*FINAL*

# SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT REPORT

# for

## Newark Bay Study Area

**Submitted to**

**U.S. Environmental Protection Agency**
**Region 2**

**and**

**U.S. Army Corps of Engineers**
**Kansas City District**

**December 15, 2008**

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# EXECUTIVE SUMMARY

A Remedial Investigation/Feasibility Study (RI/FS) is being conducted within the Newark Bay Study Area (NBSA) to characterize the nature and extent of chemical contamination, develop and evaluate appropriate remedial options, and gather necessary information to select an appropriate remedy for the site. As part of this RI/FS process, a screening-level ecological risk assessment (SLERA), described in this report, was performed. The purpose of the SLERA is to evaluate the potential risks to ecological receptors that are exposed to contaminants of potential ecological concern (COPECs) in environmental media at the site and determine whether additional ecological evaluation is necessary.

This SLERA encompasses Steps 1 and 2 of the U.S. Environmental Protection Agency's (USEPA) eight-step guidance (USEPA, 1997). These steps include developing a conceptual site model (CSM), identifying COPECs, and performing a preliminary exposure assessment using conservative assumptions. Potential risk to ecological receptors was estimated by comparing maximum exposure concentrations to chemical-specific ecotoxicity threshold values to determine whether ecological threats are negligible or substantial enough to warrant continuing with the risk assessment process in a Baseline Ecological Risk Assessment (BERA).

The NBSA consists of Newark Bay and portions of the Hackensack River, the Arthur Kill, and the Kill Van Kull. Urbanization, the expansion of industry, and the release of chemicals into Newark Bay from both point and non-point sources have resulted in elevated levels of chemical contamination in sediments (National Oceanic and Atmospheric Administration [NOAA], 1998). The primary contaminants represent a variety of different contaminant classes, including, but not limited to, metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides/herbicides, and dioxins/furans.

Due to the large area involved, the NBSA was segmented into three regions: north, middle, and south. It is recognized, however, that each of the three regions contains various geomorphological features such as channels, subtidal flats, and intertidal flats that have distinct characteristics, water depth, and depositional rates. The SLERA examines potential exposures of ecological receptors to chemicals within each region using data from previous investigations. Within each of the three regions of the bay are three predominant habitat types: 1) intertidal areas, including the wetlands and mudflats; 2) shallow subtidal areas (1 to 20 feet); and 3) transitional slopes and navigational channels (> 20 feet). The intertidal and shallow subtidal areas are not regularly disturbed by dredging; therefore, there is a high potential for ecological receptors to be exposed to contaminants. Ecological receptors that may be exposed to contaminants in these areas include benthic invertebrates, fish, mammals, and birds. They may be exposed to contaminants via direct contact with, and/or ingestion of contaminated sediment, and by ingesting contaminants that have accumulated in prey tissue.

The maximum concentrations of chemicals in sediment and tissue (fish, benthic invertebrates, crabs, mollusks, and avian embryos) in each region were compared to ecological screening benchmarks to obtain a hazard quotient (HQ). Those chemicals with HQs greater than 1 were retained as COPECs to be further evaluated in a BERA. Ecological screening benchmarks were identified for each distinct environmental media (sediment and biological tissue) and for the relevant exposure pathways. The screening benchmarks for sediment were based on the lowest of various published benchmarks (e.g., New York State Department of Environmental Conservation [NYSDEC], New Jersey Department of Environmental Protection [NJDEP], USEPA). For those contaminants that are considered bioaccumulative (USEPA, 2000), wildlife protective concentration levels (PCLs) were calculated for

sediment and tissue. These wildlife PCLs are back-calculated sediment and tissue concentrations that are derived using conservative exposure assumptions so as to be protective of bioaccumulative hazards to upper trophic level receptors. In addition, a tissue screen was performed by comparing tissue contaminant concentrations with available literature-based critical body residue (CBR) values.

As a result of the screening process, many chemicals were identified as COPECs in sediment, fish tissue, mollusk tissue, crab tissue, and other benthic invertebrates. These include 13 metals plus various forms of mercury; one VOC (ethylbenzene); four non-PAH SVOCs; 25 individual PAHs as well as the sums of high molecular weight (HMW), low molecular weight (LMW), and total PAHs; five individual Aroclors plus total PCBs; 29 pesticides/herbicides as well as the sum concentration of seven compounds; and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) plus its toxic equivalents based on dioxin and dioxin-like PCB components.

There is a degree of uncertainty associated with the results of any SLERA. Several of the uncertainties associated with this SLERA include data limitations, the conservative assumptions of the screening level approach, uncertainties associated with toxicological benchmarks and laboratory data, uncertainties associated with the occurrence of the receptors of concern in the study area, and assumptions regarding the depth exposure for the biologically active zone (BAZ). Despite these uncertainties, the SLERA provides a path forward to further evaluate the identified COPECs in a BERA. Given the complexity and spatial scale of the NBSA, considerable additional information is necessary to develop more realistic estimates of ecological exposure and effects.

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## ACRONYMS

| | |
|---|---|
| AE | assessment endpoint |
| AOC | Administrative Order on Consent |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AVS | acid volatile sulfides |
| BAF | bioaccumulation factor |
| BBL | Blasland, Bouck & Lee, Inc. |
| BAZ | Biologically Active Zone |
| BEHP | bis(2-ethylhexyl)phthalate |
| BERA | baseline ecological risk assessment |
| BMF | biological magnification factor |
| BW | body weight |
| CARP | Contaminant Assessment and Reduction Program |
| CBR | critical body residue |
| CDF | confined disposal facility |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CERCLIS | Comprehensive Environmental Response, Compensation, and Liability Act Information System |
| CSM | conceptual site model |
| CSO | combined sewer overflow |
| COPEC | contaminant of potential ecological concern |
| DDD | dichlorodiphenyldichloroethane |
| DDE | dichlorodiphenyldichloroethylene |
| DDT | dichlorodiphenyltrichloroethane |
| DDx | Dichlorodiphenyltrichloroethane (DDT) and its derivatives |
| DNA | deoxyribonucleic acid |
| DOC | dissolved organic carbon |
| DQO | data quality objective |
| EPC | exposure point concentration |
| ERA | ecological risk assessment |
| ERAGS | Ecological Risk Assessment Guidance for Superfund |
| ERED | Environmental Residue Effects Database |
| ER-L | effects range-low |
| ER-M | effects range-median |
| g | gram |
| HMW | high molecular weight |
| HQ | hazard quotient |
| Kg | kilogram |
| LMS | Lawler, Matusky, and Skelly Engineers, Inc. |
| LMW | low molecular weight |
| LOAEL | lowest observed adverse effect level |
| LPRRP | Lower Passaic River Restoration Project |

| | |
|---|---|
| MATC | maximum allowable toxicant concentration |
| MDL | method detection limit |
| ME | measurement endpoint |
| mllw | mean lower low water |
| MMPA | Marine Mammal Protection Act |
| NBSA | Newark Bay Study Area |
| NCP | National Contingency Plan |
| NJDEP | New Jersey Department of Environmental Protection |
| NJDHSS | New Jersey Department of Health and Senior Services |
| NJPDES | New Jersey Pollutant Discharge Elimination System |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanographic and Atmospheric Administration |
| NOAEL | no observed adverse effect level |
| NPL | National Priorities List |
| NS&T | National Status and Trends |
| NYCRR | New York Code of Rules and Regulations |
| NYSDEC | New York State Department of Environmental Conservation |
| NYSDOH | New York State Department of Health |
| OCC | Occidental Chemical Corporation |
| OSWER | Office of Solid Waste and Emergency Response |
| PAHs | polycyclic aromatic hydrocarbons |
| PAR | Pathways Analysis Report |
| PAS | Princeton Aquatic Sciences |
| PCBs | polychlorinated biphenyls |
| PCL | protective concentration level |
| POTW | publicly-owned treatment works |
| ppb | parts per billion |
| PRP | potentially responsible party |
| QA | quality assurance |
| RI/FS | Remedial Investigation/Feasibility Study |
| RIWP | Remedial Investigation Work Plan |
| RM | river mile |
| ROC | receptor of concern |
| SARA | Superfund Amendments and Reauthorization Act |
| SEM | simultaneously extracted metals |
| SFF | site foraging frequency |
| SI | source identification |
| SLERA | screening-level ecological risk assessment |
| SPI | sediment profiling imaging |
| SSO | sanitary sewer overflow |
| SVOC | semivolatile organic compound |
| T&E | threatened and endangered |
| TCDD | tetrachlorodibenzo-*p*-dioxin |

| | |
|---|---|
| TEF | toxic equivalency factor |
| TEPH | total extractable petroleum hydrocarbons |
| TEQ | toxic equivalency quotient |
| THQ | target hazard quotient |
| TRV | toxicity reference value |
| µg | microgram |
| USACE | United States Army Corps of Engineers |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| VOC | volatile organic compound |
| WHO | World Health Organization |

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# 1.0 INTRODUCTION

## 1.1 Objective and Purpose

Pursuant to the Administrative Order on Consent (AOC) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Index No. CERCLA 02-2004-2010, issued in February 2004 by the United States Environmental Protection Agency (USEPA), a Remedial Investigation/Feasibility Study (RI/FS) is being conducted within the Newark Bay Study Area (NBSA), described as the water column and sediments of Newark Bay and portions of the Hackensack River, the Arthur Kill, and the Kill Van Kull (USEPA, 2004) (Figure 1). The purpose of the RI/FS is to characterize the nature and extent of chemical contamination, develop and evaluate appropriate remedial options, and gather necessary information to select an appropriate remedy for the site. As part of this RI/FS process, a screening-level ecological risk assessment (SLERA), described in this report, was performed for the NBSA to identify the potential for contaminants in environmental media to adversely affect ecological receptor populations.

The ecological risk assessment (ERA) process is conducted to evaluate potential ecological risks, following guidance from USEPA (1992, 1997). It is a tiered process that encompasses eight steps, as summarized in Figure 2. The SLERA encompasses Steps 1 and 2 of USEPA guidance. These steps include developing a conceptual site model (CSM), identifying contaminants of potential ecological concern (COPECs), and performing an exposure assessment using conservative assumptions. Potential risk to ecological receptors is estimated by comparing maximum exposure concentrations to chemical-specific ecotoxicity threshold values to determine whether ecological threats are negligible or if they are substantial enough to warrant continuing with the risk assessment process. If the process continues, a baseline ecological risk assessment (BERA), encompassing Steps 3 through 7 of the USEPA process, is conducted. The BERA uses the output from the SLERA, in concert with new data collection, to refine the problem formulation and further evaluate any COPECs that may adversely affect receptors of concern (ROCs). As the final step in the risk assessment process (Step 8), the findings from the risk assessment are used in the risk-management decision-making process according to the Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-28P *Issuance of Final Guidance, Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA, 1999) to determine if active risk reduction may be necessary.

Exposure and potential adverse effects are assessed for all endpoints defined in the CSM of the problem formulation step (Step 3) and are used to characterize risks to ecological receptors. Although the CSM is finalized in the BERA, a preliminary CSM of the ecological elements is provided as part of the SLERA. As the RI/FS process moves forward and more data become available, they are incorporated into the BERA.

The goal of this SLERA is to evaluate the potential risks to ecological receptors that are exposed to COPECs in environmental media within the NBSA. SLERA-specific objectives include the following:

- Describe the physical site conditions and ecological setting.
- Present the screening-level problem formulation.
- Conduct the COPEC screening process based on analytical results from previous investigations.
- Determine if there are area(s) that may pose unacceptable ecological risks and require further evaluation in a BERA.
- Identify major sources of uncertainty associated with the screening level risk estimates.

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**Figure 1. The Newark Bay Study Area and Regional Features (Tierra, 2006a)**

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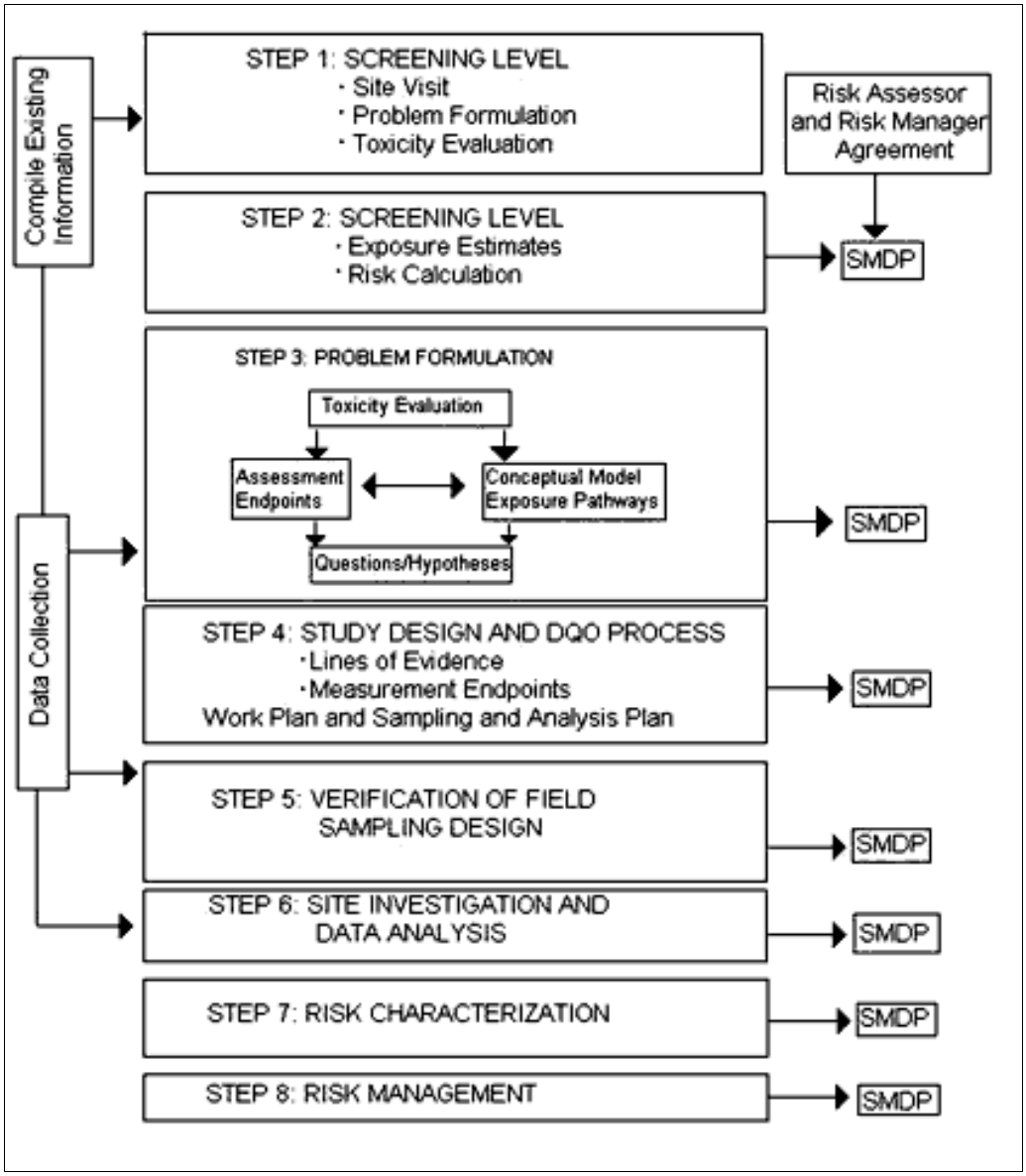


SMDP = scientific/management decision point.
DQO = data quality objective.

**Figure 2. USEPA's Eight-Step Ecological Risk Assessment Process (USEPA, 1997)**

## 1.2 Report Organization

The SLERA report is organized as follows:

Section 1.0: Introduction. This section presents an overview of the SLERA process.

Section 2.0: Site Description and History. This section provides a site description, including the biological setting, and reviews historical information from previous investigations.

Section 3.0: Screening-Level Problem Formulation. This section includes the CSM, known and suspected sources of chemical contaminants, contaminant fate and transport mechanisms, exposure pathways, and ecological receptors of concern.

Section 4.0: Screening-Level Effects Evaluation and Exposure Estimate. This section describes the contaminant concentrations in each environmental medium and the ecotoxicity threshold that is indicative of potential ecological effects. These elements are combined in the COPEC screening process to characterize the magnitude of exposures.

Section 5.0: Screening-Level Risk Characterization. This section presents the estimates of potential risks to the ecological receptors for each of the COPECs.

Section 6.0: Uncertainty Analysis. This section discusses the uncertainties associated with the screening level risk estimates.

Section 7.0: SLERA Conclusions and Recommendations.

Section 8.0: References.

## 1.3 Regulatory Framework

The NBSA RI/FS is being conducted by USEPA to address the presence of chemical stressors in Newark Bay. These chemicals were directly released to or transported into Newark Bay from various sources, including groundwater, non-point sources, point sources, and tributaries. The RI/FS is being conducted pursuant to CERCLA, the National Contingency Plan (NCP), and the Superfund Amendments and Reauthorization Act of 1986 (SARA). The work is proceeding under an AOC with one of the potentially responsible parties (PRP), Occidental Chemical Corporation (OCC). Tierra Solutions, Inc. (Tierra) is performing the RI/FS on behalf of OCC.

As a preliminary step in the RI/FS process, a Remedial Investigation Work Plan (RIWP) was prepared by Tierra (2004; 2005). Data were collected (Tierra, 2005), and a Phase II RIWP was subsequently prepared (Tierra, 2006a) with data collected in the fall of 2007. Results from this SLERA will aid and direct subsequent sampling programs intended to support a BERA, if necessary. The overall goals of the risk assessments are to identify areas posing the greatest potential for risks to human health and/or ecological receptors, and develop remedial action objectives in support of the FS.

## 1.4 SLERA Approach

This SLERA builds on information presented in the Pathways Analysis Report (PAR) (Battelle, 2006), which included preliminary elements of the SLERA, such as suggested receptors and pathways of concern. The PAR was written as a scoping document that allowed an opportunity for stakeholders to provide their input early in the risk assessment process. The SLERA is conducted using these inputs along with existing chemical data from the NBSA to evaluate the potential for adverse effects to ecological receptors from exposure to contaminants. These adverse effects may result from exposure to contaminants in sediments or from the ingestion of contaminated prey. This SLERA is written utilizing data available through 2005. Because the NBSA is a dynamic system, with ongoing anthropogenic activities, data are continually being collected from the area. Additional data collected after 2005 will need to be included in any future risk assessment work (*i.e.*, a BERA).

The SLERA focuses on three habitat types within the bay:

1. Intertidal areas, including wetlands (only those physically connected to the bay) and mudflat habitats.
2. Shallow subtidal areas (1 to 20 feet), which extend from the intertidal areas to the transitional zones or slopes associated with the navigational channels.
3. Navigational channels, which comprise the transitional zones and the dredged channels.

These areas are discussed further in Section 2.3. To evaluate the potential risks to receptors associated with these habitat areas, the first two steps of the eight-step process described in USEPA's *Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997) were followed (Figure 2).

This SLERA describes the screening process to identify COPECs based on available data from the site, literature studies, the fate and transport of those COPECs, ROCs, exposure pathways, and assessment and measurement endpoints. If necessary, additional studies will provide the data necessary to resolve spatial and temporal data gaps in the current data set for contaminant levels in the NBSA. Contaminants that do not occur at concentrations that have a potential to cause adverse effects to ecological populations are screened out in this SLERA. Contaminants that are determined to occur at sufficient concentrations to present a potential for unacceptable risks are further evaluated in a BERA. Following input from stakeholders and other involved parties, the BERA will expand on particular ecological concerns at the site. In accordance with USEPA guidance, conservative assumptions are used in this SLERA (USEPA, 1997), whereas more realistic, site-specific assumptions are considered in the BERA.

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# 2.0 SITE DESCRIPTION AND HISTORY

## 2.1 Site Description

The AOC defines the NBSA as "Newark Bay and portions of the Hackensack River, the Arthur Kill and the Kill Van Kull" (USEPA, 2004). Newark Bay itself is part of the New York/New Jersey Harbor Estuary and is located south of the convergence of the Passaic and Hackensack Rivers. To the west are the New Jersey cities of Newark and Elizabeth; to the east are the New Jersey cities of Jersey City and Bayonne; and Staten Island, New York is to the south (Tierra, 2006a). Newark Bay is approximately 6 miles long and 1 mile wide. It is linked to Upper New York Bay by the Kill Van Kull and to Raritan Bay by the Arthur Kill (Figure 1). The upper boundaries of the NBSA include the downstream boundary of the Lower Passaic River Restoration Project (LPRRP) and the Conrail Bridge in the Hackensack River. The lower boundaries (determined for the Phase I and II RIWP) consist of the Bayonne Bridge in the Kill Van Kull and the Goethals Bridge in the Arthur Kill (Tierra, 2006a) (Figure 1).

## 2.2 Physical Setting

The two major rivers that drain into Newark Bay are the Passaic and Hackensack Rivers. The Passaic River drains a 935-square-mile watershed, encompassing 10 counties from northeastern New Jersey and southeastern New York (HydroQual, 2005). The Hackensack River spans 32 miles from New York to Newark Bay and drains 185 square miles. Each of these rivers has a downstream confluence with Newark Bay, which is connected to Upper New York Bay by the Kill Van Kull and to Raritan Bay by the Arthur Kill. The Kill Van Kull is located along the north side of Staten Island and the Arthur Kill extends along the western side of Staten Island, with both waterways forming the boundary between the States of New York and New Jersey. Together, Newark Bay, its tributaries, and associated wetlands, are one of the world's largest urbanized and industrialized estuarine systems (Gunster *et al.*, 1993a).

Land use in the Newark Bay area has been primarily urban, consisting of a mix of residential, commercial, and industrial uses. During the 1700s, the City of Newark was recognized as a leading manufacturer of leather goods, carriages, and iron and brass products (Urquhart, 1913). Following World War II, Newark became a leading transportation center that included a highly developed infrastructure of highway, railway, and marine services. On the western shore of Newark Bay lies Port Newark, which is part of the port system maintained by the Port Authority of New York and New Jersey. This is one of the nation's largest and busiest ports for containerized cargo, petroleum products, and various hazardous cargo. Both the eastern and western banks of Newark Bay are dominated by numerous active and abandoned commercial and industrial properties. The banks of Newark Bay are extensively developed and consist of miles of hardened, paved shoreline. A highly developed network of combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), and publicly owned treatment works (POTWs) also exists throughout the study area (Mueller *et al.*, 1982).

## 2.3 Geomorphic Areas

Numerous distinct geomorphic features of Newark Bay are characterized based on water depth, shoreline modifications, and areas affected by dredging and filling. The dominant features are the federal navigation channels and the broad subtidal flats between the navigation channels and the shoreline. Transitional slopes occur between the channels and the subtidal flats. According to the Phase II RIWP Sediment Sampling and Source Identification (SI) Program Report (Tierra, 2006a), the navigational channels (including the port channels) occupy 30% of the study area and the subtidal flats occupy 52% of the study area. Intertidal areas are frequently exposed during low tide and occur in small, localized areas around the bay. Other important features of Newark Bay include extensively developed waterfronts with piers and shipping facilities, as well as the confined disposal facility (CDF) near Port Newark.

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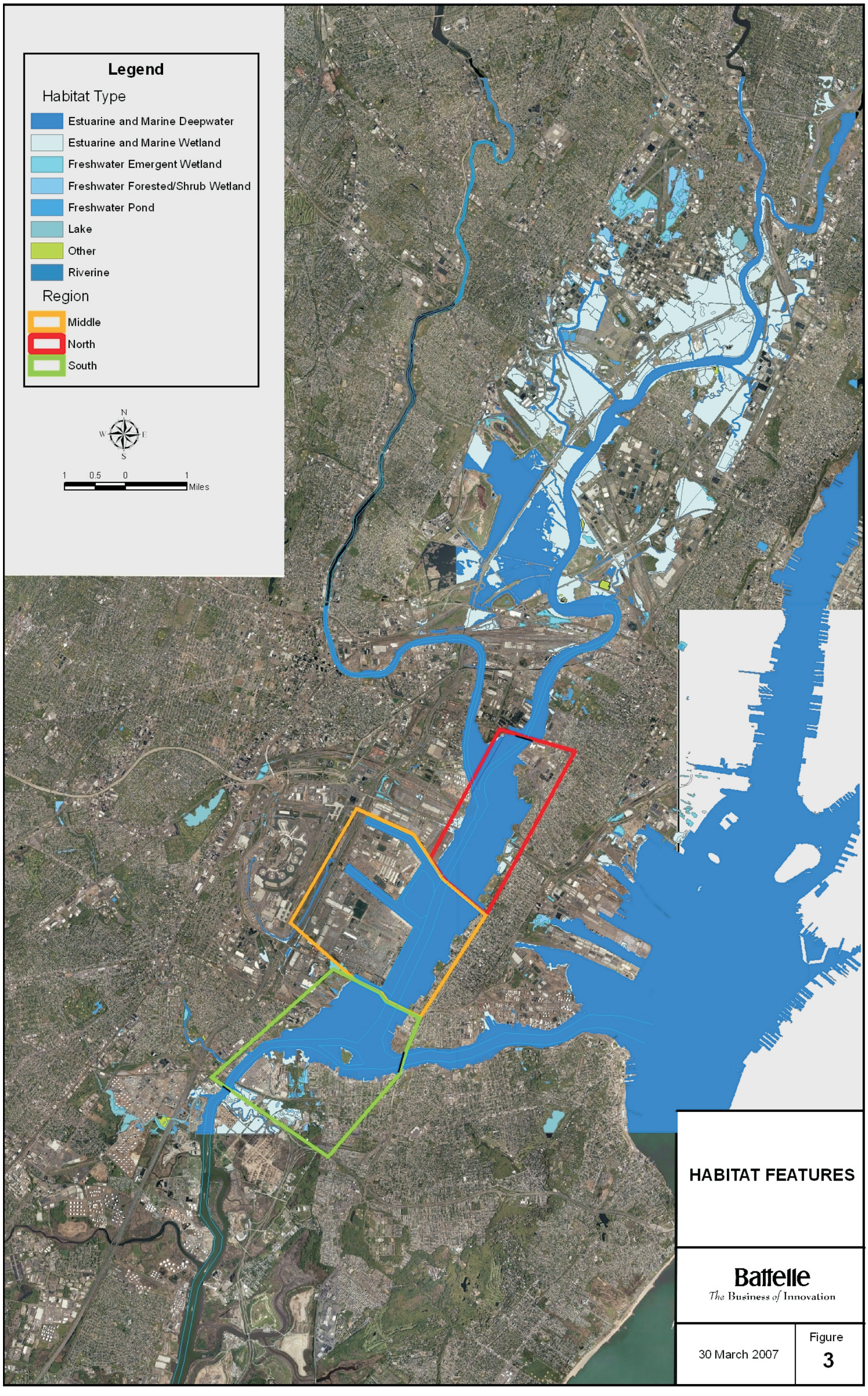
Legend
Habitat Type
Estuarine and Marine Deepwater
Estuarine and Marine Wetland
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Lake
Other
Riverine
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For the purposes of the SLERA, the NBSA was segmented into three regions. The three regions, identified as south, middle, and north, are illustrated in Figure 3. The channels that pass through each region are clearly depositional in most areas (Tierra, 2006a). The south and north regions consist mostly of shallow subtidal shoal areas that are primarily characterized as minimally depositional or non-depositional. The middle region consists mostly of navigational channels (depositional areas) and a shallow area located on the eastern side that is characterized as moderately depositional. The SLERA examines potential exposures of ecological receptors to chemicals within each region.

Extensive shoreline filling has had an impact on the sedimentation and circulation patterns within Newark Bay. For instance, Suszkowski (1978) concluded that the transition of the southwestern portion of the bay over time from erosional to depositional is significant. The greatest amount of filling occurred prior to 1934; however, a substantial amount of shoreline was also filled between 1934 and 1976 (Tierra, 2006a). Suszkowski (1978) compared National Oceanic and Atmospheric Administration (NOAA) bathymetric charts and reported a 20% reduction in the area of Newark Bay between 1855 and 1976 and noted that until 1969, over 75% of dredged material taken from the bay was deposited in adjacent upland areas as fill for use in coastline development. The western shoreline of the Port Newark area and northward appears to have had the most extensive filling (U.S. Army Corps of Engineers [USACE], 2005). Dredged material removed during bay deepening was used for nearshore fill, which may have resulted in some of the historical contamination being placed in the coastline (Tierra, 2006a). All of these activities have changed sediment transport within the bay. Furthermore, groundwater discharge through the historically contaminated dredged fill material may be a pathway for remobilization of contaminants into the bay (Tierra, 2006a).

### 2.3.1 Navigation Channels/Port Channels

To maintain the status of Newark Bay and its tributaries as one of the largest commercial ports in the nation, USACE has conducted extensive dredging operations since the 1930s to accommodate the expanding fleet of cargo vessels. Dredging operations are conducted to ensure maneuverability of the increasingly larger ships entering the bay and port system. As mentioned in the previous section, dredged material has historically been used to fill in coastal areas, potentially resulting in the relocation of historical contaminants from navigational channels and waterways to the shoreline or areas outside the navigational channels (Suszkowski, 1978; Tierra, 2006a).

Maintenance dredging of the navigational channels and harbor-deepening projects is currently ongoing throughout the bay. Figure 4 presents a history of both of these dredging activities. Although significant dredging activities have occurred since the time this evaluation was performed, these activities are not considered in this risk assessment but will need to be considered in any future updates. Furthermore, several of the dates listed in Figure 4 reflect maintenance dredging work which, although presented as covering the entire channel length, actually only includes smaller shoal areas within the channels. Figure 5 presents a map of the New York/New Jersey Harbor Deepening Project. The navigation channels shown in these areas have been dredged, are in the process of being dredged, or are scheduled to be dredged to a depth of 50 feet; these operations are expected to continue through 2013.

The navigation channels are unique from the rest of the bay in that, because of deeper water depths, they are not subject to wind-wave resuspension and they accumulate sediments resuspended from the subtidal flats (Suszkowski, 1978). Tierra (2006a) noted that in most areas, the channels have a much higher depositional rate than the rest of the bay. USACE reported a rate of 2 to 10 inches per year (approximately 50 to 250 millimeters per year) in the channel (USACE, 1986). Two other studies (NOAA, 1984; Suszkowski, 1978) reported a rate of 1 to 3 millimeters per year in the subtidal flats. In addition, higher salinities are found in the channels. Consequently, they represent a different habitat than

the rest of the bay (Suszkowski, 1978). Other shoal areas were once historical channels, turning basins, and borrow pits that have accumulated thick beds of legacy sediments due to limited maintenance dredging or abandonment (USACE, 2006).

USACE has identified 11 major navigation channel reaches in Newark Bay (Figure 1); from south to north, these are as follows:

- Gulfport Reach.
- Elizabethport Reach.
- North of Shooters Island Reach.
- South of Shooters Island Reach.
- Bergen Point West Reach.
- Newark Bay South Reach.
- Newark Bay Middle Reach.
- Newark Bay North Reach.
- Turning Basin.
- Kearny Point Reach.
- Droyers Point Reach.

In addition to the 11 reaches, Newark Bay also has three main port channels that are regularly dredged for maintenance: Port Newark Channel, Elizabeth Channel, and South Elizabeth Channel. There is no active maintenance dredging of the channel south of Shooters Island and north of Port Newark. The timing of the various dredging operations in recent years can potentially impact the usability of certain sediment data sets for characterizing sediment contamination in the bay and assessing risks. Sediment samples collected in areas that were subsequently dredged or will be dredged in the upcoming year are not relevant for assessing environmental exposures.

Transitional slopes occur between the deeper dredged channels and the subtidal flats. These slopes cover about 8% of the bay area (Tierra, 2006a). These areas may have been created by cutbacks during dredging, slumping of subtidal flats into the dredged channels, erosion, or some combination of these processes. These areas may act as sediment sinks and storage areas, with periodic resuspension of sediments occurring in response to wind, waves, and tidal currents (Tierra, 2005). Boat traffic could also lead to resuspension of sediments on the transitional slopes. Severe weather events, along with disturbances from waves or propeller wash from passing vessels, could potentially result in the redistribution of sediment from the transitional slopes into the navigation channels/port channels (Tierra, 2006a).

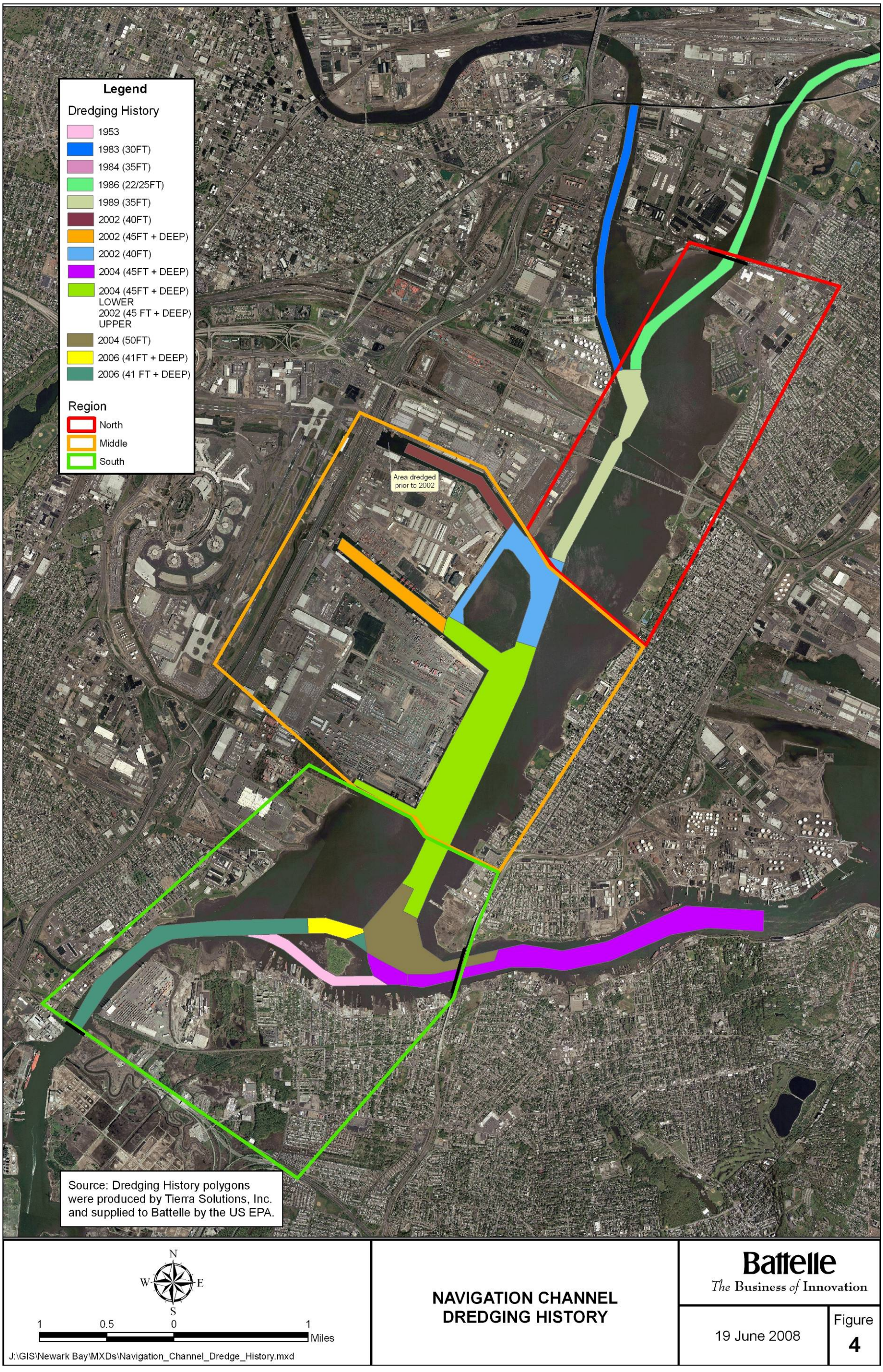


**Figure 4. Navigation Channel Dredging History**

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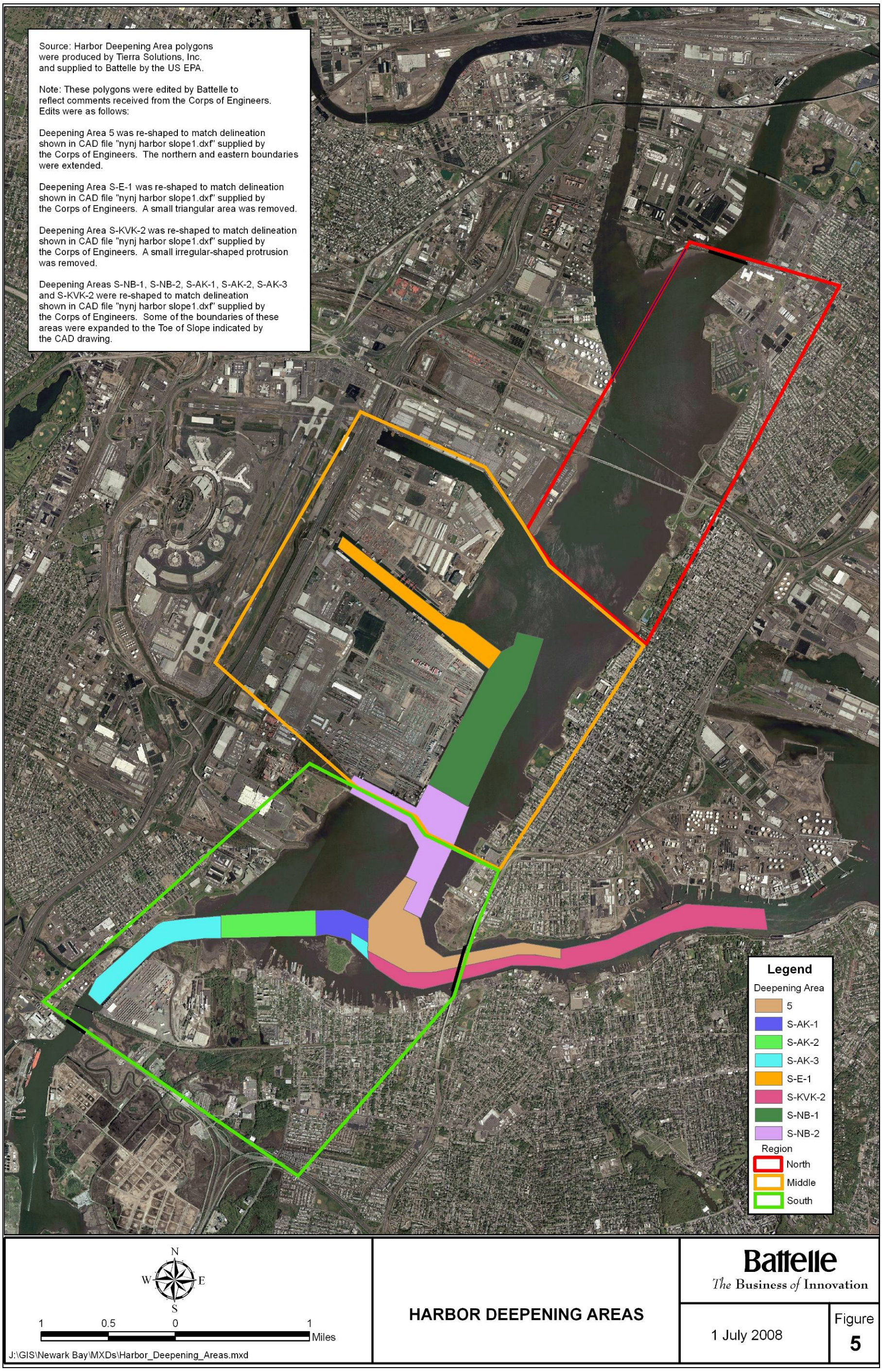


**Figure 5. Harbor Deepening Areas**

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### 2.3.2 Subtidal Flats

The broad, shallow subtidal flats located outside of the navigation channels cover the majority of Newark Bay (approximately 52% [Tierra, 2006a]). Water depths range from between 1 to 20 feet below mean lower low water (MLLW) (NOAA, 1997; 2002). These areas are characterized by relatively low sedimentation rates, relatively high bed stability, and limited mixing of buried sediments by resuspension (Tierra, 2005). It is unknown whether ice scouring periodically alters the sediment surface of the subtidal flats.

### 2.3.3 Intertidal Areas

Intertidal areas in the bay consist mostly of mudflats; however, some wetlands still remain. Most of the wetlands historically present around the fringes of Newark Bay have been filled as a result of development in the area. The small intertidal areas that remain (approximately 2% of the bay [Tierra, 2006a]) are normally exposed during low tide. It is unknown whether ice scouring periodically alters the sediment surface of these exposed areas, although it may be likely.

## 2.4 Hydrology

Newark Bay is a density-stratified estuary with the dominant freshwater contributions originating from the Passaic and Hackensack Rivers at the north end of the bay and the dominant saltwater contributions originating from tidal exchanges at its southern end through the Arthur Kill and Kill Van Kull. The tidal circulation patterns and influence of wind-driven episodic events, shipping traffic, and dredging activities play a role in the transport of sediments and contaminants within the Bay. The Hackensack River appears to be a sink for suspended sediment and contaminants from the Passaic River and Newark Bay due to estuarine circulation (Pence, 2004). The Arthur Kill and Kill Van Kull appear to be sediment sources to Newark Bay (Suszkowski, 1978; Styles *et al*., 2001; Hunter *et al*., 2002). The flow and circulation patterns within the bay, both long-term cycles and episodic events, impact the transport, deposition, and erosion of sediments by re-suspending sediments and associated contaminants and redistributing them. Suszkowski (1978) indicates that the Kill Van Kull is the largest contributor of inorganic sediment (46%) to Newark Bay, while the Passaic River contributes only 9% of suspended inorganic sediments. The Passaic and Hackensack Rivers, however, are the largest sources of freshwater flow to Newark Bay.

## 2.5 Ecological Setting

Increased urbanization and shoreline alteration have contributed to extensive habitat loss and degradation, which has greatly reduced the functional and structural integrity of ecosystems within the NBSA. Despite the impacts of urbanization on the bay, existing historical data indicate that the NBSA supports a variety of vegetation, fish, and wildlife species (Tierra, 2006a). Historical surveys and literature indicate that biological organisms are fairly abundant in Newark Bay, but species diversity is generally limited. An overview of the ecological setting of Newark Bay and adjacent waterbodies is presented in the following sections.

### 2.5.1 Benthic Invertebrates

Macroinvertebrate faunal studies suggest that the benthic invertebrate communities in Newark Bay and adjacent waterbodies have been influenced by the urban and industrial nature of the surrounding area (Tierra, 2004; Adams and Benyi, 2003; Adams *et al.*, 1998). In general, the species composition, diversity, and abundance are characteristic of a degraded estuarine environment. Overall, organism abundance is moderate and species diversity is low. The benthic invertebrate taxa are dominated by generalist and pollution-indicative species that can tolerate environmentally stressful conditions such as low dissolved oxygen. Studies conducted in the NBSA indicate that the invertebrate community is

dominated by polychaete worms (*e.g.*, *Streblospio benedicti*, *Sabellaria vulgaris*, *Scoloplos* sp.), bivalves (*e.g.*, *Mya lateralis* and *M. arenaria*), oligochaetes, and nematode worms (Lawler, Matusky, and Skelly Engineers, Inc. [LMS], 1996, as cited in USACE, 1997). The polychaetes, S. *benedicti* and *Scoloplos* sp., and the soft-shelled clam, *M. arenaria*, often represent over 25% of the total benthic infaunal abundance. Benthic infaunal abundance and species composition increase in the late winter and early spring months and decline in the summer (LMS, 1996, as cited in USACE, 1997). The combination of stressors and controlling factors influencing these seasonal patterns has not been examined sufficiently to differentiate among the possible causes.

Large invertebrates present in the channels and shoals of Newark Bay include crabs (blue, horseshoe, spider, American rock, and lady), soft clams, longfin squid, and shrimp (NOAA, 1994). Blue crab (*Callinectes sapidus*) was the predominant species collected at the channel stations and is present year-round. Blue crabs at shallow water stations appear to be more abundant in the summer and fall (May to November) and are nearly absent during the other months when they migrate into the deeper channels or off-shore (NOAA, 1994; LMS, 1996, as cited in USACE, 1997).

Benthic infauna and epibenthic species are used as a food source by many other species found in the NBSA, including fish, waterfowl, wading birds, and humans. The New York State Department of Health (NYSDOH), New Jersey Department of Environmental Protection (NJDEP), and New Jersey Department of Health and Senior Services (NJDHSS) have prohibited the harvesting, selling, or consumption of blue crabs caught in Newark Bay, the tidal Passaic River, the tidal Hackensack River, the Arthur Kill, the Kill Van Kull, and their tidal tributaries (NYSDOH, 2006; NJDEP and NJDHSS, 2006). These restrictions were issued based on high concentrations of polychlorinated biphenyls (PCBs), cadmium, and dioxin in blue crabs from these areas.

### 2.5.2 Fish

Fish communities in the NBSA consist of a mixture of marine, estuarine, and anadromous species (Woodhead, 1991). These communities are numerically dominated by a limited number of species, both resident and migratory (USACE, 1997). Several studies identified resident species that may potentially exist throughout the bay as including the mummichog, Atlantic silverside, and bluegill (Princeton Aquatic Sciences [PAS], 1982; USACE, 1987; ChemRisk, 1995a, 1995b). Historically, the most common migratory species observed were the striped bass, blue fish, winter flounder, and American eel (U.S. Fish and Wildlife Service [USFWS], 1981; USACE, 1987; NOAA, 1994). A variety of fish species use the shoal areas of Newark Bay as nursery habitat, as migration corridors, and for feeding and spawning (USACE, 1997). Fish use these shallow water areas from late spring through fall but are present year-round in the deeper navigation channels.

A total of 16 studies, which included characterizations of the fish and crustacean communities associated with Newark Bay and adjacent water bodies, were compiled and reviewed by Tierra (2004). This SLERA does not attempt to reconcile variations in sampling methods, timing, or design as a means of combining or normalizing the various data sets. Simple presence of species, collected in whichever manner proved effective, forms the basis for projecting habitat use. Nonetheless, it is interesting to note the range of biota sampling results reported.

As part of a monthly sampling program conducted in 1995 and 1996, LMS collected a total of 25 species of fish with a bottom trawl from four shoal areas in Newark Bay and a single station each in the Kill Van Kull and Arthur Kill (LMS, 1996). Twenty-three fish species were collected from the shoal areas, with bay anchovy (44-91%) being the predominant species. Atlantic silverside, blue fish, striped bass, and winter flounder accounted for 2% or more of the total number collected during each survey. Trawl catches were abundant from May through October and were low or zero from November through April.

A NOAA study conducted in 1993 and 1994 collected fish and crustaceans at 17 locations in Newark Bay (ten channel and seven shallow water trawls and gillnets). Striped bass, Atlantic tomcod, and blue crab were the most abundant animals collected from the channel trawls. Bay anchovy, Atlantic herring, and Atlantic tomcod were the most abundant animals collected from the shallow water trawl samples (NOAA, 1994). Fish were abundant year-round at the channel stations, but were abundant from May to October on the shoals.

The USACE conducted monthly fish surveys between October 1998 and September 1999 throughout the New York/New Jersey Harbor Estuary. Three stations were located in Newark Bay, two stations were located in the Arthur Kill, and one station was located in the Kill Van Kull (USACE, 1999). A total of 39 species of fish were identified in the survey. The USACE also conducted a number of fish surveys between 2001 and 2003 at eight locations within Newark Bay (five channel and three shallow water stations); these surveys resulted in the collection of 47 species of fish (USACE, 2003a; 2003b; 2003c).

Duffy-Anderson *et al.* (2003) summarized ichthyological studies conducted near man-made structures in the Arthur Kill and Kill Van Kull and also collected a total of 25 fish species, of which silver perch and naked goby were the most abundant. These two species were also present in substantial numbers during the 1993-1994 ichthyoplankton sampling (NOAA, 1994). The results of that survey indicate that both species spawn within Newark Bay, whereas the other species identified in that survey spawn elsewhere, and their larvae are transported by currents into the bay.

The NYSDOH, NJDEP, and NJDHSS have issued health advisories for eating fish caught in the NBSA, including Newark Bay, the tidal Passaic River, the tidal Hackensack River, the Arthur Kill, the Kill Van Kull, and their tidal tributaries (NYSDOH, 2006, NJDEP and NJDHSS, 2006). Fish species affected include striped bass, American eel, white perch, white catfish, gizzard shad, Atlantic needlefish, bluefish, and rainbow smelt. These advisories were issued based on high concentrations of PCBs and dioxin in these fish species.

### 2.5.3 Birds

The NBSA provides a variety of discontinuous habitats for wading birds, gulls, and waterfowl. The extent of high-quality nesting and foraging areas is limited throughout the NBSA (USACE, 1997; Blasland, Bouck, and Lee, Inc. [BBL], 2002). It is important to note the regionally important rookery habitat on Shooters Island, located at the southern end of Newark Bay, where a significant percentage of the entire New York breeding population of certain wading birds is present. Most of the avian species observed are migratory and have limited breeding activity in the NBSA. However, they do use the area for foraging and a few species use the area for nesting habitat, as well. Food sources in the area include bivalves, benthic worms, crabs, shrimp, and small fish.

A total of 48 avian species (including 28 shorebirds and piscivorous species) were observed from autumn 1999 through spring 2000 along the lower reach of the Passaic River during a four-season avian survey conducted by Tierra (BBL, 2002). Although the majority of aquatic birds observed in the survey were gulls (great black-backed, herring, laughing, and ring-billed), other commonly observed species included wading birds (egrets and herons), pelicanoformes (double-crested cormorants), shorebirds (killdeer, sandpiper, and yellowlegs), osprey, geese, and ducks. The numbers of these latter species were typically greater in spring and summer, as might be expected from their seasonal migratory distribution.

Osprey, northern harriers, and red-tailed hawks are raptors that have nearby nesting areas and are likely to forage in the NBSA (USACE, 1997). Other raptors that may have nearby nesting areas and may forage in the NBSA include falcons (American kestrel and peregrine), hawks (sharp-shinned, Cooper's, red-shouldered, and broad-winged), bald eagles, and merlins.

### 2.5.4 Mammals

It is relatively unlikely that cetaceans (whales, dolphins, porpoises) would enter the NBSA, although some species of pinnipeds (seals) could possibly be present at any time during the year (USACE, 1997). For example, the harbor seal and harbor porpoise have been noted as visitors to Newark Bay (Schoelkopf, pers. commun., 1996 as cited in USACE, 1997).

Previous ecological surveys conducted by USACE (1987) and ChemRisk (1995a) reported that terrestrial mammal species observed along the Lower Passaic River were limited to human-tolerant species commonly found in urban environments, including raccoon, eastern gray squirrel, eastern cottontail rabbit, and opossum (ChemRisk, 1995c). It is not clear, however, whether this characterization is reflective of current conditions or how applicable it is to the NBSA.

### 2.5.5 Reptiles

The northern diamondback terrapin has been reported in the Hackensack Meadowlands Complex (USACE, 1997). Individuals may possibly occur in Newark Bay as transients moving through the meadowlands and tidal creeks to the south along the Arthur Kill. Available field survey data are insufficient to determine the presence or absence of the northern diamondback terrapin in Newark Bay.

## 2.6 Previous Investigations

### 2.6.1 Historical Investigations

Various historical investigations have been conducted in Newark Bay by several agencies as well as by Tierra, from as early as 1983. These studies collected analytical chemistry data for surface sediment and tissue samples from different locations throughout the bay. Data from these historical investigations are maintained in a database at www.ourNewarkBay.org. Table 1 presents a list of these studies as they were exported from the database. The data were compiled and mapped to identify appropriate samples within the study area. Dredging activities were reviewed, and sediment data collected from dredged areas prior to subsequent dredging were removed from this evaluation. The remaining data suitable for this SLERA were included in the analysis discussed in Section 4.0.

**Table 1. Historical Investigations**

| Organization[a] | Name of Survey | Date Collected | Matrix[b] |
|---|---|---|---|
| NOAA | NS&T Hudson-Raritan Phase I | March, 1991 | Surface sediment |
| | NS&T Hudson-Raritan Phase II | January, 1993 | Surface sediment |
| USEPA | EMAP 90-92 | January, 1990 | Surface sediment |
| USEPA | Passaic 1990 Surficial Sediment Investigation | February, 1990 | Surface sediment |
| USEPA | Passaic 1991 Core Sediment Investigation | November/ December, 1991 | Surface sediment |
| USEPA | Passaic 1992 Core Sediment Investigation | December, 1992 | Surface sediment |
| USEPA | Passaic 1993 Core Sediment Investigation-01 | March, 1993 | Surface sediment |
| USEPA | Passaic 1993 Core Sediment Investigation-02 | July, 1993 | Surface sediment |
| USEPA | Passaic 1996 Newark Bay Reach A Sediment Sampling Program | May, 1996 | Surface sediment |
| USEPA | Passaic 1997 Newark Bay Reach B, C, D Sampling Program | April, 1997 | Surface sediment |
| USEPA | REMAP | August, 1993 | Surface sediment |
| USEPA | REMAP | August/ September, 1994 | Surface sediment |
| USACE | 93F64HR: Hackensack River | July, 1993 | Surface sediment |
| USACE | 93F64PE: Port Elizabeth | July, 1993 | Surface sediment Tissue |
| USACE | 96PPANYNJ: Port Authority of NY/NJ | July, 1996 | Surface sediment Tissue |
| USACE | 96PNBCDF: Newark Bay Confined Disposal Facility | July, 1996 | Surface sediment |
| NYSDEC | BSAF: Harbor Worm Sediment Collection | July, 2002 | Tissue |
| NYSDEC | HBIC: Harbor Benthic Invertebrate Collection | June, 1999- May, 2000 | Tissue |
| NYSDEC | HCC: Harbor Crustacean Collection | September, 1999 | Tissue |
| NYSDEC | HCS: Harbor Cormorant Sampling | May, 1999 | Tissue |
| NYSDEC | HFC: Harbor Fish Collection | June, 1999- May, 2000 | Tissue |
| NYSDEC | HRA: Harbor Ambient Sediment Sampling Project | September, 1998- July, 1999 | Surface sediment |
| NYSDEC | HRT: Harbor Sediment Trackdown Sampling Project | August, 2000- November, 2001 | Surface sediment |
| NYSDEC | Unknown | June, 1983 | Tissue |
| NYSDEC | Unknown | November, 1984 | Tissue |

**Table 1. Historical Investigations, continued**

| Organization[a] | Name of Survey | Date Collected | Matrix[b] |
|---|---|---|---|
| NYSDEC | Unknown | October, 1993 | Tissue |
| NYSDEC | Unknown | October, 1995 | Tissue |
| NYSDEC | Unknown | August/October, 1998 | Tissue |
| Tierra | Remedial Investigation Work Plan, Source Identification (2005) | October - December 2005 | Surface sediment |

a. The organization responsible was identified from the database output.

b. Although some programs may have collected deeper sediments in addition to the surface sediment (core sampling), only the surface sediment is used in the risk assessment.

### 2.6.2 RI/FS Investigations

The first phase of investigations for the RI/FS in the NBSA was performed in 2005 according to the Phase I RIWP (Tierra, 2005). These investigations, discussed below, included:

- An investigation of the Biologically Active Zone (BAZ).
- A bathymetric survey.
- Sediment sampling and analysis.
- Source identification activities.

#### *2.6.2.1 BAZ Investigation*

Field activities investigating the depth of the BAZ were conducted in October 2005 at 14 sampling locations. These stations were located in the intertidal mudflats, subtidal flats, and navigation channel areas. At each station, sediment profile imaging (SPI) was performed and sediment grab samples were collected for visual characterization. Particular emphasis was given to the subtidal and intertidal samples, because these regions are not regularly disturbed by dredging and are therefore likely to provide the most accurate information on the BAZ.

Results of both the SPI images and visual observations of the surface grab samples indicated that the BAZ was relatively consistent at that time of year across the three different geomorphic areas of Newark Bay (Tierra, 2006a). The reported BAZ depths averaged 5.7 inches in the intertidal areas, 5.4 inches in the subtidal flats, and 6.5 inches in the navigation channels. These results support at least a 6-inch BAZ depth; Tierra recommended that a BAZ depth of 6 inches be used for the Phase I and Phase II sediment sampling and analysis. Therefore, a 6-inch depth was carried forward for the SLERA, pending completion of USEPA's review of the Phase I and Phase II RIWP findings.

#### *2.6.2.2 Bathymetric Survey*

A bathymetric survey was conducted to confirm the geomorphic areas (navigation/port channels, transitional slopes, subtidal flats, intertidal flats, and industrial waterfront areas) that were originally delineated in the Phase I RIWP, based on the 2002 NOAA nautical chart. In general, the 2005 bathymetric survey confirmed the position and types of geomorphic areas identified in the Phase I RIWP, with a few refinements. For instance, the navigation/port channels increased in percentage of total study area in the Phase II RIWP by 1% from the Phase I RIWP; the transitional slopes increased in percentage of study area by 2%; the subtidal flats decreased in percentage of study area by 4%; the intertidal areas decreased in percentage by 1%; and the industrial waterfront areas increased by 1%.

#### *2.6.2.3 Sediment Sampling and Analysis*

Under the Phase I RIWP, sediment cores were collected from 69 locations from October through December 2005 by Tierra and analyzed for geotechnical properties, radiochemistry, and analytical chemistry. Analytical chemistry results were obtained for a variety of potential contaminants, including semivolatile organic compounds (SVOCs), pesticides, PCB Aroclors, PCB congeners, chlorinated herbicides, dioxin/furan congeners, metals, cyanide, total extractable petroleum hydrocarbons (TEPH), volatile organic compounds (VOCs), and organotins. Results indicate that many chemical constituents are present throughout Newark Bay at elevated concentrations; these data appear consistent with the historical datasets in terms of spatial distribution and concentration levels (Tierra, 2006a). General comparisons of Phase I RIWP data with historical datasets imply that all the various analytical methods used were not entirely comparable.

#### *2.6.2.4 Source Identification Activities*

Numerous contaminant sources to Newark Bay and its tributaries have been identified and are described in detail in the Phase II RIWP (Tierra, 2006a). Historical sources include industrial operations throughout the bay. Iannuzzi *et al.* (2002) identified the following types of industries that may have contributed to contaminant releases in the bay: metals refining, dye manufacturing, tanning, soap and candle making, lumber processing, hat manufacturing, carriage building, shoe making, petroleum processing, chemical manufacturing, pesticide and herbicide production, paper and textile manufacturing, copper rolling, wire manufacturing, silver manufacturing, platinum refining, ship building, coke making, decommissioning, and manufactured gas plants. The *Report on the Investigation of Sources of Pollutants and Contaminants* (Tierra, 2006b) also compiled a significant amount of information, via publicly available records (including relevant permits and federal and state databases) and through requests for information from various state and city sources. At the time of the report publication, 177 different waterfront or near-waterfront locations of interest were identified, based on historical or current land use (not including CSOs, SSOs, or POTWs, which are discussed below).

In addition to manufacturing and industrial discharges, Iannuzzi *et al*. (2002) linked contamination of the waterways and surrounding areas of the bay to a number of specific historic occurrences and non-point sources, such as those presented below:

- An oil pipeline crossing Saddle River that burst in the late 1800s, covering miles of the river from shore to shore with oil.
- A tanker spill of carbolic acid (phenol) in the spring of 1880.
- Spreading of lightweight fuel oils for vector control in mosquito-infested wetlands and marshes in the early 1900s.
- Copper fungicide application used on farmlands and watersheds to address mosquito infestation in the 1940s.
- Dichlorodiphenyltrichloroethane (DDT) application on mosquito-infested wetlands, marshes, and stormwater system infrastructure in the 1950s and 1960s.

Examples of more recent accidental releases include the following spills:

- A spill of sodium phosphate to the Arthur Kill in August 1987 (Gunster *et al*., 1993a, b).
- An oil pipeline crossing the Arthur Kill that ruptured in January 1990, releasing thousands of gallons of No. 2 fuel oil (NJDEP, 1991).
- A spill of fuel oil to Newark Bay in October 1991 (Gunster *et al.,* 1993a, b).

Tierra (2006a) also identified the discharge of raw sewage into Newark Bay and its tributaries as a significant input of contaminants and pathogens. Prior to 1960, the City of Elizabeth discharged raw

sewage into the Arthur Kill. In 1960, the city joined with Essex and Union counties to build a POTW. Jersey City, Kearney, and Port Richmond constructed POTWs in the 1950s and 1960s. All of the POTWs noted have CSOs that overflow into Newark Bay or one of its tributaries when capacity is exceeded (usually during a storm event).

The Phase I RIWP (Tierra, 2005) and the Phase II RIWP (Tierra, 2006a) examined several sources that continue to adversely impact the bay. These include POTWs, CSOs, New Jersey Pollutant Discharge Elimination System (NJPDES) permitted discharges, SSOs, and stormwater runoff. As of October 2006, when the Phase II RIWP (Tierra, 2006a) was published, the combined sewerage systems in the communities surrounding the bay still had numerous CSOs that discharge into the bay and its tributaries, including:

- The City of Elizabeth (39 overflow locations)
  - Of these 39 locations, 6 discharge directly to the Arthur Kill or Newark Bay.
  - The others discharge to the Elizabeth River, a tributary of the Arthur Kill.
- The City of Newark (30 overflow locations)
  - Of these 30 overflow locations, 8 CSOs discharge to the Peripheral Ditch – a direct tributary to Newark Bay.
  - The majority of Newark's other 22 CSOs discharge directly to the Passaic River, which is also a tributary to Newark Bay.
- The Town of Kearny (10 overflow locations)
  - All 10 CSOs discharge to the Passaic River and/or its tributaries, which flow to Newark Bay.
- The City of Jersey City (27 overflow locations)
  - Of these 27 CSOs, 2 discharge directly to Newark Bay.
  - 12 discharge to the Hackensack River and its tributaries, which are tributaries to Newark Bay.
- The City of Bayonne (35 overflow locations)
  - Of these 35 CSOs, 28 discharge directly to the Kill Van Kull or Newark Bay.
- The City of New York (through its Port Richmond combined sewer system) (35 overflow locations)
  - Of these 35 CSOs, 20 flow directly to the Kill Van Kull or Newark Bay.

As of 2004, when the Phase I RIWP was released in draft form, there were 417 active NJPDES Permits (issued post-2000) in the NBSA. There are also 11 National Priorities List (NPL) sites and 729 identified Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS), State-Listed and Other Known Hazardous Waste Sites within the NBSA (Tierra, 2004; 2006a; b). A more detailed description of these sources is reported in Newark Bay Study Area Report on Investigation of Sources of Pollutants and Contaminants (Tierra, 2006b).

# 3.0 SCREENING-LEVEL PROBLEM FORMULATION

The screening-level problem formulation consists of the development of a CSM, which is necessary to relate potential sources of contamination, fate and transport of contaminants, pathways of exposure, and ecological receptors. A CSM is a tool for evaluating the likely connection between ecological receptors and contaminated media, and for determining the number and types of complete exposure pathways that may exist in the system and their relative significance from a risk perspective. The SLERA CSM is also instructive for assessing information gaps and areas where uncertainty levels may warrant further data collection. This section presents a preliminary CSM for Newark Bay, which consists of five main elements: 1) environmental setting and known or suspected sources of contaminants, including an evaluation of the historical contamination, 2) contaminant fate and transport mechanisms, 3) ecotoxicity of contaminants and potentially affected ecological receptors, 4) potentially complete exposure pathways, and 5) ecological endpoints. A graphical representation of the CSM for Newark Bay is presented in Figure 6.

## 3.1 Environmental Setting and Contaminants at the Site

Newark Bay is part of the NY/NJ Harbor Estuary, which is one of the largest estuaries on the east coast of the United States, encompassing an area of over 42,000 square kilometers. As discussed in Section 2.0, the estuary encompasses several other major water bodies, including the Hudson River, the Raritan River, Upper New York Bay, and Lower New York Bay. Newark Bay is approximately 6 miles long and 1 mile wide. Along its northern boundary, it is formed by the confluence of the Lower Passaic River and the Hackensack River. At its southern boundary, the bay is connected to Upper New York Bay by the Kill Van Kull and to Raritan Bay by the Arthur Kill. Newark Bay is bounded on the west by the New Jersey cities of Newark and Elizabeth and on the east by Jersey City and Bayonne. It is bordered on the south by Staten Island, New York.

Although Newark Bay was originally a relatively shallow tidal estuary, deep navigational channels were created and are maintained in the bay to accommodate ocean-going container ship access to the Port Newark-Elizabeth Marine Terminal along its western shore. Federally authorized navigation channels extend through Newark Bay to the Lower Passaic River and the Hackensack River.

The banks of Newark Bay are home to numerous active and abandoned commercial and industrial properties. The banks are extensively developed and consist of miles of armored shoreline. Expanding urban and industrial development has resulted in the disposal of industrial and municipal waste in the bay and its adjoining water bodies, which in turn has resulted in sediment contamination. Like the rest of the NY/NJ Harbor Estuary, tidal currents cause the reworking of sediments, mixing suspended sediments from the bay with sediments derived from other areas. Consequently, contaminated sediments from Newark Bay may be distributed throughout the NY/NJ Harbor Estuary and contaminated sediments from other parts of the estuary are being re-distributed to the bay.

Urbanization has contributed to extensive habitat loss and degradation, which has reduced the functional and structural integrity of ecosystems within the NBSA. Since 1940, over 88% of wetlands in the Newark Bay estuary have been eliminated (Iannuzzi *et al.*, 2002). Shorelines covered by bulkheads, rip-rap, buildings and other structures, and pavement limit the available wildlife habitat, including nesting and foraging areas for birds along the bay. Increases in the extent of impervious surface within the watershed have decreased stormwater infiltration and shunted concentrated volumes of stormwater runoff directly into the bay. In addition, tidal creeks and marshes that provide critical habitat and ecosystem functions to juvenile and migratory fish have been depleted by loss of habitat, which may have contributed to the resulting decline of avian, fish, and shellfish populations in the estuary.

Despite the impacts of urbanization on the bay, existing historical data indicate that the NBSA supports a variety of vegetation, fish, and wildlife species. Key habitats that remain in the NBSA are the shallow subtidal and intertidal areas, particularly the large marsh/mudflat systems located at the north end of the bay at Kearny Point and at the southern end of the bay adjacent to Staten Island. These habitats provide foraging areas for birds and other wildlife, as well as nursery areas for fish and invertebrates (Tierra, 2006a).

### 3.1.1 Study Area Boundaries

The NBSA is bounded on the north by the Conrail Bridge that crosses over the Hackensack River and by the southern boundary of the Lower Passaic River Restoration Project Area (Figure 1). The southern boundaries of the NBSA are located at the Goethals Bridge crossing over the Arthur Kill and the Bayonne Bridge over the Kill van Kull. Within these study area boundaries, Newark Bay was segmented into three regions (south, middle, and north) to assist in data evaluation for the SLERA (see Section 2.3).

*South Region.* The southern area extends from the Goethals and Bayonne Bridges north to the point that transects the bay at the southern boundary of the South Elizabeth Channel. The south region is predominantly minimally depositional or non-depositional, with the exception of the channel areas. There is an extensive shallow-water area within this section of the bay, located west of the Newark Bay South Reach, north of the North of Shooters Island Reach, south of South Elizabeth Channel, and east of the City of Elizabeth. There is a large avian habitat at Shooters Island. Potential metals and PCB sources in the Arthur Kill may be contributing to sediment contamination in the southwestern portion of the bay.

*Middle Region.* The middle region extends north from the south region to the northern boundary of the Port Newark Channel. There are significant channels and port areas within this region. This area is characterized predominantly as depositional (*i.e.,* navigational channels) and moderately depositional (*i.e.*, shoals on the eastern side of the bay). The Newark Bay CDF is located in this section of the bay on the western side of the Newark Bay Middle Region, between the Port Newark and Port Elizabeth Channels. The CDF is 26 acres in surface area, was excavated to a depth of 70 feet below the bay bottom, and can hold up to 1.5 million cubic yards of dredged material (Tierra, 2004). Local sources of PCBs and mercury in the bay are influencing sediment contaminant concentrations in the vicinity of the port channels.

*North Region*. The north region comprises the remaining area between the Port Newark Channel and the Conrail Bridge/LPRRP Area. Like the south region, this area is predominantly characterized as minimally depositional or non-depositional, with the exception of the channel areas. There is a large shallow-water/shoal area located along the eastern side of Newark Bay within this section of the study area. Local inputs from the Passaic and Hackensack Rivers include freshwater, solids, and some contaminants to the bay.

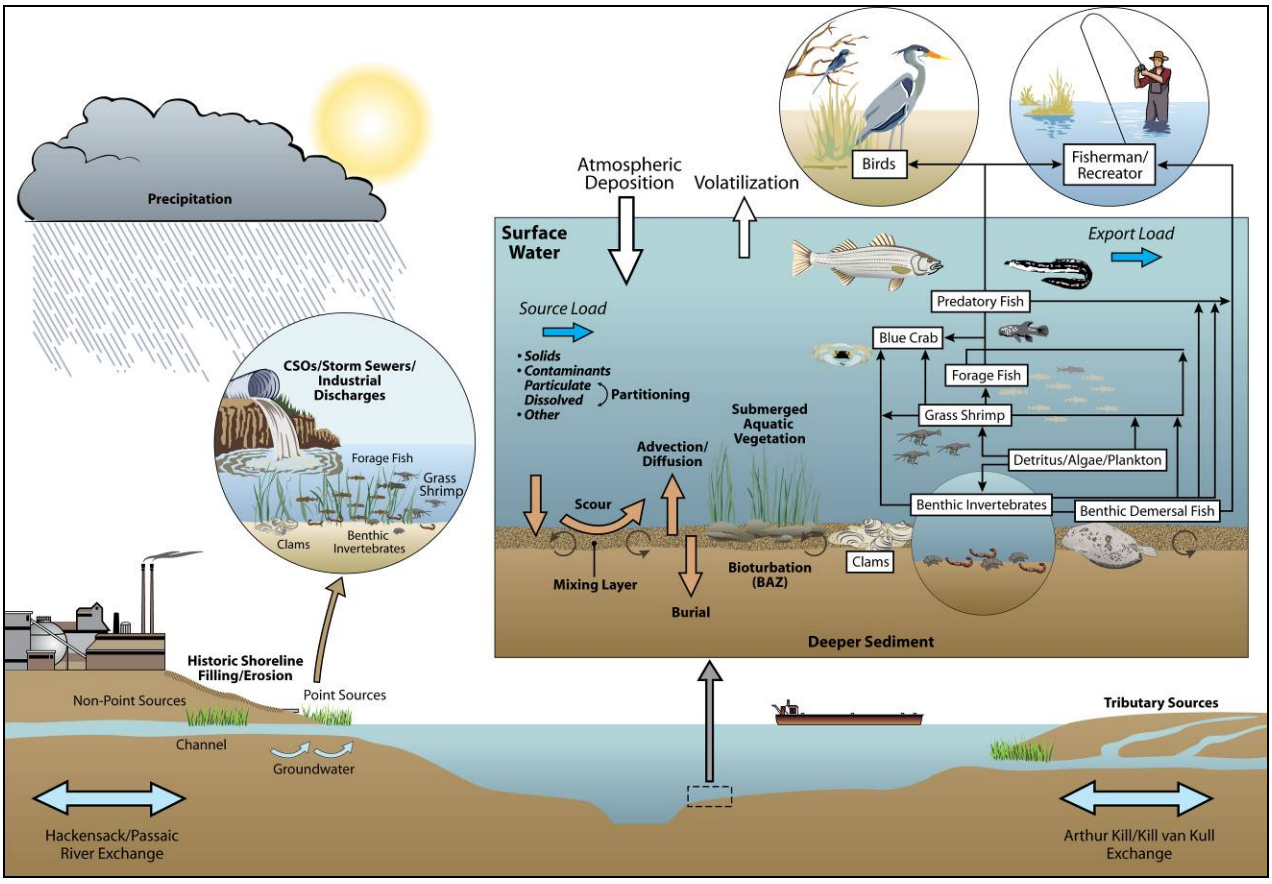


**Figure 6. CSM for the NBSA (Tierra, 2004)**

### 3.1.2 Habitat Areas

Within each of the three regions of the bay are three predominant habitat types relevant to the SLERA: 1) the intertidal areas, including the wetlands and mudflats; 2) the shallow subtidal areas; and, 3) the transitional slopes and navigational channels (Figure 7). The intertidal and subtidal areas are not regularly disturbed by dredging. They also likely provide the highest potential for ecological contact with and uptake of contaminants.

The intertidal areas comprise a small portion of the habitat within the bay and are typically characterized by the presence of emergent vegetation, mud flats, and/or historical shoreline filling. In Newark Bay, these areas are generally characterized as minimally depositional or non-depositional areas. These intertidal areas are subjected to municipal and industrial point source discharges, source and non-point source runoff, contaminants transported through tidal exchanges with tributaries such as the Hackensack and Passaic Rivers, and discharge of contaminated groundwater. These areas often provide important habitat for aquatic and piscivorous wildlife. Biological receptors may include benthic invertebrates and macroinvertebrates, such as blue crab, shrimp species, and bivalves, as well as forage fish and smaller predatory fish. Various bird species, such as the blue heron or belted kingfisher, utilize these areas for foraging.

The shallow subtidal areas make up the largest portion of habitat in the bay and are generally characterized by the presence of submerged vegetation, benthic invertebrate communities, forage fish, and predatory fish such as the striped bass. These areas are typically moderately to minimally

depositional and are subjected to various discharges from sources similar to intertidal habitats. These areas can also be subjected to disturbances from shipping traffic, including waves and propeller wash.

The transitional slopes and navigation channels are generally void of any submerged vegetation due to periodic maintenance dredging, deepening-project activities, and limited light conditions due to the increased water depth. Biological communities in the channels include benthic invertebrates, forage fish, and predatory fish. Surveys have shown macroinvertebrates and predatory fish to be especially abundant in the deeper water of the channels in the winter months. The channels have been shown to be depositional areas; contaminant releases to the intertidal and subtidal areas may be transported to the depositional areas of the channels. In addition, shipping activities and storm events can disturb bottom sediments and result in the potential slumping of the channel sidewalls and recontamination of the dredged channel bottoms.

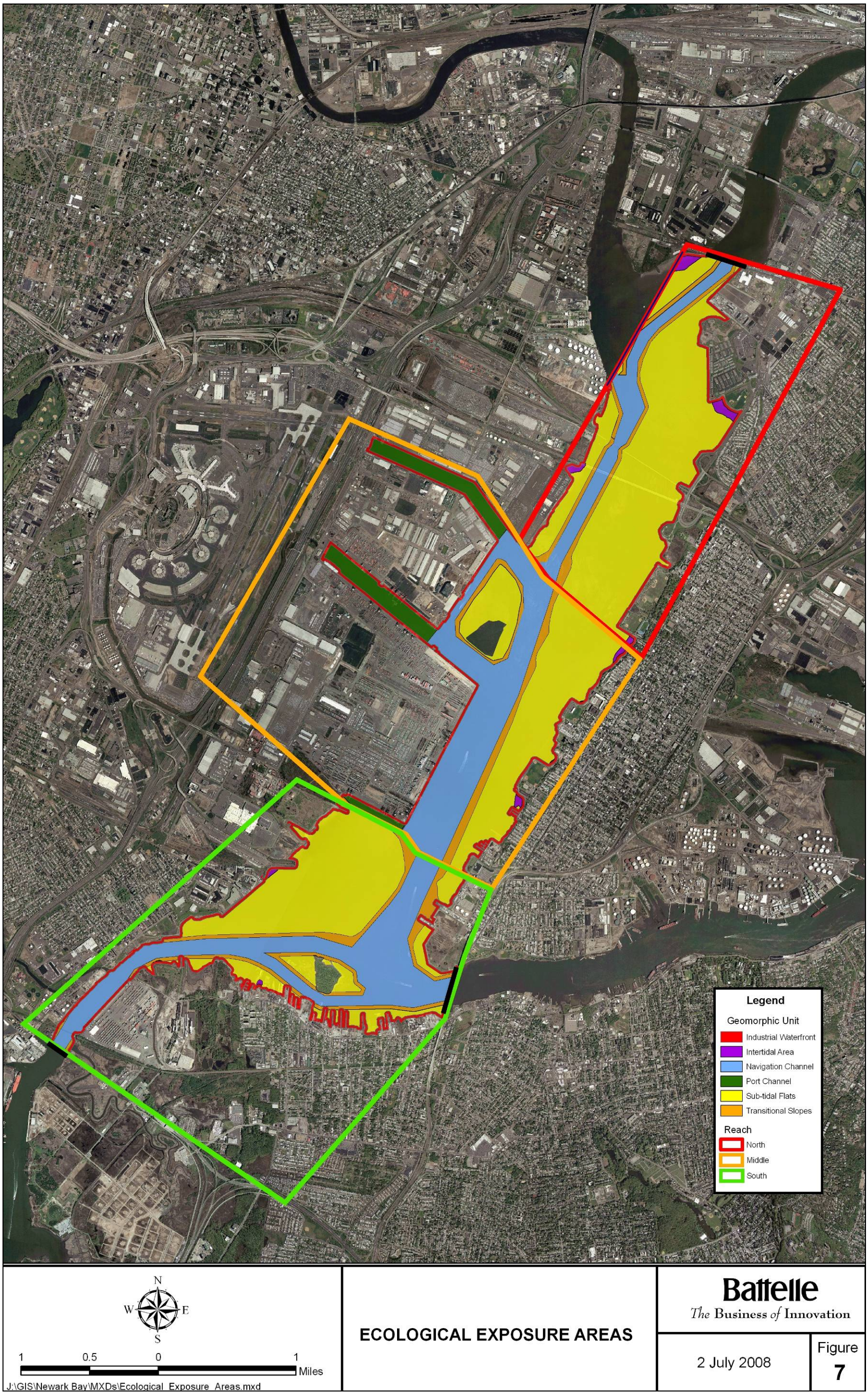


**Figure 7. Ecological Exposure Areas of the NBSA**

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## 3.2 Contaminant Fate and Transport

Urbanization, expansion of industry, and the release of chemicals (from both point and non-point sources) into Newark Bay have resulted in elevated levels of chemical contamination in sediments (NOAA, 1998). The primary contaminants represent a variety of different contaminant classes, including but not limited to metals, VOCs, SVOCs, polycyclic aromatic hydrocarbons (PAHs), PCBs, pesticides, and dioxins/furans. The physical, chemical, and biological processes that influence the transport and fate of contaminants in Newark Bay and their availability to ecological receptors are discussed below.

### 3.2.1 Contaminant Sources and Sinks

As discussed, anthropogenic influences on the natural habitat of the NBSA have included the direct release of large amounts of industrial chemicals and sewage into the NBSA as well as habitat destruction, wetlands drainage, and land alteration. Moreover, numerous historical industrial and manufacturing facilities in the NBSA potentially acted as point and non-point source discharges to the environment. Historic and potentially ongoing sources of biological, inorganic, and organic chemical contaminants include but are not limited to the following:

- Accidental spills.
- Atmospheric deposition.
- CSOs and SSOs.
- Contaminant transport from various waterbodies, including the lower Hudson River, New York Harbor, Raritan Bay, Lower Passaic River, Hackensack River, Arthur Kill, and Kill Van Kull.
- Disturbance of contaminated sediment through dredging and maritime operations.
- Groundwater discharge (both contaminated groundwater from adjacent industrial sites and groundwater infiltration through contaminated sediments that may have historically been placed along the NBSA shoreline).
- Historical direct discharge of industrial waste.
- Illegal disposal and improper handling of chemicals and solvents.
- Marine vessel discharges.
- Contaminated stormwater, potentially transporting eroded soils contaminated by surface spills and chemical product from drum/aboveground tank containment areas.
- Landfills and other hazardous waste sites.

Due to the nature of sediment transport in the bay, particle-bound contaminants are particularly persistent, resulting in a long residence time for these contaminants. Largely because of the extensive set of deep, man-made channels, Newark Bay is a net sink for suspended sediments from both upland and seaward extensions, trapping the contamination delivered by these sources. A solids mass balance performed by Lowe *et al*. (2005) suggested that the net annual accumulation of sediments is roughly offset by the annual removal of sediment by maintenance dredging. Further evaluation conducted by Malcolm Pirnie, Inc. (2006) indicated that approximately 10% of the sediment deposited annually in Newark Bay originates from the Lower Passaic River, 2% originates from the Hackensack River, 85% originates from the Kill Van Kull and Arthur Kill, and the remaining 3% originates from other sources. Consequently, the dominant loads of particle-bound contaminants to Newark Bay likely originate from the Kills and, to a lesser degree, the Lower Passaic River. Relative contributions of contamination are also dependent upon the concentrations of contaminants associated with suspended solids. The Hackensack River and other sources (*e.g*., CSOs, minor tributaries and creeks, atmospheric deposition) do not contribute a significant fraction of the solids load to the bay; therefore the corresponding particle-bound contaminant loads to the bay are also likely to be less than loads from the Kills and the Lower Passaic River. In fact, it is likely

that Newark Bay and the Lower Passaic River are a net source of solids and contamination to the Hackensack River at the current time (Pence, 2004).

### 3.2.2 Environmental Processes Affecting Contaminant Distribution

As mentioned above, the sediments within Newark Bay act as both a sink and a means for transport of contaminants throughout the bay. Contaminants may be remobilized from the sediments through bioturbation within the BAZ, sediment-porewater exchange, and sediment erosion and scour (Tierra, 2006b). Although groundwater analytical data were not available for consideration in this SLERA, it is possible that the interaction between this medium and sediment (including porewater) may represent a significant migration pathway locally within the bay.

The physical characteristics of the system can also impact the movement of chemicals through sediments. In anoxic environments, metals such as cadmium, lead, copper, and zinc are typically immobilized as sulfides. These metals can be mobilized via a change in redox potential (*i.e.*, oxidation) and/or drop in pH. However, this situation is unlikely in an estuarine environment. Microbial processes can transform elemental mercury into methyl mercury, which is more toxic and more bioavailable than the elemental form. In estuaries, methylation tends to occur at higher rates in coastal wetlands and intertidal mudflats under anaerobic conditions.

Some species of metals, PCBs, PAHs, pesticides, and dioxins/furans are hydrophobic, nonpolar contaminants that tend to tightly adsorb to sediment particles. Therefore, their transport and fate in estuarine systems are controlled by the movement of sediment particles. Surface and subsurface sediments can be mixed by physical processes such as currents, wind and wave resuspension, grounding of ship keels and propellers, dredging, scouring, and liquefaction or slumping. Surface sediment can also be mixed by biological processes (*e.g.*, bioturbation) such as feeding or burrowing. Sediments and their bound contaminants that become resuspended by these processes are likely to be moved around the system by tidal action. Sediment accumulation, vertical mixing, storms, floods, and anthropogenic disturbances (*e.g.*, dredging) control the rate at which contaminants may be buried and removed from receptor pathways.

Many contaminants found in the NBSA are known to bioaccumulate in organisms and move through the food web. This occurs when contaminants are retained within the tissues of primary consumers and are subsequently transferred to other organisms when higher-level consumers feed on them. Certain metals, PCBs, chlorinated pesticides, and dioxins/furans are known to bind to tissue and bioaccumulate in upper-trophic-level organisms. Other contaminants, like PAHs, are not known to bioaccumulate at high rates in tissues (Suedel *et al.*, 1994); the toxic effects of PAHs generally occur via direct ingestion, dermal uptake, or inhalation.

### 3.2.3 Nature and Extent of Contamination

Geochemical principles provide tools to explain the nature, extent, fate, and transport of contaminants in the bay. These findings can be further supported by a mathematical model, which is designed to emulate geochemical and other principles and is calibrated to field data. A mathematical model was not available at the time that this SLERA was performed; consequently, the following discussion on the fate and transport of contamination in the bay is explained in terms of geochemical principles. Additional modeling may be included in later studies.

As part of the Phase I RI, 69 sediment cores were collected throughout Newark Bay (Tierra, 2006a). Approximately half of the locations (35 of the 69 locations) were characterized as recently depositional,

based on the presence and concentration of beryllium-7 in the top inch of the core[1] (Tierra, 2006a). As expected, these depositional sites were primarily located in the navigation and port channels where the USACE reported depositional rates of 2 to 7 inches/year (reference cited in Tierra, 2006a). Concentration scatter plots for select contaminants at these depositional locations illustrate three general concentration distributions in Newark Bay:

- Decreasing concentration gradients from north to south across Newark Bay (*e.g.*, 2,3,7,8-TCDD) indicative of the impacts of contamination emanating from the Lower Passaic River.
- Uniform concentrations across the main body of Newark Bay, with an increasing gradient in the southwestern area (*e.g.*, arsenic), indicative of a source at the southern end of the bay.
- A distribution with local maxima near the intersection of the Port Newark Channel and the main channel of Newark Bay, as well as at the mouth of the Arthur Kill (*e.g.*, for mercury and total PCBs), indicative of the occurrence of a major source within the bay and the presence of external loads.

The presence of different concentration gradients occurring simultaneously in Newark Bay suggests that the bay is not a very efficient "mixing bowl." In other words, the tidal currents and depositional regimes are not sufficient to completely homogenize and re-distribute contaminated suspended solids evenly throughout the bay, in contrast to the conditions that exist in the Lower Passaic River. It appears that the ongoing external contaminant loads arising from source areas are sufficiently large relative to the tidal fluxes and tidal circulation, and tidal resuspension and redeposition cannot dissipate the local gradients.

Unlike the channels, the shoal areas of Newark Bay are subject to much slower rates of deposition and contain the majority of the non-depositional locations. Typical deposition rates in these areas are estimated at less than 1 inch per year. Slow deposition in these areas has resulted in significant near shore sediment impacts over the long history of contaminant discharge to Newark Bay. For example, surface sediments (defined as 0 to 6 inches for the Newark Bay remedial investigation) on the shoals are likely to be more contaminated than surface sediments from the channels, since 6 inches of sediments in the shoals capture a longer depositional history, and hence, more of the higher historic contaminant loads. This scenario explains most, but not all, of the observations regarding sediment contamination in the shoals. For example, some evidence, including detected contaminant concentrations, suggests that the shoals are impacted by local contaminant sources, particularly in the southwest and northeast corners of the bay. Other shoal areas were once historical channels, turning basins, and borrow pits that have accumulated thick beds of legacy sediments due to limited maintenance dredging or abandonment (USACE, 2006).

Ultimately, the fate of particle-bound contaminants is linked to the movements of sediments in the bay. In this manner, particle-bound contaminants are subject to slow burial in the shoals or to removal from the channels by dredging with subsequent upland disposal due their elevated toxicity. A small portion of the sediments from the bay escape via tidal exchange through the Kills, adding to contamination elsewhere in the NY/NJ Harbor Estuary (Bopp *et al*., 1991). The fate and transport of several more important contaminants are discussed below following geochemical principles for the recent deposition locations.

*2,3,7,8-TCDD Source Analysis.* The concentration scatter plot for 2,3,7,8-TCDD indicates a general decreasing north-to-south concentration gradient in Newark Bay at depositional locations (Figure 8). This 2,3,7,8-TCDD concentration gradient was suggested by Bopp *et al*. (1991), who also showed that this gradient continued through the Kill Van Kull with the lowest levels of 2,3,7,8-TCDD measured in New York Harbor. Their data indicated that the 2,3,7,8-TCDD contamination likely originated in the Lower Passaic River, using the ratio of 2,3,7,8-TCDD/total TCDD as a chemical tracer. Using data from the RI

[1] Beryllium-7 is a short-lived (54-day half-life) radioactive isotope produced in the upper portions of the earth's atmosphere. Its presence in surficial sediments of a water body is considered indicative of recently deposited sediments.

Phase I dataset (Tierra, 2006a), Malcolm Pirnie, Inc. (2007) observed that the ratio decreased across the bay from approximately 0.6 in the northern reaches to 0.3 in the southern reaches, reflecting the mixing of highly contaminated Lower Passaic River sediments with relatively cleaner sediments originating in Upper and Lower New York Bay (Figure 9). These cleaner sediments have a 2,3,7,8-TCDD/Total TCDD ratio consistent with sewage-based sources, and the 2,3,7,8-TCDD concentrations are orders of magnitude below those concentrations observed in the Lower Passaic River, suggesting that significant transfer of contaminants to the river does not occur, although transfer of some contaminants is possible (Malcolm Pirnie, Inc., 2007; Chaky, 2003). Unlike the maximum loads of other contaminants observed at the heads of the port channels (*e.g.*, total PCBs and metals), elevated concentrations are not observed for 2,3,7,8-TCDD, suggesting that, unlike total PCBs and metals, there are no indications of local sources within Newark Bay.

*Metals Source Analysis.* Concentration scatter plots for arsenic, cadmium, chromium, lead, and mercury, are presented in Figures 10 through 14. The following dominant features can be inferred from the metals scatter plots:

- A local concentration maximum in the southwestern area of Newark Bay, especially west of Shooters Island near the confluence with the Arthur Kill.
- Elevated concentrations at the head of the Port Newark Channel.
- Generally uniform surface sediment concentrations across the main body of Newark Bay, which are either equal to or lower than 2005 core top concentration measured in the Lower Passaic River (river mile [RM] 1.4).
- Generally higher concentrations in depositional sites located on the shoals versus depositional sites located in the channel.

In general, the plots show a strong concentration gradient near the Arthur Kill, with relatively uniform concentrations across the main body of the bay. This observation suggests that for these metals, concentrations on the suspended sediments delivered by the Kill Van Kull are similar to those sediments delivered by the Lower Passaic River. For several metals, surface concentrations in the middle region of the bay are possibly impacted by another source in the port channels, and surface concentrations in the north region of the bay are likely influenced by the Lower Passaic River and the Hackensack River. Based on these data, an initial fate and transport scenario suggests that several metals source areas exist and are contributing contaminant load to Newark Bay.

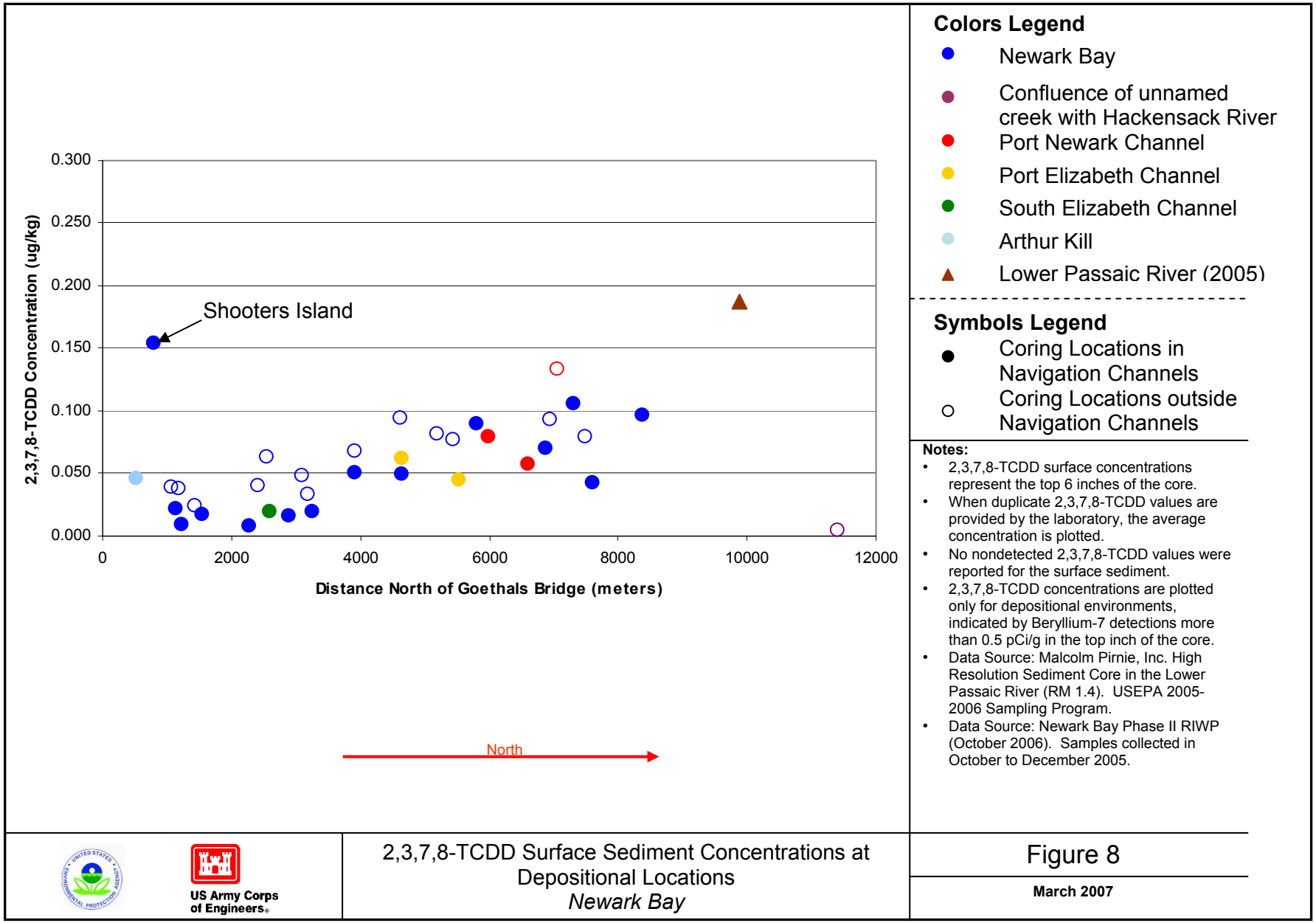
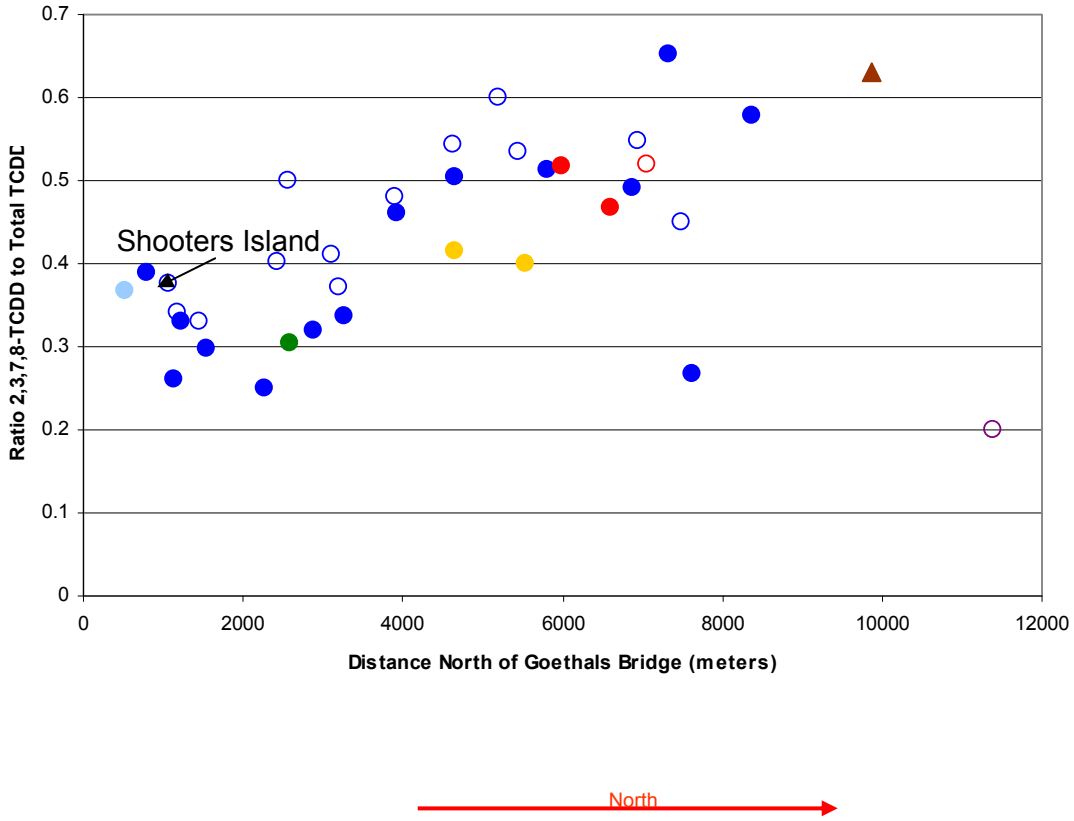



**Figure 8. 2,3,7,8-TCDD Surface Sediment Concentrations at Depositional Locations in Newark Bay**




Colors Legend

- Newark Bay
- Confluence of unnamed creek with Hackensack River
- Port Newark Channel
- Port Elizabeth Channel
- South Elizabeth Channel
- Arthur Kill
- Lower Passaic River (2005)

Symbols Legend

- Coring Locations in Navigation Channels
- Coring Locations outside Navigation Channels

Notes:

- 2,3,7,8-TCDD and total TCDD surface concentrations represent the top 6 inches of the core.
- When duplicate 2,3,7,8-TCDD or total TCDD values are provided by the laboratory, the average ratio is plotted.
- No nondetected 2,3,7,8-TCDD or total TCDD values were reported for the surface sediment.
- Concentration ratios are plotted only for depositional environments, indicated by Beryllium-7 detections more than 0.5 pCi/g in the top inch of the core.
- Data Source: Malcolm Pirnie, Inc. High Resolution Sediment Core in the Lower Passaic River (RM 1.4). USEPA 2005-2006 Sampling Program.
- Data Source: Newark Bay Phase II RIWP (October 2006). Samples collected in October to December 2005.

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Ratio of 2,3,7,8-TCDD to Total TCDD Surface Sediments Concentrations
*Newark Bay*

Figure 9

March 2007

**Figure 9. Ratio of 2,3,7,8-TCDD to Total TCDD Surface Sediment Concentrations in Newark Bay**

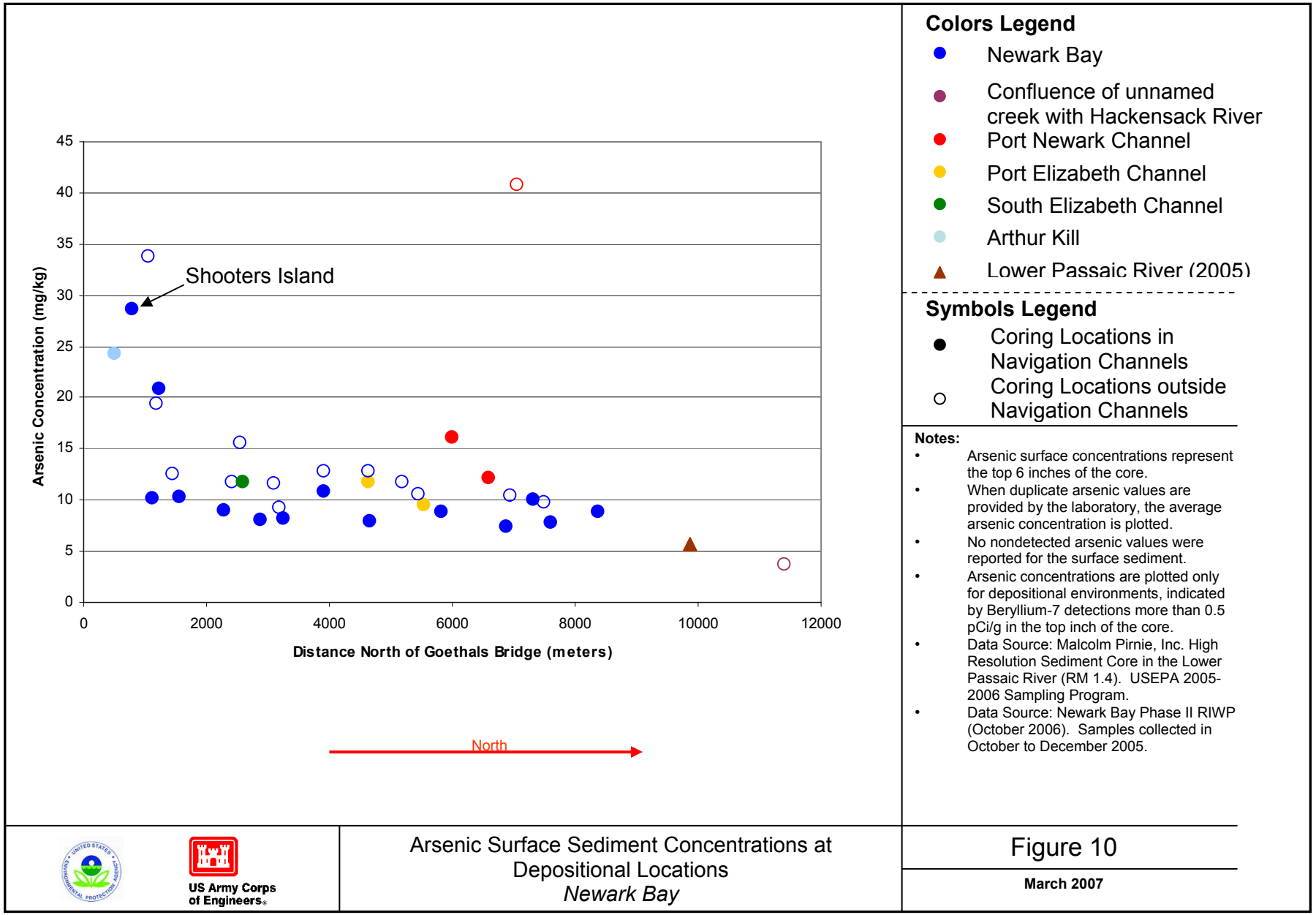
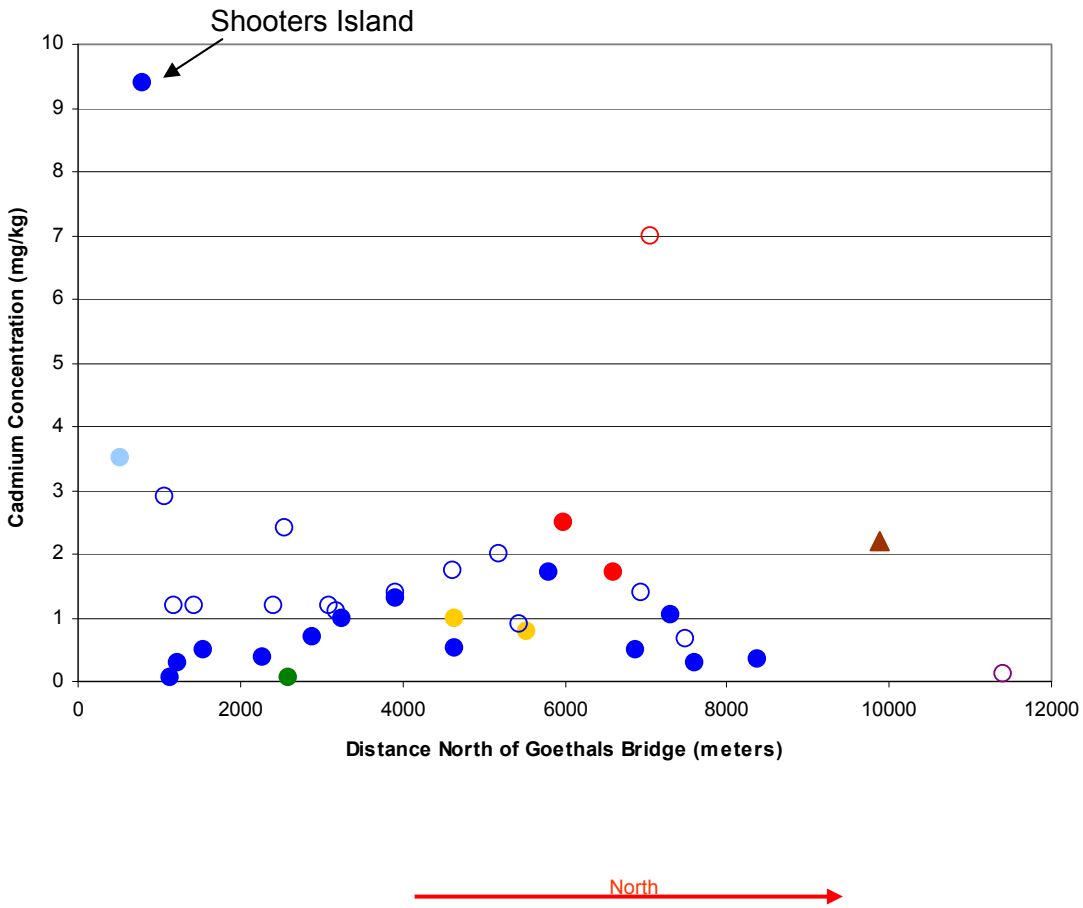



**Figure 10. Arsenic Surface Sediment Concentrations at Depositional Locations in Newark Bay**




**Colors Legend**

- Newark Bay
- Confluence of unnamed creek with Hackensack River
- Port Newark Channel
- Port Elizabeth Channel
- South Elizabeth Channel
- Arthur Kill
- Lower Passaic River (2005)

**Symbols Legend**

- Coring Locations in Navigation Channels
- Coring Locations outside Navigation Channels

**Notes:**

- Cadmium surface concentrations represent the top 6 inches of the core.
- When duplicate cadmium values are provided by the laboratory, the average cadmium concentration is plotted.
- Nondetected cadmium values were plotted at half the detection limit.
- Cadmium concentrations are plotted only for depositional environments, indicated by Beryllium-7 detections more than 0.5 pCi/g in the top inch of the core.
- Data Source: Malcolm Pirnie, Inc. High Resolution Sediment Core in the Lower Passaic River (RM 1.4). USEPA 2005-2006 Sampling Program.
- Data Source: Newark Bay Phase II RIWP (October 2006). Samples collected in October to December 2005.

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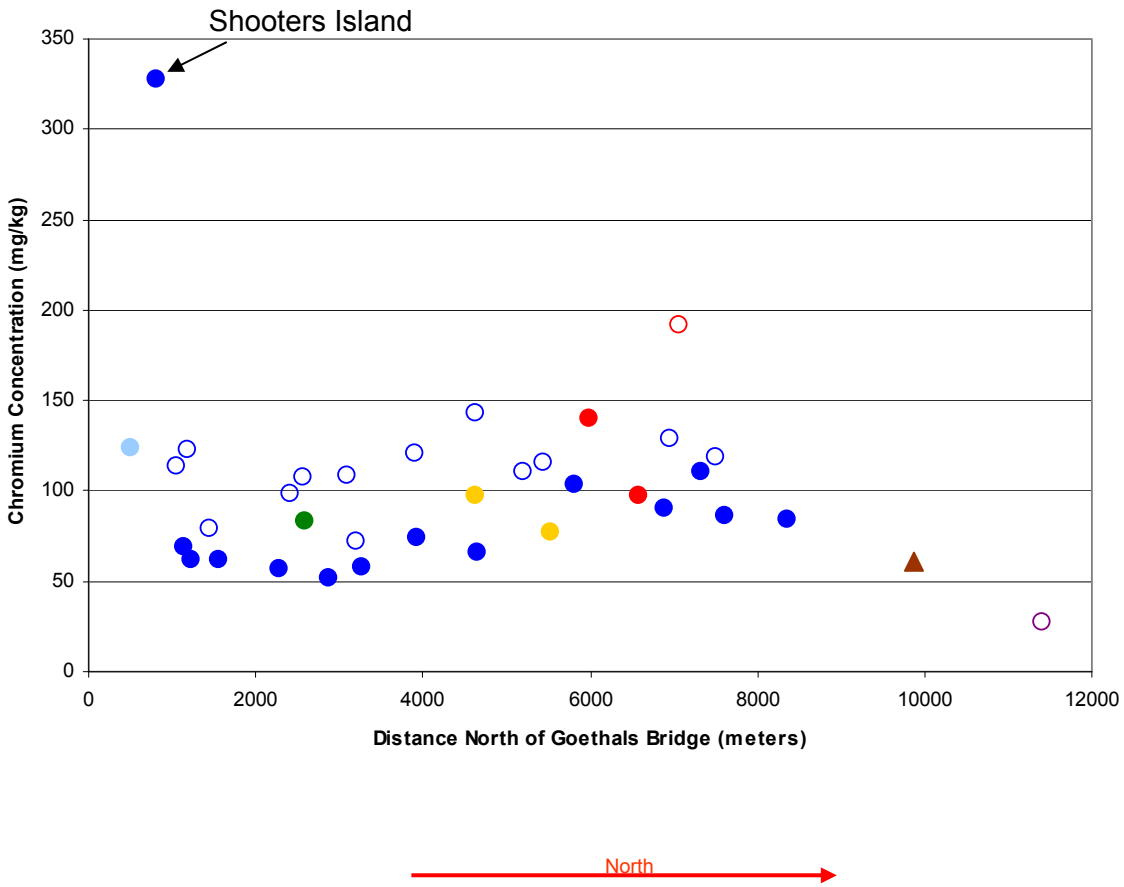
Cadmium Surface Sediment Concentrations at Depositional Locations
*Newark Bay*

Figure 11

**March 2007**

**Figure 11. Cadmium Surface Sediment Concentrations at Depositional Locations in Newark Bay**




**Colors Legend**

- Newark Bay
- Confluence of unnamed creek with Hackensack River
- Port Newark Channel
- Port Elizabeth Channel
- South Elizabeth Channel
- Arthur Kill
- Lower Passaic River (2005)

**Symbols Legend**

- Coring Locations in Navigation Channels
- Coring Locations outside Navigation Channels

**Notes:**

- Chromium surface concentrations represent the top 6 inches of the core.
- When duplicate chromium values are provided by the laboratory, the average chromium concentration is plotted.
- Nondetected chromium values were plotted at half the detection limit.
- Chromium concentrations are plotted only for depositional environments, indicated by Beryllium-7 detections more than 0.5 pCi/g in the top inch of the core.
- Data Source: Malcolm Pirnie, Inc. High Resolution Sediment Core in the Lower Passaic River (RM 1.4). USEPA 2005-2006 Sampling Program.
- Data Source: Newark Bay Phase II RIWP (October 2006). Samples collected in October to December 2005.

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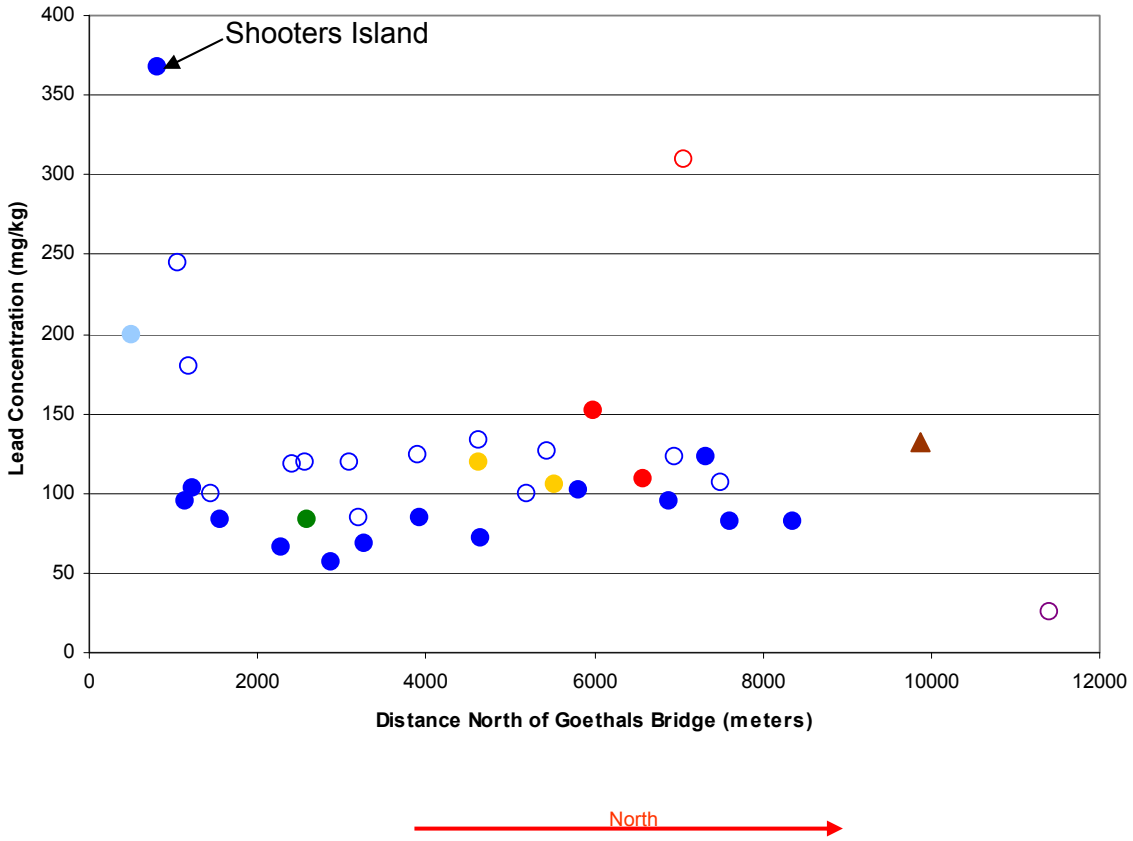
Chromium Surface Sediment Concentrations at Depositional Locations
*Newark Bay*

Figure 12

**March 2007**

**Figure 12. Chromium Surface Sediment Concentrations at Depositional Locations in Newark Bay**




**Colors Legend**

- Newark Bay
- Confluence of unnamed creek with Hackensack River
- Port Newark Channel
- Port Elizabeth Channel
- South Elizabeth Channel
- Arthur Kill
- Lower Passaic River (2005)

**Symbols Legend**

- Coring Locations in Navigation Channels
- Coring Locations outside Navigation Channels

**Notes:**

- Lead surface concentrations represent the top 6 inches of the core.
- When duplicate lead values are provided by the laboratory, the average lead concentration is plotted.
- No nondetected lead values were reported for the surface sediment.
- Lead concentrations are plotted only for depositional environments, indicated by Beryllium-7 detections more than 0.5 pCi/g in the top inch of the core.
- Data Source: Malcolm Pirnie, Inc. High Resolution Sediment Core in the Lower Passaic River (RM 1.4). USEPA 2005-2006 Sampling Program.
- Data Source: Newark Bay Phase II RIWP (October 2006). Samples collected in October to December 2005.

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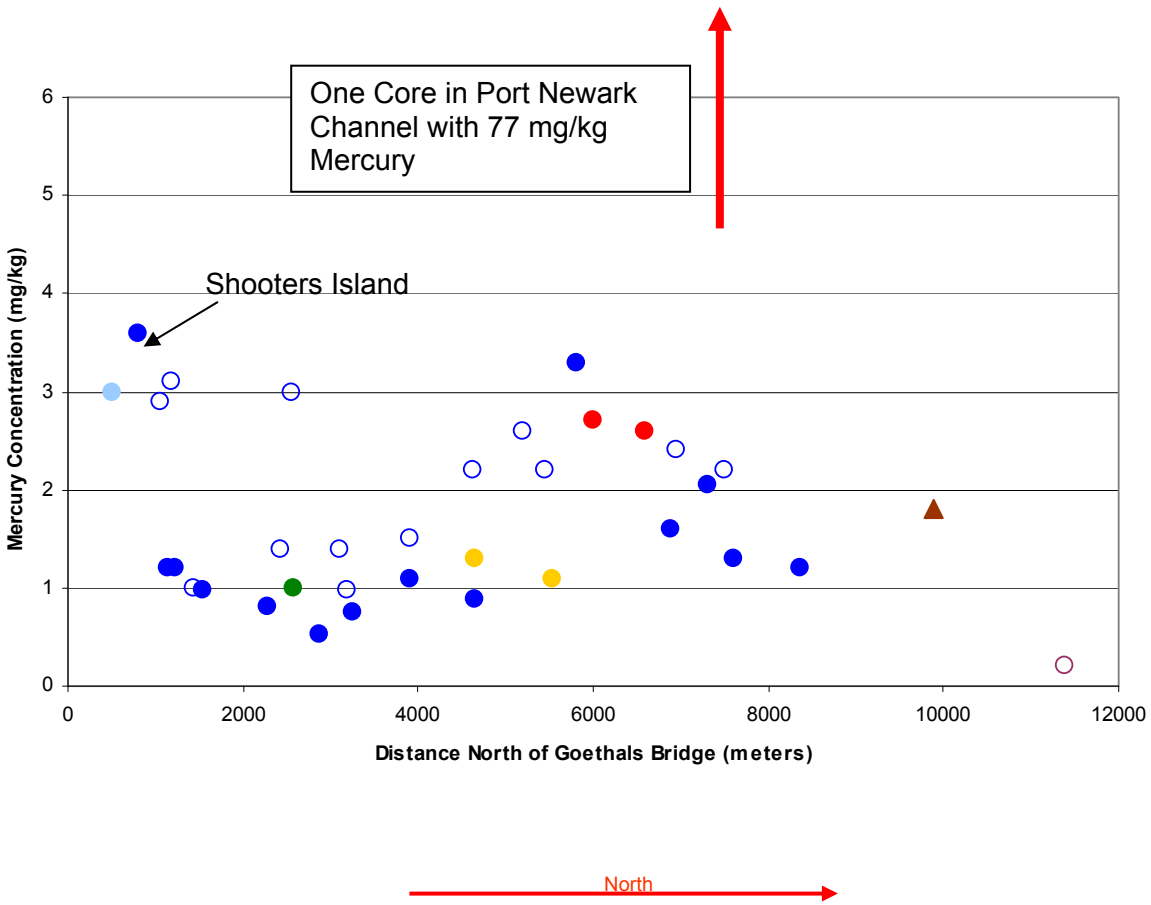
Lead Surface Sediment Concentrations at Depositional Locations
*Newark Bay*

Figure 13

**March 2007**

**Figure 13. Lead Surface Sediment Concentrations at Depositional Locations in Newark Bay**




**Colors Legend**

- Newark Bay
- Confluence of unnamed creek with Hackensack River
- Port Newark Channel
- Port Elizabeth Channel
- South Elizabeth Channel
- Arthur Kill
- Lower Passaic River (2005)

**Symbols Legend**

- Coring Locations in Navigation Channels
- Coring Locations outside Navigation Channels

**Notes:**

- Mercury surface concentrations represent the top 6 inches of the core.
- When duplicate mercury values are provided by the laboratory, the average mercury concentration is plotted.
- No nondetected mercury values were reported for the surface sediment.
- Mercury concentrations are plotted only for depositional environments, indicated by Beryllium-7 detections more than 0.5 pCi/g in the top inch of the core.
- Data Source: Malcolm Pirnie, Inc. High Resolution Sediment Core in the Lower Passaic River (RM 1.4). USEPA 2005-2006 Sampling Program.
- Data Source: Newark Bay Phase II RIWP (October 2006). Samples collected in October to December 2005.

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Mercury Surface Sediment Concentrations at Depositional Locations
*Newark Bay*

Figure 14

**March 2007**

**Figure 14. Mercury Surface Sediment Concentrations at Depositional Locations in Newark Bay**

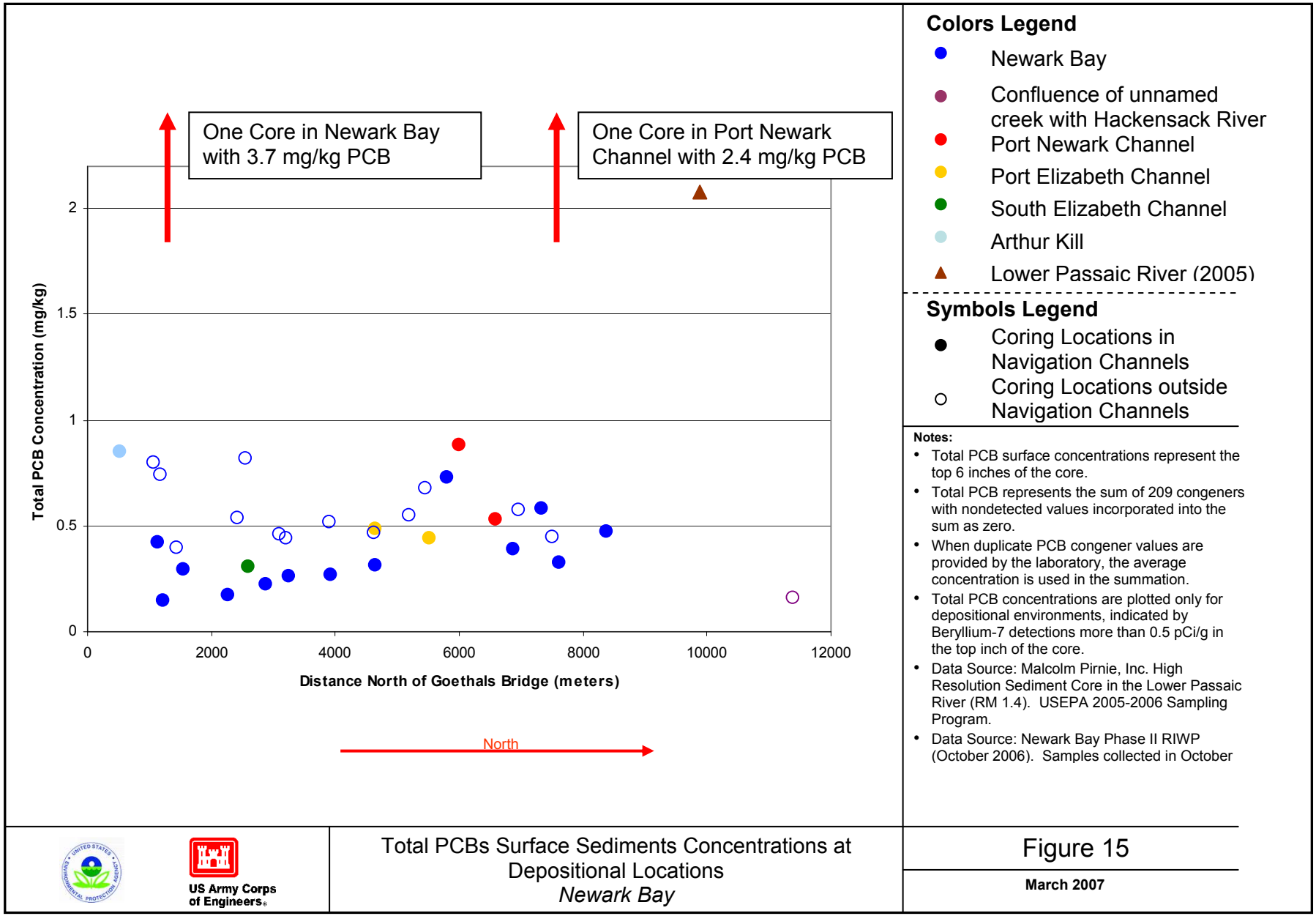


**Figure 15. Total PCBs Surface Sediment Concentrations at Depositional Locations in Newark Bay**

*PCB Source Analysis.* The distribution of total PCBs presented in Figure 15 shows the presence of at least two, and possibly several other source areas to and within Newark Bay, which are likely influencing surface sediment concentrations. These source areas include the Lower Passaic River, the port channels, and the southwestern area of Newark Bay near the Arthur Kill. Elevated concentrations of total PCBs continue to drive a concentration gradient in Newark Bay, with contaminant loading from the port channels heavily influencing surface sediment concentrations in the middle of the bay.

To summarize the CSM for Newark Bay:

- The Kill Van Kull and Arthur Kill contribute the largest share of solids to Newark Bay while the Lower Passaic River is the second largest source.
- Data indicate that the metals and PCB sources from the Arthur Kill are contributing to sediment contaminant concentrations in the southwestern portion of the bay.
- The Lower Passaic River contributes substantial loads of 2,3,7,8-TCDD, total PAHs, total PCBs, and mercury to the bay.
- Local sources of mercury and total PCBs in the bay are influencing sediment contaminant concentration in the vicinity of the port channels.
- The contributions from the Hackensack River are not well-characterized, although it is not believed that the river currently contributes a significant solids load to the bay. However, historically, the Hackensack River may have contributed more solids and contamination to the bay.

## 3.3 Ecotoxicity and Potential Receptors

An understanding of the contaminant mechanism of toxicity is necessary to evaluate the importance of potential exposure pathways (Section 3.4) and to focus the selection of assessment endpoints (Section 3.5). Furthermore, different contaminants have varying toxicological effects on different ecological receptors. Section 3.3.1 provides an ecotoxicological discussion of the major categories of COPECs with a focus on representative contaminants. It should be noted that this is not an all-inclusive discussion; a more expansive and detailed assessment of the COPEC ecotoxicology will be provided in the BERA. Section 3.3.2 discusses the types of ecological receptors likely to be exposed to contaminants in the NBSA.

### 3.3.1 Ecotoxicity

This section briefly summarizes the ecotoxicological properties of the main contaminant classes associated with NBSA environmental media. In addition, the ecotoxicity of certain individual COPECs is discussed (selected because they likely pose significant hazards to ecological receptors or because they are representative of the contaminant class).

***Metals***. Key factors that affect the partitioning and speciation, and thus the bioavailability, of sediment-associated metals include redox conditions, pH, porewater hardness, dissolved organic carbon (DOC), sediment organic carbon content and percent fines. These factors influence the oxidation state and the species of dissolved ions present. Metals exhibit a range of binding affinities with both organic and inorganic phases, resulting in varying concentrations of dissolved and particulate fractions. The total concentration of metals in sediments is generally not predictive of the bioavailability of trace metals. Concentrations of certain metals in porewater have been correlated with biological effects (DiToro *et al*., 1991). For several divalent metals, a key partitioning phase controlling cationic metal activity and toxicity in sediments appears to be acid volatile sulfides (AVS) (DiToro *et al*., 1990; 1991; Ankley *et al*., 1996). Simultaneously extracted metals (SEM) and AVS measurements can be made to assess the

potential bioavailability of SEM metals (including cadmium, copper, lead, nickel, and zinc). In general, the bioavailability of metals decreases as conditions become more reducing and pH, hardness, organic carbon, percent fines and AVS increases. Additional information on the ecotoxicity of specific individual metals is presented in the Passaic PAR (Battelle, 2006).

***Polycyclic Aromatic Hydrocarbons.*** PAHs are a group of ubiquitous chemicals that are a major component of petroleum products (*i.e.*, petrogenic) or are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances (*i.e.*, pyrogenic). There are more than 100 different PAHs, which generally occur as complex mixtures. Pyrogenically-derived PAHs mainly enter the environment as releases to air from volcanoes, forest fires, residential wood burning, and exhaust from automobiles and trucks. Petrogenically-derived PAHs are typically released as direct spills to surface water, soils, or sediments.

PAHs include some highly potent carcinogenic compounds that can produce tumors in some organisms at even single doses; however, other, non-cancer-causing effects are not well understood (Eisler, 1987). Their effects are wide-ranging within an organism, and effects have been found in many types of organisms, including non-human mammals, birds, invertebrates, plants, amphibians, fish, and humans. Because their effects are varied, generalizations cannot be readily made. Effects on benthic invertebrates include inhibited reproduction, delayed emergence, sediment avoidance, and mortality. Fish exposed to PAHs in sediment and surface water have exhibited fin erosion, liver abnormalities, cataracts, and immune system impairments leading to increased susceptibility to disease (Fabacher *et al*., 1991; Weeks and Warinner, 1984; 1986; O'Conner and Huggett, 1988; Payne *et al.*, 2003). Early mechanistic models categorized the effects of individual PAHs as either being receptor-mediated, with metabolites forming deoxyribonucleic acid (DNA) adducts, or generally narcotic in nature; however, recent studies suggest that the toxicology is more complicated (Incardona, *et al*., 2006).

Mammals can absorb PAHs by inhalation, dermal contact, or ingestion (Eisler, 1987). The oral toxicity of PAHs ranges from very toxic to moderately toxic in rats. In addition to tumor induction, other effects in mammals include adverse effects on reproduction, development, and immunity (Agency for Toxic Substances and Disease Registry [ATSDR], 1995). Although a large amount of literature on the effects of oil spills on birds is available, toxicity data for birds associated with the ingestion pathway are limited, and no PAH toxicity reference value (TRV) for this receptor group was developed. There are also limited mammalian data available for the 2- and 3-ring PAHs (which are not anticipated to be bioavailable to wildlife).

***Polychlorinated biphenyls.*** PCBs are mixtures of up to 209 individual chlorinated compounds (known as congeners). Some commercial PCB mixtures are known in the United States by their industrial trade name, Aroclor. Because they do not burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in 1977 because there was evidence that PCBs build up in the environment and may cause harmful effects. Once released into the environment, PCBs do not readily break down and therefore may remain for long periods of time, cycling between air, water, and soil. As a consequence, PCBs are found all over the world. The World Health Organization (WHO) has recognized 12 PCB congeners that are structurally similar to dioxins and have similar toxic effects.

In aquatic environments, PCBs are taken up into the bodies of benthic invertebrates and fish. They are also ingested by other animals that feed on these aquatic animals. PCBs bioaccumulate and bioconcentrate in fish and marine mammals (such as seals and whales), reaching levels that may be many thousands of times higher than in water.

Animals exposed to PCBs show various kinds of health effects, including anemia, acne-like skin conditions, as well as liver, stomach, and thyroid gland injuries (ATSDR, 2000). Other effects include reductions in the immune system function, behavioral alterations, and impaired reproduction (ATSDR, 2000). Some PCBs can mimic or block the action of hormones from the thyroid and other endocrine glands. Because hormones influence the normal functioning of many organs, some of the effects of PCBs may result from endocrine changes. While ingestion is the primary exposure pathway, inhalation and dermal exposure to PCBs may cause liver, kidney, and skin damage in animals (ATSDR, 2000).

***Pesticides***. Organochlorine pesticides include the chlorinated ethane derivatives such as DDT; cyclodiene compounds, which include chlordane, aldrin, dieldrin, heptachlor, endrin, and toxaphene; and hexachlorocyclohexanes, such as lindane. These compounds are very persistent in the environment and possess a strong tendency to accumulate in biological tissue. Organochlorine pesticides exhibit a wide range of acute toxicities. The target loci of primary toxic action of at least some organochlorine pesticides are believed to be sensory and motor neurons and the motor cortex of vertebrates (Klaassen *et al*., 1986). The organochlorine compounds DDT and dieldrin are often detected at environmental concentrations that pose a hazard to ecological receptors.

DDT and its primary metabolites (dichlorodiphenyldichloroethane [DDD] and dichlorodiphenyldichloroethylene [DDE]) are manufactured organochloride pesticides collectively referred to as DDx. DDT use in the United States was banned in 1972, but it was still manufactured for export until the mid-1980s. DDT is a broad-spectrum insecticide that was very popular due its effectiveness, long residual persistence, low acute mammalian toxicity, and low cost. DDT has been widely used to control insects on agricultural crops such as peanuts, soybeans, and cotton; it also was sprayed to decrease the incidence and spread of diseases such as malaria by controlling mosquitoes.

Upon introduction into the environment, DDT enters soil, water, or air. DDT and its metabolites are strongly adsorbed onto particulates in water and settle into sediments, where they become essentially immobile. DDT is highly toxic to aquatic life, including both invertebrates (crustaceans) and vertebrates (fish, shorebirds). Furthermore, DDT and its analogues accumulate in lipid tissues of fish and other organisms, and subsequently bioconcentrate up the food chain.

The best known effect of DDT toxicity is impairment of nerve impulse conduction. Effects of DDT on the nervous system have been observed in animals and can vary from mildly altered sensations to tremors and convulsions. Death in animals following high exposure to DDT is usually caused by respiratory arrest. In addition to being a neurotoxicant, DDT is capable of inducing marked alterations on reproduction and development, which is attributed to hormone-altering actions of DDT isomers and/or its metabolites (ATSDR, 2002a). Eggshell thinning in upper-trophic-level birds is believed to have resulted in population crashes of raptors in the 1960s and 1970s. Due to the ban on the production and use of DDT in the United States and other parts of the world, exposures of wildlife have been declining since the early 1970s, as evidenced by marked decreases in the levels of DDT compounds in fish, shellfish, aquatic mammals, and birds (ATSDR, 2002a).

The well-publicized decline in wild raptor populations, including the bald eagle, during the 1950s and 1960s was attributed partly to reproductive impairment, particularly eggshell thinning. Egg production, fertility, and hatchability were largely unaffected in numerous studies in a variety of bird species. However, increased embryolethality, decreased egg size, delayed oviposition after mating, and increased testicular effects were observed with some regularity among experimental studies in birds. Several authors speculated that the effects were due to DDT-induced hormonal imbalances. In fact, blood hormone levels of estrogen and luteinizing hormone were altered in three of four studies in birds consuming either DDT or DDE in the diet (ATSDR, 2002a).

Dieldrin and aldrin are structurally similar to each other, and aldrin readily converts to dieldrin once it enters the environment or is ingested or inhaled by organisms. These compounds are discussed together because both are COPECs for the LPRRP. Dieldrin is an organochloride pesticide, belonging to the cyclodiene group of pesticides that also includes endrin, endosulfan, and aldrin. Dieldrin is no longer produced or used, but it was once used extensively to kill insects on crops such as corn and cotton and to control termites. Aldrin is a more effective pesticide than dieldrin and therefore was more extensively used as a soil insecticide (ATSDR, 2002b).

Many species of aquatic invertebrates concentrate dieldrin from very low water concentrations, yielding high concentration factors. The bioconcentration of dieldrin in aquatic organisms is principally from water rather than ingestion of contaminated food. Aldrin and dieldrin are both highly toxic to aquatic crustaceans and fish. Effects on mammals include liver damage, central nervous system effects, and suppression of the immune system. Dieldrin and aldrin also disrupt the endocrine and reproductive systems (ATSDR, 2002a).

***2,3,7,8-TCDD.*** 2,3,7,8-TCDD belongs to a class of compounds known as chlorinated dibenzodioxins. These compounds are ubiquitous in the environment as a result of various industrial processes (*e.g.,* solid waste incineration; the production, use, and disposal of pesticides and PCBs; the bleaching process for paper manufacturing; and the production and recycling of metals). Dioxins are usually generated concurrently with other chemicals known as chlorinated dibenzofurans; both of these classes of compounds are highly persistent and have been detected in all environmental media (*i.e*., air, water, soil, animal tissue).

Laboratory toxicity data show that fish are generally more sensitive to TCDD than plants, aquatic invertebrates, and other aquatic vertebrates (*e.g.,* amphibians) (USEPA, 1993). The high lipid content in fish makes them highly susceptible to bioaccumulation of TCDD in their tissues, which can essentially be transferred up the food chain to higher-trophic-level organisms, such as birds and mammals (including humans). Effects of TCDD exposure to mammals and birds are similar to fish and include delayed mortality, a "wasting" syndrome characterized by reduced food intake and reduced body weight, reproductive toxicity, histopathological alterations, developmental abnormalities, and immunosupression (USEPA, 1993).

### 3.3.2 Receptors of Concern

The selection of ROCs for evaluation in the ecological risk assessment was presented in the PAR (Battelle, 2006) based on a review of available habitat and biota surveys, including those summarized in the NBSA Phase I RIWP (Tierra, 2004). These potential receptors are listed in Table 2. Previous studies (*e.g.,* ChemRisk, 1995c) did not identify any state or federal rare, threatened, or endangered (T&E) species inhabiting the lower portion of the Passaic River. It is also unlikely that there are any T&E species in the NBSA, however, their presence or absence at this point in time is uncertain. In the absence of such data, the receptor groups listed below include a discussion of potential T&E species that may be present.

*Benthic Macroinvertebrates*. The benthic macroinvertebrate community of the NBSA is dominated by polychaete worms (*e.g.*, *Streblospio benedicti*, *Sabellaria vulgaris*, and *Scoloplos* sp.). Dominant epibenthic species include shrimp species and blue crabs (Tierra, 2004), which are omnivorous benthic crustaceans that consume plankton, invertebrates and small fish and are in direct contact with contaminated sediments. Because of its exposure to contaminated sediment in the NBSA, the blue crab has been identified as a ROC. In addition, bivalve mollusk populations such as the blue mussel (*Mytilus edulis*), soft-shelled clam (*Mya arenaria),* and oyster (*Crassostrea virginica*) that serve as food for upper trophic-level wildlife were also selected as a receptor group.

*Fish*. Based on studies compiled and reviewed by Tierra (2004), the following fish species have been identified as preliminary ROCs for future evaluations of ecological risk: mummichog (*Fundulus heteroclitus*), American eel (*Anguilla rostrata*), striped bass (*Morone saxatilis*), winter flounder (*Pleuronectes americanus*), white perch (*Morone americana*), and Atlantic menhaden (*Brevoortia tyrannus*). These species represent a variety of habitat preferences and life histories that allow assessment of a wide range of exposure scenarios, including exposures to upper-trophic level consumers such as piscivorous birds and mammals. In addition, many of these pelagic fish (*e.g.,* white perch, mummichog) are in direct contact with bottom sediments during foraging and nesting/egg laying.

*Birds.* Although high-quality nesting and foraging areas are limited in extent throughout the NBSA, a Tierra study conducted by BBL (2002) confirms the presence of avian species for which complete exposure pathways to sediment contaminants likely exist. Bird species with the greatest potential exposure to site COPECs are sediment probing and wading birds, those with limited foraging ranges (*i.e.*, a large percentage of their foraging time is spent within the NBSA), and those that feed on prey items with small home ranges. The last of these classifications is important because it suggests that even bird species that do not forage within the NBSA for a majority of their food may have significant exposure to site COPECs bioaccumulated by resident prey species. Although the piscivorous bird species identified as ROCs for the NBSA have substantial foraging ranges, biological survey data available for Newark Bay suggest that small fish species with limited home ranges, such as the mummichog, also comprise a significant portion of the prey consumed from Newark Bay (BBL, 2002).

Based on a review of the avian survey data available for the NBSA (BBL, 2002), it is recommended that the following species be included in the list of ROCs for evaluations of ecological risk (Table 2): black-crowned night-heron (*Nycticorax nycticorax*), double-crested cormorant (*Phalacrocorax auritus*), great egret (*Ardea alba*), belted kingfisher (*Megaceryle alcyon*), herring gull (*Larus argentatus*), spotted sandpiper (*Actitis macularia*), and a dabbling duck or goose species (*e.g.*, mallard [*Anas platyrhynchos*] or Canada goose [*Branta Canadensis*]). These species were selected because they are commonly present in the study area and possess life histories (*e.g.*, foraging behavior and prey consumption) that maximize their potential exposure to contaminants in sediment and biota. Specifically, all of these species feed on forage fish and/or sediment invertebrates. Direct and potentially significant exposure to sediment contaminants is another complete exposure pathway, particularly for ducks and geese whose foraging activities include mucking and probing for sediment-dwelling organisms and plants. Although their presence in the NBSA is currently unknown, both the yellow- and black-crowned night-herons are listed as T&E species by the State of New Jersey and are included as ROCs.

*Mammals*. As with birds, mammals with the greatest potential exposure to site COPECs are those species whose foraging behavior involves direct exposure to surface and subsurface sediments, species with limited foraging ranges (*i.e.*, a large percentage of their foraging time is spent within the site), and species that feed on prey specimens with small home ranges. Mammalian wildlife species that could be exposed to contaminants in the NBSA include both piscivorous (*e.g.*, harbor seal [*Phoca vitulina*], porpoise [*Phocoena phocoena*], river otter [*Lontra canadensis*]) and omnivorous (*e.g.*, raccoon [*Procyon lotor*]) species.

The harbor porpoise, while not listed in the United States as threatened or endangered, is designated as a strategic stock under the U.S. Marine Mammal Protection Act (MMPA) because direct human-caused mortality exceeds the potential biological removal level. Three endangered marine mammals have been identified by the National Marine Fisheries Service (NMFS) as occurring within the project area. These include the northern right whale (*Eubalaena glacialis)*, the humpback whale (*Megaptera novaeangliae*), and the finback whale (*Balaenoptera physalus*) (NMFS, 1999). These migratory species use the harbor in transit to other habitat areas and have been recorded in the Lower New York Bay area, although some

individuals have been documented as far up the Hudson River as the Troy Dam. There is no recent documentation of these species in Newark Bay.

These mammalian species are potential ROCs because their life histories suggest that if present, they will be exposed directly to COPECs via ingestion of prey and sediment. Dermal exposure to site COPECs in estuarine and marshland sediments may also occur, although exposure through this route is expected to be *de minimus* relative to ingestion and is not quantified.

*Reptiles*. Field survey data are not available at this time to determine the presence of reptiles (*e.g.,* diamondback terrapin) in the study area; however, if present, they are likely to be transient and therefore are not considered in the SLERA. If diamond-backed terrapins are observed more frequently during additional fieldwork, they will be addressed qualitatively in future assessments. An ongoing study of marine turtle occurrence has documented little recent evidence of marine turtle presence in the New York and New Jersey Harbor. Four species of marine turtles—loggerhead (*Caretta caretta*), green (*Chelonias mydas*), leatherback (*Dermochelys coriacea*), and Atlantic (Kemp's) ridley (*Lepidochelys kempii*)—regularly occur in the New York Bight, including the New York/New Jersey Harbor complex. Juveniles of Atlantic ridley and larger age classes of loggerhead have been reported during the summer and fall, with other species of sea turtles occasionally entering the higher-salinity regions.

**Table 2. Receptors of Concern**

| Receptor | Exposure Media | Rationale for Selection of Receptor and Pathway |
|---|---|---|
| **Benthic Invertebrates** | | |
| Blue crab | Sediment/surface water/biota | Epibenthic omnivorous invertebrate that consumes plankton and small fish and comes into direct contact with contaminated sediments. |
| Benthic macroinvertebrate community | Sediment/surface water/biota | Various benthic invertebrate populations representing different trophic levels that are in intimate contact with contaminated sediments. |
| Mollusk populations | Sediment/surface water | Residential mollusks that have the potential to accumulate contaminants from the water column and are preyed upon by upper-trophic-level wildlife. |
| **Fish** | | |
| Mummichog | Sediment/surface water/biota | Resident planktivorous estuarine forage species. |
| American eel | Sediment/surface water/biota | Seasonal predatory, catadromous species that consumes small fish. |
| Winter flounder | Sediment/surface water/biota | Migratory benthic predator species; sport fish. |
| Striped bass | Surface water/biota | Dominant migrant predatory species that has sensitive early-life stages; sport fish. |
| White perch | Sediment/surface water/biota | Resident omnivore species; juveniles are important prey to commercially significant species. |
| Atlantic menhaden | Sediment/surface water/biota | Migratory detritivore/omnivore; important forage fish species. |
| **Piscivorous Birds** | | |
| Belted kingfisher | Sediment/surface water/biota | Piscivorous bird potentially present. |
| **Omnivorous Birds** | | |
| Ducks/geese (*e.g.*, Mallard duck) | Sediment/surface water/biota | Omnivorous avian species that inhabit wetlands, marshes, and other aquatic sites throughout their lifetime. |
| Yellow and black-crowned night-heron | Sediment/surface water/biota | NJ State T&E species; wading bird. |
| Herring gull | Sediment/surface water/biota | Omnivorous, opportunistic bird potentially present in large numbers. |
| Great egret | Sediment/surface water/biota | Bird potentially present in large numbers. |
| **Benthivorous Birds** | | |
| Spotted sandpiper | Sediment/surface water/biota | Wading, benthivorous bird that probes the sediment in search of invertebrates and small fish. |
| **Mammals** | | |
| Raccoon | Sediment/surface water/biota | Omnivorous, opportunistic mammal that consumes a variety of food, including benthic invertebrates and fish. |
| Otter | Surface water/biota | Piscivorous mammal whose diet consists entirely of fish. |

## 3.4 Complete Exposure Pathways

In general, an exposure pathway describes the route(s) a chemical takes from its source to a ROC. An exposure pathway analysis links the source, location, type of environmental release, and media affected with receptor population, location, and activity patterns to determine the primary means of potential exposure. Exposure pathways are completed by one of three exposure routes: ingestion, inhalation or dermal contact. If potentially complete and significant exposure pathways exist between COPECs and ROCs, an assessment of potential exposures and effects is conducted. Only those potentially complete exposure pathways likely to contribute significantly to the total exposure are quantitatively evaluated. All other potentially complete exposure pathways that result in minor exposures or for which there are no exposure models or insufficient toxicity data (*e.g.*, dermal contact with contaminated media) are not quantitatively evaluated in this SLERA.

An exposure pathway is considered complete if all four of the following elements are present (USEPA, 1997):

1. A source and mechanism of chemical release to the environment.
2. An environmental retention or transport medium (*e.g.*, water or sediment) for the released chemical.
3. A point of potential physical contact of a receptor with the contaminated medium (exposure point).
4. An exposure route (*e.g.*, ingestion of contaminated prey, incidental ingestion of sediment).

In the absence of links between each of these elements, a complete exposure pathway cannot exist, and no risk to ecological receptors is possible. A CSM provides the logical framework to identify complete exposure pathways. Thus, a primary function of the CSM is to define the media of concern and the ecological receptors with the greatest risk of exposure at the site.

The ecological CSM for the NBSA is presented in Figure 6. Potential historical sources of contamination include a large number of both point and non-point sources that discharged directly into the surface waters of the NBSA. Following discharge, contaminants can partition by becoming attached to sediment or they can remain suspended (or dissolved) in the water column. Contaminants enter the food web via accumulation in tissues of biota exposed directly to contaminants in the water column, in sediments, and/or in the tissues of prey items. Therefore, the media of concern are surface water, sediment, and the tissues of prey species. For the purpose of this SLERA, the existing sediment and tissue data were deemed adequate to identify chemical stressors to ecological receptors. An assessment of surface water could not be performed, however, due to the lack of reliable surface water data in the database. A range of ecological receptors potentially at risk from exposures to contaminated media was identified, including benthic invertebrates, fish, and a variety of piscivorous or aquatic avian and mammalian predatory species.

Chemical and physical properties of COPECs are important considerations in exposure pathway analysis because they are a primary determinant of whether a COPEC detected in site media is likely to pose a risk to ROCs. For example, the physicochemical properties of PCBs, PAHs, dioxins/furans, most metals, and SVOCs suggest that if these chemicals are detected in site media, receptors exposed to these media will likely be exposed to the chemical (*i.e.*, the exposure pathway is complete). Receptor exposure to VOCs, particularly in aquatic ecosystems, is generally considered *de minimis*, except in cases where extremely high concentrations are present, because VOCs generally dissipate readily. Because detected concentrations of VOCs in the NBSA are generally low (Tierra, 2006a) and these constituents do not bioaccumulate, VOC exposures to ecological receptors are considered minor and are not assessed in this risk assessment.

Dermal exposure to sediment contaminants for birds and mammals, although likely to occur, is considered to be *de minimis* in nature. Although established methods are available to assess dermal exposure to humans, limited data are available to quantitatively assess dermal exposure to wildlife. In addition, the presence of feathers and fur, along with grooming and preening activities, reduces sediment contact with skin.

The inhalation exposure route also will not be addressed in the SLERA. Exposure via inhalation of airborne contaminants is relatively minor and insignificant relative to other exposure routes. Furthermore, toxicity data for this exposure route are limited and the data that are available pertain primarily to human receptors. Based on a review of major exposure pathways, the three significant and complete exposure routes for higher-trophic-level organisms are associated with the ingestion of contaminated prey and direct/incidental ingestion of sediment. For risk assessment purposes, these are considered the primary routes of exposures for mammals and birds in the NBSA.

## 3.5 Assessment and Measurement Endpoints

The CSM also serves as the basis for identification of risk assessment endpoints (AEs). AEs are defined by USEPA (1997) as formal expressions of the actual environmental values that are to be protected at a site. AEs are required in Step 2 of USEPA Guidance and provide the basis for evaluating the screening-level risk characterization. AEs are defined based on technical considerations, including the significance of exposure pathways, the presence of ROCs, and a COPEC's biotic transfer pathway. Selection of AEs for use in the risk assessment must consider the ecosystems, communities, and species relevant to a particular site. The selection of AEs depends on:

1. The chemicals present and their concentration.
2. Media contaminated as a result of chemical releases.
3. Mechanisms of toxicity of the chemicals to different groups of organisms.
4. Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the chemicals.
5. Potentially complete exposure pathways.

The AEs for quantitative evaluation in this SLERA are based on protection of the most sensitive environmental resources identified at the site (*e.g.,* protection of the benthic-feeding and piscivorous avian and mammalian communities that may use the site) and the primary potentially complete exposure pathways identified. Receptors in other guilds (*e.g.*, sediment-dwelling organisms, fish, reptiles/amphibians) may also come into direct contact with site contaminants and, therefore, are also considered ROCs. The avian benthic-feeding and piscivorous guild is likely to have the highest potential for exposure to site contaminants potentially found in sediment and prey items, and has been selected to provide an upper-bound risk estimate that is protective of other guilds that are less exposed.

At the screening level, risks to these various guilds are evaluated generally and collectively for different levels of biological organization. The AEs for the NBSA SLERA are as follows:

- AE(1): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of benthic invertebrate communities that also serve as a forage base for fish and wildlife populations.
- AE(2): Protection and maintenance (*i.e.,* survival, growth, and reproduction) of healthy populations of crustaceans that also serve as a forage base for fish and wildlife populations.
- AE(3): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of healthy populations of mollusks that also serve as a forage base for fish and wildlife populations.

- AE(4): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of healthy fish populations that also serve as a forage base for fish and wildlife populations.
- AE(5): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of omnivorous wildlife (*i.e.*, birds and mammals).
- AE(6): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of piscivorous wildlife (*i.e.,* birds and mammals).

Assessment endpoints have corresponding measurement endpoints (MEs) that provide a means of determining whether ROCs are at risk from exposure to site-related contaminants. Measurement endpoints are measures of potential effects. Because effects cannot be measured for all ROCs, surrogate receptors are selected to represent the receptor potentially at risk. The MEs that are evaluated in this SLERA for each individual AE are discussed below:

**AE(1): Protection and maintenance (*i.e.,* survival, growth, and reproduction) of benthic invertebrate communities that also serve as a forage base for fish and wildlife populations.**

- ME(1A): Compare benthic invertebrate COPEC tissue concentrations to relevant toxicity-based critical body residue (CBR) values.
- ME (1B): Compare sediment COPEC concentrations to relevant toxicity-based screening values.

**AE(2): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of healthy populations of crustaceans that also serve as a forage base for fish and wildlife populations.**

- ME(2A): Compare sediment COPEC concentrations to relevant toxicity-based screening values.
- ME(2B): Compare crustacean COPEC tissue concentrations to relevant toxicity-based CBR values.

**AE(3): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of healthy populations of mollusks that also serve as a forage base for fish and wildlife populations.**

- ME(3A): Compare sediment COPEC concentrations to relevant toxicity-based screening values.
- ME(3B): Compare mollusk COPEC tissue concentrations to relevant toxicity-based CBR values.

**AE(4): Protection and maintenance (*i.e.,* survival, growth, and reproduction) of healthy fish populations that also serve as a forage base for fish and wildlife populations**.

- ME(4A): Compare measured concentrations or toxic equivalencies in fish tissue (including eggs) to relevant toxicity-based CBR values.

**AE(5): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of omnivorous wildlife (*i.e.*, birds and mammals).**

Potential exposure to omnivorous wildlife receptors (*e.g.*, mallard duck and raccoon) is evaluated by modeling the daily dose to these organisms associated with ingestion of COPECs in sediment and prey items. Potential risk is characterized by comparing the species-specific modeled dose estimates to TRVs or similar appropriate descriptors of threshold toxicity. Measurement endpoints include:

- ME(5A): Compare modeled dietary doses of COPECs for the mallard duck with relevant TRVs.
- ME(5B): Compare modeled dietary doses of COPECs for the raccoon with relevant TRVs.

**AE(6): Protection and maintenance (*i.e.*, survival, growth, and reproduction) of piscivorous wildlife (*i.e.,* birds and mammals).**

Potential exposure to piscivorous wildlife receptors (*e.g.*, belted kingfisher and otter) is evaluated by modeling the daily dose to these organisms associated with ingestion of COPECs in sediment and prey items. Potential risk is characterized by comparing the species-specific modeled dose estimates to TRVs or similar appropriate descriptors of threshold toxicity. Measurement endpoints include:

- ME(6A): Compare modeled dietary doses of COPECs for the belted kingfisher with relevant TRVs.
- ME(6B): Compare modeled dietary doses of COPECs for the river otter with relevant TRVs.

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# 4.0 SCREENING-LEVEL EFFECTS EVALUATION AND EXPOSURE ESTIMATE

The effects evaluation and exposure analysis of the SLERA are discussed in this section. The effects evaluation of a SLERA focuses on establishing conservative thresholds that are potentially indicative of ecological effects. This is accomplished by compiling existing benchmarks and deriving, where necessary, appropriate screening benchmarks. The exposure analysis consists of determining the maximum documented exposure concentration for each environmental exposure medium (*i.e.*, sediment and biological tissue). The following sections describe this analysis in the context of the COPEC screening process. Through this process, the maximum media concentrations (exposure point concentration [EPC]) is compared to the appropriate ecotoxicity threshold values to evaluate ecological effects and either eliminate COPECs from further evaluation or identify contaminants that may require additional evaluation in a BERA.

## 4.1 Effects Evaluation (Ecological Screening Benchmarks)

The effects evaluation for a SLERA is generally based on a comparison of EPCs with ecological screening benchmarks. These screening benchmarks represent exposure concentrations above which there is a potential for adverse ecological effects. Because effects concentrations are variable for different receptors, populations and individuals, these are usually conservative values and are used for comparison to reduce the potential for overlooking risks at the early stages of the risk assessment process.

In general, the invertebrate benchmarks employed in the screening analysis are not specific to any one species (although a receptor- and site-specific benchmark for oysters was utilized). As a result, the analytical results are intended to apply to the broad community category of invertebrate organisms that are intimately associated with NBSA sediments. The blue crab is referred to specifically because of the availability of a large tissue dataset for this species.

Ecological screening benchmarks were derived for each distinct environmental media (sediment and biological tissue) and for the relevant exposure pathways as discussed in Section 3.0. For those contaminants that are considered bioaccumulative by USEPA (2000), wildlife protective concentration levels (PCLs) were calculated for sediment and tissue. These wildlife PCLs are back-calculated sediment and tissue concentrations that were derived using conservative exposure assumptions so as to be protective of bioaccumulative hazards to upper trophic level receptors. In addition, for the tissue screen, available critical body residue (CBR) values were also used. The process is discussed in detail below.

### 4.1.1 Sediment

Both the NJDEP and the NYSDEC provide guidance and recommended benchmarks for conducting ecological screening analysis of sediments (NJDEP, 1998; NYSDEC, 1999) based on direct contact exposures to benthic organisms. NOAA screening values (Long *et al.*, 1995) are key guidelines for screening sediments under both NJDEP and NYSDEC guidance. These benchmarks include Effects Range-Low (ER-L) values that represent a concentration at which adverse benthic effects were observed in approximately 10% of the studies evaluated by Long *et al.* (1995). Effects Range-Median (ER-M) values represent a sediment concentration above which a greater than 50% incidence of adverse effects to sensitive organisms is anticipated. To be as conservative as possible in the SLERA, the ER-L values were selected over the ER-M values for the COPEC screening process. In addition, both NYSDEC and NJDEP recommend saltwater equilibrium-partitioning-based values for non-polar organic compounds lacking ER-Ls, such as benzene, ethylbenzene, tetrachloroethylene, toluene, trichloroethylene, and xylene (NYSDEC, 1999; MacDonald *et al.,* 1992).

Wildlife PCLs were also calculated to ensure that the contaminant screen evaluated the bioaccumulative exposure pathway. Equation 1 was used to estimate PCLs for piscivorous wildlife receptors in the NBSA. The river otter (*Lutra canadensis*) and belted kingfisher (*Ceryle alcyon*) were selected as the model receptors due to their relatively large dietary exposures to sediment-associated chemicals that can bioaccumulate in biological tissue, which ensures that the COPEC process is conservative. Although commonly called a "river otter", *L. canadensis* inhabits marine as well as freshwater environments. Some populations permanently reside in marine shoreline habitats, and are often mistaken for sea otters. The belted kingfisher was selected as a ROC because it is a diving bird that consumes mainly fish tissue. Other avian receptors, such as the great blue heron (used as a receptor for the Lower Passaic River Focused Feasibility Study [Battelle, 2007]), are wading birds and therefore are less likely to forage in Newark Bay than in the Passaic River.

Exposure parameters for the otter and belted kingfisher are summarized in Table 3.

$$PCL_{sed} = \frac{THQ * TRV * BW}{\left(BAF_{fish} * IR_{fish} * P_{fish} * SFF\right)} \qquad \text{Equation 1}$$

*where*:

| | | |
|---|---|---|
| $PCL_{sed}$ | = | Protective Concentration Level for sediment (protective of bioaccumulation hazards associated with the fish consumption pathway [µg COPEC/g sediment]). |
| THQ | = | Target Hazard Quotient for the COPEC based on tissue residue effects (unitless); a THQ of 1.0 was used. |
| TRV | = | Toxicity Reference Value. Receptor-specific literature-based toxicity threshold value. No- and Lowest-Observed Adverse Effect Level (NOAEL and LOAEL, respectively)-based TRV values are presented in Attachment B. The maximum allowable toxicant concentration (MATC)-based TRV is the geometric mean of the NOAEL- and LOAEL-based values (µg COPEC/g-day). |
| BW | = | Receptor body weights (kg) (summarized in Attachment B). |
| $BAF_{fish}$ | = | Bioaccumulation Factor between sediment and fish prey consumed by the receptor (µg COPEC in fish tissue [wet weight]/µg COPEC sediment [dry weight]). |
| $IR_{fish}$ | = | Daily fish ingestion rate (kg fish consumed per day). |
| $P_{fish}$ | = | Percentage of fish in the diet. |
| SFF | = | Site Foraging Frequency (unitless); fraction of time receptor is assumed to forage at the site. |

**Table 3. Summary of Exposure Parameters Used to Develop PCLs**

| Parameter | Value | Units | Reference |
|---|---|---|---|
| $PCL_{sed}$ | Calculated using Equation 1 | µg COPEC/g sediment | Calculation |
| $PCL_{biota}$ | Calculated using Equation 2 | µg COPEC/g biota | Calculation |
| THQ | 1 | unitless | Assumption |
| TRV | Chemical-specific | µg COPEC/g-day | See Attachments B and C |
| BW | 7.4 (otter) | kg | USEPA, 1993 |
| | 0.136 (kingfisher) | | USEPA, 1993; Brooks and Davis, 1987 |
| $BAF_{fish}$ | Chemical-specific | µg COPEC fish (wet weight)/µg COPEC sediment (dry weight) | See Attachments B and C |
| $IR_{fish}$ | 0.4 (otter) | kg/day | USEPA, 1993 |
| | 0.068 (kingfisher) | | USEPA, 1993; Alexander, 1977 |
| $P_{fish}$ | 100 | % | Assumption |
| SFF | 1 | unitless | Assumption |

Chemical-specific TRVs and BAFs are presented in Table B-1 (Attachment B), and the calculated PCLs for both receptors are provided in Table B-2. For each chemical, the lower of the two PCL values was identified as the wildlife PCL and used in the screening evaluation. Note that there are relatively few TRVs for avian receptors; consequently, for some COPECs, the wildlife value is based solely on the mammalian PCL.

Table 4 summarizes the available sediment screening values, including both direct contact (*i.e.*, sediment benchmarks) and bioaccumulation hazard-based values (*i.e.*, PCLs) and identifies the sediment benchmarks selected for each analyte to conduct the COPEC for this medium. In many cases, wildlife PCLs are lower than the sediment benchmarks because sediment benchmarks are protective of benthic invertebrates without consideration of bioaccumulation, while PCLs are protective of bioaccumulative hazards to higher trophic level receptors. For all analytes, the lowest of the sediment screening values was used in the assessment, as well as the wildlife PCL.

## Table 4. Sediment Screening Values

| Chemical[a] | Marine/Estuarine Values | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | |
| **Inorganics (ppb)** | | | | | | | | | | |
| Aluminum | - | | - | | - | | - | | N | |
| Antimony | - | | - | | 2,000 | 4 | 2,000 | NYSDEC | N | |
| Arsenic | 8,200 | | 8,200 | | 8,200 | | 8,200 | NOAA ER-L | Y | 173,228 |
| Barium | - | | - | | - | | - | | N | |
| Beryllium | - | | - | | - | | - | | N | |
| Cadmium | 1,200 | | 1,200 | | 1,200 | | 1,200 | NOAA ER-L | Y | 3,974 |
| Calcium | - | | - | | - | | - | | N | |
| Chromium | 81,000 | | 81,000 | | 81,000 | | 81,000 | NOAA ER-L | Y | 368 |
| Cobalt | - | | - | | - | | - | | N | |
| Copper | 34,000 | | 34,000 | | 34,000 | | 34,000 | NOAA ER-L | Y | 297 |
| Cyanide | - | | - | | - | | - | | N | |
| Iron | - | | - | | 20,000,000 | 3 | 20,000,000 | NYSDEC | N | |
| Lead | 46,700 | | 47,000 | | 46,700 | | 46,700 | NOAA ER-L | Y | 10,606 |
| Magnesium | - | | - | | - | | - | | N | |
| Manganese | - | | - | | 460,000 | 3 | 460,000 | NYSDEC | N | |
| Mercury | 150 | | 150 | | 150 | | 150 | NOAA ER-L | Y | 42 |
| Nickel | 20,900 | | 21,000 | | 20,900 | | 20,900 | NOAA ER-L | Y | 3,791 |
| Potassium | - | | - | | - | | - | | N | |
| Selenium | - | | - | | - | | - | | Y | 925 |
| Silver | 1,000 | | 1,000 | | 1,000 | | 1,000 | NOAA ER-L | Y | 569,210 |
| Silicon | - | | - | | - | | - | | N | |
| Sodium | - | | - | | - | | - | | N | |
| Thallium | - | | - | | - | | - | | N | |
| Tin | - | | - | | - | | - | | N | |
| Titanium | - | | - | | - | | - | | N | |
| Vanadium | - | | - | | - | | - | | N | |
| Zinc | 150,000 | | 150,000 | | 150,000 | | 150,000 | NOAA ER-L | Y | 487 |
| **VOCs (ppb)** | | | | | | | | | | |
| 1,1,1-Trichloroethane | - | | - | | - | | - | | N | |
| 1,1,2,2-Tetrachloroethane | - | | - | | - | | - | | N | |
| 1,1,2-Trichloroethane | - | | - | | - | | - | | N | |
| 1,1-Dichloroethene | - | | - | | - | | - | | N | |
| 1,1-Dichloroethane | - | | - | | - | | - | | N | |
| 1,2-Dichloroethane | - | | - | | - | | - | | N | |
| 1,2-Dichloroethylene | - | | - | | - | | - | | N | |
| 1,2-Dichloropropane | - | | - | | - | | - | | N | |
| 2-Hexanone | - | | - | | - | | - | | N | |
| 4-Methyl-2-Pentanone | - | | - | | - | | - | | N | |
| Acetone | - | | - | | - | | - | | N | |
| Benzene | - | | 340 | 2 | 260 | 5 | 260 | NYSDEC | N | |
| Bromoform | - | | - | | - | | - | | N | |
| Carbon Disulfide | - | | - | | - | | - | | N | |
| Carbon Tetrachloride | - | | - | | - | | - | | N | |
| Chlorobenzene | - | | - | | 35 | 5 | 35 | NYSDEC | N | |

## Table 4. Sediment Screening Values, continued

| Chemical[a] | Marine/Estuarine Values | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | |
| Chlorodibromomethane | - | | - | | - | | - | | N | |
| Chloroethane | - | | - | | - | | - | | N | |
| Chloroform | - | | - | | - | | - | | N | |
| cis-1,3-Dichloropropene | - | | - | | - | | - | | N | |
| Dichlorobromomethane | - | | - | | - | | - | | N | |
| Ethylbenzene | - | | 1,400 | 2 | 64 | 5 | 64 | NYSDEC | N | |
| Methyl Bromide | - | | - | | - | | - | | N | |
| Methyl Chloride | - | | - | | - | | - | | N | |
| Methylene Bromide | - | | - | | - | | - | | N | |
| Methylene Chloride | - | | - | | - | | - | | N | |
| Methyl Ethyl Ketone | - | | - | | - | | - | | N | |
| Styrene | - | | - | | - | | - | | N | |
| Tetrachloroethylene | - | | 450 | 2 | - | | 450 | NJDEP | N | |
| Toluene | - | | 2,500 | 2 | 450 | 5 | 450 | NYSDEC | N | |
| Total BTEX | - | | - | | - | | - | | N | |
| Trans-1,3-dichloropropene | - | | - | | - | | - | | N | |
| Trichloroethylene | - | | 1600 | 2 | - | | 1,600 | NJDEP | N | |
| Vinyl Chloride | - | | - | | - | | - | | N | |
| **SVOCs (Non-PAHs) (ppb)** | | | | | | | | | | |
| 2,2-oxybis(1-Chloropropane) | - | | - | | - | | - | | N | |
| 1,2-Dichlorobenzene | - | | - | | 120 | 5 | 120 | NYSDEC | Y | 2,746,538 |
| 1,3-Dichlorobenzene | - | | - | | 120 | 5 | 120 | NYSDEC | Y | 560,635 |
| 1,2,4-Trichlorobenzene | - | | - | | 910 | 5 | 910 | NYSDEC | Y | 3,845,153 |
| 2,4,5-Trichlorophenol | - | | - | | - | | - | | N | |
| 2,4,6-Trichlorophenol | - | | - | | - | | - | | N | |
| 2,4-Dichlorophenol | - | | - | | - | | - | | N | |
| 2,4-Dimethylphenol | - | | - | | - | | - | | N | |
| 2,4-Dinitrophenol | - | | - | | - | | - | | N | |
| 2,4-Dinitrotoluene | - | | - | | - | | - | | N | |
| 2,6/2,7-Dimethylnaphthalene | - | | - | | - | | - | | N | |
| 2,6-Dinitrotoluene | - | | - | | - | | - | | N | |
| 2-Chloronaphthalene | - | | - | | - | | - | | N | |
| 2-Chlorophenol | - | | - | | - | | - | | N | |
| 2-Methylphenol | - | | - | | - | | - | | N | |
| 2-Nitroanaline | - | | - | | - | | - | | N | |
| 2-Nitrophenol | - | | - | | - | | - | | N | |
| 3,3'-Dichlorobenzidine | - | | - | | - | | - | | N | |
| 3-Nitroaniline | - | | - | | - | | - | | N | |
| 3-Methylphenol/4-methylphenol | - | | - | | - | | - | | N | |
| 4-Bromophenyl Phenyl Ether | - | | - | | - | | - | | Y | 5,850,214 |
| 4-Chloroaniline | - | | - | | - | | - | | N | |
| 4-Chlorophenyl Phenyl Ether | - | | - | | - | | - | | Y | 73,676,722 |
| 4-Chloro-3-methylphenol | - | | - | | - | | - | | N | |
| 4-Methylphenol | - | | - | | - | | - | | N | |

## Table 4. Sediment Screening Values, continued

| Chemical[a] | Marine/Estuarine Values | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | |
| 4-Nitroaniline | - | | - | | - | | - | | N | |
| 4-Nitrophenol | - | | - | | - | | - | | N | |
| 4,6-Dinitro-2-Methylphenol | - | | - | | - | | - | | N | |
| Benzo(b)thiophene | - | | - | | - | | - | | N | |
| Bis(2-Chloroethoxy)methane | - | | - | | - | | - | | N | |
| Bis(2-Chloroethyl)ether | - | | - | | - | | - | | N | |
| Bis(2-Ethylhexyl)phthalate | - | | - | | 1,995 | 5 | 1,995 | NYSDEC | N | |
| Butyl Benzyl Phthalate | - | | - | | - | | - | | N | |
| Carbazole | - | | - | | - | | - | | N | |
| Dacthal | - | | - | | - | | - | | N | |
| Dibenzofuran | - | | - | | - | | - | | N | |
| Dibenzothiophene | - | | - | | - | | - | | N | |
| Dibutyltin | - | | - | | - | | - | | Y | 3,583 |
| Diethyl Phthalate | - | | - | | - | | - | | N | |
| Dimethylphthalate | - | | - | | - | | - | | N | |
| Di-n-butyl Phthalate | - | | - | | - | | - | | N | |
| Di-n-Octyl Phthalate | - | | - | | - | | - | | N | |
| Hexachlorobutadiene | - | | - | | 16 | 5 | 16 | NYSDEC | Y | 20,144 |
| Hexachlorocyclopentadiene | - | | - | | 7 | 5 | 7 | NYSDEC | Y | 892,967 |
| Hexachloroethane | - | | - | | - | | - | | Y | 5,345,828 |
| Isophorone | - | | - | | - | | - | | N | |
| Monobutyltin | - | | - | | - | | - | | N | |
| Nitrobenzene | - | | - | | - | | - | | N | |
| N-nitroso-di-n-propylamine | - | | - | | - | | - | | N | |
| N-Nitrosodiphenylamine | - | | - | | - | | - | | N | |
| Pentachloroanisole | - | | - | | - | | | | Y | 2 |
| Pentachlorophenol | - | | - | | 400 | 5 | 400 | NYSDEC | Y | 415,862 |
| Phenol | - | | - | | 40,000 | | 40,000 | NYSDEC | N | |
| Tetrabutyltin | - | | - | | - | | - | | N | |
| Tributyltin | | | - | | - | | - | | Y | 3,583 |
| **SVOCs (PAHs) (ppb)** | | | | | | | | | | |
| 1,4-Dichlorobenzene | - | | - | | 120 | 5 | 120 | NYSDEC | Y | 560,635 |
| 1-Methylnaphthalene | - | | - | | - | | - | | N | |
| 1-Methylphenanthrene | - | | - | | - | | - | | N | |
| 2-Methylnaphthalene | 70 | | 70 | | 70 | 5 | 70 | NOAA ER-L | N | |
| 2,3,5-Trimethylnaphthalene | - | | - | | - | | - | | N | |
| 2,6-Dimethylnaphthalene | - | | - | | - | | - | | N | |
| Acenaphthene | 16 | | 16 | | 16 | | 16 | NOAA ER-L | Y | 418,164 |
| Acenaphthylene | 44 | | 44 | | 44 | | 44 | NOAA ER-L | Y | 418,164 |
| Anthracene | 85.3 | | 85 | | 85.3 | | 85 | NJDEP | Y | 418,164 |
| Benzo[a]anthracene | 261 | | 261 | | 261 | | 261 | NOAA ER-L | Y | 34 |
| Benzo[a]pyrene | 430 | | 430 | | 430 | | 430 | NOAA ER-L | Y | 87 |
| Benzo[b]fluoranthene | - | | - | | - | | - | | Y | 6 |
| Benzo[e]pyrene | - | | - | | - | | - | | N | |
| Benzo[g,h,i]perylene | - | | 170 | 3 | - | | 170 | NJDEP | Y | 418,164 |
| Biphenyl | - | | - | | - | | - | | N | |

## Table 4. Sediment Screening Values, continued

| Chemical[a] | Marine/Estuarine Values | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | |
| Benzo[k]fluoranthene | - | | 240 | 3 | - | | 240 | NJDEP | Y | 6 |
| Benzofluoranthenes (total)[f] | - | | 240 | 3 | - | | 240 | NJDEP | Y | 6 |
| Chrysene | 384 | | 384 | | 384 | | 384 | NOAA ER-L | Y | 14 |
| Dibenz[a,h]anthracene | 63.4 | | 63 | | 63.4 | | 63 | NJDEP | Y | 17 |
| Fluoranthene | 600 | | 600 | | 600 | | 600 | NOAA ER-L | Y | 418,164 |
| Fluorene | 19 | | 19 | | 19 | | 19 | NOAA ER-L | Y | 418,164 |
| Indeno[1,2,3-c,d]-pyrene | - | | 200 | 3 | - | | 200 | NJDEP | Y | 14 |
| Naphthalene | 160 | | 160 | | 160 | | 160 | NOAA ER-L | N | |
| HMW PAHs[g,h] | 1,700 | | - | | 1,700 | | 1,700 | NOAA ER-L | Y | 6 |
| LMW PAHs[g,i] | 552 | | - | | 552 | | 552 | NOAA ER-L | Y | 418,164 |
| Total PAHs[g,j] | 4,022 | | 4,000 | | 4,022 | | 4,000 | NJDEP | Y | 6 |
| Perylene | - | | - | | - | | - | | N | |
| Phenanthrene | 240 | | 240 | | 240 | | 240 | NOAA ER-L | Y | 418,164 |
| Pyrene | 665 | | 665 | | 665 | | 665 | NOAA ER-L | Y | 418,164 |
| **PCBs (ppb)** | | | | | | | | | | |
| Aroclor 1016 | - | | 7 | 3 | - | | 7 | NJDEP | Y | 365 |
| Aroclor 1221 | - | | - | | - | | - | | Y | 365 |
| Aroclor 1232 | - | | - | | - | | - | | Y | 365 |
| Aroclor 1242 | - | | - | | - | | - | | Y | 365 |
| Aroclor 1248 | - | | 30 | 3 | - | | 30 | NJDEP | Y | 365 |
| Aroclor 1254 | - | | 60 | 3 | - | | 60 | NJDEP | Y | 365 |
| Aroclor 1260 | - | | 5 | 3 | - | | 5 | NJDEP | Y | 365 |
| Aroclor 1262 | - | | - | | - | | - | | Y | 365 |
| Aroclor-1268 | - | | - | | - | | - | | Y | 365 |
| PCB 18CONGX2 | - | | - | | - | | - | | Y | 365 |
| Total PCBs (Aroclors)[k] | - | | - | | - | | - | | Y | 365 |
| Total PCBs[l] | 22.7 | | 23 | 3 | 22.7 | | 22.7 | NOAA ER-L | Y | 365 |
| **Pesticides/Herbicides (ppb)** | | | | | | | | | | |
| 2,4,5-T | - | | - | | - | | - | | N | |
| 2,4,5-TP | - | | - | | - | | - | | N | |
| 2,4-D | - | | - | | - | | - | | N | |
| 2,4-DB | - | | - | | - | | - | | N | |
| 2,4-DDD[m] | 2 | | - | | - | | 2 | NOAA ER-L | Y | 830 |
| 2,4-DDE[m] | 2.2 | | - | | - | | 2.2 | NOAA ER-L | Y | 19 |
| 2,4-DDT[m] | 1 | | 8 | 3 | - | | 1 | NOAA ER-L | Y | 30 |
| 4,4'-DDD | 2 | | 8 | 3 | 10 | 5 | 2 | NOAA ER-L | Y | 830 |
| 4,4'-DDE | 2.2 | | 2.2 | | 2.2 | | 2.2 | NOAA ER-L | Y | 19 |
| 4,4'-DDT | 1 | | 8 | 3 | 10 | 5 | 1 | NOAA ER-L | Y | 30 |
| Total DDx[n] | 1.58 | | 1.6 | | 1.58 | | 1.58 | NOAA ER-L | Y | 19 |
| Aldrin | - | | 2 | 3 | 7.7 | 6 | 2 | NJDEP | Y | 463 |
| BHC-alpha | - | | 6 | 3 | - | | 6 | NJDEP | Y | 1,247 |
| BHC-beta | - | | 5 | 3 | - | | 5 | NJDEP | Y | 1,247 |
| BHC-gamma (Lindane) | - | | 3 | 3 | - | | 3 | NJDEP | Y | 1,247 |
| BHC-delta[f] | - | | 3 | 3 | - | | 3 | NJDEP | Y | 1,247 |
| Total BHC[o] | - | | 3 | 3 | - | | 3 | NJDEP | Y | 1,247 |
| Chlordane,alpha (cis)[f] | - | | 7 | 3 | 0.02 | 5 | 0.02 | NYSDEC | Y | 2,006 |

## Table 4. Sediment Screening Values, continued

| Chemical[a] | Marine/Estuarine Values | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | |
| Chlordane,gamma (trans)[f] | - | | 7 | 3 | 0.02 | 5 | 0.02 | NYSDEC | Y | 2,006 |
| Chlordane,oxy-[f] | - | | 7 | 3 | 0.02 | 5 | 0.02 | NYSDEC | Y | 2,006 |
| Total Chlordane[g,p] | 0.5 | | 7 | 3 | 0.02 | 5 | 0.02 | NYSDEC | Y | 2,006 |
| Dieldrin | 0.02 | | 2 | 3 | 170 | 5 | 0.02 | NOAA ER-L | Y | 271 |
| Dieldrin+aldrin, total | - | | 2 | 3 | 7.7 | 6 | 2 | NJDEP | Y | - |
| Endosulfan sulfate | - | | - | | - | | - | | N | |
| Endosulfan, alpha | - | | - | | - | | - | | Y | 4,875 |
| Endosulfan, beta | - | | - | | - | | - | | Y | 4,875 |
| Total Endosulfan[g,q] | - | | - | | 0.04 | 5 | 0.04 | NYSDEC | Y | 4,875 |
| Endrin aldehyde | - | | - | | - | | - | | Y | 35 |
| Endrin ketone | - | | - | | - | | - | | Y | 35 |
| Total Endrin[g,r] | - | | 3 | 3 | 7.3 | 5 | 3 | NJDEP | Y | 35 |
| Heptachlor epoxide | - | | 5 | 3 | 0.9 | 5 | 0.9 | NYSDEC | Y | 9,663 |
| Total Heptachlor[g,s] | - | | - | | 0.9 | 5 | 0.9 | NYSDEC | Y | 2,358 |
| Hexachlorobenzene | - | | 20 | 3 | 120 | 6 | 20 | NJDEP | Y | 92,898 |
| Methoxychlor | - | | - | | 6 | 5 | 6 | NYSDEC | Y | 114,909 |
| Mirex | - | | 7 | 3 | 7 | 5 | 7 | NJDEP | Y | 15,852 |
| Mirex, photo-[f] | - | | - | | 7 | 5 | 7 | NYSDEC | Y | 15,852 |
| Nonachlor, cis- | - | | - | | - | | - | | Y | 2,006 |
| Nonachlor, trans- | - | | - | | - | | - | | Y | 2,006 |
| Total Nonachlor[g,t] | - | | - | | - | | - | | Y | 2,006 |
| Toxaphene | - | | - | | 0.1 | 5 | 0.1 | NYSDEC | Y | 1,398 |
| **Dioxins/Furans (ppb)** | | | | | | | | | | |
| 2,3,7,8-TCDD | 0.0032 | 1 | - | | 0.002 | 6 | 0.002 | NYSDEC | Y | 2.3 |
| TEQ, sum for PCB congeners | 0.0032 | 1 | - | | 0.002 | 6 | 0.002 | NYSDEC | Y | 2.3 |
| TEQ, sum of dioxin/furan | 0.0032 | 1 | - | | 0.002 | 6 | 0.002 | NYSDEC | Y | 2.3 |
| TEQ, total | 0.0032 | 1 | - | | 0.002 | 6 | 0.002 | NYSDEC | Y | 2.3 |

a. Chemicals analyzed for and detected in Newark Bay Sediment Samples.
b. ER-L = Effects Range-Low from Long and Morgan, 1991 and Long *et al.*, 1995; except where noted.
c. Values from NJDEP Guidance For Sediment Quality Evaluations, November 1998. References Long *et al*, 1995.
d. Values from NYSDEC, 1999.
e. From USEPA, 2000. Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. USEPA-823-R-00-001.
f. Assumed value is the same as total value.
g. Summed compounds not included as an analytical parameter; rather total values were calculated by the database.
h. HMW PAHs is the total sum of >4 ring PAHs.
i. LMW PAHs is the total sum of 2 and 3 ring PAHs including methylates.
j. Total PAHs is the sum of the low and high molecular weight PAHs.
k. Total PCBs Aroclors is the sum of Aroclors.
l. Total PCBs is the sum of all PCB congeners.
m. Value for 4,4' DDT, DDD, DDE was used for 2,4' DDT, DDD, DDE.
n. Total DDx is the sum of six isomers (2,4' and 4,4' DDT, DDD, and DDE).
o. Total BHC is the sum of alpha, beta, delta, and gamma BHC.
p. Total Chlordane is the sum of alpha, beta, delta, and gamma Chlordane.
q. Total endosulfan is the sum of endosulfan sulfate, alpha, and beta.
r. Total Endrin is the sum of Endrin ketone and Endrin aldehyde.
s. Total heptachlor is the sum of heptachlor and heptachlor epoxide.
t. Total nonachlor is the sum of *cis*- and *trans*-nonachlor.

Notes:
1. Derived by USFWS using sediment chemistry for the Arthur Kill and oyster effect data presented in Wintermyer and Cooper (2003).

**Table 4. Sediment Screening Values, continued**

| Chemical[a] | Marine/Estuarine Values | | | | | | | Lowest Sediment Benchmark | Source | USEPA List of Bioaccumulators[e] | Wildlife PCL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOAA ER-L[b] | Note | NJDEP[c] | Note | NYSDEC[d] | Note | | | | | |

2. NJ Volatile Organic Sediment Screening Guidelines derived from MacDonald *et al.,* 1992.
3. Persaud *et al*., 1993.
4. Long and Morgan, 1991.
5. Benthic Aquatic Life Chronic Toxicity Criteria for saltwater used and converted to parts per billion assuming 1% organic carbon.
6. Wildlife Bioaccumulation Criteria used and are expressed in terms of organic carbon (assuming 1%) and converted to ppb.

### 4.1.2 Biological Tissue

Screening values used in the COPEC screening process for biological tissue were based on tissue concentrations considered protective of either the organism in which the concentration was measured or for consumers of these organisms. For the former approach, CBRs previously summarized for the LPRRP were used. These values were derived and presented in a Problem Formulation Technical Memorandum entitled *Refinement of Toxicity Values and Development of Critical Biota Residues and Biomagnification Factors (BMFs)* (Battelle, March 3, 2006), which is presented in Attachment C. Toxicological data used to develop the CBRs was obtained from the Army Corps of Engineers' Environmental Residue-Effects Database (ERED, available at http://el.erdc.usace.army.mil/ered; queried on 10 January 2006). This information was supplemented with data obtained from other compilations of residue effects data (*e.g.*, USEPA, 2000; Jarvinen and Ankley, 1999) as well as journal articles. The CBRs represent the maximum allowable toxicant concentration (MATC) (i.e., geometric mean) of the most conservative NOAELs and LOAELs for several selected bioaccumulative COPECs.

PCLs based on protecting wildlife consumers of contaminated prey tissue were available from NYSDEC guidance ("fish flesh criteria") for 14 chemicals (Newell *et al*., 1987). PCLs were also calculated for the additional chemicals using a similar approach as described in the previous section for sediment. These values provide a protective tissue screening value based on exposures to higher-trophic-level organisms. Equation 2 was used to estimate tissue PCLs for piscivorous wildlife receptors in the NBSA. The exposure parameters are presented in Table 3.

$$PCL_{biota} = \frac{THQ * TRV * BW}{\left(IR_{fish} * P_{fish} * SFF\right)} \qquad \text{Equation 2}$$

*where*:

| | | |
|---|---|---|
| $PCL_{biota}$ | = | Protective Concentration Level for prey tissue (protective of bioaccumulation hazards associated with the fish consumption pathway [µg COPEC/g biota]). |
| THQ | = | Target Hazard Quotient for the COPEC based on tissue residue effects (unitless); a THQ of 1.0 was used. |
| TRV | = | Toxicity Reference Value. Receptor-specific literature-based toxicity threshold value. NOAEL and LOAEL-based TRV values are presented in Attachment B. The MATC-based TRV is the geometric mean of the NOAEL- and LOAEL-based values (µg COPEC/g-day). |
| BW | = | Receptor body weights (kg) are summarized in Attachment B. |
| $IR_{fish}$ | = | Daily fish ingestion rate (kg fish consumed per day). |

| | | |
|---|---|---|
| $P_{fish}$ | = | Percentage of fish in the diet. |
| SFF | = | Site Foraging Frequency (unitless); fraction of time receptor is assumed to forage at the site. |

Table 5 summarizes the available biological tissue screening values, including both residue-based (*i.e.*, CBRs) and dose-based exposure (*i.e.,* wildlife PCL) values, and, for each chemical, identifies the value selected to conduct the COPEC screening process for this medium.

## 4.2 Summary of Available Data (Exposure Estimate)

COPECs were identified for sediment and tissue media based on a review of current and historical data that were collected by various groups, including USEPA, USACE, NOAA National Status and Trends (NS&T) program, and Tierra (Table 1). These data are currently stored in an online database at www.ourNewarkBay.org. In addition, data from the NY/NJ Contaminant Assessment and Reduction Program (CARP) were utilized for the risk assessment. Three major datasets (historical data, Phase I RIWP data, and CARP data) were reviewed for quality, comparability, and usability for the risk assessment process and are described in detail below.

Historical data retrieved from the database at www.ourNewarkBay.org include surface sediment (defined as the top 0 to 6 inches) and biological tissue data for a variety of chemicals, including metals, VOCs, SVOCs, PAHs, PCBs, pesticides, herbicides, and dioxins/furans. Historical surface sediment data are from studies dating from 1990-2000, and what was once considered "surface" sediment may no longer be representative of current surface conditions.

Although it is recognized that sediment-associated porewater is a potentially important exposure medium, this SLERA does not evaluate porewater concentrations because insufficient documentation was available regarding historic data quality for the associated investigations. There is considerable complexity associated with the collection of representative porewater samples; therefore, in the absence of the supporting details, these samples were not included in this assessment. In addition, there are too few samples identified in the database as "porewater" to support a definitive analysis. Furthermore, due to the lack of representative surface water samples, no surface water screen was included in this SLERA. A routine water quality monitoring program is anticipated for the Newark Bay Phase III RI field effort, following which, a full surface water screen is expected to be performed for the BERA.

Because the historical data were collected from multiple investigations by various investigators over more than a decade, there are discrepancies with regard to data quality, comparability, and usability. The following assumptions were made to allow for comparisons of data across studies and sampling years:

- All data points qualified with an "R" (rejected) were excluded from the data query outputs.
- Any data point with validation and/or laboratory qualifiers containing a "U" was treated as not detected. Furthermore, it was assumed that the value reported in the database was equivalent to the detection limit.
- Supporting quality assurance (QA) laboratory documentation or metadata defining laboratory qualifiers are not available in the database. With the exceptions noted above, it was assumed that all data meeting screening criteria were appropriate for conducting the SLERA, that the sediment data are reported on a dry-weight basis, and that tissue data are reported on a wet-weight basis.
- Sediment samples collected in areas that were subsequently dredged or will be dredged in the upcoming year will no longer represent relevant environmental exposure conditions. Sediment samples collected prior to known dredging operations were not included in this assessment.

## Table 5. Biological Tissue Screening Values

| Chemical[a] | List of USEPA Bioaccumulators[b] | Note | NYSDEC[c] Wildlife PCL | Derived Wildlife PCL | Selected Screening Benchmark | Source | Critical Body Residues[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish | Invertebrate | Birds | Note |
| **Inorganics (ppb)** | | | | | | | | | | |
| Aluminum | N | | - | - | | | | | | |
| Antimony | N | | - | - | | | | | | |
| Arsenic | Y | | - | 22,000 | 22,000 | Derived | | | | |
| Barium | N | | - | - | | | | | | |
| Beryllium | N | | - | - | | | | | | |
| Cadmium | Y | | - | 1,824 | 1,824 | Derived | | | | |
| Calcium | N | | - | - | | | | | | |
| Chromium | Y | | - | 4,472 | 4,472 | Derived | | | | |
| Cobalt | N | | - | - | | | | | | |
| Copper | Y | | - | 21,935 | 21,935 | Derived | 6.3 | 270 | | |
| Cyanide | N | | - | - | | | | | | |
| Iron | N | | - | - | | | | | | |
| Lead | Y | | - | 700 | 700 | Derived | 88 | 1,700 | | |
| Mercury, elemental | Y | | - | 168 | 168 | Derived | 19 | 13 | | |
| Methyl mercury | Y | 1 | - | 42 | 42 | Derived | 3.2 | | | |
| Total Mercury (Hg(II) + MeHg) | Y | 1 | - | 42 | 42 | Derived | 3.2 | 13 | | |
| Magnesium | N | | - | - | | | | | | |
| Manganese | N | | - | - | | | | | | |
| Nickel | Y | | - | 17,629 | 17,629 | Derived | 37,000 | 350 | | |
| Potassium | N | | - | - | | | | | | |
| Selenium | Y | | - | 925 | 925 | Derived | | | | |
| Silver | Y | | - | 569,210 | 569,210 | Derived | 76 | 6 | | |
| Sodium | N | | - | - | | | | | | |
| Thallium | N | | - | - | | | | | | |
| Titanium | N | | - | - | | | | | | |
| Vanadium | N | | - | - | | | | | | |
| Zinc | Y | | - | 108,782 | 108,782 | Derived | 280 | 410 | | |
| **SVOCs (Non-PAH) (ppb)** | | | | | | | | | | |
| 2,2'-oxybis(1-Chloropropane) | N | | - | - | | | | | | |
| 1,2-Dichlorobenzene | Y | | - | 2,746,538 | 2,746,538 | Derived | | | | |
| 1,3-Dichlorobenzene | Y | | - | 560,635 | 560,635 | Derived | | | | |
| 1,2,4-Trichlorobenzene | Y | | - | 3,845,153 | 3,845,153 | Derived | | | | |
| 2,4,5-Trichlorophenol | N | | - | - | | | | | | |
| 2,4,6-Trichlorophenol | N | | - | - | | | | | | |
| 2,4-Dichlorophenol | N | | - | - | | | | | | |
| 2,4-Dimethylphenol | N | | - | - | | | | | | |
| 2,4-Dinitrophenol | N | | - | - | | | | | | |
| 2,4-Dinitrotoluene | N | | - | - | | | | | | |
| 2,6-Dinitrotoluene | N | | - | - | | | | | | |
| 2-Chloronaphthalene | N | | - | - | | | | | | |
| 2-Chlorophenol | N | | - | - | | | | | | |

**Table 5. Biological Tissue Screening Values, continued**

| Chemical[a] | List of USEPA Bioaccumulators[b] | Note | NYSDEC[c] Wildlife PCL | Derived Wildlife PCL | Selected Screening Benchmark | Source | Critical Body Residues[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish | Invertebrate | Birds | Note |
| 2-Methylphenol | N | | - | - | | | | | | |
| 2-Nitroanaline | N | | - | - | | | | | | |
| 2-Nitrophenol | N | | - | - | | | | | | |
| 3,3'-Dichlorobenzidine | N | | - | - | | | | | | |
| 3-Nitroaniline | N | | - | - | | | | | | |
| 4,6-Dinitro-2-methylphenol | N | | - | - | | | | | | |
| 4-Bromophenyl Phenyl Ether | Y | | - | 5,850,214 | 5,850,214 | Derived | | | | |
| 4-Chloro-3-methylphenol | N | 1 | - | - | | | | | | |
| 4-Chloroaniline | N | | - | - | | | | | | |
| 4-Chlorophenyl Phenyl Ether | Y | | - | 5,850,214 | 5,850,214 | Derived | | | | |
| 4-Methylphenol | N | | - | - | | | | | | |
| 4-Nitroaniline | N | | - | - | | | | | | |
| 4-Nitrophenol | N | | - | - | | | | | | |
| Benzoic Acid | N | 1 | - | - | | | | | | |
| Benzyl Alcohol | N | 1 | - | - | | | | | | |
| Bis(2-Chloroethoxy)methane | N | | - | - | | | | | | |
| Bis(2-Chloroethyl)ether | N | | - | - | | | | | | |
| Bis(2-Ethylhexyl)phthalate | N | | - | - | | | | | | |
| Butyl Benzyl Phthalate | N | | - | - | | | | | | |
| Carbazole | N | | - | - | | | | | | |
| Dibenzofuran | N | 1 | - | - | | | | | | |
| Dibenzothiophene | N | | - | - | | | | | | |
| Dibutyltin | Y | 1 | - | 35,825 | 35,825 | Derived | | | | |
| Diethyl Phthalate | N | | - | - | | | | | | |
| Dimethylphthalate | N | | - | - | | | | | | |
| Di-n-butylphthalate | N | | - | - | | | | | | |
| Di-n-Octyl Phthalate | N | | - | - | | | | | | |
| Hexachlorobutadiene | Y | | 1,300 | 20,144 | 1,300 | NYSDEC | | | | |
| Hexachlorocyclopentadiene | Y | | - | 35,507 | 35,507 | Derived | | | | |
| Hexachloroethane | Y | | 14,100 | 5,345,828 | 14,100 | NYSDEC | | | | |
| Isophorone | N | | - | - | | | | | | |
| Monobutyltin | N | | - | - | | | | | | |
| Nitrobenzene | N | | - | - | | | | | | |
| N-Nitrosodiphenylamine | N | 1 | - | - | | | | | | |
| N-Nitrosodipropylamine | N | | - | - | | | | | | |
| Pentachlorophenol | Y | | 2,000 | 14,041 | 2,000 | NYSDEC | | | | |
| Phenol | N | | - | - | | | | | | |
| Tetrabutyltin | N | | - | - | | | | | | |
| Tributyltin | Y | | - | 35,825 | 35,825 | Derived | | | | |
| **SVOCs (PAHs) (ppb)** | | | | | | | | | | |
| 1-Methylnaphthalene | N | | - | - | | | | | | |
| 1-Methylphenanthrene | N | | - | - | | | | | | |
| 1,4-Dichlorobenzene | Y | | - | 560,635 | 560,635 | Derived | | | | |
| 2-Methylnaphthalene | N | | - | - | | | | | | |

**Table 5. Biological Tissue Screening Values, continued**

| Chemical[a] | List of USEPA Bioaccumulators[b] | Note | NYSDEC[c] Wildlife PCL | Derived Wildlife PCL | Selected Screening Benchmark | Source | Critical Body Residues[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish | Invertebrate | Birds | Note |
| 2-Methylphenanthrene | Y | 1 | - | 121,267 | 121,267 | Derived | | | | |
| 2,3,5-Trimethylnaphthalene | N | | - | - | | | | | | |
| 2,6-Dimethylnaphthalene | N | | - | - | | | | | | |
| 3,6-Dimethylphenanthrene | Y | 1 | - | 121,267 | 121,267 | Derived | | | | |
| Acenaphthene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Acenaphthylene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Anthracene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Benzo(a)anthracene | Y | | - | 10.0 | 10.0 | Derived | | | | |
| Benzo(a)pyrene | Y | | - | 25 | 25 | Derived | | | | |
| Benzo(b)fluoranthene | Y | | - | 1.8 | 1.8 | Derived | | | | |
| Benzo[e]pyrene | N | | - | - | | | | | | |
| Benzo(g,h,i)perylene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Benzo(k)fluoranthene | Y | | - | 1.8 | 1.8 | Derived | | | | |
| Biphenyl | N | | - | 2,068,363 | 2,068,363 | Derived | | | | |
| Chrysene | Y | | - | 4.0 | 4.0 | Derived | | | | |
| Dibenz(a,h)anthracene | Y | | - | 4.9 | 4.9 | Derived | | | | |
| Fluoranthene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Fluorene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Indeno(1,2,3-cd)pyrene | Y | | - | 4.0 | 4.0 | Derived | | | | |
| Naphthalene | N | | - | - | | | | | | |
| Perylene | N | | - | - | | | | | | |
| Phenanthrene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| Pyrene | Y | | - | 121,267 | 121,267 | Derived | | | | |
| HMW PAHs[e] | Y | 1 | - | 1.8 | 1.8 | Derived | 700 | 70 | | |
| LMW PAH[f] | Y | 1 | - | 121,267 | 121,267 | Derived | 700 | 70 | | |
| Total PAHs[g] | Y | 1 | - | 1.8 | 1.8 | Derived | 700 | 70 | | |
| **PCBs (ppb)** | | | | | | | | | | |
| Aroclor 1016 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1221 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1232 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1242 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1248 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1254 | Y | | - | 676 | 676 | Derived | | | | |
| Aroclor 1260 | Y | | - | 676 | 676 | Derived | | | | |
| Total PCBs (Aroclors)[h] | Y | 1 | 110 | 676 | 110 | NYSDEC | 7.9 | 680 | | |
| Total PCBs[i] | Y | 1 | 110 | 676 | 110 | NYSDEC | 7.9 | 680 | | |
| **Pesticides/Herbicides (ppb)** | | | | | | | | | | |
| 2,4'-DDD[j] | Y | | 200 | 232 | 200 | NYSDEC | | | | |
| 2,4'-DDE[j] | Y | | 200 | 147 | 147 | Derived | | | | |
| 2,4'-DDT[j] | Y | | 200 | 232 | 200 | NYSDEC | | | | |
| 4,4'-DDD[j] | Y | | 200 | 232 | 200 | NYSDEC | | | | |
| 4,4'-DDE[j] | Y | | 200 | 147 | 147 | Derived | | | | |
| 4,4'-DDT[j] | Y | | 200 | 232 | 200 | NYSDEC | | | | |
| Total DDx[k] | Y | 1 | 200 | 147 | 147 | Derived | 0.26 | 0.58 | | |

## Table 5. Biological Tissue Screening Values, continued

| Chemical[a] | List of USEPA Bioaccumulators[b] | Note | NYSDEC[c] Wildlife PCL | Derived Wildlife PCL | Selected Screening Benchmark | Source | Critical Body Residues[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish | Invertebrate | Birds | Note |
| 2,4,5-TP | N | | - | - | | | | | | |
| 2,4,5-T | N | | - | - | | | | | | |
| 2,4-D | N | | - | - | | | | | | |
| 2,4-DB | N | | - | - | | | | | | |
| Aldrin | Y | | 120 | 834 | 120 | NYSDEC | 35 | 28 | | |
| alpha-BHC | Y | | - | 2,245 | 2,245 | Derived | | | | |
| beta-BHC | Y | | - | 2,245 | 2,245 | Derived | | | | |
| delta-BHC | Y | | - | 2,245 | 2,245 | Derived | | | | |
| gamma-BHC (Lindane) | Y | | - | 2,245 | 2,245 | Derived | | | | |
| Total BHC[l] | Y | 1 | - | 2,245 | 2,245 | Derived | | | | |
| Chlordane,alpha (cis) | Y | | 500 | 9,570 | 500 | NYSDEC | | | | |
| Chlordane,gamma (trans) | Y | | 500 | 9,570 | 500 | NYSDEC | | | | |
| Chlordane,oxy- | Y | | 500 | 9,570 | 500 | NYSDEC | | | | |
| Total Chlordane[m] | Y | 1 | 500 | 9,570 | 500 | NYSDEC | 3.2 | 6.3 | | |
| Dieldrin | Y | | 120 | 487 | 120 | NYSDEC | 35 | 28 | | |
| Endosulfan sulfate | N | | - | 8,775 | 8,775 | Derived | | | | |
| Endosulfan, alpha | Y | | - | 8,775 | 8,775 | Derived | | | | |
| Endosulfan, beta | Y | | - | 8,775 | 8,775 | Derived | | | | |
| Total Endosulfan[n] | Y | 1 | - | 8,775 | 8,775 | Derived | 22 | 3.2 | | |
| Endrin aldehyde | N | | - | 63 | 63 | Derived | | | | |
| Endrin ketone | N | | - | 63 | 63 | Derived | | | | |
| Endrin | Y | | 25 | 63 | 25 | NYSDEC | | | | |
| Total Endrin | Y | 1 | 25 | 63 | 25 | NYSDEC | 3.6 | 3.2 | | |
| Heptachlor | Y | | 200 | 4,245 | 200 | NYSDEC | | | | |
| Heptachlor epoxide | Y | | 200 | 17,394 | 200 | NYSDEC | | | | |
| Total Heptachlor[o] | Y | 1 | 200 | 4,245 | 200 | NYSDEC | | | | |
| Hexachlorobenzene | Y | | 330 | 8,361 | 330 | NYSDEC | | | | |
| Methoxychlor | Y | | - | 206,836 | 206,836 | Derived | | | | |
| Mirex | Y | | 330 | 20,766 | 330 | NYSDEC | | | | |
| Mirex, photo- | Y | 1 | 330 | 20,766 | 330 | NYSDEC | | | | |
| Nonachlor, cis- | N | | - | - | | | | | | |
| Nonachlor, trans- | N | | - | - | | | | | | |
| Total Nonachlor[p] | Y | 1 | - | 9,570 | 9,570 | Derived | 3.2 | | | |
| Toxaphene | Y | | - | 2,517 | 2,517 | Derived | | | | |
| **Dioxins/Furans(ppb)** | | | | | | | | | | |
| 2,3,7,8-TCDD | Y | | 0.0003 | 0.059 | 0.0003 | NYSDEC | | | | |
| TEQ, sum for PCB congeners | Y | 1 | - | 0.089 | 0.089 | Derived | 0.043 | 0.002 | 0.094 | 2 |
| TEQ, sum of dioxin/furan | Y | 1 | - | 0.059 | 0.059 | Derived | 0.043 | 0.002 | 0.094 | 2 |
| TEQ, total | Y | 1 | - | | | | 0.043 | 0.002 | 0.094 | 2 |

a. Chemicals analyzed for and detected in Newark Bay tissue samples.
b. USEPA, 2000
c. Values from Newell *et al*., 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife; Technical Report 87-3, Division of Fish and Wildlife.
d. CBRs are based on MATCs as derived by Battelle (2006).

**Table 5. Biological Tissue Screening Values, continued**

| Chemical[a] | List of USEPA Bioaccumulators[b] | Note | NYSDEC[c] Wildlife PCL | Derived Wildlife PCL | Selected Screening Benchmark | Source | Critical Body Residues[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fish | Invertebrate | Birds | Note |

e. HMW PAHs is the total sum of >4 ring PAHs.
f. LMW PAHs is the total sum of 2 and 3 ring PAHs including methylates.
g. Total PAHs is the sum of the low and high molecular weight PAHs.
h. Total PCBs Aroclors is the sum of Aroclors.
i. Total PCBs is the sum of all PCB congeners.
j. Values for DDT, DDD, DDE were used for both the 2,4' and 4,4' compounds.
k. Total DDx is the sum of six isomers (2,4 and 4, 4' DDT, DDD & DDE).
l. Total BHC is the sum of alpha, beta, delta, and gamma-BHC.
m. Total Chlordane is the sum of alpha (cis), gamma (trans), and oxy-Chlordane.
n. Total endosulfan is the sum of endosulfan sulfate, alpha, and beta.
o. Total heptachlor is the sum of heptachlor and heptachlor epoxide.
p. Total nonachlor is the sum of cis- and trans-nonachlor.

Notes:
1. Parameter not listed; assumption based on similar compound**.**
2. Based on avian embryo.

- Available tissue data consists of whole-body data for a variety of aquatic organisms, which were grouped into the following categories: benthic invertebrates (including infaunal and epifaunal macroinvertebrates such as polychaetes), mollusks, crab (consisting of blue crab data), fish, and avian embryo data. Tissue data consisting of specific organs (*e.g.,* hepatopancreas) or body fillet data collected for human health exposure assessments were excluded from the database queries used to screen COPECs.
- For various analytes that are chemically related and presumably share toxicological properties, aggregate parameters were estimated as part of the database query process by combining, for each sample, the individual results for each component. Non-detected values were not differentiated during the process. The following aggregate parameters were calculated and incorporated into the screening process:
  - Total PCBs (Aroclors) – Sum of the analyzed Aroclors, including Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260, Aroclor 1262, and Aroclor 1268.
  - Low molecular weight (LMW) PAHs – Sum of 2- and 3-ring PAHs including methylated compounds.
  - High molecular weight (HMW) PAHs – Sum of 4-, 5-, and 6-ring PAH compounds.
  - Total PAHs – Sum of all analyzed PAH compounds.
  - Total DDx – Sum of 2,4'-DDD, 2,4'-DDE, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
  - Total BHC – Sum of alpha-, beta-, delta- and gamma-BHC.
  - Total chlordane – Sum of alpha, gamma, and oxy-chlordane.
  - Total endosulfan – Sum of endosulfan sulfate and alpha- and beta-endosulfan.

- Total endrin – Sum of endrin, endrin aldehyde, and endrin ketone.
- Total heptachlor – Sum of heptachlor and heptachlor epoxide.
- Total nonachlor – Sum of cis- and trans-nonachlor.

- Toxic Equivalencies Quotients (TEQs) were also calculated for dioxin, furan, and coplanar PCB congeners detected in biological tissue samples. Individual congener concentrations in a sample were multiplied by their respective Toxicity Equivalency Factor (TEF) and the resulting values were summed to derive a sample-specific TEQ (Van den Berg *et al*., 1998). TEF values are available for mammal, bird, and fish receptors, and this process allows the combined toxicological importance of all compounds to be normalized to 2,3,7,8-TCDD (believed to be the most toxic of the dioxin compounds) and quantified in a single value. Due to the uncertainties associated with this process, no TEQs were calculated for sediments; rather only the individual congener of 2,3,7,8-TCDD was evaluated in sediments. TEQs were calculated for tissue samples containing dioxin-like compounds (based separately on mammal, bird, and fish TEFs) for the following contaminant groups:
  - TEQ Dioxin/Furan congeners.
  - TEQ PCB congeners.
  - Total TEQ.

Figure 16 shows the location of all sediment samples selected for the COPEC screening process. The geomorphic units and three main reaches of the bay are also presented so that the reader can better relate the sample locations to the CSM. Figure 17 shows the location of all tissue samples selected for the COPEC screening process. Individual tissue sample types, including benthos, bird egg, crab, mollusks, and fish, are depicted for each region with individual symbols.

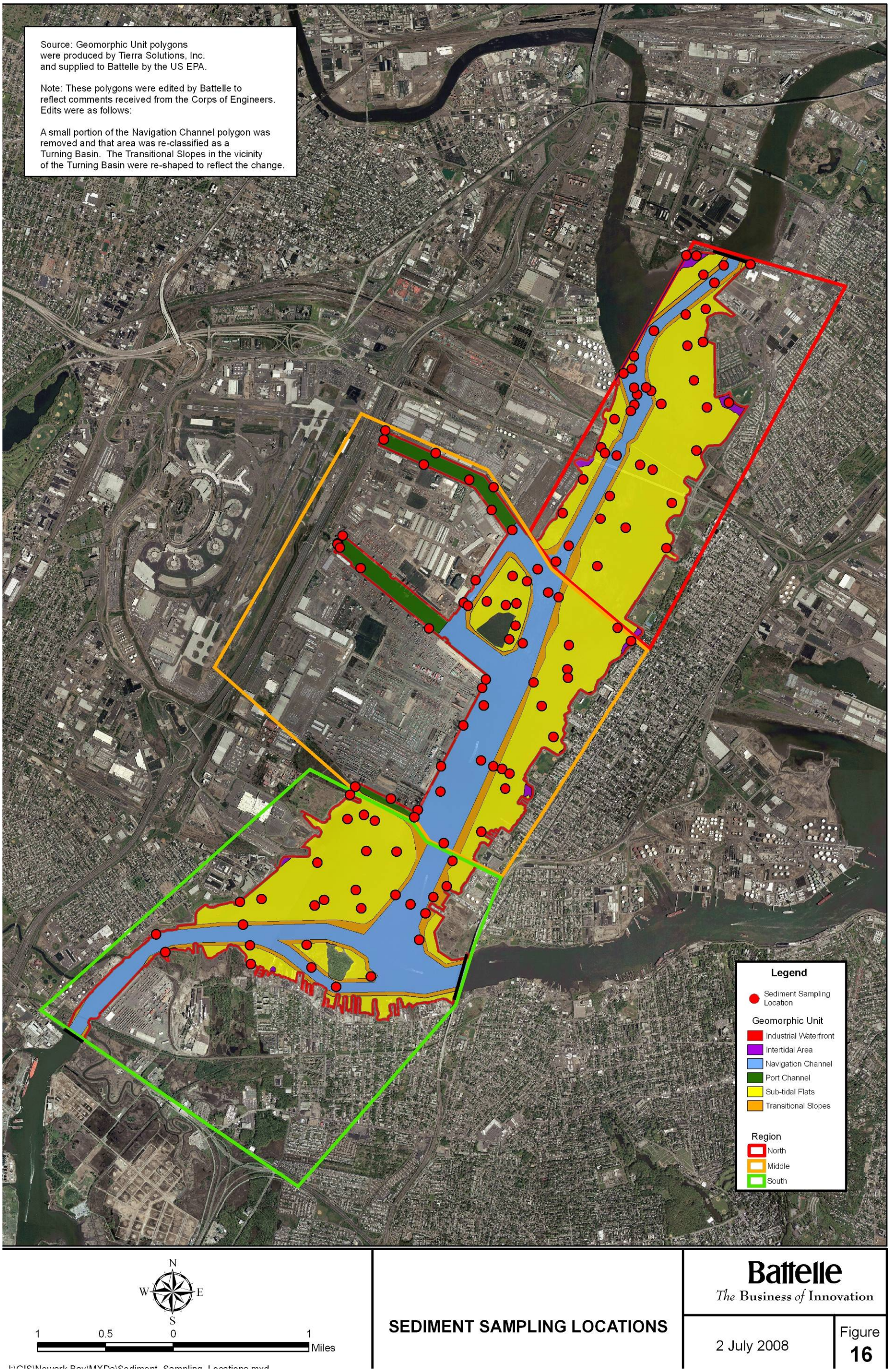


**Figure 16. Sediment Sampling Locations**

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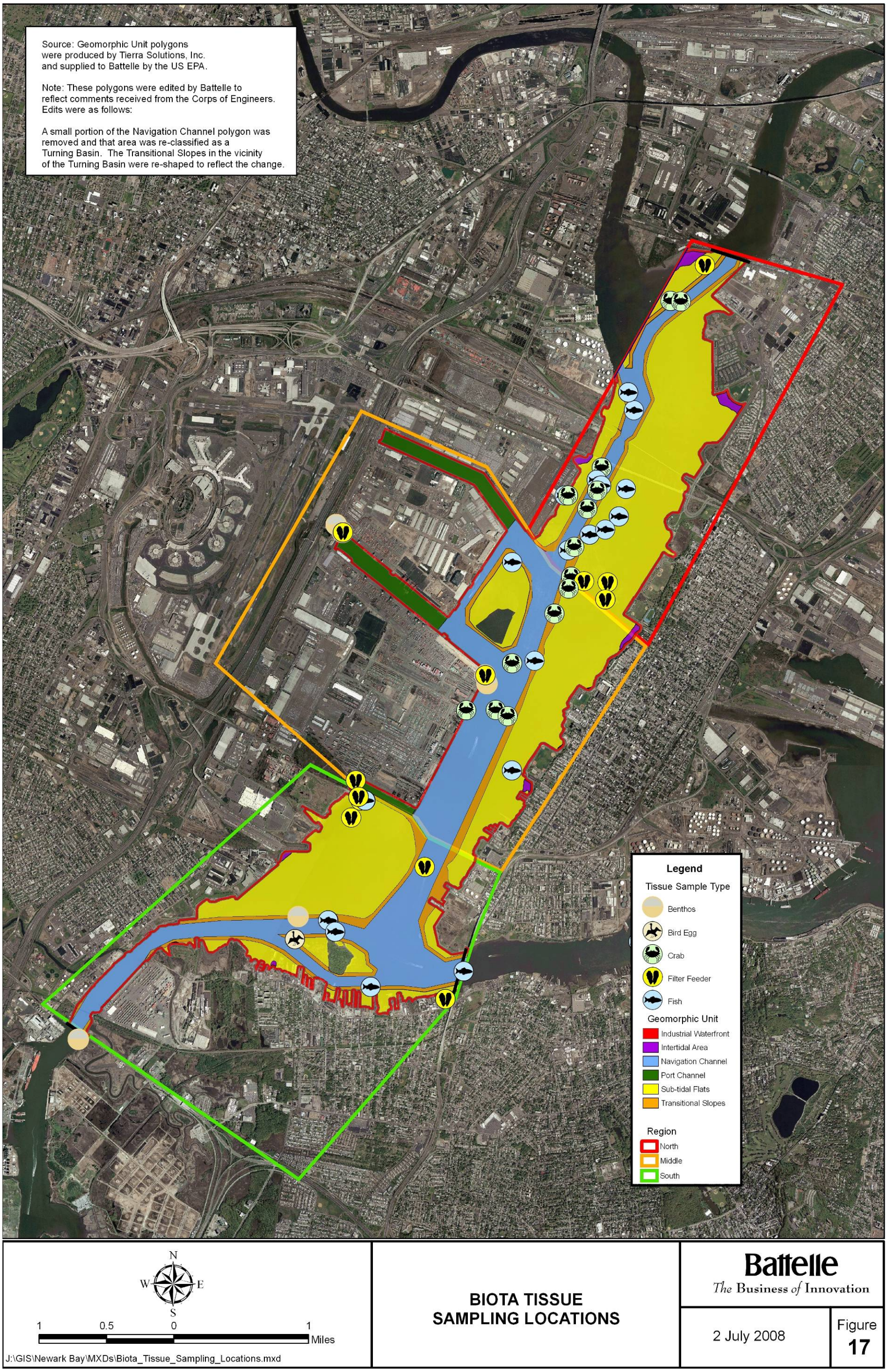


**Figure 17. Biota Tissue Sampling Locations**

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## 4.3 COPEC Screening Process (Risk Estimate)

The risk calculation process completes Step 2 of USEPA's Ecological Risk Assessment Guidance for Superfund (ERAGS) (USEPA, 1997). Data from the media-specific datasets described in the previous section were compiled and maximum analyte concentrations were compared to toxicity screening values and PCLs (bioaccumulative contaminants). These comparisons are used to derive hazard quotients (HQs) as described in Equation 3. In general, chemicals with HQs greater than 1 are retained as COPECs for further evaluation in a BERA; those with HQs less than 1 are eliminated from further evaluation. Hazard quotients are calculated using the following equation:

$$HQ = \text{maximum concentration} / \text{screening value} \qquad \text{Equation 3}$$

Hazard quotients were derived for each environmental medium based on the maximum concentration for the NBSA as well as for each of the three regions within the bay (south, middle, and north).

In addition, spatial coverage of the sediment data did not allow further examination of the contaminants associated with each habitat type (*i.e.,* intertidal, subtidal, and channel). Rather, the maximum contaminant concentration from each region (north, south, or middle) was compared to the screening benchmark. It should also be noted that for the SLERA, a conservative approach is recommended (USEPA, 1997); therefore, all chemicals lacking screening benchmarks, even ones that were not detected in any medium, were retained as COPECs because it is possible that data quality objectives were insufficient to detect contaminant concentrations at levels sufficient to compare with effect concentrations. This is addressed further in the uncertainty section (Section 6.0).

The following sections describe the screening process for each media type. The data used in this process are summarized in Attachments A, B, and C. The results of the COPEC screen are provided in Attachments D through I and are summarized by environmental medium in the following sections.

### 4.3.1 Sediment Screening Process

Sediment COPECs were identified following a screening process that included the following criteria:

1. Bioaccumulation screen.
2. Essential nutrient screen.
3. Availability of a screening benchmark.
4. Comparison to an effects value or screening benchmark.

The sediment screening process is summarized in Figure 18. A conservative screening process was used to ensure that no chemicals were eliminated without going through all steps in the process. For instance, all chemicals considered to be bioaccumulative were carried through and screened against the wildlife PCLs. In addition, all analytes lacking readily available sediment screening benchmarks identified in Table 5 were retained as potential COPECs, as were those where the maximum reported concentration exceeded the selected sediment screening benchmarks (protective of benthic exposures) and/or wildlife PCLs (protective of bioaccumulation hazards). Results are presented in Attachment D.

### 4.3.2 Biological Tissue Screening Process

A variety of biological tissue data were collected from Newark Bay and are included in the NBSA database. These include chemical concentrations in fish, crabs, mollusks, benthic invertebrates, and bird eggs. COPECs were identified for each tissue category following a screening process that included the following criteria:

1. Wildlife dose assessment bioaccumulation screen.

2. Availability of a screening benchmark.
3. Comparison to a residue-based screening benchmark.

The biological tissue screening process is summarized in Figure 19. Wildlife PCLs were calculated for all bioaccumulative compounds (USEPA, 2000) analyzed for in NBSA biological tissue. To simplify the approach, wildlife PCLs derived for piscivorous receptors were used to evaluate contaminant concentrations in all biological tissue. Table 5 identifies all chemical parameters analyzed in NBSA sediment that are included in the USEPA bioaccumulative compound list and summarizes available CBRs and wildlife PCLs used in the COPEC screening process for this medium.

All analytes lacking readily available tissue residue benchmarks (*i.e.,* CBRs) were retained as potential COPECs, as were those where the maximum reported concentration exceeds the selected CBR (protective of prey organism exposures) and/or wildlife PCLs (protective of bioaccumulation hazards associated with consuming a diet of contaminated prey specimens) Results for benthic invertebrates are presented in Attachment E, mollusks in Attachment F, crabs in Attachment G, fish in Attachment H, and avian embryos in Attachment I.

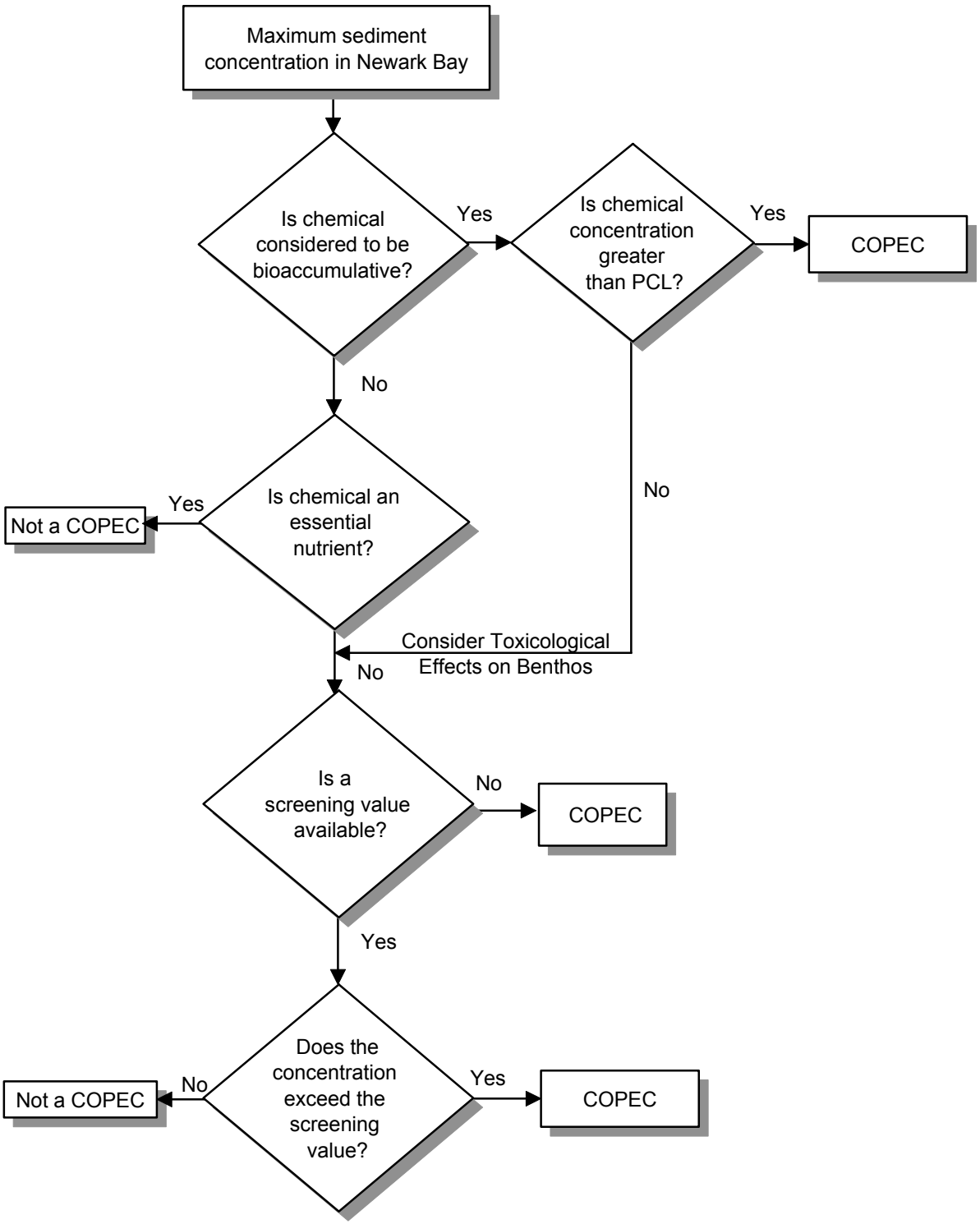


**Figure 18. Sediment COPEC Decision Diagram for the Newark Bay SLERA**

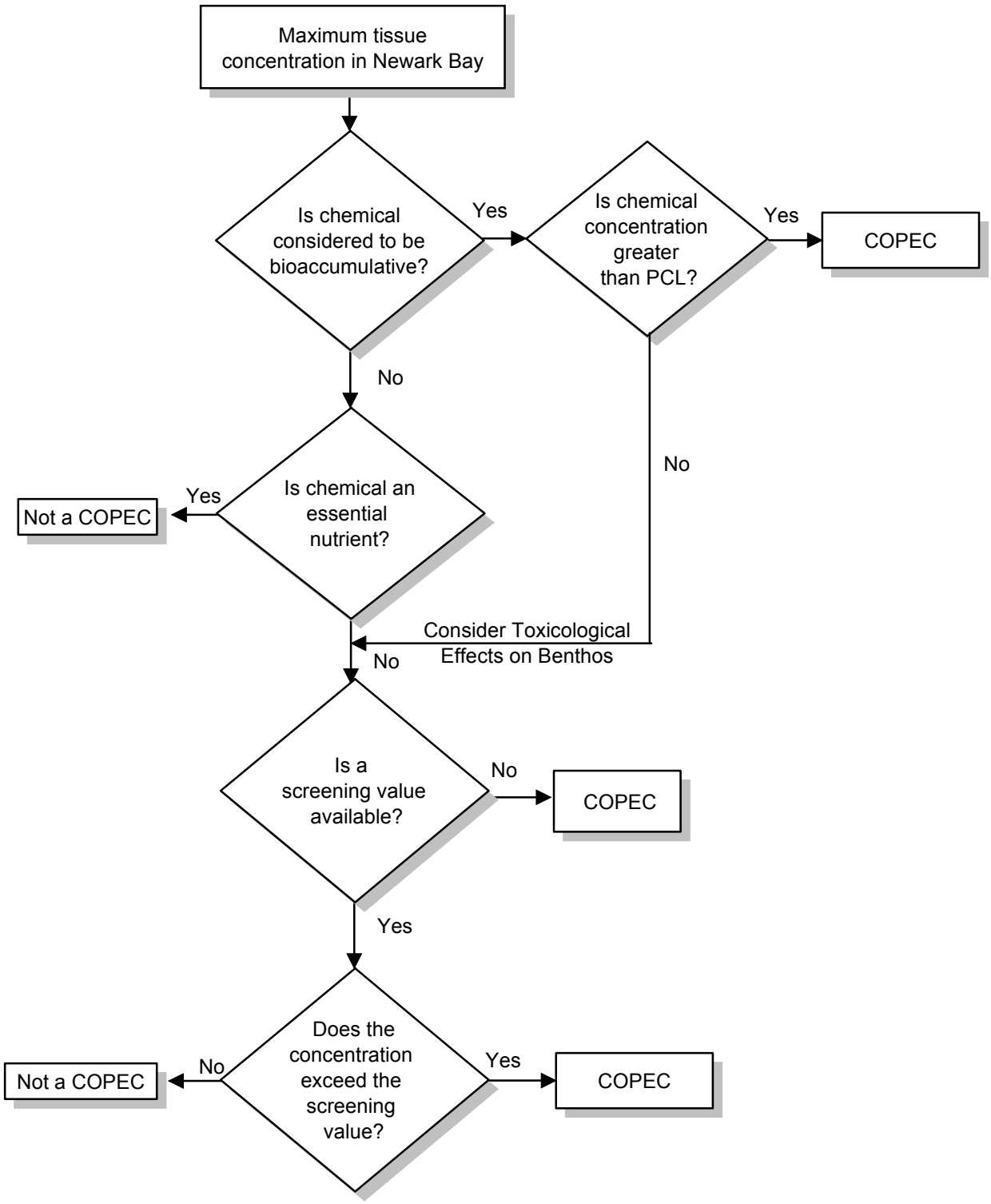


**Figure 19. Biological Tissue COPEC Decision Diagram for the Newark Bay SLERA**

# 5.0 SCREENING-LEVEL RISK CHARACTERIZATION

The screening-level risk characterization provides a conservative estimate of the potential for adverse effects to receptors in the NBSA based on the exposure concentrations and effects levels. The results provide a quantitative estimate of the potential for risks to each ecological receptor group. While the HQ is not a measure of the magnitude of effects and HQs are not comparable between chemicals, in general, chemicals with a larger HQ indicate a greater potential for adverse ecological effects. For chemicals with HQs between 1 and 10, there is a low potential for unacceptable risks; for chemicals with HQs between 10 and 100, there is a moderate potential for unacceptable risks; for chemicals with HQs greater than 100, there is a high potential for unacceptable risks. It should be noted, however, that such classifications are arbitrary and an HQ of 99 is not essentially different than an HQ of 100. Rather, the intent of characterizing the risk in this manner establishes order of magnitude differences in potential risk from various COPECs and is intended to facilitate the risk management decision-making process. The results of the COPEC screen and the characterization of the potential risks, based on exposure medium, are discussed in the following sections. Chemicals with HQs exceeding 1 are summarized in Tables 6 through 10; chemicals with HQs greater than 100 and greater than 1000 (*i.e.*, demonstrate the greatest potential for unacceptable ecological risks) are emphasized with bold text.

## 5.1 Sediment

Sediment results were evaluated for the entire NBSA and for each of the three regions. Results of the sediment screen using the invertebrate screening benchmarks helped identify the potential for adverse effects to invertebrates directly exposed to sediment. Results of the screen to wildlife PCLs identified the potential for adverse effects to upper-trophic wildlife receptors (represented by the otter and belted kingfisher) from bioaccumulative compounds in sediment.

The results of the sediment screen are provided in Attachment D and discussed in detail by contaminant class below. Table 6 presents a summary of the results of the sediment screen by chemical and region within the NBSA. For each region, the magnitude of the HQ above 1 is presented. Only chemicals that were detected in at least one sample at a maximum concentration exceeding a screening value are included. Furthermore, each chemical was screened against two benchmarks within each region: an invertebrate-based benchmark and a wildlife-based benchmark. Bolded values indicate an HQ above 100 or 1000, representing the greatest potential for adverse effects.

Metals

A total of 22 inorganic constituents was retained as COPECs, 13 of which had HQs exceeding 1, for either wildlife or benthic invertebrates. Five constituents were screened out on the basis of being essential nutrients (calcium, magnesium, potassium, silicon, and sodium). Chromium, copper, and zinc had the highest HQs for wildlife (all HQs > 1,000). In general, the highest wildlife PCL exceedances were associated with the middle region of the NBSA, with one notable exception; zinc HQ exceedances were also high in the north and middle regions. The invertebrate HQs for inorganics were all less than 100 throughout the NBSA, and no discernible differences were observed between the three regions.

VOCs

Only 10 VOCs including total BTEX were detected in sediment. One detected VOC (ethylbenzene) exceeded the invertebrate-based benchmark in the middle region and the HQ was less than 10. VOCs do not bioaccumulate through the food web, and, therefore, benchmarks were not derived for wildlife.

Non-PAH SVOCs

A total of 53 non-PAH SVOCs was retained as COPECs in sediment; the majority of which lack sediment benchmarks. Twenty-six non-PAH SVOCs were detected in sediment. Of those with available screening benchmarks, none exceeded their wildlife-based benchmarks. Only four detected non-PAH SVOCs exceeded their respective invertebrate-based benchmarks (1,2,4-trichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and bis(2-ethylhexyl)phthalate [BEHP]). BEHP has the highest potential for adverse effects to benthic invertebrates, with HQs greater than 100 in the north and middle regions.

PAHs

Eighteen detected PAHs, including total benzofluoranthenes, as well as HMW, LMW, and total PAHs, exceeded either the wildlife-based screening benchmarks, invertebrate-based benchmarks, or both. The magnitude of exceedances was consistently higher for HMW PAHs. For invertebrate exposures, the magnitude of exceedances was generally greater than 10 in the north region and higher in the middle and south regions, which frequently were between 100 and 1000. The magnitude of exceedances for wildlife PCLs was generally consistent across all three regions of the NBSA and was almost always greater than 100.

The highest exceedances (HQs > 1,000) of the wildlife PCLs were associated with benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, indeno[1,2,3-c,d]pyrene, the HMW PAHs, and total PAHs. The exceedances of the wildlife PCLs for benzo(b)fluoranthene, HMW PAHs, and total PAHs were consistently high, with wildlife HQs greater than 1,000 in all three regions. Benzo(k)fluoranthene had the highest exceedances in the south region, chrysene in the middle and south regions, and indeno[1,2,3-c,d]pyrene in the north region.

For invertebrate exposures, PAH HQs were almost always greater than 10. The HQs were often greater than 100 in the south region, occasionally greater than 100 in the middle region, and rarely greater than 100 in the north region, with the exception of indeno[1,2,3-c,d]pyrene.

PCBs

Because screening benchmarks and toxicity values for PCBs are based on PCB Aroclors, PCBs are only discussed in terms of Aroclor concentrations. Wildlife-based HQs for Aroclor mixtures were generally less than 10 with the exception of Aroclor 1248, Aroclor 1254, and Total Aroclors, which all had HQs greater than 10 in the south region. Total Aroclors also had an HQ greater than 10 in the middle region.

For invertebrates, HQs for Aroclor 1248 and 1260 were greater than 100. The HQ for Aroclor 1260 was greater than 100 in all three regions, while the invertebrate HQ for Aroclor 1248 was greater than 100 in the south region.

Pesticides/Herbicides

Twenty-one individual detected pesticide/herbicide compounds and five summed total aggregates (*e.g.,* total DDx and total chlordane) exceeded either the wildlife or invertebrate-based benchmarks. Nine compounds (2,4'-DDE, 2,4'-DDT, 4,4'-DDE, 4,4'-DDT, total DDx, dieldrin, endrin, endrin ketone, and total endrin) exceeded their respective wildlife-based PCLs. The greatest exceedances (HQ > 1000) were associated with total DDx, chlordane, dieldrin, and endosulfan. There was an observed increase in the magnitude of exceedances associated with total DDx from north to south for both the wildlife and invertebrate HQs. For all compounds, the exceedances of the invertebrate benchmarks were generally higher than the wildlife exceedances.

Dioxins

2,3,7,8-TCDD exceeded an invertebrate-based benchmark for all the regions. The HQ was highest in the north and middle regions (HQ>100) and lower in the southern region (HQ>10).

**Table 6. Summary of Hazard Quotients for Sediment**

| Chemical | Overall | | North | | Middle | | South | |
|---|---|---|---|---|---|---|---|---|
| | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate |
| **Metals** | | | | | | | | |
| Antimony | | >10 | | >1 | | >10 | | >10 |
| Arsenic | - | >1 | - | >1 | - | >1 | - | >1 |
| Cadmium | >1 | >10 | >1 | >1 | >1 | >10 | >1 | >1 |
| **Chromium** | **>1000** | >1 | **>100** | >1 | **>1000** | >1 | **>100** | >1 |
| **Copper** | **>1000** | >10 | **>100** | >1 | **>1000** | >10 | **>100** | >1 |
| Iron | | >1 | | >1 | | >1 | | >1 |
| Lead | >10 | >10 | >10 | >1 | >10 | >10 | >10 | >1 |
| Manganese | | >1 | | >1 | | >1 | | >1 |
| **Mercury** | **>100** | >10 | **>100** | >10 | **>100** | >10 | >10 | >10 |
| Nickel | >10 | >1 | >10 | >1 | >10 | >1 | >10 | >1 |
| Selenium | >10 | | >10 | | >10 | | >10 | |
| Silver | - | >10 | - | >1 | - | >10 | - | >10 |
| **Zinc** | **>1000** | >10 | **>1000** | >1 | **>1000** | >10 | **>100** | >1 |
| **VOCs** | | | | | | | | |
| Ethylbenzene | | >1 | #N/A | #N/A | | >1 | #N/D | #N/D |
| **SVOCs (Non-PAHs)** | | | | | | | | |
| 1,2,4-Trichlorobenzene | - | >1 | - | >1 | - | >1 | #N/D | #N/D |
| 1,3-Dichlorobenzene | - | >10 | - | >10 | #N/D | #N/D | #N/D | #N/D |
| 1,4-Dichlorobenzene | - | >10 | - | >10 | - | >10 | - | >10 |
| **Bis(2-ethylhexyl)phthalate** | | **>100** | | **>100** | | **>100** | | >10 |
| **SVOCs (PAHs)** | | | | | | | | |
| **2-Methylnaphthalene** | | **>100** | | >10 | | **>100** | | **>100** |
| **Acenaphthene** | - | **>100** | - | >10 | - | **>100** | - | **>100** |
| **Acenaphthylene** | - | **>100** | - | >10 | - | **>100** | - | >10 |
| Anthracene | - | >10 | - | >10 | - | >10 | - | >10 |
| **Benzo(a)anthracene** | **>100** | >10 | **>100** | >10 | **>100** | >10 | **>100** | >10 |
| **Benzo(a)pyrene** | **>100** | >10 | >10 | >10 | **>100** | >10 | >10 | >10 |
| **Benzo(b)fluoranthene** | **>1000** | | **>1000** | | **>1000** | | **>1000** | |
| Benzo(g,h,i)perylene | - | >10 | - | >10 | - | >10 | - | >10 |
| **Benzo(k)fluoranthene** | **>1000** | >10 | >100 | >10 | **>100** | >10 | **>1000** | >10 |
| Benzofluoranthenes, total | | >10 | | >10 | | >1 | | >1 |
| **Chrysene** | **>1000** | **>100** | **>100** | >10 | **>1000** | >10 | **>1000** | **>100** |
| **Dibenz(a,h)anthracene** | **>100** | >10 | >10 | >10 | **>100** | >10 | **>100** | >10 |
| **Fluoranthene** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **Fluorene** | - | **>100** | - | >10 | - | **>100** | - | **>100** |
| **Indeno[1,2,3-c,d]-pyrene** | **>1000** | **>100** | **>1000** | **>100** | **>100** | >10 | **>100** | >10 |
| Naphthalene | | >10 | | >1 | | >10 | | >10 |
| **Phenanthrene** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **Pyrene** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **Total PAHs** | **>1000** | **>100** | **>1000** | >10 | **>1000** | >10 | **>1000** | **>100** |
| **High MW PAHs** | **>1000** | **>100** | **>1000** | >10 | **>1000** | >10 | **>1000** | **>100** |
| Low MW PAHs | - | >10 | - | >10 | - | >10 | - | >10 |
| **PCBs** | | | | | | | | |
| Aroclor 1242 | >1 | | #N/D | #N/D | >1 | | #N/D | #N/D |

## Table 6. Summary of Hazard Quotients for Sediment, continued

| Chemical | Overall | | North | | Middle | | South | |
|---|---|---|---|---|---|---|---|---|
| | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate |
| **Aroclor 1248** | >10 | **>100** | >1 | >10 | >1 | >10 | >10 | **>100** |
| Aroclor 1254 | >10 | >10 | >1 | >1 | >1 | >10 | >10 | >10 |
| **Aroclor 1260** | >1 | **>100** | >1 | **>100** | >1 | **>100** | >1 | **>100** |
| PCB 18CONGX2 | >1 | | >1 | | >1 | | >1 | |
| Total Aroclor | >10 | | >1 | | >10 | | >10 | |
| Total PCBs | >1 | >10 | >1 | >10 | >1 | >10 | >1 | >10 |
| **Pesticides/Herbicides** | | | | | | | | |
| 2,4'-DDD | - | >10 | - | >10 | - | >10 | - | >10 |
| 2,4'-DDE | >1 | >10 | - | >1 | >1 | >1 | >1 | >10 |
| **2,4'-DDT** | >1 | **>100** | - | >1 | >1 | >10 | >1 | **>100** |
| **4,4'-DDD** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **4,4'-DDE** | >10 | **>100** | >1 | >10 | >1 | >10 | >10 | **>100** |
| **4,4'-DDT** | >10 | **>1000** | >1 | >10 | >10 | **>100** | >10 | **>1000** |
| **Total DDx** | **>100** | **>1000** | >1 | >10 | >10 | **>100** | **>100** | **>1000** |
| **Aldrin** | - | **>100** | - | >10 | - | >10 | - | >100 |
| alpha-BHC | - | >10 | - | >1 | - | >10 | - | >10 |
| beta-BHC | - | >10 | - | >1 | - | >10 | - | >10 |
| delta-BHC | - | >10 | - | >1 | - | >10 | - | >10 |
| gamma-BHC (Lindane) | - | >10 | - | >1 | - | >10 | - | >10 |
| **Total BHC** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **Chlordane** | - | **>1000** | - | **>100** | - | **>1000** | - | **>100** |
| **Chlordane,alpha (cis)** | - | **>1000** | - | **>1000** | - | **>1000** | - | **>1000** |
| **Chlordane,gamma (trans)** | - | **>1000** | - | **>1000** | - | **>1000** | - | **>1000** |
| Chlordane, oxy | - | >10 | - | >10 | - | >10 | #N/D | #N/D |
| **Total Chlordane** | - | **>1000** | - | **>1000** | - | **>1000** | - | **>1000** |
| **Dieldrin** | >1 | **>1000** | - | **>1000** | - | **>1000** | >1 | **>1000** |
| **Endrin** | >10 | **>100** | >1 | >10 | >1 | >10 | >10 | **>100** |
| **Total Endrin** | >10 | **>100** | >1 | >10 | >1 | >10 | >10 | **>100** |
| **Total Endosulfan** | - | **>1000** | #N/D | #N/D | - | **>1000** | #N/D | #N/D |
| **Heptachlor** | - | **>100** | - | >10 | - | >10 | #N/D | #N/D |
| **Heptachlor epoxide** | - | **>100** | - | >10 | - | >10 | - | **>100** |
| **Total Heptachlor** | - | **>100** | - | >10 | - | **>100** | - | **>100** |
| **Hexachlorobenzene** | - | **>100** | - | >10 | - | **>100** | - | **>100** |
| **Methoxychlor** | - | **>100** | #N/D | #N/D | - | **>100** | #N/D | #N/D |
| **Dioxins/Furans** | | | | | | | | |
| **2,3,7,8-TCDD** | - | **>100** | - | **>100** | - | **>100** | - | >10 |

Notes:
Refer to Tables D-1 through D-4 in Attachment D for the overall and the north, middle, and south regions, respectively.
Only chemicals detected in at least one sample at a maximum concentration exceeding a screening value are included.
#N/A – parameter not available/.
#N/D - parameter not detected.
A dash indicates that the maximum parameter value used in the screening was less than the benchmark.
Bolded chemicals have HQs greater than 100 and/or 1000.

## 5.2 Biological Tissue

To assess the risks associated with chemical contaminants in biological tissue, toxicological benchmarks were developed for benthic invertebrates, mollusks, crabs, and fish. These results helped identify the potential for adverse effects to organisms directly exposed to sediment as well as bioaccumulative dietary exposures for wildlife. The results are provided in Attachments E through I and discussed in the following sections. Tables 7 through 10 summarize the results of the tissue screen for benthic invertebrates, mollusks, crabs, fish, and birds, respectively. The tables are organized by chemical and region within the NBSA. For each region, the magnitude of the HQ above 1 is presented. Only chemicals that were detected in at least one sample at a maximum concentration exceeding a screening value are included. Furthermore, each chemical was screened against two benchmarks within each region: a receptor-based benchmark and a wildlife-based benchmark. Receptor-based benchmarks were developed for benthic invertebrates, mollusks, crabs, fish, and bird tissue and represent concentrations that if exceeded could pose an unacceptable risk to that specific receptor (e.g., high body burden in fish tissue resulting in reproductive failure in a bass population). The wildlife-based benchmarks are dietary concentrations (i.e., in prey organisms) that represent a threshold for adverse effects to the wildlife consumer of the contaminated tissue. Bolded values indicate an HQ above 100 or 1000, representing the most potential for adverse effects.

### 5.2.1 Benthic Invertebrate Tissue

The results of the benthic invertebrate risk characterization (Attachment E) are summarized in Table 7 and are discussed in the following section. There were insufficient data to calculate HQs for the north region of the NBSA.

Metals

Nine detected inorganic compounds had HQs greater than 1 for either the wildlife or invertebrate-based benchmarks. All were located in the middle region of the bay. With the exception of zinc and lead, the wildlife HQs were less than 10, but greater than 1. For the invertebrate HQs, all were greater than 10 with the exception of lead. Zinc had the highest exceedance of the invertebrate CBR, with an HQ greater than 1,000, followed by silver and copper (HQ>100).

PAHs

Seven individual PAHs, in addition to HMW and total PAHs, exceeded their respective wildlife PCLs. Exceedances were generally greater in the middle region than the south region. The highest exceedances (HQs > 1,000) were associated with total PAHs and HMW PAHs.

Although there are no invertebrate CBRs for comparison to individual PAHs; HMW PAHs, LMW PAHs, and total PAHs did exceed their respective invertebrate CBRs. Exceedances were greater than 100 in the middle region and lower in the south region.

PCBs

Total PCBs had an HQ greater than 10 for wildlife and greater than 1 for invertebrates in the middle region of the bay. In the south region of the bay, the wildlife HQ was greater than 1.

Pesticides/Herbicides

Six individual pesticide/herbicide compounds and three summed total aggregates (*e.g.,* total DDx and total chlordane) exceeded the wildlife or invertebrate-based benchmarks. The highest exceedance (HQ >1,000) of the invertebrate CBR was associated with total DDx. Aldrin and dieldrin had HQs less than 10, but greater than 1; total endosulfan and total chlordane had HQs greater than 10.

Dioxins

All of the HQs for the PCB-based TEQs were below 1. The HQs for the dioxin/furan-based TEQs were greater than 1,000. The wildlife HQs were greater than 1,000 in the middle region and decreased substantially in the south region, where all the HQs were less than 1. Dioxin and furan HQs were not calculated for benthic invertebrates due to the lack of both an appropriate toxicological benchmark and TEFs (necessary to calculate TEQs) for this receptor category.

**Table 7. Summary of Hazard Quotients for Benthic Invertebrate Critical Body Residues**

| Chemical | Overall | | Middle | | South | | Representative Species |
|---|---|---|---|---|---|---|---|
| | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | |
| **Metals** | | | | | | | |
| Arsenic | >1 | | >1 | | #N/A | #N/A | |
| Cadmium | >1 | | >1 | | - | | |
| Chromium | >1 | | >1 | | #N/A | #N/A | |
| **Copper** | >1 | **>100** | >1 | **>100** | #N/A | #N/A | *Protothaca* |
| Lead | >10 | >1 | >10 | >1 | #N/A | #N/A | *Hyalella* |
| Mercury (elemental) | >1 | >10 | >1 | >10 | - | - | zooplankton |
| Nickel | >1 | >10 | >1 | >10 | #N/A | #N/A | *Hyalella* |
| **Silver** | - | **>100** | - | **>100** | #N/A | #N/A | *Acartia* |
| **Zinc** | >10 | **>1000** | >10 | **>1000** | #N/A | #N/A | *Acartia* |
| **SVOCs (PAHs)** | | | | | | | |
| Benzo(a)anthracene | >10 | | >10 | | >1 | | |
| Benzo(a)pyrene | >10 | | >10 | | >1 | | |
| **Benzo(b)fluoranthene** | **>100** | | **>100** | | #N/A | #N/A | |
| **Benzo(k)fluoranthene** | **>100** | | **>100** | | #N/A | #N/A | |
| **Chrysene** | **>100** | | **>100** | | >10 | | |
| Dibenz(a,h)anthracene | >10 | | >10 | | >1 | ` | |
| Indeno[1,2,3-c,d]-pyrene | >10 | | >10 | | >1 | | |
| **Total PAHs** | **>1000** | **>100** | **>1000** | **>100** | **>100** | >10 | *Mytilus* |
| **HMW PAHs** | **>1000** | **>100** | **>1000** | **>100** | **>100** | >1 | *Mytilus* |
| LMW PAHs | - | >10 | - | >10 | - | >1 | *Mytilus* |
| **PCBs** | | | | | | | |
| Total PCBs | >10 | >1 | >10 | >1 | >1 | - | *Palaemonetes* |
| **Pesticides/Herbicides** | | | | | | | |
| 2,4'-DDD | >1 | | >1 | | - | | |
| 4,4'-DDD | >1 | | >1 | | - | | |
| 4,4'-DDE | >1 | | >1 | | - | | |
| 4,4'-DDT | >1 | | >1 | | - | | |
| **Total DDx** | >1 | **>1000** | >1 | **>1000** | - | >10 | *Hyalella* |
| Aldrin | - | >1 | - | >1 | - | - | *Penaeus* |
| Total Chlordane | - | >10 | - | >10 | - | - | *Crassostrea* |
| Dieldrin | - | >1 | - | >1 | - | - | *Penaeus* |
| Total Endosulfan | - | >10 | - | >10 | - | - | *Penaeus* |
| **TEQs (Database)** | | | | | | | |
| **DIOX_TEQ_BIRD** | **>1000** | | **>1000** | | - | | |
| **DIOX_TEQ_MAMMAL** | **>1000** | | **>1000** | | - | | |
| **TOTAL_TEQ_BIRD** | **>1000** | | **>1000** | | - | | |
| **TOTAL_TEQ_MAMMAL** | **>1000** | | **>1000** | | - | | |

Notes:
Refer to Tables E-1 through E-3 in Attachment E for the overall, middle, and south regions, respectively.
Representative species for the invertebrate CBRs as summarized in Table 26 in Attachment C; the wildlife based benchmarks were calculated as described in Section 4.1.3. The wildlife-based benchmarks were developed to be protective of dietary exposures to invertebrate tissue by foraging wildlife.
Only chemicals detected in at least one sample at a maximum concentration exceeding a screening value are included.

#N/A - parameter not available/analyzed; bolded chemicals have HQs greater than 100 and/or 1000.
A dash indicates that the maximum parameter value used in the screening was less than the benchmark.

### 5.2.2 Mollusk Tissue

The results of the mollusk tissue risk characterizations (Attachment F) are summarized in Table 8 and are discussed in the following section.

Metals

Ten detected inorganic compounds had HQs greater than 1 for either the wildlife or invertebrate-based CBRs. All of the wildlife-based HQs, with the exception of lead, were less than 10. The invertebrate-based HQs were greater than 10 for both lead and nickel and greater than 100 for copper, mercury, and silver. Zinc concentrations showed the highest exceedance, with an HQ greater than 1,000. Overall, the HQs are highest in the middle region of the bay.

PAHs

Seven individual PAHs, as well as HMW PAHs and total PAHs, exceeded wildlife-based PCLs. Benzo(b)fluoranthene, chrysene, HMW PAHs, and total PAHs had the highest magnitude of exceedances, with HQs greater than 1,000 in the middle region and substantially lower in the other two regions (>1 to >10).

For the invertebrate-based HQs, total, LMW, and HMW PAHs were lowest in the north region with HQs greater than 1. They increased in the south region with HQs ranging from >10 to >100 and were highest in the middle region with HQs ranging from >100 to >1000 for the total PAHs.

PCBs

Wildlife-based HQs for Aroclor 1254, total Aroclors, and total PCBs were all greater than 1. Invertebrate-based HQs for total Aroclor and total PCBs were greater than 1. Only wildlife-based HQs for total PCBs exceeded 10 in the middle region; all other HQs were less than 10.

Pesticides/Herbicides

Five individual pesticide/herbicide compounds and three summed total aggregates (*e.g.,* total DDx and total chlordane) exceeded the wildlife or invertebrate-based benchmarks. All the wildlife-based HQs were less than 10 and were associated with DDT compounds (*i.e.*, DDE, DDD, and DDT). The invertebrate-based HQs for aldrin and dieldrin were less than 10. HQs for total chlordane and total endosulfan were greater than 10 in the middle region. The HQ for total DDx exceeded 1,000 in the middle region and 100 in the other two regions. Overall, the middle region had the highest exceedances of both the invertebrate and wildlife benchmarks.

Dioxins

The wildlife-based HQs for dioxin/furan and PCB TEQs were less than 10. These patterns were consistent across all three regions of the NBSA. Mollusk tissue HQs were calculated for 2,3,7,8-TCDD; however, no TEQ could be calculated due to the lack of appropriate TEF values. The mollusk-based HQs for 2,3,7,8-TCDD were greater than 10 in all three regions of the bay.

## Table 8. Summary of Hazard Quotients for Mollusk Tissue

| Chemical | Overall | | North | | Middle | | South | | Representative Species |
|---|---|---|---|---|---|---|---|---|---|
| | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | |
| **Metals** | | | | | | | | | |
| Arsenic | >1 | | #N/A | #N/A | >1 | | - | | |
| Cadmium | >1 | | - | | >1 | | >1 | | |
| Chromium | >1 | | #N/A | #N/A | >1 | | #N/A | #N/A | |
| **Copper** | >1 | **>100** | #N/A | #N/A | >1 | **>100** | #N/A | #N/A | *Protothaca* |
| Lead | >10 | >10 | >1 | - | >10 | >10 | >1 | >1 | *Hyalella* |
| **Mercury (elemental)** | >1 | **>100** | - | >1 | >1 | **>100** | - | >1 | zooplankton |
| Mercury (total) | >1 | >1 | - | >1 | - | >1 | >1 | >1 | *Hyalella* |
| Nickel | >1 | >10 | #N/A | #N/A | >1 | >10 | #N/A | #N/A | *Acartia* |
| **Silver** | - | **>100** | #N/A | #N/A | - | **>100** | #N/A | #N/A | *Acartia* |
| **Zinc** | >1 | **>1000** | #N/A | #N/A | >1 | **>1000** | #N/A | #N/A | *Protothaca* |
| **SVOCs (PAHs)** | | | | | | | | | |
| **Benzo(a)anthracene** | **>100** | | >1 | | **>100** | | >10 | | |
| **Benzo(a)pyrene** | **>100** | | - | | **>100** | | >10 | | |
| **Benzo(b)fluoranthene** | **>1000** | | >10 | | **>1000** | | >10 | | |
| **Benzo(k)fluoranthene** | **>100** | | >10 | | **>100** | | >10 | | |
| **Chrysene** | **>1000** | | >1 | | **>1000** | | **>100** | | |
| Dibenz(a,h)anthracene | >10 | | - | | >10 | | >1 | | |
| **Indeno[1,2,3-c,d]-pyrene** | **>100** | | >1 | | **>100** | | >10 | | |
| **Total PAHs** | **>1000** | **>1000** | **>100** | >1 | **>1000** | **>1000** | **>1000** | **>100** | *Mytilus* |
| **High MW PAHs** | **>1000** | **>100** | **>100** | >1 | **>1000** | **>100** | **>1000** | **>100** | *Mytilus* |
| **Low MW PAHs** | **-** | **>100** | - | >1 | - | **>100** | - | >10 | *Mytilus* |
| **PCBs** | | | | | | | | | |
| Aroclor 1254 | >1 | | - | | - | | >1 | | |
| Total Aroclor | >1 | >1 | >1 | - | >1 | - | >1 | >1 | *Palaemonetes* |
| Total PCBs | >10 | >1 | >1 | - | >10 | >1 | >1 | >1 | *Palaemonetes* |
| **Pesticides/Herbicides** | | | | | | | | | |
| 2,4'-DDE | >1 | | - | | >1 | | - | | |
| 4,4'-DDD | >1 | | - | | >1 | | - | | |
| 4,4'-DDE | >1 | | - | | >1 | | - | | |
| **Total DDx** | >1 | **>1000** | - | **>100** | >1 | **>1000** | >1 | **>100** | *Hyalella* |
| Aldrin | - | >1 | #N/D | #N/D | - | >1 | - | - | *Penaeus* |
| Total Chlordane | - | >10 | - | >1 | - | >10 | - | >1 | *Crassostrea* |
| Dieldrin | - | >1 | - | - | - | >1 | - | - | *Penaeus* |
| Total Endosulfan | - | >10 | - | - | - | >10 | - | - | *Penaeus* |
| **TEQs (Database)** | | | | | | | | | |
| 2,3,7,8-TCDD | | >10 | | >10 | | >10 | | >10 | *Crassostrea* |
| DIOX_TEQ_BIRD | - | | - | | - | | - | | |
| DIOX TEQ_MAMMAL | - | | - | | - | | - | | |
| PCB_TEQ_BIRD | >1 | | >1 | | >1 | | >1 | | |
| PCB_TEQ_MAMMAL | >1 | | - | | - | | >1 | | |
| TOTAL_TEQ_BIRD | >1 | | >1 | | >1 | | >1 | | |
| TOTAL_TEQ_MAMMAL | >1 | | - | | - | | >1 | | |

Notes:
Refer to Tables F-1 through F-4 in Attachment F for the overall and the north, middle, and south regions, respectively.
Representative species for the invertebrate CBRs as summarized in Table 26 in Attachment C; the wildlife based benchmarks were calculated as described in Section 4.1.3. The wildlife-based benchmarks were developed to be protective of dietary exposures to invertebrate tissue by foraging wildlife.
Only chemicals detected in at least one sample at a maximum concentration exceeding a screening value are included.
#N/A - parameter not available/analyzed.
#N/D - parameter not detected.
A dash indicates that the maximum parameter value used in the screening was less than the benchmark.
Bolded chemicals have HQs greater than 100 and/or 1000.

### 5.2.3 Crab Tissue

The results of the crab tissue risk characterization (Attachment G) are summarized in Table 9 and discussed in the following section.

Metals

Mercury was the only inorganic compound that had an HQ greater than 1. Data for elemental mercury, methyl mercury, and total mercury were reported for the north and south regions; only data for methyl mercury were reported for the middle region. All the HQs for wildlife were less than 10. Exceedances of the invertebrate-based benchmark were slightly greater, with all HQs greater than 10.

PAHs

Five individual PAHs, as well as HMW PAHs and total PAHs, exceeded wildlife-based PCLs in the northern and middle regions. PAH data were not reported for the south. The HQs were less than 10 for the individual PAHs but exceeded 100 for the HMW and total PAHs. Invertebrate-based HQs were calculated for total PAHs, HMW PAHs, and LMW PAHs; all three compounds had HQs less than 10 but greater than 1. Results were similar for both the north and middle regions.

PCBs

Aroclor 1254 was the only individual Aroclor that exceeded an HQ of 1 and it occurred in the middle region, based on the wildlife PCL. Both total Aroclors and total PCBs exceeded a wildlife-based HQ of 1 in the north and middle regions; the middle region had a higher exceedance for total Aroclor (>10). Invertebrate-based HQs were exceeded for total Aroclors and total PCBs (both >1) in the north and middle regions. PCB data were not reported for the south region.

Pesticides/Herbicides

Total DDx and total chlordane were the only two pesticides that exceeded HQs of 1. Total DDx and total chlordane data were reported for the north and middle regions, but not the south. Total DDx exceeded both the invertebrate and wildlife-based HQs (>100 and >1, respectively) in the middle region and the invertebrate-based HQ in the north region (>100). Total chlordane exceeded the invertebrate-based benchmark in both regions with HQs greater than 1.

Dioxins

Wildlife-based HQs for dioxin/furan, PCB TEQs, and total TEQs were all greater than 1 in the middle region and below 1 in the other regions. Crab tissue HQs were not calculated due to the lack of both an appropriate toxicological benchmark and TEFs (necessary to calculate TEQs) for this receptor category.

**Table 9. Summary of Hazard Quotients for Crab Tissue**

| Chemical | Overall | | North | | Middle | | South | | Representative Species |
|---|---|---|---|---|---|---|---|---|---|
| | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | Wildlife | Invertebrate | |
| **Metals** | | | | | | | | | |
| Mercury (Elemental) | >1 | >10 | >1 | >10 | >1 | >10 | #N/A | #N/A | zooplankton |
| Mercury (Total) | >1 | >10 | #N/A | #N/A | >1 | >10 | #N/A | #N/A | zooplankton |
| Methyl mercury | >1 | | #N/A | #N/A | >1 | | #N/A | #N/A | zooplankton |
| **SVOCs (PAHs)** | | | | | | | | | |
| Benzo(a)anthracene | >1 | | >1 | | >1 | | #N/A | #N/A | |
| Benzo(b)fluoranthene | >1 | | >1 | | >1 | | #N/A | #N/A | |
| Benzo(k)fluoranthene | >1 | | >1 | | >1 | | #N/A | #N/A | |
| Chrysene | >1 | | >1 | | >1 | | #N/A | #N/A | |
| Indeno[1,2,3-c,d]-pyrene | >1 | | >1 | | >1 | | #N/A | #N/A | |
| **Total PAHs** | **>100** | >1 | **>100** | >1 | **>100** | >1 | #N/A | #N/A | *Mytilus* |
| **HMW PAHs** | **>100** | >1 | **>100** | >1 | >10 | >1 | #N/A | #N/A | *Mytilus* |
| LMW PAHs | - | >1 | - | >1 | - | >1 | #N/A | #N/A | *Mytilus* |
| **PCBs** | | | | | | | | | |
| Aroclor 1254 | >1 | | - | | >1 | | #N/A | #N/A | |
| Total Aroclor | >10 | >1 | >1 | - | >10 | >1 | #N/A | #N/A | *Palaemonetes* |
| Total PCBs | >1 | >1 | >1 | - | >1 | >1 | #N/A | #N/A | *Palaemonetes* |
| **Pesticides/Herbicides** | | | | | | | | | |
| **Total DDx** | >1 | **>100** | - | **>100** | >1 | **>100** | #N/A | #N/A | *Hyalella* |
| Total Chlordane | - | >1 | - | >1 | - | >1 | #N/A | #N/A | *Crassostrea* |
| **TEQs (Database)** | | | | | | | | | |
| DIOX_TEQ_BIRD | >1 | | - | | >1 | | - | | |
| DIOX_TEQ_MAMMAL | >1 | | - | | >1 | | - | | |
| PCB_TEQ_BIRD | >1 | | - | | >1 | | #N/A | #N/A | |
| PCB_TEQ_MAMMAL | >1 | | - | | >1 | | #N/A | #N/A | |
| TOTAL_TEQ_BIRD | >1 | | - | | >1 | | - | | |
| TOTAL_TEQ_MAMMAL | >1 | | - | | >1 | | - | | |

Notes:
Refer to Tables G-1 through G-4 in Attachment G for the overall and the north, middle, and south regions, respectively.
Representative species for the invertebrate CBRs as summarized in Table 26 in Attachment C; the wildlife based benchmarks were calculated as described in Section 4.1.3. The wildlife-based benchmarks were developed to be protective of dietary exposures to invertebrate tissue by foraging wildlife.
Only chemicals detected in at least one sample at a maximum concentration exceeding a screening value are included.
#N/A - parameter not available/analyzed.
A dash indicates that the maximum parameter value used in the screening was less than the benchmark.
Bolded chemicals have HQs greater than 100 and/or 1000.

### 5.2.4 Fish Tissue

The results of the fish tissue risk characterization (Attachment H) are summarized in Table 10 and are discussed in the following sections.

Metals

Mercury and lead were the only inorganic compounds that had HQs greater than 1. Data for elemental mercury, methyl mercury, and total mercury were analyzed for the north and south regions; only data for elemental mercury were reported for the middle region. There were no data reported for lead in the south region. Lead exceeded the invertebrate CBR in the north and middle regions, with HQs greater than 1. The greatest exceedances for mercury occurred in the north with wildlife-based HQs ranging from greater than 1 to greater than 10 and fish-based HQs ranging from greater than 10 to greater than 100. In the south, the HQs for mercury

were lower, ranging from greater than 1 for the wildlife-based HQ and greater than 10 for the fish-based HQ. This was also the case for elemental mercury (the only species analyzed) in the middle region.

PAHs

Four individual detected PAHs, as well as the HMW PAHs and total PAHs, exceeded wildlife-based PCLs. All of the wildlife-based HQs were less than 10 for the individual PAHs. Total PAHs and HMW PAHs exceeded 1,000 in the north region; total PAHs exceeded 100 in the middle and south regions, while the HMW PAHs were slightly lower (HQ >10) in the middle and south regions. Fish-based HQs only exceeded 1 in the north region for the summed PAHs (HMW, LMW, and total PAHs).

PCBs

Four individual Aroclors (1016, 1242, 1248, and 1254) plus total Aroclors and total PCBs all had HQs greater than 1. The wildlife-based HQs for individual Aroclors were greater than 1 in the north; Aroclor 1254 was greater than 1 in both the middle and south and Aroclor 1016 was greater than 1 in the south. Total Aroclors and total PCBs had fish-based HQs greater than 100 and the wildlife-based HQs greater than 10 in all the regions.

Pesticides/Herbicides

Three individual pesticide/herbicide compounds (4,4'-DDD, 4,4'-DDE, and dieldrin) and four summed totals (total DDx, total endrin, total chlordane, total nonachlor) had HQs greater than 1. In all the regions, exceedances of the wildlife-based HQs were all less than 10. Three pesticides (total DDx, total chlordane, and total nonachlor) exceeded the fish CBR by 10 or more in all regions. Total endrin also exceeded the invertebrate CBR in all regions but had an HQ less than 10.

Dioxins

The wildlife-based HQs for PCB TEQs and total TEQs exceeded 10 in the north and south regions; HQs for dioxin/furan TEQs were less than 10 but greater than 1. The fish-based HQs for all TEQs exceeded 1 in all regions.

### 5.2.5 Bird Tissue

The results of the bird tissue risk characterization are provided in Attachment I. These tissue values represent egg data collected from the western edge of Shooters Island in the south region of the NBSA. HQs were derived for dioxin TEQs, PCB TEQs, and total TEQs based on the avian TEF values. The resulting HQs were 2.9 for the dioxin TEQ, 11 for the PCB TEQ, and 14 for the total TEQ. The PCBs represent the majority of the risk for this exposure medium.

## Table 10. Summary of Hazard Quotients for Fish Tissue

| Chemical | Overall | | North | | Middle | | South | | Representative Species |
|---|---|---|---|---|---|---|---|---|---|
| | Wildlife | Fish | Wildlife | Fish | Wildlife | Fish | Wildlife | Fish | |
| **Metals** | | | | | | | | | |
| Lead | - | >1 | - | >1 | - | >1 | #N/A | #N/A | *Oncorhynchus* |
| Mercury (Elemental) | >1 | >10 | >1 | >10 | >1 | >10 | >1 | >10 | *Ictalurus* |
| **Mercury (Total)** | >10 | **>100** | >10 | **>100** | #N/A | #N/A | >1 | >10 | *Fundulus* (eggs) |
| **Methyl mercury** | >10 | **>100** | >10 | **>100** | #N/A | #N/A | >1 | >10 | *Fundulus* (eggs) |
| **SVOCs (PAHs)** | | | | | | | | | |
| Benzo(a)anthracene | >1 | | >1 | | >1 | | - | | |
| Chrysene | >1 | | >1 | | >1 | | - | | |
| Dibenz(a,h)anthracene | >1 | | #N/D | #N/D | - | | #N/D | #N/D | |
| Indeno[1,2,3-c,d]-pyrene | >1 | | >1 | | >1 | | >1 | | |
| **Total PAHs** | **>1000** | >1 | **>1000** | >1 | **>100** | - | **>100** | - | *Psettichthys* |
| **HMW PAHs** | **>1000** | >1 | **>1000** | >1 | >10 | - | >10 | - | *Psettichthys* |
| LMW PAHs | - | >1 | - | >1 | - | - | - | - | *Psettichthys* |
| **PCBs** | | | | | | | | | |
| Aroclor 1016 | >1 | | #N/A | #N/A | #N/A | #N/A | >1 | | |
| Aroclor 1242 | >1 | | >1 | | - | | - | | |
| Aroclor 1248 | >1 | | >1 | | - | | - | | |
| Aroclor 1254 | >1 | | >1 | | >1 | | >1 | | |
| **Total Aroclor** | >10 | **>100** | >10 | **>100** | >10 | **>100** | >10 | **>100** | *Oryzias* (eggs) |
| **Total PCBs** | >10 | **>100** | >10 | **>100** | >10 | **>100** | >10 | **>100** | *Oryzias* (eggs) |
| **Pesticides/Herbicides** | | | | | | | | | |
| 4,4'-DDD | >1 | | >1 | | - | | >1 | | |
| 4,4'-DDE | >1 | | >1 | | - | | >1 | | |
| **Total DDx** | >1 | **>1000** | >1 | **>1000** | >1 | **>100** | >1 | **>1000** | *Salvelinus* (eggs) |
| **Total Chlordane** | >1 | **>100** | >1 | **>100** | - | >10 | - | >10 | *Cyprinodon* |
| Dieldrin | >1 | >1 | >1 | >1 | - | - | - | - | *Oncorhynchus* |
| Total Endrin | - | >1 | - | >1 | - | >1 | - | >1 | *Micropterus* |
| **Total Nonachlor** | - | **>1000** | - | >10 | - | **>1000** | - | >10 | *Cyprinodon* |
| **TEQs (Database)** | | | | | | | | | |
| DIOX_TEQ_BIRD | >1 | | >1 | | - | | >1 | | |
| DIOX_TEQ_FISH | | >1 | | >1 | | >1 | | >1 | *Salvelinus* (eggs) |
| DIOX_TEQ_MAMMAL | >1 | | >1 | | >1 | | >1 | | |
| PCB_TEQ_BIRD | >10 | | >10 | | >1 | | >10 | | |
| PCB_TEQ_FISH | | >1 | | >1 | | - | | - | *Salvelinus* (eggs) |
| PCB_TEQ_MAMMAL | >10 | | >10 | | - | | >10 | | |
| TOTAL_TEQ_BIRD | >10 | | >10 | | >1 | | >10 | | |
| TOTAL_TEQ_FISH | | >1 | | >1 | | >1 | | >1 | *Salvelinus* (eggs) |
| TOTAL_TEQ_MAMMAL | >10 | | >10 | | >1 | | >10 | | |

Notes:
Refer to Tables H-1 through H-4 in Attachment H for the overall and the north, middle, and south regions, respectively.
Representative species for the fish CBRs as summarized in Table 26 in Attachment C; the wildlife based benchmarks were calculated as described in Section 4.1.3. The wildlife-based benchmarks were developed to be protective of dietary exposures to fish tissue by foraging wildlife.

Only chemicals detected in at least one sample at a maximum concentration exceeding a screening value are included.

#N/A - parameter not available/analyzed.

#N/D - parameter not detected.

A dash indicates that the maximum parameter value used in the screening was less than the benchmark.

Bolded chemicals have HQs greater than 100 and/or 1000.

# 6.0 UNCERTAINTY ANALYSIS

This section discusses major limitations of the SLERA evaluations and sources of uncertainties; it also assesses whether these uncertainties and limitations may have resulted in an over- or under-estimation of risk. Uncertainties associated with the selection of COPECs, exposure assessment, effects assessment, and overall risk characterizations are discussed.

## 6.1 Problem Formulation Uncertainties

### 6.1.1 Receptors

Section 2.5 summarizes available knowledge concerning the types of ecological receptors likely to occur within the NBSA. Several regional-scale surveys and various ongoing investigations of dredging-related activities within the NBSA have resulted in a good understanding of the nature, abundance, and seasonal variability of fish and benthic in- and epi-fauna (NOAA, 1994; USACE, 1987, 2003a, b, c; Adams *et al*., 1998; Adams and Benyi, 2003). The avian fauna, both residents and migrants, which may be exposed to NBSA contaminants, are also well-characterized, although the potential presence of several state-listed species warrants greater documentation. The frequency with which fish, reptile, and mammal species utilize these habitats is less understood. The NJ state-listed diamondback terrapin is known to occur regionally, and it is possible that sea turtles could enter the bay seasonally; however, none of this is well-studied or documented. Small piscivorous mammals can potentially receive maximum contaminant doses as a result of their foraging habitats and life-style. There is also the likelihood that the NBSA is occasionally visited by larger marine mammals (as evidenced by a dolphin sighting in the Passaic River). The significance of these exposures, when and if they occur, is an area of uncertainty that will need to be further evaluated.

Aquatic plant species were not considered specifically in this SLERA. The importance of plant species as a component of the forage base of the NBSA ecosystem and in providing subsurface structure is not well understood at this time. Further consideration is warranted to determine whether this receptor group should be the focus of additional assessments. This uncertainty is likely to result in an underestimate of risk.

### 6.1.2 Identification and Selection of COPECs

The use of conservative screening benchmarks that considered both invertebrate and wildlife protectiveness ensured that the screening process considered all relevant exposures. Concerns regarding the comparability of different sampling programs also resulted in the conservative retention of chemicals that were not reported as detected in the dataset. As a result, the risk may be overestimated.

## 6.2 Exposure Uncertainties

The major exposure-related uncertainties are associated with uncertainties in the available data, the selection of exposure parameters, using maximum concentrations as exposure concentrations, and estimation of bioaccumulation factors for various environmental media.

### 6.2.1 Uncertainties in the Available Data

A screening level risk assessment generally relies on the use of historical data to evaluate the potential for adverse effects from ecological exposures to contaminants. In some cases, available data are limited. For this SLERA, surface water data were limited, and spatially inadequate for the purposes of contaminant screening. Therefore, surface water data were not evaluated. The evaluation of the surface water medium in a BERA for Newark Bay will need to rely on additional analytical data that provide a comprehensive understanding of spatial and temporal patterns of all contaminants present in bay waters.

Additional data collected for a BERA will also need to be based on carefully selected Data Quality Objectives. These DQOs should consider effects concentrations to ensure that analytical method detection limits (MDLs) are sensitive enough to detect contaminants at ecologically significant levels. DQOs for the historical data used for the SLERA are uncertain. Therefore, even COPECs with few or no detections were retained for further evaluation if no screening benchmark was identified or if one-half the MDLs exceeded the benchmark. If no screening benchmark is identified, additional laboratory analyses will use the minimum possible MDLs.

The BERA will also need to evaluate porewater exposures as well. Porewater evaluations provide important information on the bioavailable fraction of contaminants in sediments. Some sediment contamination may partition to porewater, while some may be unavailable for uptake because it is bound to sediment particles.

As mentioned in Section 4.2, in some cases, the project database did not have sufficient information to determine whether analytical data from different programs were directly comparable or not. In particular, the reporting basis (*i.e.*, dry weight versus wet weight) and specific chemical method fields were not populated for some sediment and tissue records. Sediment concentrations are usually presented as dry weight while tissue concentrations are presented as wet weight. If sediment data were wet weight, it is possible that risks may be underestimated. Conversely, if tissue data were presented as dry weight, it is possible that risks may be overestimated. If these data are selected for use in the BERA, the original sampling reports should be obtained and reviewed.

### 6.2.2 Exposure Parameters

The relationship between receptor size and dietary intake is a critical factor in estimating exposure. In addition, dietary composition affects exposure because different food sources contain varying levels of COPECs. Although literature exists for dose calculation inputs such as body weight, ingestion rate, and dietary composition for each receptor evaluated, natural populations may exhibit considerable variability in these parameters. Use of literature-derived exposure parameters increases uncertainty, which could result in an over- or under-estimation of the typical exposures encountered by receptors in the NBSA. The wildlife exposure models were parameterized using available information for adult females for each selected receptor species, and average values were selected for the parameter values where a range of data was provided.

### 6.2.3 Exposure Concentrations

Consistent with USEPA guidance, maximum detected concentrations of contaminants are used as the exposure point concentrations for risk estimates at the screening level. It is also assumed that concentrations detected in environmental media are 100% available to the exposed receptors. These assumptions are made to ensure that potential risks are not overlooked if the available data are limited. However, average realistic exposure concentrations are likely to be less than the maximum detected concentration in any historical dataset, and it is also likely that are fraction of contaminants is bound to sediment particles and unavailable for uptake by ecological receptors. Therefore, these assumptions likely provide an overestimate of risk.

### 6.2.4 Contaminant Distribution with Sediment Depth

Consistent with recent information concerning the depth of the BAZ in the NBSA (Tierra, 2005), the evaluation of NBSA sediment analytical data was limited to samples collected from the top 6-inches of sediment only. Some mollusks and segmented worms are known to occur deeper in bed sediments and could be exposed to different contaminants or concentrations. Exposure to deeper sediments may also periodically occur following extreme weather events. Ongoing analysis of sediment core data, along with a better understanding of the benthic ecology and of the hydrodynamic processes within the NBSA, may be necessary to evaluate ecological exposures to deeper strata in subsequent analyses.

The heterogeneous distribution of the sediment contaminants noted in Section 3.2.3 warrants further investigation of the specific exposure concentrations and uptake potential in each geomorphic unit. Where necessary, these exposures will be further refined in the BERA.

### 6.2.5 Bioaccumulation Factors

Although tissue residue data are available for the NBSA, literature-derived bioaccumulation factors (BAFs) were employed to estimate PCLs. This was necessary due to the absence of consistent tissue datasets for the various receptors and chemicals evaluated. However, no attempt was made to account for the relative importance of carbon and lipid fractions in determining the potential for contaminant uptake of highly hydrophobic organic contaminants in the system. For future risk assessments, it will be necessary to derive site-specific estimates of bioavailability and bioaccumulation in the BERA to reduce the uncertainties associated with using literature-derived uptake factors. Bioaccumulation factors employed in the SLERA were selected to provide conservative estimates of uptake potential and this could have resulted in the unnecessary retention of some chemicals. Therefore, it is likely that risk was overestimated.

## 6.3 Ecological Effects Uncertainties

The primary effects-related uncertainties are associated with the selection of screening benchmarks and CBRs.

### 6.3.1 Screening Benchmarks

There are potential uncertainties related to the appropriateness of literature-derived toxicity data. The screening benchmarks used in the SLERA were based on readily available compilations of values from literature sources and have been used in similar screening-level analyses conducted for the NBSA and the Passaic River (Battelle 2006; 2007). Although these compiled values are useful tools in conducting screening analyses, information for some of the COPECs may either be out of date or not necessarily conservative enough (for instance, the TRVs for TCDD have changed).

Chronic toxicological data were selected preferentially in developing screening benchmarks. Chronic NOAELs were the preferred toxicity endpoint for selection of screening benchmarks; however, ecological toxicity data were limited for some COPECs. Therefore, other endpoints (*e.g.*, subchronic NOAELs, or $LC_{50}$ values[2]) were selected for use as benchmarks. When an endpoint other than a chronic NOAEL was selected as a benchmark, an uncertainty factor was applied to the reported value to provide an additional level of conservatism in the risk estimation process. The use of conservative uncertainty factors may result in hazards and risks being over-estimated.

Little or no toxicological data are available for some COPECs. For instance, no avian effects data were available for many of the analyzed parameters, and no information was available to establish CBRs for some of the analytes analyzed for in biota tissue. This resulted in a significant number of chemicals being retained as potential COPECs, although it is unclear whether they do in fact pose an ecological risk.

In general, uncertainty is also associated with the extrapolation of literature-derived toxicity endpoints (especially laboratory-based studies) to equivalent endpoints for measurement endpoint receptors at the site because of differences in exposure conditions. The majority of the toxicity data evaluated and used in the SLERA were derived from laboratory studies. Homogeneous laboratory conditions result in different exposures than experienced by receptors in the environment. Although controlled experiments result in a more valid interpretation of the isolated parameters, uncertainty is associated with the assumption that laboratory exposure conditions are relevant to establishing protective media concentrations under field exposures.

[2] $LC_{50}$ value is the value at which a chemical is lethal to 50% of the organisms tested.

### 6.3.2 Critical Body Residues

CBRs were generally based on either the lowest bounded or unbounded tissue concentration associated with significant effects on growth, survival, or mortality; in the case of an unbounded LOAEL, a 10 fold extrapolation factor was applied to estimate a NOAEL (Battelle, 2006). The geometric mean (MATC) was calculated for each NOAEL/LOAEL pair and employed in the SLERA to screen tissue concentration data. This is a conservative approach because the CBRs were based on the lowest reported tissue effect concentration for the most sensitive species. However, greater uncertainty regarding the degree of conservatism exists for some COPECs, such as PAHs and dieldrin, for which few residue effect data exists (Battelle, 2006).

### 6.3.3 Dioxin and Furan Congeners

Wildlife exposures to dioxin and furan congeners were estimated using TRVs similar to those recommended by USEPA (1993) and the consensus-based TEFs from Van den Berg *et al*. (1998; 2005). This approach represents the most recent risk assessment approach for evaluating dioxins and furans. This approach has been employed because there is not adequate toxicity testing for each of the hundreds of dioxin and furan congeners. Although the use of TEFs has a sound scientific basis, there is some uncertainty (including assumption of additivity and methods used to determine relative potency) associated with their use in estimating the ecological effects from exposure to dioxin-like compounds.

The TEQ approach also does not account for toxicity of dioxin/furan and PCB congeners that have a non-AhR-mediated toxicological mechanism[3]. However, risk associated with exposure to compounds that exhibit non-dioxin-like effects was separately considered using toxicological data for PCB mixtures.

[3] The aryl hydrocarbon receptor (AhR) is a protein found in the cytoplasm of somatic cell tissues. The binding of dioxin-like compounds to this receptor has been shown to be the first critical step in expression of toxicological responses in mammals, birds, and fish.

# 7.0 SLERA CONCLUSIONS AND RECOMMENDATIONS

This SLERA demonstrates that a substantial majority of chemical parameters analyzed to date in relevant environmental media for the NBSA ought to be retained as potential COPECs for further evaluation in a BERA. The COPECs identified for each ecological exposure medium are summarized in Table 12. Moreover, the magnitude by which readily available screening benchmarks were exceeded by contaminants with known ecotoxicological hazards (in some cases, by well over three orders of magnitude) indicates that the potential exists for unacceptable ecological risks to occur within the NBSA. Consequently, a more detailed and site-specific analysis of ecological exposures and potential effects within Newark Bay is warranted to better characterize the risks and identify the relative importance that chemical stressors have for imposing long-term threats to biological populations using this resource.

Given the complexity and spatial scale of this environment, considerable additional information will be necessary to develop more realistic estimates of ecological exposure and effects. It is recommended that planning efforts continue to proceed through USEPA's eight-step ecological risk assessment process so that information necessary to conduct the BERA will be available in a timely fashion.

**Table 11. Summary of COPECs for Each Ecological Exposure Medium**

| Chemical | Sediment | Benthic Invertebrates | Fish | Mollusk | Crab | Avian Embryo |
|---|---|---|---|---|---|---|
| **Metals** | | | | | | |
| Antimony | ✓ | | | | | |
| Arsenic | ✓ | ✓ | | ✓ | | |
| Cadmium | ✓ | ✓ | | ✓ | | ✓ |
| Chromium | ✓ | ✓ | | ✓ | | |
| Copper | ✓ | ✓ | | ✓ | | |
| Iron | ✓ | | | | | |
| Lead | ✓ | ✓ | ✓ | ✓ | | |
| Manganese | ✓ | | | | | |
| Mercury | ✓ | | | | | |
| Mercury (Elemental) | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mercury (Total) | | | ✓ | ✓ | ✓ | ✓ |
| Methyl mercury | | | ✓ | | ✓ | ✓ |
| Nickel | ✓ | ✓ | | ✓ | | |
| Selenium | ✓ | | | | | |
| Silver | ✓ | ✓ | | ✓ | | |
| Zinc | ✓ | ✓ | | ✓ | | |
| **VOCs** | | | | | | |
| Ethylbenzene | ✓ | | | | | |
| **SVOCs (Non-PAHs)** | | | | | | |
| 1,2,4-Trichlorobenzene | ✓ | | | | | |
| 1,3-Dichlorobenzene | ✓ | | | | | |
| 1,4-Dichlorobenzene | ✓ | | | | | |
| Bis(2-ethylhexyl)phthalate | ✓ | | | | | |
| **SVOCs (PAHs)** | | | | | | |
| 1-Methylnaphthalene | | | | | | ✓ |
| 1-Methylphenanthrene | | | | | | ✓ |

**Table 11. Summary of COPECs for Each Ecological Exposure Medium, continued**

| Chemical | Sediment | Benthic Invertebrates | Fish | Mollusk | Crab | Avian Embryo |
|---|---|---|---|---|---|---|
| 2,3,5-Trimethylnaphthalene | | | | | | ✓ |
| 2,6-Dimethylnaphthalene | | | | | | ✓ |
| 2-Methylnaphthalene | ✓ | | | | | ✓ |
| Acenaphthene | ✓ | | | | | ✓ |
| Acenaphthylene | ✓ | | | | | ✓ |
| Anthracene | ✓ | | | | | ✓ |
| Benzo(a)anthracene | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Benzo(a)pyrene | ✓ | ✓ | | ✓ | | ✓ |
| Benzo(b)fluoranthene | ✓ | ✓ | | ✓ | ✓ | |
| Benzo(g,h,i)perylene | ✓ | | | | | ✓ |
| Benzo(k)fluoranthene | ✓ | ✓ | | ✓ | ✓ | |
| Benzo[e]pyrene | | | | | | ✓ |
| Benzofluoranthenes, total | ✓ | | | | | |
| Biphenyl | | | | | | ✓ |
| Chrysene | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Dibenz(a,h)anthracene | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Fluoranthene | ✓ | | | | | ✓ |
| Fluorene | ✓ | | | | | ✓ |
| Indeno[1,2,3-c,d]-pyrene | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Naphthalene | ✓ | | | | | ✓ |
| Perylene | | | | | | ✓ |
| Phenanthrene | ✓ | | | | | ✓ |
| Pyrene | ✓ | | | | | ✓ |
| Total PAHs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| High MW PAHs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Low MW PAHs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **PCBs** | | | | | | |
| Aroclor 1016 | | | ✓ | | | |
| Aroclor 1242 | ✓ | | ✓ | | | ✓ |
| Aroclor 1248 | ✓ | | ✓ | | | ✓ |
| Aroclor 1254 | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Aroclor 1260 | ✓ | | | | | ✓ |
| PCB 18CONGX2 | ✓ | | | | | ✓ |
| Total Aroclor | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Total PCBs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Pesticides/Herbicides** | | | | | | |
| 2,4'-DDD | ✓ | ✓ | | | | ✓ |
| 2,4'-DDE | ✓ | | | ✓ | | ✓ |
| 2,4'-DDT | ✓ | | | | | ✓ |
| 4,4'-DDD | ✓ | ✓ | ✓ | ✓ | | ✓ |
| 4,4'-DDE | ✓ | ✓ | ✓ | ✓ | | ✓ |
| 4,4'-DDT | ✓ | ✓ | | | | ✓ |
| Total DDx | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Aldrin | ✓ | ✓ | | ✓ | | ✓ |

**Table 11. Summary of COPECs for Each Ecological Exposure Medium, continued**

| Chemical | Sediment | Benthic Invertebrates | Fish | Mollusk | Crab | Avian Embryo |
|---|---|---|---|---|---|---|
| alpha-BHC | ✓ | | | | | ✓ |
| beta-BHC | ✓ | | | | | ✓ |
| delta-BHC | ✓ | | | | | ✓ |
| gamma-BHC (Lindane) | ✓ | | | | | ✓ |
| Total BHC | ✓ | | | | | ✓ |
| Chlordane | ✓ | | | | | ✓ |
| Chlordane,alpha (cis) | ✓ | | | | | ✓ |
| Chlordane,gamma (trans) | ✓ | | | | | ✓ |
| Chlordane, oxy | ✓ | | | | | ✓ |
| Total chlordane | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Dieldrin | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Endrin | ✓ | | | | | ✓ |
| Endrin aldehyde | | | | | | ✓ |
| Endrin ketone | | | | | | ✓ |
| Total endrin | ✓ | | ✓ | | | ✓ |
| Endosulfan sulfate | | | | | | ✓ |
| Endosulfan, alpha | | | | | | ✓ |
| Endosulfan, beta | | | | | | ✓ |
| Total endosulfan | ✓ | ✓ | | ✓ | | ✓ |
| Heptachlor | ✓ | | | | | ✓ |
| Heptachlor epoxide | ✓ | | | | | ✓ |
| Total heptachlor | ✓ | | | | | ✓ |
| Hexachlorobenzene | ✓ | | | | | ✓ |
| Methoxychlor | ✓ | | | | | ✓ |
| Mirex | | | | | | ✓ |
| Nonachlor, cis- | | | | | | ✓ |
| Nonachlor, trans- | | | | | | ✓ |
| Total Nonachlor | | | ✓ | | | ✓ |
| **TEQs** | | | | | | |
| 2,3,7,8-TCDD | ✓ | | | | | ✓ |
| DIOX_TEQ_BIRD | | ✓ | ✓ | | ✓ | ✓ |
| DIOX_TEQ_FISH | | | ✓ | ✓ | ✓ | ✓ |
| DIOX_TEQ_MAMMAL | | ✓ | ✓ | | ✓ | ✓ |
| PCB_TEQ_BIRD | | | ✓ | ✓ | ✓ | ✓ |
| PCB_TEQ_FISH | | | ✓ | ✓ | ✓ | ✓ |
| PCB_TEQ_MAMMAL | | | ✓ | ✓ | ✓ | ✓ |
| TOTAL_TEQ_BIRD | | ✓ | ✓ | ✓ | ✓ | ✓ |
| TOTAL_TEQ_FISH | | | ✓ | ✓ | ✓ | ✓ |
| TOTAL_TEQ_MAMMAL | · | ✓ | ✓ | ✓ | ✓ | ✓ |

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