the arithmetic mean for normal distribution, 95% UCLs of the arithmetic mean for lognormal distribution, and area-weighted mean using Thiessen polygons. Area-weighted mean is the most appropriate method for developing representative site concentrations with very heterogeneous site data.

ChemRisk collected an additional 173 samples from 11 sediment core locations in the lower Passaic River in July 1993 (Tierra, 1993). Sampling locations are depicted in Figures 3-3a through 3-3i. Cores were collected to a depth of 6 ft or to refusal at each location. Cores varied in length from 0.9 ft to 14.7 ft. Sediment samples were collected for analysis from 1-in (radiochemical analyses) or 2-in (chemical analyses) segments from pre-determined sampling intervals for each core. Samples were analyzed for PCDD/Fs, ^{137}Cs, ^{210}Pb, inorganic chemicals, organotins, PCBs, pesticides, SVOCs, PAHs, TOC, TPH, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Select results from this investigation are presented in Iannuzzi and Wenning (1995) and Wallin et al. (2002). The chemicals of interest and major findings of these documents are summarized (as they pertain to the 1993 and earlier datasets) in the table below. The results of the July 1993 core sediment investigation are summarized in Table 3-26 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Author	Chemical(s) of Interest	Major Findings (as reported by the authors)
Iannuzzi and Wenning (1995)	sedimentation rates with ^{137}Cs & ^{210}Pb	Profiles of ^{137}Cs and ^{210}Pb in sediment cores collected in the lower Passaic River provide evidence of continuing sediment deposition and high rates of sediment accretion.
Wallin et al. (2002)	inorganic chemicals & several organic compounds	The presence of inorganic chemicals, DDT, and PAHs in surficial and buried sediments in the lower Passaic River has historically adversely impacted the benthic community.

ChemRisk conducted a surface sediment investigation in the lower Passaic River to evaluate the extent of chemical contaminants in the River sediment associated with the Worthington Avenue, Ivy Street, Herbert Place, and Second River CSOs (Tierra, 1994b). Ten surface sediment samples were collected in a radiating pattern in the immediate vicinity of each of the CSOs. Sampling locations are depicted in Figures 3-3a through 3-3i. In addition, one sample was collected from inside the Worthington Avenue CSO outfall pipe. Forty surface sediment grab samples were collected and analyzed for PCDD/Fs, target analyte list inorganic chemicals, total PCBs/pesticides, selected coplanar PCB congeners, SVOCs, TOC, TEPH, tetrachlorinated dibenzothiophene (TCDT) as a tentatively identified compound, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. This sampling event is described in Huntley, et al. (1997) and Iannuzzi et al. (1997). The chemicals of interest and major findings of these documents are summarized in the table below. The results of the 1994 CSO sediment investigation are summarized in Table 3-27 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Huntley et al. (1997)	PCDD/Fs & PCBs	PCA of PCBs and PCDD/Fs at CSOs suggest that CSOs are a source of contamination to the lower Passaic River.
Iannuzzi et al. (1997)	inorganic chemicals & several organic compounds	Many chemicals present in sediments adjacent to CSOs were linked to sources that discharge (or once discharged) to the CSOs.

In 1995, EA collected sediment cores from the lower 6 miles of the Passaic River for chemical, radiochemical, and geotechnical analysis as part of the RI activities (Tierra, 1995b,c; 2004a). Sampling locations are depicted in Figures 3-3a through 3-3i. A total of 658 samples (including 106 duplicates) were collected from 93 sediment core locations and analyzed for total cyanide, PCDD/Fs, ^{7}Be, ^{137}Cs, ^{210}Pb, herbicides, inorganic chemicals, PCBs, pesticides, SVOCs, PAHs, TOC, TPH, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. Select results from this sampling program are presented in Barabas et al. (2001), Scott et al. (2000), and Wallin et al. (2002), which are summarized in the table below. The results are summarized in Table 3-28a and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. A total of 1,046 (including nine duplicates) sediment samples from the 93 core locations were analyzed for ^{7}Be, ^{137}Cs, and ^{210}Pb. Results of the radiochemical analyses are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Additionally, 45 cores were collected for geotechnical analyses including specific gravity, Atterberg Limits, water content, bulk density, consolidation, grain size, rotating cylinder erosion measurements, Sedflume erosion measurements, vane shear (*in-situ* test), piezocone (*in situ*), and pocket penetrometer. Results of these geotechnical analyses are summarized in Table 3-28b and raw data are provided in Appendix D – Sediment Data.

Reference	Chemical(s) of Interest	Major Findings (as reported by the authors)
Barabas et al. (2001)	2,3,7,8-TCDD	2,3,7,8-TCDD data are used to illustrate a set of methodologies including: 1) using coordinate transformation and 3-D variography to model the spatial variability of contaminant concentrations in a river; and 2) presenting an application of indicator kriging for the assessment of uncertainty.
Scott et al. (2000)	2,3,7,8-TCDD & coplanar PCBs	Several datasets were used to evaluate three methods of determining exposure concentrations: 95% UCLs of the arithmetic mean for normal distribution, 95% UCLs of the arithmetic mean for lognormal distribution, and area-weighted mean using Thiessen polygons. Area-weighted mean is the most appropriate method for developing representative site concentrations with very heterogeneous site data.
Wallin et al. (2002)	inorganic chemicals & several organics	The presence of inorganic chemicals, DDT, and PAHs in surficial and buried sediments in the lower Passaic River has historically adversely impacted the benthic community.

EA conducted a surface sediment sampling effort on September 14, 1995, as part of the RI activities for the lower 6 miles of the Passaic River (Tierra, 1995d). Seven sediment grab samples (0 to 0.5 ft) were collected. Sampling locations are depicted in Figures 3-3a through 3-3i. The samples were analyzed for total cyanide and PCDD/Fs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-29 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

EA conducted a sediment core sampling effort on May 13, 1996, in Reach A of Newark Bay (Tierra, 1996a). Nine sediment samples were collected from four core locations. Sampling locations are depicted in Figures 3-3a through 3-3i. The samples were analyzed for total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, pesticides, percent moisture, SVOCs, PAHs, TOC, TPH, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-30 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

EA conducted a sediment core sampling effort on April 29, 1997, in Reaches B, C, and D of Newark Bay (Tierra, 1997a). Eleven sediment samples were collected from six core locations. Sampling locations are depicted in Figures 3-3a through 3-3i. The samples were analyzed for total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, pesticides, SVOCs, PAHs, TOC, TPH, and VOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-31 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

ChemRisk conducted a CSO sampling investigation in the lower Passaic River on September 18, 1997 (dry-weather conditions) and November 1, 1997 (wet-weather conditions) (Tierra, 1997b). Sampling locations are depicted in Figures 3-3a through 3-3i. Sediment sampling was conducted to evaluate and contrast analytical methods for quantifying PCBs in Passaic River sediments. Four surface sediment grab samples (0 to 0.5 ft) were collected at two locations. One sample was analyzed for cyanide, PCDD/Fs, herbicides, PCBs, inorganic chemicals, pesticides, TOC, TPH, and miscellaneous chemicals. Three of the samples were analyzed for only PCBs, pesticides, and physical properties. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-32 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

BBL collected five sediment samples from three sediment core locations in Elizabeth Channel, Newark Bay on April 7, 1998 (Tierra, 1998). Sampling locations are depicted in Figures 3-3a through 3-3i. Samples were analyzed for total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, pesticides, percent moisture, SVOCs, PAHs, TOC, and TPH. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-33 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

The PA NY/NJ periodically dredges Newark Bay Reaches A, B, C, and D to maintain sufficient channel and berth depths for commercial shipping. In May and June 1999, BBL performed two distinct dredge monitoring programs to obtain baseline sediment data in Reaches A, B, C, and D for future comparisons (May 1999 – Newark Bay Reach A, B, C, and D monitoring program) and to monitor dredging activities in Reach A (June 1999 – Newark Bay Reach A monitoring program) (Tierra, 1999a). In May 1999, sediment samples were collected from nine locations – three within Reach A, one within Reach B, two within Reach C, and three within Reach D. Sampling locations are depicted in Figures 3-3a through 3-3i. Samples were analyzed for total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, ammonia nitrogen, TKN, pesticides, percent moisture, SVOCs, PAHs, TOC, and TPH. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-34 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

In late summer/early fall 1999, Entrix conducted surface sediment sampling in the lower 6 miles of the Passaic River as part of the RI Ecological Sampling Plan (RI-ESP) activities (Tierra, 1999d; 2000c). One composite surface sediment sample was collected from each of three (i.e., upper, middle, and lower) sampling grids at 15 sampling locations (i.e., three composite samples from each location). The center of each individual grid was used to represent the location of the associated composite sample. Sampling locations are depicted in Figures 3-3a through 3-3i. A total of 45 composite sediment samples were collected and analyzed for AVS/SEM, total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, pesticides, ammonia nitrogen, pH, Organotins, grain size, percent moisture, water content, SVOCs, PAHs, TOC, and TPH. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-35a and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Again in May 2000, one composite surficial sediment sample was collected from each sampling location. A total of 20 (including two duplicates) composite sediment samples were collected and analyzed for the same suite of organic and inorganic chemicals used for the 1999 samples. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-35b and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

In June 1999, Entrix conducted a sediment sampling investigation in the lower Passaic River and Newark Bay as part of a preliminary toxicity identification evaluation (TIE) (Tierra, 1999f). Surface sediment grab samples were collected from five locations and analyzed for AVS/SEM, PCDD/Fs, inorganic chemicals, ammonia nitrogen, pH, PCBs, pesticides, grain size, SVOCs, PAHs, and TOC. Sampling locations are depicted in Figures 3-3a through 3-3i. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-36 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

In December 1999, BBL collected eight composite surface sediment samples (one for each of eight sub-areas) from the boat basin area near the Joseph G. Minish Passaic River Waterfront Park and Historic Area to monitor dredging/excavating activities associated with the Minish Park project (Tierra, 2000a). Sampling locations are depicted in Figures 3-3a through 3-3i. The sediment samples were analyzed for AVS/SEM, total cyanide, PCDD/Fs, herbicides, inorganic chemicals, PCBs, ammonia nitrogen, pH, Organotins, pesticides, SVOCs, PAHs, TOC, and TPH, as well as a limited number of physical parameters (grain size, percent moisture, and water content). Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-37 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.Additionally, sediment traps were used to capture and quantify suspended solids potentially released during dredging of the boat basin. During the baseline monitoring phase of the program, four sediment traps were deployed and retrieved twice in the vicinity of the Minish Waterfront Project (January to February 2000) to test the sediment collection methodology. Depth of sediment within the traps was recorded on both retrieval dates, with sediment weight recorded at the second retrieval.

For purposes of evaluating the BioGenesis^{SM} Sediment Washing process, BBL collected a composite sample from three locations within the lower Passaic River in September 2000 (Tierra, 2000b). There were no specific sampling locations associated with this investigation. Instead, sediments were composited from multiple areas. Approximately 4 gallons from each location were homogenized to create one composite sample. Sediment samples were analyzed for AVS/SEM, total cyanide, PCDD/Fs, herbicides, inorganic chemicals, ammonia nitrogen, pH, organotins, pesticides, grain size, percent moisture, water content, SVOCs, PAHs, TOC, and TPH. The results are summarized in Table 3-38 and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Entrix, conducted sediment sampling in the lower Passaic River in July 2000 as part of a TIE study (Tierra, 2000d). Surface sediment grab samples and pore water samples were collected from five locations. Sampling locations are depicted in Figures 3-3a through 3-3i. Both types of samples were analyzed for AVS/SEM, PCDD/Fs, PCBs, pesticides, herbicides, inorganic chemicals, PAHs, ammonia nitrogen, sulfide, total cyanide, Organotins, pH, grain size, percent moisture, water content, SVOCs, TOC, and TPH. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Tables 3-39a and 3-39b and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Dames and Moore conducted a sediment sampling investigation in 1995 to obtain data in the area of the proposed Minish Waterfront Park project (USACE, unknown). From January through February 1995, 39 composite sediment samples (including two field duplicate samples) were collected from 10 locations. Sampling locations are depicted in Figures 3-3a through 3-3i. Sediment samples were analyzed for target analyte list inorganic chemicals, PCDD/Fs, Hg, total recoverable petroleum hydrocarbons, TOC, PCBs/pesticides, VOCs, and SVOCs. Concentrations of select chemicals are presented in Figures 3-5 through 3-7p. The results are summarized in Table 3-40 and raw data provided in electronic format in Appendix D – Sediment Data.

The USEPA (unknown) conducted a surface sediment sampling program in the lower Passaic River on March 23, 1993. Four surface sediment samples were collected from depths of 0 to 0.3 ft. Sample locations are depicted in Figures 3-3a through 3-3i. Samples were analyzed for PCDD/Fs. Results for select PCDD/F congeners are presented in Figures 3-5a through 3-5p. The results are summarized below and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Analyte	Units	Minimum	Maximum
PCDD/Fs			
2,3,7,8-TCDD	ppt	24	82
2,3,7,8-TCDF	ppt	15	27
Total PCDDs	ppt	336	1,274
Total PCDFs	ppt	413	820

In 1993/1994 and 1998, the USEPA R-EMAP conducted surface sediment sampling throughout the NY/NJ Harbor Estuary, including 28 locations in the Inventory Area (USEPA, 1998; 2003). Samples were analyzed for PAHs, TOC, grain size, total recoverable inorganic chemicals, PCBs, pesticides, butyltins, AVS, SEM, and inorganic chemicals. The results are summarized in Tables 3-41a and 3-41b and raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. The sampling locations and concentrations of select chemicals are presented in Figures 3-3a through 3-3i and 3-5 through 3-7p.

3.2.2.2 Additional Sediment Studies within the Inventory Area

Associated Water & Air Resources Engineering, Inc. (AWARE, Inc.; unknown) collected 16 surface sediment grab samples from Berry's Creek and analyzed them for Hg. No sampling locations were provided. Hg results ranged from 1.8 to 1,600 mg/kg. Raw data are provided in electronic format in Appendix D – Sediment Data.

Battelle (1992b) collected surface sediment samples from 20 locations in the NY/NJ Harbor Estuary, including five locations in the Inventory Area (Figure 3-4a). Samples were analyzed for AVS, SEM, grain size, TOC, pH, redox potential, and select inorganic chemicals (Ag, As, Cd, Cu, Hg, Pb, Ni, Zn). Results of these analyses are summarized in Table 3-42. Raw data are provided in electronic format in Appendix D – Sediment Data.

In October and November 1991, Bonnevie et al. (1994) collected 35 surface sediment samples from two wetland areas located along the western bank of the Hackensack River (Figure 3-4b) The samples were analyzed for select inorganic chemicals. The results are summarized below and raw data are provided in electronic format in Appendix D – Sediment Data.

Inorganic Chemicals Concentration Range (mg/kg)					
Ca	**Cu**	**K**	**Mg**	**Na**	**Pb**
2,300 – 8,500	17 – 283	1,720 – 4,820	300 –12,500	3,200 – 93,500	25 – 487

Notes:
Ca = calcium
K = potassium
Mg = magnesium
Na = sodium

Bopp (2001) collected and analyzed samples from four sediment cores from Mill Creek and one sediment core from Sawmill Creek for radiochemistry (^{137}Cs and ^{210}Pb) in September 2000. No detailed sampling locations were provided. Net particle accumulation rates could not be determined at any site based solely on radionuclide profiles. Additionally, no detectable levels of ^{137}Cs or ^{210}Pb were present in the Sawmill Creek core. Raw data are provided in electronic format in Appendix D – Sediment Data.

Chaky (2003) collected five sediment cores from the Inventory Area between 1982 and 1996 to characterize and trace historical and current sources of PCDD/Fs (Figure 3-4a). The samples were analyzed for PCDD/Fs and PCBs. Core sediment results from 1990–1996 are summarized below. Raw data are provided in electronic format in Appendix D – Sediment Data.

Concentration (ppt)		
Location	**∑PCDD/F TEQ**	**∑PCB TEQ**
Newark Bay	260	17
Kill Van Kull	48 – 50	16 – 17
Arthur Kill	93	22

Note:
TEQ = toxic equivalency quotient

Soil and sediment sampling was conducted by Ducks Unlimited (1998) at several locations in the Hackensack Meadowlands including the Berry's Creek Canal site (a.k.a Sisselman Tract), Harrier Meadow, Skeetkill Creek Marsh, and Mill Creek Marsh from January 1996 through December 1997. Samples were analyzed for priority pollutant inorganic chemicals, pesticides, and PCBs. The authors only distinguish between soil and sediment samples when presenting the analytical results from Mill Creek. These results are summarized below. The results from the other sampling locations have not been summarized. Sampling locations and raw data were not provided.

Inorganic Chemicals Concentration Range (mg/kg)					
As	**Cd**	**Cr**	**Cu**	**Hg**	**Pb**
ND	<0.1 – 18	28 – 550	13 – 324	<0.02 – 18	8.7 – 415
Organic Compounds Concentration Range (µg/kg)					
DDT	**DDE**	**DDD**	**Dieldrin**	**Total Chlordane**	
0 – 20.9	0 – 2.3	ND	ND	0 – 585	

Eckenfelder (1993) collected surface sediments at six locations in the Hackensack Meadowlands and two locations in the Hackensack River. Six of the sampling locations are presented in Figure 3-4b; two of the sampling locations were not identified clearly in the original document. Samples were analyzed for geotechnical parameters (percent organic carbon, percent water, grain size, and specific gravity), sulfides (hydrogen sulfide, AVS, total sulfide, and mercaptan), nutrients and supplementary chemicals (calcium, magnesium, potassium, sodium, phosphate phosphorus, TKN, ammonia nitrogen, TOC, TSS, and pH) and select chemicals of concern (pesticides, PCB, Aroclors, Hg, TPH, PCDD/Fs, TCL VOCs and SVOCs). Results of these analyses are summarized in Table 3-43. Raw data are provided in electronic format in Appendix D – Sediment Data.

Fu et al. (2001) investigates 2,3,7,8-TCDD cycling in aquatic sediments and provides a conceptual dechlorination and carbon turnover model to explain the likely reactivity of 2,3,7,8-TCDD in the Passaic River Estuary. Microbial respiratory and dechlorination activity were measured in microbial enrichments that were obtained after elution of microorganisms from Passaic River sediments. The authors indicate that the likelihood of 2,3,7,8-TCDD formation decreases with increasing salinity/sulfate concentrations and in sediments exhibiting estuarine and marine characteristics. Raw data is not provided.

In 1990, a study was performed by the HMDC (1990c) to determine the extent that the Atlantic tomcod (*M. tomcod*) utilizes the Hackensack River. In conjunction with the tomcod sampling, sediment samples were collected at five locations by compositing two grab samples (Figure 3-4b). Sediment samples were analyzed for Cu, Cr, TOC, and grain size. The raw data results are presented in the following table.

Parameter	Author's Sampling Location Number				
	1	2	3	4	5
Grain Size (%)					
Pebbles	0.98	18	0	0	0
Granules	1.2	3.0	0.3	0.5	0
Sand	48	42	6.5	11	5.3
Silt/Clay	50	34	93	91	95
Organics	4.0	4.5	12	23	13

Parameter	Author's Sampling Location Number				
	1	2	3	4	5
Inorganic Chemicals (mg/kg)					
Cu	76	18	172	172	34
Cr	95	17	204	152	38

Robert Kimball and Associates, Inc. (Kimball, 2000) conducted sediment core sampling at four locations in tributaries of the Hackensack River: one location in Bucks Creek and three locations in Van Winkle Ditch (Figure 3-4b). Sediment samples were analyzed for priority pollutant VOCs, base neutral organic compounds, and inorganic chemicals. Results are summarized in Table 3-44. Raw data are provided in electronic format in Appendix D – Sediment Data.

In 1999, Langan Engineering and Environmental Services, Inc. (Langan, 1999) collected surface sediment samples and sediment cores in the Kearny Marsh. Surficial sediment samples (0 to 0.5 ft) were collected from 22 locations on May 26, 1999 (Figure 3-4b). Sediment cores were collected from 11 locations on April 29, 1999 (Figure 3-4b). Samples were analyzed for priority pollutants, TPH, TOC, pH, and grain size. The results are summarized in Table 3-45. Raw data are provided in electronic format in Appendix D – Sediment Data.

From June through October 1999, McIntyre (2000) assessed the feasibility of using the diamondback terrapin as a bioindicator for a polluted estuarine environment at two sites. As part of this investigation, one sediment core was collected within the Hackensack Meadowlands near Saw Mill Creek (Figure 3-4b). The core was segmented into 5 cm sections. The samples were analyzed for select inorganic chemicals, including As, Cd, Cr, Cu, Ni, Pb, and Zn. Results are summarized below. Raw data are provided in electronic format in Appendix D – Sediment Data.

Sediment Core Segment (cm)	Inorganic Chemicals Concentrations (mg/kg)						
	As	Cd	Cr	Cu	Ni	Pb	Zn
0 – 5	12.6	1.15	139.4	88.5	46.5	138.1	277.9
5 – 10	17	1.98	179.5	110.1	37.3	164.8	342.9
10 – 15	18.4	1.85	175.1	106.1	31.8	168.8	322.2

Sediment Core Segment (cm)	Inorganic Chemicals Concentrations (mg/kg)						
	As	Cd	Cr	Cu	Ni	Pb	Zn
15 – 20	15.2	1.9	156.2	93.3	33.6	147.7	301.5
20 – 25	11	0.15	60.5	33.7	24.4	61.8	178
25 – 30	5.8	<0.01	29.3	15.2	19.3	22.7	114
30 – 35	4.9	0.01	34.3	15	18.9	20.9	143.3
35 – 40	3.4	0.01	25.6	13	16.1	16	101.9
40 – 45	4.1	0.01	26.2	14.9	18.5	16.2	136.2

In August 1996, Mitra (1997) collected sediment cores from one location in Newark Bay (Figure 3-4a). Sediment samples were analyzed for PAHs, radiochemistry (^{210}Pb and ^{137}Cs), TOC, and grain size. Raw data are provided in electronic format in Appendix D – Sediment Data, however, the results are illegible. Accumulation rates could not be determined using ^{210}Pb geochronology due to grain size effects and the lack of a measurable decrease in ^{210}Pb activity. ^{137}Cs was detected to a depth of 110 cm and resulted in a maximum long-term sediment accumulation rate of 2.6 cm/yr. However, evidence of mixing from X-radiographs and the uniform excess ^{210}Pb activity profiles between 45 to 100 cm suggest this sediment accumulation rate is an underestimate. In addition to sediment sampling, pore water samples were collected and analyzed for DOC, PAHs, and carbon to nitrogen ratio. The results of the DOC in pore water ranged from approximately 10 to 36 mg/L. PAH results ranged from non-detect to 1 ng/g, while carbon to nitrogen ratios ranged from 11.12 to 17.3. Raw data are provided in electronic format in Appendix D – Sediment Data, although much of the data is illegible due to the font size of the data presentation.

Sediment samples and a limited number of surface water samples were collected by Mohan et al. (1999) as part of RI and corrective measures activities at the confluence of the Rahway River and Arthur Kill. Sediment samples were collected at each of 35 locations and analyzed for inorganic chemicals (As, Cu, Pb, Zn) and select pesticides (DDD, DDE, DDT). The sample area is depicted in Figure 3-4a. Results of these samples are summarized below and raw data are provided in electronic format in Appendix D – Sediment Data.

Inorganic Chemicals Concentration Range (mg/kg)				**Pesticides Concentration Range (µg/kg)**		
As	**Cu**	**Pb**	**Zn**	**DDD**	**DDE**	**DDT**
16 – 246	364 – 16,600	110 – 750	270 – 3,620	0.17 – 1,400	0.040 – 61	0.13 – 2,300

Louis Berger & Associates, Inc. conducted sediment sampling, on behalf of NJDEP (1991), in April and May 1990 to assess the extent of four oil spills in the Inventory Area. Sediment cores were collected at 36 locations (11 intensive and 25 non-intensive sampling locations) in four intertidal zones: high intertidal, medium intertidal, low intertidal, and sub-intertidal (Figure 3-4a). Sediment samples were analyzed for TPH. The average TPH concentration in sediments in high, medium, light, and no spill impact zones are presented below for each intertidal zone. Raw data are provided in electronic format in Appendix D – Sediment Data.

Tidal Zone	**Spill Impact – TPH Concentrations (µg/g)**			
	Heavy	**Medium**	**Light**	**None**
High Intertidal	13,467	40,303	2,840	740
Medium Intertidal	5,479	1,088	1,173	1,226
Low Intertidal	1,110	1,560	1,201	798
Sub Intertidal	1,787	2,050	1,830	710

Pruell et al. (1993) and Rubinstein et al. (1990) collected surface sediment samples from four locations in the lower Passaic River to determine the relative bioavailability of 2,3,7,8-tetrachlorinated dibenzo-*p*-dioxin (TCDD), 2,3,7,8-tetrachlorinated dibenzofuran (TCDF), and select PCB congeners using sandworms and shrimp. No specific sample locations were provided in these publications. Sediment samples were analyzed for 2,3,7,8-TCDD, 2,3,7,8-TCDF, select PCB congeners, and TOC. The average and standard deviation (SD) of each parameter is presented below (Pruell et al., 1993). Raw data were not provided.

Analyte	**Average**	**SD**
2,3,7,8-TCDD (pg/g)	656	97
2,3,7,8-TCDF (pg/g)	334	6
2,4,6,8-TCDT (pg/g)	3,680	1,380
PCB 52 (ng/g)	61	18
PCB 101 (ng/g)	78	21
PCB 151 (ng/g)	28	8.0
PCB 153 (ng/g)	81	16
PCB 138 (ng/g)	79	15
PCB 128 (ng/g)	18	3.0
PCB 180 (ng/g)	52	5.6
PCB 194 (ng/g)	15	1.2
PCB 206 (ng/g)	10	2.3

Analyte	Average	SD
PCB 209 (ng/g)	12	1.1
TOC (mg/g)	57	1.0

In May 1991, Rice et al. (1995) collected sediment samples from 17 sites in the NY/NJ Harbor Estuary. Of these 17 sites, three sites (Newark Bay, Shooter's Island, and Ward Point) are located in the Inventory Area (Figure 3-4a). Sediment samples were analyzed for PAHs, PCBs, pesticides, inorganic chemicals, TOC, and grain size. Results are summarized below. No raw data were provided.

Parameters	Minimum	Maximum
Inorganic Chemicals (µg/g)		
Ag	1.2	5.4
As	9.6	27
Cd	0.010	0.24
Cu	63	240
Hg	0.29	2.7
Ni	22	49
Pb	22	49
Se	0.35	1.8
Zn	140	430
Organics (ng/g)		
DDT	21	310
HMW PAHs	6,490	15,000
LMW PAHs	980	3,300
PCBs	220	470
Other CHs	<31	48
Other		
Fines (%)	20	87
TOC (%)	1.0	4.1

Notes:
HMW = high molecular weight polycyclic aromatic hydrocarbons
LMW = low molecular weight polycyclic aromatic hydrocarbons
ng/g = nanogram per gram
Other CHs = chlorinated hydrocarbons other than PCBs and DDT
µg/g = microgram per gram

Robinson (2002) presents a compilation of sediment data from the Hudson River Basin (including Kill Van Kull, Newark Bay, and Arthur Kill located within the Inventory Area). No sampling locations are provided. Analytes include DDT and radiochemistry (^{137}Cs, ^{210}Pb, and ^{7}Be). The DDT and radiochemistry datasets were combined to assign a date for each DDT result. The results of DDD for each of the areas in the Inventory Area are summarized below. Raw data are provided in electronic format in Appendix D – Sediment Data.

Location	DDD Concentration Range (ppb)
Arthur Kill	12 – 2,240
Kill Van Kull	247 – 1,885
Newark Bay	2 – 490

Rosman et al. (2003) provides an overview of chemical concentrations in sediments of the Inventory Area at the following NOAA internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

The database contains data from several studies spanning from 1985 to 2001. Specifically, Rosman et al. (2003) summarized surface sediment data (2,3,7,8-TCDD, 2,3,7,8-TCDF, 2,3,7,8-TCDD TEQs, and total PCBs) from 1990 to 2000 for various areas of NY/NJ Harbor Estuary. 2,3,7,8-TCDD and 2,3,7,8-TCDF results in the Inventory Area are summarized in the table below, total PCBs results were illegible. Additionally, subsurface sediment data are presented with TCDD concentrations in the lower Passaic River ranging from <50 to >500,000 pg/g. The majority of the data summarized in this study were derived from the investigations described in Section 3.2.2.1.

Area	Concentration Range (pg/g)	
	2,3,7,8-TCDD	2,3,7,8-TCDF
Passaic River 10 km Study Area	0.2 – 970	0.31 – 480
Passaic River North of 10 km Study Area	1.0 – 13,500	0.7 – 71
Hackensack River	2.0 – 120	2.9 – 150
Newark Bay	3.0 – 470	1.3 – 370
Kill Van Kull	6.0 – 18	3.8 – 70
Arthur Kill	4.0 – 56	1.4 – 127

The USACE (1993a; 1995a) conducted sediment sampling at the Port Elizabeth Project Area in 1993 and 1995. In 1993, sediment cores were collected from 35 locations in the Inventory Area, including 12 locations in Arthur Kill, 15 locations in Port Elizabeth, 4 locations in upper Newark Bay, and 4 locations in the Hackensack River (Figures 3-4a and 3-4b). Samples from the cores were analyzed for TOC, grain size, bulk density, PAHs, and herbicides. A summary of the results is presented in Table 3-46a. Raw data are provided in electronic format in Appendix D – Sediment Data. In 1995, sediment cores were collected from 26 locations in the Port Elizabeth (Figure 3-4a). Sediment samples were analyzed for inorganic chemicals and PCDD/Fs. Results are summarized in Table 3-46b and raw data are provided in electronic format in Appendix D – Sediment Data.

As part of the evaluation for the construction of a CDF, the PA NY/NJ sponsored a sediment sampling study at three proposed CDF areas in May 1996 (USACE, 1997a) (Figure 3-4a). These three areas are located in Newark Bay near the Port Elizabeth and Port Newark Channels. Sediment cores were collected at 22 locations. Composite samples were analyzed for PCDD/Fs, inorganic chemicals, pesticides, PAHs, VOCs, PCBs. The results for each area are summarized in Table 3-47. No specific sampling locations or raw data were provided.

As part of the NY/NJ Harbor HDP, geoprobe data were collected by the USACE (2004a) in northern Newark Bay and South Elizabeth Channel. USACE (2004a) presents very limited information pertaining to the sediment sample collection and results. Analytes included PAHs and TPH. The results presented below are approximated from Figures 41 and 42 from the report, which is provided in its entirety in electronic format in Appendix D – Sediment Data. No specific sampling locations or raw data were provided.

Location	Concentration Range (ppb)	
	Total PAHs	Total TPH
Newark Bay	ND – 2,000	500 – 18,000
South Elizabeth Channel	Difficult to read due to scale	100,000 – 1,900,000

From the late 1970s to 1993, USGS and NJDEP conducted streambed sediment sampling at 100 sites in seven drainage basins throughout New Jersey (including the Passaic River and Rahway River, which are located in the Inventory Area) to evaluate the presence and distribution of chlorinated organic compounds (USGS, 1996; Stackelberg, 1997). Surface sediment samples were collected and analyzed for pesticides and PCBs. The six most frequently detected chlorinated organic compounds in bed sediments were DDT, DDE, DDD, chlordane, dieldrin, and total PCBs. Stackelberg (1997) presents median concentrations of these chemicals; this document is provided in its entirety in electronic format in Appendix D – Sediment Data. Results for locations within the Inventory Area are summarized below. No site-specific data or specific sampling locations were provided.

Drainage Area	Concentration					
	DDT	DDE	DDD	Chlordane	Dieldrin	Total PCBs
Passaic River	0.027	0.030	0.097	0.42	0.020	0.36
Rahway River	0.17	0.070	0.41	2.7	0.040	1.6

Note:
Units in 10^5 μg/kg organic carbon.

3.2.2.3 Dredging Permit Applications

Twenty-three identified applications for dredging permits that were filed with the USACE since 1990 were obtained for this Report. It is likely that a substantial number of additional dredging permit applications exist for this time period for the Inventory Area. However, these were not obtainable for this Report. Sediment chemistry data were identified in two of the obtained dredging permit applications (Chevron, 1997; USACE, 1997d [Tosco Refining Company]). Locations of the sites described in the dredging permit applications are depicted in Figure 3-2. A summary of the sediment chemistry data from these two permit applications is provided in Table 3-48. A copy of each of the dredging permit applications from 1990 to the present that contain sediment data is provided in electronic format in Appendix C – Sediment Data.

3.2.2.4 Summary of QA/QC Information for Sediment Studies

The sediment studies were examined for descriptions of the QA/QC methods employed by the authors during the conduct of the study or its publication. QA/QC information for each sediment study from 1990–present is presented in Table 3-49.

3.2.3 Toxicity and Pathogenicity

A variety of studies have been performed in the Inventory Area to examine the potential toxicity of one or more environmental matrices (i.e., surface water, pore water, and sediment). For the purposes of this section of the report, the term toxicity is used to represent both toxic and pathogenic studies and endpoints. Forty identified toxicity studies are summarized in Table 3-50. Twenty-eight identified studies that have been conducted since 1990 are discussed in greater detail below. Figures 3-8 through 3-10e present the sampling locations and summarize the results of these toxicity tests. Raw data from these studies are provided in electronic format in Appendix E – Toxicity Data. Twelve identified toxicity and pathogenicity studies that were conducted prior to 1990 are briefly summarized in Table 3-50.

3.2.3.1 Surface Water

Prior to 1990, no studies were conducted on the toxicity of surface water in the Inventory Area. Four studies have been conducted to examine the toxicity of surface water since 1990 and these studies are discussed below.

Khan et al. (1993) conducted surface water toxicity testing using the estuarine mysid, *Mysidopsis bahia*, exposed to water collected from Arthur Kill in January, February, and March 1991. Three locations approximately 1 mile apart in the Arthur Kill were evaluated for surface water toxicity. Sampling coordinates or maps were not provided; only qualitative descriptions of the sampling locations were provided. The first site is located upstream of the effluent discharge of a major power generating station. The second site is located approximately 1 mile downstream of the discharge from the power plant and the third site is located in Piles Creek, a tributary of Arthur Kill. The approximate sampling locations are presented in Figure 3-8. Performance controls were conducted with natural seawater from Manasquan Inlet, Manasquan, NJ. Survival, growth, and effects on sexual maturity were measured. Results from this study are presented in Figure 3-8 and summarized below. Summary data, as presented in Khan et al. (1993), are presented in Appendix E – Toxicity Data.

Author's Sampling Location	*M. bahia* Average Survival (%)	*M. bahia* Average Growth Relative to Control (mg)	*M. bahia* Average Sexual Maturity Relative to Control
Site 1	96	-0.033 – -0.064	0.22 – -0.055
Site 2	94 – 96	0.025 – -0.0030	-0.38 – -0.66
Site 3	96 – 98	0.044 – -0.014	-0.51 – -0.58

SAIC (1993) conducted surface water sampling in June and July of 1991 and again in January of 1992 and performed toxicity testing using two species as part of the NY/NJ HEP. The results of this work have been reported in SAIC (1993) and Thursby et al. (2000). Water samples were collected from Newark Bay, Kill Van Kull, Arthur Kill, and several other nearby waterways. Sampling locations are presented in Figure 3-8; point sources were deliberately avoided. Toxicity testing was conducted with male and female sea urchins (*Arbacia punctulata*). The tests examined fertilization and cleavage in the presence of test waters. Reference toxicant tests were performed using sodium dodecyl sulfate and controls using natural seawater and artificial brine were also conducted. Toxicity testing was also conducted with male and female marine red algae *Champia parvula*. The testing with *C. parvula* measured the number of cytoscarps per female as evidence of sexual reproduction in the presence of the test water. Reference toxicant tests were performed on *C. parvula* using sodium dodecyl sulfate and controls using natural seawater and artificial brine were also conducted. Results of these toxicity tests are presented in Figure 3-8 and summarized below.

Sampling Location	***A. punctulata* Fertilization and Cleavage (% of control)**	***C. parvula* Cytoscarp Production (% of control)**
Newark Bay	52 – 101	18 – 117
Arthur Kill	23 – 96	8 – 94
Kill Van Kull	18 – 92	38 – 103

A limited number of samples were collected in August and September 1993 and March and July 1994 from the locations used in 1991 and 1992 and tested using *A. punctulata* as part of a TIE (Thursby et al., 2000). None of the 1993 samples were toxic to *A. punctulata*. Only Newark Bay was sampled in 1994; toxicity ranged from 9% – 93% of the performance controls, with greater toxicity observed when testing waters collected during the March sampling event than during the July sampling event. Raw data from SAIC (1993) are provided in electronic format in Appendix E – Toxicity Data.

In May 1996, the PA NY/NJ sponsored a sampling program at three sites that were proposed for use as Newark Bay Confined Disposal Facilities (USACE, 1997a). These three sites are located in Newark Bay near the Port Elizabeth and Port Newark Channels. Suspended particulate phase water column testing was conducted using *Menidia berylina*, *M. bahia*, and *Mytilus edulis*. The results are summarized in tabular format in USACE (1997a) and are provided in electronic format in Appendix E – Toxicity Data. Control surface water samples were also used in the testing; control survival values ranged from 92% – 100%. No details of this testing are provided in the report (USACE, 1997a). The LC_{50} values[1] for this testing are summarized below.

Author's Sampling Location	***M. berylina* LC_{50} (% surface water)**	***M. bahia* LC_{50} (% surface water)**	***Mytilus edulis* LC_{50} (% surface water)**
Area 1	65	58	23
Area 2S	>100	>100	23
Area 2N	32	72	21

[1] LC_{50} = the concentration of surface water (as a %) resulting in mortality of 50% of the test organisms.

3.2.3.2 Porewater Toxicity

Two studies examining the toxicity of porewater from Inventory Area sediments were identified and are discussed below.

BenKinney et al. (2001) reports the results of a Phase I TIE for pore water extracted from sediments collected at five locations in the lower Passaic River (Tierra, 2004f; Figure 3-9b). Only the results of the baseline testing are discussed in this section, as only these results are representative of *in situ* porewater toxicity. The toxicity testing was conducted with three replicates of five test organisms each (the amphipod *Ampelisca abdita)*. Unaltered porewater (i.e., 100% porewater) and various porewater dilutions (e.g., 25%, 50%, 75%) were used in the toxicity testing. Survival was reported at 24, 48, and 72 hours and 48-hr LC_{50} values[2] calculated. Results of this testing are presented in Figure 3-9b. The raw data are provided in electronic format in Appendix E – Toxicity Data. The 48-hr LC_{50} results summarized below.

Author's Sampling Location (ordered upstream to downstream)	48-hr LC_{50} (% Porewater)
12	<1%
11	>100%
7	29%
14	75%
13	33%

The USEPA (1996) conducted porewater toxicity testing as part of a TIE. Only the results of the baseline testing are discussed in this section, as only these results are representative of the toxicity of the porewater *in situ* (USEPA, 1996). Sediment was collected from Arthur Kill in September 1994. Porewater was extracted from this sediment for toxicity testing in December 1994 and again in February 1995. The December toxicity testing was conducted with the amphipod *Ampelisca abdita*, the mysid *M. bahia*, and the bivalve *M. lateralis*. The February 1995 porewater toxicity testing was performed with *A. abdita* and *Mulinia lateralis*. Unaltered porewater (i.e., 100% porewater) and various porewater dilutions (e.g., 25%, 50%, 75%) were used in the toxicity testing. Survival was reported at 24, 48, and 72 hours and 48-hr LC_{50} values[3] calculated. Results of this testing are presented in Figure 3-9a and are summarized below. The raw data are provided in electronic format in Appendix E – Toxicity Data.

[2] LC_{50} = the concentration of porewater (as a %) resulting in mortality of 50% of the test organisms.
[3] LC_{50} = the concentration of porewater resulting in 50% mortality of the test species

Test Organism	48-hr LC_{50} Range (% Porewater)
A. abdita	50 – 69
M. bahia	34 – 75
M. lateralis	12.5 (test not repeated in 1995)

3.2.3.3 Sediment Toxicity

Fourteen studies were identified in the literature that report sediment toxicity testing results conducted using sediments from the Inventory Area since 1990 (Table 3-50). Their results are presented in Figures 3-10a through 3-10e. Results have been categorized on this figure as follows:

- Toxic = each replicate had <80% survival relative to the appropriate controls;
- Marginally toxic = some replicates had <80% survival relative to the appropriate controls while other replicates had = 80% survival relative to the appropriate controls; and
- Non-toxic = each replicate had = 80% survival relative to the appropriate controls.

Battelle (1992b) measured sediment toxicity using a 10-day flow through acute toxicity test with the amphipod *A. abdita* with sediments collected in February 1992 from the Hackensack and Passaic Rivers, Newark Bay, Kill Van Kull, and Arthur Kill. Sampling locations are presented in Figures 3-10a through 3-10d. The upper 5 cm of each sediment sample was used for toxicity testing. Six replicates per sediment sample, one reference control, and a reference toxicant (i.e., Cd) were tested. Temperature, salinity, DO, and pH were recorded daily; all remained within acceptable limits except pH. Several instances of low pH were recorded; however they were not thought to affect the integrity of the testing. The results of the reference toxicant test indicated that the test organisms used for this study responded similarly, or slightly more sensitively than organisms used in the past by Battelle in this type of testing. Survival data are summarized below and presented in Figures 3-10a through 3-10d. Raw data are provided in electronic format in Appendix E – Toxicity Data.

Sampling Location	*A. abdita* Average Survival (%)
Newark Bay	37
Arthur Kill	57
Kill Van Kull	0
Hackensack River	58
Passaic River	11

Battelle (1997a) conducted sediment toxicity testing on sediments collected from Arthur Kill in August 1995 as part of an evaluation of potential impacts of USACE dredging activities. Thirty-three individual sediment cores, 37 ft long, were collected; three composite sediment samples representing each area proposed for dredging were then produced from the full length of the appropriate cores. Sampling locations are presented in Figures 3-10a and 3-10b. Reference sediment was collected from the Mud Dump Reference site and control sediments were from Sequim Bay, Washington for the *M. bahia* testing. Reference toxicant tests (96-hr water-only exposures) with Cd chloride (for amphipods) and Cu (for mysids) were performed concurrently with the sediment exposures. Native control sediments for the amphipod testing were from Narragansett Bay, Rhode Island. Static renewal tests were performed using *A. abdita* and *M. bahia.* Five replicates were run for each test, reference, and control sediment sample/composite. Salinity, temperature, DO, and pH were measured in overlying water in one replicate per treatment daily and in all replicates prior to test initiation. Water quality parameters were within acceptable ranges throughout the tests with the exception of one mysid control replicate pH that rose to 8.45 during the testing. Reference toxicant tests were within the range of observed toxicity values for the laboratory. The results of this study are summarized below and presented in Figures 3-10a and 3-10b. Raw data are provided in electronic format in Appendix E – Toxicity Data.

Sampling Location	*A. abdita* Average Survival (%)	*M. bahia* Average Survival (%)
Arthur Kill	19 – 62	85 – 90
Mud Dump Reference Site	93	91

Battelle (1997b) also conducted sediment toxicity testing on sediments collected from the Hackensack River in August 1995 as part of an evaluation of the potential impacts of USACE dredging activities. Eight individual sediment cores, 32 ft long, were collected; three composite sediment samples representing the three areas proposed for dredging were then produced from the full length of the appropriate cores. Sampling locations are presented in Figures 3-10a and 3-10c. Reference sediment was collected from the Mud Dump Reference site and control sediments were from Sequim Bay, Washington for the *M. bahia* testing. Reference toxicant tests (96-hr water-only exposures) with Cd chloride (for amphipods) and Cu (for mysids) were performed concurrently with the sediment exposures. Native control sediments for the amphipod testing were from Narragansett Bay, Rhode Island. Five replicate static renewal tests were performed with *A. abdita* and *M. bahia* and each test, reference, and control sediment sample/composite. Salinity, temperature, DO, and pH were measured in overlying water in one replicate per treatment daily and in all replicates prior to test initiation. Water quality parameters were within acceptable ranges throughout the tests with the exception of one mysid control replicate pH that rose to 8.45 during the testing. This minor deviation was not thought to affect the integrity of the test. Reference toxicant tests were within the range of observed toxicity values for the laboratory. The results of this study are summarized below and presented in Figures 3-10a and 3-10c. Raw data are provided in electronic format in Appendix E – Toxicity Data.

Sampling Location	*A. abdita* Average Survival (%)	*M. bahia* Average Survival (%)
Hackensack River	67	93
Mud Dump Reference Site	93	91

BenKinney et al. (2001) presents the results of sediment toxicity testing conducted as part of a Phase I TIE for sediments collected at five locations in the Passaic River (Tierra, 2004f; Figure 3-10d). Five replicates of 20 *A. abdita* were exposed to whole sediment for ten days and survival was recorded. The raw data from this study are provided in electronic format in Appendix E – Toxicity Data. The results of the whole sediment toxicity testing are presented in Figure 3-10d and are summarized below.

Author's Sampling Location (ordered upstream to downstream	Percent Survival
12	0%
11	0%
7	0%
14	0%
13	3%
Control	81% – 92%

A survey of surface sediment (upper 2 cm) toxicity was performed by NOAA's National Status and Trends program throughout the Inventory Area in two phases: a large-scale sampling event in 1991 (covering much of the NY/NJ Harbor Estuary) and a more focused sampling event in 1993 (with over 40 samples collected in Newark Bay, the Passaic and Hackensack Rivers, and the Arthur Kill). The sampling locations for these two events are presented in Figures 3-10a and 3-10d, along with a summary of results which are reported in NOAA (1995b) and Wolfe et al. (1996). During the first phase, three sediment toxicity tests were performed: 1) a 10-day acute survival test of solid-phase sediments with the amphipod *A. abdita*; 2) a 48-hr liquid phase test of elutriates with the embryos of the bivalve *M. lateralis* that examined survival and development; and 3) a 15-minute microbial bioluminescence test, MicroTox™, of organic solvent extracts of sediments. A small number of samples were also tested with the freshwater amphipod *Diporeia* spp. as part of methods development. During the second phase of testing only the amphipod assays were performed. Performance controls (seawater alone) were performed as appropriate. Reference tests with sediments from Central Long Island Sound were also conducted. The results of this study are summarized below. Raw data used in NOAA (1995b) and Wolfe et al. (1996) are provided in Appendix E – Toxicity Data.

Phase I Testing

Sampling Location	*A. abdita* Average Survival (%)	*Diporeia* sp. Average Survival (%)	*M. lateralis* Average Survival (as % of seawater controls)	*M. lateralis* Average Normal Development (as % of seawater controls)	MicroTox™ EC_{50} (mg/ml)[4]
Upper Newark Bay	39	NA	135	101	1.8
Upper Arthur Kill	16	NA	68	99	1.4
Middle Arthur Kill	12	55	92	99	1.7
Lower Arthur Kill	49	NA	85	88	1.7
Reference Area	92	NA	92	99	2.1

Phase II Testing

Sampling Location	*A. abdita* Average Survival (%)
Newark Bay	0 – 87
Passaic River	8 – 41
Hackensack River	57 – 76
Arthur Kill	0 – 75
Reference Area	79 – 97

Rice et al. (1995) conducted multiple toxicity tests on surface (top 2 cm) sediments from Newark Bay, Shooter's Island, and Ward and Deep Points, among other locations in the NY/NJ Harbor Estuary. Sampling locations are presented in Figures 3-10a and 3-10b. Growth and mortality of the polychaete *Armandia brevis* and the sand dollar *Dendraster excentricus* were measured after 20- and 28-day exposures, respectively. Amphipod mortality and reburial was assessed using a 10-day exposure of the amphipod *Rhepoxinius abronius*. Each test series included a minimally contaminated reference (the test organisms' native sediment) and a heavily contaminated positive control sediment from a site in Elliott Bay, Washington. pH and DO were measured at the beginning and end of the test period. No raw data were provided. The results of the polychaete assay are summarized below.

[4] EC_{50} = the concentration of organic solvent extract (in mg/ml) resulting in a 50% decrease in microbial bioluminescence.

Sampling Location	*A. brevis* Average Weight Increase (mg)	*A. brevis* Average Survival (%)
Newark Bay	9.7	93
Shooter's Island	7.2	67
Ward Point	9.9	83
Deep Point	7.1	60
Reference Area	12.1 – 24.7	80 – 100
Positive Control	-0.2 – 4.9	67 – 95

The results of the sand dollar assay are summarized below.

Sampling Location	*D. excentricus* Average Length Increase (mm)	*D. excentricus* Average Survival (%)
Newark Bay	2.2	100
Shooter's Island	1.7	98
Ward Point	2.3	100
Deep Point	2.2	98
Reference	2.1 – 2.5	100
Positive Control	0.2 – 0.6	100 – 98

Amphipod bioassays were not conducted with sediment from Deep Point. The results of the amphipod assay are summarized below.

Sampling Location	Average *R. abronius* Non-reburial (%)	Average *R. abronius* Survival (%)
Newark Bay	2	90
Shooter's Island	2	92
Ward Point	1	91
Reference	0	98
Positive Control	2	86

Entrix, Inc., conducted toxicity testing using composite surface (0 – 10 cm) sediment samples from 15 locations in the lower 6 miles of the Passaic River in September/October 1999 as part of the RI activities (Tierra, 2002f). The sampling locations are presented in Figure 3-10e. Ten day standard amphipod toxicity tests with the amphipod *A. abdita* and 28-day toxicity tests with the polychaete *Neanthes arenaceodentata* were performed. Growth and mortality were measured. The results of these studies are summarized below and presented in Figure 3-10e. Control sediments from Narragansett Bay, Rhode Island and a reference area, the Mullica River, NJ, were used. Water quality (i.e., DO, ammonia, temperature, pH, salinity) was monitored and remained acceptable throughout the exposure periods for each test type. Raw data are provided in Appendix E – Toxicity Data.

Sampling Location	*A. abdita* Average Growth (mm)	*A. abdita* Average Survival (%)	*N. arenaceodentata* Average Growth (mg/day)	*N. arenaceodentata* Average Survival (%)
Passaic River	2.38 – 2.88	43 – 85	0.090 – 0.16	84 – 100
Reference Area	2.76 – 2.89	92 – 95	0.044 – 0.14	96 – 100

Entrix conducted sediment toxicity testing in the lower Passaic River and Newark Bay as part of a preliminary TIE (Tierra, 2004e). Surface sediment samples were collected at four locations in the Passaic River and one location in the Port Newark Channel (Figures 3-10a and 3-10d). *A. abdita* and *Neanthes arenaceondentata* were exposed to whole sediment for 10 and 28 days, respectively, and survival and growth were recorded. The raw data from this study are provided in electronic format in Appendix E – Toxicity Data. The results of the whole sediment toxicity testing are presented in Figures 3-10a and 3-10d and are summarized below.

Author's Sampling Locations (ordered from upstream to downstream)	Average Amphipod Percent Survival	Average Amphipod Growth (mm)	Average Polychaete Percent Survival	Average Polychaete Dry Weight (mg)
TIE-5	32%	2.8	96%	3.0
TIE-4	1%	NA	92%	4.7
TIE-3	3%	2.6	90%	3.3
TIE-2	20%	2.7	100%	3.7
TIE-1	35%	2.8	100%	3.9
Control	92%	3.0	100%	4.3

Note:
NA = not applicable

In May 1996, the PA NY/NJ sponsored a sediment sampling program at three sites that were proposed for use as Newark Bay Confined Disposal Facilities (USACE, 1997a). These three sites are located in Newark Bay near the Port Elizabeth and Port Newark Channels and are presented in Figure 3-10a. Composite sediments from the uppermost stratigraphic unit (Holocene organic black silty clay) of these three sites and a reference and control location (unspecified) were used to assess whole sediment toxicity through 10-day exposures with the amphipod *A. abdita*, the marine polychaete *N. arenaceodentata*, and the mysid shrimp *M. bahia*. Minimal testing details are reported in USACE (1997a); the amphipod and mysid tests were conducted under flow-through conditions while the polychaete test was conducted under static conditions. The results of this testing are summarized below and presented in Figure 3-10a. No raw data were provided.

Sampling Location	*A. abdita* Average Survival (%)	*N. arenaceodentata* Average Survival (%)	*M. bahia* Average Survival (%)
Area 1	81	96	91
Area 2S	93	88	79
Area 2N	97	84	87
Reference Area	93	100	97

The USEPA (1990) also examined the use of the amphipod 10-day sediment toxicity test with *A. abdita* and *Rhepoxynius hudsoni* for dredged material evaluations in a report dated September 17, 1990 (no sampling dates are provided in the report). Sediment samples (depth unspecified) were collected from multiple stations in the NY/NJ Harbor Estuary, including 7 in the Inventory Area (Figures 3-10a and 3-10b) and from Western Long Island Sound (control site for *A. abdita*), Ninigret Pond (control site for *R. hudsoni*) and east of Sandy Hook, NJ, (reference site). Five replicate exposures were conducted per sample. No reference toxicant tests were conducted. DO, salinity, and temperature were monitored during exposure although no data or summary statements about these parameters are provided in the report. The results of this study are summarized below and the raw data are provided in electronic format in Appendix E – Toxicity Data.

Sampling Location	*A. abdita* Average Survival (%)	*Rhepoxynius hudsoni* Average Survival (%)
Ambrose Channel	89	88
Elizabeth Channel	20	91
Goethal's Bridge	0	59
Gulfport	0	81
Kearny Point Estuary	65	91
Tremley Point	0	73
Reference Area	93	89
Ward Point	69	91

As part of the R-EMAP, the USEPA conducted sediment toxicity testing in the Inventory Area in the summer of 1993/1994 and again in the summer of 1998 (USEPA, 1998; 2003). Sediment sampling locations are presented in Figures 3-10a through 3-10d. In 1993/1994, surface sediment (top 2 cm) was used in standard 10-day acute, static tests with *A. abdita.* Five replicate tests were conducted per sample and testing was performed with sodium dodecyl sulfate as a reference toxicant. Control sediment was collect from Narrow River, Rhode Island.

Reference toxicant results were all within the acceptable range for this species. MicroTox™ assays based on the inhibition of light emission by the luminescent bacterium *Photobacterium phosphoreum* were also performed in 1993/1994. Control sediments from the USACE's Central Long Island Sound reference station were also tested using the MicroTox™ assays. Ethanol reagent blanks with no sediment and sediment extraction blanks were prepared and tested. Reference toxicant testing using phenol was conducted with each set of sediment assays and the results were acceptable according to the test protocols. The results of the 1993/1994 and 1998 testing are summarized below and raw data as provided by USEPA (1998; 2003) are provided in Appendix E – Toxicity Data.

Sampling Event	*A. abdita* Average Survival (%)	Average MicroTox™ Survival (%)
1993/1994	8 – 94	9 – 100
1998	0 – 99	Not Performed

3.2.3.4 Other Toxicity Studies

A variety of toxicity studies conducted from 1990–present comparing the toxicological responses of fish from the Inventory Area, histology of various organisms, and sub-organismal level endpoints were identified (Brown et al., 1992; Burger et al., 1992b; Carletta et al., 2000; Elskus et al., 1999; McArdle, 1998; McArdle et al., 2004; Parsons, 2003; Prince and Cooper, 1995a,b; Ravit and Ehrenfeld, 2002; Smith et al., 1995; Weis et al., 1999; Yuan et al., 2001; and Zhou et al., 1999). The endpoints and results of these studies are varied and thus, are not presented on a figure; they are summarized in Table 3-51 and copies of these studies are provided in electronic format in Appendix E – Toxicity Data.

Entrix and BBL conducted a qualitative fish pathology survey of the lower 6 miles of the Passaic River in the late summer/early fall of 1999 and again in spring 2000 as part of the RI activities (Tierra, 2002e). A total of 284 individual fish representing 17 species were collected using baited minnow traps targeting mummichog, baited eel traps targeting American eel, and experimental gillnets targeting multiple species of the fish community. A gross internal and external examination was performed on each fish. Sampling stations and times were variable for the targeted types of fish. The results of this survey are summarized below. Raw data are provided in Appendix E – Toxicity Data.

Species	Scientific Name	Number analyzed
Alewife	*Alosa pseudoharengus*	--
American eel	*Anguilla rostrata*	1
Atlantic menhaden	*Brevoortia tyrannus*	11
Blueback herring	*Alosa aestivalis*	4
Bluefish	*Pomatomus saltatrix*	3
Brown bullhead	*Ameiurus nebulosus*	1
Carp	*Cyprinus carpio*	1
Channel catfish	*Ictalurus punctatus*	1
Gizzard shad	*Dorosoma cepedianum*	5
Mummichog	*Fundulus heteroclitus*	226
Red sardine	*Harengula humeralis*	--
Spot	*Leiostomus xantherus*	--
Striped bass	*Morone saxatilis*	14
Weakfish	*Cynoscion regalis*	3
White perch	*Morone americana*	13
White sucker	*Catostomus commersoni*	1
Windowpane flounder	*Scopthalmus aquosus*	--
	Total	284

3.2.3.5 Dredging Permit Applications

Thirteen dredging permit applications filed with the USACE from 1990 to the present that contain toxicity data were identified and obtained. It is likely that a substantial number of additional dredging permit applications exist for this time period for the Inventory Area. However, these were not obtainable for this Report. The toxicity testing data that are presented in the 13 obtained permit applications are summarized in Table 3-52. The locations of the proposed dredging activities are depicted in Figure 3-2. A copy of each of the dredging permit applications from 1990 to the present that contain toxicity data are provided in electronic format in Appendix D – Toxicity Data.

3.2.3.6 Summary of QA/QC Information for Toxicity Studies

The toxicity studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. Available QA/QC information for each toxicity study from 1990–present is presented in Table 3-53.

3.2.4 Bioaccumulation

A variety of studies have been performed in the Inventory Area to examine bioaccumulation of various contaminants in one or more organisms. Seventy-two identified bioaccumulation studies are summarized in Table 3-54. The following sections present greater detail on the 35 studies conducted since 1990. Figures 3-11a through 3-11c depict the sampling locations of these bioaccumulation studies. Raw data from several of these studies (as noted in the following sections) are provided in tables or electronic format in Appendix F – Bioaccumulation Data. Thirty-seven identified bioaccumulation studies that were conducted prior to 1990 are briefly summarized in Table 3-54.

3.2.4.1 Fish

Twenty studies have examined bioaccumulation in various fish species in the Inventory Area since 1990. These studies are summarized below. The sampling locations for these studies (when available) are presented in Figures 3-11a through 3-11c.

Ashley and Horwitz (2000) conducted an assessment of PCBs, select pesticides, and Hg in fish of New Jersey's coastal waters. Specimens of fish were collected throughout New Jersey during 1998 and 1999. Two sampling locations were located within the Inventory Area. Sampling was conducted in the Passaic River: Elmwood Park and Pompton. The precise sampling locations were not provided. Species collected at these locations included the following: brown bullhead (*Ameiurus nebulosus*), common carp (*Cyprinus carpio*), large-mouth bass (*Micropterus salmoides*), and redbreast sunfish (*Lepomis auritus*). The Passaic River samples were analyzed for PCBs and select pesticides. Summary results are presented below and raw data are provided in Table 3-55.

Sampling Location Species	**Concentration Range (ng/g)**					
	Total PCBs	**Pesticides[a]**				
		Dieldrin	**Total Chlordanes**	**Total DDD**	**Total DDT**	**Total DDE**
Elmwood Park						
Brown bullhead	26 – 264	0.97 - 9.7	2.9 - 39	1.4 - 15	1.7 - 22	2.3 - 34
Common carp	309 - 2,238	4.4 - 23	19 - 127	16 - 68	14 - 103	39 - 259
Redbreast sunfish	50 - 76	1.4 - 2.0	1.9 - 2.3	2.3 - 2.8	4.0 - 9.6	5.6 - 8.7
Largemouth bass	119 – 252	3.2 - 6.4	3.2 - 15	4.8 - 14	3.9 - 16	11 - 23
Pompton						
Common Carp	775 – 971	17 - 33	31 - 85	31 - 87	23 - 45	47 - 206
Redbreast sunfish	46 – 71	0.84 - 2.8	1.7 - 5.9	2.6 - 4.9	3.8 - 10	4.5 - 10
Largemouth bass	51 - 117	1.2 - 2.9	2.4 - 5.2	2.7 - 6.0	4.5 - 10	7.8 - 10

Note:
a. Not an exhaustive list of pesticide results available in source.

Cooper et al. (1992) examined bioaccumulation of TCDD/Fs in the food web of a saltmarsh mudflat in Elizabeth, NJ. Species collected for analysis included Atlantic menhaden (*Brevoortia tyrannus*) and killifish (*Fundulus* sp.) No specific sampling location information or raw data were provided; summary results are presented below.

Species	**Concentration (ppb)**	
	2,3,7,8-TCDD	**2,3,7,8-TCDF**
Atlantic menhaden	9.4	2.3
Killifish	9.1	3.8

Eckenfelder (1993) investigated the bioaccumulation of Hg, PCDD/Fs, TPHs, select pesticides, PCBs, VOCs, and SVOCs in mummichog from the Hackensack River. Samples were collected from six locations within the study site (Figure 3-11b). Two composite samples were obtained at each location and were analyzed for the above contaminants. Raw data are provided at the following internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

Summary results from Eckenfelder (1993) are presented below.

Analyte[a]	Author's Sampling Locations		
	Site 23/43	Site 15/35	Site 27/36
4,4'DDE (mg/kg)	0.084	0.070	0.096
4,4'DDD (mg/kg)	0.12	0.11	0.15
Aroclor 1254 (mg/kg)	0.63	0.58	0.84
Total SVOCs (mg/kg)	7,808	11,283	6,124
Total TEQ for PCDD/Fs (ng/kg)	5.3	4.9	14

Note:
a. Chemicals that were not detected are not listed in this summary table.

Elskus et al. (1999) presented PCB concentration in eggs of field-caught fish that were resident to Newark Bay. The study's main focus, however, was to examine effects after injecting depurated mummichog with PCBs. The fish were collected from the Roanoke Yacht Club (Newark Bay) and Flax Pond, NY, (reference site) in September 1995. No specific sampling locations were provided. Raw data were not provided, but summary results are presented below.

Author's Sampling Location	N	PCB Concentration in Eggs (µg/g)	
		Average	SD
Flax Pond	3	0.20	0.020
Newark Bay	3	2.0	0.90

In a study by Fernandez et al. (2004), full congener-specific PCB and partial congener-specific PCDD/F analysis were performed on livers of young-of-the-year (YOY) and adult Atlantic tomcod collected from the Hudson River Estuary. Samples from the Hackensack River and Newark Bay were included in the study. These samples were collected in either December 1996 or August 1998. Samples were composited from 6 to 11 individual livers. The approximate locations of the samples are presented in Figure 3-11b. Raw data were not provided, but spatial and temporal trends are discussed. Summary data are presented below.

Chemical	Growth Stage, Sex	Concentration
Hepatic Total PCB and Total PCDD/F	YOY, sex unknown	43 – 1,736 pg/g
Total PCB	Adult, female	4.0 µg/g
Total PCDD/F	Adult, female	573 pg/g
Total PCB	Adult, male	12 µg/g
Total PCDD/F	Adult, male	1,178 pg/g

Finley et al. (1997) determined Aroclor mixture and specific PCB congener concentrations for striped bass and mummichog specimens collected from the lower Passaic River by ChemRisk in September 1995 (Tierra, 1995a). Two striped bass (*Morone saxatilis*) and five mummichog samples were collected from the locations presented in Figure 3-11c. The results of the PCB analysis are summarized below and raw data provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Sediment PCB data, from samples collected in a similar timeframe, were used in a food web model (Iannuzzi et al., 1996) to develop expected concentrations of PCBs. Based on the PCB concentrations measured in the fish, TEQs and health risk estimates were also evaluated (Finley et al., 1997).

Total PCB Range (µg/kg)	
Striped Bass	**Mummichog**
81 – 141	199 – 370

During the development of a probabilistic model to assess bioaccumulation of xenobiotic chemicals in an estuarine food web, exposure factor distribution functions for striped bass and mummichog were established (Iannuzzi and Ludwig, 2000; Iannuzzi et al., 1996). PCB and TCDD/F concentrations estimated from the model were compared with concentrations measured in a field study. Samples for the field study were collected from the lower Passaic River in August 1995 and are the same as those used in Finley et al. (1997) (i.e., Tierra, 1995a; Figure 3-11c). Estimated concentrations from the model and a summary of measured concentrations were published by the authors and are provided below.

Chemical	Estimated Concentration (µg/kg)		Measured Concentration (µg/kg)		
	Range	Average	Range	N[a]	Average
Mummichog (whole body)					
3,3',4,4'-TeCB (77)	1.1 – 1.9	6.7	0.92 – 2.4	5	1.3
2,3,3',4,4'-PeCB (105)	2.2 – 41	14	13 – 22	5	18
2,3',4,4',5-PeCB (118)	3.6 – 86	26	48 – 78	5	63
3,3',4,4',5-PeCB (126)	0.063 – 0.59	0.22	0.12 – 0.2	5	0.16
3,3',4,4',5,5'-HxCB (169)	0.0015 – 0.017	0.0060	ND – 0.0044	5	0.0028
2,3,7,8-TCDD	0.014 – 0.12	0.057	0.03 – 0.075	5	0.053
2,3,7,8-TCDF	0.0019 – 0.016	0.0065	0.00096 – 0.0021	5	0.0013
Striped Bass (muscle)					
3,3',4,4'-TeCB (77)	0.067 – 6.4	1.3	2.1 – 2.1	2	2.1
2,3,3',4,4'-PeCB (105)	0.21 – 13	2.8	9.9 – 18	2	14
2,3',4,4',5-PeCB (118)	0.20 – 23	5.0	40 – 69	2	55
3,3',4,4',5-PeCB (126)	0.0032 – 0.23	0.043	0.11 – 0.17	2	0.14
3,3',4,4',5,5'-HxCB (169)	0.000075 – 0.0061	0.00092	0.005 – 0.0085	2	0.0068
2,3,7,8-TCDD	0.00054 – 0.064	0.0090	0.026 – 0.026	2	0.026
2,3,7,8-TCDF	0.000054 – 0.0060	0.00098	0.0017 – 0.0029	2	0.0023

Notes:
a. Each sample consists of a composite of tissues from several individual organisms.
ND = not detected

Monosson et al. (2003) analyzed PCB concentration and congener profiles for tissues of mummichog collected from the Hudson River Estuary and Newark Bay. Tissues analyzed included muscle, liver, and gonad. The Newark Bay sample location was along Roanoke Yacht Club creek, but no specific sampling locations were provided. Two reference sites were sampled as well. Mummichog were collected in the summer of 1994. Four composite samples were taken from the Newark Bay location, each including 8 to 10 individual organs. Raw data were not provided, but summary results are presented below. Published figures show the congener profiles for each organ type from Newark Bay.

Average Total PCB Concentration (± SD) (ng/g)		
Muscle	**Liver**	**Gonad**
209 (15)	1,312 (318)	1,596 (419)

Under the NY/NJ HEP CARP, the NYSDEC conducted biota sampling with chemical tissue analysis at two areas within the Inventory Area (NY/NJ HEP, 2004a). Fish species were collected in spring, summer, and fall 1999, winter 1999–2000, and spring 2000. American eel (*Anguilla rostrata*) were collected during the summer 1999 sampling event, as indicated in Table 3-56. Each of the fish samples was analyzed for the following chemicals: aldrin, beta hexachlorocyclohexane (BHC) isomers, chlordane compounds, DDT & metabolites, dieldrin, endrin, heptachlor, heptachlor epoxide, mirex, photomirex, HCB, Hg, PCDD/Fs, PAHs, and PCB congeners. A draft Microsoft® Access database of the CARP biota tissue data was made available by the NYSDEC during the development of this Inventory Report. However, an interpretive file was not provided with the database to determine the locations where specific samples were collected. As a result, summary tables could not be generated for the data that were collected in the Inventory Area. The CARP Microsoft® Access database is presented in its electronic format (as provided by the NYSDEC) in Appendix F – Bioaccumulation Data.

From 1993 to 1994, the NYSDEC sponsored a large-scale survey of chemical residues in fish, molluscs, crustaceans, and a cephalopod from the NY/NJ Harbor Estuary. Samples were pooled into geographic regions of the Estuary, including a grouping consisting of Newark Bay, Arthur Kill, and Kill Van Kull (referred to in the study as Area 3). Edible parts of the collected organisms were analyzed for various chemicals and results were provided in several NYSDEC publications. Among the organisms collected in Area 3 were American eel, Atlantic tomcod, bluefish (*Pomatomus saltatrix*), butterfish, cunner (*Tautogolabrus adspersus*), porgy (species not specified), spot (*Leiostomus xanthurus*), spotted hake (*Urophycis regia*), striped bass, weakfish (*Cynoscion regalis*), white perch (*Morone americana*), windowpane flounder (*Scophthalmus aquosus*), and winter flounder (*Pseudopleuronectes americanus*). These fish were analyzed for PCBs, organochlorine pesticides, and Hg (NYSDEC, 1996). Raw data were not provided, but summary results are presented below. A subset of these fish (American eel, white perch, and winter flounder) were also analyzed for PCDD/Fs (NYSDEC, 1997a). Raw data for PCDD/Fs are provided in Table 3-57, and summary results are presented below. One species, winter flounder, was also analyzed for PAHs (NYSDEC, 1997b), which were not detected in the samples. The locations of samples are presented in Figure 3-11a.

Species	N	Average Concentration ± SD				
		Total PCBs (µg/g)	Total DDT (ng/g)	Total Chlordane (ng/g)	Dieldrin (ng/g)	Hg (ng/g)
American eel	5	4.0 ± 1.5 (1.7 – 5.2)	4,902 ± 2,232 (1,700 – 6,895)	223 ± 68 (130 – 290)	50 ± 17 (20 – 60)	338 ± 208 (107 – 648)
Atlantic tomcod	3	0.30 ± 0.17 (0.17 – 0.49)	38 ± 6.0[a] (35 – 45)	32 ± 3 (30 – 35)	5.0[a] (5.0 – 5.0)	283 ± 138 (156 – 430)
Bluefish <305 mm	1	3.1	295	110	10	527
Butterfish	3	1.1 ± 0.70 (0.42 – 1.8)	67 ± 21 (50 – 90)	37 ± 12[a] (30 – 50)	7.0 ± 3.0[a] (5.0 – 10)	43 ± 31 (25 – 78)
Cunner	3	0.99 ± 0.12 (0.92 – 1.1)	197 ± 15 (180 – 210)	57 ± 6.0 (50 – 60)	10 (10 – 10)	209 ± 61 (170 – 280)
Porgy	1	1.4	125	55	5.0[a]	60
Spot	1	2.9	1,400	70	20	25[a]
Spotted hake	3	0.12 ± 0.050 (0.070 – 0.16)	32 ± 3.0 (30 – 35)	30[a] (30 – 30)	5[a] (5 – 5)	77 ± 46 (25 – 110)
Striped bass <457 mm	5	1.2 ± 0.34 (0.60 – 1.5)	204 ± 87 (110 – 345)	60 ± 24 (30 – 95)	6 ± 2[a] (5 – 10)	377 ± 130 (185 – 588)
Striped bass 457–610 mm	5	2.1 ± 0.82 (1.4 – 3.5)	369 ± 145 (250 – 610)	99 ± 31 (65 – 145)	18 ± 4 (10 – 20)	325 ± 110 (221 – 480)
Weakfish	3	0.68 ± 0.85 (0.37 – 1.6)	103 ± 38 (60 – 130)	40 ± 17[a] (30 – 60)	7 ± 3[a] (5 – 10)	177 ± 78 (124 – 267)
White perch	6	4.7 ± 3.6 (1.7 – 11)	328 ± 153 (200 – 530)	277 ± 66 (195 – 380)	33 ± 12 (20 – 50)	397 ± 179 (71 – 617)
Windowpane flounder	2	0.25 (0.25 – 0.25)	53[a] (35 – 70)	30[a] (30 – 30)	5.0[a] (5.0 – 5.0)	105 ± 40 (66 – 146)
Winter flounder	3	0.73 ± 0.70 (0.090 – 1.5)	93 ± 81 (30 – 185)	43 ± 23[a] (30 – 70)	5.0[a] (5.0 – 5.0)	35 ± 18 (25 – 56)

Note:
a. The average has increased by 50% or more through the use of ½ the detection limit for computations.

Species	Concentration Range (pg/g)	
	Total PCDD[a]	Total PCDF[b]
American eel (N=2)	14 – 20	4.5 – 7.4
White perch (N=1)	3.5	9.9
Winter flounder (N=2)	1.7 – 3.4	3.7 – 8.2

Notes:
a. Total PCDD with 2,3,7,8-chlorine substitution.
b. Total PCDF with 2,3,7,8-chlorine substitution.

The NYSDEC maintains a database of extensive contaminant data that includes PCB, pesticide, and inorganic chemical concentrations in various fish and crustaceans of the Hudson River basin. The database is regularly updated and contains data from 1975 to 1996 (NYSDEC, 2004c). The database can be accessed at the following internet site:

http://www.harborestuary.org/datadepo.htm

As part of a thesis on DDT and chlordane in the Hudson River basin, Robinson (2002) summarized relevant data from NYSDEC (2004c) and used these data to examine behavior of DDT and chlordane in American eel and striped bass.

Rappe et al. (1991) investigated levels and patterns of PCDD/Fs in specimens of striped bass collected from Newark Bay. Timing of sampling was not specified. Tissue samples were analyzed for PCDD/F congeners. In many samples, an unknown substance, possibly TCDT, was predominant. Specific sampling locations were not provided. Raw data can be found on NOAA's Coastal Protection and Restoration Division internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

Summary results from Rappe et al. (1991) are presented below.

Analyte	Concentration Range (pg/g)
	Striped Bass
Total TCDD	85 – 734
Total TCDF	77 – 108
Total PCDD	5.2 – 10
Total PCDF	34 – 83
Total HexaCDD	0.60 – 0.70
Total HexaCDF	2.0 – 4.4

ChemRisk conducted fish sampling on the lower Passaic River in September 1995 (Tierra, 1995a). Samples were collected from six locations as presented in Figure 3-11c. Two fish species were analyzed: mummichog (whole body) and striped bass (fillet). Samples were analyzed for PCDD/Fs, PCBs congeners, PCB Aroclors, pesticides, PAHs, SVOCs, inorganic chemicals, cyanide, organotin, methyl Hg, TEPH, and percent lipid. A summary of the species collected and analyses performed for the various RI investigations in the lower 6 miles of the Passaic River is presented in Table 3-58. The results of these studies are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Entrix and BBL conducted bioaccumulation sampling in the lower 6 miles of the Passaic River in the late summer/early fall of 1999 as part of the RI activities (Tierra, 1999d). Samples were collected from 15 locations as presented in Figure 3-11c. Six fish species were collected and analyzed: Atlantic menhaden (whole body), Atlantic silverside (whole body), bluefish (whole body and fillet), mummichog (whole body), adult striped bass (whole body and fillet), juvenile striped bass (whole body), and white perch (whole body). Samples were analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, PCBs homologue groups, pesticides, herbicides, PAHs, SVOCs, inorganic chemicals, organotin, and percent lipid (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Entrix and BBL conducted sampling in the lower 6 miles of the Passaic River in May 2000 as part of the RI activities (Tierra, 2000c). Samples were collected from four locations presented in Figure 3-11c. Four species were analyzed: American eel (whole body), mummichog (whole body), adult striped bass (whole body and fillet), and white perch (whole body and fillet). Samples were analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, PCB homologue groups, pesticides, herbicides, PAHs, SVOCs, inorganic chemicals, organotin, and percent lipid (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

BBL conducted sampling within the lower 6 miles of the Passaic River in August 2001 as part of the RI activities (Tierra, 2001a). Samples were collected from 10 locations as presented in Figure 3-11c. Two species were analyzed: American eel (fillet with skin on) and brown bullhead (fillet with skin off). Samples were analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, PCB homologue groups, pesticides, herbicides, PAHs, SVOCs, inorganic chemicals, organotin, and percent lipid (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Yuan et al. (2001) evaluated the use of hepatic cytochrome P4501A1 (CYP1A1) as an indicator of PAH contamination in aquatic ecosystems for Atlantic tomcod. The study included sampling of 444 YOY tomcod at 39 sites along the mainstem of the Hudson River and within the Newark Bay Estuary. This sampling took place from late June to early August each year from 1994–1998. Livers from these specimens were analyzed for CYP1A1 messenger riboxynucleic acid. At a subset of 11 sample locations, pooled livers (5–10 per site) were analyzed for PCDD/Fs and PCBs. One sampling location in Newark Bay and one in the lower Hackensack River were included in this subset. Specific sampling locations were not provided. Raw data from these analyses are presented in Table 3-60, and summary results are presented below.

Chemical	Concentration	
	Newark Bay	Hackensack River
Total PCDD (pg/g)	728	1,039
Total PCDF (pg/g)	380	697
Total Coplanar PCBs (pg/g)	100,472	118,085
Total Mono-ortho PCBs (ng/g)	4,233	4,663
Total Di-ortho PCBs (ng/g)	9,554	11,531

3.2.4.2 Crustaceans

Twenty-two studies have examined bioaccumulation in various crustacean species in the Inventory Area since 1990. These studies are summarized below. The sampling locations for these studies (as available) are depicted in Figures 3-11a through 3-11c.

Only one study since 1990 was identified that evaluated bioaccumulation in American lobster (*Homarus americanus*) within the Inventory Area. Buser and Rappe (1991) estimated the concentration of polychlorinated dibenzothiophenes (PCDTs) in lobster and blue crab collected from Elizabeth, NJ. Details on the exact sample location, timing of sampling, and number of samples are not provided. A table published by the authors is reproduced below; however, it is not evident whether this table presents raw data from single specimens or averages from numerous specimens.

Chemical	Estimated Concentration (pg/g)	
	Blue Crab	Lobster
tri-CDT	140	ND
2,4,6,8-tetra-CDT	8,300	1,000
Other tetra-CDT	500	ND
penta-CDT (1)	1,300	60
penta-CDT (2)	240	25
2,3,7,8-tetra-CDF	600	300

Note:
ND = not detected (<5 – 20 pg/g)

Several studies reported on the levels of PCDD/Fs and PCDTs in blue crab tissues that were collected from the Newark/Raritan Bay system in September 1991 and June 1992 (Cai et al. 1994a,b; Cristini, 1992; Cristini and Gross 1993). Five crabs were collected from one location within Newark Bay. Hepatopancreas and muscle tissue from the collected specimens were homogenized into two samples per sampling location and analyzed for PCDD/Fs and PCDTs. Only Cai et al. 1994b discussed the results for PCDTs. The sampling locations are presented in Figure 3-11a. Raw data can be found on NOAA's Coastal Protection and Restoration Division internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

Summary results from Cai et al. (1994a,b) are presented below.

Chemical	Concentration Range (ppt) from 1991 and 1992	
	Muscle	Hepatopancreas
2,3,7,8-TCDD	20 – 45	40 – 940
2,3,7,8-TCDF	<6 – 15	130 – 200
1,2,3,7,8-PCDF	NA	25 – 70
2,3,4,7,8-PCDF	NA	15 – 90
1,2,3,4,7,8-HCDF	NA	45 – 95
2,4,6,8-TCDT	260 – 610	290 – 10,000

Cooper et al. (1992) examined bioaccumulation of TCDD/Fs in the food web of a saltmarsh mudflat in Elizabeth, NJ. Organisms collected for analysis included grass shrimp (*Palaemonetes pugio*). Specific sampling locations were not provided. No raw data were provided, but summary results are presented below.

Species	**Concentration (ppt)**	
	2,3,7,8-TCDD	**2,3,7,8-TCDF**
Grass Shrimp	3.9	2.1

Eckenfelder (1993) investigated the bioaccumulation of Hg, PCDD/Fs, TPHs, select pesticides, PCBs, VOCs, and SVOCs in blue crab. Blue crab sampling was conducted in two areas within the Hackensack Meadowlands: the study site (six sampling locations) and the Hackensack River (two sampling locations). These locations are presented in Figure 3-11b. Four composite samples of blue crab, both muscle and hepatopancreas tissue, were obtained at each sampling location and were analyzed for the above contaminants. Raw data can be found on NOAA's Coastal Protection and Restoration Division internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

Summary results from Eckenfelder (1993) are presented below.

Analyte[a]	**Concentration**				
	Study Sites 23/43	**Study Sites 15/35**	**Study Sites 27/36**	**HK**[b] **Cayuga Site**	**HK**[b] **Standard Chlorine Site**
Muscle Tissue					
4,4'DDE (mg/kg)	ND[c]	0.025	0.024	0.045	0.098
4,4'DDD (mg/kg)	ND	0.022	NM[d]	0.024	0.038
Aldrin (mg/kg)	0.017	ND	ND	ND	ND
Dieldrin (mg/kg)	0.082	ND	ND	ND	ND
Heptachlor epoxide (mg/kg)	ND	ND	ND	ND	0.0080
Total SVOCs (mg/kg)	1,096	1,596	1,067	754	1,656
Hg (mg/kg)	ND	ND	ND	1.0	1.4
Total PCDD/F TEQ (ng/kg)	1.3	3.0	3.9	22	26
Hepatopancreas Tissue					
4,4'DDE (mg/kg)	0.010	0.55	0.53	1.7	2.1
4,4'DDD (mg/kg)	0.012	0.42	0.36	0.94	1.2
Aroclor 1254 (mg/kg)	0.13	ND	ND	ND	ND
Aroclor 1260 (mg/kg)	ND	3.9	3.9	5.6	ND
Total SVOCs (mg/kg)	7,574	55,000	50,000	10,422	6,738

Analyte[a]	Concentration				
	Study Sites 23/43	Study Sites 15/35	Study Sites 27/36	HK[b] Cayuga Site	HK[b] Standard Chlorine Site
Hg (mg/kg)	ND	ND	ND	0.39	ND
Total PCDD/F TEQ (ng/kg)	61	46	144	763	597

Notes:
a. Contaminants not detected are not listed in this summary table.
b. HK = Hackensack River
c. ND = not detected
d. NM = results were reported as not meaningful

Finley et al. (1997) reported on Aroclor mixture and specific PCB congener concentrations for blue crab samples collected from the lower Passaic River that were collected by ChemRisk in September 1995 (Tierra, 1995a). Four samples of male blue crab muscle and two samples of male blue crab hepatopancreas were collected from the two locations presented in Figure 3-11c. The results of the PCB analysis are summarized below and raw data are available in Tierra (1995a), which can be found in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Sediment PCB data, from samples collected in a similar timeframe, were used in a food web model (Iannuzzi et al., 1996) to develop expected concentrations of PCBs. Based on the PCB concentrations measured in the blue crabs, PCB TEQ toxic and health risk estimates were also evaluated.

Total PCB Concentration Range (µg/kg)	
Muscle	**Hepatopancreas**
22 – 38	1,155 – 1,314

During the development of a probabilistic model to assess bioaccumulation of xenobiotic chemicals in an estuarine food web, exposure factor distribution functions for blue crab were established (Iannuzzi and Ludwig, 2000; Iannuzzi et al., 1996). PCB and TCDD/F concentrations estimated from the model were compared with concentrations measured in a field study. Samples for the field study were collected from the lower Passaic River in September 1995 and are the same as those used in Finley et al. (1997) (i.e., Tierra, 1995a; Figure 3-11c). Estimated concentrations from the model and a summary of measured concentrations that were published by the authors are provided below.

Chemical	Estimated Concentration (µg/kg)		Measured Concentration (µg/kg)		
	Range	Average	Range	N[a]	Average
Muscle					
3,3',4,4'-TeCB (77)	0.094 – 42	5.3	0.40 – 0.70	4	0.56
2,3,3',4,4'-PeCB (105)	0.069 – 77	12	1.4 – 2.8	4	2.0
2,3',4,4',5-PeCB (118)	0.015 – 281	21	4.6 – 10	4	6.9
3,3',4,4',5-PeCB (126)	0.0048 – 1.3	0.17	0.010 – 0.025	4	0.016
3,3',4,4',5,5'-HxCB (169)	0.000022 – 0.034	0.0036	ND – 0.0035	4	0.0018
2,3,7,8-TCDD	0.000058 – 0.384	0.035	0.0066 – 0.16	4	0.011
2,3,7,8-TCDF	0.000035 – 0.044	0.0039	0.0011 – 0.0023	4	0.0026
Hepatopancreas					
3,3',4,4'-TeCB (77)	3.1 – 235	52	44 – 71	2	58
2,3,3',4,4'-PeCB (105)	9.7 – 615	112	140 – 200	2	170
2,3',4,4',5-PeCB (118)	4.6 – 1,520	199	250 – 790	2	520
3,3',4,4',5-PeCB (126)	0.076 – 11	1.7	1.4 – 2.1	2	1.8
3,3',4,4',5,5'-HxCB (169)	0.0015 – 0.26	0.036	0.087 – 0.15	2	0.12
2,3,7,8-TCDD	0.017 – 1.8	0.33	0.48 – 0.67	2	0.575
2,3,7,8-TCDF	0.00086 – 0.28	0.038	0.12 – 0.15	2	0.135

Notes:
a. Each sample consists of a composite of tissues from several organisms.
ND = not detected

The New Jersey Department of Environmental Protection and Energy (NJDEPE) conducted an investigation of Cr bioaccumulation in blue crabs for the Hackensack River (NJDEP, 1993a). Blue crab samples were collected from three locations in the Hackensack River, as presented in Figure 3-11b, and at one reference location in southern New Jersey. At each location, four composite samples were created from five individual specimens. Body muscle, claw muscle, and hepatopancreas tissues were analyzed for Cr. Also, previous sampling performed between 1986 and 1988 for the NJDEPE's Toxics in Biota Technical Committee was reviewed. Raw data is provided in Table 3-61, and summary results are presented below.

Study Site	Average Cr Concentration (mg/kg) SD in Parentheses		
	Body Muscle	Claw Muscle	Hepatopancreas
Berry's Creek	1.8 (2.7)	1.2 (1.3)	3.4 (3.8)
Sawmill Creek	0.99 (0.82)	1.6 (2.1)	2.0 (1.4)
Diamond Shamrock	1.1 (1.3)	1.2 (1.7)	1.7 (0.78)

Under the NY/NJ HEP CARP, the NYSDEC conducted biota tissue sampling at two locations within the Inventory Area (NY/NJ HEP, 2004a). Blue crab were collected in summer 1999 from two locations; Newark Bay and the Passaic River at Harrison. Shrimp and amphipods were collected in spring 1999 and spring 2000 from both the Newark Bay and the Passaic River sampling sites. The seasons and numbers of samples are presented in Table 3-56. There were five blue crab samples collected in Newark Bay and four samples collected in the Passaic River at Harrison in summer 1999. There were six shrimp/amphipod samples collected in Newark Bay and one sample collected in the Passaic River at Harrison in spring 2000. Crustacean samples were analyzed for the following parameters: aldrin, BHC isomers, chlordane compounds, DDT & metabolites, dieldrin, endrin, heptachlor, heptachlor epoxide, mirex, photomirex, HCB, Hg, PCDD/Fs, PAHs, and PCB congeners. A draft Microsoft® Access database of the CARP biota tissue data was made available by the NYSDEC during the development of this Inventory Report. However, an interpretive file was not provided with the database to identify the location of collection for specific samples. As a result, summary tables could not be generated for the data that were collected in the Inventory Area. The CARP Microsoft® Access database is presented in its electronic format (as provided by the NYSDEC) in Appendix F – Bioaccumulation Data.

From 1993 to 1994, the NYSDEC sponsored a large scale survey of chemical residues in fish, molluscs, crustaceans, and a cephalopod from the NY/NJ Harbor Estuary. Samples were pooled into regions of the Estuary, including a collective grouping of Newark Bay, Arthur Kill, and Kill Van Kull (referred to in the study as Area 3). Edible parts of the collected organisms were analyzed for various chemicals and results were provided in several NYSDEC publications. Blue crab was one of the organisms collected in the Inventory Area, and both muscle and hepatopancreas samples were analyzed for PCBs, organochlorine pesticides, and Hg (NYSDEC, 1996). Raw data were not provided, but summary results are presented below. Blue crab samples were also analyzed for PDDD/Fs (NYSDEC, 1997a). Raw data are provided in Table 3-62, and summary data are presented below. This study also included supplemental samples collected in Newark Bay during 1995, but details on the location of these 1995 samples are not provided. The locations of samples from 1993 to 1994 are presented in Figures 3-11a and 3-11c.

Tissue Type	N	Average Concentration ± SD				
		Total PCBs (μg/g)	**Total DDT** (ng/g)	**Total Chlordane** (ng/g)	**Dieldrin** (ng/g)	**Hg** (ng/g)
Blue crab Muscle	5	0.050 ± 0.020 (<0.030 – 0.070)	43 ± 12[a] (35 – 60)	31 ± 2.0[a] (30 – 35)	5.0[a] (5.0 – 5.0)	199 ± 68 (140 – 315)
Blue crab hepatopancreas	5	6.6 ± 4.1 (4.4 – 14)	785 ± 364 (335 – 1,185)	329 ± 50 (255 – 370)	70 ± 28 (40 – 100)	84 ± 68 (25 – 190)

Note:
a. The average has increased by 50% or more through the use of 1/2 the detection limit for computations.

Tissue Type	N	Concentration Range (pg/g)	
		Total PCDD[a]	Total PDCF[b]
Blue crab Muscle	8	3.0 – 8.5	3.3 – 5.8
Blue crab Hepatopancreas	8	202 – 283	276 – 513

Notes:
a. Total PCDD with 2,3,7,8-chlorine substitution.
b. Total PCDF with 2,3,7,8-chlorine substitution.

The NYSDEC maintains a database of extensive contaminant data that includes PCB, pesticide and inorganic chemical concentrations in various fish and crustaceans of the Hudson River basin. The database is regularly updated and contains data from 1975 to 1996 (NYSDEC, 2004c). The database can be accessed at the following internet site:

http://www.harborestuary.org/datadepo.htm

As part of a thesis on DDT and chlordane in the Hudson River basin, Robinson (2002) summarized relevant data from NYSDEC (2004c) and used these data to examine behavior of DDT and chlordane in blue crabs.

Rappe et al. (1991) collected samples of blue crab in Newark Bay to investigate levels and patterns of PCDD/Fs in muscle and hepatopancreas tissue. Timing of sampling was not specified. Tissue samples were analyzed for PCDD/Fs. In many samples, an unknown substance, possibly TCDT, was predominant. Specific sampling locations were not provided. Raw data can be found on NOAA's Coastal Protection and Restoration Division internet site:

http://response.restoration.noaa.gov/cpr/watershed/watershedtools.html

Summary results from Rappe et al. (1991) are depicted below.

Chemical	Concentration Range (pg/g)	
	Muscle	Hepatopancreas
Total TCDD	118 – 150	4,336 – 6,872
Total TCDF	133 – 165	6,338 – 7,761
Total PCDD	17 – 18	713 – 1,230
Total PCDF	90 – 94	2,866 – 5,572
Total HexaCDD	0.3 – 1.5	143 – 332
Total HexaCDF	9.3 – 9.4	514 – 1,092

Using data from Rubinstein et al. (1990) (study summarized below), combined with extractable lipid concentration from the grass shrimp tissue and TOC concentration from the contaminated sediment, Pruell et al. (1993) determined accumulation factors (AFs) for 2,3,7,8-TCDD/F and PCB congeners for grass shrimp. It was also determined that 2,4,6,8-TCDT was being bioaccumulated by grass shrimp. After the longest exposure time (28 days), the distribution of AFs for 10 PCB congeners was determined. Raw data were not provided, but summary results, estimated from a published figure, are presented below.

Chemical	Estimated Average AF[a]
2,3,7,8-TCDD	0.75
2,3,7,8-TCDF	0.60
2,4,6,8-TCDT	1.0
PCB 153	2.3

Note:
a. 28-day exposure duration.

Rubinstein et al. (1990) examined bioaccumulation of 2,3,7,8-TCDD, 2,3,7,8-TCDF, and PCBs in several organisms, including grass shrimp. Grass shrimp were incubated with contaminated sediments from the Passaic River for 28 days to determine uptake of these contaminants. The specific location along the Passaic River where sediment was collected for the incubations is not provided. Raw data were not provided, but the results are summarized below.

Chemical	Average Concentration Bioaccumulated after 28 Days (pg/g)
2,3,7,8-TCDD	138 ± 20
2,3,7,8-TCDF	59 ± 7.7
Total PCBs	840 ± 191

Tavolaro and Stern (1990) provided a review of bioaccumulation and depuration data for grass shrimp, clams, and sandworms that were collected by Rubinstein et al. (1990). No new data were reported in this investigation.

ChemRisk collected blue crab sampled from the lower Passaic River in September 1995 (Tierra, 1995a). Samples were collected from six locations as presented in Figure 3-11c. Edible muscle and hepatopancreas tissue samples were analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, pesticides, PAHs, SVOCs, inorganic chemicals, cyanide, organotin, methyl Hg, TEPH, and percent lipid (Table 3-58). The results are and summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Entrix and BBL conducted bioaccumulation sampling in the lower 6 miles of the Passaic River in the late summer/early fall of 1999 as part of the RI activities (Tierra, 1999d). Samples were collected from 15 locations as presented in Figure 3-11c. Blue crab whole body soft tissue, edible muscle, and hepatopancreas tissue samples were analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, PCB homologue groups, pesticides, herbicides, PAHs, SVOCs, inorganic chemicals, organotin, and percent lipid (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. Entrix and BBL conducted sampling in four of the same locations in May 2000 (Tierra, 2000c) (Figure 3-11c). Blue crab whole body soft tissue and edible muscle tissue samples were analyzed for the same suite of analytes (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

3.2.4.3 Molluscs

Eight studies have examined bioaccumulation in various mollusc species in the Inventory Area since 1990. These studies are summarized below. The sampling locations for these studies (as available) are presented in Figures 3-11a through 3-11c.

Cooper et al. (1992) examined bioaccumulation of TCDD/Fs in the food web of a saltmarsh mudflat in Elizabeth, NJ. Organisms collected for analysis included *Macoma sp.*, softshell clam, and snail (*Nassarias sp.*). Specific sampling locations were not provided by the authors. No raw data were provided, but summary results are presented below.

Species	Concentration (ppt)	
	2,3,7,8-TCDD	2,3,7,8-TCDF
Macoma sp.	13	7.0
Softshell clam	6.9	4.8
Snail	11	8.2

Under the NY/NJ HEP CARP, the NYSDEC conducted biota sampling at two areas within the Inventory Area (NY/NJ HEP, 2004a). Bivalves were collected in summer 1999, fall 1999, winter 1999–2000, and spring 2000 at two locations: Newark Bay and the Passaic River at Harrison. Six samples of bivalve species were collected from each location, as indicated in Table 3-56. Samples were analyzed for aldrin, BHC isomers, chlordane compounds, DDT & metabolites, dieldrin, endrin, heptachlor, heptachlor epoxide, mirex, photomirex, HCB, Hg, PCDD/Fs, PAHs, and PCB congeners. A draft Microsoft® Access database of the CARP biota tissue data was made available by the NYSDEC during the development of this Inventory Report. However, an interpretive file was not provided with the database to identify the location of collection for specific samples. As a result, summary tables could not be generated for the data that were collected in the Inventory Area. The CARP Microsoft® Access database is presented in its electronic format (as provided by the NYSDEC) in Appendix F – Bioaccumulation Data.

From 1993 to 1994, the NYSDEC sponsored a large scale survey of chemical residues in fish, molluscs, crustaceans, and a cephalopod from the NY/NJ Harbor Estuary. Samples were pooled into regions of the Estuary, including a collective grouping of Newark Bay, Arthur Kill, and Kill Van Kull (referred to in the study as Area 3). Edible parts of the collected organisms were analyzed for various chemicals and results were provided in several NYSDEC publications. Three mollusc species were collected from the Inventory Area. Samples were analyzed for PCBs, organochlorine pesticides, and Hg (NYSDEC, 1996). One species, softshell clam, was analyzed for PAHs (NYSDEC, 1997b). The sampling locations are presented in Figures 3-11a and 3-11c. Raw data were not provided, but summary results are presented below.

Species	**N**	**Average ± SD Concentration Range**				
		Total PCBs (µg/g)	**Total DDT** (ng/g)	**Total Chlordane** (ng/g)	**Dieldrin** (ng/g)	**Hg** (ng/g)
Eastern Oyster	3	0.28 ± 0.070 (0.22 – 0.35)	103 ± 60 (40 – 160)	32 ± 3.0[a] (30 – 35)	5.0[a] (5.0 – 5.0)	91± 21 (67 – 105)
Horse Mussel	3	<0.030 (<0.030 – <0.030)	128 ± 8 (30 – 200)	30[a] (30 – 30)	5.0[a] (5.0 – 5.0)	42 ± 29 (25 – 75)
Softshell Clam	3	0.21 ± 0.33 (<0.030 – 0.59)	67 ± 55 (30 – 130)	33 ± 6.0[a] (30 – 40)	5.0[a] (5.0 – 5.0)	101 ± 11 (90 – 112)

Note:
a. The average has increased by 50% or more through the use of 1/2 the detection limit for computations.

Species	**Fluoranthene** (ng/g)	**Pyrene** (ng/g)
Softshell Clam – specimen 1	73	150
Softshell Clam – specimen 2	46	100

Notes:
All reported concentrations were between detection limit and PQL and must be considered maximum concentrations.

PAHs not detected include: naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, benzo(a)anthracene, chrysene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, benzo(b)fluoranthene, phenanthrene.

Paulson et al. (2003) investigated bioaccumulation of various inorganic chemicals in ribbed mussels (*Geukensia demissa*). In September 1996 and May 1997, samples were collected from six locations along the Arthur Kill and a reference location at Sandy Hook, NJ. The Arthur Kill sampling locations included two sites that had been inundated with oil from a 1990 fuel oil spill and replanted with saltmarsh cordgrass, two sites that were inundated with oil and not replanted, and two sites not affected by the oil spill. The soft tissue of mussels was analyzed for Ag, Cd, Cr, Cu, iron, Hg, Ni, and Zn concentration. Sampling locations are presented in Figure 3-11a. No raw data were provided, but average concentrations of inorganic chemicals in oiled sites, not oiled sites, and the reference site are presented below.

Study Site	Concentration (µg/g)							
	Ag	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Ni**	**Zn**
Arthur Kill (oiled)	0.72	4.6	1.9	20	301	0.29	0.67	67
Tufts Point (not oiled)	0.50	6.1	1.5	16	200	0.17	0.74	65
Mill Creek (not oiled)	0.23	1.6	0.40	14	132	0.070	0.39	50
Sandy Hook (reference)	0.49	0.60	0.70	10	69	0.11	0.43	43

Note:
Fe = iron

Using the data from Rubinstein et al. (1990) (study summarized below), combined with extractable lipid concentrations from the clam tissue and TOC concentrations from the contaminated sediment, Pruell et al. (1993) determined AFs for 2,3,7,8-TCDD/F and PCB congeners for the clams. It was also determined that 2,4,6,8-TCDT was being bioaccumulated by the clams. AFs for the clams did not show a progressive increase over time, indicating that steady state might have been reached after only 10 days. AFs for PCB congener 153 were greater than those for 2,3,7,8-TCDD/F. After the longest exposure time (120 days), the distribution of AFs for 10 PCB congeners was determined. Raw data were not provided, but summary results, estimated from a published figure, are presented below.

Days of Exposure	Average AF				
	10	**28**	**42**	**70**	**120**
2,3,7,8-TCDD	0.70	0.85	0.65	.80	1.0
2,3,7,8-TCDF	0.70	0.75	0.55	.65	0.70
PCB 153	1.2	1.3	1.5	1.8	1.8

Rubinstein et al. (1990) examined bioaccumulation of 2,3,7,8-TCDD, 2,3,7,8-TCDF, and PCBs in several organisms, including clams (*Macoma nasuta*). Clams were incubated with contaminated sediments from the Passaic River for up to 190 days to determine uptake and depuration of these contaminants. Bioaccumulation results are summarized below. After exposure to contaminated sediment for 70 days, clams exposed to control sediments showed a reduction in 2,3,7,8-TCDD/F and PCB concentration to nearly background level. The specific location along the Passaic River where sediment was collected for the incubations is not provided. Raw data were not provided, but summary results are presented below.

Chemical	Time for Concentration to Reach Steady State (days)	Average Concentration Bioaccumulated after 120 Days (pg/g)
2,3,7,8-TCDD	40	142 ± 20
2,3,7,8-TCDF	40	51 ± 6.8
Total PCBs	40	887 ± 19

Tavolaro and Stern (1990) provided a review of bioaccumulation and depuration data for grass shrimp, clams, and sandworms that were collected by Rubinstein et al. (1990). No new data were reported in this investigation.

Entrix conducted a caged bivalve investigation in September–October 1999 on the lower 6 miles of the Passaic River as part of the RI activities (Tierra, 1999d). Ribbed mussel were placed in cages at 15 locations in the River as presented in Figure 3-11c. Following the termination of the 28-day exposure period, tissue samples from each cage were collected and analyzed for PCDD/Fs, PCB congeners, PCB Aroclors, PCB homologue groups, pesticides, herbicides, PAHs, SVOCs, inorganic chemicals, organotin, and percent lipid (Table 3-58). The results are summarized in Table 3-59. Raw data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

3.2.4.4 Benthic (Infaunal) Invertebrates

Four studies have examined bioaccumulation in various benthic (infaunal) invertebrate species in the Inventory Area since 1990. These studies are summarized below.

Cooper et al. (1992) examined bioaccumulation of TCDD/Fs in the food web of a saltmarsh mudflat in Elizabeth, NJ. Although the exact location within Elizabeth is not specified, the study site is presumed to be on the Arthur Kill or in Newark Bay. Blood worms were collected for analysis. Specific sampling locations were not provided. No raw data were provided, but summary results are presented below.

Species	Concentration (ppt)	
	2,3,7,8-TCDD	2,3,7,8-TCDF
Blood worm	4.9	3.9

Using the data from Rubinstein et al. (1990) (see below), combined with extractable lipid concentrations from the sandworm tissue and TOC concentrations from the contaminated sediment, Pruell et al. (1993) determined AFs of 2,3,7,8-TCDD/F and PCB congeners for the sandworms. It was also determined that 2,4,6,8-TCDT was being bioaccumulated by the sandworms. AFs for the sandworms increased gradually over 180 days for 2,3,7,8-TCDD/F and PCB congener 153, but AFs for PCB congener 153 were significantly greater than those for 2,3,7,8-TCDD/F. After the longest exposure time (180 days), the distribution of AFs for 10 PCB congeners was determined. Raw data were not provided, but summary results, estimated from a published figure, are presented below.

Days of Exposure	Average AF					
	10	28	42	70	120	180
2,3,7,8-TCDD	0.020	0.10	0.20	0.35	0.50	0.50
2,3,7,8-TCDF	0.10	0.15	0.20	0.25	0.30	0.25
PCB 153	0.25	0.50	0.85	0.65	1.3	1.3

Rubinstein et al. (1990) examined bioaccumulation of 2,3,7,8-TCDD, 2,3,7,8-TCDF, and PCBs in several organisms, including sandworm. Sandworms were incubated with contaminated sediments from the Passaic River for up to 190 days to determine uptake and depuration of these contaminants. Bioaccumulation results are summarized below. After exposure to contaminated sediment for 70 days, sandworms exposed to control sediments showed approximately a 50% reduction in 2,3,7,8-TCDD/F, but little reduction in PCB concentration. The specific location along the Passaic River where sediment was collected for the incubations is not provided. Raw data were not provided, but summary results are presented below.

Chemical	Time for Concentration to Reach Steady State (days)	Average Concentration Bioaccumulated after 180 Days (pg/g)
2,3,7,8-TCDD	120	422 ± 103
2,3,7,8-TCDF	42	112 ± 51
Total PCBs	> 180	2,930 ± 607

Tavolaro and Stern (1990) provided a review of bioaccumulation and depuration data for grass shrimp, clams, and sandworms that were collected by Rubinstein et al. (1990). No new data were reported in this investigation.

3.2.4.5 Plants and Algae

Three studies have examined bioaccumulation in various plant or algae species in the Inventory Area since 1990. These studies are summarized in the table and text below.

Species	Tissue Analyzed	Contaminants	Reference
Green algae	wet tissue	PCDD/Fs	Cooper et al. (1992)
Common reed	leaf	Hg	Windham et al. (2001)
Common reed	leaf	Cr, Cu, Pb, Zn	Burke et al. (2000)
Saltmarsh cordgrass	leaf	Hg	Windham et al. (2001)
Saltmarsh cordgrass	leaf	Cr, Cu, Pb, Zn	Burke et al. (2000)
Saltmarsh cordgrass	wet tissue	PCDD/Fs	Cooper et al. (1992)

Burke et al. (2000) evaluated bioaccumulation of Cr, Cu, Pb, and Zn in the leaves of saltmarsh cordgrass and common reed (*Phragmites australis*). The study consisted of a laboratory phase, where field-collected plants were grown indoors for one week before being sampled, and a field phase. The field site, for both plant collection and field sampling, was located in the Hackensack Meadowlands along a tidal creek called the Jersey City Aqueduct (Hackensack River watershed); specific sampling locations were not provided. Plant collection for the indoor growth study occurred in May 1998, and field sampling occurred in August 1998. Inorganic chemicals concentrations were determined using a Perkin-Elmer 603 atomic absorption spectrophotometer. No raw data were provided, but summary results are presented below.

Inorganic Chemical	Phase of Study	Number of Samples	Average Concentration (µg/g) ± SE	
			Common Reed	Cordgrass
Cr	Lab	7	0.28 ± 0.080	0.85 ± 0.12
	Field	5	0.29 ± 0.030	0.67 ± 0.080
Cu	Lab	7	8.2 ± 1.2	7.5 ± 0.51
	Field	5	7.1 ± 0.91	6.1 ± 0.59
Pb	Lab	7	0.33 ± 0.090	0.77 ± 0.090
	Field	5	0.50 ± 0.12	0.89 ± 0.090
Zn	Lab	7	24. ± 3.8	24 ± 3.6
	Field	5	22 ± 3.7	30 ± 4.9

Note:
SE = standard error

Cooper et al. (1992) examined bioaccumulation of TCDD/Fs in the food web of a saltmarsh mudflat in Elizabeth, NJ. Organisms collected for analysis included green algae and saltmarsh cordgrass. Specific sampling locations were not provided. No raw data were provided, but summary results are presented below.

Species	Concentration (ppt)	
	2,3,7,8-TCDD	2,3,7,8-TCDF
Green algae	0.60	0.30
Grasses (*Spartina sp.)*	2.5	1.3

Windham et al. (2001) conducted a study at the same Hackensack Meadowlands field site as Burke et al. (2000) to investigate bioaccumulation of Hg in saltmarsh cordgrass and common reed. Samples were collected in late May, June, and July of 1999. Plant leaves were collected from both upper and lower portions of the plants and from both shaded and unshaded field plots and analyzed for Hg. No raw data were provided, but summary results, estimated from a published figure, are presented below.

Month	95% Confidence Interval Hg Concentration (ng/g)	
	Common Reed	Cordgrass
May	20 – 35	82 – 100
June	17 – 19	25 – 34
July	17 – 20	29 – 32

3.2.4.6 Other Organisms

Three studies have examined bioaccumulation in organisms other than those discussed above in the Inventory Area since 1990. These studies are summarized in the text below.

McIntyre (2000) studied bioaccumulation of heavy inorganic chemicals in diamondback terrapin at two estuarine sites in New Jersey. One of the study areas was the Hackensack Meadowlands along the Hackensack River. During July 1999, six turtles were collected from Sawmill Creek. The sampling locations are presented in Figure 3-11b. Tissues sampled for heavy inorganic chemicals analysis included livers and stomach contents. Raw data were published for a subset of inorganic chemicals analysis, and these are presented in Table 3-63.

Under the NY/NJ HEP CARP, the NYSDEC conducted biota sampling at two areas within the Inventory Area (NY/NJ HEP, 2004a). Zooplankton were collected in spring 1999 and spring 2000 at two locations: Newark Bay and the Passaic River at Harrison. Five samples were collected at each location, as indicated in Table 3-56. Samples were analyzed for aldrin, BHC isomers, chlordane compounds, DDT & metabolites, dieldrin, endrin, heptachlor, heptachlor epoxide, mirex, photomirex, HCB, Hg, PCDD/Fs, PAHs, and PCB congeners. A draft Microsoft® Access database of the CARP biota tissue data was made available by the NYSDEC during the development of this Inventory Report. However, an interpretive file was not provided with the database to determine the location of collection for specific samples. As a result, summary tables could not be generated for the data that were collected in the Inventory Area. The CARP Microsoft® Access database is presented in its electronic format (as provided by the NYSDEC) in Appendix F – Bioaccumulation Data.

Also part of the NY/NJ HEP CARP, Parsons (2003) performed an extensive evaluation of chemical residues in double-crested cormorants (*Phalacrocorax auritus*) in the Inventory Area. This is the only published report of CARP bioaccumulation data to date. Eggs, blood, and tissue samples were obtained from cormorants on three islands during 1999, including Shooter's Island, located at the confluence of Newark Bay, the Arthur Kill, and the Kill Van Kull. The location of Shooter's Island is presented in Figure 3-11a. Sixteen eggs and 10 to 11 blood samples from Shooter's Island specimens were analyzed for Hg, methyl-Hg, Cd, PAHs, pesticides, PCB Aroclors, PCB congeners, and PCDD/Fs. Also, reproductive success was studied at 61 nest sites on Shooter's Island. Raw data were not provided in this report, but extensive summary tables and associated discussions are presented. A draft Microsoft® Access database of the CARP biota tissue data was made available by the NYSDEC during the development of this Inventory Report. However, an interpretive file was not provided with the database to determine the location of collection for specific samples. As a result, summary tables could not be generated for the data that were collected in the Inventory Area. The CARP Microsoft® Access database is presented in its electronic format (as provided by the NYSDEC) in Appendix F – Bioaccumulation Data. Parsons (2003) is provided in electronic format in Appendix F – Bioaccumulation Data. Summary results are presented below.

Analyte	Concentration (ng/g) Range (N)			
	Eggs	**Blood Plasma**	**Down**	**Feathers**
Hg	85 – 1,130 (14)	66 – 401 (11)	2,540 – 5,560 (10)	2,310 – 13,800 (11)
Methyl-Hg	175 – 320 (3)	160 – 167 (2)	3,160 – 5,900 (2)	2,750 – 3,310 (2)
Cd	ND – 16 (14)	ND (11)	13 – 295 (10)	ND (11)

Analyte	**Eggs** (n = 14)	**Blood Plasma** (n = 10 or 11)
PAHs[a](ng/g)		
1-Methylnapthalene	0.31 – 5.6	1.2 – 3.1
C1 Napthalene	0.69 – 12	3.2 – 8.3
C2 Napthalene	0.60 – 11	2.4 – 6.5
C3 Napthalene	0.50 – 4.6	2.8 – 6.2
Napthalene	2.6 – 9.6	5.5 – 11
Biphenyl	NA	0.79 – 2.6
Phenanthrene	NA	1.4 – 2.1
Pesticides[b] (pg/g)		
4,4'-DDD	2,590 – 2,150,000	168 – 8,000
4,4'-DDE	487,000 – 12,100,000	12,800 – 88,900
Oxychlordane	747 – 491,000	1,570 – 6,260
Dieldrin	5,640 – 102,000	0 – 4,690
Total PCB Aroclors (ng/g)	3,380 – 69,200	158 – 544
Total PCB Congeners (ng/g)	1,980 – 40,400	105 – 331

Analyte	**Eggs** (n = 14)	**Blood Plasma** (n = 10 or 11)
Total PCDD (pg/g)	38 – 353	3.6 – 15
Total PCDF (pg/g)	5.9 – 92	1.1 – 5.3

Notes:
a. Not exhaustive list of PAHs reported in source. List includes those PAHs detected with average concentration >1.0 ng/g-ww.
b. Not exhaustive list of pesticides. List includes those pesticides detected with average concentration >25,000 and >2,000 pg/g-ww in eggs and blood plasma, respectively.
ND = not detected
NA = not applicable

3.2.4.7 Dredging Permit Applications

Twelve dredging permit applications filed with the USACE in 1990 or later that contain bioaccumulation data were identified and obtained. It is likely that a substantial number of additional dredging permit applications exist for this time period for the Inventory Area. However, these were not obtainable for this Report. The results of the bioaccumulation testing presented in these permit applications are summarized in Tables 3-64a through 3-64d. Locations of the sites described in the dredging permit applications are depicted in Figure 3-2. A copy of each of the dredging permit applications from 1990 to the present that contain bioaccumulation data is provided in electronic format in Appendix F – Bioaccumulation Data.

3.2.4.8 Summary of QA/QC Information for Bioaccumulation Studies

The bioaccumulation studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. Available QA/QC information for each bioaccumulation study from 1990–present is presented in Table 3-65.

3.3 Non-Chemical Data and Information for the Inventory Area

3.3.1 Habitats

A variety of studies have been performed in the Inventory Area to characterize aquatic, wetland, and terrestrial habitats. Seventy-four identified studies are summarized in Table 3-66. The following sections summarize the 34 studies conducted since 1990. Where available, the habitat data/information presented in these studies are provided in tables or are presented in electronic format scanned from the source document and included in Appendix G – Habitat Data. For many of the habitat studies, the area of the survey is too broad and undefined to include on a figure. Estimated habitat survey areas for select studies with more defined study areas are depicted in Figure 3-12. Forty identified habitats studies that were conducted prior to 1990 are briefly summarized in Table 3-66.

3.3.1.1 Land Use

There are eight identified studies conducted since 1990 that report on land use in the Inventory Area.

An Islanded Nature (Blanchard et al., 2001) provides an overview of conservation and natural area restoration projects in the vicinity of Staten Island, NY. As part of this report, residential, commercial, and industrial land use is presented for western Staten Island along the Arthur Kill. A copy of this map is available at the following internet site:

http://tpl.org/content_documents/main_map.pdf

Coastal Environmental Services, Inc. (1996) presents natural resource mapping for the City of Bayonne, Hudson County, NJ, as presented in Figure 3-12. This information is presented in a series of layers on a base map, and contains information regarding bedrock geology, land use/land cover, floodprone areas, environmentally sensitive areas, and topography for the City of Bayonne. These data are presented in an electronic format that is not compatible with geographic information systems (GIS). The electronic map files are provided in Appendix G – Habitat Data.

Greiling (1993) provides a summary of previously published documentation of habitats in the 130-square-mile Arthur Kill watershed, which includes the drainage of six tributaries: Elizabeth, Rahway and Woodbridge Rivers; and Morses, Piles, and Smith Creeks. Elements of the Arthur Kill tributaries presented in this document include public parkland, privately owned open space, and over 80 protected and unprotected habitat and natural resources sites. Current initiatives in the Arthur Kill watershed, include the Lower Rahway Greenway, Elizabeth River Parkway, and the 1991 Woodbridge River natural resources inventory. Wetlands, parkland, private open areas, and existing and proposed greenways are presented as fold-out maps in the back cover of this document. This document is not provided in this Report as a result of poor quality of scanning due to the small size and level of detail on each map. However, this document is available upon request from The New Jersey Conservation Foundation.

The Rahway River Corridor Study, prepared on behalf of the City of Rahway Environmental Commission, inventories the significant natural features of the river corridor and develops a strategy to enhance the river corridor (Grossmueller Enterprises, 1996). As part of this study a habitat evaluation is presented that includes habitat types and aquatic resources. Vegetative communities identified in this report include manicured lawn, forested wetlands, forested uplands, tidal wetlands, and vegetated bank. Land use designations within the study area include residential, commercial, industrial, and parkland. The investigation for this study was divided into four reaches: Robinson's Branch, North Branch of the Rahway River, South Branch of the Rahway River, and the Rahway River Mainstem. The respective number of City of Rahway land use block and lot numbers for each area are presented below, along with the vegetative community types and land use. An electronic copy of this document is provided in Appendix G – Habitat Data (Grossmueller Enterprises, 1996).

Rahway River Study Area	Number of Blocks	Number of Lots	Vegetative Community	Land Use
Robinson's Branch	10	103	ML, FW, FU, VB	RES, COM, PK
North Branch	13	81	ML, FW, FU, VB	RES, COM, PK
South Branch	6	65	ML, FW, FU, VB	RES, COM, IND
Mainstem	9	22	TW, VB	RES, IND

Notes:
COM = commercial
FU = forested uplands
FW = forested wetlands
IND = industrial
ML = manicured lawn
PK = parkland
RES = residential
TW = tidal wetlands
VB = vegetated bank

Figures 3-13a through 3-13d contain GIS land use data for the Inventory Area. The New Jersey data have been taken from the NJDEP GIS spatial data download webpage (NJDEP, 2004a). These data are presented using the Anderson et al. (1976) land use classification scheme, broken down into six major classifications: urban land, agricultural land, forested areas, water, wetland, and barren land.

NJDWSC (2002) provides information on wetland coverage and land use in Passaic River Basin Watershed Management Area 4 (WMA#4), including the lower Passaic River and Saddle River. This report presents summary information based on data from approximately 1972 to 2002. However, data summaries do not distinguish information by year and cover the entire Watershed Management Area. Because there is no presentation of raw data for the Inventory Area, there is no means of presenting land use information. These data are presented in an electronic format that is not compatible with GIS. The electronic map files are provided in Appendix G – Habitat Data.

NJMC (2002) presents a land use map for the Hackensack Meadowlands, with an emphasis on natural areas. Designated land use types include transportation services, recreation parks and recreation areas, preservation areas, wetlands, landfill restoration areas and waterbodies. An electronic version of this map is provided in Appendix G – Habitat Data.

NY/NJ HEP (2000) lists NY/NJ HEP priority acquisition and restoration wetlands and other habitats in the NY/NJ Harbor estuary. A list of NY/NJ HEP acquisition priorities and restoration priorities in the Inventory Area are presented in Table 3-67. A map of these locations is presented in Appendix G – Habitat Data.

3.3.1.2 Aquatic Habitats

There are eight studies conducted since 1990 that characterize aquatic habitat data in the Inventory Area.

ChemRisk (1995), characterized shoreline features within the lower 6 miles of the Passaic River (Figure 3-12). The shoreline consisted of 61% bulkhead, 12% riprap, 16% with a mixture of riprap and aquatic vegetation, and 10% aquatic vegetation. Shoreline type by river reach for the lower 6 miles of the Passaic River is provided in electronic format in Appendix G – Habitat Data.

The New York District of the USACE conducted a study of benthic habitats in the NY/NJ Harbor Estuary and smaller inland bays to evaluate how those habitats would be affected by different dredged material management alternatives (Iocco et al., 2000). As part of this study, sediment characterization was conducted in Newark Bay in June 1995 (19 locations) and October 1995 (10 locations). Data collected from these surveys suggest that the sediments of Newark Bay are composed primarily of silts, with a few patches of sand occurring. Gas voids were observed infrequently in both surveys, while voids due to feeding and anoxia were abundant in June and much less commonly observed in October. Sandy habitats primarily had bedforms, and all sandy stations contained shell hash, although no live shell beds were found in Newark Bay in these surveys. Benthic habitat maps as presented in Iocco et al. (2000) are available for download at the NOAA Coastal Services Center internet site:

http://www.csc.noaa.gov/lcr/nyharbor/

NJDEP (1990c) presented the shellfish growing water classification chart for 1990–1991, including maps of the Arthur Kill, Raritan Bay, and Lower Bay. Shellfish Growing Water Classification Chart 1 depicts the lower Arthur Kill extending from Isle of Meadows to Raritan Bay being classified as a prohibited area with waters condemned and closed to the harvest of clams, mussels, and oysters. Waters of the Arthur Kill above Isle of Meadows are classified as being condemned and closed to the harvest of clams, mussels, and oysters. No raw data were provided.

Entrix and BBL conducted shoreline habitat surveys of the lower 6 miles of the Passaic River in August 1999 and May 2000 as part of the RI activities (Tierra, 2002a) (Figure 3-12). The entire shoreline of this stretch of the River was photographed, videotaped, and characterized during each of the two seasonal surveys. Shoreline habitat types were then quantified by category: bulkhead, riprap, mixed vegetation, or aquatic vegetation. Bulkhead included horizontal or vertical wood timbers, metal sheet pile, or large stone blocks constructed to form a vertical face perpendicular to the water surface. Riprap included cobble to boulder-sized stone and/or concrete rubble placed along the shoreline on a sloped bank. Mixed vegetation included areas with aquatic vegetation interspersed (laterally and/or longitudinally) with riprap and/or bulkhead. Areas of riprap shoreline with significant over-hanging riparian vegetation were also included as mixed vegetation to acknowledge the minor contribution to aquatic habitat provided by the adjacent riparian vegetation. Aquatic vegetation included areas with emergent wetland plant species such as *Spartina alterniflora* or *P. australis*. The combined results from the two surveys are presented in the following table. Raw data tables are provided in electronic format in Appendix G – Habitat Data.

Shoreline Habitat Type	Linear Ft	Percent of Total
Bulkhead	35,290	52%
Riprap	20,330	30%
Mixed vegetation	8,307	12%
Aquatic vegetation	3,843	6%
Total Shoreline	67,770	100%

The USACE (2000b) conducted a reconnaissance study of the NY/NJ Harbor Estuary to evaluate the "potential for Federal interest in implementing solutions to environmental degradation and other related water resource and sediment problems and needs, including environmental restoration and protection, within the New York and New Jersey Port District." Two habitat complexes within the Inventory Area were evaluated: Arthur Kill and the Hackensack Meadowlands. The study provides descriptive information on current habitat conditions, lists the federal- and state-listed species, identifies problems, opportunities, and potential ecosystem restoration sites, including the Passaic River in Passaic, Essex, and Bergen Counties, NJ. No data or specific locations are provided in this document.

A habitat mitigation plan was completed as part of the NY/NJ HDP (USACE, 2004d). As part of this mitigation report, existing wetland and upland community areas are characterized for six locations within the Inventory Area. Existing community types and acreages were based on geo-referenced aerial photography taken in 2001. This information is presented in the following table. Raw data are not provided.

Location	Acreage							
	High Marsh	Open Water	Low Marsh	*Phragmites*	Shrubs	Mud Flat	Salt Panne	Other
Old Place Creek	6.5	0.3	0.1	9.2	3.7	0.0	0.4	1.3
Saw Mill Creek East	0.8	0.0	0.0	8.2	1.9	0.0	0.0	1.0
Saw Mill Creek West	0.6	0.0	0.0	0.2	0.0	0.0	0.0	3.6
Saw Mill Creek North	6.9	1.5	0.0	3.1	0.0	0.0	0.0	8.8
Woodbridge Creek	0.6	3.5	0.0	8.2	9.7	0.0	0.0	2.5
Goethals Bridge South	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.9

An essential fish habitat (EFH) assessment was completed as part of the NY/NJ HDP (USACE, 2004e). EFH areas consist of waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Newark Bay contains EFH for 14 species in the vicinity of the Newark Bay Channel to the Elizabeth Port Authority Marine Terminal. Arthur Kill contains EFH for 12 species in the vicinity of the Arthur Kill Channel to Howland Hook. Kill Van Kull contains EFH for 15 species in the vicinity of the Kill Van Kull Channel. EFH designations for Newark Bay, Arthur Kill and Kill Van Kull are presented in following table.

Species Name	Newark Bay				Arthur Kill				Kill Van Kull			
	E	L	J	A	E	L	J	A	E	L	J	A
Atlantic herring		X	X	X		X	X	X		X	X	X
Black sea bass			X	X							X	X
Bluefish	X	X	X	X			X	X			X	X
Butterfish		X	X	X		X	X	X		X	X	X
Cobia	X	X	X	X	X	X	X	X	X	X	X	X
Dusky shark		X	X							X	X	
King mackerel	X	X	X	X	X	X	X	X	X	X	X	X
Red hake	X	X	X	X	X	X	X		X	X	X	
Sand tiger shark		X								X		
Sandbar shark		X	X	X		X		X		X		X
Scup	X	X	X	X	X	X	X	X	X	X	X	X
Spanish mackerel	X	X	X	X	X	X	X	X	X	X	X	X
Summer flounder		X	X	X		X	X	X		X	X	X
Windowpane flounder	X	X	X	X	X	X	X	X	X	X	X	X
Winter flounder	X	X	X	X	X	X	X	X	X	X	X	X

Notes:
E = eggs
L = larvae
J = Juvenile
A = adult

The U.S. Fish and Wildlife Service (USFWS, 1997) provides a map of significant water habitats in the Arthur Kill. This map is available at the following USFWS internet site:

http://training.fws.gov/library/pubs5/web_link/images/fig20a.jpg

3.3.1.3 Wetlands

There were seven studies conducted since 1990 that characterize wetlands in the Inventory Area.

Hartman (2000) presents the results of an annual monitoring survey at a Skeetkill Creek Marsh wetlands mitigation site in the Hackensack Meadowlands. No map was provided for this location. This site supported a dense monoculture of common reed with very little open water and reduced tidal flow prior to mitigation activities. Completed in December 1998, the mitigation construction included the creation of 3 acres of open water, enhancement of 5.12 acres of wetlands via excavation, and the creation of 1.2 acres of upland islands. Four habitats noted during the second post-mitigation growing season monitoring event include open water (including mudflats at low tide), low marsh, high marsh and upland transition. Both the low and high marsh habitats are dominated by obligate and facultative species including *Pluchea purpurascens*, *Eleocharis parvula*, *P. australis*, and *Atriplex patula*. The upland transition areas had facultative wetland species including *P. australis* and *A. patula* as well as numerous upland species. In total, 50 vascular plants were noted in 24 monitoring plots during the spring 2000 monitoring event. During a monitoring event in the summer of 2000, 36 vascular plants were noted in the 24 monitoring plots at the site. In total 80 species and 38 unknowns were identified in 1999 and 2000 monitoring events. Dominant plants for each monitoring plot for the spring and summer 2000 events are presented in this document. This information, along with a list of species identified in the spring 2000 and summer 2000 monitoring events and a summary of 1999 and 2000 monitoring events is provided in electronic format in Appendix G – Habitat Data.

Hartman (2003a) presents the results of a fifth annual monitoring survey in 2002 at a Harrier Meadow wetlands mitigation site in the Hackensack Meadowlands, as presented in Figure 3-12. Results of the vegetation sampling in permanent plots are presented in this document. This document is available at the MERI Library internet site:

http://cimic.rutgers.edu/meri/library.html.

Hartman (2003b) presents the results of an annual monitoring survey in 2003 at a Mill Creek wetlands mitigation site in the Hackensack Meadowlands, as presented in Figure 3-12. The objective of this project was to enhance or restore 45 acres of wetlands for impacts to 13.1 acres of wetlands associated with the Secaucus Transfer Station project (NJDEP Permit #0909-92-003; USACE Permit #93-03412). Prior to mitigation, the site supported a dense monoculture of common reed. During the 2003 monitoring events, 82 species of plants were noted in the 69 permanent monitoring plots at the site, located in channels/mudflats, low marsh, high marsh, and upland habitats. A list of species identified in the spring 2003 and summer 2003 monitoring events and a list of species for each plot is provided in electronic format in Appendix F – Habitat Data.

HMDC (1995a,b) present an ongoing investigation of declining populations of saltmarsh cordgrass in the Hackensack Meadowlands. This study is part of an ongoing effort to study factors involved in cordgrass growth, productivity and restoration, including the monitoring of seeded cordgrass at two brackish marsh mitigation site locations. These documents do not present habitat data.

Louis Berger & Associates, Inc. (LBA, 1993) presents the results of a wetland delineation conducted in November 1992 for a site along the lower Hackensack River, as presented in Figure 3-12. The main habitats identified in this report include low marshland, scrub/shrub, landscaped areas, and tidal open water habitat with mudflats at low tide. The dominant species identified within tidal zones at the site was common reed. Plant species identified in the report are listed below. This document does not present habitat data.

Common Name	Scientific Name
Black cherry	*Prunus serotina*
Common reed	*Phragmites australis*
Cottonwood	*Populus detoides*
Early goldenrod	*Solidago juncea*
Ragweed	*Ambrosia artemisifolia*
Rough-leaved goldenrod	*Solidago patula*
Rough stemmed goldenrod	*Solidago rugosa*
Seaside goldenrod	*Solidago sempervirens*
Staghorn sumac	*Rhus typhina*
Tree-of-heaven	*Ailanthus altisima*
Winged sumac	*Rhus coppalina*

Figures 3-13a through 3-13d contain GIS wetlands information for the Inventory Area. These data were downloaded from the NJDEP GIS spatial data download internet site:

http://www.state.nj.us/dep/gis/lists.html

as well as the USFWS National Wetland Inventory download internet site (USFWS, 2004):

http://www.nwi.fws.gov/

New Jersey land use data for the Inventory Area are presented using the five wetland classification subclasses as described in Anderson et al. (1976): saline marshes, freshwater tidal marshes, non-tidal marshes, interior wetlands, and vegetated dune communities. Wetlands habitat data for Staten Island, NY, has been presented following USFWS National Wetland Inventory classification (Cowardin et al., 1979). Mudflat data has been included in New Jersey habitat areas where mudflats are not indicated within the Anderson et al. (1976) classification scheme.

3.3.1.4 Terrestrial Habitats

Eight studies conducted since 1990 characterize terrestrial habitats in the Inventory Area.

Barrett (1990b) characterizes the habitat representativeness (i.e., a measure of the range of different habitats) found within 20 geographic sites throughout the NY/NJ Harbor Estuary. Geographic locations within the Inventory Area include Hackensack Meadowlands, Staten Island Northwest and Staten Island South. Nine habitat categories were adapted from subclasses of the USFWS National Wetland Inventory (Cowardin et al., 1979). Habitat representativeness is presented below for a 5.6 km radius (100 km^2) surrounding each geographic site within the Inventory Area. No raw data are provided.

Habitat Type	Geographic Site (acres)		
	Hackensack Meadowlands	Staten Island Northwest	Staten Island South
Urban	50.9	53.8	40.1
Water	12.9	13.4	37.4
Flats	3.5	3.3	5.6
Beach	0.0	0.0	0.0
Estuarine	22.3	5.8	1.3
Palustrine	2.0	3.0	1.0
Non-forest	6.0	13.6	6.4
Forest	0.2	5.1	7.6
Semi-natural	2.2	2.0	0.6
Total	*100*	*100*	*100*

An Islanded Nature (Blanchard et al., 2001) provides an overview of conservation and natural area restoration projects in the vicinity of Staten Island, NY. This document also evaluates changes in the Harbor Herons landscape that have occurred in the 10 years since the appearance of *The Harbor Herons Report* (The Trust for Public Land and New York City Audubon Society, 1990). A map of land use along the eastern shoreline of the Arthur Kill, including State preserves, parkland, and residential and commercial/industrial land is available at the following internet site:

http://tpl.org/content_documents/main_map.pdf

This map of the Harbor Herons area provides a total of approximately 2,196 acres of undeveloped land area. As of December 2000, some 619 acres have been fully protected (Blanchard et al., 2001).

Eckenfelder (1993) provides inventories of plant species at a site along the Hackensack River. This site is presented in Figure 3-12. Vegetative species inhabiting the study site were identified during various field activities in 1991. In total, 29 shrub species and five tree species were identified. An electronic copy of this vegetative species list is provided in Appendix G – Habitat Data.

Kerlinger (1997b) provides an overview of restoration of habitat for shorebird species within the NY/NJ Harbor Estuary. No raw data are provided regarding species presence in the Inventory Area.

Figures 3-13a through 3-13d contain GIS terrestrial habitat data for the Inventory Area. The New Jersey data have been taken from the NJDEP GIS spatial data download internet site (NJDEP, 2004a). The New Jersey land use data are presented using the Anderson et al. (1976) land use classification scheme, broken down into six major classifications: urban land, agricultural land, forested areas, water, wetland, and barren land.

In the book *Fields of Sun and Grass: An Artist's Journal of the New Jersey Meadowlands*, Quinn (1997) presents an overview of past and present wildlife presence and habitat conditions of the Hackensack Meadowlands. There are no habitat data provided in this book.

USFWS (1997) provides a summary of habitats and species of special concern in areas included within the Inventory Area. A map of significant habitat complexes in the NY/NJ Harbor Estuary is presented at the following internet site:

http://training.fws.gov/library/pubs5/web_link/images/fig20a.jpg

This map indicates the location of urban open space along Newark Bay, Passaic River, and Arthur Kill. The Arthur Kill Complex supports seasonal or year-round populations of 178 species of special emphasis, including 10 vascular plant species. The Hackensack Meadows Complex contains regionally significant brackish marshes, and supports seasonal or year-round populations of 88 species of special emphasis or listed species, including one vascular plant (saltmarsh bulrush). Significant habitat along the Arthur Kill and Hackensack River, and significant water habitat along the Arthur Kill are also mapped.

3.3.1.5 Historical Changes in Habitats

Six studies conducted since 1990 report on historical changes in habitats in the Inventory Area.

Berger (1992) discusses the history of the Hackensack Meadowlands, and major changes to the area since 1969. This document also discusses the establishment of the HMDC, and its efforts to improve environmental conditions in the Hackensack Meadowlands. There are no data provided.

Crawford et al. (1994) provides a review of ecological conditions of the Newark Bay Estuary over the past century. This document indicates that both diversity and abundance of aquatic species within the estuary have been substantially reduced due to the loss of habitat through intense urbanization and industrialization. There are no habitat data summaries dated 1990–present provided .

Iannuzzi et al. (2002) provides an overview of historical habitat alterations to the lower Passaic River and Newark Bay area. Maps included in this book consist of wetlands of Newark Bay and the Hackensack River in 1870, and the extent of wetlands over time (1905, 1932, 1954, 1976, and 1997) based on data provided in Intrasearch (1999). Estimates of historical wetland losses in the lower Passaic River and Newark Bay Region provided in Iannuzzi et al. (2002) are provided below.

Year	Acres of Wetlands	Wetland Losses			
		Incremental		Cumulative	
		Acres	Percent	Acres	Percent
Pre-1816[a]	24,728	-	-	-	-
1870	18,428	6,300	26	6,300	26
1905	15,356	3,072	17	9,372	38
1932	12,030	3,326	22	12,698	51
1940	11,180	850	7	13,548	55
1954	8,738	2,442	22	15,990	65
1966	5,574	3,164	36	19,154	77
1976	3,570	2,004	36	21,158	86
1989	3,058	512	14	21,670	88
1997	2,921	137	4	21,807	88

Note:
a. Based on sum of mapped wetlands in 1870 and reported wetland losses from period of 1816–1870.

Intrasearch (1999; 2001) presents a summary of wetland acreage losses over time for the Arthur Kill, Hackensack, and Passaic Watershed Management Areas. This information is presented in the following table.

Year	Total Wetland Acres	WMA (Acres)		
		Arthur Kill	Hackensack	Passaic
1870	18,166	6,013	9,280	2,873
1905	15,790	5,465	7,553	2,772
1932	11,968	4,153	6,184	1,631
1940	11,180	3,954	5,754	1,472
1954	8,738	2,583	5,051	1,104
1966	5,574	878	3,939	757
1976	3,570	242	2,900	428
1989	3,058	133	2,522	403
1997	2,921	87	2,436	398

A set of maps with estimated historical wetland areas for the years 1870, 1905, 1932, 1940, 1954, 1966, 1976, 1989, and 1997 is provided in Appendix G – Habitat Data.

Regional Planning Association (RPA, 2004) provides a GIS-generated historic tidelands map entitled *Nature's Estuary: The Historic Tidelands of the New York and New Jersey Harbor Estuary*. Former waterway shorelines, tidal wetlands and tidal flats prior to human alteration are presented for the entire Inventory Area, including Newark Bay, Arthur Kill, Kill Van Kull, Rahway River, Passaic River, and Hackensack River. This information was compiled by the Regional Planning Association of New York, New Jersey, and Connecticut based on 19th century topographic maps from the USGS, New Jersey Geologic Survey, and the U.S Coast Guard (USCG). This map is available for download at the Regional Planning Association internet site:

http://www.rpa.org/maps/maps.html

3.3.1.6 Summary of QA/QC Information for Habitats Studies

The habitat studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided for any of these studies.

3.3.2 Biological Communities

A variety of studies have been performed in the Inventory Area to examine the diversity and abundance of aquatic, wetland, and terrestrial wildlife communities. One hundred sixteen identified studies are summarized in Table 3-68. The following sections discuss in greater detail the 46 studies that provide biological communities data and information collected since 1990. This information is presented below under the following subsections: plankton, benthic invertebrates, fish and crustaceans, avian species, mammals, amphibians, reptiles, other wildlife species, and other studies. The sampling locations (as available for several of these studies) are presented in Figures 3-14a through 3-15c. As available, the biological community data from these studies are provided in tables or in electronic format in Appendix H – Biological Communities Data. Seventy identified biological community studies that were conducted prior to 1990 are briefly summarized in Table 3-68.

3.3.2.1 Plankton

Two studies conducted by the USACE (2003a,b) provide ichthyoplankton collection, diversity, and abundance data in the NY/NJ Harbor Estuary during 2001–2002 and 2002–2003 collection periods, respectively. Samples were collected at seven locations within Newark Bay, as presented in Figure 3-14a. There were 34 species of ichthyoplankton (one unidentified) as summarized in Table 3-69. A raw data file provided by the USACE contains Newark Bay data collected from more than 35 sampling events between December 2000 and July 2003, including Newark data presented in USACE (2003a) and USACE (2003b). These data are presented in electronic format Appendix H – Biological Communities Data.

3.3.2.2 Benthic Invertebrates

Fourteen identified benthic invertebrate studies have been conducted in the Inventory Area since 1990.

In a personal communication, Bragin (2004) provided benthic invertebrate community data from 25 monthly survey events (2001–2003) from 21 sampling locations in the lower Hackensack River. In total, 13 invertebrate species were identified as listed below. Raw data are provided in electronic format in Appendix H – Biological Communities Data.

Taxa – Scientific Name
Amphipod
Balanus improvisus
Bryozoa

Taxa – Scientific Name
Callinectes sapidus
Crangon septemspinosa
Crassostrea virginica
Ctenophora pleurobrachia
Isopoda
Molgula sp.
Mya arenaria
Neomysis Americana
Palaeomonetes pugio
Rhithropanopeus harrissi

Note:
Taxa listed in alphabetical order.

In August 1994, ChemRisk (1995), conducted benthic invertebrate community surveys at six locations within the lower Passaic River (Figure 3-14d). In total, 16 taxa were identified, with an average of 4,512 individuals per square meter for the entire study area. Results of the ChemRisk (1995) survey, including diversity and abundance summaries and raw data are provided in electronic format document in Appendix H – Biological Communities Data.

From 1999–2001, Hartman (2003a) conducted nine benthic invertebrate community surveys as part of the Harrier Meadow Wetlands Mitigation Site monitoring program. The nine sampling locations at the study site are presented in Figure 3-14c. In total, 33 taxa were identified. A summary of benthic invertebrate taxa, total density, and relative abundance are provided in electronic format in Appendix H – Biological Communities Data.

In June and October 1995, Iocco et al. (2000) conducted sampling as part of a USACE study of benthic habitats in NY/NJ Harbor Estuary to examine how those habitats would be affected by different dredged material management alternatives. Sampling was conducted at 10 different locations within Newark Bay as presented in Figure 3-14a. Results from these surveys indicated a shift in seasonal species dominance. *Streblospio benedicti* (>2,875 individuals/m^2), *Cirratulidae* (lowest practical identification level; >1,375 individuals/m^2), and *Leitoscoloplos* (lowest practical identification level; >650 individuals/m^2) had the highest average abundances in June while *M. lateralis* (>1,240 individuals/m^2), *Mediomastus* (lowest practical identification level; >1,025 individuals/m^2), and *S. benedicti* (>1,000 individuals/m^2) had the highest average abundances in October. The 10 most abundant species (average number per m^2) surveyed in June and October 1995 are presented in Table 3-70. Biological data (e.g., abundance, biomass, and community parameters), sediment data (e.g., grain size and organic content), and sediment profile imagery data are available at the NOAA Coastal Services Center internet site:

http://www.csc.noaa.gov/lcr/nyharbor/

In 1995–1996, LMS (1996, as presented in USACE, 1997a; 1999a) conducted a monthly benthic invertebrate survey for seven locations in the Inventory Area, including five Newark Bay shoal areas and single stations in the adjacent Kill Van Kull and Arthur Kill channels. Sampling locations are presented in Figures 3-14a and 3-14b. In total, 19 invertebrate taxa were identified in Newark Bay (11 taxa), Arthur Kill (7 taxa), and Kill Van Kull (16 taxa). Polychaetes dominated the species collected at the five Newark Bay stations. The top 10 benthic invertebrate species in Newark Bay by abundance included: six polychaete worms – *Scoloplos sp.* (28.5%), *S. benedicti* (23.7%), the family Paraonidae (7.0%), the family Phyllodocidae (1.7%), *Glycera sp.* (1.7%) and *P. ligni* (1.6%); two bivalves – *M. lateralis* (15.4%) and *M. arenaria* (4.4%); the estuarine isopod *Cyathura polita* (5.8%); and the cumacean *Oxyurostylis smithii* (1.9%). The composition and abundance patterns of benthic invertebrates were similar among the five Newark Bay stations. Similar trends in composition and abundance were also observed in Arthur Kill and Kill Van Kull samples. Raw benthic invertebrate data for Newark Bay, Arthur Kill, and Kill Van Kull are provided in electronic format in Appendix H – Biological Communities Data.

From May 1993–April 1994, the NOAA National Marine Fisheries Service (NOAA, 1994) conducted a biological and hydrographic characterization of Newark Bay. Twenty-five stations (18 channel and seven shallow water stations) were sampled. In total, 76 benthic invertebrate taxa were identified, as summarized in Table 3-71. Sampling locations are presented in Figures 3-14a and 3-14c. These data are presented in a Draft Environmental Impact Statement for the USACE New York District draft feasibility report for the NY/NJ Harbor Navigation Investigation Study (USACE, 1999a). The raw data are provided in electronic format in Appendix H – Biological Communities Data.

In 1999 and 2000, Raichel (2001) conducted a benthic invertebrate community survey in Mill Creek, NJ, within the Hackensack Meadowlands. The area, within which the 12 sampling stations are located, is presented in Figure 3-14c. In 1999, 108 samples and 5,596 individuals were collected at six locations in three habitat types (*Spartina alterniflora*-dominated, *P. australis*-dominated, and bare ground). In 2000, 108 samples and 20,291 individuals were collected at six locations in two habitat types (*S. alterniflora*-dominated and *P. australis*-dominated). A list of invertebrate taxa from the 2000 sampling event and taxa abundance in each habitat type are provided in electronic format in Appendix H – Biological Communities Data.

Entrix and BBL conducted benthic invertebrate community surveys during September 1999 and May 2000 as part of the RI activities in the lower 6 miles of the Passaic River (Tierra, 2002b). Triplicate surface sediment grab samples were collected from 15 sampling locations as presented in Figure 3-14d. Invertebrates within the samples were sorted, counted, and identified to the lowest practicable taxon. The results of the survey are summarized in Table 3-72. In total, 30 benthic invertebrate taxa were identified during the two seasonal surveys. Available raw data from these surveys are provided in electronic format in Appendix H – Biological Communities Data.

In November 1998 and February and April 1999, the USACE New York District conducted surveys at 20 locations throughout the NY/NJ Harbor Estuary (USACE, 1999a). Six of these locations are located within the Inventory Area at depths of 30–40 ft mean low water: three stations in Newark Bay; two stations in Arthur Kill, and one station in Kill Van Kull. Sampling locations are presented in Figures 3-14a and 3-14b. In total, 48 benthic invertebrate taxa were identified in Newark Bay (37 taxa), Arthur Kill (30 taxa), and Kill Van Kull (23 taxa). The bivalve mollusc *M. lateralis* accounted for 31.4% of the total number of organisms collected at these stations. The raw data for are provided in electronic format in Appendix H – Biological Communities Data. In addition, the USACE (1999a) reports the results of a study conducted in 1994, by the USCG who collected and identified benthic invertebrate taxa near the Goethals Bridge and Old Place Creek in the Arthur Kill. The sampling locations are depicted as USACE (1999a) in Figures 3-14a and 3-14b. In total, 49 taxa were identified in this survey. Temporal and spatial variability, primarily related to reproduction patterns, were noted in the seasonal collections. Benthic invertebrate data for these two locations are provided in electronic format in Appendix H – Biological Communities Data.

As part of the USEPA R-EMAP, benthic invertebrate sampling was conducted in the Inventory Area in the summer of 1993/1994 and again in the summer of 1998 (USEPA, 1998; 2003). Sampling locations are presented in Figures 3-14a, 3-14b, and 3-14d. A total of 91 infaunal species were identified at 28 sampling locations within Newark Bay in 1993–1994. A list of benthic invertebrate taxa identified at each of the 28 Newark Bay sampling locations is presented in Table 3-73a (USEPA, 1998). In 1998, a total of 125 infaunal species were identified at 29 sampling locations within Newark Bay during the 5 year revisit of the R-EMAP stations (USEPA, 2003). A summary of identified benthic invertebrate taxa from the 1998 survey is presented in Table 3-73b. Raw abundance data from the 1993/1994 and 1998 surveys are provided in electronic format in Appendix H – Biological Communities Data.

In September 1996 and May 1997, Vitaliano et al. (2002) conducted benthic invertebrate community surveys within areas of the Arthur Kill impacted by a January 1990 oil spill. Sampling was conduced on two occasions at each of six locations: Old Place, north and south Saw Mill Creek, Tower Point, Tufts Point, and Mill Creek. The six study sites in the Arthur Kill are presented in Figure 3-14b. Forty-one taxa were identified. The three most abundant taxa comprising 94% of all individuals counted were oligochaetes (60%), nematodes (20%), and the small tube-building fan worm *Manayunka aestuarina* (14%). The entire document is provided in electronic format in Appendix H – Biological Communities Data.

In 1999, Yuhas (2001) conducted benthic invertebrate community surveys from June to September at five locations within the vicinity of Mill Creek in the Hackensack Meadowlands. No detailed sample location maps were provided. This work was conducted as part of a thesis with the objective of determining differences in benthic communities between common reed and saltmarsh grass-dominated salt marshes. Total abundances by location at a phylum level of taxa identification are presented in this document. In addition, benthic indices such as taxa richness, and Shannon-Wiener and Simpson's Taxa Diversity Indices are presented. While complete, raw data are not provided, the data that are presented are provided in electronic format Appendix G – Biological Community Data.

3.3.2.3 Fish and Crustaceans

Sixteen identified studies on fish and crustacean communities have been conducted in the Inventory Area since 1990 are discussed below.

In a personal communication, Bragin (2004) provided fish survey data from 25 monthly survey events (2001–2003) from 21 sampling locations in the lower Hackensack River using bottom trawl, trap net, beach seine, and gillnet gear types. In total, 42 fish species were identified as presented below. Raw data are provided in electronic format on the Appendix H – Biological Communities Data.

Fish Species – Common Name	
Alosa sp/Clupeidae	Inland silverside
Alewife	Mummichog
American eel	Naked goby
American shad	Northern pipefish
Atlantic croaker	Pumpkinseed
Atlantic menhaden	Rainbow smelt
Atlantic silverside	Seaboard goby
Atlantic tomcod	Spot
Bay anchovy	Spotted hake
Black crappie	Striped bass
Blueback herring	Striped killifish
Bluefish	Striped mullet
Bluegill	Summer flounder
Brown bullhead	Threespine stickleback
Carp	Weakfish
Conger eel	White catfish
Crevalle jack	White perch
Gizzard shad	Window pane
Golden shiner	Winter flounder
Goldfish	Yellow bullhead
Green sunfish	Yellow perch

In August 1994, ChemRisk (1995), conducted fish surveys in the lower Passaic River. Sampling locations are presented in Figure 3-14d. A total of five gillnet deployments were conducted. In addition, baited minnow traps were used, and dip net sweeps were conducted in vegetated areas along the river banks. In total, three taxa were identified, including mummichog, Atlantic silverside (*Medidia menidia*), and carp. The number of individuals of each fish species is not noted within this document as the study focused primarily on collecting fish for bioaccumulation analyses; therefore, no raw data are available.

Duffy-Anderson et al. (2003) provided a summary of fish surveys conducted at three locations within the Arthur Kill (1995) and two locations in the Kill Van Kull (1996). Sampling was conducted near wrecks, pile fields, piers, and in open water areas. The five sampling locations are presented in Figures 3-14a and 3-14b. Out of a total of 25 species that were identified in these locations, 7,812 individuals were caught in the Arthur Kill and 224 were caught in the Kill Van Kull, of which 98% were YOY individuals. The two most abundant species caught were silver perch (*Bairdiella chrysoura*) and naked goby (*Gobiosoma bosc*). A complete list of species caught, location, size range, and dominance by sampling location is provided in electronic format in Appendix H – Biological Communities Data.

In April 1997, Empire (1998) conducted fish surveys in the Hackensack Meadowlands on a property bordering the Hackensack River to the east, Losen Slate Creek to the northeast, and with three tributaries crossing the property: Bashes Creek, Moonachie Creek, and Muddabach Creek. Overnight gill net surveys were conducted at five locations for three consecutive nights. The site and survey locations are presented in Figure 3-14c. In total, four fish species were caught: carp, brown bullhead (*Ictalurus nebulosus*), pumpkinseed (*Lepomis gibbosus*), and mummichog. The number of individuals and a range of lengths (min-max) for these species are summarized in the following table:

Common Name	Count	Length – Range (mm)
Brown bullhead	9	200 – 290
Common carp	24	83 – 80
Pumpkinseed	1	95
Mummichog	53	85 – 100

Empire (1998) is provided in its entirety in Appendix H – Biological Communities Data.

Hartman (2003a) conducted fish surveys during the summer months from 1999–2002 at Harrier Meadow in the Hackensack Meadowlands (Figure 3-14c). In total, 13 species were identified in this monitoring effort. This sampling event is summarized in the table below. Sampling date, location, species count, and mean length is provided for the 1999–2002 sampling events in electronic format in Appendix H – Biological Communities Data.

Year	Sampling Locations	Number of Species	Species Name
1999	1, 2, 3	5	MC, MM, IS, TSS, WP
2000	1, 2, 3, 4, 5, 6, 7, 8	5	MC, MM, IS, TSS, WP
2001	1, 2, 3, 4, 5, 8	9	MC, TSS, WP, IS, PS, NG, GS, BA, AS
2002	1, 2, 3, 4, 5, 8	5	MC, TSS, IS, AS, SK
2003	1, 2, 3, 4, 5, 6, 7, 8	9	AE, CC, SK, WM, TSS, PS, IS, AS, WP

Note: Abbreviations are provided in the following table.

Abbreviation	Common Name	Scientific Name
AE	American eel	*Anguilla rostrata*
AS	Atlantic silverside	*Menidia menidia*
BA	bay anchovy	*Anchoa mitchilli*
CC	Common carp	*Cyprinus carpio*
GS	gizzard shad	*Dorosoma cepedianum*

Abbreviation	Common Name	Scientific Name
IS	inland silverside	*Menidia beryllina*
MC	mummichog	*Fundulus heteroclitus*
MM	Unknown silverside	*Menidia majalis (?)*
NG	naked goby	*Gobiosoma bosci*
PS	pumpkinseed	*Lepomis gibbosus*
SK	striped killifish	*Fundulus heteroclitus, F. majalis*
TSS	three-spine stickleback	*Gasterosteus aculeutus*
WM	eastern mosquitofish	*Gambusia holbrooki*
WP	white perch	*Morone americana*

In 1995–1996, LMS (1996, as presented in USACE, 1997a and USACE, 1999a) conducted monthly fish and benthic invertebrate surveys at seven locations in the Inventory Area, including five Newark Bay shoal areas and single stations in the adjacent Kill Van Kull and Arthur Kill channels. Six of the seven sampling locations are presented in Figures 3-14a and 3-14b; one Newark Bay location was not identified in the report. In total, 25 species were identified in this study. The results are summarized in electronic format in Appendix H – Biological Communities Data.

NOAA (1994) conducted a biological characterization of Newark Bay from May 1993–April 1994. Fish surveys were conducted at 17 locations (10 channel trawls and seven shallow water trawls and gillnet stations). The sampling locations are presented in Figures 3-14a and 3-14c. During each catch, species were collectively weighed and individual lengths were taken. In total, 56 fish species were identified. The three most dominant species caught in 299 otter trawl tows in the channels were striped bass, Atlantic tomcod, and blue crab. The three most dominant species caught in the 105 shallow water shrimp trawl tows were bay anchovy, Atlantic herring, and Atlantic tomcod. The three most dominant species caught in the 92 gill net sets were Atlantic menhaden, striped bass, and blue crab. Most species were noted in each of the areas sampled with the exception of white perch, which were never identified in water with a DO level less than 6.23 mg/l. Seasonal presence of fish species caught in this survey is summarized in Table 3-74. Summary information is available at the NOAA Fisheries Northeast Fisheries Science Center internet site:

http://sh.nefsc.noaa.gov/NEWRKbay.htm

Monthly catch data for each fish species by gear type are provided in electronic format in Appendix H – Biological Communities Data.

In July and August of 1999 and 2000, Raichel (2001) sampled mummichog during 12 sampling events using minnow traps and pit traps in the Hackensack Meadowlands. The areas in which the 12 sampling locations are situated are presented in Figure 3-14c. In total, 371 mummichog and 13 inland silverside individuals were identified. No other data or information were provided.

A supplemental fish collection program was undertaken by BBL in August 2001 in the lower 6 miles of the Passaic River (Tierra, 2001b). The objective of this survey was to collect additional fish species (beyond those collected in 1999 and 2000) for chemical contaminant analyses (Section 3.2.4 – Bioaccumulation). Multiple sampling gear types were used including eel traps, experimental gillnets, trotlines, and trap nets. The sample locations are depicted in Figure 3-14d. Six fish species (American eel, Atlantic menhaden, brown bullhead, striped bass, white catfish, and white perch) and blue crab were captured during this survey. A list of the fish collected during this supplemental survey is provided in Table 3-75.

Entrix and BBL conducted fish community surveys in September/October 1999 and May 2000 in the lower 6 miles of the Passaic River as part of the RI activities (Tierra, 2002c). The objectives of the surveys were to characterize the fish and crustacean communities, and to collect samples of fish and blue crab tissue for chemical contaminant analyses (Section 3.2.4 – Bioaccumulation). The surveys were conducted using various gear types, including baited minnow, eel, and crab traps, and experimental gillnets. The sample locations are presented in Figure 3-14d. A total of 22 fish species and blue crab were captured during the two surveys. Sixteen fish species were captured in the fall 1999 survey, and 12 species in the spring 2000 survey. Of the 22 species captured, six species comprised 98% of the total catch from the two surveys. Mummichog comprised more than 75% of the total catch. The other dominant species included inland silverside, white perch, Atlantic menhaden, striped bass, and gizzard shad. A summary of the results of these surveys is provided in Table 3-76. Raw data from these surveys are provided in electronic format in Appendix H – Biological Communities Data.

From October 1998–September 1999, the USACE (1999a) conducted monthly fish surveys at 20 locations throughout the NY/NJ Harbor Estuary. Six of the locations in this survey were located within the Inventory Area at depths of 30–40 ft mean low water: three stations in Newark Bay; two stations in Arthur Kill, and one station in Kill Van Kull (Figures 3-14a and 3-14b). There were 39 fish species identified in this survey. Summary data; raw data for the Newark Bay stations; and a raw data file provided by the USACE containing

Newark Bay data collected between October 1998 and June 2003, including Newark data presented in USACE (1999a) are provided in electronic format in Appendix H – Biological Communities Data.

USACE (2003a,b,c) provide fish survey data for the NY/NJ Harbor Estuary collected during 2001–2002 and 2002–2003. Surveys were conducted at eight locations within Newark Bay: five channel stations and three shallow water stations as presented in Figure 3-14a. Seasonal presence of fish species caught in this survey is summarized in Table 3-74 In total, there were 47 fish species identified and 5,397 individuals captured as summarized in Table 3-77 An electronic file provided by the USACE contains Newark Bay data collected between October 1998 and June 2003, including Newark data presented in USACE (2003a,b,c). These data are provided in electronic format in Appendix H – Biological Communities Data.

USFWS (1997) provides a summary of habitats and species of special concern in areas included within the Inventory Area. The Arthur Kill Complex supports seasonal or year-round populations of 178 species of special emphasis[5], including 37 species of fish. A listing of these species is presented in Table 3-78a The Hackensack Meadows Complex contains regionally significant brackish marshes, and supports seasonal or year-round populations of 88 species of special emphasis or listed species, including 29 species of fish, blue crab, and horseshoe crab. A listing of these species is presented in Table 3-78b. Species information is also available in electronic format at the following USFWS internet site:

http://training.fws.gov/library/pubs5/begin.htm

3.3.2.4 Birds

Eighteen identified studies on birds have been conducted in the Inventory Area since 1990.

There are at least 277 bird species with recorded observations within the Inventory Report documentation as summarized in Table 3-79. The majority of bird species were noted within the Hackensack River (89%),

[5] The USFWS defines species of special emphasis as: all federally listed and state listed species and candidates, including species listed under the Convention on International Trade in Endangered Species and states' watch-list species; anadromous fish (marine fish that migrate into and breed in freshwater); marine and estuarine fish species of commercial, recreational, and/or ecological importance in the NY/NJ Harbor estuary; and communities and habitats of special concern in the region (http://training.fws.gov/library/pubs5/begin.htm).

followed by the Arthur Kill (74%), Rahway River (57%), Kill Van Kull (21%), Passaic River (18%) and Newark Bay (10%).

The National Audubon Society of New York State provides an overview of the Harbor Heron's Complex and a summary of surveys conducted at the Isle of Meadow and Prall's Island in the Arthur Kill and Shooter's Island in the Kill Van Kull in 1995 (Audubon New York, 2004). Island locations are presented in Figure 3-15a. The following summary table documents the number of pairs of the following species observed at the Isle of Meadows, and the percentage represented in this habitat for the entire New York State population.

	Active Nests at Isle of Meadows	
Common Name	**Number of Pairs**	**Percentage of New York State Population**
Black-crowned night heron	643	57%
Great egret	108	21%
Snowy egret	192	28%
Cattle egret	25	57%
Glossy ibis	263	35%

The 1995 study also lists the following species abundances: little blue heron (2 pr.), yellow-crowned night heron (12 pr.), great black-backed gulls (10+ pr.), herring gulls (619 pr.), and double-crested cormorants (121 pr.). Raw data are available at the Audubon New York internet site:

http://ny.audubon.org/iba/

Blanchard et al. (2001) provides a summary from a 1999 active nest survey at Isle of Meadows in the Arthur Kill (Figure 3-15a). MacCarone and Brzorad (2000) provide a summary from a 1998 active nest survey for five species at the same site. This information is summarized below (as presented in these two documents).

Common Name	Active Nests at Isle of Meadows	
	1998	1999
Black-crowned night heron	278	389
Cattle egret	9	3
Glossy ibis	211	155
Great egret	73	95
Green heron	---	1
Herring gull	---	57
Little blue heron	---	2
Snowy egret	87	94
Unidentified wader	---	22
Yellow-crowned night heron	---	1

Note: --- = not provided

In addition, there were 91 active double-crested cormorant nests observed at Shooter's Island in the Kill Van Kull. The author notes that there may also be active nests of both yellow-crowned night heron and green heron species. This document also states there were no active nests observed at Prall's Island in 1999 (Blanchard et al., 2001). No additional data are provided.

Eckenfelder (1993) conducted a bird survey at a site along the Hackensack River in Hudson County, NJ. This location is presented in Figure 3-15b. Any bird species seen or heard during various field activities were noted as residing in the study area. Observations were also made during boat travel through the study area. In total, 32 bird species were noted. Raw data are provided in electronic format in Appendix H – Biological Communities Data.

From February 1996 to February 1997, Empire (1998) conducted bird surveys in the Hackensack Meadowlands (Transco Marsh). Observations were made during weekly or bi-weekly surveys. Bird surveys were conducted from three transects and five observation towers. The site location is presented in Figure 3-15b. There were 29 bird species observed which were consider permanent residents, and 28 bird species considered summer residents. The eight most common permanent residents in order of abundance include the red-winged blackbird, American crow, Canada goose, mallard, European starling, song sparrow, ring-necked pheasant, and the American goldfinch. The eight most common summer residents in order of abundance include the swamp sparrow, common yellowthroat, barn swallow, marsh wren, American robin, tree swallow, gray catbird, and the willow flycatcher. Raw data are provided in electronic format in Appendix H – Biological Communities Data.

Fisher and Bezener (1998) present a review of bird species in New York City, western Long Island and the surrounding ocean habitats, including portions of the Inventory Area. No bird survey maps are provided. Prime recreational bird watching locations are provided and include areas near the Hackensack River such as the Hackensack Meadowlands and Kearny Marsh, and areas adjacent to the Arthur Kill such as Fresh Kills Park. Information on species characteristics, breeding biology, and seasonal presence are discussed. A checklist of 308 bird species in New York City, western Long Island and the surrounding ocean habitats is provided. The seasonal occurrence, breeding status, and abundance of each bird species is noted. This publication is provided in electronic format in Appendix H – Biological Communities Data.

Bird surveys were conducted by Hartman (2003a), both pre-restoration (1996–1997) and post-restoration (2000–2003), as part of the Harrier Meadow Wetlands Mitigation Site monitoring program. Surveys were conducted at eight stations within the area presented in Figure 3-15b. Survey frequency was weekly across all seasons, with the exception of winter, where surveys were conducted every third week. In total, 71 species were observed in 1996–1997, while 116 species were observed in 2000–2003. Raw data are provided in electronic format in Appendix H – Biological Communities Data.

HMDC (unknown) provides a listing of 263 observed bird species of the Hackensack Meadowlands. The seasonal occurrence and relative abundance of each bird species is noted. No bird survey maps are provided. This pamphlet listing was generated by the HMDC Environmental Center. This pamphlet is provided in electronic format in Appendix H – Biological Communities Data.

Kane et al. (1991) presents a summary of select bird species of the Arthur Kill and its tributaries. Surveys were conducted on a weekly basis from March to December 1990 along the Arthur Kill tributaries, including the Elizabeth River, Woodbridge Creek, Morses Creek, Piles Creek, Smith Creek, and the lower Rahway River. These locations are presented in Figure 3-15a. The following summary table was taken from Kane et al. (1991) and provides a species check list for select sites. A list of 259 bird species including seasonal presence and abundance as recorded during this study is provided in electronic format in Appendix H – Biological Communities Data.

Species	Morses Creek	Piles Creek	Smith Creek	Rahway River
Black-crowned night heron	X	X	X	X
Cattle egret		X		X
Glossy ibis		X	X	X
Great blue heron	X	X	X	X
Great egret	X	X	X	X
Little blue heron		X		X
Snowy egret	X	X	X	X
Tri-colored heron	X			X
Yellow-crowned night heron			X	X

Kerlinger (1996a) documents the results of a September–October 1996 survey conducted on Shooter's Island in the Newark Bay and on Prall's Island and the Isle of Meadows in the Arthur Kill. These locations are presented in Figure 3-15a. During 14 recorded survey events at each island, a total of 62 species of migrating birds were observed, among which 79% were songbirds and 13% were diurnal raptors. A list of species and collected data by location and survey date are provided in electronic format in Appendix H – Biological Communities Data. Kerlinger (1996a) also presents the summary data of the numbers of pairs based on nest and adult counts from a 1995 study. These data are presented in Table 3-80.

Kerlinger (1997a) documents the findings of a population study of birds nesting on five islands of the NY/NJ Harbor Estuary, from May–June 1997. A total of 3,058 pairs of long-legged waders, cormorants, gulls, and waterfowl were observed in 1997. There were 611 nests observed at Shooter's Island, 16 nests at Prall's Island, and 53 nests at the Isle of Meadows. Based on these studies and additional data from 1995 as presented in Kerlinger (1996a), the numbers of pairs based on nest and adult counts are summarized in Table 3-80. Kerlinger (1997a) is provided in its entirety in Appendix H - Biological Communities Data.

The New Jersey Audubon Society (NJAS, 1997) reports migratory birds found along the lower Hackensack River, and provides recommendations for the conservation of these species and important habitat found in this area. In total, 20 migratory bird observation sites are presented, including both tidal and freshwater portions of the Hackensack River. Weekly migratory bird counts are provided as an appendix to this report. Migratory bird counts were conducted from April–November 1995 along the lower Hackensack River at Berry's Creek, Mill

Creek, Cromakill Creek, and Bellman's Creek. These locations are presented in Figure 3-15b. A summary of survey results from the lower Hackensack River is presented below. The entire survey dataset is provided in electronic format in Appendix H – Biological Communities Data.

Location	Number of Surveys			Number of Species		
	Spring	Summer	Fall	Spring	Summer	Fall
Berry's Creek	6	7	6	64	54	65
Mill Creek	6	7	6	22	22	18
Cromakill Creek	6	7	6	15	25	28
Bellman's Creek	6	7	6	20	27	18

The New Jersey Audubon Society's *Birds of New Jersey* (NJAS, 1999) presents a bird inventory with information on the occurrence, distribution, and status of more than 440 listed avian species for New Jersey. This publication is the result of 5 years of survey effort conducted throughout the state to map the ranges of New Jersey's breeding birds as part of the New Jersey Breeding Bird Atlas project. This document also provides a historical summary of breeding bird distributions in the early 1900s, a summary of bird migration routes, a review of rare birds, and a compilation of wintering bird information. Species distribution maps are provided for New Jersey based on the 7.5 minute USGS topographic maps (168 for New Jersey). Each USGS map was subdivided into six blocks: northwest, northeast, central west, central east, southwest, and southeast. Birds observed in the Inventory Area based on these species distribution maps and as listed in this publication are presented in Table 3-79. No raw data were provided.

The NYSDEC provides the New York State Breeding Bird Atlas interim data for 2000–2003 (NYSDEC, 2004a). Two breeding bird atlas blocks are within the Inventory Area: Block 5649B (Lower Newark Bay, and western portion of the Kill Van Kull) and block 5649A, B, and C (upper, middle and lower Arthur Kill). These coverages are presented in Figure 3-15a. A summary for each block is provided below. Raw data are available online at the NYSDEC Breeding Bird Atlas internet site:

http://www.dec.state.ny.us/apps/bba/results/index.cfm

Breeding Bird Atlas Block	Area	Number of Species Sitings			
		Possible	Probable	Confirmed	Total Species
5649B	Kill Van Kull (western) including Shooter's Island	17	14	43	74
5649A	Arthur Kill (upper) including Prall's Island	12	7	54	73
5649C	Arthur Kill (middle) including Isle of Meadows	4	20	47	71
5548B	Arthur Kill (lower)	12	24	33	69

Parsons and Wright (1994) document bird species diversity and abundance at several islands in the NY/NJ Harbor Estuary, including the Isle of Meadows and Prall's Island in the Arthur Kill and Shooter's Island in Newark Bay/Kill Van Kull. These locations are presented in Figure 3-15a. Sites were visited in May–June 1994. Active nests and species counts were completed during each survey effort. The numbers of pairs based on nest and adult counts are presented in Table 3-80. No additional data are provided.

Scarlatelli (1992) provides an overview of bird species observed during summer 1992 surveys conducted at eight ponds located within a landfill area in the Hackensack Meadowlands. The site location is presented in Figure 3-15b. In total, 40 species were observed, consisting of 12 passerines, 10 shorebirds, six swimmers, five waders, three aerialist, three birds of prey, and one waterfowl species. A complete species list and the number of individuals observed per species are not provided.

BBL conducted four seasonal bird surveys in the lower 6 miles of the Passaic River in 1999–2000 as part of the RI activities (Tierra, 2002d). Surveys were conducted in the fall of 1999 (September), and winter (March), spring (May), and summer (August) of 2000. The sampling locations are presented in Figure 3-15c. Each survey included multiple counts of all birds observed on mudflats, along the shoreline, and on bridge abutments. The fall, spring, and summer surveys were each conducted for three consecutive days, and included counts coinciding with morning and evening low tides (expected period of maximum bird activity), mid-day high tides (expected period of minimum bird activity), mid-day low tides, and morning and evening high tides. The winter survey was a 1 day effort that included similar counts during morning and evening low tides and mid-day high tide. Each survey included multiple counts of gulls flying over the river in addition to the total counts of perched, swimming, and foraging birds. In total, 49 species of birds were observed. These are listed in Table

3-81. Gulls were by far the most abundant bird observed in the River, followed by common species of duck and the bridge-nesting swallows. Raw data from this survey are provided in electronic format in Appendix H – Biological Communities Data.

USFWS (1997) provides a summary of habitats and species of special concern in areas included within the Inventory Area. The Arthur Kill Complex supports seasonal or year-round populations of 178 species of special emphasis, including 128 species of birds. A listing of these species is presented in Table 3-78a. No study boundaries were provided. The Hackensack Meadows Complex contains regionally significant brackish marshes, and supports seasonal or year-round populations of 88 species of special emphasis or listed species, including 55 species of birds. A listing of these species is presented in Table 3-78b. No study boundaries were provided. Species information is also available in electronic format at the following USFWS internet site:

http://training.fws.gov/library/pubs5/begin.htm

3.3.2.5 Mammals, Amphibians, Reptiles and Other Wildlife Species

Two studies that have been conducted since 1990 report on mammals, amphibians, reptiles, and/or other wildlife. These are discussed below.

From February 1996 to February 1997, mammal surveys were conducted in the Hackensack Meadowlands on a property bordering the Hackensack River (Empire, 1998). Observations were made during weekly or bi-weekly surveys. Surveys were conducted from three transects and five observation towers. The approximate survey locations are presented in Figure 3-15b. In total, 10 mammals were observed at the site as listed below. No additional data were provided.

Common Name	Scientific Name
Cat	*Felis domesticus*
Eastern chipmunk	*Tamias striatus*
Eastern cottontail	*Sylvilagus floridanus*
Eastern gray squirrel	*Scirius carolinensis*
Meadow vole	*Microtus pennsylvanicus*
Muskrat	*Ondatra zibethicus*
Norway rat	*Rattus norvegicus*
Raccoon	*Procyon lotor*
Striped skunk	*Mephitis mephitis*
Woodchuck	*Marmota monax*

USFWS (1997) provides a summary of habitats and species of special concern in areas included within the Inventory Area. The Arthur Kill Complex supports seasonal or year-round populations of 178 species of special emphasis, including one amphibian (southern leopard frog) and two reptiles (eastern mud turtle and northern diamondback terrapin). A listing of these species is presented in Table 3-78a. The Hackensack Meadows Complex contains regionally significant brackish marshes, and supports seasonal or year-round populations of 88 species of special emphasis or listed species, including one amphibian (southern leopard frog) and one reptile (northern diamondback terrapin). A list of these species is presented in Table 3-78b. No raw data were provided.

3.3.2.6 Other Studies

Eleven identified studies, primarily dealing with various impacts to biological communities in the Inventory Area, have been conducted since 1990.

Beans and Niles (2003) presents endangered and threatened wildlife of New Jersey, including mammals, birds, reptiles, amphibians, fish, insects, and freshwater bivalves. Species-specific habitat requirements, distribution, diet, breeding biology, and status and conservation measures are provided. There were five noted species within the Inventory Area: black-crowned night heron, least tern, peregrine falcon, savannah sparrow, and sedge wren. No additional data were provided.

Burger et al. (1992a) reviews reproductive success of marine birds from the NY/NJ Harbor Estuary, Barnegat Bay, and Massachusetts. No new data are provided in this report.

Iannuzzi et al. (2002) reviews the extent of biological communities in the Newark Bay region and describes impacts to these communities from a variety of sources. No new data are provided.

Kerlinger (1996b) presents recovery, restoration, management, and conservation plans for bird species of the NY/NJ Harbor Estuary. The author cites several studies that discuss habitat restoration plans to protect and help enhance bird populations in the Arthur Kill, Kill Van Kull, and the Hackensack River. No raw data are provided.

MacCarone and Brzorad (1998) and MacCarone and Brzorad (2000) summarize ongoing studies (1988–1997 and 1988–1999) of wading bird usage of foraging habitats in estuarine feeding sites that have been largely abandoned after a series of oil spills in 1990. Foraging behavior of the great egret, snowy egret, and glossy ibis in the Arthur Kill are the focus of these studies. No raw data are provided.

NJDEP (1991) presents the findings of a comprehensive study to determine the biological impacts within the Arthur Kill estuary following 1990 oil spills in the Arthur Kill. During the cleanup process, 64 birds were found dead, 40 birds were treated but died, and 110 were treated and survived. Parsons (1993) presents a summary of documented biological effects (e.g., changes in clutch size) on bird populations following the 1990 oil spills. Snowy egret and glossy ibis experienced major declines in the number of young raised successfully to a fledgling stage. Data for this study are provided in Section 3.3.6.

Quinn (1997) provides a naturalist's narrative of the Hackensack Meadowlands in his book *Fields of Sun and Grass*. Issues discussed in the book include past alterations to the Meadowlands, present conditions, and proposed future development and its impacts on the present habitat. Quinn (1998) emphasizes the improvements of water quality of the Hackensack Meadowlands and its effect on aquatic species. No raw data are provided.

USFWS (1997) provides a summary of habitats and species of special concern in areas included within the Inventory Area. As summarized in Table 3-82, there are 37 federal and state listed species that are threatened, endangered, or species of concern within the Arthur Kill and Hackensack Meadowlands. Species information is also available in electronic format at the following USFWS internet site:

http://training.fws.gov/library/pubs5/begin.htm

3.3.2.7 Summary of Available QA/QC for Biological Community Studies

The biological communities studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided. One of these studies, Beans and Niles (2003) is a peer-reviewed journal publication.

3.3.3 Hydrodynamics

A variety of studies have been conducted within in the NY/NJ Harbor Estuary to evaluate estuarine circulation patterns. These studies include some or all of the Inventory Area. As part of these studies, hydrodynamic information consisting of water surface elevation measurements, velocity measurements, and river flow measurements have been collected. Many of these studies involved the collection of data to support circulation and water quality modeling.

Thirty-two identified hydrodynamic studies are briefly summarized in Table 3-83. Figure 3-16a through 3-17 present the locations of available hydrodynamic measurements taken since 1990 in the Inventory Area; these 27 studies are summarized in greater detail below. Details of water quality sampling (such as conductivity, salinity, density, and suspended sediment) and water quality modeling are described in Section 3.2.1. Five identified hydrodynamics studies that were conducted prior to 1990 are briefly summarized in Table 3-83.

3.3.3.1 Water Surface Elevation and Velocity Measurements

There are 17 identified studies conducted since 1990 that report on water surface elevation and velocity measurements in the Inventory Area.

The PA NY/NJ Operational Forecast System (NYOFS) has been created by the National Ocean Service to provide the maritime community with improved short-term predictions of water levels and currents in the PA NY/NJ (NOAA/NOS, 2004). NYOFS runs a numerical model hourly to simulate water levels and current velocities for the past hour (the nowcast) and four times a day to produce a forecast of the water levels and current velocities for the next 30 hours. The numerical model is described in NOAA (2001; 2002a). The model nowcasts/forecasts can be found at the following internet site:

http://co-ops.nos.noaa.gov/NYOFS/nyofs.shtml

As part of NYOFS, the National Ocean Service currently measures water surface elevation at the Bayonne Bridge. The approximate location of the Bayonne Bridge gage is presented in Figure 3-16a and the data can be accessed at the following internet site:

http://co-ops.nos.noaa.gov/NYOFS/bayo_wl.shtml

The National Ocean Service also collects current measurements as part of NYOFS at Bergen Point. The approximate location of the Bergen Point monitoring station is presented in Figure 3-16a and the data can be accessed at the following internet site:

http://www.co-ops.nos.noaa.gov/nyports/3CURTS_bp.html

As part of the New Jersey Toxics Reduction Work Plan for Newark Bay (which is the New Jersey component of the NY/NJ HEP CARP), hydrodynamic data were collected between June 2000 and May 2002 within Newark Bay, Arthur Kill, and Kill Van Kull (NY/NJ HEP, 2004a). These investigations involved the collections of hydrodynamic data such as water surface elevations and currents. In addition to the water surface elevation measurements collected by NOAA at Bayonne Bridge, water surface elevation measurements were also collected at two other locations within the Inventory Area (Newark Bay and Perth Amboy). The approximate locations of the measurements are presented in Figure 3-16a and information about the program can be found at the New Jersey Toxics Reduction Work Plan – Newark Bay internet site:

http://www.dl.stevens-tech.edu/newark_bay/newark_bay_intro.htm

Table 3-84 summarizes the deployment dates, instruments, and locations for the data collected as part of the CARP program.

Several studies described in Table 3-84 reference work and data collected as part of the NY/NJ HEP CARP program, such as Burke et al. (2002), Chant et al. (2001), Creed et al. (2001), Haldeman et al. (2002), Hunter et al. (2002), Rankin (2001), Rankin et al. (2001; 2002), and Styles et al. (2001). Currents were also measured as part of the New Jersey Toxics Reduction Work Plan for Newark Bay. Currents were measured using an ADCP from both stationary vessels and mooring locations. The approximate locations of the measurements are presented in Figure 3-16a and information about the program can be found at the New Jersey Toxics Reduction Work Plan – Newark Bay internet site:

http://www.dl.stevens-tech.edu/newark_bay /newark_bay_intro.htm

A brief summary of the major findings of these reports is presented below.

Reference	Parameters Measured	Major Findings
Burke et al. (2002)	Suspended sediment, currents, CTD, water surface elevation	Sediment suspension occurs on the side banks of the navigation channel under moderate current and wave conditions. Another study should be conducted during a spring tide with strong winds before any definitive conclusions on suspension and transport can be made.
Chant et al. (2001)	Suspended sediment, currents, CTD, water surface elevation	Tidal period motion in the system exhibits significant spring neap tide variability. The variability is most pronounced at Perth Amboy and least pronounced in the Kill Van Kull. Tidal monthly variations in bottom stress produce appreciable variations in the suspended load. This likely has important consequences on the transport of sediments. Two-layer estuarine circulation is most persistent in Newark Bay, weakest in Kill Van Kull, and most variable at the Perth Amboy mooring. The variability is in part related to meteorological forcing. Meteorologically forced flows in the Kills are composed of two modes, one characterized by simple emptying/filling and the second by a flow through the system.
Creed et al. (2001)	Suspended sediment	Comparisons among the time histories from a laser *in situ* scattering and transmissometer and optical backscatter sensor and an acoustic backscatter signal from an ADCP can be useful in determining the conditions under which an optical backscatter sensor and an ADCP may be calibrated. It is possible to determine grain-size distribution at the study site, which is necessary for explaining some of the variance in the acoustic/optical signals that is not due to fluctuations in the concentration of suspended sediment

Reference	Parameters Measured	Major Findings
Haldeman et al. (2002)	Suspended sediment, currents, CTD, water surface elevation	Marked differences exist in the sediment size distributions and transport characteristics at different sampling locations. Tidal frequency fluctuations in the suspended load are seen at both sites for at least some particle sizes. The distribution of total concentration by particle size class is an important feature at all sites. At Perth Amboy, a particularly strong tidal signal is observed in the concentrations, and the net transport is directed up the Estuary. At Kill Van Kull, there is a net flux of large particles into the Estuary and small particles out, but the overall net transport of particles appears to be into the Estuary.
Hunter et al. (2002)	Suspended sediment, currents, CTD, water surface elevation	Tidal period motion in the system exhibits significant spring-neap tide variability. The variability is most pronounced at Perth Amboy and least pronounced in the Kill Van Kull. Two-layer estuarine circulation is most persistent in Newark Bay, weakest in Kill Van Kull, and most variable at the Perth Amboy mooring. The variability is in part related to meteorological forcing. Meteorologically forced flows in the Kills are composed of two modes, one characterized by simple emptying/filling and the second by a flow through the system. Moored data suggest that sediment transport at the head of Newark Bay is directed northward. In Kill Van Kull, three of four mooring deployments indicate transport into Newark Bay.
Rankin (2001)	Suspended sediment, currents, CTD, water surface elevation	The Kills system responds to a complex combination of forcing influences, including tide, wind, and freshwater inflow. These influences are responsible for dramatic variations in hydrodynamic and residue flow within the Newark Bay-Kills system and the location intensity of the turbidity maxima in Newark Bay and the Arthur Kill.

Reference	Parameters Measured	Major Findings
Rankin et al. (2001)	Suspended sediment, currents, CTD, water surface elevation	Tidal period motion in the system exhibits significant spring-neap tide variability. The variability is most pronounced at Perth Amboy and least pronounced in the Kill Van Kull. Tidal monthly variations in bottom stress produce appreciable variations in the suspended load. This likely has important consequences on the transport of sediments. Two layer estuarine circulation is most persistent in Newark Bay, weakest in Kill Van Kull, and most variable at the Perth Amboy mooring. The variability is in part related to meteorological forcing. Meteorologically forced flows in the Kills is composed of two modes, one characterized by simple emptying/filling and the second by a flow through the system. Three turbidity maxima were identified in Newark Bay and its tributaries where suspended material tends to accumulate. In the Arthur Kill, material accumulates at the head of the salt wedge, about 10 km from Perth Amboy. In both the Hackensack and Raritan Rivers, turbidity maxima were also found at the head of the salt wedge.
Rankin et al. (2002)	Suspended sediment, currents, CTD, water surface elevation	Two-layer estuarine circulation is most persistent in Newark Bay, weakest in Kill Van Kull, and most variable at the Perth Amboy mooring. The variability is in part related to meteorological forcing. Wind and meteorological events play a strong role in the structure and circulation in the Newark Bay system. Mass transport in Raritan Bay may drive the flows through the Kills, allowing for episodic flushing of the Arthur Kill into Raritan Bay during meteorological events.
Styles et al. (2001)	Suspended sediment, currents, CTD, water surface elevation	Marked differences exist in the sediment size distribution and transport characteristics at the three sampling locations. Tidal frequency fluctuations in the suspended load are seen at all sites for at least some particles sizes. The distribution of total concentration by particle size class is an important feature at all sampling sites.

As part of the hydrodynamic model developed for Arthur Kill to study circulation patterns in a tidal strait, three tide gages and moored current meters were placed in the Arthur Kill from September 6 to October 10, 1990 (Sajan, 1993). The raw data were not provided in this report and only limited summary information was made available in support of the model in this dissertation. The locations of theses tide gages and moored current meters are presented in Figure 3-16a.

In support of the hydrodynamic model developed for the DEIS for the NY/NJ Harbor Navigation Study, hydrodynamic data for model calibration and verification were collected by the USACE (1999a) in 1991 and 1994–1995. Data were measured water level recorders, moored current meters, moored conductivity and temperature sensors, CTD probes, and grab samples. According to the USACE, hydrodynamic data from 1991 were collected for a 4 to 6 week period and from approximately November 1994 to October 1995. No raw or summary data were provided. Figure 3-16a shows the locations of hydrodynamic measurements collected in the Inventory Area.

In addition to the water surface elevations collected by NOAA and the USGS, water surface elevation measurements were also collected in 1995 and 1996 by OSI in the lower 6 miles of the Passaic River as part of the RI activities (Tierra, 2004b). Measurements were collected from three locations in the River: lower, middle, and upper. The locations of these gages are presented in Figure 3-17. Raw data are provided in electronic format in Appendix I – Hydrodynamics Data. The results are summarized below:

Location	Dates of Data Collection	Minimum Elevation (ft)	Maximum Elevation (ft)
Lower Gage	April 14, 1995 to May 1, 1996	-2.0	9.5
Middle Gage	April 14, 1995 to June 11, 1996	-1.8	9.6
Upper Gage	April 14, 1995 to June 11, 1996	-2.2	9.5

Note: All elevations referenced to the USACE mean low water datum.

Water current measurements were collected in 1995 and 1996 by EA in the lower 6 miles of the Passaic River as part of the RI activities (Tierra, 2004c). Current measurements were made from moored current meters as well as from a boat-mounted ADCP at River transect locations. The locations of the moored current meter moorings and ADCP measurement transects are presented in Figure 3-17. The moored current meter measurements are provided in electronic format in Appendix I – Hydrodynamics Data. The locations and dates are summarized below.

Location	Dates of Data Collection
Mooring 1	July 6, 1995 to May 31, 1996
Mooring 2	July 7, 1995 to May 31, 1996
Mooring 3	July 7, 1995 to May 31, 1996

The ADCP measurements are provided in electronic format in Appendix I – Hydrodynamics Data. The locations and dates of the measurements are summarized below:

Transect	Date	Number of Transect Crossings
-1	7/26/1995	6
	8/1/1995	6
	4/22/1996	5
	5/7/1996	5
	5/17/1996	3
0	7/20/1995	2
	4/8/1996	5
	4/18/1996	3
	5/14/1996	6
	5/22/1996	3
1	7/17/1995	2
	7/18/1995	4
	4/5/1996	6
	4/19/1996	6
	5/6/1996	3
	5/17/1996	6
10	7/12/1995	6
	4/4/1996	6
	4/15/1996	3
	5/10/1996	6
	5/16/1996	3
15	719/1995	6
	4/14/1996	7
	5/15/1996	6
	5/20/1996	2
19	7/27/1995	6
	8/1/1995	6
	4/13/1996	8
	5/9/1996	6
	5/16/1996	3
	5/20/1996	3

Transect	Date	Number of Transect Crossings
26	7/31/1995	4
	8/1/1995	2
	4/12/1996	4
	4/18/1996	3
	5/8/1996	6
	5/21/1996	3
27	7/28/1995	6
	4/11/1996	6
	4/17/1996	3
	5/13/1996	6
	5/21/1996	2

The USGS collects water surface elevation data in both the Passaic and Hackensack River. The two USGS water level recorders are (USGS, 2004):

- Gage 01378570 – Hackensack River at Hackensack, NJ; and
- Gage 01392590 – Passaic River at Newark, NJ

The USGS has been collecting real-time water surface elevation measurements in the Passaic River since 1993 near Newark, although the instrument was damaged in September 1999 by Hurricane Floyd. It was re-installed in March 2001. The location of this gage is presented in Figure 3-16c and information about the gage can be found at the following internet site:

http://waterdata.usgs.gov/nj/nwis/nwisman/?site_no=01392590&agency_cd=USGS

The USGS also measures water surface elevations in the Hackensack River near Hackensack (Figure 3-16b). The location of this gage as well as information about the gage can be found at the following internet site:

http://waterdata.usgs.gov/nj/nwis/nwisman/?site_no= 01378570& agency_cd=USGS

Historic water surface elevation measurements and real-time measurements are available at these internet sites.

3.3.3.2 River Flow

There was one study conducted since 1990 that characterized river flow in the Inventory Area.

The USGS collects continuous flow measurements at several locations in the Passaic, Hackensack, Elizabeth, and Rahway Rivers in the Inventory Area (USGS, 2004). These locations and raw data can be accessed at the following USGS internet site:

http://waterdata.usgs.gov/nj/nwis

Table 3-85 summarizes the flow information as well as select flow statistics for select gages located on the Passaic, Hackensack, Elizabeth, and Rahway Rivers. Gages on these rivers and tributaries can also be accessed on the USGS internet site.

3.3.3.3 Hydrodynamic Modeling

Several hydrodynamic modeling efforts have been undertaken since 1990, some are currently underway, to study flow and circulation patterns for the NY/NJ Harbor Estuary (including the Inventory Area). These efforts include modeling activities to evaluate flood elevations, to support navigation in the area, and to support water quality modeling. The following modeling studies pertaining to the Inventory Area have been identified since 1990. Raw data are not provided in the available reports from modeling studies, although in some instances data were used to calibrate these models.

- The Estuarine, Coastal, and Ocean Model of the New York Harbor complex, Long Island Sound, and the New York Bight to simulate estuarine circulation as part of the System Wide Eutrophication Model (Blumberg, 1999; Hydroqual, 2002; Hydroqual unknown; Kaluarachchi et al., 2003);
- The 3-dimensional (3D) Princeton Ocean Model of the Port of NY/NJ to provide nowcasts and forecasts of water levels and current velocities (NOAA, 2001; 2002a);
- On-going hydrodynamic and sediment transport modeling efforts as part of the NY/NJ HEP CARP program (NY/NJ HEP, 2004a).
- A 3D model of Arthur Kill to study the effect of wind, water surface elevation, and buoyancy forcing on the distribution of temperature, salinity, and velocity (Sajan, 1993);

- A 2-dimensional dynamic estuary model to estimate flood frequencies for the Passaic River Basin Flood Protection Project (USACE, 1992a);
- A 3D hydrodynamic model, CH3D-WES (extending up the Hudson River to near Troy, NY, through the NY/NJ Harbor system and on to the continental shelf), to support a water quality model and study to evaluate impacts from the proposed Passaic River Flood Diversion Tunnel (USACE, 1997j). The hydrodynamic model was used with the CE-QUAL-ICM water quality model; and
- A 3D model (MIKE3) of the PA NY/NJ to evaluate the impacts to hydrodynamics and water quality for the NY/NJ Harbor Navigation Study (USACE, 1999a; 2004c). This model was used as part of the HPM3D model to evaluate salinity, temperature, and DO in NY/NJ Harbor.

Caplow et al. (2003) injected sulfur hexafluoride into Newark Bay in July 2002 to investigate circulation, mixing, and the transport and fate of solutes. The sulfur hexafluoride tracer was observed over 11 consecutive days. Air-water gas exchange was estimated to account for 56% of tracer mass loss, upon the basis of wind speed/gas exchange parameterization. Large-scale tidal transfer of solutes through the Kill Van Kull caused net seaward flushing contrary to the apparent residual circulation. Seaward transport via the Arthur Kill appeared to depend upon longitudinal dispersion, residual circulation, and freshwater discharge. The average residence time for water and solutes in Newark Bay was estimated to be approximately 8 days (without gas exchange). This document, including data figures, is provided in electronic format in Appendix I – Hydrodynamics Data.

3.3.3.4 Storm Surge and Flooding

There are three studies conducted since 1990 that characterize storm surge and flooding in the Inventory Area.

Najarian (2002), on behalf of the New Jersey Meadowlands Commission, reviewed the stormwater drainage design for the Meadowlands Mills project. An overview of the Losen Slote watershed is presented, along with a review of modeling results for existing conditions in this tributary of the Hackensack River. An evaluation of the maintenance required for the proposed stormwater control structures is presented, and includes stormwater retention basins, pump stations, and freshwater and brackish water marshes. Modeling is based on rainfall events and stormwater discharges into this waterway. There are no raw data (as used in the modeling effort) provided in this report.

The USACE (1992a) presented storm surge analysis modeling for the Passaic River Basin, New Jersey. As part of this plan, two underground tunnels were proposed to convey central basin flood waters to an outlet in the vicinity of Kearny Point in Newark Bay, NJ. This report investigates the effects of tunnel discharges on tidal elevations in the lower Passaic River, Hackensack River, and Newark Bay. Water diversion modeling is discussed, and modeling procedures are provided in electronic format in Appendix I – Hydrodynamics Data. Predicted tidal heights through 2050 for Kearny Point, Newark Airport, and East Newark are predicted based on 1976 tide data. There are no raw data provided from 1990–present.

The USACE (1995b) presented the *General Design Memorandum Main Report and Supplement of the Environmental Impact Statement* for the Passaic River Flood Damage Reduction Project. This document presents information on Passaic River Basin and vicinity flooding, including historical information, flood impacts, environmental analysis, and socioeconomic and community information. Several options are provided as part of the Passaic River Flood Damage Reduction Project. Flood delineation maps for the lower Passaic River, Newark Bay, and Hackensack River are provided in electronic format in Appendix I – Hydrodynamics Data.

3.3.3.5 Sediment Transport

Sediment transport and sediment budget studies have been conducted in the Inventory Area including one pre-1990 study and one study conducted since 1990 (Table 3-83). It should be noted that the sediment transport studies are based on several data sets that are described or presented in other sections of this Inventory Report. This section only describes sediment transport studies that were performed for the Inventory Area. Data used in the sediments transport studies such as hydrodynamics, water quality (such as salinity and suspended sediments), solute tracer studies, and radionuclide analysis of sediment samples, are presented in other sections of this Inventory Report. Prior and subsequent to 1990, several studies have used radiochemical analysis of sediments to estimate sedimentation rates with the NY/NJ Harbor Estuary. These studies are described in Section 3.2.2.

Since 1990, USACE (2004c) conducted a sediment transport/shoaling study for the NY/NJ HDP. This report evaluated shoaling rates for Newark Bay, Arthur Kill, and Kill Van Kull. Currently, as part of the New Jersey Toxics Reduction Work Plan for Newark Bay (which is part of the New Jersey component of the NY/NJ HEP CARP), sediment transport is being studied for Newark Bay. In addition, a sediment budget is being created for the PA NY/NJ. Studies such as Burke et al. (2002), Chant et al. (2001), Creed et al. (2001), Haldeman et al. (2002), Hunter et al. (2002), Rankin (2001), Rankin et al. (2001; 2002), and Styles et al. (2001), which are referenced in Section 3.3.3, describe the studies and data collection activities that have been performed and are currently underway. The raw data from these studies are not provided in these reports.

3.3.3.6 Summary of Available QA/QC for Hydrodynamics Studies

The hydrodynamics studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided. One of these studies, Blumberg (1999), is a peer-reviewed journal publication.

3.3.4 Dredging

A variety of investigations summarizing dredging in the Inventory Area, as well as permit applications to the USACE for dredging activities were identified. These are summarized in Table 3-86. Documents pertaining to dredging and a summary of dredging permits issued in the Inventory Area since 1990 are summarized in greater detail below.

3.3.4.1 Federal Maintenance Dredging and Channel Deepening

As part of this inventory report, a table listing past (post-1940), present, and future dredging activities in the Inventory Area was compiled (Table 3-87). Additionally, summary information on federal navigation channels within the Inventory Area, their current condition, and dredging status are presented in Table 3-88 and presented in Figures 3-18 and 3-19.

The PA NY/NJ (2004) posted a Fact Sheet on its internet site:

http://www.panynj.com

This Fact Sheet describes the status of its current dredging and deepening projects in Port Newark, Port Elizabeth, the Arthur Kill, and the Kill Van Kull. Information on recently completed and future work within the Inventory Area is also included. PA NY/NJ projects that are currently ongoing include the Kill Van Kull and Newark Bay 45-ft Deepening Project, the Arthur Kill Channel and Howland Hook Marine Terminal Project, and the Port Newark/Elizabeth Port Authority Marine Terminal Berth Deepening Project. No raw data were provided in this Fact Sheet.

In June 1996 the USACE (1997b) published the *Waterborne Seismic Reflection Study of the Kill Van Kull and Newark Bay Shipping Channels in New York/New Jersey* containing information on the lithography and thickness of the sub-bottom geologic units and identification of near-surface sediment layers. This information was intended to be used to prepare plans and specifications for the proposed deepening and widening activities in the NY/NJ channels according to the authors. The results of the study are summarized below. No raw data were provided.

Study Area	Number of Survey Lines	Bottom/Sub-bottom Description
Kill Van Kull	5	Sands intermixed with or containing varying quantities of silts, gravels, cobbles, or fractured rock
Newark Bay Shipping Channels	11	Bedrock, glacial till, silt, clay, and organic sediments

The USACE (2004a) published a limited reevaluation report and environmental assessment on consolidated implementation of the NY/NJ HDP describing proposed dredging activities for Newark Bay, Arthur Kill, and Kill Van Kull. The project calls for deepening of the federal navigation channel within the project area to 50 ft, modifying three currently ongoing projects to be dredged to a depth of 50 ft, as opposed to the original permitted depths, and widening of the federal navigation channel at specified locations. Figure 3-19 summarizes the extent and preliminary schedule of dredging activities for this project. No raw data were provided in this report.

The USACE has also published a hydrodynamic and water quality modeling/sediment transport/coastal erosion evaluation (USACE, 2004c) as an appendix to USACE (2004a) to evaluate the short-term impacts in the three areas to be deepened to 50 ft as part of the consolidation effort. The purpose of the study was to evaluate the short-term effects on hydraulics, salinity, temperature, and DO in the NY/NJ Harbor Estuary until the vertical portions of the project have been completed. In addition, a sediment transport evaluation with particular regard to changes in shoaling rates is also presented. Based on the hydrodynamic modeling and sediment transport evaluation, it was determined that consolidation of specified areas with the HDP will produce no worse or very similar conditions in the NY/NJ Harbor Estuary. No raw data were provided.

3.3.4.2 Dredge Permits

As part of this inventory report, a list of permitted dredging activities in the Inventory Area from 1940 to the present was compiled (Table 3-89). In addition to permitted dredging activities, identifiable and readily obtainable permit applications within the Inventory Area were also compiled (Table 3-86). The locations of the potential dredging activities from 1990 to the present are presented in Figure 3-2 and summarized below by waterway. It is likely that substantially more dredging permit applications exist for the Inventory Area. The list in Table 3-86 includes those that were obtainable for this Report. These permit applications are provided in electronic format in Appendix J – Dredging Data.

Waterway	Number of Permits
Newark Bay	7
Arthur Kill	11
Kill Van Kull	3
Passaic River	2
Hackensack River	0

3.3.4.3 Dredged Material Disposal

Su et al. (2001) discusses and reviews the process by which the USACE determines whether open ocean disposal of dredged material is appropriate for sediments removed from Newark Bay, Arthur Kill, Kill Van Kull, and the Passaic River. A technical review of the bioaccumulation criteria used in determining disposal location has shown that some values are risk-based while others are based on historical background concentrations, Food and Drug Administration Action Levels, limits of detection, and other non-risk-based methodologies. Therefore, the degree of uncertainty and health protection in the criteria varies considerably among the chemicals. The outcomes of several permit applications were also reviewed and it was determined that bioaccumulation criteria were not applied consistently. Based on these findings, three refinements to the decision-making process have been proposed. No raw data were provided.

The USACE (1996) has provided, in the *Dredged Material Management Plan for the Port of NY & NJ*, a list of options from which federal, state, and local decision makers can select the proper plan for the management of dredged material from the PA NY/NJ. Dredged material disposal options outlined by the USACE include ocean placement, aquatic CDFs, upland disposal, short-term sites, beneficial use, decontamination, sediment reduction/minimization, and delivery. No raw data were provided.

In September 1999, the USACE drafted the *Dredged Material Management Plan for the Port of NY & NJ – Implementation Report* (USACE, 1999b) to identify the primary and contingency options needed to meet the dredging requirements of the PA NY/NJ through the year 2040, giving special emphasis to beneficial uses. This document is a review of the immediate (1999–2000), short-term (2000–2010), and long-term (2011–2040) dredging needs of Newark Bay, Arthur Kill, Kill Van Kull, and the NY/NJ Harbor Estuary, as well as proposed locations of dredged material placement. No raw data were provided.

3.3.4.4 Newark Bay CDF

The Newark Bay CDF is located on the western side of the Newark Bay Middle Reach between the Port Newark and Port Elizabeth channels. It is 26 acres in surface area, was excavated to a depth of 70 ft below the Bay bottom, and can hold up to 1.5 million cubic yards of dredged material.

Knoesel et al. (1998) provides an overview of the construction and operation and maintenance plan of the Newark Bay CDF. No raw data are provided.

Matthew et al. (1999) provides an overview of the operation and management of the Newark Bay CDF. Included is a list of projects disposed of in the CDF through February 1, 1999, a description of the water quality monitoring program and bathymetric survey programs required by the operations and maintenance plan. No raw data are provided.

In April 1997, the USACE released the Final Environmental Impact Statement on the Newark Bay CDF (USACE, 1997a). This document presents the selected option for construction of a CDF at Cell 1S (located on a submerged island, east of the Port Newark Pierhead Channel and west of the main channel) followed by the construction of CDFs at Cells 2S and 2N (located north of Cell 1S and west of the main channel). Cell 1S was constructed from June to November 1997; to date, only this cell has been constructed. No raw data are provided.

3.3.4.5 Summary of Available QA/QC for Dredging Studies

The dredging studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided.

3.3.5 Bathymetry

Several bathymetric measurement programs have been conducted in the Inventory Area. These include a number of pre- and post-dredging bathymetric mapping efforts conducted by the USACE. In addition, NOAA collects measurements of bathymetry as part of the development of navigation charts (NOAA, 1997; 1999; 2002b). Two studies discussing bathymetry measurements collected after 1990 were identified and readily obtainable; these studies are briefly summarized in Table 3-90 and presented in greater detail below. Three studies discussing bathymetry measurements collected prior to 1990 were identified and readily obtainable; these studies are briefly summarized in Table 3-90.

Figures 3-20a through 3-20h present the NOAA navigation charts for the Inventory Area. These charts are constructed based on surveys conducted by both NOAA and the USACE; these maps can be obtained from NOAA. Several of the hydrodynamic modeling studies described in Section 3.3.3 used bathymetry data obtained from the USACE and NOAA.

OSI performed bathymetry surveys of the lower 6 miles of the Passaic River as part of the RI activities (Tierra, 2004d). The objective of these surveys was to collect bathymetry for a sediment mobility study. Bathymetry data from the river were collected in March/April 1995 (as part of the 1995 RI) and also in November 1996, May 1997, June 1999, and August 2001. The locations and numbers of measurements are summarized below. The raw data is provided in electronic format in Appendix K – Bathymetry Data.

Date	Detail
March–April 1995	A total of 397 tracklines (spaced @100 foot intervals) between Stations –19+00 to 383+00
11–19 Nov. 1996	A total of 331 tracklines (spaced @100 foot intervals) between Stations –19+00 to 317+00
May 1997	A total of 331 tracklines (spaced @100 foot intervals) between Stations –19+00 to 317+00
4–12 June 1999	A total of 312 tracklines (spaced @100 foot intervals) between Stations –1+00 to 318+00

Date	Detail
August 2001	312 tracklines plus repeats as required for methods comparison using different hardware between ~Stations –1+00 to 318+00

A seismic reflection and side scan sonar investigation was conducted by the USACE (1997b) in Newark Bay, Arthur Kill, and Kill Van Kull in June 1997. The objective of the study was to determine the depth to bedrock and delineate the geologic stratigraphy. Interpretation of the side scan sonar and seismic reflection data indicates that the bottom and subbottom sediments of the Kill Van Kull are composed primarily of sands intermixed with or containing varying quantities of silts, gravels, cobbles, or fractured rock. Two well-defined relic stream channels are noted in Kill Van Kull south of Constable Hook. The composition of overlying sediments in Newark Bay is primarily silt and clay, with areas of organic sediments. Raw data, including geologic cross-sections, from this study are provided in electronic format in Appendix K – Bathymetry Data.

3.3.5.1 Summary of Available QA/QC for Bathymetry Studies

The bathymetric studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided.

3.3.6 Pollutant and Contaminant Sources

There are potentially thousands of industrial, non-industrial, and municipal sources of pollutants and contaminants to the Inventory Area, and most of the documentation for these sources is contained in regulatory files, letters, memoranda, notifications, or other publicly or privately held documents. A search for such documents could not be conducted within the timeframe allowed for development of the RIWP. Instead, a characterization of specific sources to the Inventory Area will be performed as part of a characterization of storm water outfalls and CSOs that will be conducted under the RIWP pursuant to Paragraph 44 of the AOC, and Section B.3.iii.2) of the SOW. It also is anticipated that data and information on pollutant and contaminant sources to the Inventory Area will be collected under a work plan to be developed by USEPA (pursuant to Section B.3.iii.1) of the SOW) focused upon contaminant fate and transport modeling for the Inventory Area. A thorough source inventory and characterization of sources will be compiled through the implementation of these work plans.

Much of the data and information presented in this section was derived from the files pertaining to the RI activities for the lower 6 miles of the Passaic River. As such, there is a substantially larger amount of data and information presented for the lower Passaic River relative to the other Inventory Area waterways. The data gaps for these other waterways will be filled during the implementation of the Source Identification Program under the RIWP for the Newark Bay Study Area.

A number of maps and publicly available documents developed since 1990 documenting the sources of chemical and non-chemical pollutants and contaminants to the Inventory Area were identified. For summary purposes, these are broken down into three categories: water contaminant discharges, accidental oil and hazardous chemical spills, and land-based point sources. The 34 investigations conducted since 1990 are presented in Table 3-91 and discussed in greater detail below. When available and appropriate, raw data from these studies are provided in electronic format in Appendix L – Contaminant Sources Data. Twenty-seven reports were identified that present information on investigations into chemical contaminant sources to the Inventory Area that were conducted prior to 1990; these studies are briefly summarized in Table 3-91.

3.3.6.1 Water Contaminant Discharges

Sixteen investigations were identified containing information on water contaminant discharges collected since 1990. These documents include information on CSOs, POTWs, urban runoff, and flooding. These documents are summarized in greater detail in the following paragraphs and raw data from these studies are presented in tables or in electronic format in Appendix L – Contaminant Sources Data. Documents containing information on water contaminant discharges prior to 1990 are briefly presented in Table 3-91.

The locations of CSOs and POTWs identified to date in the Inventory Area are presented in Figure 3-21. Additionally, stormwater outfalls located within the lower Passaic River are presented in Figure 3-22.

As part of the Inventory Report, a listing of the New Jersey Pollutant Discharge Elimination System (NJPDES) permit holders within the Inventory Area (excluding City of Newark permit holders and upstream municipalities along the Hackensack and Passaic Rivers) from 1990 through the present was developed from the following internet site:

http://www.state.nj.us/dep/dwq/database.htm

The resulting database is provided in electronic format in Appendix L – Contaminant Sources Data. This database combines two types of NJPDES information sources: 1) NJDEP-provided database spreadsheet of NJPDES permit holders up to and including the year 2000 (referred to as archived); and 2) NJPDES permit holders from post-2000 to the present (referred to as active). The following is a geographic summary of the NJPDES permits issued since 2000.

Permit Location	Number of Permits
Bayonne City	64
Carteret Boro	2
Elizabeth City	90
Jersey City	102
Linden City	146
Montvale Boro	0
Newark	13
Rahway City	0

Battelle (1992c) examined various analytical methodologies to determine their efficacy in quantifying low-level PCB loadings from effluent from one POTW and from an ambient Passaic River water sample. The concentrations of the sum of PCB congeners (1, 3, 4, 6, 8, 15, 18, 28, 52, 44, 66, 101, 118, 153, 105, 138, 187, 128, 180, 170, 195, 206, and 209) in the influent and effluent of the POTW and the river are summarized below. Raw data from this study are provided in electronic format in Appendix L – Contaminant Sources Data. The locations of the POTWs in the Inventory Area are presented in Figure 3-21.

Sampling Location	Sum of PCB Congeners (ng/L)
Passaic Valley POTW – Influent	365 – 434
Passaic Valley POTW – Effluent	ND – 1,887
Passaic River	300

In a companion study, Battelle (1993) quantified PCB concentrations in influent samples collected during storm events when CSOs were triggered, thus representing CSO discharge from a major POTW and effluent samples from a major POTW in the Inventory Area, and in water from the Passaic and Hackensack Rivers. The results of this study are summarized below and the raw data are provided in electronic format in Appendix L – Contaminant Sources Data. The locations of the POTWs in the Inventory Area are presented in Figure 3-21.

Sampling Location	Sum of PCB Congeners (ng/L)
Passaic Valley POTW – Influent	381 – 382
Passaic Valley POTW – Effluent	91 – 96
Passaic River	23
Hackensack River	24

The NY/NJ HEP CARP is attempting to understand the fate and transport of contaminants discharged into the NY/NJ Harbor Estuary, including the Inventory Area. The New Jersey Toxics Reduction Inventory is a component of CARP that is dealing with source identification/evaluation in the New Jersey portion of the NY/NJ Harbor Estuary. Only limited data have been made available to date from CARP. A complete description of the program is available at the following internet site:

http://www.carpweb.org/main.html

The data from this program will be very important to the study and characterization of contaminant sources to the Inventory Area.

A summary of the CARP sediment sampling program is provided in Bonin et al. (2000), and the data contained within this report is provided below. The program, as presented, is designed to determine the magnitudes of dissolved and sediment-bound organic contaminants, inorganic chemicals, and suspended sediment transported from the major tributaries entering Newark Bay. In addition, contaminant loads within the estuary and from major point sources will be measured. Limited results are presented in the paper and summarized below. No raw data were provided.

Water Type	PCB Concentration (pg/L)	PCDD/F Concentration (pg/L)	Organochlorine Pesticides Concentration (pg/L)
Estuary Water (salinities up to seawater)	1 – 337	13 – 1,190	6 – 6,310
Treated Waste Effluent	3 – 385	26 – 2,170	11 – 3,710

The IEC, formerly the ISC, publishes annual reports on water and air pollution in the New York/New Jersey/Connecticut area (IEC, 2000–2002; 2004; ISC, 1995). The reports from 2000 through 2003 are available at the following internet site:

http://www.iec-nynjct.org

The reports include raw data on POTW capacity and sludge generated in the Inventory Area (IEC, 2000–2002; 2004). Data from the 2003 annual report are summarized below by state.

State	Flow Avg. (MGD)	Type of Treatment	Sludge Generated (tons/yr)	Sludge (percent solids)	Sludge Disposal Method
Connecticut	2 – 34	Secondary	159 – 52,126	3% – 27%	Incineration, compost, landfill
New Jersey	3.1 – 142	Secondary	1,120 – 221,741	4.9 – 51	Beneficial reuse, landfill, incineration, land application, trucked out
New York	0.5 – 195	Secondary	3 – 134,500	4 – 30	Landfill, trucked out, compost, land application, landfill cover

Killam Associates identified and classified the tributary discharges to the peripheral ditch near Newark International Airport (Killam, 1995). The report includes information on CSOs nearby in Newark and Elizabeth (CSOs in the Inventory Area are presented in Figure 3-21), non-domestic industrial sanitary discharges, permitted discharges to surface water, and indirect discharges. The Passaic Valley Sewerage Commission has 39 facilities on its industrial inventory list. Various lists of permit violations are included in this document. A list of 72 facilities with known contamination in New Jersey is also included in the document. Twenty-five facilities in the Comprehensive Environmental Response, Compensation, Liability Information System (CERCLIS) and/or NPL were identified in the documents. These lists are provided in electronic format in Appendix L – Contaminant Sources Data.

Malcom Pirnie (1998) developed a CSO solids and floatables control measures plan for the City of Newark, NJ. The plan contains a hybrid of several approaches and technologies for various CSOs discharging to the Passaic River. Proposed technologies include screens and nets on select CSOs, and separation of sewers in order to reclassify many CSOs as storm outfalls. There are no data provided in this report.

Najarian Associates (Najarian, 1992), on behalf of Clinton Bogert Associates, performed an impact analysis of sewage treatment plant discharges on the water quality of the lower Hackensack River (CBA, 1990) in 1990 and amended the report in 1992 (Najarian, 1992). The authors conducted an impact analysis of sewage treatment plant discharges on the water quality of the lower Hackensack River. Summary data from the report on CSO average dry weather flow and sewage treatment plant and industrial discharge flow are provided below. No raw data were presented in this document. The locations of CSOs in the Inventory Area are presented in Figure 3-21.

CSO Basin Location	CSO Area (acres)	Flow (cfs)	BOD_5 (ppm)	NH_3-N (ppm)
Jersey City – North	871	6.4	112	5.6
Jersey City – South	1,170	8.5	130	12

Note:
NH_3-N = ammonia nitrogen

Discharge	Average Flow (MGD)	Average BOD_5 (lbs/day)
Bergen County Sewerage Authority	82	27,355
Henkel Corp.	1.5	313
Jersey City West	15.8	17,026
Kearny	2.0	353
North Arlington	1.7	1,353
North Bergen – Central and Northern	3.7	3,836
PSE&G – Jersey City	835	NA
PSE&G – Kearny	212	NA
PSE&G – Ridgefield/Bergen	455	NA
Rutherford	3.1	5,817
Secaucus	1.2	350
Woodridge	0.6	133

Notes:
NA = not applicable
MGD = million gallons per day

The North Jersey District Water Supply Commission of the State of New Jersey, as part of the Passaic River Basin Watershed Management Project, has characterized and assessed the Passaic River Basin Watershed (NJDWSC, 2002). The report from this effort is available at the following internet site:

http://www.njdwsc.com/prbwmp/wma4/ doc/wma4wca_11_02.htm

The report includes descriptive information on potential sources of contamination such as surface runoff, CSOs, and permitted dischargers.

The NY/NJ HEP has produced a fact sheet on CSOs in the NY/NJ Harbor Estuary. This fact sheet defines a CSO, describes CSO planning programs, and provides information on how citizens can help (NY/NJ HEP, unknown). No data are presented in this fact sheet. The location of CSOs in the Inventory Area is presented in Figure 3-21.

Shear et al. (1996) evaluate the relationship between CSOs and sediment contamination in the lower Passaic River. The total number of facilities permitted to discharge to the Passaic Valley Sewerage Commission is presented below; however, no raw data developed after 1990 are presented in the document. CSOs located within the Inventory Area are presented in Figure 3-21.

Industry	Total Number of Facilities Permitted to Discharge to PVSC
Non-categorical	147
Electroplating	54
Organic Chemicals	44
Textiles	34
Metal Finishing	24
Inorganic Chemicals	5
Plastics	5
Pulp and Paper	5
Pesticides	3
Cu	2
Leather Tanning	2
Non-ferrous Inorganic chemicals	2
Steam Electric Power	2
Aluminum	1
Total	330

Note:
PVSC = Passaic Valley Sewerage Commission

URS Greiner (URS, 1998) developed a modeling work plan for the City of Newark, New Jersey's CSO Discharge Characterization Study. The objectives of the plan are to evaluate the existing sewer system in terms of CSO discharges and pollutant loads, and evaluate alternatives to abate CSO discharges using the model that is developed. No raw data are provided.

Walker et al. (1999) used existing urban runoff data from the National Urban Runoff Program (collected prior to 1990) and the USEPA for the NY/NJ Harbor Estuary (collected after 1990) to estimate the contribution of urban runoff to recent sediment chemistry in the Passaic River. The urban runoff data for the Estuary and the results of this study are summarized below. No raw data are provided.

Analyte	Urban Runoff Concentration (µg/L)	Estimated % Chemical Presence in Passaic River Sediments Due to Urban Runoff
As	NR	NR
Cd	5	18%
Cu	80 – 209	14%
Pb	80 – 1,240	49%
Ni	28 – 51	24%
Zn	180 – 964	22%
Naphthalene	NR	37%
Phenanthrene	NR	110%
Fluoranthene	NR	37%
Pyrene	NR	32%
Benzo(a)anthracene	NR	86%
Chrysene	NR	59%
Total PAHs	NR	NR
Total DDT	NR	77%
Total PCBs	NR	8.0%

Note:
NR = not reported

Zdepski (1992) provides a discussion of industrial development and land-use practices and their impact on groundwater contamination in Newark, NJ. This examined City, State, and Federal records through April 1990 and identified 108 groundwater contamination cases within the Newark city limits. Many of the contamination cases correlate with former salt marsh areas that now have fresh groundwater within man-made fill. This document, including the locations of groundwater contamination sites, is provided in electronic format in Appendix L – Contaminant Sources Data.

3.3.6.2 Accidental Spills (Oil and Hazardous Chemicals)

Six studies were identified that contain data/information on accidental oil spills that occurred within the Inventory Area since 1990. These are discussed in greater detail below. Raw data from these studies are provided in tables or electronic format in Appendix L – Contaminant Sources Data. Documents that were identified containing information on pre-1990 oil spills within the Inventory Area are summarized briefly in Table 3-91.

As part of the Inventory Report, a search was conducted of the *USCG Pollution Incidents In and Around U.S. Waters – A Spill/Release Compendium: 1969–2001*. This database is available at the following internet site:

http://www.uscg.mil/hq/g-m/nmc/response/stats/aa.htm

A summary of the findings are presented below; the listing of oil and hazardous chemical releases reported within the Inventory Area (since 1990) is presented in Appendix L – Contaminant Sources Data.

County	Number of Oil/Chemical Spills Reported
Essex	287
Hudson	496
Middlesex	473
Richmond	467
Somerset	55
Union	450

An extensive discussion of the impacts of oil spills on ecological receptors within the Inventory Area is presented in a multi-author book edited by Burger (1994). The book includes a section on response and cleanup, biological effects, and a conclusions section. The effects of oil spills on vegetation, invertebrates, fish, birds, and mammals are presented in individual chapters within the book. No raw data are provided.

A history of petroleum and hazardous chemical spills in Newark Bay from 1982 to 1991 was compiled by Gunster et al. (1993a). A companion article assessing chemical loadings to Newark Bay from spills occurring from 1986 to 1991 was also published by Gunster et al. (1993b). The bulk of the materials released to the aquatic environment during this time consisted of petroleum products, specifically No. 6 Fuel Oil (103 spills), and gasoline (207 spills). The majority of the reported incidents occurred in the Arthur Kill and its tributaries as well as in the Kill Van Kull and the lower Passaic River. Summary data broken down by waterbody for 1990 and 1991 are presented below (Gunster et al., 1993a). These studies are provided in their entirety in electronic format in Appendix L – Contaminant Sources Data.

Receiving Water	1990 – No. of Incidents	1990 – Total Volume (U.S. Gallons)	1991 – No. of Incidents	1991 – Total Volume (U.S. Gallons)
Arthur Kill	124	15,349	69	16,600
Elizabeth River	0	0	3	20
Hackensack River	13	660	4	1,500
Kill Van Kull	52	1,982	37	3,339
Morses Creek	1	1	0	0

Receiving Water	1990 – No. of Incidents	1990 – Total Volume (U.S. Gallons)	1991 – No. of Incidents	1991 – Total Volume (U.S. Gallons)
Newark Bay	14	23	16	3,506
Passaic River	8	10	11	310
Rahway River	3	50	0	0
Woodbridge Creek	2	126	1	Not quantified
Unknown Location	7	22	11	392
Sewer	37	203,893	25	19,248

Hurley (1992) presents a descriptive account of oil spills in the Arthur Kill and Kill Van Kull in 1990 and a history of the oil refining industry in the Inventory Area, including a number of illustrations of early oil refineries and shipping in the area. No raw or summary data are provided.

The NJDEP prepared a study of the short-term impacts of the January 1, 1990, Exxon Arthur Kill oil spill (NJDEP, 1991). Sediment and benthic invertebrate communities were sampled at 37 locations concurrently during the winter/spring of 1990. Zero to 100% of the ribbed mussels encountered at each sampling location were found dead. At the sampling locations, 654 birds were found dead and 150 were found alive, with mallards being the most common species observed dead at each sampling location. Sediment from Goethals, Elizabethport Marsh, adjacent to Neck Creek, Howland, Old Place Creek, Sawmill Creek, Neck Creek, and Prall's Island had the same petroleum hydrocarbon signature as that of the Arthur Kill discharge on January 1, 1990. Additional results from this study are summarized below; raw data from this study are provided in electronic format in Appendix L – Contaminant Sources Data.

Location	Number of Benthic Invertebrates
High Intertidal	0 – 150 ribbed mussels; 0 soft-shelled clams
Medium Intertidal	0 – 3 ribbed mussels; 0 – 26 soft-shelled clams
Low Intertidal	0 ribbed mussels; 0 – 1 soft-shelled clams
Subtidal	0 ribbed mussels; 0 – 5 soft-shelled clams

The NY/NJ Harbor Spill Restoration Committee prepared *Natural Resource Restoration Plan for Oil and Chemical Releases in the NY/NJ Harbor Estuary* (NOAA, 1996). The restoration plan includes an introduction, a description of the state of the NY/NJ Harbor Estuary Ecosystem at the time of publication, a section on evaluating, choosing, and monitoring restoration alternatives, options, and sites, and several appendices, including narrative descriptions of specific oil spills in the region. The restoration plan does not contain raw or summary data.

3.3.6.3 Point-Source Contaminant Discharges

Twelve studies conducted since 1990 were identified that contain data/information on point-source contaminant discharges in the Inventory Area. These documents are summarized in Table 3-91 and discussed in greater detail below. Thirteen studies were identified that contain pre-1990 data/information on point-source contaminant discharges within the Inventory Area. These are summarized briefly in Table 3-91.

Huntley et al. (1994) investigated potential sources of PCDTs in the Passaic River. PCDTs have been found in pulp and paper mill effluents and waste incinerator fly ash, and are associated with metal reclamation processes and incineration of PCBs. Chemical processes similar to those that have resulted in the formation of PCDFs such as dye, pigment, paint, pesticides, and raw chemical production are likely significant sources of PCDTs if sulfur-containing organic chemicals are used in the manufacturing process. Elevated levels of PCDTs and PCBs in lower Passaic River sediments suggest that PCDT contamination of these sediments may be related to several sources. The data are provided in Appendix L – Contaminant Sources Data.

A history of the Passaic River from the pre-colonial era to the present is provided by Iannuzzi et al. (2002). This book also includes historical information about the development of the environs surrounding Newark Bay. The book includes a general discussion of sources of contaminants in the river including industrial contaminants and sewage. The authors present no new data; the majority of material in the book is reviewed from primary references.

Sources of Hg contamination in New Jersey are discussed in a report by the Toxics in Biota Committee of the NJDEP, New Jersey Department of Health, and the New Jersey Department of Agriculture (NJDEP, 1994a). The report includes information on anthropogenic sources of Hg such as agriculture, industries/utilities, consumer products, and atmospheric deposition. Limited data are presented in the report; a summary of emissions from New Jersey incinerators and a list of Hg contaminated sites are included in the report and provided below. No raw data are provided.

Incinerator Type	Number Operating	Range of Hg Emissions (lbs/yr)
Apt. and Crematoriums	130	96 – 142
Hazardous Waste	6	20 – 1,800
Medical Waste	8	8 – 80
Municipal Solid Waste	5	650 – 3,300
Sewage Sludge	10	450 – 800

Hg-Contaminated Site	Location	County
Calgon	Hawthorne	Passaic
City of Camden Well Contamination	Pennsauken	Camden
Electron Technology	Kearny	Hudson
Gordos Corp.	Bloomfield	Essex
Hg Trading	Hammonton	Atlantic
LCP Chemicals	Linden	Union
Nuodex	Elizabeth	Union
Owens Illinois	Vineland	Cumberland
Ventron/Velsicol	Wood Ridge	Bergen
Vineland Develop. Corp.	Vineland	Cumberland
WA Cleary	Franklin Twp.	Somerset

Three potential sources of Hg contamination in the Hackensack River Basin, in addition to the Ventron Velsicol site, are identified in NJDEP (1994b). This document notes the presence of a former chemical manufacturing facility whose products left various levels of inorganic chemicals and high concentrations of PCBs in soils and sediments of Ackerman's Creek, a tributary to Berry's Creek. In addition, a second site, a former solvent recovery and fuel blending operation located on Peach Island Creek, a tributary to Berry's Creek, and a third site, located at the head of Nevertouch Creek that supported Zn and sulfur operations, were also identified as possible point-sources of Hg contamination in the area. No data are presented in this document.

In a series of papers by Wenning et al. (1992a,b; 1993a,b,c), sources of PCDD/Fs to Newark Bay and Passaic River sediments are examined. These papers utilized sediment data collected by ChemRisk in 1990 (i.e., Tierra, 1990). These data are provided in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. No raw data, aside from sediment chemistry (which is summarized in Section 3.2.2), are presented in these papers. The findings of these studies are summarized below.

Wenning et al. (1992a) conduct a chemometric comparison of PCDD/F residues in Newark Bay to other industrialized waterways using PCA and the complete linkage:farthest neighbor cluster method. Similarities in PCDD/F patterns among the waterways were related to the presence of similar municipal and industrial sources, including effluents from pentachlorophenol and PCB manufacturing facilities, pulp and paper mills, automobile and shipping traffic, and municipal solid waste incinerators. Similar findings are reported in Wenning et al. (1993a).

Wenning et al. (1992b) investigated potential sources of 1,2,8,9-TCDD in Newark Bay by performing a literature review to evaluate whether this PCDD congener is associated with the formulation of 2,4,5-T and whether 1,2,8,9-TCDD is commonly found in the aquatic environment. Based on their analysis of the primary literature, the authors conclude that the presence of 1,2,8,9-TCDD in Newark Bay biota is not associated with 2,4,5-T manufacturers, but rather, the result of various commercial, residential, municipal, and industrial combustion processes.

The distributions of PCDD/Fs measured in surficial sediments from Newark Bay and the lower Passaic River were compared to those reported in various industrial process residues and effluents, contaminated soils, chemical formulations, and municipal waste disposal activities that are known or suspected to be sources of these compounds in aquatic environments in Wenning et al. (1993b). Pattern similarities and differences between congener groups and isomers were obtained by PCA. The congener and isomer fingerprint patterns found in surficial sediments appear to be the result of releases from several industrial and municipal sources commonly found in heavily industrialized and populated urban environments, including municipal sewer sludge, municipal solid waste incinerator fly ash, pentachlorophenol, sodium pentachlorophenate, newsprint, scrap metal reclamation incinerators, combustion engines, and pulp and paper mill black liquor recovery furnaces.

PVA and PCA were used to compare surficial sediment PCDD/F patterns from Newark Bay and the lower Passaic River to various known or suspected industrial, residential, and municipal sources of PCDD/Fs by Wenning et al. (1993c). The results of PCA modeling indicated that the congener and isomer fingerprint patterns in surficial sediments were similar to those found in municipal sewage sludge, municipal solid waste incinerator fly ash, pentachlorophenol, sodium pentachlorophenate, soils from scrap metal reclamation plants, combustion engines, and pulp and paper mill black liquor recovery furnaces. PVA modeling suggested at least four unique PCDD/F patterns in sediments, one of which closely resembled the PCDD/F fingerprint found in municipal sewage sludge.

Weston (1991) provides extensive chemical analyses of sediment/soil and surface water samples collected from three locations in the peripheral ditch at Newark International Airport. The peripheral ditch is connected to Newark Bay and acts as a source of sediment and contaminants to the Inventory Area. Samples were analyzed for inorganic chemicals, herbicides, PCBs, pesticides, petroleum hydrocarbons, SVOCs, and VOCs. No summary data were provided. This report contains six volumes of raw laboratory data, including chromatograms where applicable, for these samples. These six volumes are provided in electronic format in Appendix L – Contaminant Sources Data.

An environmental characterization of the Passaic River and its estuary was conducted by Wolfskill and McNutt (1998). This study included maps of the locations of facilities that may have contributed to chemical discharges in the estuary and facility locations for recipients of USEPA CERCLA information request letters. About 500 facilities that might have contributed Pb, 300 facilities that might have contributed Hg, and approximately 300 facilities that might have contributed PCDD to the estuary were identified. The locations of CSOs in the lower Passaic were also provided. The locations of CSOs in the Inventory Area are presented in Figure 3-21. Information on CSO and storm water discharges to the Passaic River exceeding national or New Jersey water quality criteria in 1997 are summarized below.

Analyte	Detection Frequency (%)	Exceedance Frequency (%)
As	64	64
Cu	82	82
Pb	45	45
Hg	18	18
Phosphorus	100	100
Total PCBs	100	9
2,3,7,8-TCDD	36	36

3.3.6.4 Summary of Available QA/QC for Contaminant Sources Studies

The sources studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. Available QA/QC information for each sources study from 1990–present is presented in Table 3-92.

3.3.7 Human Use

A variety of studies were identified pertaining to human use and/or human valuation of resources within the Inventory Area since 1990. Twenty-nine studies are summarized in Table 3-93 and are discussed in greater detail below. Sampling/surveying locations are presented in Figure 3-23, as appropriate. Raw data from these studies, as available, are presented in tables or in electronic format in Appendix M – Human Use Data. Twenty-two studies containing data/information published prior to 1990 related to the Inventory Area were also identified; these are briefly presented in Table 3-93.

Burger (2003) interviewed 240 people in the Newark Bay area (118 people), Manasquan Inlet (57 people), and Barnegat Bay (65 people), asking a series of questions about each interviewee and their perceptions of possible ecosystem management and restoration options. The Newark Bay survey area is presented in Figure 3-23. Survey participants were asked three open-ended questions: 1) what they considered the most important environmental problems in New Jersey; 2) how they used the estuary, and; 3) what improvements should be made. They were then asked to rate a list of environmental problems, possible uses of the estuary, and possible improvements on a scale of 1 (least important) to five (most important). Demographic information concerning the participants was also solicited. Nearly 90% of the people interviewed listed pollution as New Jersey's most important environmental problem. Most people (68%) used the habitat for outdoor sports, but rated communing with nature, walking, and the provision of open 'green' space as the most valued uses. Pollution prevention was the most often mentioned habitat improvement desired, and people rated removing pollution, cleaning up garbage, and creating more fish breeding habitat the highest. Demographic information provided by the respondents and statistics calculated based on that demographic information are provided in electronic format in Appendix M – Human Use Data. The average ratings of people in the Newark Bay area are presented below.

Use of Newark Bay for:	Average Rating[a]	Importance of Doing the Following:	Average Rating[a]
Commune with nature	3.63	Create more breeding fish habitat	3.83
For a place without people	3.52	Build (more) fishing piers	3.70
Bicycling along	3.01	Remove feral dogs/cats	3.52
Fishing	2.87	Build boardwalks	3.43
Finding and watching animals	2.72	Improve native vegetation	3.39
Crabbing	2.58	Improve habitats for birds	3.39
Boating	2.23	Better paths for walking	3.33
Sunbathing	2.07	Better paths for jogging	3.17
Collecting plants and herbs	1.41	Stock fish/crabs	2.82
Swimming	1.30	Keep natural-not mowed	2.43

Note:
a. Average rating on a scale of 1 to 5 with 1 being least important and 5 being most important to respondent.

Burger et al. (1999) examined fishing behavior, sources of information, perceptions, and compliance with fishing advisories as a function of ethnicity for people fishing in the Newark Bay area. The authors tested the null hypothesis that there were no ethnic differences in sources of information, perceptions of the safety of fish consumption, and compliance with advisories by interviewing 300 anglers in the Passaic River, Hackensack River, Newark Bay, Arthur Kill, and Kill Van Kull (Figure 3-23). Contingency tables were used to compare the responses to questions with the demographic data (using the following categories: ethnic (white, black, Hispanic, and Asian), education, and income. The authors report that there were ethnic differences in consumption rates, sources of information about fishing, knowledge about the safety of the fish, awareness of fishing advisories or of the correct advisories, and knowledge about risks for increased cancer and to unborn and young children. In general, the knowledge base was much lower for Hispanics, was intermediate for blacks, and was greatest for whites. When presented with a statement about the potential risks from eating fish, there were no differences in their willingness to stop eating fish or to encourage pregnant women to stop. According to the authors, these results indicate a willingness to comply with advisories regardless of ethnicity, but a vast difference in the base knowledge necessary to make informed risk decisions about the safety of fish and shellfish. A limited amount of raw data (i.e., demographic and income information) were provided in this study and are provided in electronic format in Appendix M – Human Use Data. The percent responding affirmatively to each question is summarized below (interpolated from bar graphs):

Race	Fish are Safe for Consumption	Fish Might Increase Cancer Risk	Fish Might Pose Risk to Unborn Child	Aware of Warnings Regarding Fish
Black	62%	36%	31%	60%
Hispanic	55%	25%	20%	37%
White	48%	48%	42%	70%

Conniff and Farlow (2001) provides a perspective on development in the Hackensack Meadowlands area interspersed with the opinions of local scientists, politicians, environmentalists, and residents in a National Geographic article filled with large photographs of the area and the people who live nearby. This article summarizes the conflicting views of development in the area, presenting a wide array of viewpoints. Information/viewpoints are presented as direct quotes from the individuals the author spoke with while researching this article. There are no data associated with this article.

Finley et al. (1997) conducted a risk assessment for PCBs associated with fish and crab consumption in the lower Passaic River. Fish and crab samples were collected from multiple locations in the River (as described in Section 3.2.4) and analyzed for Aroclors 1248, 1254, and 1260, and selected non-ortho, mono-ortho, di-ortho coplanar PCB congeners and selected non-coplanar congeners. Tissue concentrations were used to evaluate PCB risks using four different risk calculation methodologies. Increased cancer risk estimates associated with fish and crab consumption were obtaining using each calculation method and are summarized below. Raw data are provided (as Tierra, 1995a) in Appendix B – Newark Bay Study Area Analytical Database Version 1.0.

Risk Assessment Method	PCB Concentration (µg/kg) – Striped Bass	PCB Concentration (µg/kg) – Blue Crab Muscle	PCB Slope Factor (mg/kg-day)	Increased Cancer Risk – Striped Bass	Increased Cancer Risk – Blue Crab Muscle	Increased Cancer Risk – Total Risk
Aroclor	16.5[a]	16.5[a]	2.2	2.0×10^{-6}	5.6×10^{-7}	2.6×10^{-6}
Total PCBs	140[b]	56.7[c]	2.2	1.7×10^{-5}	1.9×10^{-6}	1.0×10^{-5}
PCB TEQ	0.071	0.016	1.56×10^{5}	6.1×10^{-4}	3.7×10^{-5}	6.5×10^{-4}
USEPA dioxin- and non-dioxin-like PCBs	39.5[d]	25.6[e]	2.2	4.8×10^{-6}	8.6×10^{-7}	6.6×10^{-4}

Notes:
a. Represents ½ the limit of detection of 33 µg/kg.
b. Represents sum of maximum detected concentration of each PCB congener measured in two striped bass samples (using ½ the limit of detection for nondetected congeners).
c. Represents 95th UCL of the arithmetic mean of the total PCB congeners measured in four blue crab muscle samples (using ½ the limit of detection for nondetected congeners).
d. Represents sum of maximum detected concentration of each di-ortho and noncoplanar PCB congener measured in two striped bass samples (using ½ the limit of detection for nondetected congeners).
e. Represents the 95th UCL of the arithmetic mean of the di-ortho and noncoplanar PCB congeners measured in four blue crab muscle samples (using ½ the limit of detection for nondetected congeners).

The New Jersey Conservation Foundation published a greenway plan for the Arthur Kill and its tributaries (Greiling, 1993), that describes land and water use in and surrounding Arthur Kill. At the time of the publication of the greenway report, approximately 690,000 people lived in 31 municipalities wholly or partially within the Arthur Kill watershed boundary, with an average density of 5,326 people per square mile. Industry withdraws the greatest amount of surface water in the watershed, and generally uses it for cooling, boiler feed makeup, and process water. Water is taken from the Rahway River basin through wells and river diversion to supplement the City of Rahway's potable water supply. The Elizabeth River and various watershed creeks are not considered suitable for public water supply due to salinity and pollution; however water companies draw water from local well fields. Both commercial and recreational navigational use of waterways occurs primarily in the Arthur Kill and the tributaries' lower reaches. Major ports are located along the Rahway River and the Arthur Kill. According to the report's author, "The volume of commercial shipping in the Arthur Kill is tremendous; it is one of the nation's most heavily used waterways." Land use information for the Arthur Kill watershed, summarized in the report, is presented below. No raw data are provided; most information provided is in the form of assertions without supporting primary literature.

Land Use	Total Acreage	Percentage
Residential	35,335	41.99%
Public/Semipublic	19,512	23.10%

Land Use	Total Acreage	Percentage
Transportation/Utilities	11,781	13.95%
Industrial	7,846	9.29%
Vacant	4,986	5.91%
Commercial	4,480	5.31%
Water	340	0.40%
Mixed Use	22	0.030%
Farm/Nursery	19	0.020%
Total	84,321	100%

Iannuzzi et al. (2002) contains a review of the environmental history of the lower Passaic River. This book summarizes available data and information regarding local inhabitants and their usage of the River, including commercial and recreational fishing/crabbing/shellfish collection, rowing, boating, and other recreational activities such as swimming. No raw data are provided.

ICF Technology (ICF, 1994) prepared a Community Relations Plan (CRP) for the lower 6 miles of the Passaic River portion of the Diamond Alkali Superfund Site. This document was as an update and modification of a 1987 CRP prepared by the NJDEP and a 1992 CRP prepared by the USEPA for the same site. The 1992 CRP was modified to add the lower 6 miles of the Passaic River to the NPL site. The area covered by the ICF (1994) CRP is presented in Figure 3-23. The CRP identifies key contacts in the community, describes concerns held by community members regarding the NPL site, and develops community relations activities to be conducted throughout the CERCLA process to address those concerns (ICF, 1994). There are no data provided in this report.

Johnson et al. (2000) conducted a telephone survey of 4,650 respondents from New Jersey and New York households located with 400 miles of the lower Passaic River. The survey obtained a useable sample of 706 complete interviews and was designed to determine which individuals have economic standing with respect to nonuse losses from natural resource injuries. Johnson et al. (2000) develop a conceptual model for determining compensable nonuse losses and apply the model to the results obtained from the survey. One proposition from their model indicates that only people who have knowledge of the injured resource (i.e., 10 to 44 percent of respondents) can incur a compensable nonuse loss. A second proposition from the model indicates that demand for information about an injury to a familiar resource is a necessary condition for compensable nonuse losses. The authors found that 81 percent of the respondents who were familiar with the lower Passaic River were likely to read, listen to, or watch a news story about the river. However, far fewer respondents familiar with the lower Passaic River were willing to engage in more active, and costly, information-acquisition activities (such as conducting research at the library and attending public meetings). Finally, the model suggests that geographic proximity to nondescript resources may affect nonuse values, information costs, or both, helping define the potentially affected population. The empirical results for the lower Passaic River support this third proposition. The authors therefore conclude that only a small fraction of the population in New Jersey and New York might reasonably experience a nonuse loss as a result of industrial water pollution in the lower Passaic River. The report summarizes the model input and output parameters. No raw data are provided.

May and Burger (1996) examined fishing behavior, fish consumption, and potential risk to anglers by interviewing 318 anglers and crabbers in the Arthur Kill, Raritan Bay, and New Jersey shore (Figure 3-23). Interviews were conducted in the Arthur Kill from mid-May to the end of September 1994. All anglers/crabbers present at a particular site were approached and most willingly participated in the survey, in which they were asked a series of questions about their fishing/crabbing and consumption habits, as well as their perception of risk from eating what they caught. The percentage of anglers/crabbers interviewed in Arthur Kill responding affirmatively to each question is summarized below. Raw data concerning knowledge of fish species/habitat and sources of information on fish consumption advisories from the publication is provided in electronic format in Appendix M – Human Use Data.

Questions	Affirmative Responses	
	Shore-based Anglers/Crabbers (n = 119)	Boat Angler/Crabbers (n = 49)
Is the water safe?	56%	90%
Are the fish safe to eat?	47%	94%
Heard any warnings about eating the fish here?	60%	61%
Do you eat your catch?	61%	94%

Additionally, a risk assessment for anglers and crabbers in the Arthur Kill, using an estimated fish/crab tissue concentration of 2 ppm PCBs and data from the fishing survey was performed (May and Burger, 1996). The daily consumption of PCBs estimated in this study is summarized below.

Scenario	PCBs Consumed[a] (µg/kg/day)
Fish – average consumption	1.5
Fish – worst case consumption	6.3
Crabs – average consumption	0.94

Scenario	PCBs Consumed[a] (µg/kg/day)
Crabs – worst case consumption	4.1

Note:
a. Assuming 70 kg body weight for human adult, and a concentration of 2ppm PCBs in edible fish and crab tissue.

Mysak and Schiffer (1997) provide an illustrated history of the PA NY/NJ, including a behind-the-scenes look at the stories and people who shaped the engineering activities in the NY/NJ Harbor area such as the construction of the major bridges, airports, tunnels, and the World Trade Center buildings. The book includes many color and black-and-white photographs of the area. No raw data are presented.

Five documents were identified dealing with fish and crab health advisories for New Jersey waters (NJDEP, 2002b,c; 2003a,b; NJDEP and NJDHSS, 1997). Each document provides fish and crab consumption advisories for the general population and high risk individuals by waterway and species, as well as health information, and preparation and cooking guidelines. The most recent consumption advisories (NJDEP, 2003a) that are applicable to the Inventory Area are summarized below. No raw data were provided.

Location	Species	General Population	High Risk Individuals
New Jersey Statewide	American eel	do not eat more than once a week	do not eat
	bluefish (over 6 lbs)	do not eat more than once a week	do not eat
	American lobster	Do not eat green glands	do not eat green glands
Newark Bay Complex[a]	striped bass	do not eat	do not eat
	American eel	do not eat more than once a week	do not eat
	blue crab	do not eat or harvest	do not eat or harvest
	bluefish (over 6 lbs), white perch, white catfish	do not eat more than once a week	do not eat
Passaic River and tributaries downstream of Dundee Dam	all fish and shellfish	do not eat	do not eat
	blue crab	do not eat or harvest	do not eat or harvest

Note:
a. This complex includes Newark Bay, Hackensack River downstream of Oradell Dam, Arthur Kill, Kill Van Kull, and tidal portions of all rivers and streams that feed into these water bodies.

In addition, an estimate of cancer risk to consumers of crab caught in the Newark Bay area from 2,3,7,8-TCDD TEQ is provided in NJDEP (2002c). This risk assessment was conducted using crab tissue data from Tierra

(1999d; 2000c; 2001a). These data are available in Appendix B – Newark Bay Study Area Analytical Database Version 1.0. In addition, the assessment uses the crab consumption data collected by Pflugh et al. (1999), which is summarized in a subsequent paragraph below. To conduct the assessment, NJDEP used standard USEPA human health risk assessment methods and assumptions. The exposure concentrations used for 2,3,7,8-TCDD ranged from 42 to 480 ppt. The estimated cancer risks based on average exposures ranged from 0.005 to 1.007 ($\times 10^0$). The estimated cancer risks based on maximum exposure scenarios ranged from 0.008 to 1.15 ($\times 10^0$). This report contains data regarding risk equations, exposure assumptions, and other data manipulations. It does not provide raw or original data. The report is provided in electronic format in Appendix M – Human Use Data.

The New Jersey Meadowlands Commission, formerly the HMDC, publishes a "Green Map" of the Meadowlands area on a regular basis (NJMC, 2002). The map shows ecological resources such as parks, bird migration routes, canoeing areas, landform/geological features, wildlife habitat, recreational opportunities, regional compost sites, etc. This map is provided in electronic format in Appendix M – Human Use Data.

The NY/NJ HEP (2002) provides a summary report regarding the health of the NY/NJ Harbor Estuary, and the relatedness of the health of the 20 million people that live in the areas surrounding the Estuary. This report is a summary of a variety of data and information that have been reported on in the previous sections of this Inventory Report. It discussed temporal trends in the Estuary health benchmark indicators and focuses primarily on contamination by sewage and industrial/municipal sources. The overall conclusion is that federal and state regulatory programs have resulted in an improvement in the health of the waterways that comprise the Estuary, and that concurrently, human health has been improved. This report does not provide raw or original data.

Olsen (1999) provides a maritime history of the Passaic River, Hackensack River, and Newark Bay. This publication includes information on the types of boats and ships used in these waterways, their role in commercial activities, historical land and water use information, and descriptions of community involvement in the waterways' usage and maintenance. This information is provided in a narrative format with citations to primary literature. No raw data are provided.

Pflugh et al. (1999) conducted a survey of Newark Bay area anglers' information sources and risk perceptions. The authors interviewed 300 anglers at 26 locations during the summer and early fall of 1995 (Figure 3-23). The objectives of the study were to learn urban anglers': 1) knowledge of fish consumption advisories; 2) belief in the advisories; 3) perception of how safe fish are to eat; 4) sources for information about fish and fishing, and; 5) sources for information on fish consumption advisories. The study concluded that while 60% of the surveyed anglers had heard about advisories, they either did not believe or were unconcerned about health effects from eating contaminated species (almost 50% said the fish that they caught in local waters were safe to eat). Only about 15% of the surveyed anglers knew the correct fish advisories. The most used source for information about fish and fishing was other anglers, while newspapers were selected as a source for information about community news, health, and food safety according to the study authors. Limited raw data are presented in the study, which is provided in electronic format in Appendix M – Human Use Data.

Proctor et al. (2002) reported on a survey conducted regarding the human use of the lower Passaic River. This survey was conducted in conjunction with the creel/angler survey that was conducted by TER (2001) and summarized by Finley et al. (2003). The objective was to collect information that could be used to build a conceptual site model for human exposure to chemical contaminants in the River. The survey was conducted by boat from November 2000 through July 2001 at a frequency of 8–17 days per month. Perceived human use activities were documented, as well as any noted human contacts with surface water, drain discharge, or sediment. Raw data are not presented in this report. The summary data that are presented are as follows. A total of 896 observations of human use of the River were made during the course of the investigation. About 98% of these were adults, and about 50% were located in River Front Park in the City of Newark. In addition, most of these observations were during the summer months. The breakdown of observed activities as reported by the authors are summarized below.

Perceived Activities	Percent of Observations
Standing away from shoreline	36
Boating	22.6
Living	18
Standing on the shoreline	13.5
Picking up trash	3.5
Washing clothes	1.6
Working	1.1
Surveying	1.0
Wading in water	0.94
Bathing	0.9
Putting water in container	0.7
Collecting water from drain pipe	0.28

There were 35 observations of contact with water; 83% of these were hand contact, and 26% were foot contact. There were also five observations of individuals collecting water or drinking from a drain pipe.

Sullivan (1998) provides personal insight and anecdotes, combined with factual information of an ecological, historical, and archaeological nature, in *The Meadowlands – Wilderness Adventures on the Edge of a City*. The book is a narrative description of the author's explorations of the area and does not contain any data.

Triangle Economic Research (TER) (2001) and Finley et al. (2003) report on a creel/angler survey that was conducted in 2000 and 2001 to provide site-specific information on recreational fishing in the lower 6 miles of the Passaic River (Figure 3-23). The TER (2001) data report focuses on the conduct of the survey, and includes the survey data and findings. The Finley et al. (2003) article focuses on the role of an expert panel in reviewing the survey, and the findings and recommendations of the expert panel. The authors conducted 57 individual angler interviews and prepared 27 missed creel reports. The species that were reported as being consumed consisted of carp, catfish, striped bass, white perch, and eel. No anglers reported that crabs that they caught and kept would be consumed. The report raw data and information for this survey are provided in electronic format in Appendix N – Human Use Data.

The USACE (1997c) produced its Final Design Memorandum on the Joseph G. Minish Passaic River Waterfront Park and Historic Area. The project entails developing a waterfront park along the west bank of the Passaic River between Bridge and Brill Streets in downtown Newark. The Minish Park project was authorized in the Water Resources Development Act of 1990 as an element of the Passaic River Flood Damage Reduction Project and has three phases. The first phase provides 6,000 ft of new bulkhead, 3,200 ft of restored riverbank, and wetlands creation. The second phase adds a 9,200-ft waterfront walkway and the third phase adds park facilities, plazas, and landscaping. The Minish Park project will also have links to the New Jersey Performing Arts Center, Riverbank Park Ironbound, and other Newark sites. The project will reduce flooding and erosion and provide environmental restoration, recreation, and economic development benefits. There are no environmental data presented in this report.

Von Stackelberg et al. (2002) developed a probabilistic conceptual model to attempt to evaluate the uncertainties and variabilities associated with estimating human health risks from trophic transfer of PCBs in dredge sediments. This was primarily an exercise in model evaluation. There is very little in the way of risk assessment results related to dredge materials. The authors' conclusions are that, given the substantial uncertainties and variabilities in the data for such a model, it would be more practical to collect fish tissue data to conduct a risk assessment for humans, as opposed to modeling from sediment through the food web to obtain risk estimates. The authors did not cite a specific source for the model input data that they used. No raw data are provided.

3.3.7.1 Summary of Available QA/QC for Human Use Studies

The human use studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. Available QA/QC information for each human use study from 1990–present is presented in Table 3-94.

3.3.8 Miscellaneous

This section includes an inventory of documents containing subject matter that is not included in other sections of the Inventory Report such as air quality, meteorology, and geology. These studies are described briefly in Table 3-95 and presented in Figures 3-24a and 3-24b, as applicable.

3.3.8.1 Air Quality

Twelve studies were identified that contain air quality measurements collected since 1990. These studies are summarized in greater detail below and the monitoring station locations are presented in Figures 3-24a and 3-24b. Seven studies pertaining to air quality in the Inventory Area conducted prior to 1990 are summarized briefly in Table 3-95.

The HMDC conducted an Environmental Impact Assessment for the Meadowlands Town Center (HMDC, 1992b). This document summarizes the results of a short-term monitoring program for carbon monoxide that was conducted over seven consecutive days in October 1991 at three locations (Figure 3-24b). These data are summarized below and raw data are provided in electronic format in Appendix N – Miscellaneous Data.

Sampling Location	1-hour Average Carbon Monoxide Concentration (ppm)	8-hour Average Carbon Monoxide Concentration (ppm)
Meadowlands Sports Complex	<0.1 – 4.3	<0.1 – 2.7
Empire Blvd./Washington Ave.	<0.1 – 3.8	<0.1 – 2.6
Commerce Blvd.	<0.1 – 4.0	<0.1 – 2.6

Note:
ppm = parts per million

The MERI is developing a network of 15 continuous, automated monitoring stations for weather, water quality, and air quality (MERI, 2004b). Presently, three stations are installed and operating, however, the air quality monitoring station has been taken offline. The location of the air quality sampling station is presented in Figure 3-24b. The data can be accessed at the following internet site:

http://cimic.rutgers.edu/hmdc_public/stations/stationsbody.html

The New Jersey Atmospheric Deposition Network was established in 1997 and is a collaborative effort of the NJDEP, the Hudson River Foundation, and Rutgers University (NJADN, 2004). Target chemicals/species are PCBs, PAHs, a suite of chlorinated pesticides, selected inorganic chemicals, Hg, and nitrogen. The research and monitoring network is established at the following sites: Rutgers/New Brunswick, Sandy Hook, the Liberty Science Center, Rutgers/Camden, the Pinelands Research Center, and Tuckerton. Additional sites were established in 1999 at Chester, Salem, and Washington Crossing. Air quality data are available by request at the following internet site:

http://www.cep.rutgers.edu/research/datasets/realtime/index.shtml

Some of the data collected between 1997 and 2000 has been published in Eisenreich (2000) and is summarized below. Additional data are available in Rutgers (2002), which is included in electronic format in Appendix N – Miscellaneous Data.

Sampling Location	Concentration of total PCBs (pg/m^3)
Jersey City	100 – 3,300
Over water near suburban areas	60 – 2,340
Over water near coastal areas	90 – 1,600
New Jersey Pinelands	45 – 550

The NJDEP Bureau of Air Monitoring provides yearly air quality reports that summarize the general air quality for the state, as well as air quality at some specific sampling locations (NJDEP, 2002a). These reports are available at the following internet site:

http://www.state.nj.us/dep/airmon/reports.htm

The most recently completed report is for 2001. The report provides information on the Air Quality Index, and concentrations of individual pollutants including carbon monoxide, Pb, nitrogen oxides, ozone, particulate matter, and sulfur dioxide. Data on acid precipitation, sulfates, nitrates, and other constituents of particulate matter, ozone precursors, and toxic air contaminants are also provided. In addition, current air quality readings are available at the following internet site (NJDEP, 2004b):

http://www.state.nj.us/dep/airmon/

Air monitoring stations are presented in Figure 3-24a.

Similar to the reports generated by the NJDEP Bureau of Air Monitoring, the NYSDEC Division of Air Resources also publishes annual air quality reports from a network of ambient air quality monitoring stations (NYSDEC, 2002a). Ambient air quality data (including ozone, sulfur dioxide, nitrogen oxides, carbon monoxide, Pb, and particulate matter) collected from 1996 through 2001 is available at the following internet site:

http://www.dec.state.ny.us/website/dar/reports/index.html

Summaries of VOCs data from 1990 through 1998 are also available on this internet site. Air monitoring stations within the Inventory Area are presented in Figure 3-24a. Near real time air monitoring data is available at the following internet site:

http://www.dec.state.ny.us/website/dar/bts/airmon/index.htm

New York State also maintains an acid rain monitoring network that collects and analyzes precipitation parameters such as pH, sulfate, nitrate, calcium, and magnesium (NYSDEC, 2002b; 2004b). Summary data from 1987 through 2001 from this network is available at the following internet site:

http://www.dec.state.ny.us/website/dar/baqs/acidrain/index.html

The USEPA conducted extensive air quality monitoring in the NY/NJ Harbor Estuary in response to the attacks on the World Trade Center on September 11, 2001 (USEPA, 2004). The sampling stations for this program are located primarily in Lower Manhattan, and thus are not presented in Figure 3-24a. The USEPA monitoring included analysis of air samples for: asbestos, benzene, inorganic chemicals, particulate matter, PCBs, PCDD/Fs, PAHs, and VOCs. These data are available in summarized format at the following internet site:

http://www.epa.gov/wtc/summary.html

Some of these data for PCDD/Fs have been presented in Chaky (2003).

3.3.8.2 Meteorology

The MERI is developing a network of 15 continuous, automated monitoring stations for weather, water quality, and air quality (MERI, 2004b). Presently, three stations are installed and operating; one of these stations measures meteorological data including: air temperature, relative humidity, solar radiation, rainfall, wind direction and speed, and barometric pressure. The location of this sampling station is presented in Figure 3-24b. The data are made available to the public and can be accessed at the following internet site:

http://cimic.rutgers.edu/hmdc_public/stations/stationsbody.html

Average values of the meteorological parameters on a yearly basis are presented below.

Year	Air Temperature (°C)	Relative Humidity (%)	Solar Radiation (Watts/m^3)	Rainfall (mm)	Wind Direction (Degrees)	Wind Speed (m/sec)	Barometric Pressure (mm Hg)
2001	12	65	160	0.016	189	2.6	703
2002	14	64	154	0.073	194	2.4	625
2003	7.5	65	122	0.078	134	3.0	627
2004	2.1	61	115	0.018	194	3.1	764

NOAA (2004) maintains the National Climatic Data Center which provides access to current and historical climate data (air temperature, precipitation) from the local to the national scale at the following internet site:

http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html

A weather station from this program is located at Newark International Airport (Figure 3-24a). NOAA also has created the NYOFS to provide the maritime community with improved short-term predictions of water level and currents in the PA NY/NJ (NOAA/NOS, 2004). The meteorological predictions are provided at the following internet site:

http://co-ops.nos.noaa.gov/nyports/nyports.html

There are three locations in the Inventory Area, including one each in Newark Bay, Arthur Kill, and Kill Van Kull.

3.3.8.3 Geology

No studies pertaining to the geology of the Inventory Area conducted since 1990 were identified. Six pre-1990 documents containing geological information are summarized briefly in Table 3-95.

3.3.8.4 Other Studies

NY/NJ HEP (1996) provides a summary of the comprehensive conservation and management plan for the NY/NJ HEP, including the Bight Restoration Plan. It includes a historical perspective on the state of the NY/NJ Harbor Estuary and the NY/NJ HEP, a description of the current status of the NY/NJ Harbor Estuary, and the plans for: habitat and living resources, toxics, dredged material management, pathogens, floatables, nutrients and organic enrichment, rainfall-induced discharges, and public involvement and education. Additionally the document describes steps for implementing this plan. No raw data is included in this summary document.

NY/NJ HEP (2004b) provides a comprehensive review of the state of the NY/NJ Harbor Estuary, including the Inventory Area. The report describes the conditions of habitats and key species, pollution and chemical contamination, pathogens, floatable debris, and nutrients and organic enrichment. The authors' summarize and discuss a number of datasets that have been presented in this Inventory Report. No raw data are presented. The report concludes with a summary of the trends of key indicators on the condition of the NY/NJ Harbor Estuary. The authors provide a list of available data and a description of future data needs.

Tierra (2003) provides a briefing-level executive summary of the findings to date of the RI/FS being conducted for the lower 6 miles of the Passaic River pursuant to the 1994 AOC. The report includes a description of the site setting/background, data collection activities, the Study Area database, RI report development, and preliminary data summaries/interpretations. The data presented in the Tierra (2003) report are presented within individual subsections of this Inventory Report; a copy of the Tierra (2003) report is presented in electronic format in Appendix N – Miscellaneous Data.

3.3.8.5 Summary of Available QA/QC for Miscellaneous Studies

The air quality, meteorology, and geology studies that are summarized above (i.e., 1990 to present) were examined for descriptions of the QA/QC procedures employed during the implementation of the study or its publication. No QA/QC information was provided.

3.4 Major Government Investigations in the Inventory Area

A summary of large-scale government investigation and initiatives for the NY/NJ Harbor Estuary, that include the Inventory Area, are listed and summarized in Tables 3-96a and 3-96b. The list includes programs/initiatives through which substantial environmental data and information (in the categories developed in this Inventory Report) have been collected, or are currently being collected, in the Inventory Area.

4. Conclusions

This Report includes those environmental data and information potentially relevant to the Inventory Area that were identified and obtained through April 30, 2004. The substantial amount of data and information summarized in Section 3 and provided in tables, figures, and appendices to this Report can be used to identify data gaps and to help design additional studies needed to be conducted under the RI for the Newark Bay Study Area pursuant to the AOC. An attempt has been made to identify, to the extent possible, additional data and information that have been collected to date, but that were not obtainable in time for inclusion in this Inventory Report. It is likely that data from additional studies, beyond those identified in this Report also are available or currently are being collected.

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