Draft

Gowanus Canal Remedial Investigation Report

Volume 1

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Executive Summary

This draft remedial investigation (RI) report was prepared for the United States Environmental Protection Agency (USEPA) Region 2 by Henningson, Durham & Richardson Architecture & Engineering, P.C., in association with HDR Engineering, Inc. (HDR) and CH2M HILL to present the results of the RI activities completed at the Gowanus Canal Superfund Site, in Brooklyn, Kings County, New York. This draft RI report has been prepared under Work Assignment Number 013-RICO-02ZP, under the USEPA Region 2 RAC II Contract Number EP-W-09-009.

On March 2, 2010, USEPA placed the Gowanus Canal (USEPA ID#: NYN000206222) on its National Priorities List (NPL) of hazardous waste sites requiring further evaluation. Accordingly, USEPA Region 2 is performing a remedial investigation and feasibility study (RI/FS) of the canal according to the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, or "Superfund"), as amended. This report presents the results of the RI activities performed at the canal in 2010.

Remedial Investigation Objectives and Scope of Work

The overall objective of the RI is to characterize the canal to a degree sufficient to develop and select a remedy to reduce risks to human health and the environment from exposure to contaminants in the canal sediments. Accordingly, the field-sampling and data-collection activities described here were designed specifically to accomplish the following:

- Characterize the nature and extent of contamination in the Gowanus Canal to the degree necessary to evaluate the human health and ecological risks and to develop a remedy to reduce these risks
- Document the sources of contamination to the Gowanus Canal and provide a preliminary evaluation of ongoing sources of contamination to the canal that need to be addressed so that a sustainable remedy can be developed and implemented
- Determine the human health and ecological risks from exposure to contamination in the canal
- Determine the physical and chemical characteristics of the canal that will influence the development, evaluation, and selection of remedial alternatives

These activities were performed in three phases starting in January 2010 and continuing through November 2010. The RI scope and approach were developed by USEPA, and the work was completed with support from four entities: the USEPA Region 2 contractor team of HDR, CH2M HILL, and GRB Environmental, Inc.; the USEPA Emergency Response Team (ERT); New York City; and National Grid. The following activities were performed in each phase of work:

- Phase 1
  - Bathymetric survey
  - Survey of outfall features, including identifying outfall features, collecting and analyzing outfall water samples, and tracing outfall features to their origin
  - Cultural resources survey, including bulkhead study
- Phase 2: Sediment coring
- Phase 3
  - Surface sediment sample collection and analysis
  - Surface water sample collection and analysis
  - Fish and shellfish tissue sample collection and analysis
  - Air sample collection and analysis
  - Combined sewer overflow (CSO) sediment and water sample collection and analysis
  - Hydrogeologic investigation, which included (1) groundwater-monitoring-well installation and development; (2) groundwater sampling; (3) groundwater–surface water interaction sampling; (4) synoptic measurements of water levels; (5) tidal evaluation; and (6) oversight of well installation and soil-sampling activities performed by National Grid and New York City

Summary of Remedial Investigation Results

Field observations and analytical data collected for the RI indicate that the nature and extent of contamination within the Gowanus Canal have been defined to the degree necessary to complete the risk assessments and the FS. The primary findings were as follows:

- In surface sediments (0-to-6-inch depth interval), concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and eight metals (barium, cadmium, chromium, copper, lead, mercury, nickel and silver) were significantly higher in the canal than at reference locations in Gowanus Bay and Upper New York Bay. Concentrations of many of these constituents were higher than ecological and human health screening values.
- The sediment-coring effort indicates that non-aqueous-phase liquid (NAPL) contamination is pervasive in native sediments underneath the canal between the head of the canal and the Gowanus Expressway, and in the overlying soft sediment in the middle reach of the canal. The NAPL appears to be coal tar waste from the three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan) that is migrating through subsurface soils, under or through the bulkheads, and into the more permeable native sediments under the canal. PAHs and the volatile organic compounds (VOCs) benzene, toluene, ethylbenzene, and xylenes (BTEX) are major constituents of coal tar.
- Total PAHs and VOCs, particularly the BTEX constituents, were frequently detected at high concentrations in both the soft and native sediment units. Pesticides, PCBs, and metals were all frequently detected in the soft sediment but were infrequently detected or detected at lower concentrations in the native sediments.

- In the deeper soft sediment, VOCs (primarily BTEX), semivolatile organic compounds (SVOCs) (primarily PAHs), pesticides, PCBs, and metals were all detected at higher concentrations than those found in the surface sediments.
- In most areas north of the Gowanus Expressway, NAPL and high-PAH concentrations were found in sediment at the maximum depth of the investigation activities, which was 6 feet below the contact between the soft and native sediment layers. The purpose of the sediment coring investigation was to delineate the degree of vertical contamination within the practical limits of a potential remedy rather than to define the vertical extent of contamination to its maximum depth.

The primary sources of contamination to the Gowanus Canal include (1) direct discharges from historical industrial activities, including historical contributions from CSOs, (2) CSO and stormwater discharges, (3) discharges from outfalls other than CSO or stormwater outfalls, and (4) known and potential discharges from contaminated sites adjacent to the canal, including the transport of contaminants in groundwater discharging to the canal. Estimating the magnitude of the ongoing sources of contamination to the canal will be a key component of the FS.

The potential ecological risks to wildlife from exposure to surface water and sediment in the Gowanus Canal were evaluated in the ecological risk assessment. The Baseline Ecological Risk Assessment evaluated potential risks to benthic (sediment-dwelling) organisms and water-column-dwelling organisms from exposure to contaminants in sediment and surface water, and risks to wildlife from consuming contaminated prey items and sediment during feeding. Benthic organisms may be at risk from exposure to contaminated sediment, primarily due to the PAHs present. Other chemicals contributing to the risk include PCBs and metals (barium, cadmium, copper, lead, mercury, nickel and silver). Water-column dwelling organisms may be adversely affected by lead during wet weather events. Aquatic herbivores such as the black duck may be at risk from exposure to PAHs, and avian omnivores such as the heron may be at risk from exposure to mercury. There is no potential risk to avian piscivores such as the double-crested cormorant from the ingestion of fish in the canal.

The Human Health Risk Assessment (HHRA) evaluated potential risks to recreational users, anglers, residents, and industrial workers near the canal. The HHRA evaluated the potential human health risks associated with direct contact with surface sediment and surface water in the Gowanus Canal, ingestion of fish and crabs, direct contact with sediment and surface water that overtops the canal during extreme tidal or storm surge conditions, and inhalation of emissions from the canal into the ambient air near the canal. Adults, adolescents, and children using the canal for recreational purposes may be at risk due to exposure to PAHs in surface water and surface sediment, assuming that the recreational use/swimming in the canal would occur at frequencies, durations, and exposures that are typical of most water bodies. Adults and children may also be at risk from exposure to PAHs in sediments and surface water in canal overflow. Exposure to lead in sediment and surface water by children (based on residential exposure assumptions, including potable use of the surface water) may result in adverse effects. Adults, adolescents, and children may also be at risk from exposure to PCBs if they consume fish and crabs caught in the canal. The HHRA assumed fishing/crabbing and ingestion of the fish /crab from the canal at typical recreational consumption rates, which are conservative given the nature of the canal.

Some of the important site characteristics that will influence the development, evaluation, and selection of remedial alternatives for the Gowanus Canal in the FS include (1) the degraded condition of the bulkheads that line most of the shoreline, (2) the presence of debris and sunken vessels throughout the canal, (3) New York City Department of Environmental Protection activities related to Gowanus Pump Station upgrades, and (4) the frequent use of the middle and lower reaches of the canal by tugs and barges.

Conceptual Site Model

The RI report presents a conceptual site model (CSM) for the Gowanus Canal based on the data collected for this RI and on other studies that have been completed for the canal. The CSM summarizes and integrates information about historical and ongoing sources of contamination, nature and extent of contamination, contaminant fate and transport mechanisms, and risks to humans and wildlife from exposure to contaminated sediments in the canal. This CSM will be used to evaluate the potential effectiveness of remedial alternatives for the canal and will be continually refined as new information becomes available.

Conclusion

The results of this RI indicate that chemical contamination in the Gowanus Canal sediments presents unacceptable ecological and human health risks, primarily due to exposure to PAHs, PCBs, and metals (barium, cadmium, copper, lead, mercury, nickel and silver). All of these contaminants are thought to have been deposited in the canal as a result of current and historical discharges to the canal. High PAH concentrations are found in coal tar waste adjacent to the three former MGP sites along the canal. PAHs and metals are the most prevalent contaminants detected in present-day CSO discharges to the canal, as well as in low volume discharges from a limited number of other outfalls. PAHs and metals are also present in various concentrations in contaminated groundwater discharging to the canal at different locations. Contaminated sites adjacent to the canal and discharges from outfalls represent ongoing sources of contamination to the canal.

The overall objectives of the Gowanus Canal RI were met, and sufficient data have been collected to proceed with the development of remedial alternatives in the FS. The results of the ERA and HHRA will support the definition of remedial action objectives and target areas for remediation.

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Abbreviations and Acronyms

a.k.a.	also known as
AVS/SEM	acid volatile sulfide/simultaneously extracted metals
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CLP	Contract Laboratory Program
COP	constituents of potential concern
CSM	conceptual site model
CSO	combined sewer overflow
DNAPL	dense non-aqueous-phase liquid
DO	dissolved oxygen
DOC	dissolved organic carbon
dpm/g	disintegrations per minute per gram
ERA	ecological risk assessment
ERT	Emergency Response Team
eV	electron volt
FS	feasibility study
GEI	GEI Consultants, Inc.
GPR	ground-penetrating radar
GPS	global positioning system
HDR	HDR Engineering, Inc.
HHRA	human health risk assessment
HSA	hollow-stem auger
JMA	John Milner Associates, Inc.
L/min	liters per minute
LTCP	long-term control plan
MEK	methyl ethyl ketone
MGP	manufactured gas plant
MLLW	mean lower low water
NAPL	non-aqueous-phase liquid
NAVD88	North American Vertical Datum of 1988
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
NPL	National Priorities List
NRHP	National Register of Historic Places
NTU	nephelometric turbidity unit
NYC	New York City

NYCDEP	New York City Department of Environmental Protection
NYCDOT	New York City Department of Transportation
NYSDEC	New York State Department of Environmental Conservation
ORP	oxidation reduction potential
OSI	Ocean Surveys, Inc.
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PID	photoionization detector
PRP	potentially responsible party
psig	pounds per square inch gauge
PUF	polyurethane foam
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RAGS	Risk Assessment Guidance for Superfund
RI	remedial investigation
RIOPA	Relationships of Indoor, Outdoor, and Personal Air
RME	reasonable maximum exposure
RMS	root mean squared
RPD	relative percent difference
RSL	regional screening level
SARA	Superfund Amendments and Reauthorization Act of 1986
SOP	standard operating procedure
SPDES	State Pollutant Discharge Elimination System
SVOC	semivolatile organic compound
TAL	Target Analyte List
TCE	trichloroethylene
TCL	Target Compound List
TCLP	Toxic Characteristic Leaching Procedure
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WPCP	water pollution control plant
WRS	Wilcoxon rank-sum

SECTION 1

Introduction

This draft remedial investigation (RI) report was prepared for the United States Environmental Protection Agency (USEPA) Region 2 by Henningson, Durham & Richardson Architecture & Engineering, P.C., in association with HDR Engineering, Inc. (HDR) and CH2M HILL to present the results of the RI activities completed at the Gowanus Canal Superfund Site, in Brooklyn, Kings County, New York. This draft RI report has been prepared under Work Assignment Number 013-RICO-02ZP, under the USEPA Region 2 RAC II Contract Number EP-W-09-009.

The Gowanus Canal is a 1.8-mile-long, man-made canal in the New York City borough of Brooklyn, Kings County, New York (Figure 1-1). The canal was built in the 1860s by bulkheading and dredging a tidal creek and surrounding lowland marshes. Following construction, the canal quickly became one of the nation's busiest industrial waterways, servicing heavy industries that included manufactured-gas plants (MGPs), coal yards, cement manufacturers, tanneries, paint and ink factories, machine shops, chemical plants, and oil refineries. It was also the repository of untreated industrial wastes, raw sewage, and surface-water runoff for decades, causing it to become one of New York's most polluted waterways. Although the level of industrial activity along the canal has declined over the years, high levels of contamination remain in the sediments.

On March 2, 2010, USEPA placed the Gowanus Canal (USEPA ID#: NYN000206222) on its National Priorities List (NPL) of hazardous waste sites requiring further evaluation. Accordingly, USEPA Region 2 is performing a remedial investigation and feasibility study (RI/FS) of the canal according to the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, or "Superfund"), as amended. This report presents the results of the RI activities performed at the canal in 2010.

1.1 Background and Objectives

The Gowanus Canal study area is shown in Figure 1-1. There are five east–west bridge crossings over the canal, at Union Street, Carroll Street, Third Street, Ninth Street, and Hamilton Avenue. The Gowanus Expressway and the Culver Line of the New York City Subway pass overhead. The canal is located in a mixed residential-commercial-industrial area, and it borders several residential neighborhoods, including Gowanus, Park Slope, Cobble Hill, Carroll Gardens, and Red Hook. The waterfront properties abutting the canal are primarily commercial and industrial.

Environmental sampling performed before this RI revealed that the sediments throughout the Gowanus Canal are contaminated with a variety of pollutants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and heavy metals (USACE, 2004, 2006; GEI, 2007). No environmental remediation activities have been performed to date.

The overall objective of the RI activities performed by USEPA is to characterize the canal to a degree sufficient to develop and select a remedy to reduce risks to human health and the environment from exposure to contaminants in the canal sediments. Accordingly, the field-sampling and data-collection activities described here were designed specifically to accomplish the following:

- Characterize the nature and extent of contamination in the Gowanus Canal to the degree necessary to evaluate the human health and ecological risks and develop a remedy to reduce these risks
- Document the sources of contamination to the Gowanus Canal, and provide a preliminary evaluation of ongoing sources of contamination to the canal that need to be addressed so that a sustainable remedy can be developed and implemented
- Determine the human health and ecological risks from exposure to contamination in the canal
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This work builds on previous studies completed by the U.S. Army Corps of Engineers (USACE) and National Grid[1] (see Section 1.4.). In addition, the Gowanus Canal RI work performed by USEPA is supplemented by work performed simultaneously by National Grid and New York City under related Administrative Orders.[2] Investigations and response actions related to upland properties adjacent to the canal are under the purview of the New York State Department of Environmental Conservation (NYSDEC). The New York City Department of Environmental Protection (NYCDEP) is addressing compliance with existing water quality standards under an Administrative Order on Consent[3] with NYSDEC.

1.2 Report Organization

This RI report is organized into the following eight sections:

1. **Introduction**. Briefly describes the regulatory framework, RI approach and objectives, and site history and setting, and summarizes previous investigations.
2. **Remedial Investigation Activities**. Summarizes the field investigation activities performed in 2010 by USEPA, National Grid, and New York City.
3. **Gowanus Canal Physical Characteristics**. Describes the characteristics of the Gowanus Canal that are relevant to determining the nature and extent of contamination and that will influence the development and evaluation of remedial alternatives. These characteristics include bathymetry, presence of debris and obstructions, sediment stratigraphy and physical properties, locations of pipes actively discharging to the canal, the condition of the bulkheads, and the local geology and hydrogeology, including interactions between groundwater and surface water and the effects of tides.
4. **Nature and Extent of Contamination**. Presents the standards and criteria against which RI sample results were compared and describes the occurrence and distribution of

[1] National Grid is the successor to KeySpan Energy Corp. and Brooklyn Gas Company; these companies and all other related entities are referred to herein as National Grid.

[2] Administrative Order and Settlement Agreement for Investigation, Sampling and Analysis, Index Nos. CERCLA 02-2010-2009 and CERCLA 02-2010-2011 for National Grid and the City of New York, respectively.

[3] DEC Case #CO2-20000107-8 dated January 14, 2005, and updated April 14, 2008.

contaminants in sediment, surface water, fish and crab tissue, air, combined sewer overflow (CSO) outfall water and sediment, and groundwater that may be discharging to the canal. Also included are the results of soil sampling performed in the process of installing groundwater-monitoring wells on properties adjacent to the canal for the purpose of evaluating groundwater contamination and surface water-groundwater interactions and tidal influences on groundwater.

5. **Summary of Ecological and Human Health Risk Assessments**. Summarizes the ecological risk assessment (ERA) and human health risk assessment (HHRA), including descriptions of the exposure pathways and receptors evaluated. Complete risk assessment reports are provided as appendices.

6. **Conceptual Site Model**. Section 6 presents a conceptual site model (CSM) of the Gowanus Canal that summarizes contaminant sources and release pathways, the extent of contamination due to these releases, and a summary of contaminant fate and transport mechanisms. A summary of the exposure pathways and receptors that drive unacceptable ecological and human health risk is provided in the risk assessment reports.

7. **Conclusions and Recommendations**. Summarizes the RI conclusions and recommendations.

8. **References.** Provides the references cited in the report.

The report appendixes provide supporting information, including field documentation and laboratory analytical data that were collected for the RI:

A—Sample-tracking tables (summaries of collected samples)
B—Bathymetric survey report
C—Evaluation criteria
D—Field documentation
E—Evaluation of results of tidal survey
F—Evaluation of groundwater–surface water interactions
G—Survey of outfall features to the Gowanus Canal
H—Data quality evaluation
I—Tissue analytical data
J—Statistical support information
K—ERA
L—HHRA
M—Historic preservation
N—Sediment core depth profiles
O—Upland investigation summary

1.3 Overview of the Gowanus Canal

The following is a brief history of the Gowanus Canal; a description of the site setting, the dredging history, and adjacent land usage; and a short discussion of NYCDEP's CSO long-term control plan (LTCP) activities that affect the canal.

1.3.1 History

Prior to being developed, the area around the Gowanus Canal was occupied by Gowanus Creek, its tributaries, and lowland marshes, as shown in Figure 1-2. Before the mid-1840s, the creek and its tributaries had been dammed and used primarily to power tide mills (Hunter Research et al., 2004). By the mid-1840s, Brooklyn was rapidly growing, and the Gowanus marshes were considered to be a detriment to local development. In 1848, the State of New York authorized construction of the Gowanus Canal to open the area to barge traffic, flush away sewage, receive stormwater, and fill the adjacent lowlands for development. The canal was constructed between 1853 and approximately 1868, and rapid industrial development followed.

In 1911, the City of New York constructed and began operating the Gowanus Canal Flushing Tunnel to address serious water quality issues in the canal. The tunnel was constructed to connect the head of the canal with Buttermilk Channel in Upper New York Bay. It was designed to improve circulation and flush pollutants from the canal by pumping water in either direction. The tunnel starts at Degraw Street on Buttermilk Channel and ends on the west side of the canal at Douglas Street. The tunnel was operated until the mid-1960s, when it fell into disrepair and no funding was available to fix it. The flushing tunnel was rehabilitated and reactivated in 1999 by the NYCDEP, pumping water only from Buttermilk Channel to the Gowanus Canal using the 1911 technology. The flushing tunnel was shut down by the NYCDEP on July 19, 2010, for an extended period of facility improvements to modernize the technology and improve operations (see Section 1.3.5). Figure 1-3 shows the Gowanus Canal in relation to the locations of other waterways in the area, including Buttermilk Channel, from where the flushing tunnel draws water.

1.3.2 Site Setting

The Gowanus Canal is a tidally influenced, dead-end channel that opens to Gowanus Bay and Upper New York Bay. The canal experiences a semidiurnal tidal cycle (i.e., two high tides and two low tides of unequal height each tidal day), with a vertical tidal range from 4.7 to 5.7 feet. The entire canal is classified as a saline tributary to Upper New York Bay, and the reach between the head of the canal and 22nd Street, which encompasses the entire study area of this RI, is classified as a “minor river, tidal tributary.”[4] The only freshwater inflows to the canal are wet-weather CSO and stormwater discharges. Because of its narrow width, limited freshwater input, and enclosed upper end, the canal has low current speeds and limited tidal exchange with Gowanus Bay. Circulation is enhanced by the addition of water from the flushing tunnel when it is operating (NYCDEP, 2008a).

North of the Hamilton Avenue bridge, the canal is approximately 5,600 feet long and 100 feet wide, with a maximum depth of approximately 15 feet in the main channel at low tide. There are four short turning basins that branch to the east of the main channel at 4th Street, 6th Street, 7th Street, and 11th Street (Figure 1-1). A former basin at 1st Street and an extension of the 4th Street basin that had been referred to as the 5th Street basin were filled in between 1953 and 1965 (Hunter Research et al., 2004). The bottom sediments near the head of the canal and at the heads of the turning basins are exposed at low tide. South of the Hamilton Avenue bridge, the canal widens to approximately 2,200 feet and ranges in depth from -15 to -35 feet mean lower low water (MLLW).[5] The entire shoreline of Gowanus Canal is built with retaining structures or bulkheads. These are described in greater detail in Section 3.4.

The sediments within and beneath the Gowanus Canal consist of two distinct layers, as shown in Figure 1-4. The upper layer is referred to in this report as “soft” sediment. The soft sediments

[4] Title 6 of the New York Code of Rules and Regulations, Chapter X, Part 890.

[5] The average of the lower low water height each tidal day.

have accumulated in the canal over time since the canal was first constructed. The soft sediment layer ranges in thickness from approximately 1 foot to greater than 20 feet and generally consists of a dark-gray-to-black mixture of sand, silt, and clay. The soft sediments are underlain by the alluvial and marsh deposits of the Gowanus Creek complex that were originally present. These deposits are referred to as "native" sediments in this report and include sands, silts, silty sand, sandy clay, clay, and peat.

1.3.3 Dredging History

Minimal recent dredging of the Gowanus Canal has been performed, and documentation of historical dredging is sparse. North of the Hamilton Avenue bridge, any dredging would have been performed by New York City or local commercial interests. Reviews of historical documents suggest that dredging was very limited and, when it was performed, most likely targeted the accumulation of material near outfalls on the canal (Hunter Research et al., 2004). The most recent dredging in the upper reaches of the canal was performed by NYCDEP in 1975 (NYCDEP, 2008a). In 1998, the area near the flushing tunnel was dredged, and nearly 1,100 cubic yards of material was removed to allow the tunnel to be reactivated (GEI, 2007). These sediments were removed to facilitate construction and assure an unobstructed discharge from the tunnel.

Below Hamilton Avenue, USACE previously performed maintenance dredging. USACE suspended regular maintenance dredging of the Gowanus Creek Channel in 1955, and the last dredging occurred in 1971, where nearly 74,000 cubic yards of sediment was removed between 28th Street and the Hamilton Avenue bridge (GEI, 2007; NYCDEP, 2008a).

1.3.4 Current and Historical Adjacent Land Use

The watershed drainage area of the Gowanus Canal is 1,758 acres, and the canal waterfront, or riparian area (defined as all blocks wholly or partially within one quarter mile of the canal), is occupied primarily by commercial and industrial properties. The riparian areas are classified as 18 percent residential, 6 percent park, and 76 percent mixed use. The entire watershed is 53 percent residential, 2 percent park, and 45 percent mixed use (NYCDEP, 2008a).

General current land use and historic industries along the canal are shown in Figure 1-5. Current land use was identified in October 2010 based on a windshield survey of the properties along the canal coupled with a review of current tax maps. The survey did not include interviews with property owners or property inspections to refine property-use classification. Based on this survey, the waterfront properties along the canal are currently used mostly for consumer-oriented businesses and operations (e.g., retail stores, small business offices), commercial purposes, municipal operations, and industrial purposes.

The historical industries along the canal include three former MGPs: the Fulton former MGP site, the Citizens Gas Works former MGP site (currently known as and referred to throughout the report as Carroll Gardens/Public Place former MGP site), and the Metropolitan Gas Light Company former MGP site (referred to throughout the report as Metropolitan former MGP site). National Grid is performing environmental investigations of the Fulton and Carroll Gardens former MGP sites, and contaminated soils have been partially removed from the Metropolitan former MGP site. Other sites along the canal where historical commercial or industrial activities occurred include a former New York City incinerator, Navy facilities, various industrial facilities, and oil storage facilities.

1.3.5 Combined Sewer Overflow and Stormwater Discharges

As noted, CSO and stormwater discharges are the only sources of freshwater to the Gowanus Canal. Combined sewers (i.e., sewers that receive both sewage and stormwater flows) serve 92 percent of the Gowanus Canal watershed, storm sewers serve only 2 percent, and direct runoff drains 6 percent of the watershed (NYCDEP, 2008a). During wet weather, runoff enters the combined sewers and exceeds the capacity of the system when an appreciable rate of rainfall occurs. There are two combined sewer systems in the watershed that overflow to the canal: the Red Hook and Owls Head water pollution control plants (WPCPs). Between these systems, there are 12 permitted CSOs to the study area; 10 of these are active. In addition, there are three known stormwater outfalls discharging to Gowanus Canal. Figure 1-6 shows the locations of the outfalls. There are also highway drains discharging to the canal (not shown in Figure 1-6).

The greatest annual discharge volumes are from outfalls RH-034, at the head of the canal; RH-035, at the intersection of Bond and 4th Streets; and OH-007, at the north end of 2nd Avenue (121, 111, and 69 million gallons, respectively; NYCDEP, 2008a). A floatables boom is installed in the canal at Sackett Street to detain floating debris that enters the canal from the RH-034 outfall.

In 2008, the NYCDEP prepared the *Gowanus Canal Waterbody/Watershed Facility Plan Report* as part of its City-Wide Long-Term CSO Control Planning Project (NYCDEP, 2008a). This work is being performed under an Administrative Order on Consent between NYCDEP and NYSDEC.[6] The goal of the project is to implement a series of improvements to achieve compliance with water quality standards. Specific objectives of the plan include eliminating odors, reducing floatables, and improving dissolved oxygen (DO) concentrations to meet surface-water-quality standards. NYCDEP's planned improvements for the Gowanus Canal have the following six components:

1. **Continued implementation of programmatic controls.** This activity will periodically evaluate programs currently in place to reduce CSO effects. The current floatables reduction plans, targeted sewer cleaning, and other operations and maintenance controls will continue, in addition to implementation of 14 specific best management practices, sustainable stormwater management initiatives, and the City-Wide Comprehensive CSO Floatable Plan.

2. **Modernization of the Gowanus Canal Flushing Tunnel.** This effort includes replacing the flushing tunnel pumping system with more-efficient pumping systems. This modernization effort will increase the volume of water conveyed through the tunnel by approximately 40 percent. In early 2010, an aeration pipe was installed within the canal to circulate super-oxygenated water when the flushing tunnel was shut down for repair. The aeration pipe went online in early July 2010, and the repairs were initiated with the flushing tunnel shut down on July 19, 2010. The completion date is anticipated to be September 2014.

3. **Reconstruction of the Gowanus Wastewater Pump Station.** This component of the LTCP will address the pumping station at the head of the canal. The reconstruction will increase the pump station capacity, restore force main flow, and add floatables-screening devices at outfall RH-034 at the head of the canal. These improvements are anticipated to decrease CSO discharges to the canal by 127 million gallons per year (approximately 34 percent) and

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6 NYSDEC Case No. CO2-20000107-8 dated January 14, 2005, and updated on April 14, 2008.

provide screening for 32 percent of the annual CSO discharge. Improvements to the RH-034 pumping facility were initiated in February–March 2010. The completion date of this construction is also anticipated to be September 2014.

4. **Cleaning/inspection of the OH-007 floatables/solids trap.** This trap is a 35-foot by 70-foot chamber designed to prevent the discharge of floatables and solids immediately upstream from the OH-007 outfall. The LTCP includes a provision for regularly inspecting and cleaning this trap to assure that it remains functional. NYCDEP performed an initial cleaning in April 2006 and an inspection in June 2006. Inspections had been planned to occur monthly thereafter, until an understanding of how quickly material accumulates in the trap is established.

5. **Periodic water body floatables skimming.** Upon completion of the reconstruction of the Gowanus Wastewater Pump Station and implementation of the floatables screening station, the interim floatables containment boom near the end of Sackett Street will be removed, and NYCDEP will dispatch a skimmer vessel to remove floatables from the canal on a periodic, as-needed basis. This component of the LTCP will not be implemented until the pump station is completed (expected September 2014).

6. **Dredging.** NYCDEP proposes dredging 750 feet of the canal from its head downstream and applying a 2-foot-thick sand cap so that the final water depth will be -3 feet MLLW. The dredging is intended to eliminate exposed sediments and associated odors observed at low tide, improve aesthetics, and provide improved benthic habitat. The canal has not yet been dredged. The timeline specified by the LTCP indicated that permit applications would be submitted by June 2010 and that dredging would begin within 3 years, and be completed within 5 years, of receipt of the final permits.

These improvements were proposed collectively to reduce the loading of contaminants to the canal in addition to improving overall water quality.

1.4 Previous Investigations

The Gowanus Canal has been studied extensively during the last decade. The studies used directly in the development of this RI are listed below. The list includes the report title and date, investigator, and a summary of the work performed. The results of these studies are incorporated into Sections 3 through 6 of this report, as appropriate. Additional reports, literature, and media pertaining to the canal were also reviewed to develop a holistic understanding of the study area, but these are not cited directly in this report.

1.4.1 National Grid

The following investigations were performed by GEI Consultants Inc. (GEI) for National Grid:

- *Draft Remedial Investigation Technical Report, Gowanus Canal, Brooklyn, New York, ACO Index No. A2-0523-0705*. Prepared April 2007. The scope of work performed included:
  - Bulkhead and outfall reconnaissance
  - Geophysical surveys, including bathymetry, sub-bottom profiling, and magnetometer surveys
  - Collection of 100 surface sediment grab samples for fecal coliform analysis

- Collection of 279 sediment samples for chemical analysis from 103 sediment vibracoring locations
- Sampling of water from 11 actively flowing and 45 submerged outfalls and sediment from 10 inactive outfall pipes
- Age dating of six sediment cores based on radioisotope profiling
- Installation of five subsurface borings in street right-of-ways adjacent to the canal and collection of 10 subsurface soil samples
- Collection and analysis of 138 surface water samples from 70 locations
- Environmental forensic testing of non-aqueous-phase liquid (NAPL), material collected from tar seeps, and selected sediment samples

Some of this information—the geophysical survey data, the analytical chemistry results for soft sediment samples, and the age dating results—has been incorporated directly into this RI report.

- *Final Remedial Investigation Report, Carroll Gardens/Public Place, Brooklyn, New York, VCA Index No. A2-0460-0502, Site No.V00360-2*. Prepared October 2005. The scope of work performed included:
  - Excavation of 17 test pits and collection of 16 associated soil samples
  - Advancement of 53 soil borings and collection of 152 subsurface soil samples; 23 surface soil samples were collected from 14 locations
  - Installation of 35 monitoring wells and collection of 59 groundwater samples from 30 wells; six dense non-aqueous-phase liquid (DNAPL) tar samples were also collected
  - Installation of 13 soil vapor probes and collection of 13 associated samples
  - A tidal survey using the canal and 17 monitoring wells
  - Evaluation of tar recovery in six monitoring wells

1.4.2 New York City Department of Environmental Protection

The following investigations were performed by NYCDEP:

- *Draft Site Investigation Report for Environmental Investigations at Three City-Owned Properties: The NYCDEP Gowanus Pumping Station, The NYCDOT Hamilton Avenue Asphalt Plant, The Former Brooklyn BRT Power Station*. Prepared by Louis Berger & Associates, PC, August 2010. The scope of work performed included:
  - Collection of 67 soil samples from 14 borings
  - Installation, development, and sampling of 14 groundwater-monitoring wells for chemical analysis
  - Tidal gauging at three well pairs over a period of 3 days to monitor tidal and barometric changes

  - Synoptic monitoring well and surface water level measurements
  - Hydraulic conductivity (slug) testing at three well pairs
  - Collection of three surface water samples for chemical analysis

- *Gowanus Canal Waterbody/Watershed Facility Plan Report,* 2008. Parts of this document are summarized in Section 1.3.5. It presents a summary of the current conditions in the canal and outlines the wastewater disposal improvements planned through 2014.
- New York Harbor Water Quality Studies, 1997–2004. The City of New York conducts annual water quality monitoring of New York Harbor and tributaries. Water quality parameters collected include DO, coliform, Secchi disk transparency, chlorophyll-a, and turbidity. The data collected at monitoring locations within the Gowanus Canal are included in the ERA.
- New York City Shoreline Survey Program Reports for Owls Head and Red Hook drainage areas identifying pipe openings along the length of the canal:
  - *Shoreline Survey Report*, March 31, 2008
  - *Shoreline Survey Report – Cycle II*, March 31, 1993
  - *Shoreline Survey Report – Cycle I*, February 28, 1991

1.4.3 U.S. Army Corps of Engineers

The following investigations were performed by USACE:

- *Site Investigation Gowanus Bay and Gowanus Canal – Final Report, Kings Count, Volumes 1–3, New York,* October 2003. This report summarizes sampling performed in early 2003 and lists the conclusions and recommendations made by USACE in support of the Gowanus Restoration Project. The sampling scope of work included:
  - Collection of subsurface sediment samples using split-spoon collection methods from 30 boring locations
  - Analysis of approximately 300 sediment samples for geotechnical, chemical, and bacteriological parameters
- *Final Report Sediment Quality Evaluation Report Gowanus Canal and Bay Ecological Restoration Project,* October 2004. The scope of work for this investigation included collection of sediment samples from 30 locations beginning at the head of the canal to Gowanus Bay. Samples were analyzed for chemical and biological parameters.
- *Final Report National Register of Historic Places Eligibility Evaluation and Cultural Resources Assessment for the Gowanus Canal, Borough of Brooklyn, Kings County, New York in Connection with the Proposed Ecosystem Restoration Study.* Prepared by Hunter Research, Rabner Associates, and Northern Ecological Associates, December 2004. The scope of work presented in this report included background research, acquisition of historic maps, field investigations, and data analysis.
- *Final Sediment Sampling Report, Gowanus Canal and Bay Ecosystem Restoration Project (DACW51-01-D-0014 Delivery Order Number 003).* Prepared by DMA, Inc., and AMEC Earth & Environmental, Inc., August 2006. This report summarizes a 2005 sampling event that included collection of 6-foot vibracore sediment samples from 10 locations within the canal.

Sediment samples were analyzed for chemical parameters and toxicity testing in order to support a habitat evaluation procedures model and ecological risk assessment.

SECTION 2

Remedial Investigation Activities

This section describes the RI activities led by USEPA at the Gowanus Canal Superfund Site. These activities were performed in three phases starting in January 2010 and continuing through November 2010. Table 2-1 summarizes in chronological order the investigation activities, the dates they were performed, and the general scope of each activity. The RI scope and approach were developed by USEPA, and the work was completed with support from four entities, including the USEPA Region 2 contractor team of HDR, CH2M HILL, and GRB Environmental, Inc. (referred to as USEPA work throughout the document), USEPA Emergency Response Team (ERT), New York City, and National Grid. The RI activities performed under each phase of work by each entity are listed below.

Phase	Activity	Entity
Phase 1 RI	Bathymetric survey	USEPA
	Survey of outfall features:	
	Phase 1—identifying outfall features, and collecting and analyzing outfall water samples	USEPA
	Phase 2—tracing outfall features to origin	USEPA ERT
	Cultural resources survey, including bulkhead study	USEPA
Phase 2 RI	Sediment coring	USEPA, USEPA ERT
Phase 3 RI	Surface sediment sample collection and analysis	USEPA
	Surface water sample collection and analysis	USEPA
	Fish and shellfish tissue sample collection and analysis	USEPA
	Air sample collection and analysis	USEPA
	CSO sediment and water sample collection and analysis	USEPA
	Hydrogeologic investigation:	
	Groundwater-monitoring-well installation and development	USEPA ERT, National Grid, New York City
	Groundwater sampling	USEPA, National Grid, New York City
	Groundwater–surface water interaction sampling	USEPA
	Synoptic water levels	USEPA, National Grid, New York City
	Tidal evaluation	USEPA
Oversight activities	Oversight of well installation and soil-sampling activities performed by National Grid and New York City	USEPA

Table 2-2 lists the number of samples collected during each RI activity, and the analyses performed. The scope of each RI activity is summarized further below. Results are presented in Sections 3 and 4.

2.1 Bathymetric Survey

A bathymetric survey was performed by CR Environmental, Inc., on all navigable and accessible portions of the Gowanus Canal on January 5, 2010. The purpose of this survey was to map the sediment surface elevation within the canal. The survey was performed using a 25-foot aluminum work boat and a 12-foot skiff outfitted with appropriate global positioning system (GPS)–based navigation systems and single-beam echo sounders to collect depth measurements. Data were collected along a series of survey transects; transects parallel to the canal shoreline were approximately 10 to 50 feet apart, and transects perpendicular to the shoreline were spaced 100 feet apart. Ice in the eastern ends of the turning basins during the survey prevented data from being collected from those areas.

The complete bathymetric survey report, including descriptions of the survey methods, details of vessels used, data acquisition systems, vertical control points, and bathymetric data processing procedures, is provided in Appendix B.

2.2 Sediment Coring

Two sediment-coring investigations were conducted within the Gowanus Canal during January, March, and April 2010. Technical details are presented in Appendix D. The sediment coring effort built on the previous investigation completed by National Grid (GEI, 2007). The objectives of the effort were to characterize the horizontal extent of contamination as well as the vertical extent within the practical limits of a potential remedy. Specific objectives of the efforts were to (1) collect sediment samples to a depth of 6 feet below the contact between soft sediment and native sediment at all locations, (2) obtain continuous vertical profiles of contaminant concentrations at a subset of locations adjacent to potential sources of contamination, (3) confirm sampling results at a subset of locations previously sampled by National Grid, and (4) provide additional spatial coverage in specific areas of the canal. Sediment core sampling locations are shown in Figures 2-1a through 2-1c.

In January 2010, USEPA ERT collected sediment cores from 10 locations that might not have been accessible after construction activities related to the flushing tunnel repairs were initiated by New York City. Nine of the locations were on three transects between the Union Street bridge and the head of the canal; a 10th location was on the east side of the channel immediately south of the Union Street bridge (Figure 2-1a). Sediment cores were collected using vibratory coring equipment to a depth of 12 to 16 feet below the sediment surface. The cores were sampled continuously in 1-foot sampling intervals, except for the top interval, which was sampled from 0 to 0.5 foot and from 0.5 to 1.0 foot. Soft and native sediments were sampled separately. Samples were analyzed for Target Compound List (TCL) organics and Target Analyte List (TAL) metals (including mercury and cyanide).

In March and April 2010, USEPA collected sediment cores from the following locations using vibratory coring equipment:

- 88 locations on transects previously sampled by National Grid (native sediment only)
- 21 new sampling locations along seven transects
- 17 new sampling locations not located on a transect
- Nine additional contingency sampling locations identified in the field by USEPA

The rationale for the placement of the new sampling locations is provided in Table 2-3. A diagram of the core-sampling strategy is presented in Figure 2-2.

For cores collected from the previously sampled National Grid locations, up to three samples (2-foot composites) of native sediment were collected from each core. At the new locations and transects, cores were sampled continuously in 2-foot composite sample intervals from the top of the core to a depth of 6 feet into the native sediment. Soft sediment and native sediment were sampled separately.

A detailed description of the sampling methods is provided in Appendix D. Briefly, the core from each location was split lengthwise using an electric slot cutter, photographed, and described with respect to stratigraphy (i.e., sediment layers), sediment type, grain size, color, odor, and any other notable characteristics. Samples for VOC and sulfide analysis were collected from each sampling interval prior to sediment homogenization. The remaining sediment from each sample interval was transferred to a dedicated aluminum pan and homogenized until a uniform texture and color were achieved. Sediment directly in contact with the core catcher, nose cone, or core liner was not included in the material that was homogenized and submitted for analytical testing. The homogenized sediment was then transferred to the laboratory-specified bottleware, labeled, and bagged for shipment to the analytical laboratories.

Table 2-2 summarizes the number of samples collected and analytical parameters. A total of 618 unique sediment samples (not including field quality control samples) from 143 locations were submitted for chemical analysis.

Appendix A contains a sample-tracking table listing all samples collected, the associated analyses, and quality assurance/quality control (QA/QC) samples. All sediment samples were analyzed for TCL organics, TAL metals (including mercury and cyanide), grain size, total organic carbon (TOC), and sulfide. For the new core locations not positioned on transects, one composite sample of the entire soft-sediment thickness was collected and analyzed for Toxic Characteristic Leaching Procedure (TCLP) parameters and hazardous waste characteristics.

The objectives of the sediment core sampling efforts were met except in instances where field conditions prevented recovery of 6 feet of native sediment. These exceptions were generally in three areas:

- Where the soft sediment thickness was greater than 14 feet and the depth of penetration was limited by the core barrel length of 20 feet (e.g., at the head of the canal and in the 11th Street turning basin)
- Where the sediment surface was covered with gravel (e.g., the entire channel south of a concrete plant located at the end of 5th Street to south of the 9th Street bridge and the area adjacent to the New York City asphalt plant immediately south of Hamilton Avenue on the east side of the canal)
- Where widespread debris was present (e.g., stations positioned near the ends of streets and along the west side of the channel downstream of the Hamilton Avenue bridge)

Although less than 6 feet of native material was recovered and sampled at some locations, the data set generated is sufficient to meet the RI/FS objectives.

2.3 Surface Sediment Sample Collection and Analysis

Surface-sediment-sampling activities were conducted in the Gowanus Canal and at reference locations in Gowanus Bay and Upper New York Bay between June 17 and July 1, 2010. Surface sediment samples were collected from the 0-to-6-inch depth interval to support the ERA and HHRA. The 0-to-6-inch depth interval is considered to be the biologically active zone. This section summarizes these activities and notes any deviations from the planned technical approach. Supporting field documentation is presented in Appendix D.

The objectives of the surface sediment sampling were as follows:

- Collect information on contaminant concentrations in surface sediments over the length of the canal and at reference locations outside of the Gowanus Canal study area
- Characterize surface sediment contamination at locations where exposed sediments are observed at low tide to support the HHRA

USEPA CERCLA guidance addresses the importance of establishing background concentrations during the RI. The term "background" refers to chemical concentrations (or locations) that are not influenced by contamination from a specific CERCLA site. USEPA's guidance for comparing background and chemical concentrations in soil at CERCLA sites (USEPA, 2002) states the following:

> A background reference area is the area where background samples will be collected for comparison with the samples collected on the site. A background reference area should have the same physical, chemical, geological, and biological characteristics as the site being investigated, but has not been affected by activities on the site.... [T]he ideal background reference area would have the same distribution of concentrations of the chemicals of concern as those which would be expected on the site if the site had never been impacted. In most situations, this ideal reference area does not exist.

A background reference area for the Gowanus Canal would ideally be located upgradient of the reaches affected by contaminant releases; however, this was not possible because the entire canal is contaminated. Other nearby water bodies with similar characteristics that were known to be uncontaminated could not be identified. Therefore, reference locations in Gowanus Bay and Upper New York Bay were selected for consideration in the ERA and HHRA. The reference locations were positioned on an approximate grid with increased spacing with increasing distance from the mouth of the canal to characterize gradients in contaminant concentrations and biological effects, if present.

Surface sediment samples were collected from the following locations using a Ponar grab-sampling device:

- 27 locations within Gowanus Canal
- 10 reference locations in Gowanus Bay and Upper New York Bay, outside the mouth of the canal

The locations where the surface sediment samples were collected within the canal are shown in Figures 2-3a through 2-3c. The reference locations are shown in Figure 2-4. The rationale for the selection of each sampling location is presented in Table 2-4.

Sediment samples were composited upon collection except for sample volumes sent for VOC analysis, which were collected from the area of highest photoionization detector (PID) response or from an area with visual evidence of contamination. Sediment samples from each location were described on field data sheets with respect to gross grain size, color, odor, and any other notable observations.

A summary of the samples collected and analyses performed is provided in Table 2-2. Appendix A contains a sample-tracking table listing all samples collected, the associated analyses, and QA/QC samples. Sediment samples from all locations were analyzed for TCL organics, TAL metals (including mercury and cyanide), grain size, TOC, and acid volatile sulfide/simultaneously extracted metals (AVS/SEM). Nineteen samples from the canal and three samples from reference locations were also analyzed for PCB congeners. These locations are identified in Table 2-4. The Gowanus Canal locations for PCB congener analyses were selected to provide (1) data for areas with the greatest potential for human exposure (e.g., the canoe launch), (2) data for areas where high-PCB concentrations were previously measured in sediment, (3) spatial coverage throughout the canal, and (4) data for all locations in the canal where sediment toxicity testing was performed. Additional sample volume was collected at each sampling location and archived for future analysis should it be needed.

Sediment samples were collected for sediment toxicity tests at twelve Gowanus Canal locations and five reference locations as identified in Table 2-4. The toxicity tests were performed using two species: amphipod (*L. plumulosus*) and a polycheate (*Nereis*). Both acute and chronic toxicity testing were performed during each toxicity test. Further details are provided in the ecological risk assessment (Appendix K).

Surface sediment samples were collected from all 37 planned locations. The following are noteworthy details or deviations from the planned sampling program:

- All samples sent for PCB congener analysis were delayed for an extended period of time in international customs during transit to the laboratory in Canada. The temperature of the samples when received by the laboratory was 18°C, exceeding the required 4°C temperature for sample preservation. Following consultation with project chemists and the USEPA sample manager, it was determined that elevated sample temperatures would not have a significant adverse effect on the results.

- The sediment sample at location 319 was collected approximately 500 feet north of the planned sampling location. The planned location was in an area containing widespread debris along the bottom of the canal, resulting in the collection of inadequate sample volume. The sample was collected at a new location as close to the original sample location as possible.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.4 Surface Water Sample Collection and Analysis

Surface water samples were collected from the Gowanus Canal, at reference locations in Gowanus Bay and Upper New York Bay, and from Buttermilk Channel during two sampling events representing dry-weather (June 19, 2010) and wet-weather (July 13, 2010) conditions. This section provides a brief summary of these activities and notes any deviations from the planned technical approach. Supporting field documentation is provided in Appendix D.

The objectives of the surface water sampling effort were as follows:

- Collect information on contaminants in surface water over the length of the canal and at reference locations outside of the Gowanus Canal study area to support the ERA and HHRA
- Evaluate differences in surface water contaminant concentrations in the canal during dry weather and following rainfall and discharges from the CSOs

Surface water samples were collected using a decontaminated stainless steel bacon bomb discrete sampler. Because of the shallow water depth, a single sample was collected from each location at a depth of 6 inches below the water surface. The surface water sample locations generally coincided with the surface sediment sample locations except for locations 301 and 325. The sampling locations included the following:

- 27 locations within the Gowanus Canal
- 10 reference locations in Gowanus Bay and Upper New York Bay, outside the mouth of the canal
- One sample from Buttermilk Channel at the intake location of the flushing tunnel
- One additional sample in the Gowanus Canal at the end of Sackett Street; collected in response to a resident's concern about a sheen on the water surface

The locations where the surface water samples were collected within the canal are shown in Figures 2-5a through 2-5c. The reference locations and Buttermilk Channel sampling location are shown in Figure 2-6.

Surface water sampling was performed during both dry- and wet-weather conditions. Dry-weather sampling was defined as sampling after a minimum of 2–3 days after a CSO discharge event. Wet-weather sampling could occur only after at least 0.1 inches of rainfall within an hour with accompanying low tide conditions in the canal; this sampling needed to begin within 3–6 hours after the occurrence of these conditions.

Weather conditions were continuously recorded using an onsite Davis Vantage Pro 2 weather station and internet resources, including the National Weather Service. Wet-weather flow conditions in the combined sewer system were also confirmed by calling the Owls Head and Red Hook WPCPs for influent-flow conditions. Observations were also made of receiving-water conditions in the canal to identify evidence such as floatables on the water surface that would indicate that a CSO discharge had occurred. Appendix D contains relevant weather-tracking information.

The dry-weather surface water samples were collected on June 19, 2010, following 2 days of dry weather and no CSO discharges. Thirty-eight surface water samples were collected during the dry-weather event. Wet-weather surface water samples were collected on July 13, 2010, following a rain event which produced 1.02 inches of rain over a 2-hour period during mid- to low-tide conditions. CSO discharges were visually confirmed during the rain event, and both Owls Head and Red Hook WPCPs reported operating near-maximum flow rates before the wet-weather sampling event was begun. Thirty-seven surface water samples were collected during the wet-weather event.

A summary of the samples collected and analyses performed is provided in Table 2-2. Appendix A contains a sample-tracking table listing the samples that were collected, the associated analyses, and QA/QC samples. Surface water samples from all locations were analyzed for TCL organics, TAL metals (total and dissolved, including mercury and cyanide), and total suspended solids (TSS). Field measurements of the following water quality parameters were collected from each surface water sampling location at the time of sampling: salinity, pH, specific conductance, DO, oxidation reduction potential (ORP), temperature, and turbidity.

Surface water samples were collected from most of the planned locations. The following are the deviations from the planned sampling program:

- As described in Section 2.3, the surface sediment sample planned at location 319 was collected approximately 500 feet north of the original proposed location due to the presence of debris in the area. However, the surface water samples collected during both sampling events were collected at the originally planned location.
- The wet-weather surface water sample at location 301 was collected 250 feet south of the planned location because of low-tide conditions.
- The sample from location 325 could not be collected during the wet-weather sampling event owing to the presence of a docked barge at the planned location.
- One additional sample in the Gowanus Canal at the end of Sackett Street was collected in response to a resident's concern about a sheen on the water surface.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.5 Fish and Shellfish Tissue Sample Collection and Analysis

Fish and crab tissue samples were collected from the Gowanus Canal and reference locations in Gowanus Bay and Upper New York Bay to support the ERA and HHRA. Fish and crab caught in the field were processed in the laboratory and composited for analysis. The approach and methods used for tissue analysis are described below.

2.5.1 Field Collection and Initial Sorting

Fish and crab samples were collected in the Gowanus Canal and reference locations in Gowanus Bay and Upper New York Bay from June 21 through July 9, 2010. Two to three vessels and crews sampled simultaneously in these areas during the collection period.

Fish and shellfish were collected in six reaches of the canal and in three reference areas (Figures 2-7 and 2-8). Species targeted for sampling included mummichog, blue crab, striped bass, and white perch. Alternate species included killifish, rock crab, spider crab, American eel, cunner, tautog, and winter flounder. Additional species caught with some frequency included scup, summer flounder, gunnel, weakfish, and rock bass.

During the first week of collection, all fish captured were retained on ice for possible use in tissue residue analysis. During the second week of collection (after species availability in the canal and reference locations was better defined during the first week), species that were not viable candidates for tissue residue analysis were counted and released. Once a sufficient mass of tissue from a particular species was caught from one sample area, emphasis was then placed on capturing that species from the remaining areas where tissue was still needed.

The gear used to collect fish and crabs included fish traps, minnow traps, crab traps, trawls, hook and line, gill nets, and fyke nets. All selected gear types caught at least some of the target or alternate fish species. Some gear types worked better than others in some locations due to tidal fluctuations, current velocities, congested shipping channels, and constricted canal reaches. Sampling gear was checked and redeployed multiple times during a day and was allowed to remain in place (as appropriate) overnight. Vessel captains created sampling logs and recorded the gear type, sample location, times and dates of deployment and collection, and the number and types of species collected during each deployment. The sampling log was closed out when the gear was retrieved and fish species were identified and quantified. Sample equipment was redeployed on the basis of collection success and the number and types of species still required from a given sample reach.

The pots and traps for mummichug and crab collections within each reach were initially set at locations where surface sediment samples for toxicity testing and PCB congener analysis were collected. The traps had to be moved from these initial locations because sufficient sample volume could not be collected at any single sample location within a reach. Therefore, samples had to be collected from multiple locations within each reach.

Immediately following collection, fish were brought to the main processing boat where the collected species were formally identified, weighed, measured, packaged, labeled, and placed on ice for further processing by the analytical laboratory. Samples were shipped to the laboratory daily for additional preparation and analysis.

2.5.2 Laboratory Tissue Preparation and Grouping for Analysis

Following receipt by the analytical laboratory, fish and crab samples were sorted and grouped by species and sample reach as part of the final preparation for chemical analysis. The following target and alternate species were collected from one or more canal or reference sample reaches and were identified for analysis:

- Small prey fish: Atlantic tomcod, hake, mummichog
- Crab: blue crab
- Larger fish species: American eel, scup, striped bass, weakfish, white perch

Each species was prepared for analysis based on sample type:

- Small prey fish: Small prey fish were analyzed for whole body tissue residue only. These species represent potential prey for wildlife, are not consumed by humans, and therefore will be evaluated only in the ERA.

- Crab: Crabs are consumed by both humans and wildlife and will be evaluated in both the HHRA and ERA. The analytical laboratory picked and separated the tissues of each crab into three separate components: edible tissue, hepatopancreas, and eggs. Eggs were found on a limited proportion of females, all of which were captured in the outer reaches of the reference area. These crab eggs were archived and will not be included in the risk assessments.

- Larger fish species: Larger fish species are consumed by both humans and wildlife and will be evaluated in both the HHRA and ERA. The analytical laboratory separated the tissues of each larger fish into fillet and remaining carcass components. Fillet samples will be evaluated in the HHRA, while both fillet and carcass samples will be evaluated in the ERA.

Following tissue preparation, samples were combined by tissue type (whole body, edible crab, hepatopancreas, fillet, carcass) to create the mass necessary for chemical analysis.

The following guidelines were followed to create the final sample groupings for chemical analysis:

- Only samples of the same species and tissue type (e.g., fillet, carcass) were combined for analysis.
- When adequate tissue was available, at least one sample of each species and tissue type was created for each sample reach within the canal (six reaches) and reference (three reaches). Up to six small prey fish and six larger fish species samples of each tissue type were accordingly targeted for analysis in the canal, while up to three prey fish and three larger fish species samples of each tissue type were targeted for analysis in the reference area. A larger number of crab samples was created for analysis.
- Samples taken from more than one reach were combined when necessary to create adequate tissue mass for analysis. However, canal and reference tissues were never combined. When combining tissues from more than one reach, samples from contiguous reaches were preferentially grouped for analysis. Tissues from noncontiguous reaches were grouped for analysis only when necessary to create adequate sample mass for analysis.
- If adequate tissue mass of a given type was not available for all sample reaches, then multiple samples were created with tissues collected from a single sample reach (when available) to create the total number of samples targeted for the canal and/or reference area.
- Crab and larger fish samples were grouped according to body size so that organisms of a similar age class were combined for chemical analysis. To meet this objective, the smallest organism within a sample grouping was targeted to be at least 75 percent of the length of the largest organism within that sample group. Organisms falling outside of the targeted size range were included when necessary to achieve the mass necessary for chemical analysis. Small prey fish were not grouped according to this guideline because of the similar sizes of these species.
- At least five organisms were grouped together, whenever possible, to create a representative composite sample for analysis, and no more than one sample was taken from a single larger organism.

Table 2-5 summarizes the tissue samples that were created for analysis within the canal and reference area based on the above guidelines. All remaining tissues were archived for possible future analysis. The total number of samples and analytical parameters are summarized in Table 2-2. Appendix A contains sample-tracking tables listing the samples that were created, the associated analyses, and QA/QC samples.

Summarized below are the analyses performed on each tissue type:

Blue crab samples were analyzed for the following:

- TCL semivolatile organic compounds (SVOCs)
- TCL pesticides
- PCB congeners
- TAL metals (including mercury)

All fish tissue samples were analyzed for the same list of parameters as the blue crab except TCL SVOCs.

Samples were also analyzed for percent moisture and lipid content when adequate tissue mass was available.

2.6 Air Sample Collection and Analysis

Air-sampling activities were conducted along the Gowanus Canal and at background locations during two sampling events to evaluate whether emissions from canal sediments are a potential human health concern. This section summarizes these activities and notes any deviations from the planned technical approach.

The objectives of the air-sampling efforts were to measure and compare contaminant concentrations in ambient air samples collected from the following locations:

- Within the breathing zone of a recreational canoeist on the canal
- Within the breathing zone at the street level along the canal
- At background locations (i.e., outside of the area potentially impacted by emissions from the canal)
- Before and after the start of the canal aeration to evaluate potential effects of the aeration system

The first round of air samples was collected between July 7 and 9, 2010, prior to the activation of the canal aeration system. A second round of air sampling was conducted over July 28 and 29, 2010, following system startup.

The locations where the air samples were collected are shown in Figure 2-9 and include:

- 10 locations along the length of the canal with two samples collected at each location—one at canoe level and one at street level
- Three background locations at street level

Air samples were collected at all 13 sampling locations during the first sampling event. The three background locations were not sampled during the second sampling event because the first sampling event was performed only to evaluate the effects of the canal aeration system, and the background locations are outside of the system's potential zone of influence.

Both sampling events were performed during dry-weather conditions, as planned. Weather conditions were continuously recorded using an onsite weather station. Appendix D contains relevant weather-tracking information.

A summary of the samples collected and analyses performed is provided in Table 2-2. Appendix A contains a sample-tracking table listing the samples that were collected, the associated analyses, and QA/QC samples.

Air samples along the canal were analyzed for VOCs and PAHs. Location 506 at the street level was also analyzed for PCBs during the first sampling event. Samples for VOC analysis were collected using individually laboratory certified clean Summa canisters equipped with flow controllers. Samples for analyses for PAHs were collected using low-volume samplers and polyurethane foam (PUF) cartridges. The sample for PCB analysis was collected using a high-volume sampler and a PUF cartridge. This sampler was situated near a power source and operated over a 24-hour period in order to evaluate conditions near the canal over a full 1-day cycle. Sample collection details are presented in Appendix D.

Samples were analyzed for VOCs using Method TO-15, for PCBs using Method TO-4, and for PAHs using Method TO-13. The following are the deviations from the planned sampling program:

- The street-level VOC sample at location 501 was collected during the first sampling round over a 40-hour period as opposed to the planned 24-hour period due to a problem with the flow regulator attached to the Summa canister.
- The exact shut-off time of the low-volume sampling pump is unknown at location 513. It is estimated that the pump stopped after 20 hours of sample collection.
- During the second round of sampling, a PCB sample was not collected at location 506 because the start of the aeration system was not expected to have an effect on PCB concentrations, and samples were not collected at the background locations because they were considered to be outside the zone of potential influence from canal emissions.
- Low-volume samplers used to collect PAH samples from the 504 and 507 canal-level locations during the second air-sampling event were suspected of malfunctioning during sample collection. As a result, the amount of air that passed through the PUF cartridges at these two locations was unclear; therefore, results for these two samples are reported in micrograms per cartridge unit as opposed to micrograms per cubic meter.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.7 Outfall Evaluation

Field investigations were performed to identify and characterize discharges from outfalls to the Gowanus Canal, including the CSOs and discharges from other pipe outfalls. These investigations included collection of sediment and water samples from CSOs, and the identification and investigation of other pipe outfall discharges to the canal. Investigation activities are summarized below. Supporting field documentation is presented in Appendix D.

2.7.1 Combined Sewer Overflow Sediment and Water Sample Collection and Analysis

Sampling was performed at multiple locations in the combined sewer system to characterize CSO discharges to the Gowanus Canal. The objective of the sampling was to characterize contaminant concentrations in sediments and combined sewage that may be discharging through the CSOs to the canal. The CSOs listed in Table 2-6 discharge to the Gowanus Canal and were included in the sampling program. Also listed in the table are the locations of the CSO regulators.

Prior to the start of the sampling activities, a field reconnaissance was performed to identify the locations of the CSO regulators and/or reliefs and potential monitoring locations upstream of these. A follow-up reconnaissance was then performed with a representative of the NYCDEP, Bureau of Wastewater Treatment, Collections Facilities South. The objectives of these reconnaissance activities were the following:

- Identify and confirm that the selected monitoring locations were upstream of the combined sewer regulators and/or reliefs discharging via CSOs to the Gowanus Canal, which would eliminate potential backflow (tidal intrusion) from the canal.
- Determine the traffic control needs during sampling and the associated permit requirements.

The locations to be sampled were then clearly marked at manholes in the streets or at the Gowanus Pump Station. Appendix D contains the traffic management plan that was prepared and implemented by Traffic Management, Inc., in accordance with federal Department of Transportation requirements. Figure 2-10 shows the locations of CSO outfalls discharging to the canal that were targeted for sampling and the locations of the manholes selected as described above to collect the samples; Table 2-7 describes the street locations of the sampled manholes.

CSO sampling was performed during both dry and wet weather conditions. Dry weather sampling was defined as sampling after a minimum of 2 to 3 days after a CSO discharge event. Wet weather sampling could occur only after at least 0.10 inches of rainfall within an hour; this sampling needed to begin shortly (within 3–6 hours) after the occurrence of these conditions.

Weather conditions were continuously recorded using an onsite Davis Vantage Pro 2 weather station and internet resources, including the National Weather Service. Wet weather flow conditions in the combined sewer system were also confirmed by calling the Owls Head and Red Hook WPCPs for influent flow conditions. Observations were also made of receiving water conditions in the canal to identify evidence such as floatables on the water surface that would indicate that a CSO discharge had occurred. Appendix D contains relevant weather-tracking information.

Dry weather sampling of sediments and water from the combined sewer system was performed between June 30 and July 1, 2010. Wet weather sampling of the flow was performed during three wet-weather events—July 13, September 28, and September 30 to October 1, 2010. A summary of the samples collected and analyses performed is provided in Table 2-2. Appendix A contains a sample-tracking table listing the samples that were collected, the associated analyses, and QA/QC samples.

During dry weather, the sampled CSO flow is expected to be representative of the sewage inflow to the WPCPs and during wet weather, the sampled flow is expected to reflect the mixing of sewage with stormwater runoff. For the purposes of this report, the term "CSO water" is used to reflect the sampled CSO flow during both dry- and wet-weather conditions.

CSO Sediment Sampling

Sediment samples were collected from the combined sewer system only during dry-weather conditions. Sediment samples were collected from the following seven CSO monitoring locations:

- Red Hook WPCP service area: RH-031, RH-033, RH-035, RH-036, and RH-037
- Owls Head WPCP service area: OH-005 and OH-007

Sediment samples could not be collected from the RH-034, RH-038, and OH-006 CSO monitoring locations due to the high velocity of the flow. The samples were collected using a Nasco Swing Sampler with a certified clean polyethylene collection bottle. The samples were described on field log sheets with respect to gross grain size, color, odor, and other notable characteristics. Samples were composited upon collection except for sample volumes sent for VOC analysis, which were collected from the area of highest PID response or from an area with visual evidence of contamination. Sediment samples were sent for the following analyses: TCL organics, TAL metals (including mercury and cyanide), TOC, and grain size.

CSO Water Sampling

Water samples were collected from the combined sewer system during both dry- and wet-weather conditions at all CSO monitoring locations. Field measurements of salinity, pH, specific conductance, DO, ORP, temperature, and turbidity were taken at each CSO-sampling location during both dry and wet weather sampling events.

During the dry-weather sampling event, the discrete water samples were collected from nine CSO monitoring locations by use of a certified clean polyethylene collection bottle. At the Gowanus Pump Station (RH-034), a composite sample was collected over a 24-hour period by use of an ISCO composite sampler. Water samples were collected from CSO monitoring locations during three wet-weather events as follows:

- Samples were collected on July 13, 2010, from six of the 10 monitoring locations: RH-034, RH-036, RH-037, RH-038, OH-005, and OH-006. The sample from RH-034 was a 24-hour composite sample. Sampling of all locations could not be completed because precipitation in the area ceased, wastewater flows observed in the combined sewers began to transition back to dry-weather flow conditions, and influent wastewater flow at the WPCPs were reported to be returning to dry-weather conditions. A total of 1.02 inches of rainfall was recorded by the onsite weather station between 12:15 and 2:00 p.m.

- Samples were collected on September 28, 2010, from three monitoring locations: RH-031, RH-034, and RH-035. As in the first event, sampling could not be completed at all CSO monitoring locations because precipitation ended, wastewater flow observed in the combined sewer system dropped, and influent wastewater flow at the WPCP was reported to be returning to dry weather conditions. A total of 0.21 inches of rainfall were recorded by the onsite weather station between 11:30 and 12:30 p.m.

- Water samples were collected between September 30 and October 1, 2010, from all 10 CSO monitoring locations. A total of approximately 1 inch of rainfall was recorded by the onsite weather station between 5:30 and 7:30 a.m. on September 30 and a total of approximately 4 inches of rainfall was recorded at the local Park Slope weather station between 4:30 and 9:30 a.m.

The dry-weather and wet-weather CSO water samples were analyzed for TCL organics, TAL metals (total and dissolved, including mercury and cyanide), and TSS. Water samples from OH-007 and RH-034 were also analyzed for the following parameters: alkalinity, ammonia, nitrates, total Kjeldahl nitrogen (TKN), TOC, dissolved organic carbon (DOC), total hardness, silica, sulfates, and TDS. A field test for ferrous (+II) iron was also performed.

The CSO sediment- and water-sampling program was mostly implemented as planned. The following are noteworthy details or deviations from the planned sampling program:

- A composite sample was collected from RH-034 during dry weather and sent for TCL organics and TAL metals analysis on July 1, 2010. Additional composite sample volume was collected for analysis of geochemistry parameters on July 7, 2010, under similar dry-weather conditions.

- Geochemistry samples from locations RH-034 and OH-007 were scheduled to be collected during the dry and first wet-weather sampling events. Geochemistry samples were collected from both locations during the dry-weather sampling event; however, the wet-weather samples were collected during two separate events. RH-034 was sampled during the second wet-weather sampling event due to limitations in sample volume (see further explanation below) and a shortened sampling period. The geochemistry sample from OH-007 was collected during the third wet-weather sampling event.

- During the first wet weather sampling event, the ISCO composite sampler stopped collecting sample volume at RH-034 after approximately 12 hours. Because limited sample volume had been collected, the sample was sent to the laboratory only for the following analyses: TAL metals (total and dissolved), cyanide, SVOCs, and TSS.

- During the last sampling event, the manhole for RH-035 overflowed with floatables. The sample was collected directly from the discharge of the manhole onto the street.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.7.2 Identification of Other Outfall Features

An evaluation was performed to identify and characterize outfall features other than CSOs and collect information on the potential for contaminant contributions from these outfall features to the canal. The survey was performed in the following two phases:

1. Field survey during dry weather to identify outfall features and sample any outfalls discharging to the canal.
2. Video camera survey of outfall features to trace their layout, measure how far they extend from the canal (origin), identify lateral connections, and collect other information, where possible.

Each activity is summarized below. Supporting field documentation is presented in Appendixes D and G.

Phase 1 Identification and Sampling of Outfall Features

A field survey of the canal bulkheads was performed over a 6-day period from September 1 to 9, 2010. The objectives of the survey were to inspect the canal bulkheads during low tide conditions and identify pipe outfalls, seeps, or other features that have or had the potential to discharge to the canal. Low-tide conditions provide the greatest height of canal bulkhead above the water surface; therefore, all sections of the bulkheads were inspected during low-tide conditions. This was accomplished except in the areas listed below. At these locations, barges were stationed, and the survey was performed irrespective of tide conditions, when the barges were moved to allow access to the bulkheads:

- New York City Department of Transportation (NYCDOT) Hamilton Avenue asphalt plant
- Amerada Hess Corporation—Brooklyn Terminal (764 Court Street)
- Greco Bros. Ready Mix Concrete Company Brothers (281 Hamilton Avenue)
- Ferrara Brothers Building Material (435 Hoyt Street)
- Benson Scrap Metal (543 Smith Street)

The feature identification survey was executed from small skiffs with a shallow keel (low water displacement) capable of maneuvering in shallow water at low tide. Two teams performed the survey. Upon locating a pipe or feature, the team assigned a unique number to the feature and utilized a survey form to collect consistent information at each location. Each location was photographed and its coordinates recorded using a Trimble Geo XH handheld GPS unit with GeoBeacon with real-time corrections. The survey was limited to the collection of information that could be observed without the use of intrusive techniques.

When a feature was observed to discharge into the canal, the field team recorded the headspace readings at the discharge using a cleaned and calibrated MiniRae 2000 PID with a 10.6-eV lamp capable of detecting VOCs. Salinity measurements were also collected and recorded using a cleaned and calibrated Horiba U-52 with a salinity probe. The salinity result was then compared to "background" water in the canal to determine whether the observed discharge was the result of tidal flux or of an unknown discharge. If the discharge could not be attributed to tidal flux, a sample of the effluent was collected for laboratory analysis.

In total, 25 features were observed to discharge to the canal, with the discharge from 11 appearing to be tidal drainage. The discharges from these 11 features were not sampled. From the remaining 14 features, the discharges from 12 were sampled; the discharges from two could not be sampled due to the small rate of the discharge.

In total, 12 samples were collected from features with observed flows. The features that were sampled during this event are shown in Figure 2-10, along with the CSO sample locations. Table 2-2 summarizes the number of samples collected and the analyses performed. Appendix A contains a sample-tracking table listing the samples that were collected, the associated analyses, and QA/QC samples. Samples from all except two outfalls were sent for the analysis of TCL organics and TAL metals (total and dissolved, including mercury and cyanide). At two outfalls (E-29 and W-44), the samples were sent for fewer analyses because the flow was a trickle and only limited volume could be obtained in a reasonable amount of time. Field measurements of salinity, pH, specific conductance, DO, ORP, temperature, and turbidity were taken at each CSO sampling location.

Phase 2 Collection of Additional Information on Outfall Features

The Phase 2 outfall feature survey consisted of a video camera survey of the features referred for further investigation from Phase 1. The objective of this phase was to trace each feature as far inland as possible but at least two blocks from the bulkheads of the canal and collect the following information:

- Approximate diameter, construction material, and condition of the pipe or feature
- Number and approximate diameter, construction material, and condition of lateral lines
- Distance of lateral line entry points from outfall entry point
- Distance of survey end point from outfall entry point
- Sediment deposition, evidence of recent flow, and any obstructions
- Direction of surveyed pipe (perpendicular or at an angle to the canal)
- Direction of lateral connection pipes

The field survey was performed by USEPA ERT from October 18 to mid-December, 2010. The survey was performed using a small skiff and a subcontractor (City Sewer) to operate the video camera equipment. Two types of equipment were utilized: a push camera was used for the small pipes, and a tractor-based camera was used for the larger pipes. The push camera was operated by plugging it in to either an on-vessel generator or a truck generator provided by the subcontractor. The tractor-based camera was operated from the subcontractor's truck; access to the canal from the street was needed to complete the inspection of the larger pipes. The camera was guided as far as possible up to two blocks east or west of the canal. In cases where the camera could not reach two blocks due to obstructions in the pipe, a note was made, and the investigation of the pipe was terminated. Appendix G contains a report of the observations from the field video survey.

2.8 Hydrogeologic Evaluation

The hydrogeologic evaluation was performed to evaluate the following: (1) shallow subsurface (0 to 60 feet below grade) conditions adjacent to the canal; (2) groundwater flow directions and gradients adjacent to the canal; (3) the magnitude of tidal fluctuation in the canal and its influence on groundwater levels; (4) groundwater–surface water interaction conditions along the length of the canal; and (5) potential for associated contaminant contributions through groundwater discharges to the canal. The hydrogeologic investigation consisted of the following tasks:

- Installing and developing monitoring wells and associated soil sampling
- Sampling groundwater from the installed monitoring wells
- Collecting samples from both the Gowanus Canal and the monitoring wells
- Collecting synoptic water level measurements
- Performing a tidal study

The activities performed under each of the above tasks are outlined below. Supporting field documentation is provided in Appendix D.

2.8.1 Groundwater-Monitoring-Well Installation and Development and Soil Sampling

Groundwater-monitoring wells were installed along the Gowanus Canal through a coordinated effort among USEPA, National Grid, and New York City. National Grid and New York City installed the monitoring wells on their respective properties. USEPA installed monitoring wells on the remaining properties along the length of the canal. The scope of work performed by each entity and deviations from their respective work planning documents are summarized below.

The monitoring wells were installed in May and June 2010. In total, 42 monitoring well pairs (shallow and intermediate) and four single monitoring wells (intermediate) were installed along approximately 3 miles of canal frontage (east and west sides of the canal), for a total of 88 new monitoring wells that were installed (Table 2-8). In addition, three existing shallow monitoring wells were integrated into the monitoring well network for a total of 91 wells that were included in the groundwater sampling program. Figure 2-11 shows the locations of monitoring wells that constitute the network. The rationale for selecting the monitoring well locations was based on geographic distribution across the length of the canal, potential for upland contamination impacts to the canal, and accessibility to specific work locations. The rationale for the vertical elevations for the monitoring well screens was to intersect the water table in the shallow wells and to intersect groundwater immediately below the top of the native sediment in the intermediate wells. Screen intervals were selected specifically to characterize groundwater–surface water interactions through examination of gradients, water chemistry, flow nets, and contaminant chemistry.

Screen intervals in shallow monitoring wells straddled the water table, which occurs between 2 and 12 feet below ground surface (bgs). The shallow wells were constructed with a 10-foot-long screen. Screen intervals in intermediate monitoring wells were installed so that the top of the 5-foot-long screen was positioned approximately 5 feet below the top of the native sediment lining the bottom of the canal. The top of the well screens in the intermediate wells ranged from approximately 28 to 55 feet bgs. The depth of the native sediments in the canal was determined on the basis of results of the Phase 2 sediment-coring investigation. An idealized cross section showing the relative layout of the shallow and intermediate wells with respect to the Gowanus Canal is shown in Figure 2-12.

Soil samples were collected from the soil borings for the intermediate wells. At each location, soil sampling was performed over 5-foot intervals along the full length of the boring. Each 5-foot interval was screened with a PID. Samples for VOC analyses were collected in the middle of the 6-inch interval exhibiting the highest PID reading or at intervals of visual contamination. If noncontaminated conditions were observed in the 5-foot interval, then a VOC sample was collected from the middle of the interval. The rest of the soil within the 5-foot interval was homogenized, and a sample collected for the remaining laboratory analyses. In cases where split samples were collected, the homogenized soil was split into two parts, providing sample volume for the split samples.

At each intermediate location, lithologic descriptions, PID readings, and visual/olfactory observations of the soil column were recorded on the soil boring logs. The lithology of the soil samples was logged using the Unified Soil Classification System in accordance with ASTM 422-D. Soil-boring logs and well construction diagrams are presented in Appendix D.

A summary of the soil samples collected and analyses performed is provided in Table 2-2. All soil samples were analyzed for TCL organics and TAL metals including mercury and cyanide.

The following sections present additional details of the well installation, well development, and soil-sampling activities performed by USEPA, National Grid, and New York City.

USEPA Well Installation Activities

Monitoring wells were installed by USEPA between May 15 and June 28, 2010. Prior to initiating work at specific properties, street-opening permits were obtained from the NYCDOT for monitoring well locations within the public right-of-way, while USEPA secured property access for monitoring well locations on private properties.

Prior to drilling, DigNet of New York City and Long Island marked out underground utilities. In addition, monitoring well locations were cleared of underground utilities to a maximum depth of 8 feet using either hand auger or air knife/vacuum truck techniques.

Well borings were drilled employing the rotary sonic drilling method. Drill rigs, rod, bits, and other tools were decontaminated prior to initiating drilling, between well locations, and following the drilling effort. In total, USEPA installed 32 well pairs, and one single intermediate well (MW-46I). A total of 233 soil samples were collected for laboratory analyses.

Monitoring wells were constructed of 2-inch-diameter polyvinyl chloride (PVC) Schedule 40 casing and screen, or Type 304 stainless steel casing and screen if NAPL was observed in the soil boring. Well pairs were completed as nested construction where one borehole is drilled to accommodate two individual wells (shallow and intermediate), as depicted in Figure 2-12. The wells were developed by a combination of surging and pumping using an inertial pump or by pumping using a submersible pump.

The following describe deviations from the planned sampling program:

- One additional monitoring well (GCMW-46I) was installed as a single (not nested) well. Note that this well was initially labeled in the field as GCMW-46D but the screened interval lies within the intermediate zone and the well is therefore discussed in this report as MW-46I.
- The well screen lengths at location GCMW-47 consisted of a 5-foot-long screen on the shallow well and a 10-foot-long screen on the intermediate well.
- Monitoring well MW-22 was not installed due to underground utility obstructions, and MW-23 was relocated closer to the planned MW-22 location in order to provide the desired spatial coverage to meet the objectives.

National Grid Well Installation Activities

Installation of monitoring wells was performed by National Grid between June 23 and 30, 2010. National Grid installed nine monitoring wells in support of the RI activities. National Grid also installed four bedrock wells for another study. However, the lithologic information from all of the well borings was integrated with the USEPA data. The monitoring wells installed by National Grid in support of the RI activities included the following:

- Well pairs GCMW-23, GCMW-40, and GCMW-41
- Intermediate wells GCMW-30I, GCMW-31I, and GCMW-32I

The three intermediate monitoring wells were installed at the Fulton former MGP site to supplement existing shallow wells on the property: FW-MW-10 (a.k.a. MW-30S), FW-MW-10 (a.k.a. MW-31S), and FW-MW-16 (a.k.a. MW-32S).

Prior to drilling, each monitoring well location was cleared using manual or vacuum clearance methods to a depth of 5 feet or 1 foot below the estimated depth of any nearby known utility, whichever was deeper.

Drilling activities were completed using the rotary sonic drilling method with drilling equipment decontaminated between well locations. A total of 56 soil samples was collected for laboratory analyses.

The wells were constructed by installing 2-inch-diameter stainless steel casing and screen. Each monitoring well was installed in a separate borehole approximately 5 feet apart. Wells were developed by alternately surging the wells with a surge block and pumping the wells with a submersible pump.

The following are the deviations from the planned sampling program:

- Monitoring well MW-32I was initially drilled and installed to a depth of 40 feet below grade, which was less than the planned depth of 45 feet for this location. An additional monitoring well was installed approximately 10 feet east of this initial location and extended to the desired depth of 45 feet below grade.
- Sand of No. 1 size was specified for well pack construction in the work plan, but No. 0 sand was used instead.

- Some composite soil samples were collected over 4-foot and 6-foot intervals instead of the specified 5-foot interval because of the nature of the soil-sampling methods.

New York City Well Installation Activities

Between June 2 and 8, 2010, New York City installed the following 14 monitoring wells in support of the RI activities: well pairs MW-1, MW-2, MW-9, MW-10, MW-17, MW-18, and MW-19. Prior to commencing drilling activities New York City conducted a geophysical survey using ground-penetrating radar (GPR) to clear each location for subsurface utilities. Following the completion of the geophysical survey, a vacuum truck equipped with an air knife cleared the top 5 feet of soil at the proposed shallow well locations. The top 5 feet of the intermediate well borings were not cleared with the air knife in order to maintain the integrity of the shallow soil for undisturbed soil sampling.

Drilling activities were completed using hollow-stem auger (HSA) drill rigs with drilling equipment decontaminated between well locations. New York City collected 67 samples in six borings for laboratory analyses.

The wells were constructed by installing 2-inch-diameter PVC Schedule 40 casing and screen. The wells were developed using a submersible pump.

The following are the deviations from the planned sampling program:

- Only 1 foot of filter sand pack above the top of the screen was installed at well MW-2S, as opposed to the 2 feet that was originally planned. The construction deviation was necessary due to the high water table encountered at approximately 2.5 feet at this location. The top of the screen was set at 3 feet bgs with the filter pack extending to 2 feet bgs. No. 00 sand was set from 1.5 to 2.0 feet bgs, while the remaining annular space was filled with grout.

- During development of the 14 monitoring wells, a target turbidity measurement of less than 50 nephelometric turbidity units (NTUs) was not always achievable. Poorly consolidated, fine-grained sediments adjacent to the canal prevented removal of elevated turbidity during development over a reasonable duration. Generally, development achieved stable but elevated turbidity values.

The deviations noted during the monitoring well installation did not affect the data set, which was found to be sufficient to support the RI/FS objectives.

2.8.2 Groundwater Sampling

Groundwater-sampling activities at monitoring wells located along the length of the canal were conducted in June and July 2010. The objectives of this sampling effort were to characterize water quality from the shallow and intermediate depth intervals, including geochemistry and contaminant distribution along the length of the canal. Groundwater samples were collected from the following 91 locations:

- 32 shallow and 33 intermediate wells installed and sampled by USEPA
- Six shallow (including three previously existing shallow wells) and six intermediate wells installed and sampled by National Grid
- Seven shallow and seven intermediate wells installed and sampled by New York City

The locations of the sampled monitoring wells are shown in Figure 2-11.

USEPA, National Grid, and New York City each sampled their own wells no earlier than 2 weeks following development. All samples were collected following USEPA's low-flow groundwater-sampling procedures. Water level measurements were collected from each well prior to the pump being placed in the well. Low-flow purging of each well was maintained between 100 and 500 mL/min. Groundwater discharged from the wells was generally monitored throughout the purging activities for salinity, pH, specific conductance, DO, ORP, temperature, and turbidity. Field chemistry measurements were recorded on field log sheets. Upon stabilization of field chemistry parameters, groundwater samples were collected directly from the Teflon-lined effluent tubing.

The samples collected and analyses performed are summarized in Table 2-2. Appendix A contains a sample-tracking table listing the samples, the associated analyses, and QA/QC samples. Groundwater samples collected by the three entities were analyzed for slightly different constituents:

- USEPA and National Grid—TCL organics, TAL metals (total and dissolved, including mercury and cyanide)
- New York City—TCL organics, TAL metals (total, including mercury and cyanide), and dissolved iron

The following are noteworthy details or deviations from the planned sampling program:

- Groundwater samples from the following wells on New York City properties were not analyzed for dissolved TAL metals: MW-1, MW-10, MW-17, and MW-19.
- Monitoring well cluster MW-22 was not installed, and therefore no groundwater samples were collected at this location.
- Because poor recovery rates restricted sample volumes, groundwater samples from MW-28S and MW-29S were collected over a 3-day period. Both wells purged dry on the first day under low-flow procedures and were allowed to equilibrate prior to collecting the initial sample volume. Both wells went dry during sample collection and did not recharge sufficiently over the initial sampling period. Field teams returned to the wells on the following 2 days to collect additional sample volume. No further purging was attempted.
- An electronic oil–water interface probe failed to accurately measure water levels in wells MW-7S and MW-14I because of potential electronic interference.
- Water quality parameters stabilized at wells MW-24S and MW-43S, but both wells went dry during sample collection. Remaining sample volume was collected after 80 percent of the original water column in the well recovered.
- Due to problems with the sample bottleware after collecting a sample from MW-26S, this well was resampled for total and dissolved metals (only) approximately 7 hours after the initial sample volume was collected.
- No sample was collected at National Grid monitoring well MW-40S due to the presence of NAPL.

- The sample from monitoring well MW-3S was not analyzed for cyanide because the pH of this sample, upon its arrival at the laboratory, was out of the appropriate range for proper sample preservation.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.8.3 Groundwater–Surface Water Interactions Sampling

Samples collected from monitoring wells and surface water locations in the Gowanus Canal were analyzed for general water quality parameters in June and July 2010. These constituents provide a wealth of information on geochemical conditions beneath the area, including oxidation/reduction characteristics, the abundance/absence of nutrients, and hydraulic interconnections between the shallow and intermediate zones. Most importantly, these constituents can help characterize the hydraulic connection between the shallow aquifer system and the canal. Ultimately, these data define geochemical conditions that may constrain or enhance contaminant contributions from the shallow groundwater system to the canal.

This section summarizes the performed activities and notes any deviations from the planned technical approach. To achieve the above objectives, samples were collected from the following locations:

- 12 monitoring well pairs (shallow and intermediate zones—24 wells total):
  - MW-02, MW-09, and MW-18 well pairs collected by New York City
  - MW-31 well pair collected by National Grid
  - MW-3, MW-4, MW-15, MW-16, MW-20, MW-21, MW-37, and MW-39 collected by USEPA
- Nine surface water samples from the canal, adjacent to monitoring well pairs:
  - SWMW-02, SWMW-09, and SWMW-18 collected by New York City
  - SWMW-23 and SWMW-31 collected by National Grid
  - SWMW-03, SWMW-37, SWMW-20, and SWMW-15 collected by USEPA

Groundwater–surface water interaction sampling locations are shown in Figure 2-13. Sampling activities were conducted concurrent with groundwater-sampling activities following installation and development of the new monitoring well pairs. USEPA collected surface water samples from a decontaminated Van Dorn horizontal alpha sampler, and all other surface water samples were collected from a Kemmerer-style bomb sampler. All surface water samples were collected from the canal, adjacent to the bulkhead, approximately 6 to 12 inches above the soft sediment at the bottom of the canal.

The samples collected and analyses performed are summarized in Table 2-2. Appendix A contains sample-tracking tables listing the samples that were collected and the associated analyses and QA/QC samples. Samples were analyzed for the following water quality parameters: alkalinity, ammonia, calcium, chlorides, total and dissolved iron, magnesium, total and dissolved manganese, aluminum, nitrates, TKN, DOC, TOC, potassium, phosphate, total hardness, silica, sodium, sulfates, TDS, and TSS.

Field measurements of the following water quality parameters were collected during the collection of groundwater samples and are included on field log sheets presented in Appendix D: ferrous (+II) iron, salinity, pH, specific conductance, DO, ORP, temperature, and turbidity.

Section 3 provides an evaluation of the chemistry of the groundwater and canal water including cation/anion composition, ORP, and the presence of nutrients, biological activity, and native acidity. These analyses are used in concert with water levels to evaluate the groundwater–surface water interactions and contributions from groundwater to the canal.

The following are the combined deviations for all sampling entities from the planned sampling program:

- Water quality samples were collected from well pairs MW-20 and MW-21 and surface water location SWMW-20 instead of MW-11, MW-12, and SWMW-11 because of restricted access during the sampling event. These locations fall within the same general vicinity of the canal.
- A water quality sample from proposed location SWMW-37 was not collected. Water quality data from sampling location SWMW-39 will be used to characterize water quality in this area of the canal.
- Ferrous iron analysis was not performed on samples from SWMW-20, SWMW-37, MW-20S, MW-20I, MW-21S, and MW-21I.
- Field measurements for ferrous iron were not collected from GC-MW23I and GC-SWMW23. These samples were analyzed for ferrous iron by TestAmerica in place of the field measurement.
- The metals analyses (total and dissolved) were not performed on the samples from locations SWMW-15, SWMW-20, SWMW-37, and SWMW-03.
- TDS and TSS analyses were not performed at SWMW-23 and SWMW-31.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.8.4 Synoptic Water Levels

Synoptic water level measurements were collected at monitoring wells and reference measurement point benchmarks (staff gauges) along the length of the canal by USEPA, National Grid, and New York City during six monthly events between July and December 2010.

The objectives of these survey events were to evaluate the piezometric surface (e.g., water elevations) in the shallow and intermediate groundwater zones, quantify hydraulic gradients (horizontal and vertical), and establish groundwater flow directions. Six months of water level measurements were collected to characterize seasonal variations; the measurements were collected during various tidal stages. Water level measurements were collected from the following 99 well locations and 17 staff gauges using oil–water interface probes during different stages of tidal cycles:

- 32 shallow and 33 intermediate wells installed by the USEPA
- Six shallow (including three previously existing shallow wells) and six intermediate wells installed by National Grid and included in the groundwater sampling program, plus five previously existing shallow wells and three previously existing intermediate wells that were used only for water level measurements
- Seven shallow and seven intermediate wells installed by New York City
- 17 reference point staff gauges at geographically distributed locations along the length of the canal

Prior to beginning each measurement event, the individual oil–water interface probes were field checked to a reference point to verify that each probe produced the same measurement. Synoptic measurement events were coordinated among the three entities with the goal of measuring all locations within approximately a 1-hour time period.

The locations of the monitoring wells included in the survey are shown in Figure 2-11. Reference point staff gauge benchmark locations are shown in Figure 2-14. Monthly water level measurements are presented in Appendix D. There were no deviations from the planned program under this task.

2.8.5 Tidal Evaluation

A tidal evaluation was performed between August 2 and 5, 2010. This section provides a brief summary of these activities and notes any deviations from the planned technical approach. The objectives of this work were to determine the following:

- Influence of tidal fluctuations on groundwater levels and thus on horizontal and vertical groundwater flow
- Potential for and frequency of hydraulic gradient reversals (i.e., changes between losing and gaining recharge in canal)
- Determine whether the synoptic water level monitoring events should be performed over a duration of less than 3 hours

To achieve these objectives, pressure transducers were installed at the following locations:

- 12 monitoring well pairs spatially distributed along the length of the canal (MW-33, -3, -4, -27, -26, -25, -20, -21, -14, -13, -16, and -15)
- Six locations within the canal surface water body, also spatially distributed along the length of the canal (TSMW-33, -3, -25, -20, -13, and -15)

One barometric transducer was also installed at location MW-25 to provide information for atmospheric barometric corrections.

Figure 2-14 shows the monitoring wells where transducers were installed.

Schlumberger Micro-Diver transducers were utilized together with SWS Diver-Office Software (Version 3.2). Transducers were rated at 14 pounds per square inch gauge (psig). Measurements were recorded every 15 minutes for the duration of the study. Data from the pressure transducer measurements are presented in Appendix E. Data were also compared to daily precipitation and changes in barometric pressure.

The following deviations from the planned tidal study evaluation were noted:

- Two additional transducers were installed at location MW-27. These transducers had been rented in case problems were experienced during the setup of the remaining transducers. Since no problems were encountered during the setup, these transducers were installed in an additional well pair.
- The transducer at location TSMW-25 in the canal was removed on the last day of monitoring (1:15 a.m. on August 5). This transducer was not reinstalled, but data from initiation of the test through removal of the transducer was used in the tidal evaluation.

The deviations noted above did not affect the data set, which was found to be sufficient to perform the planned analyses to meet the RI/FS objectives.

2.9 Potentially Responsible Party Oversight Activities

National Grid and New York City installed and sampled the monitoring wells located on properties they owned or had access to. This section summarizes the field oversight and split sampling performed by the USEPA. The locations of these monitoring wells are color-coded and shown on Figure 2-11.

Monitoring well installation and sampling activities were performed by GEI on behalf of National Grid and by Louis Berger & Associates on behalf New York City. Field oversight activities performed by the USEPA consisted of observing installation activities during times of planned split sample collection. During those times, field procedures were observed and compared to general industry standards and the specific procedures outlined in the respective planning documents for the purpose of noting deviations and assessing their significance.

2.9.1 Monitoring Well Drilling and Soil Sampling

New York City monitoring well installation and soil sampling activities and corresponding oversight activities were performed between June 2 and 8, 2010, as described in Section 2.8.1. National Grid monitoring well installation and soil-sampling activities and corresponding oversight activities were performed between June 23 and 30, 2010, as described in Section 2.8.1. No deviations in the sampling procedures from those in the planning documents were observed.

National Grid and New York City collected soil samples over 5-foot intervals along the full length of each intermediate monitoring well soil boring, as described in Section 2.8.1. From these, USEPA collected split soil samples from two predetermined depth intervals: the 5-foot interval immediately below the groundwater table and the 5-foot interval at the bottom of the borehole where the monitoring well screen was planned.

Split soil samples were collected from all planned locations and depths. The only deviation from the planned sampling was at location MW-32I, where the interval below the water table was sampled at the first MW-32 location, and the intervals corresponding to the wells screens were sampled at both MW-32 locations. Split soil samples were sent for TCL organics and TAL metals analyses.

Oversight was provided during development of selected monitoring wells to assess whether field procedures followed the procedures specified in the respective planning documents. No deviations in the procedures from those in the planning documents were observed.

2.9.2 Groundwater-Sampling Activities

New York City groundwater sampling and corresponding oversight activities were performed between June 24 and 28, 2010. National Grid groundwater sampling and corresponding oversight activities were performed between July 19 and 22, 2010. During the same time periods, National Grid and New York City also collected surface water samples for geochemistry parameters in support of the groundwater–surface water interaction evaluation.

Oversight was provided of all sampling activities, but split samples were collected only from monitoring wells. No deviations in the sampling procedures from those in the planning documents and from the USEPA's low-stress groundwater-sampling procedure were observed.

Split samples were collected from all monitoring wells with the exception of the following:

- New York City: MW-10S (sample was collected for VOC analysis only due to closing of the facility).
- National Grid: MW-30I, MW-40S, and MW-40I.

Split groundwater samples were sent for TCL organics and TAL metals analyses.

2.10 Historic and Cultural Survey

Preliminary investigations of historic properties along the Gowanus Canal were carried out in compliance with Section 106 of the National Historic Preservation Act (NHPA) between August and November, 2010. Dolan Research, Inc., and John Milner Associates, Inc. (JMA) performed a review of the bulkheads along the canal to assess their significance and their potential eligibility for nomination to the National Register of Historic Places (NRHP). The survey consisted of the following tasks:

- Review available cultural resources reports that provide information on the Gowanus Canal to assess their adequacy in supporting the needs of the RI/FS, determine the scope of subsequent work beyond that addressed in these studies, and assess the likely effects of the current project on the historic properties identified in these existing reports. The reports that were reviewed included the following:
  - *Final Report National Register of Historic Places Eligibility Evaluation and Cultural Resources Assessment for the Gowanus Canal*, prepared by Hunter Research et al., 2004.
  - *Gowanus Canal Bulkhead Inventory Survey*, prepared for Gowanus Canal Community Development Corporation, prepared by Adam Brown Marine Consulting, July 2000.

- Review the bulkheads that line the Gowanus Canal to evaluate their historic significance and integrity and recommend possible treatment strategies for historically significant bulkheads. This review was based on reviewing historic information as well as on a 1-day bulkhead inspection from water conducted on October 19, 2010.
- Review federal undertakings in which historic bulkheads were affected to provide background on available mitigation actions and considerations.
- Perform a side-scan sonar survey to identify debris of significance at the bottom of the canal.

The complete report from this evaluation is provided in Appendix M.

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SECTION 3

Gowanus Canal Physical Characteristics

This section describes the physical characteristics of the Gowanus Canal and surrounding area on the basis of previous work and studies performed in support of this RI. Many of these characteristics will influence the development and selection of remedial alternatives for canal sediments.

3.1 Bathymetry

The bathymetry of the Gowanus Canal is illustrated in Figures 3-1a through 3-1c and is based on a survey conducted in January 2010 by CR Environmental; a full-color figure from this survey is included in Appendix B. The measured bottom depth elevations ranged from approximately -0.13 feet to -38 feet relative to North American Vertical Datum of 1988 (NAVD88). The bottom depth elevations measured within the canal north of Hamilton Avenue were typically between -0.13 feet and approximately -18 feet NAVD88; much lower sediment surface elevations were measured south of Hamilton Avenue. The sediment surface at the head of the canal and in the eastern ends of many of the turning basins is exposed at low tide. Evidence of propeller scour in the form of a deeper sediment surface was noted in the southern portion of the canal; this area is subject to frequent tugboat activity to move and position oil and gravel barges at the various commercial terminals near the mouth of the canal.

The bathymetry data collected in 2010 were compared to a 2003 survey that was also performed by CR Environmental. Areas that showed a positive change in elevation were inferred to reflect net sediment deposition over the period from 2003 to 2010, whereas areas with a negative change in elevation were inferred to reflect net sediment erosion. Maps of the elevation differences are shown in Figures 3-2a through 3-2c, and a cross-section is presented in Figure 3-3. The combined uncertainty of the two surveys was determined to be as high as ±0.6 feet, with greater uncertainty associated with areas along the shoreline and less uncertainty along the centerline or deepest part of the channel (the thalweg). The highest confidence is given to estimates of elevation differences greater than ±0.6 feet. Appendix B contains additional detail regarding the methodology and limitations of the comparison. Key observations were as follows:

- Elevation differences appeared minor upstream of the NYCDEP floatables containment boom that is across the canal at Sackett Street (about 530 feet downstream from the head of the canal).
- Some erosion was indicated along the western shoreline between the head of the canal and Sackett Street, which is immediately downstream of the flushing tunnel outlet.
- Approximately 2 to 3 feet of sediment accumulation is apparent between the floatables containment boom and the Carroll Street bridge (about 1,400 feet downstream of the head of the canal).

- Approximately 1 to 2 feet of sediment accumulation is apparent at the northern end of the canal between Carroll Street and 3rd Street.
- Elevation differences of approximately -1 to 1 foot were noted in most of the reach between 3rd Street and Hamilton Avenue. Lack of accumulation in this reach may be the result of frequent tug and barge traffic adjacent to a gravel-shipping yard between 5th Street and Huntington Street.
- At the southern end of the canal, the surface comparison suggests a wide (nearly 80,000 ft^2) region of sediment accumulation along the thalweg adjacent to Halleck Street. There were also many smaller areas of substantial elevation difference, either erosional or depositional, in this reach.

3.2 Presence and Distribution of Debris and Obstructions

Debris such as tires, sunken barges, concrete rubble, timbers, gravel, and general trash is widespread throughout the canal. The presence of debris interfered with sediment core collection in several areas. The presence of debris was also noted in numerous areas during the 2010 bathymetry survey (Appendix B). Ocean Surveys, Inc. (OSI) performed a debris survey in late 2005 on behalf of National Grid using magnetometer, sub-bottom profiling, and side-scan sonar technologies. The combined observations from the 2005 geophysical surveys and the 2010 field observations are illustrated in Figures 3-4a through 3-4c. Briefly, the key observations are as follows:

- Gravel covers the sediment surface of the entire main channel south of the concrete plant at the end of 5th Street to south of the 9th Street bridge, and the area adjacent to the New York City asphalt plant south of Hamilton Avenue.
- Debris piles (generally concrete, iron beams, and other large, construction-type debris) were often observed near the ends of streets that ended at the canal.
- The channel, particularly the western shoreline, approximately one city block downstream of the Hamilton Avenue bridge is covered with debris.
- All the turning basins have significant accumulations of debris, including a sunken barge in the 6th Street turning basin and multiple large debris piles and wreckage of a small boat in the 4th Street turning basin.
- Tires and smaller objects identified as anomalies by side-scan sonar and magnetometer surveys are widespread throughout the canal.

A second high-resolution side-scan sonar survey was performed in 2010 as part of the cultural resources survey. Several areas of debris were also identified during this survey, as shown in Figures 3-4d through 3-4f. The 2010 survey identified a number of anomalies with potentially significant historical characteristics, as detailed in Appendix M. The results of the 2005 and 2010 surveys are very similar, and the recent survey confirms that the data collected earlier are still usable.

3.3 Sediment Stratigraphy and Characteristics

Two distinct stratigraphic units are present within the canal: the native Gowanus Creek sediment deposits and the overlying soft sediment that has accumulated within the canal since its initial construction. Field observations from the sediment-coring investigation indicate that the overlying soft sediment is generally a very dark gray to black sand-silt-clay mixture that contains variable amounts of gravel, organic matter (e.g., leaves, twigs, vegetative debris), and trash. Odors described as "organic," "septic-like," "sulfur-like," and "hydrocarbon-like" were commonly observed in the soft sediment, as were visible sheens.

Maps of soft sediment thickness are presented in Figures 3-5a through 3-5c. The soft-sediment layer ranges from approximately 1 foot to greater than 20 feet in thickness, with an average thickness of 9.8 feet.[1] The thickest deposits were observed generally near the head of the canal and within the turning basins. Gravel was observed on the sediment surface from the concrete plant at the end of 5th Street to south of the 9th Street bridge, and in the area adjacent to the New York City asphalt plant on the east side of the canal south of Hamilton Avenue (Figures 3-4b and 3-4c). The gravel observed in these areas is likely related to the gravel barges that traverse the canal and are unloaded in these areas.

The native Gowanus Creek deposits consist of brown, tan, and light gray sands, silts, silty sand, sandy clay, clay, and peat. GEI (2007) noted that a layer of relatively clean (e.g., minimal silt or clay content) sands representing glacial outwash is present beneath the Gowanus Creek sediments. For the purposes of this RI, all the Gowanus Creek deposits and the glacial outwash are considered a single stratigraphic unit of native material. As shown in Figures 3-6a through 3-6c, the elevation of the native sediment surface ranges from approximately -13 feet to -44 feet NAVD88. The elevation of the native sediment surface within the canal north of 9th Avenue is typically between -18 and -20 feet NAVD88 and is generally slightly higher within the turning basins. The native sediment surface begins to deepen between the 9th Street and Hamilton Avenue bridges.

Table 3-1 summarizes the TOC content, grain size distribution and total percent fines content (silt plus clay fractions), percent solids, sulfide, bulk density, and percent moisture for each stratigraphic unit within the canal. Results for surface sediment (0-to-6-inch depth interval) in the canal and the Gowanus Bay and Upper New York Bay reference locations are shown separately. Data summarized in this table include the results from the USEPA's 2010 sediment-coring investigation, the USEPA's 2010 surface sediment sampling, and selected data for the soft sediment samples collected by National Grid in 2005 (GEI, 2007).

The TOC content was higher in the canal surface sediments than in the reference area sediment, with averages of 64,385 mg/kg and 28,358 mg/kg (6.4 and 2.8 percent), respectively. The TOC content was much higher in the soft sediment within the canal than in the native sediment, with averages of 119,650 mg/kg and 18,677 mg/kg (11.9 percent and 1.8 percent), respectively. The high TOC content of the soft sediment most likely reflects the CSO inputs to the canal. As part of the LTCP, NYCDEP estimated the loading of biological

[1] Soft sediment thickness was corrected for less than 100 percent core recovery. It is based on the difference between the elevation of the mudline (soft sediment surface) and elevation of the contact between the soft and native sediment units. The mudline elevation was determined from water depth measurements, tide stage readings, and bathymetry data. The elevation of the contact between the soft and native units was determined by the depth of core penetration and recovered thickness of native sediment. Surface deposits of gravel were considered part of the soft sediment layer.

oxygen demand (BOD) to the canal and noted that CSOs dominate these loadings relative to stormwater runoff (NYCDEP, 2008a). BOD is another measure of organic matter in a sample. High concentrations of organic contaminants (i.e., PAHs associated with NAPL) appear to have influenced TOC measurements in some samples; however, the overall high TOC content in the soft sediment is most likely attributable to CSO discharges.

The fines content in the canal surface sediment was slightly lower than that of the reference area. The percent fines in the surface sediment in the canal ranged from 41.5 to 89.9, with an average of 61.0. The percent fines in the reference area ranged from 56.4 to 90.3, with an average of 71.9. The percent fines content was generally similar in the soft and native sediment units. The percent fines in the soft sediment ranged from 20.4 to 89.8, with an average of 65.3. The percent fines in the native sediments ranged from 0.5 to 100, with an average of 49.3.

The solids content of surface sediment in the canal was lower than that of the reference area, with average values of 35.5 and 40.9 percent, respectively. The solids content in the soft sediment was much lower than in the native sediments, with average values of 53.8 percent and 81.2 percent, respectively.

The average sulfide concentrations in canal and reference surface sediments were 3,448 and 1,167 mg/kg, respectively. The average sulfide concentration was much higher in the soft sediments relative to the native sediments, with average concentrations of 3,909 mg/kg and 145 mg/kg, respectively.

Bulk density data were not collected during the USEPA 2010 investigation and the results summarized herein are from sampling performed by National Grid in 2005 (GEI, 2007). The bulk density of the soft sediments ranged from 0.31 to 1.98 g/cm^3, with an average value of 0.83 g/cm^3. Bulk density of native sediment ranged from 0.59 to 2.1 g/cm^3, with an average value of 1.5 g/cm^3.

3.4 Bulkhead Characteristics

A bulkhead inventory performed along the entire length of the canal by Brown Marine Consulting (2000) indicated that there are four primary types of bulkhead along the canal:

- Crib-type bulkheads, constructed of interlocking timbers or logs that are filled with backfill to form a type of gravity retaining structure
- Gravity retaining walls, built so that the weight of the wall itself provides stability
- Relieving platforms, which consist of a deck of timber or concrete supported on piles, typically timbers or logs, at an elevation high enough above the mean low water line to not require underwater construction techniques but low enough to keep the pilings continuously submerged
- Steel sheet pile bulkheads, which are a flexible wall constructed of steel sheets with interlocking joints. The steel is capped with concrete or masonry construction. Anchorage systems prevent outward movement and consist of a tie-rod and anchors (e.g., structures buried inshore of the bulkhead, such as massive concrete blocks or steel sheet piles)

NYCDEP (2008b) documented that the shorelines of the Gowanus Canal are entirely altered and are dominantly bulkheads with small areas of rip-rap or piers; the bulkheads north of Hamilton Avenue are generally constructed of wood or steel. The NYCDEP report also noted four areas within the study area where the shoreline consisted of rip-rap: between 11th Street and the Gowanus Expressway, between 17th and 19th Streets on the eastern side of the canal, between Sigourney Street and Halleck Street, and on the eastern end of Bryant Street on the western side of the canal.

Hunter Research et al. (2004) also surveyed bulkhead conditions, in 2003. That survey determined that approximately 73 percent of the bulkheads along the main canal and turning basins were crib-type bulkheads with timber construction. Approximately 10 percent of the bulkheads consisted of concrete or bridge abutments and 17 percent were timber or steel sheet piling-type barriers.

Figures 3-7a through 3-7e are representative photographs of the Gowanus Canal shoreline.

The 2000 survey (Brown Marine Consulting, 2000) concluded that the existing structures were sufficient only to support present loading conditions, and that any type of dredging activities could threaten bulkhead stability due to the deteriorated condition of the structures. The 2000 survey was based only on visual examinations of structures without physical or laboratory testing and recommended that a more thorough investigation of bulkhead integrity be performed if dredging is planned. The report also noted that an estimated 41.7 percent of the bulkhead length was in fair condition or worse.

Most recently, as part of the RI activities, Dolan Research, Inc., and JMA performed a review of the bulkheads along the canal to assess their significance and their potential eligibility for nomination to the NRHP. This review was based on historic information from the sources previously cited in this section as well as on a 1-day bulkhead inspection from water conducted on October 19, 2010. The report from Dolan Engineering and JMA is provided in Appendix M.

Documentary research and a high-resolution side-scan sonar survey identified known historic resources in the form of the canal bulkheads, as well as anomalies on the canal bottom, that will be subject to further investigation. The variety of bulkheads reflects an evolution of technology, a varied use of materials, and an effective means of maintaining the function of the canal, thus ensuring its role in the commercial development of Brooklyn. These resources, depending on their individual integrity, are considered to be eligible for nomination to the NRHP. Should the bulkheads be subject to adverse effects as a result of cleanup actions, a wide range of mitigating measures would be investigated and considered as part of the remedy. These measures would likely include additional documentation of bulkhead characteristics and the incorporation of archaeological and architectural investigations as appropriate.

Potential configurations of new construction that are in keeping with the historic character of the setting will be considered. As remediation methods are considered, further examination of anomalies on and within the sediments will be examined. This investigation could encompass further remote sensing or direct examination of the canal bottom.

3.5 CSOs, Storm Sewer Outfalls, and Other Outfall Features

The watershed for the Gowanus Canal is entirely urbanized. As described in Section 1.3.5, the majority of the drainage from the watershed is directed to storm sewer and combined sewer systems. Table 3-2 summarizes the physical and discharge characteristics of the New York City CSOs and storm sewer outfalls discharging to the canal (NYCDEP, 2008a). The permits for the outfalls are issued as part of the State Pollutant Discharge Elimination System (SPDES); permits are issued by the State of New York for the WPCPs.

Appendix G summarizes the results of the Phase 1 and Phase 2 outfall feature survey and lists identified features and physical information for each feature. The checklists completed in the field served as the basis for the table in Appendix G; these checklists are maintained in the project files. Figures 3-8a through 3-8h show the locations of the identified features. Also shown are the boundaries of the properties along the canal where a feature is physically located. Note that this does not imply that the property is or is not the origin of any effluent discharging through the outfall, but only that the outfall is physically located on the bulkhead along the property.

The Phase 1 survey located 220 features of interest, most of which were pipe outfalls. At the completion of the survey, the observed outfall features were correlated with outfalls identified in the following New York City Shoreline Survey Program reports for Owls Head and Red Hook WPCP service areas:

- *Shoreline Survey Report – Cycle I*, February 28, 2001
- *Shoreline Survey Report – Cycle II*, March 31, 2003
- *Shoreline Survey Report*, March 31, 2008

The pipe outfalls identified in these reports as being CSOs and storm sewers owned and operated by New York City are highlighted in green in the table in Appendix G. These outfalls were not investigated further as part of this RI.

For several outfall features, it could not be clearly determined whether they are associated with pipes owned and operated by New York City. These outfalls are highlighted in gray in the table in Appendix G.

All pipe outfalls other than the ones identified as being owned and operated by New York City were referred for further investigation in Phase 2 of this task.

Note that a number of outfalls identified in the New York City Shoreline Survey Program reports were not observed or could not be directly correlated to the observations during the pipe reconnaissance. These outfalls are listed in Table 3-3. It is not known whether these outfalls still exist.

The Phase 2 outfall feature survey obtained additional information on the outfalls identified along the canal. The Phase 2 survey also identified 27 additional features.

Appendix G presents the Phase 2 results, including information on the length of the traced features, feature diameter and material, distance from the outfall of observed lateral connections, whether the features were blocked, and other information.

3.6 Geology and Hydrogeology

The geology and hydrogeology of the area surrounding the Gowanus Canal are described below. Groundwater–surface water interactions are also characterized on the basis of the results of the hydrogeologic evaluation and water quality sampling performed in support of this RI.

3.6.1 Geology

Regional Geology

The following geologic units (in order of increasing depth and age) lie beneath the area surrounding the Gowanus Canal:

- Fill
- Alluvial/marsh deposits
- Glacial sands and silts
- Bedrock

Fill materials are associated with canal construction and subsequent industrialization and recontouring of the area, much of which was originally marshland. The fill consists of silts, sands, and gravels mixed with fragments of brick, metal, glass, concrete, wood, and other debris.

The alluvial/marsh deposits lie below the fill and are composed of sands (alluvial deposits from flowing water bodies), peat, organic silts, and clays (marsh deposits). These alluvial/marsh deposits are associated with the original wetlands complex that was present when the area was settled.

A thick sequence of glacial deposits occurs below the alluvial/marsh deposits. The full thickness of the glacial deposits was not penetrated in this investigation, but the observed glacial deposits were composed mostly of coarser grain sediments (sands and gravel) but also occasional beds of silt. These glacial sands, silts, and gravel were deposited as glacial ice melted during the retreat of the last ice age. At the base of the glacial sequence lies a layer of dense clay, deposited by the glacier or prior to glaciation.

Weathered and competent bedrock underlies the glacial deposits. The bedrock consists of a medium- to coarse-grained metamorphic rock known as the Fordham Gneiss (GEI, 2005).

Site-Specific Geology

Soil borings and monitoring wells were installed at properties adjacent to the Gowanus Canal and in the vicinity of the canal during the RI. Site-specific geological cross-sections were developed based on lithologic descriptions of soil samples recorded on boring logs during drilling activities. Figure 3-9 is a plan-view map of the area showing the cross-section locations. Cross-section A-A′ (Figure 3-10a) extends along the length of the canal, running roughly perpendicular to Gowanus Bay. Cross-sections B-B′, C-C′, D-D′, and E-E′ (Figures 3-10b through 3-10e) lie roughly perpendicular to the canal and are spaced from the head of the canal (section B-B′) to where the canal connects to Gowanus Bay (section E-E′). The cross-sections show a vertical slice of the geologic materials found below ground along the line of the section and are used to visually assess the general nature and stratigraphic relationships (presence, thickness, sediment type, etc.) of the geologic deposits.

Section A-A′ (Figure 3-10a) shows that geologic deposits encountered during drilling activities include fill, alluvial/marsh deposits, and glacial deposits. The fill along this section ranges from 5 to 15 feet thick and is underlain by alluvial/marsh deposits. The alluvial/marsh deposits are about 10 to 45 feet thick, with the thickness increasing toward Gowanus Bay. Two large sand lenses occur within the alluvial/marsh deposits. Glacial deposits consisting mainly of sands and gravels underlie the alluvial/marsh deposits. The depth to the top of the glacial deposits also increases toward Gowanus Bay. Boring logs reveal well-marked contacts between the fill and the alluvial/marsh deposits and between the alluvial/marsh deposits and the glacial deposits, suggesting deposition of the overlying unit on the eroded surface of the underlying unit.

Based on these cross-sections, the depositional history along the canal starts with sands and gravels deposited by melting glaciers followed by a period of erosion, creating an uneven surface sloped toward Gowanus Bay. Alluvial/marsh sediments (including organic silts and peats) were deposited on top of the eroded surface along the Gowanus Bay shoreline and continued to accumulate until the land was developed. Recontouring the marshes generated the fill deposits noted in the upper 5 to 15 feet of the ground surface.

The cross-sections across the canal (Figures 3-10b to 3-10e), are consistent with the section A-A′ and show a general layer-cake-like stratigraphy. Cross-sections B-B′ and C-C′ (Figures 3-10c and 3-10c, respectively), located across the upper reaches of the canal, exhibit a thin layer of peat within the alluvial/marsh deposits, which are truncated by the channel of the canal. Cross-section D-D′ (Figure 3-10d) shows the canal cutting into one of the large sand layers within the alluvial/marsh deposits. Cross-section E-E′, located near Gowanus Bay, shows that the original canal bottom (i.e., below the soft sediments) extended through the alluvial/marsh deposits down into the glacial deposits.

3.6.2 Hydrogeology

Regional Hydrogeology

The primary aquifer beneath the Gowanus Canal and surrounding uplands is identified as the Upper Glacial Aquifer, which generally occurs in the thick sequence of glacial deposits but may include sandy units in the alluvial/marsh sediments. The Upper Glacial Aquifer extends across Kings County, Queens County, and contiguous Long Island, in places forming an important source of groundwater supplies (NYCDEP, 2010a).

The Upper Glacial Aquifer appears generally unconfined, although local beds of silt and clay may confine underlying sand beds. In the Upper Glacial Aquifer, regional groundwater flows to the west/southwest toward Gowanus Bay. Groundwater-bearing zones in the fill and alluvial/marsh deposits discharge to the Gowanus Canal. Tidal influences in Gowanus Bay and in Gowanus Canal affect the specific groundwater discharge rates and flow conditions.

Site-Specific Hydrogeology

Groundwater-monitoring wells in the area are installed at depths of about 15 feet (shallow well) and about 35 to 45 feet (intermediate well). The shallow wells intersect the water table, typically screening the fill and alluvial/marsh deposits. Intermediate-well screen zones are in the glacial deposits, as depicted in the geologic cross-sections (Figures 3-10a to 3-10e). A review of the cross-sections shows that the first-encountered groundwater occurs in the fill deposits.

Groundwater Elevations

Groundwater elevations were measured in the shallow and intermediate wells over a 6-month period, from July to December 2010, to characterize seasonal conditions. Water level measurements in monitoring wells and in the canal were collected over approximately a 1-hour period to minimize tidal effects. Monthly measurement events typically captured a period of peak high or low tide.

The elevations for the shallow wells are shown in Figures 3-11a through 3-11f and for the intermediate wells in Figures 3-11g and 3-11h.

A review of the elevations from the shallow wells indicate that in general, the water level elevations in wells closer to the canal are lower than in wells further away from the canal. Thus, shallow groundwater flows toward the canal, at both high and low tide. As an example, wells MW-39, MW-38, and MW-37 show a consistent decreasing groundwater elevation toward the canal during low tide (4.77 feet NAVD88 to 1.49 feet NAVD88 in July; Figure 3-11a), indicating groundwater flow toward the canal.

A review of the elevations from the intermediate wells indicates that groundwater elevations are relatively consistent during the high and low tides, except in the wells closest to Gowanus Bay. In these wells (i.e., monitoring wells MW-13, MW-14, MW-15, and MW-16), the intermediate groundwater elevations during high tide were about 0.5 to 1 foot higher on average than during low tide. These data indicate that there is a tidal influence on the intermediate groundwater elevations, which would affect the intermediate groundwater flow conditions.

3.6.3 Tidal Effects on Gowanus Canal Surface Water and Groundwater

A 1-week tidal study was performed by installing pressure transducers in the Gowanus Canal and selected monitoring wells screened within both the shallow and intermediate groundwater zones along the canal. The results of the tidal evaluation are summarized below, with the full tidal evaluation analysis and supporting details in Appendix E.

The following conclusions were drawn from the tidal evaluation:

- Observed distribution of lateral groundwater gradients in relation to Gowanus Canal indicates that local groundwater flows toward and discharges to the canal.
- Strong sinusoidal, oscillating, potentiometric fluctuations in the shallow monitoring wells indicate that the shallow water-bearing zone maintains a strong hydraulic connection with Gowanus Canal.
- The direction of vertical gradients displayed in monitoring well clusters adjacent to Gowanus Canal appeared invariably upward, the expected direction of flow in a location where groundwater discharges to a surface water body.

- With only one exception, the direction of vertical gradients in monitoring well clusters located 150 feet from the canal were downward, typical of the direction of groundwater flow in an upland, recharge area.
- The maximum tidal fluctuation in Gowanus Canal ranged between 4.2 and 4.3 feet along its full length, extending from Gowanus Bay to 8,000 feet inland. Tidal fluctuations within the canal exhibited no evidence of attenuation with distance from the bay.
- Potentiometric fluctuations attributable to tidal oscillations (changes in groundwater elevations due to tidal influences) ranged up to a maximum of 3.75 feet at MW-3S, located within 13 feet of the canal. Conversely, hydrographs from several shallow monitoring wells located farther than 150 feet from the canal displayed no tidal influence.
- As is typical in unconfined aquifer systems, sinusoidal potentiometric oscillations (i.e., regularly spaced changes in groundwater levels due to tidal influences) attenuated to less than 0.1 feet at distances greater than 300 feet from Gowanus Canal in the shallow monitoring wells.
- All of the intermediate monitoring wells exhibited sinusoidal oscillations typifying tidal influences. Potentiometric fluctuations ranged to greater than 3.0 feet in wells adjacent to Gowanus Canal.
- Distance from Gowanus Bay also appeared to influence the magnitude of potentiometric fluctuations in the intermediate wells. Most of the intermediate wells screen sediments below the base of Gowanus Canal. Thus, loading/unloading of the tidal wedge promoted a potentiometric response, rather than direct infiltration of surface water into the intermediate water-bearing unit.
- By the use of graphical methods to predict attenuation of tidal fluctuations in the intermediate wells, sinusoidal potentiometric oscillations attenuated to less than 0.1 feet at distances greater than 500 feet from Gowanus Canal.

3.7 Water Chemistry Evaluation

The interaction of surface water and groundwater adjacent to the Gowanus Canal was characterized by examining water quality data collected from shallow monitoring wells, intermediate monitoring wells, and surface water locations in the canal. Comparison of geochemical signatures in water and analytical results for specific constituents support characterizing the contribution of groundwater to a surface water body. A summary of the results of the groundwater–surface water evaluation is presented below, with the full analysis and supporting detail provided in Appendix F.

3.7.1 Gowanus Canal Surface Water Chemistry

- The pH of canal water ranged from mildly acidic (6.2) to mildly alkaline (7.9). Sea and estuarine waters like Gowanus Bay exhibit relatively alkaline values, from 7.9 to 8.2 (Hem, 1985). Thus, appearance of acidic pH values in the canal water may reflect areas influenced by inflow of groundwater to the canal.

- Most DO measurements in the canal ranged between 2 and 5 mg/L, which are relatively low concentrations for surface water.
- Canal water (cation/anion) chemistry closely matched representative sea water samples (Hem, 1985), suggesting that tidal incursion from the bay exceeds groundwater contributions to the canal.
- Total dissolved solids (TDS) concentrations in Gowanus Canal exhibited no systematic decline with distance from Gowanus Bay. The absence of a declining trend proceeding upgradient (inland) implies a minimal contribution of groundwater to the canal as base flow.
- Elevated TOC concentrations appear in soft sediment lining the canal and in groundwater samples (TOC > 10 mg/L) from proximal, shallow monitoring wells. In these locations, elevated TOC concentrations were also encountered in surface water samples from Gowanus Canal. TOC is typically absent from representative sea and estuarine water samples.

3.7.2 Groundwater Chemistry in Monitoring Wells

Groundwater Chemistry in Shallow Monitoring Wells

Shallow monitoring wells included in the water quality study are screened in saturated materials in the fill and/or alluvial/marsh deposits.

- The pH of groundwater from the shallow monitoring wells ranged nearly two units from 6.5 to 8.3, with an average of 6.7.
- None of the samples exhibited TDS concentrations equaling those in the freshwater range (TDS results were greater than 500 mg/L, which is the threshold for freshwater).
- In well pairs adjacent to the canal and in the uplands, TDS concentrations consistently declined with distance from the canal. Although factors such as road deicing and saline misting of seawater onto the Brooklyn peninsula can increase shallow groundwater salinity, the narrow distribution of elevated TDS concentrations adjacent to Gowanus Canal suggests infiltration from the canal controls water quality in the shallow monitoring wells.
- Major cation and anion composition displays several different water types in the shallow water-bearing zone, including sodium chloride, sodium bicarbonate, and calcium bicarbonate types. Sodium chloride water can originate from the Gowanus Canal, whereas calcium and sodium bicarbonate suggest infiltration of precipitation and freshwater recharge.
- DO concentrations fall in the anoxic range (DO less than 1.1 mg/L; Stuyfzand, 1994), which is typical of an urban environment where oxygen-rich recharge from precipitation is reduced by impervious cover.
- TOC concentrations at individual wells appeared to be consistent with DOC concentrations, indicating equilibrium with materials in the subsurface. Areas showing elevated TOC concentrations coincided with elevated concentrations of VOCs and SVOCs at MW-9S, MW-16S, and MW-18S.

Groundwater Chemistry in Intermediate Monitoring Wells

Most intermediate wells are screened in the glacial deposits, although screens from several wells spanned both the alluvial and glacial deposits.

- Regarding most constituents, the intermediate monitoring wells as a group exhibited more uniform water chemistry than the shallow wells.
- The pH of water sampled at the intermediate monitoring wells ranged from 6.3 to 8.0 and averaged 7.1.
- With three exceptions, TDS concentrations in the intermediate monitoring wells fell in the brackish classification. With two exceptions, TDS concentrations progressively declined with distance from Gowanus Bay.
- As with the shallow wells, TDS concentrations decreased with distance from Gowanus Canal. With the exception of two wells, all water samples displayed a sodium-chloride water type. The remaining two wells, located at the northeastern end of the canal, exhibited mixed cation-bicarbonate water types, along with lower TDS concentrations, which is suggestive of mixing with groundwater recharge.
- Average DO concentrations measured in the intermediate wells appeared in the anoxic range, as with the shallow wells.
- With two exceptions, TOC concentrations in the intermediate wells were less than 3.0 mg/L.

3.7.3 Interactions Between Shallow and Intermediate Zones

- Differences in water temperatures and TDS concentrations indicate that the shallow fill/alluvium and intermediate glacial deposits represent separate hydrologic systems at most locations.

3.7.4 Interactions Between Groundwater and Surface Water

- Based on differences in water temperatures and TDS concentrations between the intermediate monitoring wells (glacial deposits) and the shallow wells (fill/alluvium), along with the observed decline in TDS concentrations with distance from the canal, it is concluded that Gowanus Canal water influences water quality in the shallow fill/alluvium to a greater degree than water in the intermediate glacial deposits does.
- Sodium-chloride water predominates in both the shallow alluvium and intermediate glacial deposits adjacent to the canal, which indicates that recharge from the canal is taking place.
- Moving away from the canal, groundwater chemistry in the shallow alluvium beneath the uplands exhibits calcium-bicarbonate chemistry, which is more typical of water recharged by precipitation (e.g., rain).
- Geochemical water characteristics exhibit differing patterns with well depth and distance from the Gowanus Bay and with distance from the canal. Groundwater at wells adjacent to the canal in the shallow alluvium/fill exhibits sodium-chloride concentrations, that suggest recharge of groundwater from the canal. By comparison,

groundwater in the glacial deposits and away from Gowanus Bay consists of mixed cation-bicarbonates and lower TDS concentrations, suggesting fresh water recharge.

- Three of the monitoring well/canal stations were used for both the tidal and water quality study. In all three locations, canal water elevations exceeded groundwater potentiometric elevations in the shallow fill/alluvium at high tide. Canal elevations exceeded potentiometric elevations in the glacial deposits intermittently during high tide at two of the three locations creating hydraulic conditions for surface water to flow into shallow aquifer sediments.

- The uniformity of water chemistry along the length of Gowanus Canal in regard to TDS and cation/anion type shows little evidence of dilution by inflow of groundwater. The water quality in Gowanus Canal appears to impose a strong imprint on the water chemistry of the shallow groundwater and at specific locations in the intermediate groundwater located near the canal. Other than TOC, water chemistry in the canal exhibits minimal evidence of a groundwater contribution although the volumetric fluctuation in canal water volume makes measurement of comparatively lower volume contributions from groundwater difficult to measure.

3.8 Overview of Groundwater–Surface Water Interaction

Combined results of the synoptic, tidal and groundwater-surface water chemistry studies provide multiple lines of evidence to characterize the hydraulic relationships between local groundwater and the Gowanus Canal. Potentiometric surfaces developed from the synoptic (instantaneous point in time) measurement events suggests that, at the water table, groundwater flows toward Gowanus Canal. Potentiometric data from intermediate wells depicts a more-complex pattern, with groundwater generally flowing upward toward the canal, which is typical of a discharge area.

Data from the 5-day tidal evaluation portrays a more temporally controlled flow pattern than the synoptic study. At specific locations, canal elevations consistently exceeded groundwater elevations in the shallow fill/alluvium at high tide, creating hydraulic conditions for surface water to flow into shallow aquifer sediments. These conditions, although apparent, appeared more intermittent over the tidal study period than in wells screened in the intermediate glacial deposits.

- Gowanus Canal exhibits a uniform chemical signature (TDS, temperature, cation/anions, etc.) along its entire length, suggesting minimal influence by groundwater flow contribution. Furthermore, water chemistry in monitoring wells near the canal exhibit chemical signatures similar to the canal’s, suggesting infiltration of surface water into the fill/alluvium. Only the spatial distribution of pH in surface water samples along the canal’s length and a concentration gradient of TOC toward the canal imply that the contribution of groundwater locally affects canal water chemistry. The volumetric fluctuation in canal water volume, however, makes measurement of comparatively lower volume contributions from groundwater difficult to measure.

Given its saline nature, the ionic strength of surface water from the Gowanus Canal ranges several orders of magnitude greater than most groundwater in the fill/alluvium and glacial deposits. Thus, a large contribution of groundwater is necessary to significantly influence the chemistry of water in the canal. However, given its saline nature, even short periods of reversed flow from the canal into fill/alluvium and glacial deposits could alter groundwater signatures.

Although evaluation of data from the synoptic and tidal studies produced lateral and vertical gradients supporting the flow of groundwater to the canal, temporal exceptions to this flow pattern emerged. Hydraulic data from these studies generally support the similarity in canal and groundwater chemistries proximal to Gowanus Canal. The three studies suggest that local groundwater from the fill/alluvium and glacial deposits flows generally toward the Gowanus Canal, although the flow pattern appears to reverse locally and with temporal regularity. Groundwater flow volumes into Gowanus Canal appear insufficient to alter its basic chemical signature. Conversely, because of its saline nature, infiltration of canal water even for brief diurnal periods influences groundwater chemistry in the fill/alluvium.

SECTION 4

Nature and Extent of Contamination

This section summarizes the analytical results for the samples collected for the Gowanus Canal RI and evaluates the nature and extent of the contamination. It is organized as follows:

- Overview of the quality of the RI data
- Description of the standards and criteria (collectively referred to as screening values) used to evaluate the sampling results
- Summary of the results for the media that were sampled, including sediment, surface water, tissue, outfall discharges (CSOs and other pipe outfalls), air, soil, and groundwater

Because of the large quantity of data collected (over 1300 samples), the tables in this section provide only statistical summaries of the analytical results for constituents detected in each media. The statistical summaries indicate the total number of samples, how frequently each constituent was detected, the range of concentrations, and the average concentrations. The tables also provide the ecological and human health screening values that were used to assess the magnitude of contamination, and the number of samples with concentrations higher than the screening values. The standards and criteria used to evaluate the results are discussed further in Section 4.2.

Complete analytical results are provided in Appendix I. Two sets of tables are provided in the appendix: one set with all results for all samples (including detection limits for non-detected results), and another set showing only detected concentrations. The tables with only detected concentrations compare the results to the screening values identified for each medium and identify results that are higher than these values. The purpose of these comparisons is to assess the magnitude of the measured chemical concentrations; however, the specific chemicals that are likely to be causing unacceptable ecological and human health risks are identified in the ERA and HHRA.

4.1 Data Quality Review

A data quality evaluation was performed on all analytical data (primary, secondary, definitive, screening) for this project. All samples were collected and analyzed according to Phase II Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) and Phase III UFP-QAPP. Data underwent various levels of verification and validation as specified in the respective UFP-QAPPs (Worksheets 34, 35, and 36).

- Primary definitive data, which are used in the risk assessments and to determine the nature and extent of contamination, underwent Level IV validation via the EPA CLP program using Region II Standard Operating Procedures (SOPs). This was done on all data generated via the EPA CLP program. This is the most in-depth level of validation.

- Air data underwent internal Level III validation against the limits specified in the Phase III UFP-QAPP. If an exceedance was noted, the data were qualified, as applicable, using the qualifiers specified in the Region II SOPs. Level III validation includes all laboratory QC forms, including those for calibration.
- Primary screening data, such as wet chemistry analyses, underwent Level III validation against the limits specified in the Phase III UFP-QAPP. If an exceedance was noted, the data were qualified, as applicable, using the qualifiers specified in the Region II SOPs.
- Primary screening data, such as AVS/SEM and grain size distribution, underwent Level II validation (laboratory QC forms only). If an exceedance was noted, the data were qualified, as applicable, using the qualifiers specified in the Region II SOPs. Level II validation includes all laboratory QC forms provided.
- Primary data to support waste characterization and disposal underwent a cursory review and check for completeness.
- Secondary data (definitive and screening) were validated by the contractor that generated the data as specified in their respective UFP-QAPP. These data were used considering the restrictions placed on secondary data in the Phase III UFP-QAPP. They were not used for estimating the potential human health and ecological risks associated with the canal. Rather, they were used for evaluating general environmental conditions. As above, secondary data were included in the data quality evaluation.

All reported data are accompanied by their qualifiers, if applicable. Appendix H provides the complete data quality evaluation. All data are available for use by the project team as qualified with the exception of rejected data. Rejected data are not usable as detects or non-detects for any purpose. Rejected data accounted for 2.20 percent of this data set, and thus 97.80 percent of data are available for use, qualified as applicable. This outcome exceeds the 90 percent completeness goal for this project.

Table 4-1 provides the definitions and general distribution of data qualifiers including their general effect on the data use.

4.2 Evaluation Criteria

Chemical concentrations detected in various media were compared with federal or state standards and criteria or literature-based values to help define the nature and extent of contamination. The sources of these standards and criteria and values (collectively referred to as screening values in this report) are listed in Table 4-2. Because numerous sources were used to obtain standards and criteria for as many constituents as possible, a letter was assigned to each source. These letters are used in the data tables in Appendix I and in the statistical summary tables in this section to identify chemicals with detected concentrations that are higher than the standards and criteria.

Table 4-2 also describes how the standards and criteria were applied to each medium sampled; specifically, a prioritization order was designated for media with multiple standards and criteria. Table 4-3 summarizes the letters that represent the various standards and criteria applied to each medium. The complete list of standards and criteria is provided in Appendix C.

4.3 Sediment

The nature and extent of contamination in Gowanus Canal sediments, including the occurrence and distribution of NAPL and sediment-associated contaminants in surface and subsurface sediments, are described below.

4.3.1 Surface Sediment

Sampling results for surface sediment (0-to-6-inch depth interval) are presented below. Complete analytical results for all sediment samples are provided in Appendix I.

Surface sediment data for the 27 locations within Gowanus Canal were evaluated by:

- Calculating summary statistics for detected parameters
- Comparing results with screening values to assess the relative magnitude of contamination, and
- Identifying constituents that were present in concentrations significantly higher in the canal than in the 10 Gowanus Bay and Upper New York Bay reference locations.

Concentrations for a subset of constituents were also mapped to illustrate spatial distribution. Although analytical results are compared with screening levels in this section, the constituents of potential concern (COPCs) that may be causing unacceptable risk are identified in the ERA and HHRA (Appendixes K and L, respectively).

Statistical summaries for constituents detected in the canal and the reference area surface sediment samples are provided in Tables 4-4a and 4-4b, respectively; screening values are also included in Table 4-4a. The complete analytical results for surface sediment samples are provided in Appendix I, Tables I-1a through I-6a, and a sample-by-sample comparison with ecological and human health screening values is provided in Tables I-1b through I-6b. The results are discussed in general terms by parameter class below. Results of AVS/SEM analyses are included in the BERA.

VOCs

Eighteen VOCs were detected in surface sediment samples from the canal. Three VOCs exceeded screening values, as follows:

- Ethylbenzene concentrations were higher than the ecological screening value in four samples, with a maximum concentration of 3,600 µg/kg at location 315, at the mouth of the 7th Street turning basin (Figure 2-3a).
- Concentrations of m,p-xylenes and o-xylene were higher than the ecological screening value in the sample from location 315, at 810 and 1200 µg/kg, respectively.

None of the concentrations were higher than human health screening values.

The results from the reference area sediments are summarized in Table 4-4b; only three VOCs were detected, with a maximum concentration of 41 µg/kg for acetone.

SVOCs

Twenty three individual SVOCs were detected in surface sediment samples from the canal. PAHs were the most frequently detected SVOCs.

- PAHs were detected in all samples at higher concentrations than any other SVOC; the only other detected parameters were biphenyl, carbazole, dibenzofuran, and phthalates.
- Total PAH[1] concentrations are higher than the ecological screening value of 4,022 µg/kg in all samples, and in most cases by a large magnitude.
- The range of total PAH concentrations was 10,900 to 8,000,000 µg/kg (0.8 percent), with a mean value of 527,000 µg/kg (0.05 percent).
- Total PAHs were detected in all samples from the reference area; however, the concentrations were markedly lower, ranging from 1,030 to 14,400 µg/kg, with a mean of 5,790 µg/kg.

Figures 4-1a through 4-1d illustrate the concentrations of total PAHs in the canal and reference area surface sediments.

- Total PAH concentrations in the upper reach of the canal were variable, ranging from 10,890 µg/kg at location 301, near the head of the canal, to 142,880 µg/kg at location 308A, at the north end of the canoe launch near 2nd Street (Figure 4-1a).
- Total PAH concentrations in the middle canal (Figure 4-1b) are uniformly higher, particularly within and downstream of the 6th Street turning basin to immediately downstream of the Gowanus Expressway, with total PAH concentrations ranging from 15,830 µg/kg at location 313 to 8,001,000 µg/kg (0.8 percent), the highest total PAH concentration observed, at location 315 at the mouth of the 7th Street turning basin.
- Below the Gowanus Expressway, total PAH concentrations in surface sediment sharply drop, ranging from 16,350 to 83,220 µg/kg (Figure 4-1c).
- Total PAH concentrations were variable in the reference area sediment, but were lower than concentrations observed within the canal (Figure 4-1d). Total PAH concentrations at reference locations ranged from 1,030 to 14,410 µg/kg.

Pesticides

Seven pesticides were detected in surface sediment samples from the canal. Pesticides were detected infrequently (i.e., between one and five detections in 27 total samples).

- Detected pesticides were alpha-chlordane, gamma-chlordane, the DDT isomers,[2] beta endosulfan, endosulfan sulfate, and methoxychlor.

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[1] Total PAHs were calculated by summing the detected values of the 16 priority pollutant PAHs; if any PAH constituent had a rejected, or "R"-flagged, result, a total PAH value was not calculated for the sample.

[2] DDT isomers include p,p'-DDD, p,p'-DDE, and p,p'-DDT. Total DDT concentrations were calculated by summing the detected values of the DDT isomers; if any individual constituent had a rejected, or "R"-flagged, result, a total DDT value was not calculated for the sample.

- The detected pesticide concentrations were all higher than ecological screening values, with a maximum concentration of 1,100 µg/kg for total DDT at location 315 at the mouth of the 7th Street turning basin (Figure 2-3b).
- Pesticides were not detected in any of the reference area samples.

PCBs

Total PCBs, calculated as the sum of detected Aroclors, were detected at 10 of the 27 sample locations within the canal, with the maximum detected concentration of 3,400 µg/kg found at location 314 at the head of the 6th Street basin (Figure 2-3b). Aroclors 1016 and 1260 were the most frequently detected PCBs. Total PCB concentrations were higher than the ecological and human health screening values at all 10 locations where PCBs were detected. PCB Aroclors were not detected in any of the reference area samples.

Figures 4-2a through 4-2d show the concentrations of total PCBs within the canal and reference area surface sediments. Although total PCBs were not frequently detected, they are a concern because of their tendency to bioaccumulate in the food chain. PCBs were primarily detected in surface sediments collected from the middle section of the canal (Figure 4-2b).

- The highest concentrations were observed within or near the 6th Street and 7th Street turning basins, at locations 314 (3,400 µg/kg), 315 (2,400 µg/kg), and 316 (2,200 µg/kg).
- Downstream of the 7th Street turning basin, total PCB concentrations are lower.
- PCBs were detected only at location 308A in the upper reach of the canal (Figure 4-2a) and at locations 320 and 325 downstream of the Gowanus Expressway (Figure 4-2c).
- PCBs were not detected in reference area sediments (Figure 4-2d).

Data for PCB congeners that were used in support of the human health and ecological risk assessments are provided in Appendix I, Table I-5.

Metals and Cyanide

Twenty one metals and cyanide were detected in surface sediments samples.

- Cadmium, copper, lead, and mercury concentrations were higher than the ecological screening values at all 27 locations sampled.
- Other metals with concentrations higher than the ecological screening value were arsenic, barium, chromium, manganese, nickel, silver and zinc.
- Concentrations of a different set of metals were higher than the human health screening values – aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, and vanadium.

Location 308A, at the north end of the canoe launch, had the greatest number of maximum detected metals concentrations, including cadmium (20.2 mg/kg), copper (790 mg/kg) and lead (4,220 mg/kg) (Figure 2-3a). Metals were detected in all reference area samples but were typically observed at concentrations lower than those in the canal.

Figures 4-3a through 4-3d illustrate the concentrations of lead within the canal and reference area surface sediments. Lead was selected for mapping because it had the highest concentrations relative to screening values and reference concentrations. The lead concentrations in surface sediment in the upper canal ranged from 184 mg/kg at location 309 to 4,220 mg/kg at location 308A, at the north end of the canoe launch (Figure 4-3a). Lead concentrations in the middle canal ranged from 355 mg/kg at location 313 to 1,600 mg/kg at location 315 (Figures 4-3b). Lead concentrations sharply decreased below the Gowanus Expressway and ranged from 146 to 360 mg/kg (Figure 4-3c). Lead concentrations in reference area surface sediments were lower than those observed within the canal (Figure 4-3d). Lead concentrations at the reference locations ranged from 25.5 to 244 mg/kg.

Comparison to Reference

Analytical results for Gowanus Canal surface sediment samples were compared with reference sample results using a test that compared the central tendencies of canal and reference area data sets. The test of central tendency can determine with statistical confidence whether the canal and reference area populations, on average, differ from one another (USEPA, 2006). Either the Wilcoxon rank-sum (WRS) test or Gehan's test was applied to determine with 95 percent confidence whether contaminant concentrations in the canal were greater than those at the reference locations. The WRS test was used when the detection frequency in each data set was at least 60 percent; otherwise, Gehan's test was used. Statistical comparisons were not performed when fewer than 10 results were available in either the canal or reference area data sets.

The results of the statistical comparison of canal and reference area surface sediment samples are provided in Table 4-5. The comparisons indicated that there were no significant differences between the VOC and pesticide concentrations in canal and reference area surface sediments. The concentrations of individual PAH compounds, total PAHs, bis(2-ethylhexyl)phthalate, Aroclor 1260, total PCBs, barium, cadmium, chromium, copper, lead, mercury, nickel, and silver in surface sediment were significantly greater in the canal than in the reference area.

4.3.2 Subsurface Sediment

Sampling results for subsurface sediment (soft and native sediments below a depth of 6 inches) are presented below. Complete analytical results for all sediment samples are provided in Appendix I. Subsurface sediment data within Gowanus Canal were evaluated in the same manner as surface sediments.

Previous investigations of the Gowanus Canal established that soft sediments were contaminated throughout the study area (USACE, 2004, 2006; GEI, 2007). Therefore, the specific objectives of the sediment coring effort performed for this RI were to confirm the chemical concentrations in soft sediment, establish continuous profiles of chemical concentrations at a subset of coring locations, and comprehensively characterize chemical concentrations in native sediment to delineate the vertical extent of contamination within the practical limits of the potential remedy. The most comprehensive previous evaluation of the canal sediments was the RI performed by National Grid between 2005 and 2007 (GEI, 2007); soft-sediment data from the National Grid investigation along with new soft sediment data collected by USEPA from continuous cores at specific locations are used herein to characterize the overall nature and extent of contamination in soft sediment. Only the

USEPA data set was used to characterize the native sediment because the USEPA sample design focused on a systematic, continuous characterization of native sediment to a target depth of 6 feet below the contact between soft and native sediments.

Soft sediment and native sediment data collected at the sediment coring locations in the Gowanus Canal were evaluated by (1) calculating summary statistics for detected parameters, (2) comparing results with ecological and human health screening values, and (3) comparing chemical concentrations in soft and native sediment. Even though the subsurface sediments are buried and not accessible to humans or wildlife, the comparison to screening values was performed to assess the magnitude of contaminant concentrations. In addition, vertical profiles of total PAH, total PCB, and lead concentrations were mapped at locations with continuous core profiles. The scale for each core profile is based on the range of concentrations measured in that core. The full set of profiles is provided in Appendix N, and a subset of core profiles is presented below. Total PAH concentrations in sediment at the vertical limit of the investigation also were evaluated and longitudinal profiles (i.e., along the length of the canal) for key constituents were prepared.

Statistical summaries for chemicals detected in soft sediment and native sediment samples are provided in Tables 4-6 and 4-7a. The analytical data results for the soft sediment samples are provided in Tables I-8a through I-12a; comparisons of individual sample results to ecological and human health screening values are presented in Tables I-8b through I-12b. The complete analytical and screening results for the native sediment samples are provided in Tables I-14a through I-18a and I-14b through I-18b, respectively. Selected whole-core composite samples were collected for TCLP, reactivity, ignitibility, and corrosivity testing. These results are presented in Table I-20 and are not discussed in the RI. These data will be used in the FS to determine appropriate material-handling technologies and to guide potential additional testing for treatability studies or disposal characterization.

Overall, a wide variety of VOCs, SVOCs, pesticides, PCBs and metals were detected in the subsurface sediments. Generally, chemical concentrations were higher in subsurface soft sediment than in surface sediment, and concentrations of all constituents except VOCs and PAHs were substantially lower in native sediment than in the soft sediment.

Non-Aqueous Phase Liquid

NAPL is free-phase hydrocarbon product that was visually evident in sediment cores. NAPL was commonly observed in sediment cores collected from the canal and in soil borings advanced at upland locations adjacent to the canal. NAPL is described in this report on the basis of field observations using the following three categories: (1) no visual evidence of NAPL; (2) presence of NAPL coatings, stains, sheens, or blebs; and (3) NAPL saturation (i.e., pore spaces completely filled with NAPL). NAPL samples were not collected and submitted to a laboratory for analysis; NAPL consists of pure organic products such as PAHs, benzene, toluene, ethylbenzene, and xylenes (BTEX compounds).

Selected photographs of sediment cores showing soft sediment, native sediment, and examples of NAPL-saturated sediment are presented in Figure 4-4a through 4-4c. The locations depicted are representative of the sediments observed in the canal.

Maps showing the distribution of NAPL in soft sediment and adjacent upland soils above -20 feet NAVD88 (the approximate elevation of the bottom of the soft sediment) are shown in Figures 4-5a through 4-5c. The distribution of NAPL in the native Gowanus Creek sediments and upland soils below -20 feet NAVD is shown in Figures 4-5d through 4-5f. Cross-sections illustrating the vertical distribution of NAPL in soft and native sediments along the length of the canal were also prepared. Cross-section locations are shown in Figure 4-6a, and the cross-sections are presented in Figures 4-6b through 4-6d. These maps and cross-sections are based on visual observations recorded on field logs. Note that soft sediment thicknesses shown on the cross-sections were corrected for less than 100 percent core recovery as described in Section 3.3. At locations where no soft sediment was recovered, the inferred soft sediment thickness is shown as a single vertical line.

NAPL is less common and typically present in smaller amounts in soft sediment than in native sediments. As shown in Figures 4-5a through 4-5c, NAPL is most commonly observed in the soft sediment north of the Hamilton Avenue bridge, particularly near the head of the canal and in the middle canal adjacent to the Carroll Gardens/Public Place and Metropolitan former MGP sites. NAPL was observed in soft sediment at only five locations south of Hamilton Avenue. In soft sediment, NAPL occurred primarily as coatings, stains, sheens, or blebs; NAPL-saturated soft sediment was primarily observed at sampling locations near the Carroll Gardens/Public Place former MGP site. NAPL coatings, stains, and sheens were often observed in shallow soils in borings adjacent to the canal near the three former MGP sites. Soils were NAPL-saturated in four shallow soil borings: two near the Fulton former MGP site and two between the Metropolitan and Carroll Gardens/Public Place former MGP sites.

As shown in Figures 4-5d through 4-5f, NAPL was present in native sediment at nearly all of the sampling locations where it was recovered. The degree of NAPL contamination in the native sediments is much greater than in the soft sediments, as evidenced by the presence of NAPL-saturated native sediments throughout most of the canal north of Hamilton Avenue. NAPL impacts in native sediment were less severe south of Hamilton Avenue, with sediments at eight locations exhibiting coatings, staining, sheens, or blebs and no NAPL saturation.

As shown in Figures 4-6b through 4-6d, the native sediments at the bottoms of the cores at most locations in the upper and middle canal were affected by NAPL. The greatest thicknesses of NAPL-contaminated native sediment were recovered between Carroll Street and 3rd Street (Figure 4-6b), and between 5th Street and Huntington Street (Figure 4-6c). Up to 16 feet of NAPL-saturated native sediment were recovered within this area. Below Hamilton Avenue, NAPL occurrence in the native sediments is markedly lower (Figure 4-6d).

VOCs

Seven VOCs were detected in more than half of the soft-sediment samples (Table 4-6), and five were detected in more than half of the native samples[3] (Table 4-7a). The most frequently detected VOCs in both soft and native sediment were benzene, toluene, ethylbenzene, and xylenes (BTEX compounds). These chemicals exhibit the highest concentrations and were frequently higher than ecological and human health screening values. The highest concentration of total BTEX was 3,810,000 µg/kg (0.38 percent) in soft sediment was

[3] 1,4-dioxane was not included in this count because results were available for only three samples.

observed at location 51A near the Carroll Gardens/Public Place former MGP site (Figure 2-1b), which was sampled in 2005 by National Grid. The highest concentration of total BTEX in native sediment was 2,700,000 µg/kg (0.27 percent) at location 114, which is in the same area. Mean concentrations of BTEX compounds in soft and native sediments were similar.

SVOCs

Over 30 SVOCs were detected in soft and native sediments. PAHs were the most frequently detected parameters and were present at the highest concentrations (Tables 4-6 and 4-7a). The detection frequencies of PAHs are similar in soft and native sediments, and the concentrations frequently were greater than both the ecological and human health screening values. Total PAH concentrations in soft sediment ranged from 120 to 45,000,000 µg/kg (4.5 percent), with an average concentration of 3,490,000 µg/kg (0.35 percent). The maximum total PAH concentration in soft sediment was observed at location 51A. Total PAH concentrations in the native sediment ranged from 8.40 to 47,500,000 µg/kg (4.8 percent), with an average concentration of 2,920,000 µg/kg (0.29 percent). The maximum total PAH concentration in native sediment is observed at location 115 near the Carroll Gardens/Public Place former MGP site.

Figures 4-7a through 4-7c illustrate the vertical distribution of total PAHs at selected core locations in the upper, middle, and lower canal, respectively (a complete set of profiles is provided in Appendix N). The highest total PAH concentrations are observed at depth. In some cases, the peak concentration occurs in the soft sediment, often near the contact with the native sediment. At locations 146, ERT4-3, 108, 116, and 122, the highest total PAH concentrations are observed in the native sediments. In some instances such as location 107, the total PAH concentrations decrease in the native sediment.

Pesticides

Twenty pesticides were detected in both soft and native sediments. The statistical summaries presented in Tables 4-6 and 4-7a indicate that the maximum and mean concentrations were much lower in native sediment than in soft sediment. Where detected, pesticides were typically higher than ecological screening values. Concentrations greater than the human health screening value were generally less frequent. Concentrations of p,p′-DDD most frequently exceeded the ecological screening value of 1.22 µg/kg. The maximum concentration of p,p′-DDD in soft and native sediment was 1,900 and 470 µg/kg, respectively.

PCBs

Five Aroclors were detected in both soft and native sediment. The most frequently detected Aroclors in soft sediment were Aroclors 1242, 1254, and 1260 (Table 4-6). The statistical summaries in Tables 4-6 and 4-7a clearly show that the detection frequency and average concentration of PCBs in native sediment are much lower than in soft sediment. Total PCBs were detected in approximately 5 percent of the of native sediment samples and in 85 percent of the soft sediment samples. Total PCB concentrations in soft sediment ranged from 38 to 50,700 µg/kg, with a mean of 3,470 µg/kg. The maximum detection was at location 117, in the 7th Street turning basin (Figure 2-1b). In the native sediments, total PCBs ranged from 39 to 2,610 µg/kg, with a mean of 26.1 µg/kg. The maximum observed total PCB concentration in native sediment is at location ERT2-1, in the upper reach of the canal

(Figure 2-1a). Total PCBs in soft sediment were higher than both the ecological and human health screening values in over 200 samples. In the native sediment, total PCBs were higher than the ecological screening value in 19 samples and the human health screening value in 11 samples.

Figures 4-8a through 4-8c illustrate the vertical distribution of total PCBs at selected core locations in the upper, middle, and lower canal, respectively. Total PCB concentrations are highest in the soft sediment and consistently drop to lower concentrations in the native sediment. The shapes of the profiles vary among the different cores; however, in most cases, a well-defined peak of maximum total PCB concentration is observed in the subsurface soft sediment (e.g., 111, 107, 117, 116, 113, 140, and 133).

Metals and Cyanide

Over twenty metals and total cyanide were detected in both soft and native sediment. The statistical summaries (Tables 4-6 and 4-7a) indicate that overall concentrations are notably higher in soft sediment than in native sediment. Concentrations of 16 constituents in the soft sediment were greater than the ecological and human health screening values. Copper concentrations in soft sediment ranged from 6 to 1,610 mg/kg, with a mean of 388 mg/kg, and lead concentrations ranged from 5.2 to 2,880 mg/kg, with a mean of 770 mg/kg. In the native sediment, 16 constituents had concentrations higher than the ecological and human health screening values. Copper concentrations in native sediment ranged from 2.4 to 483 mg/kg, with a mean of 12.4 mg/kg, and lead concentrations ranged from 2.0 to 1,360 mg/kg, with a mean of 14.4 mg/kg.

Selected core profiles for lead are shown in Figures 4-9a through 4-9c. As with total PCBs, lead exhibited the highest concentrations in the soft sediment and consistently dropped to much lower concentrations in the native sediment.

Vertical Limit of Investigation

The purpose of the sediment core investigation was to delineate the degree of vertical contamination within the practical limits of a potential remedy. Native sediment samples were collected at depth intervals of 0-2 feet, 2-4 feet, and 4-6 feet below the contact in every core, except where native sediment was not recovered. Table 4-7b summarizes the average total PAH concentration in each of these depth horizons on each of the sampling transects along the length of the canal. Average total PAH concentrations in the native sediment were greater than 100,000 µg/kg in the 2-4 foot and/or 4-6 foot depth intervals in most areas of the canal with the following exceptions (core locations are shown in Figures 2-1a through 2-1c):

- The northernmost transect at the head of the canal (transect ERT-1, core locations ERT1-1, 1-2, and 1-3)
- Immediately south of the Gowanus Expressway (transect W, core locations 67B, 68A, and 69C)
- In the southern part of the Gowanus Channel (transect Y, core locations 73E, 74E, and 75C and southward).
- The 4th Street turning basin.

Figures 4-10a through 4-10c present the total PAH concentrations measured in the deepest sample from each core where native sediment was recovered, along with the elevation of the bottom of the sediment core. In the upper canal, most sampling locations had greater than 10,000 µg/kg total PAHs in the deepest sample collected, with exceptions noted at the head of the canal, at one location between Carroll Street and 3rd Street, and within the 4th Street turning basin. In the middle section of the canal (between approximately 4th Street and the Gowanus Expressway), the total PAH concentrations at the bottom of the sediment cores were greater than 1,000,000 µg/kg (0.1 percent) at most sampling locations and were typically greater than 3,000,000 µg/kg (0.3 percent). The coring locations at the eastern end of the 6th Street turning basin and within the 7th Street turning basin had much lower total PAH concentrations in the deepest sample, with concentrations between 20 and 10,000 µg/kg. The concentrations at the bottom of the sediment cores were notably lower immediately upstream of and downstream of the Gowanus Expressway, as shown in Figure 4-10c.

Longitudinal Profiles

Total BTEX and total PAH concentrations in soft and native sediment are shown in Figures 4-11a and 4-11b, respectively. The major trends that can be seen along the canal are as follows:

- Soft sediments with total PAH concentrations greater than 1 percent are generally found at the head of the canal near the Fulton former MGP site and the RH-034 outfall, immediately upstream of 3rd Street, and in the vicinity of the Carroll Gardens/Public Place and Metropolitan former MGP sites.
- Native sediments with total PAH concentrations greater than 1 percent are generally found in the reach between 3rd Street and the Gowanus Expressway. A greater number of native sediment samples have total PAH concentrations between 0.5 and 1 percent compared to soft sediment between the head of the canal and the Gowanus Expressway.
- The concentration distributions of total BTEX and total PAH in soft sediment are similar, as are the concentration distributions of these constituents in native sediment.

Longitudinal profiles of copper and lead in soft sediment along the length of the canal are provided in Figure 4-11c (copper and lead concentrations in native sediment were substantially lower). The major trends that can be seen along the canal are as follows:

- Copper concentrations vary along the length of the canal, with the highest concentrations found at the head of the canal, at outfall OH-007, in the 6th Street turning basin (shown as a short distance upstream of OH-007), and near the Carroll Gardens/Public Place former MGP site.
- Lead concentrations vary along the length of the canal, with the highest concentrations found at the head of the canal and at outfall RH-035.

Mercury and total PCB concentrations in soft sediment along the length of the canal are shown in Figure 4-11d (mercury and total PCB concentrations in native sediment were much lower). The major trends in the canal are as follows:

- Mercury concentrations are variable, with the highest concentrations found at the head of the canal (including a sample with 61.6 mg/kg mercury which is not shown on the plot).
- Total PCB concentrations are highest in the 7th Street turning basin (approximately 4000 feet from the head of the canal), at the RH-035 outfall, near the Carroll Gardens/Public Place former MGP site, near the Gowanus Expressway, and near south end of canal.

4.3.3 Summary

The evaluation of analytical results for the surface and subsurface sediment samples indicates the following:

- Visual evidence of NAPL is more pervasive in native sediments than in soft sediments, and in sediments north of the Gowanus Expressway than in sediments south of the expressway. Longitudinal profiles of total PAH and total BTEX concentrations in soft and native sediment correspond with these observations.
- Average concentrations of PAHs, PCBs, and eight metals (barium, cadmium, chromium, copper, lead, mercury, nickel and silver) in surface sediment are significantly higher in the canal than at the reference locations.
- Concentrations of a variety of chemicals exceed ecological and human health screening values in one or more sediment samples, as follows:

	Number of Constituents Exceeding Screening Values		
	Surface Sediment	Soft Sediment	Native Sediment
VOCs	3	10	10
SVOCs	21	30	24
Pesticides	6	17	14
PCBs	5	6	6
Metals and Cyanide	15	16	16

- Average chemical concentrations are higher in the subsurface soft sediment than in surface sediment:

Key Constituent	Ecological Screening Value	Surface Sediment Average Concentration	Soft Sediment Average Concentration
Total BTEX (µg/kg)	NA	364	188,000
Total PAHs (µg/kg)	4,022	527,000	3,490,000
Total DDT(µg/kg)	1.58	235	441
Total PCBs (µg/kg)	22.7	432	3,470
Copper (mg/kg)	34	226	388
Lead (mg/kg)	46.7	533	770
Mercury (mg/kg)	0.15	1.27	2.63

- Pesticides, PCBs, and metals were all frequently detected in the soft sediment but were infrequently detected and/or detected at lower concentrations in the native sediments; whereas total PAHs and BTEX constituents were frequently detected at high concentrations in both the soft and native sediment units:

Key Constituent	Ecological Screening Value	Soft Sediment		Native Sediment	
		Frequency of Detection (%)	Average Concentration	Frequency of Detection (%)	Average Concentration
Total BTEX (µg/kg)	NA	86.8	188,000	85.3	233,000
Total PAHs (µg/kg)	4,022	100	3,490,000	95.4	2,920,000
Total DDT(µg/kg)	1.58	88.7	441	62.6	46.6
Total PCBs (µg/kg)	22.7	84.8	3470	4.9	26.1
Copper (mg/kg)	34	100	388	99.5	12.4
Lead (mg/kg)	46.7	99.7	770	100	14.4
Mercury (mg/kg)	0.15	98.1	2.63	8.4	0.0947

- Chemical concentrations in soft sediment are variable within the canal north of the Gowanus Expressway and are notably higher than concentrations south of the Gowanus Expressway. Maximum concentrations of key constituents were found at the following locations:

Key Constituent	Ecological Screening Value	Surface Sediment		Soft Sediment	
		Maximum Concentration	Location	Maximum Concentration	Location
Total BTEX (µg/kg)	NA	5,669	315	3,810,000	GC-SED-51
Total PAHs (µg/kg)	4,022	8,000,000	315	45,000,000	GC-SED-51
Total DDT(µg/kg)	1.58	1,100	315	3,600	GC-SED-85B
Total PCBs (µg/kg)	22.7	3,400	314	50,700	GC-SD-117
Copper (mg/kg)	34	790	308A	1,610	GC-SD-112
Lead (mg/kg)	46.7	4,220	308A	2,880	ERT1-2
Mercury (mg/kg)	0.15	2.30	313	61.6	ERT1-3

Locations 315 and GC-SED-51 are in the main channel adjacent to the Carroll Gardens/Public Place former MGP site.
Location 314 is at the head of the 6th Street turning basin, and location GC-SED-85B is near the mouth of the basin.
Location 308A is at the north end of the canoe launch at the end of 2nd Street.
Location GC-SED-117 is in the 7th Street turning basin, and location GC-SED-112 is adjacent to the RH-035 outfall at the end of Bond Street.
Locations ERT1-2 and ERT1-3 are at the head of the canal.

- In most areas north of the Gowanus Expressway, NAPL and high-PAH concentrations were found in sediment at the vertical limit of the investigation.
- The highest total PAH and BTEX concentrations in soft sediment along the length of the canal are found near the three former MGP sites. Total PAH and BTEX concentrations in native sediment between the head of the canal and the Gowanus Expressway are generally higher than those in soft sediment. The highest concentrations in native sediment are found near the Carroll Gardens/Public Place former MGP site. High PAH and BTEX concentrations are characteristic of coal tar releases.
- Copper, lead and mercury concentrations in soft sediment along the length of the canal are variable. Lead and mercury concentrations are highest at the head of the canal. Copper concentrations are highest near the OH-007 outfall.
- Total PCB concentrations in soft sediment are highest in the 7th Street basin, near the RH-035 outfall and near the Carroll Gardens/Public Place former MGP site.

4.4 Surface Water

Two rounds of surface water samples were collected from the canal and the reference area: one under wet-weather conditions and one under dry-weather conditions. Twenty-seven locations were sampled within the canal during the dry-weather event and 26 locations were sampled during the wet-weather event. Eleven reference locations were sampled during both the wet and dry sampling events, including one location in the Buttermilk Channel, near the Gowanus Canal Flushing Tunnel intake (sampling location 336, shown in Figure 2-6).

A single grab sample was also collected on the western side of the canal south of Bond Street in response to community concerns about sheen on the water surface (location SWM3). The analytical results for this sample are presented in Appendix I, Tables I-63a through I-67a, and comparisons to ecological and human health screening values are presented in Tables I-63b through I-67b. The results for this sample were similar to other samples within the canal.

The surface water data were evaluated using a step-wise approach similar to that used for surface sediments. Summary statistics were calculated for surface water samples from the canal and reference area under dry and wet conditions. Initially, sample results were compared to ecological and human health screening values to evaluate the magnitude of contamination. As with sediment, COPCs were identified in the ERA and HHRA. Additional statistical comparisons were performed to determine whether there were any significant differences within the canal during wet- and dry-weather events and to identify constituents that were significantly higher in the canal relative to the reference area under both wet- and dry-weather conditions.

The summary statistics for dry-weather samples from the canal and reference area are presented in Tables 4-8a and 4-8b, respectively. Tables 4-9a and 4-9b present summary statistics for the wet-weather samples collected from each area. Complete analytical results are presented in Tables I-21a through I-25a, and screening results for individual samples are provided in Tables I-21b through I-25b. The results of the statistical comparisons are presented in Tables 4-10 and 4-11. The analytical results are discussed below in general terms by parameter class and weather event.

4.4.1 VOCs

Nine VOCs were detected in surface water in the dry weather event and 21 were detected in the wet weather event. Fewer VOCs also were detected in the reference area during the dry-weather sampling event than during the wet-weather sampling event. The most frequently detected constituents in the canal during both sampling events were the BTEX compounds (Tables 4-8a and 4-9a). During the wet-weather sampling event, tetrachloroethylene (PCE) was detected at all but two sampling locations. Acetone was frequently detected during the dry-weather sampling event. Although VOC concentrations were below ecological screening values, they were greater than human health screening values for three constituents (benzene, ethylbenzene, and PCE). Acetone and methylene chloride were the only VOCs detected in reference area surface water samples during the dry-weather event.

4.4.2 SVOCs

PAHs were detected at similar frequencies in surface water samples from both sampling events. Phthalates were sporadically detected. Total PAHs were detected in 25 of 26 locations during the wet weather event and in 24 of 27 locations during the dry weather event. PAHs and phthalates were detected in the reference area during the wet- and dry-sampling events. The detection frequency for the PAHs was generally lower during the dry-weather event. None of the results from the canal samples collected during either event were higher than the ecological screening values. Six PAH compound concentrations were greater than the human health screening value during the dry-weather event and eight were higher in the wet-weather event, as shown in Tables 4-8a and 4-9a, respectively. Bis(2-ethylhexyl)phthalate also exceeded the human health screening value in the dry weather event. The maximum total PAH concentrations were 13.3 and 6.9 µg/L in the dry- and wet-weather events, respectively. The maximum concentration was measured on the north side of the channel at the south end of the study area (location 325) in the dry weather event, and at the head of the 7th Street basin (location 316) in the wet-weather event.

4.4.3 Pesticides and PCBs

Pesticides and PCBs were not detected in surface water samples from the canal or reference area during either the wet- or dry-weather sampling events.

4.4.4 Metals and Cyanide

A variety of inorganic constituents was detected in both the wet- and dry-weather sampling events in both the canal and reference area samples. Concentrations of seven constituents were greater than ecological and human health screening values in both the dry and wet weather events. Arsenic, chromium, cobalt, mercury, and nickel concentrations were higher than screening values in at least one sample in both events. Copper and thallium concentrations also exceeded a screening value in the dry weather event, and iron and lead exceeded a screening value in the wet weather event. Average concentrations of total suspended solids in the canal were slightly higher under dry-weather conditions than wet-weather conditions (80 mg/L and 53 mg/L, respectively).

4.4.5 Statistical Comparisons

Statistical comparisons were performed as described in Section 4.3 to determine whether constituent concentrations were significantly different in the canal surface water under dry- and wet-weather conditions, and whether surface water concentrations in the canal were significantly higher than those at the reference area locations. Results for the comparison of wet- and dry-weather results for the canal are presented in Table 4-10. Where significant differences were observed, concentrations of VOCs (with the exception of benzene) were higher in wet-weather conditions than in dry. No consistent trends in PAH and metals concentrations were observed; some parameters exhibited significantly greater concentrations during dry weather and others during wet weather.

The results of the comparison between the canal and reference area samples in wet- and dry-weather conditions are presented in Table 4-11. During the wet-weather event, more constituents were present at significantly higher concentrations in the canal than at the reference locations, particularly for VOCs. Benzene, acenapthene, fluoranthene, phenanthrene, total PAHs, and total and dissolved manganese were significantly greater in surface water from the canal relative to the reference area during both the wet and dry sampling events.

4.4.6 Summary

The evaluation of analytical results for the surface water samples indicates the following:

- VOCs, SVOCs, and metals were detected in surface water samples. Pesticides and PCBs were not detected.
- The following constituents exceeded ecological and human health screening values in at least one sample during the dry- and wet-weather sampling events:

Constituents Exceeding Screening Values

	Dry Weather		Wet Weather	
	Ecological	Human Health	Ecological	Human Health
VOCs	None	Benzene	None	Ethylbenzene PCE
SVOCs	None	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene Indeno(1,2,3-cd)pyrene Bis(2-ethylhexyphthalate)	None	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene Naphthalene
Metals	Cobalt Copper Nickel	Arsenic Chromium Cobalt Copper Mercury Thallium	Cobalt Iron Lead Nickel	Arsenic Chromium Cobalt Lead Mercury

- Concentrations of some VOCs in canal surface water were significantly higher in wet weather conditions than in dry weather conditions. Concentrations of some PAHs and metals were higher in wet weather conditions while others were higher in dry weather conditions.
- Concentrations of benzene, PAHs, and manganese in canal surface water were significantly higher than concentrations at reference locations in both dry- and wet-weather conditions.

4.5 CSO Discharges

Samples were collected from combined sewer systems around the canal and analyzed to provide a preliminary indication of contaminant loading to the canal from these sources. The media tested included sediment from the bottoms of pipes and water. Sediment samples were collected during dry weather at locations where sediment was present and accessible for collection. Water samples were collected during both dry- and wet-weather conditions. Analytical results were compared to the screening values identified in Section 4.2 to evaluate the relative magnitude of contamination. Although these screening values are not directly applicable to these media, they are used to provide perspective on the results.

4.5.1 CSO Sediment

Sediment samples were collected at seven CSO sampling locations (RH-031, RH-033, RH-035, RH-036, RH-037, OH-005, and OH-007). CSO sampling locations are shown in Figure 2-10. Samples were not collected where no sediment was present or where sewer flow conditions prevented sampling. Therefore, the sample results provide a “snapshot” of residual sediment in the sewer system at the sampled locations that may be mobilized and discharged to the canal during wet weather or may constitute a source in the sewer system to combined sewage that may be discharged to the canal during wet weather.

A statistical summary of the sample results is provided in Table 4-12. The complete analytical results are presented in Appendix I, Tables I-43a through I-47a. Table I-48 presents the TOC and grain size results. Appendix I, Tables I-43b through I-47b compare the results to the screening values identified in Section 4.2.

VOCs

Fifteen VOCs were detected in sediments collected from CSO sampling locations. The sample from OH-007 had the greatest number of maximum detected results (11). All but one (1,4-dichlorobenzene) of the detected results were below screening values. The VOC 1,4-dichlorobenzene was detected at OH-007 at 870 µg/kg, exceeding the ecological screening value of 240 µg/kg.

SVOCs

Eighteen SVOCs (including PAHs) were detected in sediments collected from CSO sampling locations. Most of the SVOCs were PAHs, which were detected in most samples. The sample from RH-031 had the greatest number of maximum detected results (10). Concentrations for 17 of the SVOCs including PAHs were higher than the ecological and/or human health screening values in one or more samples. The following two PAHs exceeded their screening values at all locations:

- The human health screening value for benzo(b)fluoranthene (150 µg/kg) was exceeded in all samples with a maximum detection of 4,500 µg/kg at OH-007.
- The human health screening value for indeno(1,2,3-c,d)pyrene (150 µg/kg) was exceeded in all samples with a maximum detection of 1,800 µg/kg at RH-031.

Pesticides

Of the seven CSO sediment sampling locations, pesticides were detected only in the sample from RH-033. Five pesticides were detected (dieldrin, endosulfan sulfate, endrin aldehyde, gamma-chlordane, and P'P'-DDT). The following three pesticides exceeded their screening values at all locations:

- The human health screening value for dieldrin (30 µg/kg) was exceeded with a detection of 85.0 µg/kg.
- The ecological screening values for gamma-chlordane and p,p'-DDT (0.04 and 20 µg/kg, respectively) were exceeded with detections of 48 and 210 µg/kg, respectively.

PCBs

Aroclor 1260 was the only detected Aroclor. It was detected in only two of the seven CSO sediment samples, RH-033 and RH-037. The total PCB concentration was therefore the same as the Aroclor 1260 concentration. Aroclor 1260 exceeded screening values as follows:

- The concentration at RH-033 (1,200 µg/kg) exceeded the human health screening value of 220 µg/kg.
- The concentrations at RH-033 and RH-037 (220 µg/kg and 1,200 µg/kg, respectively) exceeded the ecological screening value of 22.7 µg/kg..

Metals and Cyanide

Twenty-one metals and total cyanide were detected in sediments collected from the seven CSO sampling locations. The sample from RH-031 had the greatest number of maximum detected results (13). Concentrations of fourteen metals were higher than screening values in some samples. The following metals exceeded their screening values at all locations:

- Concentrations of copper, lead, mercury, and zinc exceeded the ecological screening values in all samples.
- Concentrations of chromium and cobalt exceeded the human health screening values in all samples.

4.5.2 CSO Water

Sanitary and combined sewage samples were collected at CSO sampling locations during dry- and wet-weather conditions. Dry-weather sampling provides data representative of sanitary sewage in the sewer system. Sanitary sewage is not discharged to Gowanus Canal during dry weather. Wet-weather sampling provides data representative of combined sewage in the sewer system that is discharged to the Gowanus Canal when the capacities of the sewer systems are exceeded. Combined sewage includes sanitary sewage as well as runoff from streets, sidewalks, parking lots, roof tops, and other surfaces that drain to the sewer system. Table 3-2 lists the annual discharge from each CSO. Outfalls RH-034 and RH-035 represent 66 percent of the total annual discharge, and outfalls RH-031 and OH-007 represent 29 percent of the total. Both discharge volume and chemical concentration must be taken into account when estimating the contaminant load to the canal from the CSOs.

One round of dry-weather samples and three rounds of wet weather samples were collected. CSO sampling locations are shown in Figure 2-10. Statistical summaries of dry- and wet-weather sample results are provided in Tables 4-13 and 4-14, respectively. The results for the three wet-weather sampling events were combined in the statistical summary. The analytical results for CSO water analyses are presented in Appendix I, Tables I-49a through I-53a. Table I-53a also presents TSS concentrations and Table I-54 presents the geochemistry parameter results. Appendix I, Tables I-49b through I-53b compare the results to the screening values identified in Section 4.2.

VOCs

Twenty-seven VOCs were detected in the dry weather CSO sewage samples. The sample from RH-033 had the greatest number of compounds at maximum concentrations (8). Twenty-five VOCs were detected in CSO water samples collected during the wet weather sampling events. The sample from RH-037 had the greatest number of compounds at maximum concentrations (7). The frequency of VOCs detection was higher in dry weather samples compared to wet weather samples.

The VOC compounds detected during both dry and wet sampling events were generally the same with the exception of the following:

- 1,2-dibromo-3-chloropropane, 1,2-dichloroethane, carbon disulfide, and styrene were detected during the dry weather sampling event only.
- 1,1,1-trichloroethane and methyl isobutyl ketone were detected during wet weather sampling events only.

No dry weather detections exceeded ecological screening values for VOCs. The following compounds exceeded human health screening values in the dry-weather samples: 1,2-dibromo-3-chloropropane, benzene, ethylbenzene, PCE, and vinyl chloride.

Similar to dry weather sampling, no wet weather detections exceeded ecological screening values for VOCs. The following compounds exceeded human health screening values in the wet weather samples: benzene, ethylbenzene, PCE, vinyl chloride, and 2-hexanone.

SVOCs

Twenty-six SVOCs including PAHs were detected in dry-weather CSO sewage samples. The sample from RH-033 had the greatest number of compounds at maximum concentrations (6). Twenty-seven SVOCs were detected in CSO water samples collected during wet weather. The sample from RH-031 had the greatest number of compounds at maximum concentrations (9). The frequency of SVOCs detection was higher in wet weather samples compared to dry weather samples.

The SVOCs detected during both dry and wet sampling events were generally the same with the exception of the following:

- 4-nitroaniline, acetophenone, biphenyl, and di-n-butyl phthalate were detected during dry weather sampling events only.
- Anthracene, benzaldhyde, benzo(a)pyrene, di-n-octylphthalate, and pentachlorophenol were detected during wet weather sampling events.

The average concentration of total PAHs in dry weather CSO sewage was 14.3 µg/L and in wet weather was 7.3 µg/L. The following compounds exceeded screening values during both the dry and wet sampling events:

- Concentrations of diethyl phthalate, dimethyl phthalate, and naphthalene exceeded ecological screening values in a limited number of both the dry and wet weather samples.
- Concentrations of 4-methylphenol (p-cresol), benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene, and naphthalene exceeded human health screening values in both the dry and wet weather samples.

Pesticides

One pesticide (alpha-chlordane) was detected in the dry weather sample from RH-034. The alpha-chlordane concentration of 0.069 µg/L was higher than the ecological screening value of 0.004 µg/L. No pesticides were detected in the wet weather samples.

PCBs

PCBs were not detected in the dry-weather samples. Only Aroclor 1260 was detected in the wet-weather sample from OH-006. The total PCB concentration was therefore the same as the Aroclor 1260 concentration. The single detected concentration (0.57 µg/L) exceeded the ecological screening value of 0.03 µg/L and the human health screening value of 0.000001 µg/L for both Aroclor 1260 and total PCBs.

Metals and Cyanide

Twenty metals and total cyanide were detected in the dry-weather CSO samples. The sample from RH-038 had the greatest number of maximum detected concentrations (5). Nineteen metals were detected in the CSO water samples collected during wet weather. The sample from RH-036 had the greatest number of maximum detected concentrations (7).

The frequency of detection was higher in wet-weather samples than in dry-weather samples. The inorganic constituents detected during both dry and wet sampling events were generally the same with the exception of the following:

- Antimony, dissolved silver, silver, dissolved thallium, and total cyanide were detected during dry weather only.
- Dissolved cadmium, dissolved mercury, mercury, and dissolved vanadium were detected in wet weather samples only.

Eleven metals and total cyanide concentrations were higher than screening values in one or more dry weather samples. Concentrations of 12 metals were higher than screening values in at least one wet weather sample. The following metals exceeded screening values in all dry and / or wet weather samples:

- Arsenic, dissolved arsenic, chromium, and dissolved chromium concentrations exceeded the human health screening values in all wet weather samples. Arsenic, dissolved arsenic, and chromium exceeded the human health screening values in all dry weather samples as well.
- Copper concentrations exceeded the ecological screening value in all dry and wet weather samples.

The results for the dissolved and total metals indicate that metals are bound to solids discharging to the canal by CSOs. Solids would be expected to settle along the length of the canal and contribute to the metal concentrations found in bottom sediments.

4.5.3 Summary

Sediment and water samples were collected from combined sewers tributary to the canal during dry and wet weather. Wet weather sampling was performed to characterize discharges to the canal. Dry weather sampling of sewage was performed to identify potential sources of contaminants.

Sediment samples were collected at seven CSO sampling locations where sediment was present and sewer flow conditions allowed safe and representative sampling. The sample results provide a “snapshot” of residual sediment in the sewer system at the sampled locations that may be mobilized and discharged to the canal during wet weather or may constitute a source in the sewer system to combined sewage that may be discharged to the canal during wet weather. Specifically:

- VOCs, SVOCs, PAHs, pesticides, PCBs, metals and cyanide were detected in sediment samples with some concentrations exceeding human and / or ecological screening values.
- If mobilized during wet weather events due to scour during high flow periods, ongoing loadings to the canal of contaminants bound to solids would occur.

The evaluation of analytical results for the dry and wet weather sampling of sewage indicate the following:

- VOCs were consistently detected in dry and wet weather samples at concentrations below ecological screening values. Several VOCs exceeded human health screening values in both dry and wet weather samples.
- SVOCs were consistently detected in dry weather and wet weather samples at concentrations above ecological and human health screening values.
- Only one pesticide was detected in a dry weather sample at a concentration above the ecological screening value. No pesticides were detected in wet weather samples.

- No PCBs were detected in dry weather samples. Aroclor 1260 was detected in combined sewage during wet weather only at OH-006 at a concentration exceeding the ecological and human health screening values.
- Metals were detected in dry and wet weather samples with concentrations of several constituents exceeding the ecological and human health screening values. Specific metals (arsenic, chromium, copper) exceeded screening values in both unfiltered (total metal concentrations) and filtered (dissolved metal concentrations) samples.
- Total cyanide was detected in dry weather samples with some concentrations exceeding the ecological screening value. There were no detections in wet weather samples.

A summary of the constituents detected in CSO sediment and wet weather samples that are discharged to the canal at concentrations higher than either the ecological or human health screening values is provided below.

Constituents Exceeding Screening Values

	CSO Sediment		**CSO Wet Weather Water**	
	Ecological	**Human Health**	**Ecological**	**Human Health**
VOCs	1,4-dichlorobenzene	None	None	2-hexanone Benzene Ethylbenzene Tetrachloroethylene (PCE) Vinyl Chloride
SVOCs	2-methylnaphthalene 4-methylphenol (p-cresol) Acenaphthene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo (g,h,i) perylene Bis(2-ethylhexyl) phthalate Chrysene Dibenz(a,h)anthracene Fluoranthene Fluorene Indeno (1,2,3-c,d) pyrene Naphthalene Phenanthrene Pyrene Total PAHs	Benzo(a)anthracene Benzo(a)pyrene Benzo(b) fluoranthene Indeno (1,2,3-c,d) pyrene	Diethyl phthalate Dimethyl phthalate Naphthalene	4-methylphenol (p-cresol) Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Bis(2-ethylhexyl) phthalate Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-c,d)pyrene Naphthalene
Pesticides	Gamma-chlordane p,p'-DDT	Dieldrin	None	None
PCBs	Aroclor 1260 Total PCBs	Aroclor 1260 Total PCBs	Aroclor 1260 Total PCBs	Aroclor 1260 Total PCBs
Metals	Barium Cadmium Chromium Copper Lead Manganese Mercury Nickel Silver Zinc	Arsenic Chromium Cobalt Copper Iron Lead Manganese Vanadium	Cobalt Dissolved Cobalt Copper Dissolved Copper Iron Dissolved Iron Lead Manganese Dissolved Manganese	Arsenic Dissolved Arsenic Cadmium Chromium Dissolved Chromium Cobalt Dissolved Cobalt Copper Dissolved Copper Iron Dissolved

Constituents Exceeding Screening Values

	CSO Sediment		CSO Wet Weather Water	
	Ecological	Human Health	Ecological	Human Health
			Nickel Zinc Dissolved Zinc	Iron Lead Manganese Dissolved Manganese Mercury Dissolved Mercury Vanadium

The sampling results indicate the following for CSO discharges to the canal:

- CSOs are currently discharging VOCs, SVOCs including PAHs, PCBs, and metals in combined sewage during wet weather to the canal.
- If mobilized during wet weather, CSO sediments may discharge VOCs, SVOCs including PAHs, PCBs, pesticides, and metals to the canal.
- There are no specific trends in the data that can be used to identify sources in the collection system leading to the various CSO regulators.
- Dry weather sampling indicates that both sanitary sewage and runoff are possible sources of contaminants.

4.6 Other Pipe Outfalls

A two-phase survey of the canal bulkheads was performed from a boat to identify pipe outfall features to the canal. Features observed to be discharging were sampled during Phase 1. Outfalls previously identified as CSOs and municipal stormwater were excluded from these surveys. Observations and sampling were performed during dry weather conditions.

Analytical results were compared to the screening values identified in Section 4.2 to evaluate the relative magnitude of contamination. Although these screening values are not directly applicable to these media, they are used to provide perspective on the results.

4.6.1 Phase 1 Outfall Features Survey

A total of 220 outfall features to the canal were identified. From these, 25 features were observed to discharge to the canal as follows:

- The discharge from 11 features appeared to be tidal drainage - these discharges were not sampled.
- The discharges from five of the features could not be clearly attributed to tidal drainage - these discharges were sampled.
- The discharges from nine features were determined not to be tidal drainage - the discharges from seven of these features were sampled; the discharges from two could not be sampled due to the small rate of the discharge.

The following 12 features were sampled:

GC-CF-E-027	GC-CF-E-063	GC-CF-W-046
GC-CF-E-029	GC-CF-W-001	GC-CF-W-048
GC-CF-E-033	GC-CF-W-037	GC-CF-W-077
GC-CF-E-035	GC-CF-W-044	GC-CF-T1-003

The following two features with active flow not attributed to tidal drainage were not sampled due to the small rate of the discharge:

GC-CF-W-040	GC-CF-T2-003

The features that were sampled are shown in Figure 2-10, along with the CSO sample locations.

4.6.2 Phase 2 Outfall Features Survey

A total of 27 additional outfall features were identified in Phase 2 that were not identified in Phase 1. Nine features were observed to discharge to the canal. Of these nine, three were not observed during the Phase 1 outfall survey (bolded and italicized in below list):

GC-CF-E-009A	GC-CF-T3-015	GC-CF-W-051
GC-CF-E-033	***GC-CF-W-012A***	***GC-CF-W-044***
GC-CF-T3-012A	GC-CF-W-048	GC-CF-E-072 (CSO OH-006)

Note that:

- GC-CF-E-033 and W-048 were discharging during both phases (samples collected during Phase 1).
- GC-CF-T3-015 and GC-CF-W-044 were discharging during Phase 2 but not during Phase 1 (therefore, samples were not collected).
- GC-CF-W-051 was discharging during both phases but salinity was similar to the canal during Phase 1 and therefore, the discharge was not sampled.

The presence of oil was noted at the following outfall features:

GC-CF-W-042	GC-CF-W-044	GC-CF-T3-013
GC-CF-W-002	GC-CF-W-045	GC-CF-E-007
GC-CF-W-002A	GC-CF-W-018	GC-CF-T3-012
GC-CF-W-015A	GC-CF-W-098	GC-CF-W-043

4.6.3 Sampling Results

All of the pipes were discharging at a very low rate, at or less than 2 L/min, except for location GC-CF-W-001, which had water streaming out of the 12-inch-diameter pipe. Because of the low volume of discharge from several of the outfall features, some of the samples were analyzed only for a subset of parameters. The pipe outfall sample results provide a snapshot of chemical concentrations in discharges from these pipes.

A statistical summary of the sample results is provided in Table 4-15. Complete analytical results for the samples collected from the pipe outfalls are presented in Appendix I, Tables I-38a through I-42a. Appendix I, Tables I-38b through I-42b compare these results to the screening values identified in Section 4.2.

The analytical results indicate that contaminants are present in the discharges although the loading of contaminants to the canal from the sampled pipe outfall features may be low because of the low discharge rates. Nevertheless, this contamination would contribute to the overall sediment and water quality conditions in the canal.

VOCs

- Eighteen VOCs were detected in the sampled discharges.
- None of the VOC concentrations was higher than the ecological or human health screening values.
- Outfall feature GC-CF-W-044 contained the greatest number of maximum concentrations of VOCs (8) although as noted above, these concentrations were below screening values.

SVOCs

- Twenty-one SVOCs were detected in the sampled discharges. Detected compounds include PAHs, phthalates, and pentachlorophenol.
- Eight PAHs and 3 phthalates were found at concentrations higher than the ecological and human health screening values.
- The PAHs exceeding the screening values most frequently are listed below along with the maximum concentration compared to the corresponding human health screening value of 0.018 µg/L (ecological screening values were not exceeded for these compounds):
    - Indeno(1,2,3-c,d)pyrene at ten locations at maximum concentration of 0.54 µg/L.
    - Benzo(b)fluoranthene at three locations at maximum concentration of 0.54 µg/L.
    - Benzo(k)fluoranthene at three locations at maximum concentration of 0.14 µg/L.
    - Dibenz(a,h)anthracene at three locations at maximum concentration of 0.25 µg/L.
- Location GC-CF-W-001 contained the highest number of PAHs above screening values (seven, with six found at their maximum concentrations at this location) followed by location GC-CF-E-063 (four PAHs at concentrations above screening values). As noted above, water was streaming from the 12-inch diameter pipe at location GC-CF-W-001 at the time of sampling.

Pesticides and PCBs

Pesticides and PCBs were not detected.

Metals

- Eighteen metals and total cyanide were detected in the sampled discharges.

- The following nine metals were detected in all ten samples analyzed for metals: arsenic, barium, calcium, copper, magnesium, manganese, nickel, potassium, and zinc.
- Nine metals were found at concentrations higher than either the human health or ecological screening values.
- The metals exceeding their screening values most frequently are listed below along with the maximum concentration compared to the screening value that was exceeded:
  - Arsenic at ten locations with maximum concentrations of 8.2 µg/L and 7.8 µg/L for dissolved and total concentrations, respectively, compared to the human health screening value of 0.14 µg/L.
  - Copper at nine locations with maximum concentration of 16 µg/L compared to the ecological screening value of 3.1 µg/L.
  - Iron at nine locations with a maximum concentration of 4,910 µg/L compared to the ecological screening value of 50 µg/L and the human health screening value of 2,600 µg/L.
  - Chromium at eight locations with maximum concentrations of 1.8 µg/L and 1.5 µg/L for dissolved and total concentrations, respectively compared to the human health screening value of 0.043 µg/L.
- The locations where the highest number of metals above screening values were found are:
  - GC-CF-T1-003 (seven metals)
  - GC-CF-E-035 and GC-CF-W-046 (six metals)
  - GC-CF-E-063, GC-CF-E-037, and GC-CF-W-048 (five metals)

4.6.4 Summary

- A two-phase survey of the canal bulkheads was performed to identify pipe outfall features to the canal and collect samples from features observed to be discharging to provide a preliminary indication of contaminant loading to the canal from these sources.
- A total of 220 outfall features to the canal were identified during Phase 1. An additional 27 outfall features were identified during Phase 2.
- During Phase 1, 25 features were observed to discharge to the canal. Twelve of these were sampled. The discharges from the remaining features were either attributed to tidal drainage from the feature or were too low to collect a sample. Three additional features were observed to discharge during Phase 2 but these discharges were not sampled.
- During Phase 2, oil was noted to be present in 12 of the outfall features.
- The analytical results indicate that while the loading of contaminants to the canal from the sampled pipe outfall features may be low because of the low discharge rate

observed, contaminants were present in the discharges. These contaminants would contribute to the overall sediment and water quality conditions in the canal.

- The table below summarizes where compounds were found to exceed ecological and human health screening values in the sampled outfall features.

Outfall Feature	Location	No. of SVOCs Exceeding Screening Value	No. of Metals Exceeding Screening Value
GC-CF-W-001	Head of canal	8	4
GC-CF-E-033	Between Carroll Street and 3rd Street	2	4
GC-CF-E-035	Between Carroll Street and 3rd Street	1	6
GC-CF-W-046	Between Carroll Street and 3rd Street	1	6
GC-CF-E-027	Immediately downstream of 3rd Street Bridge	2	4
GC-CF-E-029	Immediately downstream of 3rd Street Bridge	1	
GC-CF-T1-003	Within 4th Street turning basin	4	7
GC-CF-W-037	At turn of canal by 4th Street	1	5
GC-CF-W-048	At turn of canal by 4th Street	0	5
GC-CF-E-063	By Gowanus Expressway	5	5
GC-CF-W-077	Near mouth of canal	4	4

- Location GC-CF-W-001 contained the highest number of PAHs above screening values (seven PAHs, with six found at their maximum concentrations at this location). As noted above, water was streaming from the 12-inch diameter pipe at location GC-CF-W-001 at the time of sampling.

4.7 Air

Two rounds of air samples were collected – one before and one after the start of the canal aeration system. Air-sampling locations are shown in Figure 2-9. Statistical summaries of the sample results are provided in Tables 4-16 and 4-17. The analytical results for the ambient air samples are presented in Appendix I, Tables I-55a through I-57a. Tables I-55b through I-57b show a comparison of the results to the screening values (the Regional Screening Level [RSLs] for residential air) identified in Section 4.2.

The analytical results were also compared to the mean concentrations in outdoor air in three large U.S. cities measured during a 2006 study (the Relationships of Indoor, Outdoor, and Personal Air [RIOPA] study), referenced by NYSDOH (2006). Specifically, the RIOPA study provides information on air toxics and particulate matter in urban air for 16 separate VOCs. The information is based on VOC concentrations measured in outdoor air during two 48-hour periods, during different seasons, between summer 1999 and spring 2001. Three cities with different air pollution sources and weather conditions are covered by the study: Los Angeles, CA; Houston, TX; and Elizabeth, NJ. The mean concentrations from the RIOPA study for the compounds detected in air samples above the human health screening values (RSLs) during this investigation are listed below:

- Benzene—2.15 $\mu g/m^3$

- Chloroform—0.32 µg/m^3
- Ethylbenzene—1.29 µg/m^3
- Methylene chloride—0.95 µg/m^3
- Total xylene—1.49 µg/m^3

As noted in Section 2.6, two air samples collected for PAH analysis during the second sampling event at canoe-level locations 504 and 507 were reported in micrograms instead of in micrograms per cubic meter. This is because, due to equipment malfunction, the exact volume of air that passed through the sampling media at these locations is unknown. As a result, data for these two samples can be used to confirm the presence of detected compounds but cannot be used to verify the absence of nondetected compounds. While the numerical results are analytically sound on a micrograms-per-cartridge basis, the equipment malfunction affected the representativeness of the samples.

4.7.1 VOCs

The following VOCs were detected in both canoe- and street-level samples along the canal: BTEX compounds, trichloroethylene (TCE), acetone, bromoform, carbon disulfide, chloroform, chloromethane, methyl ethyl ketone (MEK), and methylene chloride. These compounds, with the exception of three (TCE, bromoform, and carbon disulfide), were also detected at background locations approximately 600–1,000 feet west of the canal.

The VOCs detected in samples at canoe level during the first and second sampling events were the same with the exception of bromoform, which was detected only during the first sampling event. The VOCs detected in samples at the street level during the first and second sampling events were the same with the exception of bromoform and carbon disulfide, which were detected only during the first sampling event.

Benzene, ethylbenzene, xylenes, and chloroform were detected at concentrations exceeding the RSLs in the canoe air samples collected along the canal. Benzene, ethylbenzene, chloroform, and methylene chloride were detected at concentrations exceeding the RSLs in the samples collected at the background locations.

Detections of BTEX compounds occurred at each canal and street level sample location and at each of the three background locations. Measured concentrations of benzene exceeded the RSL at every location (including background). Measured concentrations of ethylbenzene exceeded the RSL at five canoe-level and five street-level locations and at one background location. Measured concentrations of xylene exceeded the RSL at two canoe locations, but not at background locations. Measured concentrations of toluene did not exceed the RSL at the sampled locations.

BTEX compounds are combustion byproducts commonly found in urban areas at low concentrations from tobacco smoke, automobile service stations, exhaust from motor vehicles, and industrial emissions. The measured BTEX concentrations were compared to the urban background concentrations for these compounds noted in the RIOPA study.

The benzene concentrations at nine canoe-level and nine street-level locations were below the RIOPA mean average concentration for benzene; benzene concentrations were higher than the RIOPA mean average concentration by a factor of nearly 2 at one canoe location

(510, south of the Gowanus Expressway) and only slightly higher at one street-level location (501, at the head of the canal).

The concentrations of ethylbenzene at five canoe-level and seven street-level locations were below the RIOPA mean average concentration for ethylbenzene. The concentrations of xylene at all locations along the canal and at the three background locations were above the RIOPA mean average concentration for xylene.

Chloroform was detected at seven of the 10 canoe-level locations during the first round of sampling and at eight of the 10 canoe-level locations during the second round. The measured chloroform concentrations exceeded the RSL when detected (chloroform was not detected at canoe-level locations 509 and 510 during either round). Chloroform was also detected in nine samples collected from the 10 street-level locations; each of the detected concentrations exceeded the RSL (note that at a few locations, chloroform was detected during one round but not during the other). Measured concentrations of chloroform at two of the three background locations exceeded the RSL. Chloroform concentrations were above the RIOPA mean concentration at only two locations (street level locations 501 and 505).

Chloroform is a trihalomethane produced from the chlorination of public water to remove bacteria, viruses, and parasites. New York City uses chlorine to meet the New York State Sanitary Code Safe Drinking Water Act disinfection requirements (NYCDEP, 2010b). Chlorinated water from the New York City distribution system travels to residential and commercial buildings and ultimately enters the canal through CSO discharges. A study (Vermont Department of Health, 1993) for which indoor air sampling was performed in both homes supplied by private well water and homes supplied by public water concluded that chlorinated drinking water was the major source of chloroform in the air of homes.

Methylene chloride was the only other VOC that exceeded its RSL. Methylene chloride was detected at six of the 10 canoe-level locations and six of the 10 street-level locations. Concentrations were below the RSL. Methylene chloride was detected at two of the three background locations; at one of these locations the measured concentration exceeded the RSL. All detected concentrations of methylene chloride were above the RIOPA mean average concentration but within the same order of magnitude. Individual VOC concentrations were generally within the same order of magnitude among canoe-level, street-level, and background locations. The individual VOC concentrations detected during both sampling rounds were also generally within the same order of magnitude.

Analytical results for air samples collected at canoe level were compared with results for samples collected at street level for both round 1 and round 2 samples. Either a WRS test or Gehan’s test was applied to determine with 95 percent confidence whether contaminant concentrations in the canoe-level samples were, on average, significantly different than those at street level. The WRS test was used when the detection frequency in each data set was at least 60 percent; otherwise, the Gehan's test was used. Only detected constituents were evaluated.

The results of the statistical comparisons are summarized in Table 4-18. There were no significant differences between the concentrations of VOCs in air at canoe level and those at street level in round 1 or round 2.

The highest concentration of VOCs at canoe level occurred at location 509 during the second air-sampling round. The highest concentration of VOCs at street level occurred at location 507 during the second round. Measured concentrations of acetone were the major contributor to the high VOC concentrations at both locations; however, these concentrations did not exceed the RSL.

4.7.2 PAHs

Air samples were analyzed for PAHs. Eight PAHs (acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were detected in samples collected from both canal- and street-level locations. These same eight PAHs were detected at one or more of the background locations.

Three PAHs (benzo(a)anthracene, benzo(b)fluoranthene, and chrysene) were detected in samples collected at the canoe level but not in samples collected at the street level. Benzo(a)anthracene was detected at five of the 10 canoe level locations. Chrysene was detected at two of the 10 canoe level locations. Benzo(b)fluoranthene was detected at one of the 10 canoe level locations. However, measured concentrations of these three PAHs did not exceed the RSLs.

The following PAHs were detected at one or more of the background locations: acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene. Naphthalene was the only PAH detected at concentrations above the RSL; measured concentrations exceeded the RSL at each of the locations along the canal (canoe and street level) and each of the three background locations. Measured concentrations of the other detected PAHs were below the RSLs.

PAH compounds detected in samples at the canoe and street level during the first and second sampling events were generally the same with the exception of benzo(b)fluoranthene, which was detected at one canoe-level location during the first sampling round but was not detected during the second round.

The PAH-sampling results from locations 504 and 507 are not included in the discussion below because the units in which the results were reported were different than for the remaining samples as a result of the malfunction of the air-sampling pump (see Section 2.6).

The PAH concentrations were generally within the same order of magnitude between the canoe level and street level locations. As shown in Table 4-18, PAHs were not significantly different between canoe and street levels in Round 2. In Round 1, concentrations of three PAHs (anthracene, phenanthrene, and pyrene) were significantly higher at canoe level than at street level. For PAHs detected along the canal and at the background locations, the concentrations are also generally within the same order of magnitude.

The PAH concentrations were also generally within the same order of magnitude during both sampling rounds. The total PAH concentrations in the northern part of the canal at location 501 decreased between the first and second sampling rounds. The total PAH concentrations in the southern part of the canal (506, 508, 509, and 510) increased between the first and second sampling rounds.

The highest concentration of total PAHs at canoe level occurred at location 502 during the first sampling event; measured concentrations of acenaphthene, phenanthrene, and fluorene were the major contributors to the high total PAH concentration. The highest concentration of total PAHs at street level occurred at location 507 during the second round; measured concentrations of acenaphthene and naphthalene were the major contributors to the high total PAH concentration.

4.7.3 PCBs

One street level air sample and a field duplicate were submitted for PCB analysis. No PCBs were detected.

4.7.4 Summary

- Five VOCs and one PAH (naphthalene) were found at concentrations above screening values. Three VOCs and naphthalene were found to exceed the screening values at the canoe-level, street-level, and reference locations.
- No PCBs were detected.
- The table below summarizes the maximum concentrations of these compounds, with concentrations that were above the screening values shown in bold font.

	Canoe level		Street level		Background	
	Round 1 Without Aeration System	Round 2 With Aeration System	Round 1 Without Aeration System	Round 2 With Aeration System	Location About 1000 feet from Canal	RIOPA Study
Volatile Organic Compounds ($\mu g/m^3$)						
Benzene	1.1	**3.8**	**2.3**	**1.4**	**0.91**	2.15
Chloroform	**0.28**	**0.24**	**0.39**	**0.45**	**0.29**	0.32
Ethylbenzene	**5.1**	**4.4**	**1.7**	**1.8**	**1.2**	1.29
Methylene chloride	4.5	2	5.1	2	**5.4**	0.95
Xylenes (total)	**16**	**28**	6.8	7.6	4.6	1.49
Semi-Volatile Organic Compounds ($\mu g/m^3$)						
Naphthalene	**3.4**	**2.6**	**1.3**	**4.4**	**0.17**	Not available

- The table below summarizes the number of samples where these compounds were found above their screening value over the total number of samples analyzed.

	Canoe		Street		Background
	Round 1 Without Aeration System	Round 2 With Aeration System	Round 1 Without Aeration System	Round 2 With Aeration System	Location About 1000 feet from Canal
Volatile Organic Compounds					
Benzene	10/10	10/10	10/10	10/10	3/3
Chloroform	7/10	8/10	6/10	9/10	2/3
Ethylbenzene	3/10	5/10	3/10	3/10	1/3
Methylene chloride	none	none	none	none	1/3
Xylenes (total)	1/10	1/10	none	none	none

	Canoe		Street		Background
	Round 1 Without Aeration System	Round 2 With Aeration System	Round 1 Without Aeration System	Round 2 With Aeration System	Location About 1000 feet from Canal
Semi-Volatile Organic Compounds					
Naphthalene	10/10	8/8	10/10	10/10	3/3

VOCs

- A statistical comparison was performed which indicated no significant differences between the concentrations of VOCs in air at canoe level and those at street level during both the first and second sampling rounds.
- The maximum concentrations of VOCs were generally within the same order of magnitude among the canoe-level, street-level, and background locations and between the first and second sampling rounds, with the exception of the maximum concentration of xylene, which was higher at the canoe level during both rounds. The human health risk assessment in Appendix L provides a quantitative assessment of the significance of the concentrations measured at each level and during each sampling event.
- BTEX compounds were among the five VOCs detected above the screening values. BTEX compounds are combustion byproducts commonly found in urban areas at low concentrations from tobacco smoke, automobile service stations, exhaust from motor vehicles, and industrial emissions.
- Chloroform is another VOC that exceeded the screening value. Chloroform is a trihalomethane produced from the chlorination of public water to remove bacteria, viruses, and parasites. New York City uses chlorine to meet the New York State Sanitary Code Safe Drinking Water Act disinfection requirements (NYCDEP, 2010b). Chlorinated water from the New York City distribution system travels to residential and commercial buildings and ultimately enters the canal through CSO discharges.
- The highest concentration of total VOCs at canoe level occurred at location 509 (near the Gowanus Expressway – 319.05 $\mu g/m^3$) during the second air-sampling round. The highest concentration of total VOCs at street level occurred at location 507 (near the curve of the canal – 506.6 $\mu g/m^3$) during the second round. Acetone was the major contributor to the high VOC concentrations at both locations (300$\mu g/m^3$ and 460 $\mu g/m^3$, respectively); however, these concentrations did not exceed the screening value (3,200 $\mu g/m^3$).

PAHs

- A statistical comparison was performed which indicated no significant differences between the concentrations of PAHs in air at canoe level and those at street level during Round 2 (when the aeration system was operational). In Round 1, concentrations of three PAHs (anthracene, phenanthrene, and pyrene) were significantly higher at canoe level than at street level. However, the concentrations are generally within the same order of magnitude. The human health risk assessment in Appendix L provides a quantitative assessment of the significance of the concentrations measured at each level and during each sampling event.

- The PAH naphthalene was found above its screening value at both the canoe and street level and at the reference location, although the maximum concentration at the reference location was lower than the maximum concentrations along the canal.
- The highest concentration of total PAHs at canoe level occurred at location 502 (near the Union Street Bridge – 20.98 $\mu g/m^3$) during the first sampling event. The highest concentration of total PAHs at street level occurred at location 507 (near the curve of the canal 7.54 $\mu g/m^3$) during the second round.

4.8 Soil

Subsurface soil samples were collected during installation of monitoring wells along the length of the canal. While the primary objective for installing the monitoring wells was to evaluate hydrogeologic characteristics and groundwater–surface water interactions, environmental samples were collected to identify the types and relative concentrations of contaminants in soil. Although the soil sampling does not constitute a complete environmental characterization of the specific properties where wells were installed or along the length of the canal as a whole, it does provide an indication of the range and magnitude of contaminants potentially affecting the canal.

The evaluation of soil data included identification of constituents detected in samples, comparison of detected concentrations to screening values with respect to potential impact to groundwater, and assessment of the distribution of contaminants both laterally along the length of the canal and vertically in the soil profile.

4.8.1 Sample Results

Sample locations are shown in Figure 2-11. The complete analytical results for soil samples are provided in Appendix I, Tables I-27a through I-31a, and a sample-by-sample comparison with screening values is provided in Tables I-27b through I-31b. Appendix O presents the results grouped by the physical property / geographical location along the canal where the soil borings and monitoring wells were installed.

A statistical summary of the soil sample results is presented in Table 4-19a. Table 4-19b summarizes the sampling results at each soil boring location. Listed are the total number of samples collected at each location, the total number of detected constituents, and the total number of constituents exceeding screening values. Please refer to Appendix O for soil results by geographical location along the canal and sampling depths at each location.

All classes of constituents (VOCs, SVOCs, pesticides, PCBs, and metals) were detected in soil samples from borings throughout the length of the canal. Chemical concentrations were relatively higher in borings where NAPL saturation was observed and noted on the soil boring logs. Soil results show that contaminants are distributed laterally along both sides of the canal from the bay to the head of the canal with no discernable trends in distribution between geographical areas within the study area.

VOC concentrations were higher than screening values at nearly all locations sampled along the canal, with most exceedances occurring at depths greater than 15 feet bgs. Similarly, SVOC concentrations were higher than screening values at nearly all locations sampled, but unlike the VOCs, there was no differentiation in the vertical distribution of higher SVOC concentrations. While pesticides were detected at most locations along the length of the canal, concentrations in only six samples were higher than the screening values. PCBs were detected at six locations, but none of the concentrations were higher than the screening values. Most of the locations that were sampled contained some metals with concentrations that exceeded screening values. While the vertical distribution of high metal concentrations spanned all depths sampled, most screening value exceedances were between ground surface and 15 feet bgs.

These results indicate that at the sampled locations, contamination is found in the soils. Because, as described in Section 4.8.2, contamination is also generally found in the groundwater at these locations, it can be concluded that soil contamination is contributing to groundwater contamination, which in turn discharges to the canal and may affect the sediment and water quality in the canal. Although tidal flux may alter hydraulic gradients in the immediate vicinity of the canal and cause water from the canal to flow locally inland at times, the hydrogeologic evaluation indicated that the flow reversals are local and that the prevailing direction of groundwater flow is towards the canal.

The following represents a more detailed discussion of the contaminants found in the sampled soils. Refer to Table 4-19b for specific information at each soil boring location.

VOCs

- VOCs were detected in soils from all 46 soil boring locations along the canal. Soils from GC-MW-11 contained the highest number of VOC detections (77) followed by GC-MW-40 (66) and GC-MW-12 (65).
- Soils from GC-MW-40 contained the greatest number of maximum detected concentrations of VOCs (7) followed by GC-MW-3 (5) and GC-MW-31 (4).
- Exceedances of the screening values occurred in soils at 40 of the 46 soil borings with most exceedances occurring at depths greater than 15 feet bgs. Soils from GC-MW-35 and GC-MW-27 had the highest number of detections exceeding the screening values (21) followed by GC-MW-47 (19) and GC-MW-23 and GC-MW-45 (both had 17). Soils from the following 6 remaining monitoring well locations, while containing detections of VOCs, did not exceed VOC screening values: GC-MW-4, GC-MW-14, GC-MW-15, GC-MW-16, and GC-MW-26, and GC-MW-42.
- The VOCs exceeding the screening values most frequently are listed below along with the maximum concentration and screening value:
    - Acetone was detected in 53 percent of the soil samples, exceeded the screening value in 24 percent of the soil samples, with a maximum concentration of 420,000 µg/kg at GC-MW-35 (screening value is 50 µg/kg).
    - Benzene was detected in 42 percent of the soil samples, exceeded the screening value in 16 percent of the soil samples, with a maximum concentration of 1,100,000 µg/kg at GC-MW-40 (screening value is 60 µg/kg).

  - Ethylbenzene was detected in 52 percent of the soil samples, exceeded the screening value in 13 percent of the soil samples, with a maximum concentration of 790,000 µg/kg at GC-MW-32 (screening value is 1,000 µg/kg).
  - m,p xylenes was detected in 56 percent of the soil samples, exceeded the screening value in 11 percent of the soil samples, samples at a maximum concentration of 570,000 µg/kg at GC-MW-40 (screening value is 1,600 µg/kg).
  - o-xylene was detected in 46 percent of all soil samples, exceeded the screening value in 11 percent of the soil samples, with a maximum concentration of 260,000 µg/kg at GC-MW-32 (screening value is 1,600 µg/kg).

The following compounds were also found at concentrations exceeding the screening values with the number of exceedances shown in parentheses: toluene (32), cis-1,2-dichloroethylene (5), methylene chloride (5), trichloroethylene (4), methyl ethyl ketone (3), trans-1,2-dichloroethene (2), 1,2-dichlorobenzene (1), 1,3-dichlorobenzene (1), and 1,4-dichlorobenzene (1).

SVOCs

- SVOCs were detected in soils from all 46 monitoring well locations along the canal. Soils from GC-MW-18 contained the highest number of SVOC detections (199) followed by GC-MW-39 (181) and GC-MW-11 (171).
- Soils from GC-MW-41 contained the greatest number of maximum detected concentrations of SVOCs (15) followed by GC-MW-40 (9) and GC-MW-11 and GC-MW-23 (each had 2).
- Screening values were exceeded in soils at 32 of the 46 soil borings with generally no differentiation in the vertical distribution of higher SVOC concentrations. Soils from GC-MW-40 had the highest number of detections exceeding the screening values (44) followed by GC-MW-27 (37) and GC-MW-11 (29). Soils from the following locations, while containing detections of SVOCs, did not exceed screening values: GC-MW-02, GC-MW-05, GC-MW-06, GC-MW-08, GC-MW-12, GC-MW-13, GC-MW-14, GC-MW-19, GC-MW-21, GC-MW-26, GC-MW-29, GC-MW-38, GC-MW-42, and GC-MW-46.
- The SVOCs exceeding the screening values most frequently are listed below along with their maximum concentration and screening value:
  - Benzo(a)anthracene was detected in 58 percent of the soil samples, exceeded the screening value in 23 percent of the soil samples, at a maximum concentration of 1,100,000 µg/kg at GC-MW-41 (screening value is 1,000 µg/kg).
  - Chrysene was detected in 57 percent of the soil samples, exceeded the screening value in 23 percent of the soil samples, at a maximum concentration of 1,100,000 µg/kg at GC-MW-41 (screening value is 1,000 µg/kg).
  - Benzo(b)fluoranthene was detected in 54 percent of the soil samples, exceeded the screening value in 19 percent of the soil samples, at a maximum concentration of 720,000 µg /kg at GC-MW-41 (screening value is 1,700 µg /kg).

- Benzo(k)fluoranthene was detected in 51 percent of the soil samples, exceeded the screening value in 16 percent of the soil samples, at a maximum concentration of 810,000 µg/kg (screening value is 1,700 µg/kg).
- Naphthalene was detected in 78 percent of the soil samples, exceeded the screening value in 12 percent of the soil samples, at a maximum concentration of 11,000,000 µg/kg at MW-40 (screening value is 12,000 µg/kg).

The following compounds were also found at concentrations exceeding the screening values with the number of exceedances shown in parentheses: benzo(a)pyrene (28), indeno(1,2,3-c,d)pyrene (28), acenaphthene (19), acenaphthylene (9), 4-methylphenol (8), phenanthrene (5), fluorene (4), 2-methylphenol (3), phenol (8), fluoranthene (3), dibenzofuran (3), pyrene (2), and anthracene (1).

Pesticides

- Pesticides were detected in soils from 42 of the 46 monitoring well locations along the canal. Soils from GC-MW-23 contained the highest number of pesticide detections (37) followed by GC-MW-11 (29) and GC-MW-27 (24). Pesticides were not detected at the following monitoring well locations: GC-MW-17, GC-MW-19, GC-MW-33, and GC-MW-46.
- Soils from soil boring GC-MW-27 contained the greatest number of maximum detected concentrations of pesticides (11) followed by GC-MW-23 (4) and GC-MW-11 (2).
- Screening values were exceeded in soils at 3 of the 46 soil borings. Soils from GC-MW-27 had the highest number of detections exceeding the screening values (3) followed by GC-MW-47 (2) and GC-MW-43 (1).
- The pesticides exceeding the screening values are listed below along with their maximum concentration and screening value:
    - Alpha BHC was detected in 4percent of all soil samples, exceeded the screening value in less than 1 percent of the soil samples, at a maximum concentration of 130 µg/kg at GC-MW-27 (screening value is 20 µg/kg).
    - Endrin was detected in 8percent of all soil samples, exceeded the screening value in less than 1 percent of the soil samples, at a maximum concentration of 110 µg /kg at GC-MW-27 (screening value is 60 µg/kg).
    - p,p'-DDE was detected in 9percent of all soil samples, exceeded the screening value in less than 1 percent of the soil samples, at a maximum concentration of 19,000 µg/kg at GC-MW-27 (screening value is 17,000 µg/kg).

PCBs

- PCBs were detected in soils from 6 of the 46 monitoring well locations. At each of the six monitoring well locations, only one compound was detected and no concentrations exceeded screening values. The following PCBs were detected below the screening values: Aroclor 1242 (GC-MW-31), Aroclor 1248 (GC-MW-42), Aroclor 1254 (GC-MW-01, GC-MW-32, GC-MW-40), Aroclor 1260 (GC-MW-25).

Metals and Cyanide

- Metals were detected in soils from all 46 monitoring well locations along the canal. Soils from GC-MW-41 contained the highest number of metal detections (208) followed by GC-MW-40 (193) and GC-MW-18 (174).
- Soils from GC-MW-25 contained the greatest number of detected maximum concentrations of metals (10) followed by GC-MW-23, GC-MW-24, GC-MW-37, and GC-MW-42 (each had 2).
- Screening values were exceeded in soils at 29 of the 46 soil borings with most exceedances occurring between ground surface and 15 feet bgs. Soils from GC-MW-27 had the highest number of metal detections exceeding the screening values (16) followed by GC-MW-25 (12) and GC-MW-32 and GC-MW-39 (each had 7).
- The metals exceeding the screening values most frequently are listed below along with the maximum concentration and screening value:
    - Mercury was detected in 32 percent of all soil samples, exceeded the screening value in 11 percent of the soil samples, at a maximum concentration of 45.2 mg/kg at GC-MW-39 (screening value is 0.73 mg/kg).
    - Arsenic was detected in 89 percent of all soil samples, exceeded the screening value in 7 percent of the soil samples, at a maximum concentration of 116 mg/kg at GC-MW-37 (screening value is 16 mg/kg).
    - Lead was detected in 98 percent of all soil samples, exceeded the screening value in 5 percent of the soil samples, at a maximum concentration of 34,700 mg/kg at GC-MW-25 (screening value is 450 mg/kg).

  The following metals were also found at concentrations exceeding the screening values with the number of exceedances shown in parentheses: barium (4), cadmium (4), silver (3), selenium (2), manganese (1), nickel (1), and zinc (1).

4.8.2 Summary

- Subsurface soil samples were collected from soil borings during the installation of monitoring wells to provide an indication of the range and concentrations of contaminants present both laterally and vertically in soils along the canal.
- Soil samples were collected from a total of 46 soil borings along the canal resulting in a total of 357 soil samples.
- At all soil boring locations, at least one contaminant concentration was higher than a screening value with the exception of GC-MW-14 and GC-MW-42 where there were no exceedances.
- The following summarizes the total number of detections and total number of exceedances noted in the 356 soil samples for each group of analytes.

Total Number of Detections in Soils				
VOCs	SVOCs	Metals	Pesticides	PCBs
1608	4701	5810	391	6

Total Number of Screening Value Exceedances in Soils				
VOCs	SVOCs	Metals	Pesticides	PCBs
308	443	101	6	0

- SVOCs exceeded screening values most frequently, followed by VOCs , metals, and pesticides. PCBs did not exceed screening values.

4.8.3 Split Sampling

During installation of the soil borings and monitoring wells, the USEPA collected split samples at locations that were being completed by National Grid and New York City. The split sample was collocated with the parent sample that was collected and analyzed by either National Grid or New York City. While some degree of heterogeneity is expected during soil sampling, a statistical comparison was performed between the split and parent sample results to evaluate the comparability of the data.

The results from the split soil sampling were evaluated by calculating relative percent differences (RPDs) between each associated pair of parent (*N* sample) and split (*S* sample) detects. The RPD was calculated using the following equation:

$$\text{RPD} = \frac{(N_{\text{value}} - S_{\text{value}}) \times 100\%}{(N_{\text{value}} + S_{\text{value}})/2}$$

Of the 3,279 pairs of results, neither the *N* value nor the *S* value was detected in 2,355 cases. In 65 cases the *N* value was detected but the *S* value was not, while in 246 cases the *S* value was detected but the *N* value was not. The RPD was calculated for the 613 remaining cases where both *S* and *N* values were detected.

Acceptable precision was defined as an RPD of less than 45 percent. The evaluated results had a mean RPD of 31.7 percent, which is considered within the acceptable range. The percentile of RPDs below 45 percent was 75.4 percent. Individual results varied as expected due to matrix, sampling, and laboratory considerations.

4.9 Groundwater

As with the soil sampling, groundwater samples were collected and analyzed to identify the types and relative concentrations of contaminants in groundwater in the vicinity of the canal. The evaluation of groundwater data included identification of the types of analytes detected in samples in the shallow and intermediate zones, comparison of detected concentrations to screening values, and assessment of the distribution of contaminants along the length of the canal.

4.9.1 Sample Results

Sample locations are shown in Figure 2-11. The complete analytical results for groundwater samples are provided in Appendix I, Tables I-32a through I-36a, and a sample-by-sample comparison with screening values is provided in Tables I-32b through I-36b. Appendix O presents the results grouped by the physical property / geographical location along the canal where the groundwater samples were collected.

A statistical summary was also compiled from the results of the groundwater analysis. This summary is presented in Table 4-20a for the shallow groundwater and in Table 4-20b for the intermediate groundwater. Table 4-20c summarizes the shallow groundwater results at each monitoring well location including the total number of detected constituents and the total number of constituents found to exceed screening values. Table 4-20d provides the same information for the intermediate groundwater. Please refer to Appendix O for groundwater results by geographical location along the canal and sampling depths at each monitoring well.

All classes of constituents (VOCs, SVOCs, pesticides, and metals) except PCBs were detected in samples from both the shallow and intermediate groundwater throughout the length of the canal. PCBs were not detected in any of the sampled monitoring wells. Chemical concentrations in groundwater were relatively higher in wells where NAPL saturation was observed in the soil borings. Measureable thicknesses of NAPL were observed in eight wells (GC-MW-7I, GC-MW-11S, GC-MW-23I, GC-MW-28S, GC-MW-29S, MW-35S, MW-40S, MW-47I) during at least one monthly measurement event, and four additional wells (GC-MW-11I, GC-MW-12I, GC-MW-23S, GC-MW-43I) had evidence of NAPL on the measuring tape, but measureable thicknesses were not reported.

VOC concentrations were higher than screening values in approximately 33 percent of the shallow monitoring wells and 67 percent of the intermediate monitoring wells along the canal. Similarly, SVOC concentrations were higher than screening values in approximately 33 percent of the shallow monitoring wells and in half of the intermediate monitoring wells. Pesticides, however, were detected in only one shallow monitoring well and in one intermediate monitoring well and exceeded the screening value at the intermediate monitoring well location. As noted above, PCBs were not detected in either the shallow or intermediate zones. The following metals exceeded their screening values: arsenic, barium, lead, nickel, and sodium. Sodium concentrations were higher than screening values in all monitoring wells (shallow and intermediate).

The following represents a more detailed discussion of the contaminants found in the sampled groundwater.

Shallow Groundwater Zone

VOCs

- VOCs were detected in groundwater samples from 38 of the 44 shallow monitoring wells located along the canal. Monitoring well GC-MW-33S contained the highest number of VOC detections (14) followed by GC-MW-43S (13) and GC-MW-05S (12).
- Groundwater results from GC-MW-12S contained the greatest number of maximum detected concentrations of VOCs (9) followed by GC-MW-26S (6) and GC-MW-33S and GC-MW-24S (3 each).
- Screening values were exceeded in groundwater samples from 17 of the 44 shallow monitoring wells. Groundwater samples from GC-MW-11S had the highest number of

detections exceeding the screening values (7) followed by GC-MW-12S and GC-MW-47S (both had 6); and GC-MW-13S, GC-MW-26S, GC-MW-39S, and GC-MW-41S (each had 5).

- The VOCs exceeding the screening values most frequently are listed below along with the maximum concentration and screening value:
  - Benzene was detected in 42 percent of the shallow groundwater samples, exceeded the screening value in 30 percent of the samples, at a maximum concentration of 7,600 μg/L at GC-MW-12S (screening value is 1 μg/L).
  - Ethylbenzene was detected in 52 percent of the shallow groundwater samples, exceeded the screening value in 30 percent of the samples, at a maximum concentration of 1,600 μg/L at GC-MW-12S (screening value is 5 μg/L).
  - o-xylene was detected in 52 percent of the shallow groundwater samples, exceeded the screening value in 27 percent of the samples, at a maximum concentration of 2,600 μg/L at GC-MW-12S (screening value is 5 μg/L).

The following compounds were also found at concentrations exceeding the screening values with the number of exceedances shown in parentheses: isopropylbenzene (8), toluene (6), chlorobenzene (3), 1,2-dichloroethane (2), styrene (2), 1,3-dichlorobenzene (1), 1,4-dichlorobenzene (1), chloroform (1), cis-1,2-dichloroethylene (1), vinyl chloride (1).

SVOCs

- SVOCs were detected in groundwater samples from 41 of the 44 shallow monitoring wells located along the canal. Monitoring well GC-MW-23S contained the highest number of SVOC detections (20) followed by GC-MW-35S (19) and GC-MW-32S and GC-MW-45S (18).
- Groundwater results from GC-MW-47S contained the greatest number of maximum detected concentrations of SVOCs (7) followed by GC-MW-41S (6) and GC-MW-13S (5).
- Screening values were exceeded in groundwater samples from 16 of the 44 shallow monitoring wells. Groundwater samples from GC-MW-13S contained the highest number of detections exceeding the screening values (4) followed by GC-MW-45S and GC-MW-41S (each had 3), and GC-MW-11S, GC-MW-23S and GC-MW-47S (each had 2).
- The SVOCs exceeding the screening values most frequently are listed below along with their maximum concentration and screening value:
  - Biphenyl was detected in 39 percent of shallow groundwater samples, exceeded the screening value in 18 percent of the samples, at a maximum concentration of 64 μg/L at GC-MW-13S (screening value is 5 μg/L).
  - Benzo(a)pyrene was detected in 14 percent of shallow groundwater samples, exceeded the screening value in 11 percent of the samples, at a maximum concentration of 2.1 μg/L at GC-MW-47S (screening value is 0.2 μg/L).
  - 2,4-dinitrotoluene was detected in 7 percent of shallow groundwater samples, exceeded the screening value in 7 percent of the samples, at a maximum concentration of 290 μg/L at GC-MW-13S (screening value is 5 μg/L).

The following compounds also exceeded the screening values with the number of exceedances shown in parentheses: bis(2-ethylhexyl)phthalate (2) and 4-chloroaniline (1).

Pesticides

- One pesticide (alpha endosulfan) was detected below the screening value in one groundwater monitoring well (GC-MW-18S).

PCBs

- PCBs were not detected in any of the shallow groundwater monitoring wells.

Total Metals and Cyanide

- Metals were detected in groundwater samples from all 44 shallow monitoring wells located along the canal. Groundwater sample GC-MW-24S contained the highest number of metal detections (21) followed by GC-MW-15S, GC-MW-28S, and GC-MW-29S (each had 19); and GC-MW-04S, GC-MW-12S, GC-MW-39S, and GC-MW-43S (each had 18).

- Groundwater results from GC-MW-24S contained the greatest number of maximum detected concentrations of metals (9) followed by GC-MW-09S (4) and GC-MW-27S (3).

- Screening values were exceeded in groundwater samples from all 44 shallow monitoring wells. Groundwater samples from GC-MW-24S contained the highest number of detections exceeding the screening values (7) followed by GC-MW-09S and GC-MW-29S (6), and GC-MW-12S and GC-MW-15S (both had 5).

- The metals exceeding the screening values most frequently are listed below along with their maximum concentration and screening value:

  - Sodium was detected in 100 percent of shallow groundwater samples, exceeded the screening value in 100 percent of the samples, at a maximum concentration of 7,080,000 µg/L at GC-MW-27S (screening value is 20,000 µg/L).

  - Arsenic was detected in 93 percent of shallow groundwater samples, exceeded the screening value in 29 percent of the samples, at a maximum concentration of 40 µg/L at GC-MW-24S (screening value is 10 µg/L).

  - Chromium was detected in 75 percent of shallow groundwater samples, exceeded the screening value in 9 percent of the samples, at a maximum concentration of 834 µg/L at GC-MW-24S (screening value is 50 µg/L).

  - Nickel was detected in 81 percent of shallow groundwater samples, exceeded the screening value in 2 percent of the samples, at a maximum concentration of 441 µg/L at GC-MW-24S (screening value is 100 µg/L).

No other metals exceeded their screening values.

Intermediate Groundwater Zone

VOCs

- VOCs were detected in groundwater samples from 42 of the 46 intermediate monitoring wells located along the canal. Groundwater samples GC-MW-18I and GC-MW-26I contained the highest number of VOC detections (each had 14) followed by GC-MW-01I and GC-MW-29I (each had 13) and GC-MW-27I (12).

- Groundwater results from GC-MW-33I contained the greatest number of maximum detected concentrations of VOCs (8) followed by GC-MW-25I (4) and GC-MW-32I (3).
- Screening values were exceeded in groundwater samples from 32 of the 46 intermediate monitoring wells. Groundwater from GC-MW-11I, GC-MW-18I, and GC-MW-46I contained the highest number of detections exceeding the screening values (each had 7) followed by GC-MW-20I and GC-MW-47I (each had 6).
- The VOCs exceeding the screening values most frequently are listed below along with the maximum concentration and screening value:
  - Benzene was detected in 54 percent of intermediate groundwater samples, exceeded the screening value in 43 percent of the samples, at a maximum concentration of 5,200 μg/L at GC-MW-30I (screening value is 1 μg/L).
  - Ethylbenzene was detected in 67 percent of intermediate groundwater samples, exceeded the screening value in 43 percent of the samples, at a maximum concentration of 6,300 μg/L at GC-MW-32I (screening value is 5 μg/L).
  - o-xylene was detected in 63 percent of intermediate groundwater samples, exceeded the screening value in 41 percent of the samples, at a maximum concentration of 2,000 μg/L at GC-MW-32I (screening value is 5 μg/L).

  The following compounds also exceeded the screening values with the number of exceedances shown in parentheses: toluene (16), cis-1,2-dichloroethylene (12), isopropylbenzene (11), trichloroethylene (TCE – 6), vinyl chloride (6), 1,2-dichloroethane (3), 1,2,3-trichlorobenzene (1), 1,2,4-trichlorobenzene (1), styrene (3), tetrachloroethylene (PCE - 1), trans-1,2-dichloroethene (2), and trichlorofluoromethane (1).

SVOCs

- SVOCs were detected in groundwater samples from 45 of the 46 intermediate monitoring wells located along the canal. Groundwater sample GC-MW-47I had the highest number of SVOC detections (22) followed by GC-MW-45I (20) and GC-MW-43I (19). SVOCs were not detected in GC-MW-19I.
- Groundwater results from GC-MW-07I contained the greatest number of maximum detected concentrations of SVOCs (13) followed by GC-MW-40I (4) and GC-MW-47I (3).
- Screening values were exceeded in groundwater samples from 23 of the 46 intermediate monitoring wells. Groundwater samples from GC-MW-47I and GC-MW-45I contained the highest number of detections exceeding the screening values (each had 3) followed by GC-MW-07I, GC-MW-09I, GC-MW-18I, GC-MW-23I, GC-MW-39I, and GC-MW-40I (each had 2).
- The SVOCs exceeding the screening values most frequently are listed below along with the maximum concentration and screening value:

- Biphenyl was detected in 50 percent of intermediate groundwater samples, exceeded the screening value in 41 percent of the samples, at a maximum concentration of 80 µg/L at GC-MW-31I (screening value is 5 µg/L).
- Benzo(a)pyrene was detected in 17 percent of intermediate groundwater samples, exceeded the screening value in 13 percent of the samples, at a maximum concentration of 11 µg/L at GC-MW-07I (screening value is 0.2 µg/L).
- Bis(2-ethylhexyl) phthalate was detected in 41 percent of intermediate groundwater samples, exceeded the screening value in 4 percent of the samples, at a maximum concentration of 77 µg/L at GC-MW-04I (screening value is 5 µg/L).

The following compounds also exceeded the screening values with the number of exceedances shown in parentheses: 2,4-dinitrotoluene (1) and hexachloroethane (1).

Pesticides

- Two pesticides (alpha endosulfan and beta BHC) were detected at GC-MW-31I. Beta BHC was detected above its screening value (0.084 µg/L compared to screening value of 0.04 µg/L)

PCBs

- PCBs were not detected in any of the intermediate monitoring wells.

Total Metals and Cyanide

- Metals were detected in groundwater samples from all 46 intermediate monitoring wells located along the canal. Groundwater sample GC-MW-20I contained the highest number of metal detections (19) followed by GC-MW-39I (17) and GC-MW-07I, GC-MW-15I, and GC-MW-43I (each had 16).
- Groundwater results from GC-MW-01I and GC-MW-39I contained the greatest number of maximum detected concentrations of metals (4) followed by GC-MW-20I (3) and GC-MW-13I and MW-09I (both had 2).
- Screening values were exceeded in groundwater samples from all of the 46 intermediate monitoring wells. Groundwater samples from GC-MW-01I, GC-MW-07I, GC-MW-09I, GC-MW-11I, GC-MW-18I had the highest number of metals exceeding the screening values (5) followed by GC-MW-06I, GC-MW-10I, GC-MW-12I, GC-MW-15I, GC-MW-17I, GC-MW-38I, GC-MW-39I, GC-MW-43I, and GC-MW-44I (each had 4).
- The metals exceeding the screening values are listed below along with the maximum concentration and screening value:
  - Sodium was detected in 100 percent of intermediate groundwater samples, exceeded the screening value in 100 percent of the samples, at a maximum concentration of 3,760,000 µg/L at GC-MW-39I (screening value is 20,000 µg/L).
  - Arsenic was detected in 89 percent of intermediate groundwater samples, exceeded the screening value in 30 percent of the samples, at a maximum concentration of 107 µg/L at GC-MW-21I (screening value is 10 µg/L).

- Barium was detected in 93 percent of intermediate groundwater samples, exceeded the screening value in 9 percent of the samples, at a maximum concentration of 2,900 µg/L at GC-MW-39I (screening value is 1,000 µg/L).
- Lead was detected in 75 percent of intermediate groundwater samples, exceeded the screening value in 9 percent of the samples, at a maximum concentration of 277 µg/L at GC-MW-09I (screening value is 15 µg/L).
- Nickel was detected in 90 percent of intermediate groundwater samples, exceeded the screening value in 2 percent of the samples, at a maximum concentration of 194 µg/L at GC-MW-07I (screening value is 100 µg/L).

No other metals exceeded their screening values.

4.9.2 Summary

- Groundwater samples were collected from shallow and intermediate monitoring wells to provide an indication of the range and concentrations of contaminants present both laterally and vertically in groundwater along the canal.
- Groundwater samples from all shallow monitoring wells contained at least one constituent that exceeded a screening value.
- The following summarizes the total number of detections and total number of exceedances noted in the shallow monitoring wells for each group of analytes.

Total Number of Detections in Shallow Groundwater

VOCs	SVOCs	Pesticides	PCBs	Metals
245	468	1	0	628

Total Number of Screening Value Exceedances in Shallow Groundwater

VOCs	SVOCs	Pesticides	PCBs	Metals
64	26	0	0	150

- In shallow groundwater, metals exceeded screening values most frequently, followed by VOCs and SVOCs. Pesticides did not exceed screening values and PCBs were not detected.
- Similarly, groundwater samples from all intermediate monitoring wells contained at least one constituent that exceeded a screening value.
- The following summarizes the total number of detections and total number of exceedances noted in the intermediate monitoring wells for each group of analytes.

Total Number of Detections in Intermediate Groundwater				
VOCs	**SVOCs**	**Pesticides**	**PCBs**	**Metals**
307	507	2	0	597

Total Number of Screening Value Exceedances in Intermediate Groundwater				
VOCs	**SVOCs**	**Pesticides**	**PCBs**	**Metals**
118	33	1	0	151

- Similar to shallow groundwater, metals exceeded screening values most frequently in intermediate groundwater, followed by VOCs and SVOCs. One pesticide concentration exceeded the screening value and PCBs were not detected.

4.9.3 Split Sampling

Split samples were also collected by USEPA during groundwater sampling performed by National Grid and New York City. The approach used for the soil was used to evaluate the groundwater split sample results.

Of the 4,094 pairs of results, neither the *N* value nor the *S* value was detected in 3,076 cases. In 81 cases the *N* value was detected but the *S* value was not, while in 308 cases the *S* value was detected but the *N* value was not. The RPD was calculated for the 629 remaining cases where both *S* and *N* values were detected.

Acceptable repeatability was defined as an RPD of less than 35 percent. The evaluated results had a mean RPD of 31.7 percent, which is considered within the acceptable range. The percentile of RPDs below 35 percent was 70.7. Individual results varied as expected due to matrix, sampling, and laboratory considerations.

4.10 Tissue

Fish and crab tissue samples were collected from the Gowanus Canal and reference areas in Gowanus Bay and Upper New York Bay and composited for analysis as described in Section 2.5. Fish and crab tissue samples were analyzed for pesticides, PCB congeners and metals; crab tissue samples were also analyzed for PAHs. Analytical results for small prey fish, crab edible tissue, crab hepatopancreas, larger fish fillets, and larger fish carcass samples are provided in Tables I-68 through I-84. The results for crab edible tissue and crab hepatopancreas, and larger fish fillets and larger fish carcasses, were mathematically combined to calculate whole body tissue concentrations. The calculated whole body tissue sample results are provided in Tables I-85 through I-91.

Table 4-21a presents a summary of the tissue data used in the ecological risk assessment and Table 4-21b presents a summary of the data used in the human health risk assessment. All tissue concentration data are reported on a wet weight basis. The significance of the measured concentrations is evaluated in the ecological and human health risk assessments presented in Appendices K and L, respectively.

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SECTION 5

Summary of Ecological and Human Health Risk Assessments

This section summarizes the ERA and HHRA performed for the Gowanus Canal Superfund Site. It includes background information, a description of the approach used for each assessment, and preliminary Conceptual Site Models. The complete ERA and HHRA are presented in Appendixes K and L, respectively.

5.1 Ecological Risk Assessment

The primary objective of the ERA is to evaluate the potential for risk to ecological receptors from contamination associated with the Gowanus Canal in the absence of any remedial action. The evaluation in Appendix K completes steps 1 through 7 of the ERA process as provided in USEPA's (1997) *Ecological Risk Assessment Guidance for Superfund* and its updates. A screening-level ERA (SLERA) and an ERA are presented in Appendix K of this RI report.

Over the years, significant industrial activity took place along the canal, as discussed in Section 1. Although much of the industrial activity has stopped, high contaminant levels have been measured in the canal sediments. The canal also continues to receive discharges from CSOs during significant storm events.

Habitats in the Gowanus Canal have been significantly influenced by surrounding industries and historic development activities. No areas of natural shoreline, wetlands, or natural upland remain along this water body. The entire length of the canal is bordered by wooden piers, bulkheads, concrete walls, and large boulders used for bank stabilization. Due to the highly urbanized nature of this water body and its surrounding habitats, the Gowanus Canal is expected to support a limited community of potential ecological receptors.

The adjacent upland areas bordering the canal provide minimal habitat for wildlife, and the bulkheaded shoreline is expected to eliminate the potential for most terrestrial wildlife to access the canal. There is the potential for some avian wildlife to directly access and use the canal as a habitat and foraging area. Piscivorous (fish-eating) species such as the double-crested cormorant *(Phalacrocorax auritus)* and great blue heron *(Ardea herodias)*, as well as dabblers like black duck *(Anas rubripes)*, *do* use the canal to forage for small prey fish, invertebrates, and algae.

The Gowanus Canal is expected to support aquatic life including benthic macroinvertebrates, zooplankton, and brackish and saltwater fish species. Benthic macroinvertebrates, including annelid worms (polychaetes and oligochaetes), amphipods, and small mollusks, were observed in canal sediments during the Phase 3 sample collection. Blue crabs (*Callinectes sapidus*) were captured in relatively large numbers during the Phase 3 RI activities. Planktonic organisms, including copepods and fish larvae and eggs, also have been captured during site surveys. A number of marine and brackish fish species present within the Upper New York Bay are also expected to occur within the canal. With the exception of a limited number of resident species such as mummichog (*Fundulus* sp.), most of the fish species expected to occur in this water body are migratory, seasonally transient, or move daily as part of their normal behavior. Limitations in the habitat and food resources provided by the canal and habitat conditions (seasonal high temperatures and low-oxygen conditions) are expected to limit the overall abundance and diversity of fish.

A CSM for ecological exposures presents an overview of site conditions, potential sources of contamination, potential contaminant migration pathways, and potential exposure pathways to potential receptors. Figure 5-1 presents the preliminary CSM for ecological receptor exposures developed for the Gowanus Canal. The physical and chemical aspects of the CSM are discussed further in Section 6.

The ERA evaluates the chemical analytical data from sampling of the following media during the Phase 3 RI:

- Surface sediment (0 to 6 inches)
- Surface water (wet and dry conditions)
- Fish and crab tissue residue

Fish tissue evaluated in the ERA included both smaller prey species (Atlantic tomcod and mummichog) and several larger fish species (American eel, striped bass, and white perch). In addition, the ERA evaluated the results of *Leptocheirus plumulosus* and *Nereis virens* chronic sediment bioassays conducted with splits of the surface sediment samples that were collected for chemical analysis. Data collected prior to the Phase 3 RI were not quantitatively evaluated in the ERA.

The following assessment endpoints were selected for evaluation in the ERA:

- **Benthic macroinvertebrate community survival and reproduction.** Benthic macroinvertebrates have direct contact with and frequently ingest sediment and could be directly exposed to chemicals in this medium. Surface sediment chemical analytical data and the results of the sediment bioassays with *Leptocheirus plumulosus* and *Nereis virens* were used to evaluate the potential for adverse effects to this receptor.

- **Water column-dwelling aquatic life community survival and reproduction.** Aquatic life in the canal could be exposed to chemicals in surface water by direct contact, respiration, and the ingestion of surface water. Surface water chemical analytical data (wet and dry events) were used to evaluate the potential for adverse effects to this receptor.

- **Avian herbivore survival and reproduction.** Avian herbivores (e.g., dabbling ducks) could be exposed through ingestion to chemicals that bioaccumulate in aquatic plants. Sediment chemical analytical data were used to model potential exposure and risks to this receptor.

- **Avian piscivores/omnivores survival and reproduction.** Avian piscivores/omnivores (e.g., heron) are top-level consumers and are thus exposed to bioaccumulative chemicals, especially those that have the potential to biomagnify through aquatic food chains. Fish and crab tissue chemical analytical data were used to model potential exposure and risks to this receptor group.

The results of all analyses and the risk characterization are provided in the ERA report in Appendix K.

5.2 Human Health Risk Assessment

The primary objective of the baseline HHRA is to assess the potential and current future health risks from contamination associated with the Gowanus Canal, in the absence of any remedial action. The risk assessment evaluates the carcinogenic risks and noncarcinogenic hazards to a reasonably maximally exposed individual, which is consistent with the National Contingency Plan (NCP) and Risk Assessment Guidance for Superfund (RAGS) HHRA guidance documents (USEPA, 1989, 1991, 2001, 2004, 2009). The reasonable maximum exposure (RME) is the highest exposure that is reasonably expected to occur at a site (USEPA, 1989). The baseline HHRA is presented as Appendix K of this RI report.

The preliminary CSM for human exposures presents an overview of site conditions, potential sources of contamination, potential contaminant-migration pathways, and potential exposure pathways to potential receptors. Figure 5-2 presents the preliminary CSM for human exposures developed for the Gowanus Canal. As noted, the physical and chemical aspects of the CSM are presented in Section 6.

As noted, chemical contamination has been found in sediments and other media associated with the Gowanus Canal. Potential current and future receptors to this contamination may include recreational users, anglers, local residents, and nearby industrial workers. The recreational receptors may contact surface water and sediment through incidental ingestion and dermal absorption; ambient air (volatile and particulate emissions from the surface water and sediment) at canal level while boating, fishing, and crabbing in the canal; and potentially, although less common and less likely, while swimming or diving in the canal.

Swimming or diving in the canal, although reported to occur, is rare due to the general conditions of the canal, which are associated largely with the CSO discharges. Anglers and children of anglers may also ingest the fish or crabs caught in the canal. Residents and industrial workers may inhale ambient air (associated with volatile and particulate emissions from the canal) at street level. Also, as it has been noted that during significant rainfall events, the canal can overflow (two or three times per year); these residents and industrial workers may contact surface water and sediment that has overtopped the canal through incidental ingestion and dermal contact. If any of the sediment that has overtopped the canal is not washed away with rain, it is usually swept up by the local residents or workers and does not accumulate.

Future use of the area surrounding the canal is most likely to remain the same as current use, with the potential for the construction of new housing, resulting in additional residents living close to the canal.

Currently, the NYSDOH has fish-consumption advisories for the Upper Bay of the New York Harbor (north of the Verrazano Narrows Bridge), of which the Gowanus Canal is part (NYSDOH, 2010). Despite the advisories, fishing and fish consumption do occur. The main contaminants of concern noted for these waters in the advisories are PCBs and dioxin in fish and cadmium, dioxin, and PCBs in crab and lobster. The advisories include the following:

- For women under 50 years and children under 15 years: Do not eat any fish from these waters, eat no more than a few meals per year of crab meat from these waters, and avoid eating the crab tomalley (hepatopancras) or cooking liquid.

- For all others: Do not eat gizzard shad, white perch, or crab and lobster tomalley (hepatopancreas) and cooking liquid; eat only one meal per month of altantic needlefish, bluefish, rainbow smelt, and striped bass; eat no more than four meals per month of all other fish species and blue crab meat.

The HHRA evaluates the chemical analytical data sampled from the following media during the Phase 3 remedial investigation of the Gowanus Canal:

- Surface sediment (0 to 6 inches, exposed and shallow sediment)
- Surface water (wet and dry conditions)
- Ambient air (canoe and street level from both sampling events)
- Fish and crab tissue residue

Data collected prior to the Phase 3 RI were not quantitatively evaluated in the HHRA.

Fish and crab that were used for quantitative evaluation in the HHRA included striped bass, white perch, eel, and blue crab. Edible tissue (filet only) samples were analyzed to assess potential human health risks associated with ingestion of striped bass, white perch, and eel. For blue crab, edible portion samples and hepatopancreas samples were analyzed. Risks were quantified for the combined edible portion and hepatopancreas samples.

The exposure scenarios and pathways evaluated in the HHRA include the following:

- Adult, adolescent (12–18 years old), and child (0–6 years old) recreational: incidental ingestion and dermal contact with canal surface water (during both wet and dry sampling events), incidental ingestion and dermal contact with exposed and near shore sediment in the canal, and inhalation of ambient air at canal level (both prior to and during aeration system operation).

- Adult and adolescent (12–18 years old) anglers and child (0–6 years old) of angler: ingestion of fish (striped bass, white perch, and eel) and crab caught in the canal.

- Adult and child (0–6 years) residents: inhalation of ambient air at street level (both prior to and during aeration system operation), incidental ingestion and dermal contact with canal overflow surface water (using surface water collected during wet events), and incidental ingestion and dermal contact with sediment deposited adjacent to the canal (using surface sediment data) during canal overflow events.

- Adult industrial worker: inhalation of ambient air at street level (both prior to and during aeration system operation), incidental ingestion and dermal contact with canal overflow surface water (using surface water collected during wet events), and incidental ingestion and dermal contact with sediment deposited adjacent to the canal (using surface sediment data) during canal overflow events.

The results of all analyses and the risk characterization are provided in the HHRA report in Appendix L.

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SECTION 6

Conceptual Site Model

This section presents a CSM for the Gowanus Canal based on the data collected for this RI and on other studies that have been completed for the canal. The CSM summarizes and integrates information about historical and ongoing sources of contamination, nature and extent of contamination, contaminant fate and transport mechanisms, and risks to humans and wildlife from exposure to contaminated sediments in the canal. As noted in USEPA's (2005) contaminated sediment remediation guidance, the CSM is an important tool for evaluating the potential effectiveness of remedial alternatives. Three CSMs are often developed for complex sediment sites: (1) a CSM of the physical and chemical aspects of the system, (2) an ecological CSM, and (3) a human health CSM. The preliminary CSMs showing the exposure pathways and receptors that were evaluated in the ERA and HHRA are presented in Figures 5-1 and 5-2, respectively.

Diagrams illustrating the major components of the physical and chemical CSM are presented in Figures 6-1 and 6-2a through 6-2c. Figure 6-1 illustrates the movement of contaminants from the original sources to surface water and sediment in the canal and the processes that affect the fate and transport of the contaminants. This physical and chemical CSM is presented in the same format as the ecological and human health CSMs. Figures 6-2a through 6-2c summarize the primary aspects of the physical and chemical CSM on maps of the canal. The receptors that were determined to be at risk from exposure to contamination in the canal and the associated exposure pathways were integrated to create an overall CSM. The overall CSM will then be used to guide the development of remedial alternatives in the FS and will be continually refined as new information becomes available.

6.1 Contaminant Sources and Release Pathways

The Gowanus Canal has been affected by numerous known and potential sources of contamination for a period of about 140 years. These sources and the release pathway(s) for each include the following (Figure 6-2a):

- **Direct discharges of waste from historical industrial activities.** These activities included manufactured-gas production; bulk handling of products such as petroleum, coal, chemical fertilizers, oil, and scrap metal; various manufacturing activities; and other industrial operations. The industrial use of the canal began in the 1870s, peaked in the period from 1900 to 1932, and has declined to the present day (Hunter Research et al., 2004). Wastes from many of these operations were discharged directly into the canal. Based on the site history and the poor environmental practices typical of the era, a large quantity of waste was likely released via this pathway. Given the decline of industrial activity since the early 1900s and the implementation of the Clean Water Act in the early 1970s, direct discharges from industrial activities were substantially reduced or controlled over time. The declining level of contaminant loading to the canal is apparent in the vertical profiles of chemical concentrations in sediment cores (Figures 4-7a through 4-9c).

- **Discharges of sewage and stormwater.** The Gowanus Canal served as an open sewer when it was initially constructed in the late 1860s. By the late 1870s, sewers entering the canal carried a combination of household waste, industrial effluent from gas works and other industries, and stormwater runoff (Hunter Research et al., 2004). Prior to the implementation of the Clean Water Act, the contaminant load in sewage and stormwater discharges to the canal was greater than it is under present-day conditions. New York City has taken various measures over the years to mitigate the impacts of sewage and stormwater discharges, and a variety of additional upgrades and control measures is in progress or planned as part of the LTCP. Today, CSOs occur only during wet weather, discharging a mixture of sanitary sewage and stormwater to the canal. Of the 10 active CSOs, two discharge 66 percent of the total annual wet-weather discharge, and two others discharge another 29 percent. The reconstruction of the Gowanus Wastewater Pump Station is expected to decrease CSO discharges to the canal by approximately 34 percent. The CSO water sampling performed for this RI, in conjunction with information about discharge volumes, can be used to estimate contaminant loading from the CSOs under present-day conditions. The RI sampling results indicate that PAHs and metals are the most prevalent contaminants in the CSO discharges. The highest concentrations of some metals in soft sediment are found near CSO outfalls (e.g., lead and mercury at the head of the canal near RH-034, copper near OH-007, lead (and PCBs) at RH-035).

- **Ongoing direct discharges from pipe outfalls.** A number of pipe outfalls other than the 13 active New York City CSO and stormwater outfalls line the canal. A number of discharges to the canal are permitted under the National Pollutant Discharge Elimination System (NPDES)/SPDES, including three stormwater industrial permits, one stormwater construction permit, and three individual permits. The pipe outfall survey performed for the RI was the initial step in identifying and characterizing potential ongoing contaminant discharges to the canal from these pipes. The pipe outfall sampling provides a snapshot survey of 12 of the 14 active discharges present at the time of the survey. The flow rates from all but one of the active discharges were less than 1 L/min.

- **Discharges to the canal from contaminated sites.** Contaminated sites adjacent to Gowanus Canal are identified and investigated under the purview of the New York State Department of Environmental Conservation (NYSDEC). Environmental investigations are in progress at three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan). Contaminants from these sites appear to have been transported to the canal via surface runoff (i.e., overland transport of contaminated soils), migration of NAPL through subsurface soils into canal sediments, and groundwater discharge of dissolved-phase contaminants to the canal. The sediment-coring effort performed for this RI indicates that NAPL contamination is pervasive in native sediments underneath the canal between the head of the canal and the Gowanus Expressway, and in soft sediment in the middle reach of the canal. The NAPL is thought to be coal tar waste from the three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan) that has migrated through subsurface soils, under or through the bulkheads, and into the more permeable native sediments under the canal. PAHs and BTEX are major constituents of coal tar.

The hydrogeologic investigation indicates that groundwater discharges to the canal, although flow reversals occur at some locations and tidal stages. Groundwater contamination was found on some of the properties abutting the canal; therefore, the transport of dissolved-phase contaminants to the canal via groundwater discharge is expected to occur at certain locations.

Sediments and contaminants can also be transported into the Gowanus Canal from Gowanus Bay and Upper New York Bay via tidal flow and from Buttermilk Channel via flow through the flushing tunnel. The surface sediment and surface water data from the reference locations in Gowanus Bay and Upper New York Bay and the surface water data from Buttermilk Channel suggest that contaminant contributions from these sources are minor compared to the sources identified above. Contaminants could also be introduced into the canal via atmospheric deposition, although this contribution is expected to be minor given the small surface area of the canal.

As noted above, the primary sources of contamination to the canal have decreased over time due to the decline of industrial activity and improved environmental practices in response to the implementation of the Clean Water Act. Contaminant loads are expected to decrease further with improvements to the wastewater and stormwater systems and identification and remediation of adjacent upland contaminated sites. Estimating the magnitude of the ongoing sources of contamination to the canal will be a key component of the FS.

6.2 Extent of Contaminated Media

A variety of contaminants has been detected in sediments in the canal (Figure 6-2b). BTEX, PAHs and other SVOCs, pesticides, PCBs, and metals are ubiquitous in soft sediment, particularly north of the Gowanus Expressway. Table 6-1 summarizes the average concentrations of the VOCs, SVOCs, pesticides, and metals that are higher than ecological screening values in the greatest number of surface sediment samples. The average concentrations are substantially lower in the top 6 inches of sediment than in buried soft sediments, reflecting the reduction in contaminant loading over time. Average concentrations of NAPL-related constituents (BTEX and total PAHs) are relatively high in both soft and native sediments, whereas concentrations of total PCBs, total DDT, and metals are substantially lower in the native sediment when compared to the concentrations in soft sediment.

The NAPL in the native sediments is found primarily north of the Gowanus Expressway. NAPL is known to migrate into the canal from the three former MGP sites through subsurface soils and through the bulkheads. High PAH concentrations are present in native sediment at the vertical limit of the investigation, which was 6 feet below the contact between the native and soft sediment layers. The purpose of the sediment coring investigation was to delineate the degree of vertical contamination within the practical limits of a potential remedy.

Overall, the average concentrations of copper and lead in surface sediment decrease from the head of the canal to Gowanus Bay, and total PAH concentrations are highest in the middle reach of the canal and decrease south of the Gowanus Expressway (Figure 6-3). Contaminant concentrations in surface sediments in Gowanus Bay and Upper New York Bay are substantially lower than those in the canal study area.

Average contaminant concentrations in soft sediment show spatial trends similar to those for surface sediment (Figure 6-4). Average copper and lead concentrations are highest in the upper reach of the canal, and decrease in a downstream direction. Average concentrations of BTEX, total PAHs, total DDT, and total PCBs are highest in the middle reach of the canal and drop sharply in the lower reach. Average concentrations of BTEX and total PAHs in native sediment show the same trends as those for soft sediment.

VOCs (primarily BTEX), PAHs, and metals were the most commonly detected constituents in surface water samples. Concentrations of benzene, PAHs, and manganese were significantly higher in surface water from the canal than in Gowanus Bay and Upper New York Bay in both dry- and wet-weather conditions. In dry weather, the only discharges to the canal appear to be small volumes of effluent from outfalls other than CSO or stormwater outfalls. Therefore, the surface water concentrations that are significantly higher than reference in dry weather are most likely the result of flux from the sediment bed, which is the process by which contaminants in the sediment pore water (the spaces between the solid sediment particles) move into the surface water as dissolved-phase contamination.

In wet-weather conditions, concentrations of some VOCs and several PAHs in canal surface water were significantly higher than in dry-weather conditions, indicating some additional contaminant loading from the CSO and stormwater discharges. However, the concentrations of benzene, several PAHs, arsenic, and major cations (calcium, magnesium, potassium, and sodium) were significantly higher in dry-weather conditions.

6.3 Contaminant Fate and Transport

A variety of physical and chemical processes influences the fate and transport of contaminants in the Gowanus Canal sediments (Figure 6-2c). All of the classes of contaminants detected in canal sediments (VOCs, SVOCs, pesticides, PCBs, and metals) could have been present in sources identified in Section 6.1. Many of these contaminants have a low solubility and an affinity for fine-grained sediment particles and organic matter. Therefore, the accumulation of soft sediments in the canal over time has resulted in the accumulation of high levels of persistent contaminants. Because of low current velocities and limited tidal exchange with Gowanus Bay, the contaminated sediments accumulate in the canal rather than being flushed out to the bay. Contaminants with a higher solubility and volatility (i.e., VOCs and some of the low-molecular-weight SVOCs) would tend to disperse in the water column.

Because many of the contaminants that are present at high levels in the Gowanus Canal soft sediments have an affinity for fine-grained sediment particles and organic matter, the fate and transport of these contaminants is related to the fate and transport of the sediments. Sediments can remain relatively stable and undisturbed after they are deposited, or they can be resuspended by tidal currents, propeller wash, and dredging or other disturbances; transported by currents; and redeposited in relatively low-energy areas. The sediments tend to accumulate in the canal, as evidenced by the following:

- **Site history.** Siltation in the canal was a problem from the time construction was completed. As described in Section 1.3.3, dredging north of Hamilton Avenue was irregular and infrequent. Even after the flushing tunnel was constructed in 1911, pollution and siltation were still a problem due to continued inflow of waste and stormwater and the absence of dredging (Hunter Research et al., 2004).

- **Bathymetric changes.** The bathymetric differencing evaluation presented in Section 3.1 identified 2 to 3 feet of sediment accumulation between 2003 and 2010 in the reach between the floatables containment boom at Sackett Street and Carroll Street, and 1 to 2 feet of accumulation between Carroll Street and 3rd Street. An area of erosion was identified near the outlet of the flushing tunnel, and minimal sediment accumulation was noted upstream of the floatables containment boom, which indicates that sediments transported by the currents generated by the flushing tunnel are deposited farther down the canal where current velocities decrease. Areas of sediment accumulation in the lower reach of the canal were also identified.

- **Radioisotope analysis.** Radioisotope profiling is a useful tool for dating sediment layers in an undisturbed core and determining the net accumulation rate of sediments (USGS, 1998). Lead-210 and cesium-137 are two radioisotopes that are commonly used for this purpose. National Grid performed radioisotope analysis of seven cores collected in the canal in 2005 (GEI, 2007). Although most of the cores showed evidence of disturbances that reduce the accuracy of the age dating estimates, the cores that could be dated indicated net sediment accumulation rates on the order of 2 to 6 cm/year.

Sediments deposited in Gowanus Canal may be resuspended by currents, propeller wash, dredging, and other disturbances. The canal is a low-velocity environment, with current velocities generally less than 0.5 feet/second (USACE ERDC, undated). These current speeds are insufficient to substantially erode sediment deposits on the bottom of the canal. Currents generated by the flushing tunnel appear to erode sediments near the outlet of the tunnel, but the sediments settle out where the current velocities decrease farther down the canal.

Sediments in Gowanus Canal appear to be frequently resuspended and mixed by propeller wash from vessel traffic in the canal. The effects of propeller wash are particularly evident in the reach between the Gowanus Expressway and 3rd Street, where minimal sediment accumulation was observed between 2003 and 2010. This reach experiences frequent tug and barge traffic associated with the concrete plant at the end of 5th Street. Evidence of propeller scour was also seen near the southern end of the canal study area in the 2010 bathymetric survey. Significant tug activity was observed on the eastern and western sides of the canal in the southern part of the study area during the RI field investigations.

In addition to providing age-dating estimates, radioisotope profiles can be used to evaluate the long-term stability of the sediment bed. In an undisturbed sediment profile where sediments are deposited continuously at a constant rate, lead-210 concentrations decrease exponentially with increasing depth, and cesium-137 shows a clearly defined subsurface peak that corresponds with the early 1960s, when the amount of atmospheric nuclear testing peaked. As shown in Figure 6-5, the lead-210 and cesium-137 profiles in the radioisotope cores collected by National Grid in the main channel of the canal deviate from the ideal profile, which indicates that the sediments were disturbed after they were initially deposited (and were probably not deposited at a constant rate). Only the profiles of the cores collected in the 4th and 6th Streets turning basins, which experience less vessel traffic, show evidence of a stable profile.

Given the low-current velocities in the canal, most of the sediments resuspended by propeller wash likely settle out relatively quickly in the same reach of the canal. However, finer-grained sediment particles that remain suspended in the water column for a longer period of time may be transported out of the canal by tidal currents. The amount of sediment transported out of (or into) the canal in typical weather conditions or during storm events has not been measured or estimated; however, the steep drop in total PAH concentration in surface sediments from the middle reach of the canal to the lower reach, and the additional drop from the lower reach of the canal to the Gowanus Bay and Upper New York Bay reference locations (Figure 6-3) indicates that much of the sediment-associated contamination remains relatively close to its source.

Other processes that physically mix sediments include bioturbation and ebullition. Bioturbation is the mixing of surface sediments in the biologically active zone by benthic organisms such as worms and crabs. The decomposition of organic material in sediment generates gas bubbles, which can mix sediment as they rise to the water surface. Ebullition also can facilitate the transport of NAPL to the surface, generating sheen on the surface of the water.

Different classes of contaminants are influenced by different fate and transport processes. VOCs and the low-molecular-weight PAHs such as naphthalene are more soluble than the other contaminants and therefore have a greater tendency to dissolve in the water column and volatilize to the atmosphere. In the RI, VOC and PAH concentrations in two rounds of air samples collected from the breathing zone of a canoeist within the canal, at street level next to the canal, and at background locations were similar. The constituents detected were typical of those found in urban environments.

PAHs are a class of hydrocarbon compounds composed of two or more fused aromatic rings. The low-molecular-weight PAHs have one to five rings, and the high-molecular-weight PAHs have four to six rings. PAH mixtures are commonly categorized as pyrogenic (combustion-related), petrogenic (petroleum-related), or biogenic (synthesized by plants or animals). Petrogenic sources of PAHs (e.g., crude oil and refined petroleum products) are generally enriched in two- and three-ring PAHs relative to pyrogenic sources, and pyrogenic sources (e.g., coal tar) are generally enriched in four- to six-ring PAHs. The composition of a PAH mixture from a specific source changes after it enters a waterway due to a variety of weathering processes, including dissolution and biodegradation (decomposition by microorganisms).These processes preferentially reduce the proportion of two- and three-ring PAHs, thereby increasing the proportion of four- to six-ring PAHs over time (Boehm, 2006). The high-molecular-weight PAHs are resistant to degradation and tend to persist in the environment for long periods of time.

Many of the metals of environmental concern (cadmium, copper, lead, nickel, silver, and zinc) bind with sulfides in a geochemically reducing environment, forming insoluble sulfides. The high sulfide concentrations in surface sediment and soft sediment in the canal indicate that the metals are immobilized in the sediment as sulfide compounds. Further analysis of metals availability based on AVS/SEM analyses is provided in the ERA. Mercury concentrations in Gowanus Canal surface sediments were slightly higher than concentrations at reference locations in Gowanus Bay and Upper New York Bay. It should be noted that the Northeast Regional Total Maximum Daily Load has provided a strategy for reducing sources of mercury to the environment on a regional basis (CDEP et al., 2007).

A number of factors influence the degree to which chemicals in sediment are bioavailable and toxic to aquatic organisms, including the TOC and reactive sulfide concentrations of the sediment. The bioavailability of the contaminants in Gowanus Canal sediments was evaluated in the ERA. In addition, some contaminants are known to bioaccumulate in the tissues of aquatic organisms. The tissue sample results indicate that PCBs, pesticides, and some metals are found in the tissues of fish and crab collected from the canal at concentrations greater than those found in samples from the reference area in Gowanus Bay and Upper New York Bay. PAHs were also found in crab tissues at concentrations higher than those found in the reference area.

6.4 Risks to Humans and Wildlife

The Baseline Ecological Risk Assessment evaluated potential risks to benthic (sediment-dwelling) organisms and water-column-dwelling organisms from exposure to contaminants in sediment and surface water, and risks to wildlife from consuming contaminated prey items and sediment during feeding. Benthic organisms may be at risk from exposure to contaminated sediment, primarily due to the PAHs present. Other chemicals contributing to the risk include PCBs and metals (barium, cadmium, copper, lead, mercury, nickel and silver). Water-column dwelling organisms may be adversely affected by lead during wet weather events. Aquatic herbivores such as the black duck may be at risk from exposure to PAHs, and avian omnivores such as the heron may be at risk from exposure to mercury. There is no potential risk to avian piscivores such as the double-crested cormorant from the ingestion of fish in the canal..

The Human Health Risk Assessment evaluated the potential human health risks associated with direct contact with surface sediment and surface water in the Gowanus Canal, ingestion of fish and crabs, direct contact with sediment and surface water that overtops the canal during extreme tidal or storm surge conditions, and inhalation of emissions from the canal into the ambient air near the canal. Adults, adolescents and children using the canal for recreational purposes may be at risk due to exposure to PAHs in surface water and surface sediment, assuming that the recreational use/swimming in the canal would occur at frequencies, durations, and exposures is typical of most water bodies. Adults and children may also be at risk from exposure to PAHs in sediments and surface water in canal overflow. Exposure to lead in sediment and surface water by children swimming in and living near the canal (based on residential exposure assumptions, including potable use of the surface water) may result in adverse effects. Adults, adolescents, and children may also be at risk from exposure to PCBs if they consume fish and crabs caught in the canal. The HHRA assumed fishing/crabbing and ingestion of the fish /crab from the canal at typical recreational consumption rates, which are conservative given the nature of the canal.

6.5 Summary

Unacceptable ecological and human health risks have been identified based on potential exposure to contaminated sediment, surface water, and prey in the Gowanus Canal. These risks are attributed primarily to PAHs, PCBs, and metals (barium, cadmium, copper, lead, mercury, nickel and silver). All of these contaminants have been deposited in the canal as a result of historical and current discharges to the canal. High PAH concentrations are found in coal tar waste adjacent to the three former MGP sites along the canal. PAHs and metals are the most prevalent contaminants detected in present-day CSO discharges to the canal, as well as in discharges from other outfalls. PAHs and metals are also present in contaminated groundwater discharging to the canal.

PAHs, PCBs, and the metals identified above are found in the Gowanus Canal surface sediments at concentrations that are significantly higher than those found in the Gowanus Bay and Upper New York Bay reference area. PAHs and metals were also detected in surface water in the canal, with PAH concentrations significantly higher than those in the reference area under both dry and wet weather conditions. PAH concentrations in crab tissue collected from the canal were higher than in crab tissue collected from the reference area, and PCB concentrations were also higher in fish and crab tissue samples collected in the canal. Concentrations of metals in fish and crab tissue samples from the canal and reference area are varied.

This CSM can serve as the basis for developing remedial alternatives for the canal in the FS.

SECTION 7
Summary and Conclusions

This section summarizes the results of the Gowanus Canal RI with respect to the four primary goals of the investigation, which are the following:

- Characterize the nature and extent of contamination in the Gowanus Canal to the degree necessary to evaluate the human health and ecological risks and to develop a remedy to reduce these risks
- Document the sources of contamination to the Gowanus Canal, including a preliminary evaluation of ongoing sources of contamination that need to be addressed so that a sustainable remedy can be developed and implemented
- Determine the human health and ecological risks from exposure to contamination in the canal
- Determine the physical and chemical characteristics of the canal that will influence the development, evaluation, and selection of remedial alternatives.

The primary findings related to each of these objectives are summarized below.

7.1 Nature and Extent of Contamination

The nature and extent of contamination within the Gowanus Canal have been defined to the degree necessary to complete the risk assessments and the FS. The horizontal and vertical distribution and extent of contamination in surface sediment (0-to-6-inch depth interval), soft sediment (from a depth of 6 inches below the sediment surface to the contact with the native Gowanus Creek sediments) and native sediment (i.e., original Gowanus Creek alluvial and marsh deposits) was characterized on the basis of field observations and analysis of sediment samples as follows:

7.1.1 Surface Sediment

In surface sediment, concentrations of PAHs, PCBs, and eight metals (barium, cadmium, chromium, copper, lead, mercury, nickel and silver) were significantly higher in the canal than at reference locations in Gowanus Bay and Upper New York Bay. Concentrations of many of these constituents were higher than ecological and human health screening values. Lead and copper were detected most frequently and at the highest concentrations.

In surface sediment, average concentrations of total PAHs were highest in the middle reach of the canal and decreased steeply between the middle and lower reaches of the canal. Average concentrations of lead and copper were highest in the upper reach of the canal and decreased in a downstream direction, with the steepest drop occurring between the middle and lower reaches of the canal.

7.1.2 Subsurface Sediment

The sediment-coring effort performed for this RI indicates that NAPL contamination is pervasive in native sediments underneath the canal between the head of the canal and the Gowanus Expressway, and in soft sediment in the middle reach of the canal. The NAPL appears to be coal tar waste from the three former MGP sites (Fulton, Carroll Gardens/Public Place, and Metropolitan) that is migrating through subsurface soils, under or through the bulkheads, and into the more permeable native sediments under the canal. PAHs and BTEX are major constituents of coal tar.

Total PAHs and VOCs, particularly the BTEX constituents, were frequently detected at high concentrations in both the soft and native sediment units. Pesticides, PCBs, and metals were all frequently detected in the soft sediment but were infrequently detected or detected at lower concentrations in the native sediments.

In the deeper soft sediment, VOCs (primarily BTEX), SVOCs (primarily PAHs), pesticides, PCBs, and metals were all detected at higher concentrations than those found in the surface sediments. The highest total PAH and BTEX concentrations in soft sediment along the length of the canal were found near the three former MGP sites and between 1st and 3rd Streets, in the vicinity of the old Power Station. Copper, lead and mercury concentrations in soft sediment along the length of the canal were variable. Lead and mercury concentrations were highest at the head of the canal adjacent to the RH-034 outfall, and copper concentrations were highest near the OH-007 outfall. Total PCB concentrations in soft sediment were highest in the 7th Street turning basin, near the RH-035 outfall and near the Carroll Gardens/Public Place former MGP site.

In native sediment, NAPL-related constituents (BTEX and total PAHs) were frequently detected at high concentrations. High BTEX and total PAH concentrations were found between the head of the canal and the Gowanus Expressway, adjacent to the three former MGP sites. The maximum concentrations were found in the middle reach of the canal.

In most areas north of the Gowanus Expressway, NAPL and high-PAH concentrations were found in sediment at the maximum depth of the investigation activities, which was 6 feet below the contact between the soft and native sediment layers. The purpose of the sediment coring investigation was to delineate the degree of vertical contamination within the practical limits of a potential remedy rather than to define the vertical extent of contamination to its maximum depth.

7.1.3 Surface Water

The major findings related to the nature and extent of contamination in surface water in the canal were as follows:

- VOCs, SVOCs, and metals were detected in surface water samples. Pesticides and PCBs were not detected. BTEX compounds were the most common VOCs detected, and PAHs were the most common SVOCs detected.
- Concentrations of some VOCs in canal surface water were significantly higher in wet-weather conditions than in dry-weather conditions. Concentrations of some PAHs and metals were higher in wet-weather conditions, whereas others were higher in dry-weather conditions.

- Concentrations of benzene, PAHs, and manganese in the canal surface water were significantly higher than their concentrations at the reference locations in both dry- and wet-weather conditions.

7.1.4 Ambient Air

The sampling results for air samples collected from canoe-level and street-level locations along the length of the canal and from three background locations indicate that the types and concentrations of VOCs and PAHs detected in air samples were similar regardless of sample location. The constituents detected were typical of those found in urban environments.

7.2 Sources of Contamination

Major findings related to the assessment of historical and ongoing sources of contamination to the Gowanus Canal are summarized below.

- **Direct discharges from historical industrial activities.** The higher concentrations of most contaminants in subsurface (buried) soft sediments compared to those in surface sediments reflect the contribution of historical sources of contamination that are no longer present along the canal as well as historical contributions from CSOs.

- **CSO and stormwater discharges.** Sampling results for wet-weather flow samples collected from the CSO system indicate that VOCs, SVOCs (primarily PAHs), and metals are discharged to the canal during overflow events. Pesticides and/or PCBs were detected in the CSO sediment at two locations at concentrations that substantially exceeded the human health and/or ecological screening values. VOCs, SVOCs (primarily PAHs), and metals were also detected in residual sediment collected from the CSO pipes during dry-weather conditions. In addition, the highest concentrations of lead and mercury in soft sediment were found at the head of the canal, adjacent to the RH-034 outfalls.

- **Discharges from other pipe outfalls.** Nearly 250 outfall features were identified in the RI, most of which were pipes. Twenty-five of these pipe outfalls were observed to be actively discharging during dry weather. The effluent from 14 of the 25 active outfalls could not be attributed to tidal drainage (i.e., drainage of seawater that entered the pipe at high tide). Samples from 12 of these 14 outfall discharges contained VOCs, SVOCs (primarily PAHs), and metals (two of the discharges were not sampled due to low flow rates). Pesticides and PCBs were not detected. The flow rate from all but one of the active outfalls was very small (< 1 L/min).

- **Permitted discharges.** A review of NYSDEC and USEPA databases identified five active permitted discharges to the canal. Three of these permitted outfalls were not observed to discharge during the RI. Two of the permitted outfalls could not be clearly identified during the RI because of the number of outfall features in their vicinity.

- **Discharges and potential discharges to the canal from contaminated sites adjacent to the canal.** The RI sampling results indicate that NAPL contamination is present in native and soft sediment, primarily in native sediment north of the Gowanus Expressway. The

NAPL appears to have migrated and continues to migrate from the three former MGP sites through subsurface soils into the native sediments beneath the canal.

- **Transport of contaminants in groundwater discharging to the canal.** The soil-sampling results from borings in selected areas adjacent to the canal indicate the presence of all classes of contaminants (VOCs, SVOCs, pesticides, PCBs, and metals). The same types of contaminants, with the exception of PCBs, were detected in groundwater samples. The hydrogeologic evaluation indicates that groundwater flows towards and discharges to the canal, with episodic flow reversals related to tidal fluctuations. Therefore, the transport of dissolved-phase contaminants to the canal via groundwater discharge is occurring at some locations.

7.3 Ecological and Human Health Risks

The Gowanus Canal has no natural shoreline, wetlands, or upland areas. The community of potential ecological receptors using the canal includes fish-eating birds; dabbling ducks; invertebrates such as worms, amphipods, and mollusks; and crabs and fish. The potential ecological risk to these receptors from exposure to surface water and sediment in the canal was evaluated in the ERA. The HHRA evaluated potential risks to recreational users, anglers, residents, and industrial workers near the canal.

7.3.1 Ecological Risks

The combined SLERA and BERA performed for the Gowanus Canal completes Steps 1 and 7 of the 8-step ERA process as described in the USEPA (1997) Ecological Risk Assessment Guidance for Superfund and its updates. As described in Section 5.1, the survival and reproduction of following receptor groups were selected for evaluation in the ERA:

- Benthic- (sediment-) dwelling macroinvertebrate communities;
- Water column-dwelling aquatic life communities; and,
- Avian wildlife (aquatic herbivores, aquatic omnivores, and aquatic piscivores).

The following summarizes the key investigation methods and findings and conclusions for each receptor group.

Benthic Macroinvertebrate Communities

Risks to benthic macroinvertebrate communities were evaluated primarily through the use of laboratory-based sediment bioassays, which were conducted with two sediment-dwelling invertebrates (amphipods and polycheates), and through the comparison of sediment chemical concentrations to literature-based screening benchmarks. The analyses indicate the following:

- Sediment bioassays indicate a site-related potential for adverse effects to benthic communities from the presence of chemicals in sediment, with the greatest potential for adverse effects occurring in the central portion of the canal. The bioassay results also indicate the potential for less severe, but site-related adverse affects to the benthic community at several other locations scattered throughout the canal.

- Chemical analysis indicates the presence of organic chemicals (primarily PAHs and PCBs) and metals in sediment at concentrations that are likely to be causing the adverse effects observed in the sediment bioassays. The highest concentrations of those chemicals were detected primarily in the central portion of the canal, which coincides with the locations where the most severe effects to the sediment bioassay organisms were also observed.

- PAHs were consistently detected in sediment at the highest concentrations relative to their ecological screening benchmarks and are considered to represent the greatest site-related risk to the benthic community. Other chemicals, most notably PCBs and several metals (barium, cadmium, copper, lead, mercury, nickel, and silver), were also detected at concentrations above their ecological screening benchmarks and at concentrations above those detected in offsite sediments, and are also considered to represent a potential site-related risk to the benthic community.

Water Column-Dwelling Aquatic Life Communities

Risks to water column-dwelling aquatic life communities were evaluated primarily through the comparison of surface water chemical concentrations, which were sampled both during a dry and wet (while CSO outfalls were discharging) periods to literature-based screening benchmarks. The analyses indicate the following:

- Chemical concentrations in surface water indicate very little site-related potential for adverse effects to water column-dwelling aquatic life.
  - In surface water collected during the dry period, no chemicals were detected at concentrations that could adversely affect aquatic life.
  - In surface water collected during the wet period, only lead was detected at a concentration exceeding its ecological screening benchmark and at a concentration above that detected in offsite surface water, indicating it represents a site-related risk to aquatic life.

Wildlife (Avian Aquatic Herbivores, Omnivores, and Piscivores)

Risks to avian aquatic wildlife were evaluated by modeling the potential exposure of these receptors to chemicals ingested in prey (fish and crabs) and via the ingestion of sediment. The analyses indicate the following:

- Potential risk to aquatic herbivores (represented by black duck) from exposure to PAHs. PAHs were detected onsite (in sediments) at a concentration above those detected in offsite locations and represent a site-related risk to aquatic herbivores.
- Potential risk to avian omnivores (represented by heron) from exposure to mercury and selenium. However, mercury was the only metal that was frequently detected at elevated concentrations in fish and crab tissues, and that was also detected onsite (in sediments) at a concentration above those detected in offsite locations, and thus represents a site-related risk to avian omnivores.
- There is no potential risk to avian piscivores such as the double-crested cormorant from the ingestion of fish in the canal.

7.3.2 Human Health Risks

The HHRA was conducted to evaluate the potential human health risks associated with direct contact with surface sediment and surface water in the Gowanus Canal, ingestion of fish and crabs, direct contact of sediment and surface water that overtops the canal during extreme tidal or storm surge conditions, and inhalation of emissions from the canal into the ambient air near the canal. Two scenarios were evaluated: 1) a reasonable maximum exposure (RME), which uses conservative exposure factors to estimate the reasonable maximum exposures anticipated for the canal, and 2) a central tendency exposure (CTE), which describes a more typical or average exposure. Two types of effects were evaluated – non-carcinogenic hazards and carcinogenic risks. Acceptable risk levels are defined in USEPA HHRA guidance (40CFR300.430(e)(2)(I)(A)).

For an adult, an adolescent, and a child using the canal for recreational purposes, the risks associated with exposure to surface water and surface sediment (from exposed and near shore locations) in the canal and from ambient air at canal level while swimming were evaluated. The HHRA assumed that recreational use/swimming in the canal would occur at frequencies, durations, and exposures that are typical of most water bodies, even though the actual use of the canal is lower given its nature. The total RME non-carcinogenic hazard associated with exposure to all of the media for all recreational users was within USEPA acceptable risk levels. However, exposure to all of the media by recreational adults, adolescents and children may result in carcinogenic risks above USEPA's target risk range. These risks are primarily associated with exposure to carcinogenic PAHs in the surface water and the surface sediment. The total non-carcinogenic hazard based on the CTE assumptions was within or below USEPA's acceptable risk levels; however, carcinogenic risk was above USEPA's target range. Exposure to lead in sediment by adult and adolescent recreational users would not result in any adverse effects; however, exposure to lead in sediment and surface water by recreational children (based on residential exposure assumptions, including potable use of the surface water) may result in adverse effects.

For residential adults and children and for industrial workers, the risks associated with exposure to ambient air at street level and with surface water and surface sediment from canal overflow were evaluated. RME non-carcinogenic hazards and carcinogenic risks associated with exposure to these media by the industrial worker are within acceptable levels. Exposure to all of the media by residential adults and children may result in carcinogenic risks above USEPA's acceptable risk levels. The RME carcinogenic risk for the adult/child resident is associated with carcinogenic PAHs in sediment (with a smaller contribution from surface water). The total carcinogenic risk evaluated under the CTE assumptions was within or below USEPA's acceptable risk levels. Exposure to lead in sediment by industrial workers would not result in any adverse effects; however, exposure to lead in sediment and surface water by residential children (based on residential exposure assumptions, including potable use of the surface water) may result in adverse effects.

Risks associated with ingestion of fish and crabs from the Gowanus Canal were evaluated for the angler adult, adolescent, and child. The HHRA assumed fishing/crabbing and ingestion of the fish /crab from the canal at typical recreational angler fish/crab consumption rates, which is very conservative given the nature of the canal. The RME and CTE total non-carcinogenic hazards and/or carcinogenic risks for all receptors exceeded USEPA acceptable levels. The non-carcinogenic hazards and carcinogenic risks are associated with PCBs in fish and crab. The average concentrations of PCBs in the canal fish and crab samples were about two times higher than the average PCB concentrations in the reference area samples collected from Gowanus Bay and Upper New York Bay. However, the PCB concentrations in the reference samples would also result in non-carcinogenic hazards and carcinogenic risks above USEPA acceptable levels..

7.4 Canal Characteristics

There are a number of overall site characteristics that will influence the development, evaluation, and selection of remedial alternatives for the Gowanus Canal in the FS. These characteristics include the following:

- **Presence and condition of bulkheads.** The physical condition of the bulkheads has been qualitatively described as degraded. The structural integrity of the bulkheads has not been tested, but preliminary surveys indicated that any type of dredging activities could threaten their stability (Brown Marine Consulting, 2000).
- **Presence of debris in the canal.** Debris of various shapes, sizes, and composition is pervasive throughout the canal. Sunken vessels are present in the 4th and 6th Streets turning basins. Accumulations of trash and construction debris are found near the ends of streets that abut the canal, and gravel covers large areas of the sediment surface in the middle and lower reaches of the canal.
- **NYCDEP activities associated with Gowanus Pump Station upgrades.** The upgrades to the flushing tunnel will increase the volume of water discharged to the canal from Buttermilk Channel by 40 percent, which will increase the current velocities and bottom shear stresses in the upper reach of the canal. The aeration pipe currently present in the canal will be removed before a sediment remedy is implemented.
- **Barge traffic.** Tugs and barges frequently move between the middle and lower reaches of the canal. The propeller wash from vessel movements is sufficient to resuspend sediments on the bottom of the canal.

7.5 Conclusions

The results of this RI indicate that chemical contamination in the Gowanus Canal sediments presents unacceptable ecological and human health risks, primarily due to exposure to PAHs, PCBs, and metals (barium, cadmium, copper, lead, mercury, nickel and silver). All of these contaminants are thought to have been deposited in the canal as a result of current and historical discharges to the canal. High PAH concentrations are found in coal tar waste adjacent to the three former MGP sites along the canal. PAHs and metals are the most prevalent contaminants detected in present-day CSO discharges to the canal, as well as in low volume discharges from a limited number of other outfalls. PAHs and metals are also present in various concentrations in contaminated groundwater discharging to the canal at different locations. Contaminated sites adjacent to the canal and discharges from outfalls represent ongoing sources of contamination to the canal.

The overall objectives of the Gowanus Canal RI were met, and sufficient data have been collected to proceed with the development of remedial alternatives in the FS. The results of the ERA and HHRA will support the definition of remedial action objectives and target areas for remediation.

SECTION 8
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