FINAL RCRA FACILITY INVESTIGATION REPORT

Former Bethlehem Steel Corporation Facility
Lackawanna, New York

PART II
SITE DESCRIPTION, INVESTIGATIONS AND RESULTS

October 2004

Submitted by:
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FORMER BETHLEHEM STEEL CORPORATION FACILITY
LACKAWANNA, NEW YORK

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FINAL RCRA FACILITY INVESTIGATION REPORT

Former Bethlehem Steel Corporation Facility
Lackawanna, New York

PART II
SECTIONS 1.0 & 2.0

OCTOBER 2004

TECUMSEH REDEVELOPMENT, INCORPORATED
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RCRA FACILITY INVESTIGATION
FORMER BETHLEHEM STEEL CORPORATION FACILITY
LACKAWANNA, NEW YORK

FOREWORD

Tecumseh Redevelopment, Inc. ("Tecumseh") owns approximately 1100 acres of property located along the west side of Route 5, Lackawanna, New York (the "Tecumseh Property") comprising a significant portion of the former Bethlehem Steel Corporation – Lackawanna facility (referred to in this Foreward and in the Executive Summary as the "Site" and by various terms in the remainder fo this document[1]) that was the subject of an Administrative Order on Consent (Docket No. II RCRA-90-3008(h)-0201) (the "AOC") entered into between Bethlehem Steel Corporation ("BSC") and the United States Environmental Protection Agency, dated August 13, 1990.

Subsequent to the entry of the Order, BSC filed for protection under the United States Bankruptcy Code and Tecumseh acquired the Tecumseh Property pursuant to an Asset Purchase Agreement that was approved by the United States Bankruptcy Court for the Southern District of New York on April 23, 2003 (Case No. 01-15288 (Jointly Administered)).

Tecumseh thereafter assumed the related cleanup obligations at the Tecumseh Property, including completion of this Final RCRA Facility Investigation Report (the "RFI Report"). Tecumseh, however is not the owner of several portions of the Site that were included in the scope of the AOC, including the manufacturing operations formerly owned by BSC on the east side of Route 5 (which are now owned in part by ISG Lackawanna, Inc. and in part by Republic Engineered Products, Inc.) and approximately 232 acres of property on the west side of Route 5 that were sold by BSC prior to the April 23, 2003 asset purchase agreement and which, upon information and belief, are currently owned by Gateway Trade Center, Inc. and Genesee & Wyoming, Inc.

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[1] Terms used in the remainder of this document to refer to the facility that was the subject of the AOC include but are not limited to "Lackawanna site," "BSC Lackawanna site," "site," "Lackawanna property," "BSC facility," "Lackawanna Plant," "BSC Lackawanna, New York Facility, " and "Bethlehem Steel site."

As the field investigation for the RFI Report was completed by BSC before Tecumseh's acquisition of the Tecumseh Property, portions of this RFI Report may not draw a clear distinction between those areas that, while subject to the AOC and part of the Site, are neither owned nor operated by Tecumseh and that therefore are not Tecumseh's responsibility. To the extent that this RFI Report does include information regarding areas formerly owned by Bethlehem but not now owned by Tecumseh, this information is included for the benefit of EPA and shall not be construed in any way as an assumption of responsibility by Tecumseh for those areas or a waiver of any defenses or claims that Tecumseh may have relating to those areas outside of the Tecumseh Property.

ACRONYMS AND ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1,1-TCA	1,1,1-trichloroethane
1,1,2-TCA	1,1,2-trichloroethane
1,1,2,2-PCE	1,1,2,2-tetrachloroethene (perchloroethylene)
95UCL	95% upper confidence limit
ADD	average daily doses
Agencies	NYSDEC and USEPA
amsl	above mean sea level
AOC	Administrative Order on Consent
AST	aboveground storage tank
ATP	acid tar pit
AVS/SEM	acid volatile sulfide/simultaneously extracted metals
BAF	bioaccumulation factor
BCS	Buffalo Crushed Stone
bgs	below ground surface
BOF	basic oxygen furnace
BSAF	bio-sediment accumulation factor
BSC	former Bethlehem Steel Corporation
BTEX	benzene, toluene, ethylbenzene, xylenes
BUD	beneficial use determination
cfs	cubic feet per second
CLP	Contract Laboratory Protocol
CMS	Corrective Measures Study
cm/sec	centimeter per second
COA	Coke Oven Area
COE	Unites States Army Corps of Engineers
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
COPI	chemical of potential interest
CSA	coal storage area
CSM	conceptual site model
DCA	dichloroethane
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
DOT	United States Department of Transportation
DUSR	Data Usability Summary Report
ECDOH	Erie County Department of Health
EPA	United States Environmental Protection Agency
ERA	Ecological Risk Assessment
ft	foot/feet
ft/day	feet per day
ft/ft	feet per foot
ft/s	feet per second
ft/sec	feet per second
ft/yr	feet per year
ft^3/ft^2	cubic feet per square feet

GIS	Geographic Information System
GMSC	Gateway Metroport Ship Canal
gpd	gallons per day
gpm	gallons per minute
GTC	Gateway Trade Center
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
HWM	hazardous waste management
ICM	interim corrective measure
ID	inside diameter
ID #1	Interim Deliverable Number 1
ID #2	Interim Deliverable Number 2
IEUBK	integrated exposure uptake biokinetic
IGLD	International Great Lakes Datum
IRIS	Integrated Risk Information System
IS #1	Interim Submittal Number 1
IS #2	Interim Submittal Number 2
K	hydraulic conductivity
lb	pound
lbs/yr	pounds per year
L/min	liters per minute
LNAPL	light nonaqueous-phase liquid
LOAEL	lowest observed adverse effects level
MEK	methyl ethyl ketone
mgd	million gallons per day
mg/kg	milligram per kilogram
mg/L	milligram per liter
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ND	not detected
NEIC	National Enforcement Investigations Center
NFA	No Further Assessment
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observable adverse effects level
NRTMP	Niagara River Toxics Management Plan
NRWT	North Return Water Trench
NYSDEC	New York State Department of Environmental Conservation
O&M	operation and maintenance
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
ppb	parts per billion
ppm	parts per million
PUF	plant uptake factor
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RBC	risk-based concentration
RBSL	risk-based screening level

RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RfDs	reference doses
RfCs	reference concentrations
RFI	RCRA Facility Investigation
ROI	receptor of interest
RTI	Republic Technologies International
SF	slope factor
SLCR	screening level cancer risk
SLHI	screening level hazard index
SLHQ	screening level hazard quotient
SFA	slag fill area
SPDES	(New York) State Pollutant Discharge Elimination System
SPL	spent pickle liquor
SPLP	synthetic precipitation leaching procedure
SRWT	South Return Water Trench
SSL	soil screening level
STP	Lackawanna Sewage Treatment Plant
SVOC	semi-volatile organic compound
SWMU	solid waste management unit
TCA	trichloroethane
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TDC	Tecumseh Development Corporation
TF	Tank Farm
TFA	Tank Farm Area
THI	target hazard index
TIC	tentatively identified compound
TOC	total organic carbon
TR	target cancer risk level
TRV	toxicity reference value
UCL	upper confidence level
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
µg/kg	microgram per kiliogram
µg/L	microgram per liter
µm/s	micrometer per second
VOC	volatile organic compound
WQCS	Water Quality Control Station

1.0 INTRODUCTION

The Bethlehem Steel Corporation's (BSC) Lackawanna property (also referred to as the "site") is located on the eastern end of Lake Erie, south of the City of Buffalo. A site vicinity map is provided in Figure 1-1.

Prior to the Fall of 1983, the site housed a large, fully integrated steel plant that included a whole range of iron- and steel-making operations. After 1983, only a coke oven operation and a galvanized products mill remained in operation. The Coke Ovens were closed on September 28, 2001; the Galvanizing Mill is now the only BSC operation at the site.

In 1988, on behalf of the United States Environmental Protection Agency (USEPA) Region II, the EPA National Enforcement Investigations Center (NEIC) conducted a Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) of the Lackawanna site. The investigation identified 104 Solid Waste Management Units (SWMUs) and six surface water bodies (watercourses) that received or could have received solid wastes containing hazardous constituents (EPA NEIC, 1988). These SWMUs and watercourses are listed on Table 1-1 and shown on Figure 1-2.

On August 13, 1990, BSC and USEPA Region II entered into an Administrative Order on Consent (AOC or the Order) pursuant to Section 3008(h) of RCRA. In broad terms, BSC agreed to perform a RCRA Facility Investigation (RFI) to identify the nature and extent of any release(s) of hazardous constituents from SWMUs to the environment, and mitigate any emergency situations that might be discovered during the course of the investigation. No Interim Corrective Measures (ICMs) were prescribed by the 1990 Order.

The AOC included as an attachment a document entitled "Final Work Plan for Phased Site Investigation". This Phased Site Investigation was to be completed during the RFI. The phased approach was developed to address their issues in order of importance and as to their potential threat to human health and the environment. The Phased Site Investigation work plan was developed with input from and approval of both USEPA and the New York State Department of Environmental Conservation (NYSDEC) (agencies) and provided the details for Phase I of the investigation. A total of five phases of investigation (Phases I, II-A, II-B, II-C and III) as well as four supplemental investigations (1999 Comprehensive Groundwater Investigation, 2000 Shoreline Investigation, 2000 Supplemental SWMW Investigation, and 2001 Supplemental Ecological Investigation) were performed. Formal reports on Phase I (BSC 1992a), Phase II-A (BSC 1993a), Phase II-B (BSC 1994a and BSC 1995b) were submitted to and reviewed by the Agencies. BSC also submitted to the Agencies all of the data collected during each phased field investigation shortly after the field work was completed. These data subsequently were submitted to the Agencies in summary and electronic form (BSC 1996, 1997a and 1997b).

The AOC also specified that Preliminary SWMU Assessments should be conducted concurrently with the phased RFI investigation. As such, a Preliminary SWMU Assessment Plan was included as an additional attachment to the AOC. The purpose of the Preliminary SWMU Assessments was to efficiently evaluate selected SWMUs and watercourses in order to eliminate from further extensive investigation those units considered to be of little or no concern. This process would allow investigative resources to be focused on SWMUs and watercourses considered to be of greater concern.

Preliminary Assessment Reports for 86 SWMUs and six watercourses were submitted to and reviewed by the Agencies between December 1988 and July 1992. On the basis of these reports, the Agencies determined that 59 SWMUs and one watercourse did not require further assessment under the RFI. Supplemental Assessment Reports have been prepared for the 27 SWMUs and five watercourses for which further assessment was required by the Agencies. In addition, Assessment Reports have been prepared for the remaining 18 SWMUs not addressed in the original Preliminary Assessment Reports submittals. The assessment report status for each of the SWMUs and watercourses is summarized in Tables 1-2 and 1-3.

Major work elements included in various phases of the RFI are as follows.

Activity	Phase I	Phase II-A	Phase II-B	Phase II-C	Phase III	1999 Comprehensive Groundwater Sampling Program	Shoreline Investigation	Supplemental SWMU Investigation
Installation of Groundwater Monitoring Wells	✓	✓	✓	✓	✓		✓	✓
Groundwater Unit Testing	✓	✓	✓		✓			✓
Groundwater Sampling	✓	✓	✓	✓	✓	✓		✓
Surface Water Sampling	✓	✓	✓	✓	✓			
Data Validation and Interpretation	✓	✓	✓	✓	✓	✓	✓	✓
Groundwater Modeling	✓	✓			✓			
Preliminary Health Risk Assessment	✓	✓						
Installation of Piezometers		✓			✓		✓	✓
Soil Gas Survey	✓	✓	✓	✓	✓			
Ecological Surveys		✓		✓	✓			✓
SWMU/Source Characterization			✓	✓	✓			✓
Investigation of Surface Water/Groundwater Relationships	✓	✓	✓		✓		✓	
Preliminary Evaluation of Corrective Measure Technologies			✓		✓			
Human Health and Ecological Risk Assessment				✓	✓			✓

This RFI report for BSC's Lackawanna Plant site incorporates either directly or by reference findings of Phases I, II-A and II-B of the investigation. The report also contains the findings of the more recent Phases II-C and III investigations and four supplemental investigations, which were not previously presented in a formal report.

1.1 **Site History**

The site has been used for iron and steel production since the beginning of the 20th century. The majority of these operations at the site were discontinued by the end of 1983. The initial facilities were built along the lakeshore. During the time of integrated steel-making operations, the site area was extended into Lake Erie by placing large volumes of blast furnace iron-making slag as well as open hearth furnace and basic oxygen furnace steel-making slag along the shoreline. This activity was conducted in an area that included two Federal Dumping Grounds that were used as a dumping ground for dredge spoils and other materials by the U.S. Army Corps of Engineers (USACE) and possibly others. The locations of the Federal Dumping Grounds are shown on Figure 1-2a. Three cross sections through the northern portion of the Federal Dumping Ground are shown on Figure 1-2b.

The placement of the slag fill over the Federal Dumping grounds created approximately 440 acres of man-made land, and created a new water-bearing zone within the fill. The 440 acres, which comprise the western portion of the site, are referred to as the Slag Fill Area (SFA).

BSC records and aerial photographs from 1938 to the present indicate that the SFA was also used for the management of waste materials, including: sludges from wastewater treatment plants; sludges, dusts, and liquids from iron-making, steel-making, steel-forming, steel-finishing, and coke-making operations; and dredge materials from Smokes Creek. The SFA has also been the site of management areas for various types of debris from BSC's Lackawanna Plant operations.

As noted previously, BSC currently has one active manufacturing operations at the site: the galvanized steel mill (Galvanized Products Division). The coking operation, closed in

September 2001, is located north of Smokes Creek and west of the Gateway Metroport Ship Canal (formerly the Lackawanna Ship Canal, and referred to hereafter as the Ship Canal). The presently operating Galvanizing Products Division is located south of Smokes Creek and east of the Hamburg Turnpike (New York State Route 5).

BSC has initiated a program to reclaim slag from the SFA. Five SFA zones have been designated. Zones 1, 3 and 5 are to be reclaimed while Zones 2 and 4 are waste management areas. The five SFA zones are shown on Figure 1-3.

The initial reclamation program has focused on Zone 1, which was used for the placement of non-hazardous, molten blast furnace slag and associated entrapped iron. Buffalo Crushed Stone, Inc., currently operates the slag recovery operation within this zone. Slag reclamation involves the excavation and crushing of the slag, which subsequently is sold as a gravel substitute. The NYSDEC issued a Beneficial Use Determination (BUD) for this use of slag from Zone 1 of the Lackawanna site.

The SWMUs that are considered of greatest potential concern are located in SFA Zones 2 and 4. However, potential releases from SWMUs outside, but in the vicinity of the SFA, also are of potential concern. These include SWMUs in the Coke Oven Area and possibly the Tank Farm Area (shown on Figure 1-2).

1.2 Pre-RFI Investigations

In the late 1970s, BSC filed an application with NYSDEC under 6 NYCRR Part 360 for a permit to operate an industrial landfill in the SFA. The permit was granted in June 1978. As required by the Permit, a plan for a groundwater and surface water monitoring program was prepared and approved by NYSDEC in 1979. The monitoring program included installation of 11 wells (increased to 13 wells in 1982), limited groundwater unit tests, and groundwater sampling and analysis. The results of this program were presented in a Summary Report entitled, Monitoring Well Program (Dames & Moore 1981) (see Appendix A.1). Groundwater quality monitoring was continued during 1982 and 1983, and monitoring reports were submitted to USEPA Region II and NYSDEC in April 1983 and July 1984. The majority of the wells installed in the early 1980s have been destroyed. However, three well pairs (MW-6A/B, MW-7A/B, and MW-8A/B) still exist and were used during the RFI.

On November 18, 1980, pursuant to RCRA Section 3005(e), BSC submitted a Part A "interim status" application to USEPA for two solid waste disposal facilities (designated Hazardous Waste Management Unit No. 1 [HWM-1] and Hazardous Waste Management Unit No. 2 [HWM-2]) within the SFA. Unit HWM-1 actually comprises two units: HWM-1A (SWMU S-13) and HWM-1B (SWMU S-16). Unit HWM-2 is also referred to as SWMU S-3.

Interim status for these units terminated on November 8, 1985, pursuant to RCRA § 3005(e)(2). Consistent with interim status standards and as part of the requirements of a Consent Agreement and Consent Order entered into by BSC and USEPA Region II on August 6, 1985, additional monitoring wells were installed around HWM-1 and HWM-2. One upgradient well (MW-1U1) and four downgradient wells (MW-1D1, MW-1D2, MW-1D3, and MW-1D4) were installed at HWM-1; and one upgradient well (MW-2U1) and three downgradient wells (MW-2D2, MW-2D3, and MW-2D4) were installed around HWM-2 (see Figure 1-4). Groundwater monitoring was conducted and the results were reported to the agencies (Baker/TSA 1985; Baker/TSA 1986).

In late 1986 and early 1987, apparent statistically significant variability in certain indicator parameter data (namely, pH and total organic halogens [TOX] data) from the wells monitoring HWM-1 and HWM-2 resulted in preparation of a groundwater monitoring plan (Ecology & Environment 1988). In conjunction with the development of the groundwater monitoring plan, a groundwater quality assessment study of the HWM-1 and HWM-2 areas was conducted by Ecology & Environment in 1987 and 1988. It was found that the wells around the two units generally showed similar levels of constituents upgradient and downgradient (Ecology & Environment 1988). Purgeable aromatic hydrocarbons (e.g., benzene, toluene, xylenes, and ethylbenzene); acid extractable hydrocarbons (e.g., phenol, cresols, and 2,4-dimethylphenol); and polynuclear aromatic hydrocarbons (PAHs) (e.g., naphthalene and phenanthrene) were detected in upgradient and downgradient wells monitoring HWM-1. Because these compounds were detected in both the upgradient and downgradient monitoring wells, the source for these compounds were assumed to be upgradient of both HWM-1A and HWM-1B. However, subsequent groundwater sampling of an expanded monitoring well network in the vicinity of these two units indicated that some of the compounds detected in the downgradient wells were higher than in upgradient wells. Section 3.0 of the RFI provides a discussion of potential impacts and sources of groundwater contamination in the vicinity of the HWM-1 units.

At HWM-2, similar aromatic compounds (i.e., benzene, toluene, and ethylbenzene) were observed, although at generally lower concentrations. Phenolics and PAHs were also found in both upgradient and downgradient wells, but chlorinated organics (e.g., 1,1-dichloroethane) were detected only in the upgradient monitoring well (MW-2U1) and only at low levels.

Groundwater quality monitoring of HWM-1 and HWM-2 has continued to the present. In 1994, BSC voluntarily expanded the monitoring well network to include MWN-12, MW-1D6, MW-1D7 and MW-1D8. In addition, groundwater level monitoring specifically for these units was initiated in 1994. The wells and piezometers used in this program include the five wells in the HWM-1 monitoring network and the four wells in the HWM-2 network (see previous page) in addition to the four voluntary wells, plus wells MWN-4 and MWN-5 and Piezometers P-4, P-5, P-6 and P-7. The locations of all of these monitoring points are shown on Figure 1-4. Analytical results have been submitted to the agencies in accordance with requirements of the groundwater monitoring plan (BSC 1994b).

HWM-1A, also known as the Tar Sludge Impoundment, was closed in October 1988 in accordance with a NYSDEC approved closure plan (BSC 1986, revised 1987). This unit is maintained in accordance with the post closure care provisions of the closure plan.

Petitions to delist the wastes (that is, to remove them from regulation under federal hazardous waste laws) in HWM-2 and HWM-1B were submitted by BSC to USEPA (Headquarters) on July 18, 1984 and June 20, 1985, respectively (BSC 1984 and 1985). Preparation of the petitions (including supplemental submittals for HWM-2) involved the collection of waste characterization data, and modeling/analysis of the fate and effect of potential releases from the units on human health and the environment. On April 24, 1996, USEPA granted the delisting petition for HWM-2. Subsequently, in October of 1997, NYSDEC agreed to delist the waste in HWM-2. The petition for HWM-1B is still pending.

The 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA [Section 3004 (u)], require that a RCRA permit must address releases of hazardous wastes or constituents from any SWMU. As a result of this requirement, USEPA Region II conducted a RCRA Preliminary Review of the Lackawanna plant during the spring of 1986. A Preliminary Review is the initial element of an RFA. Following completion of the Preliminary Review, USEPA determined that a second phase of the RFA (visual inspection) was necessary. USEPA subsequently requested NEIC to conduct the second phase of the RFA. NEIC personnel made three site visits during the period January 1988 through May 1988. NEIC's RFA report was issued in September 1988.

1.3 RCRA Facility Investigation (RFI) and Report

The RFI was initiated in August 1990. Phased field investigations were conducted from January 1991 through May of 1996. Additional RFI field work was conducted in the Fall of 1996, the spring of 1997, the fall and winter of 2000 and the summer of 2001.

The RFI has consisted of the following components:

- Preparation and submittal of workplans for: Phase I, Phases II-A, II-B, II-C and Phase III, of the RFI; the 1999 Comprehensive Groundwater Sampling Program, the 2000 Shoreline Investigation, the 2000 Supplemental SWMU Investigation, and the 2001 Supplemental Ecological Investigation; and a special fisheries study (BSC 1990a, 1992b, 1994c, 1884d, 1995, 1999, 2000a, 2000b, and Ogden 2000). Voluntary studies not conducted as part of the RFI, have also been included. These include a study of natural attenuation processes potentially occurring within site groundwater and a preliminary technology assessments for two site areas (the Acid Tar Pits Area (SWMUs S-11 and S-22) and the Coking Operations By-Products Area (SWMU P-11). Data from the voluntary investigations are included in the RFI when RFI QA/QC requirements have been met.
- Collection and analysis of data to characterize the nature and extent of contaminants present within the site SWMUs
- Collection and analysis of data to characterize geological and hydrological regimes at the site and potential contaminant migration pathways

- Collection and analysis of data to characterize the nature and extent of contaminants present within the site watercourses and groundwater that might be present as a possible result of releases from the site SWMUs
- Collection of data to characterize the fate and transport of contaminants identified in the groundwater
- Collection and analysis of data to characterize potential ecological and human receptors of contaminants that may be released from the site
- Assessments to define the risks to potential human and ecological receptors from releases of contaminants, if any, from SWMUs, groundwater or watercourses
- Preparation of Preliminary and Supplemental SWMU Reports
- Preparation of Draft RFI Reports following Phase I, Phase II-A, and Phase II-B
- Preparation of the Human Health Risk Assessment and the Ecological Risk Assessment.

This report is the culmination of all of the above components. It is divided into seven parts, each bound separately, as follows:

- Part I - Executive Summary
- Part II - Site Description, Investigations and Results
- Part III - Ecological Risk Assessment Report (stand-alone document)
- Part IV - Human Health Risk Assessment Report (stand-alone document)
- Part V - Slag Fill Area SWMU Assessment Reports (stand-alone documents)
- Part VI - Process Area SWMU Assessment Reports (stand-alone documents)
- Part VII - Watercourse Assessment Reports (stand-alone documents)

1.4 **Spill History**

On September 5, 2002, a Freedom of Information Letter (FOIL) was submitted to NYSDEC requesting available information regarding reported spills associated with the BSC property. In addition to the information collected from the FOIL, additional spill data was obtained from the NYSDEC public website and interviews with onsite personnel. The information was compiled and summarized in Table 1-4. Copies of the spill reports are provided in Appendix A.2.

Material associated with the spills at the site have included; process waters, coal tar pitch volatiles, waste oil, fuel oil, PCB oil, wash water, ammonium sulfate, kerosene, hydraulic oil, pickle liquor, sulfuric acid, lube oil, coal, tar, asbestos and petroleum.

Available spill data was compiled from late 1985 through August 31, 2002. According to available records, 323 spills were reported. Of the 323 spills, 17 were unable to be confirmed as to whether or not they were directly located on BSC property. The majority of these spills were associated with the former South Buffalo Railway (currently owned by the Genesee and Wyoming Railroad) and it is assumed that the majority of the spills were located along railroad rights of way that could be located onsite or offsite.

All but five of the 323 spills have met NYSDEC clean-up criteria and have been closed. Open Spill No. 9805875 is associated with the former South Buffalo Railway and, therefore, was not confirmed on BSC property and the status is unknown. Open Spill No. 9701951, which occurred in the Galvanized Products Division Mill area on 5/14/97, is currently under remediation.

The remaining 3 open spills occurred in 2002. On 5/6/02, oil from an intersecting drain was observed in the North Return Water Trench (Spill No. 0201338). Cleanup was conducted and BSC is presently waiting for the NYSDEC to re-inspect the tunnel for spill closure. Oil from the coke oven gas field was observed in the South Return Water Trench on 6/3/02 (Spill No. 0202301). This spill was cleaned up and inspected by the NYSDEC. However, closure has not been issued as of the writing of this RFI report. Lastly, on 6/10/02, hydraulic oil was spilled due to rupture of an equipment line by the Genesee and Wyoming Railroad near the Galvanized Products Division Mill (Spill No. 0275129). The spill was cleaned up, but because the spiller was not BSC, the status of closure is not known.

2.0 SITE DESCRIPTION

2.1 Location and Setting

2.1.1 Introduction

The BSC Lackawanna site currently consists of an industrial complex comprising light manufacturing, warehousing, distribution and transportation, waste management, and slag reclamation activities and facilities. The general location of the site is shown on Figure 1-1. A site layout is provided in Figure 2-1. The majority of the Bethlehem Steel property is located within the City of Lackawanna, although portions extend south into the Town of Hamburg, the Village of Blasdell, and north into the City of Buffalo. The site is located entirely within the limits of Erie County, New York.

The property comprises approximately 1,600 acres and is zoned for medium-density industrial use. The property extends a distance of about 2-1/2 miles from Blasdell Creek on the south to the Buffalo Outer Harbor on the north, and extends about 1 mile east from Lake Erie. The site is bordered by the New York State Route 5 (Hamburg Turnpike) on the east-northeast, except for a small portion of the site that lies to the east of the turnpike. A residential area (Woodlawn) is located to the south of the site, Lake Erie is to the west, and the Buffalo Outer Harbor extension of the lake borders the site on the north.

Approximately 440 acres of the site were created by the placement of fill materials within an area that was formerly within the boundaries of Lake Erie. This area extends from the former lake shore an average of 1,300 feet westward, and now forms the eastern shoreline of the lake. This filling activity was conducted in an area that was used as a dumping ground by the United States Army Corps of Engineers and others prior to the time that the BSC filling operation occurred. The 440 acres which comprise the fill area is referred to throughout this RFI report as the Slag Fill Area or SFA. The SFA extends along the entire, current western boundary (lake shore) of the site (see Figure 1-3).

The primary fill material placed in the SFA was slag from iron and steel production. Other materials included construction and demolition debris. Discrete and identified areas within these 440 acres were used for the management of waste materials, including sludges from wastewater treatment plants; sludges, dusts and liquids from iron-making, steel-making, steel-forming, steel-finishing, and coke-making operations; and sediments dredged from Smokes Creek by BSC and the USACE.

The site is fenced on the landward sides, with access being controlled through security gates, which are guarded 24 hours a day. Security patrols are conducted routinely within the complex to prevent unauthorized access or activities.

2.1.2 Topography

In general, the topography is relatively flat at the site, with slopes of only a few feet per mile. Within the site, the only slopes of any consequence are primarily "man-made" and occur in the SFA. South of Smokes Creek, in Zone 1 of the SFA (see Figure 1-3), much of the slag has been reclaimed and removed by Buffalo Crushed Stone, Inc., creating a roughly level platform less than 10 feet above the lake. In Zone 2, also south of Smokes Creek, the fill rises to approximately 60 feet above the lake level before dropping off sharply to the lake. North of Smokes Creek, within SFA Zones 3, 4 and 5, the fill rises from lake level to more than 70 feet in some locations, with the highest mounds toward the north end of the area.

2.1.3 Climate

The site area has a humid continental climate with warm summers and relatively long, cold winters. Precipitation is generally evenly distributed throughout the year, with slightly higher average precipitation rates from September through December. Normal annual total precipitation is approximately 36 inches, and normal annual snowfall is around 90 inches. Rainfall intensity probabilities are estimated at 1 inch in one hour once in two years; 1.25 inches in one hour once in five years; 1.5 inches in one hour once in 10 years; and more than 2 inches in one hour once in 25 years. A 10-year, 24-hour storm event is estimated to produce 3.5 inches of rainfall. The mean number of days in which precipitation exceeds 0.01 inches is approximately

160. Normal monthly average temperatures range from 25°F in January to 70°F in July. The mean annual number of days with a maximum temperature of 90°F or higher is six. The mean length of the freeze-free period is approximately 170 days (NOAA, Buffalo, New York).

Temperature recordings at the National Oceanic and Atmospheric Administration (NOAA) Weather Station at the Buffalo Airport and at the BSC on-site weather station for the period January 15, 1991, through March 15, 1992 are presented on Figures 2-1(a) and 2-1(b) in Appendix A.3. Its location on Lake Erie tends to moderate temperatures at the BSC site. Thus, site temperatures are generally cooler in the summer and warmer in the winter than those at the Buffalo Airport.

Precipitation recorded at the BSC site from January 15, 1991, through March 15, 1992, period is presented on Figure 2-1(c) in Appendix A.3. Comparisons of site and regional major precipitation events for April, September, October, and December 1991, respectively, also are presented on Figures 2-2(a) through 2-2(d) in Appendix A.3. As shown on these figures, total precipitation at the site tends to be less than that at the airport. This may be in part because area storms tend to become more severe inland than at the lake. Approximately 7.5 to 8 inches of the winter/spring precipitation are in the form of snow. Although some evaporation occurs, much of the snow melts and is available as recharge to groundwater. Because of the exposed location of the SFA, adjacent to the lake, accumulation of snow is less than regional averages, because some snow is blown off-site by strong winds.

Annual mean lake evaporation is 27 inches; approximately 79% of this occurs during the period from May through October. The approximate excess of precipitation over lake evaporation during the November through April season is 12.6 inches.

Wind rose diagrams of NOAA data from the Buffalo airport and site data are presented on Figures 2-3(a) through 2-3(j) in Appendix A.3. The wind roses cover the period January 1, 1991, through March 15, 1992. In general, for both locations, the wind blows from the west-southwest, with an average intensity range between 10 and 15 mph.

2.1.4 Ecological Setting

Including the SFA, approximately one-half of the site is not vegetated due to the presence of buildings, foundations, concrete pads, coal piles, roads, railroad tracks and slag fill. The remainder of the site is vegetated primarily by grasses, shrubs and small trees. The man-made slag substrate is ecologically inert material, so the process of soil and plant community development on slag is primary succession, equivalent to what occurs on newly emerged volcanic islands or substrate left behind by retreating glaciers. Thus, almost all of the vegetated areas are in a very early stage of succession, lack substantive diversity, and are not fully functional in terms of habitat quality. Details of the terrestrial ecological investigations and observations made at the site are contained in the Ecological Risk Assessment Report, which is presented as Part III of this RFI report.

The site is located within the Erie-Niagara River basin. Viable aquatic habitats at the site include Smokes Creek, Blasdell Creek, and Lake Erie. An aquatic habitat investigation in 1995 focused on the two natural waterways on the site, Smokes Creek and Blasdell Creek. Smokes Creek is a Class C stream (designated by NYSDEC to support propagation and survival of game fishes), with a drainage area of approximately 329 square miles. Silt deposition and bank erosion in the creek are notable, and bottom substrate is less than 30 percent gravel or rubble. Blasdell Creek is a Class D stream (designated as suitable for fish survival, but not propagation) that flows along the southern boundary of the site and discharges to Lake Erie. Details regarding the aquatic investigations at the Lackawanna site and other information about the aquatic ecology are contained in the Ecological Risk Assessment Report, which is presented as Part III of this RFI report.

Much of the land area within a 1.5-mile radius to the north-northeast of the site is composed of low-lying areas with extensive surface water and marsh areas. Over time, these areas have been altered, primarily by filling, to create stable, usable land areas. The most recent NYSDEC Freshwater Wetland Map (NYSDEC, 1977; updated 1986) was reviewed to identify any defined wetland areas near the BSC site. The closest New York State-designated wetland areas to the BSC site are located within a few hundred feet to one-half mile of the southeast boundary of the site and are identified as BU-4 and BU-14 on Figure 2-2. These wetland areas occupy an area along a railroad right of way and were probably created by a disruption of drainage when the railroad tracks were constructed. The next closest wetlands, BU-7 and BU-15, are located between 0.5 and 1.5 miles north of the site boundary (see Figure 2-2). These nearby wetlands appear to be remnants of what was probably, before industrialization of the area, a much larger wetland associated with the Buffalo River. Part of these wetlands lie within the Tifft Farm Nature Preserve operated by the Buffalo Museum of Science. One other designated area that lies northeast of the site is the wetland BU-1.

2.1.5 Demography and Land Use

2.1.5.1 Demographics

According to the U.S. Census Bureau, the population of Erie County was estimated to be 968,532 in 1990, 954,021 in 1996 and 950,265 in 2000. Erie County lost over 40,000 residents during the 1980 to 1996 period (Saratoga Associates, 1996). Although this loss is significant, the decline is only half the rate experienced in the 1970's. This population loss coincides with the decline in the heavy manufacturing industry, a former mainstay for employment in the metropolitan Buffalo area.

2.1.5.2 Land Use

Current ownership of the Lackawanna site is identified on Figure 2-3. Areas surrounding the site include residential, light and heavy industrial, and commercial properties. These areas are described in the following paragraphs.

2.1.5.2.1 Residential

South of Smokes Creek and east of the site is the Bethlehem Park housing community. The residential community of Woodlawn is also located south of Blasdell Creek and the site. East of the Hamburg Turnpike and north of the area occupied by BSC's Galvanized Products Division, is Bethlehem Park and other, small residential areas, as shown on Figure 1-1.

2.1.5.2.2 Commercial

Gateway Trade Center Inc. (G.T.C.) owns the Ship Canal and occupies a small portion of the site along both sides of the Ship Canal. The former Bethlehem Steel Corporation office complex, now owned by Buffalo Crushed Stone, is located off-site, south of Blasdell Creek and east of Woodlawn Beach.

2.1.5.2.3 Industrial

The site is bounded on the northwest by the USACE's Dredge Disposal Area No. 4, on the north by the Buffalo Outer Harbor and on the northeast by the Union Ship Canal. The USACE disposal area contains, among other materials, dredge spoils from the Buffalo River, a potential source of contaminants. The USACE disposal area was identified in the 1988 Niagara River Toxics Management Plan (NRTMP) which identifies sites as potential sources of contaminant loadings to Lake Erie and the Niagara River.

Buffalo Specialties (facility presently shutdown) and Buffalo Crushed Stone (BCS) have operations in the southern portion of the site. Other site areas formerly owned by BSC include: (1) an area amounting to 8.8 acres west of Route 5 and south of Smokes Creek, presently owned by the Genesee and Wyoming Railroad, that contains a rail yard, an office building, and a warehouse; and (2) an area east of Hamburg Turnpike and south of BSC's galvanizing mill that is owned and operated by Republic Technologies International.

2.1.5.2.4 Hazardous Waste Sites

Several inactive hazardous waste sites have been identified within approximately 2 miles of the BSC facility (NYSDEC 2000). These are:

- Bethlehem Steel Corporation
- Republic Steel (LTV) (Marilla Street Landfill)
- Ramco Steel Site

- Alltift Landfill
- Lehigh Valley Railroad Site
- Tifft Farm Nature Preserve
- Tifft and Hopkins
- Ameron Site
- Lehigh Industrial Park
- Shanango Steel Mold Site
- Donna Hanna Coke Site

The locations of these Inactive Hazardous Waste Sites are shown on Figure 2-4.

The Marilla Street Landfill and the Donna Hanna Coke Site are addressed in the document *South Buffalo Redevelopment Plan: Steel Manufacturing Site,* Voluntary Clean-Up Site Assessment Report (the Steel Plant Plan) (Malcolm Pirnie, 1997). The redevelopment plan is the product of a partnership consisting of the City of Buffalo, the City of Lackawanna, Erie County, the Erie County Industrial Development Agency and others. According to Malcolm Pirnie (1997), an industrial/commercial corridor and the Southtowns Connector Highway comprise the cornerstone of the South Buffalo Redevelopment Plan. These developments are currently planned for the Former Donna Hanna Coke Site.

The Donna Hanna Coke Site, approximately 33 acres in size, was formerly used for the storage of coke and coal and allegedly the disposal of acid sludge and tar from former Republic Steel Plant and the Donna Hanna Coke Plant (Malcolm Pirnie, 1997). Preliminary Phase I and Phase II Investigations were performed by Recra Environmental in July 1990. According to Malcolm Pirnie (1997), contamination found during the Recra Environmental investigation at the site includes detectable levels of benzene, as well as other volatile organic compounds, and PAHs in soil, groundwater and surface water. Groundwater from the southern part of the site probably flows toward Lake Erie (Malcolm Pirnie, 1997). None of this groundwater is expected to affect the Lackawanna site.

The Marilla Street Landfill site was designated in the South Buffalo Plan for "relocation and expansion of the South Park golf course and related wildlife habitat and recreational uses" (Malcolm Pirnie, 1997). According to Malcolm Pirnie (1997), the "landfill was formerly used for disposal of slag, construction and demolition debris, and other steel-making wastes." Cleanup has consisted of placement of a low-permeability cover over the landfill (1993) and the ongoing remediation of the associated wetlands (Malcolm Pirnie, 1997). Remediation of 16 acres of wetlands which consisted of excavation of sediments from ponds and ditches and covering the excavated area with clean soil, wetland restoration, and upland enhancement started in 1998 and was completed in 1999 (NYSDEC 2000). The site will be monitored under a long-term operation and management (O&M) plan (NYSDEC 2000).

The Ramco Steel Site is approximately 8 acres in size and approximately 0.5 mile northeast of the site. A pond at the rear of the steel processing plant was used to dispose of waste pickle liquors, rinse water, lime sludge and metals. A record of Decisions was issued for the site by the NYSDEC in March 1996. The remedy involves excavation of contaminated soil and sediment and disposed at the Alltift Landfill. The pond was to be subsequently restored as a wetland. Work was scheduled for 2001.

The Alltift Landfill is a 25-acre landfill located 0.5-mile northeast of the site. Alltift received domestic industrial wastes from 1930 to 1975. Documentation presented in a Phase II Investigation revealed that National Aniline Division (Allied Corp.) disposed of monthly quantities of organic chemicals, chrome sludge, copper sulfate, nitrobenzene, monochlorobenzene, and naphthalene. In addition, a secondary landfill containing automobile shredder wastes, fly-ash and sand wastes was built on the original landfill and operated until 1984. Remedial Investigation and Feasibility Studies have indicated that contaminants of concern in the groundwater include metals, pesticides, PCBs, chlorinated solvents and PAHs. The Record of Decision selected the remedy of capping, waste consolidation, wetland restoration and groundwater collection. Construction was scheduled for 2001.

The Lehigh Valley Railroad site is 5-acres and located approximately 0.75-mile northeast of the site. Two 100,000-gallon aboveground tanks were used to store a mixture of waste oil and chlorinated volatile organic compounds in the tanks. The tanks were subsequently removed in

1991. In 1996, the New York State Department of Transportation encountered hazardous waste containing chlorobenzene, chloroanilines, nitroanilines and PAHs while constructing a landfill. These wastes will require remediation.

The Tifft Farm Nature Preserve is located approximately 1.5 miles northeast of the Lackawanna site, near the intersection of Tifft Street and Fuhrmann Boulevard. The preserve, which is open to the public, occupies approximately 80 acres and is currently owned and operated by the Buffalo Museum of Science. From 1955 to 1972, this area was owned and operated by Republic Steel Company, when it was reportedly used as a disposal site for slag, fly ash, and other waste materials. In 1972, the City of Buffalo bought the site and transferred sludges from Squaw Island, the location of the City's waste water treatment facility, to Tifft Farm for disposal. Other materials that have been disposed of on the Tifft Farm site include acid sludges from a local automobile manufacturer and drums that were found to contain metals, PAHs, and phenolic compounds. In 1983, more than 100 drums were removed from the two on-site ponds. Elevated levels of metals, particularly lead, and PAHs have been detected in samples of site soils (E.A. Science and Technology 1988). Samples of fish collected by NYSDEC from the Tifft Farm ponds contained metals, PCBs, and pesticides (E.A. Science and Technology 1988). It is highly unlikely that past or current operations at the Lackawanna site and the Tifft Farm location could impact the other, given the distance between and the hydrogeological separation of the two locations.

The Lehigh Industrial Park, is located approximately 0.5 mile east of the Lackawanna site. According to the NYSDEC (NYSDEC 2000), the site was formerly called Roblin Steel Company Scrap Metal Yard and Scrap Processing Facility. During a NYSDEC Spill Response site visit conducted in January 1988, open and inverted transformer casings were observed along with an area of oil-drenched soil. A Preliminary Remedial Investigation (RI) confirmed PCB contamination and a Record of Decision (ROD) was signed in March 1994. Remediation activities were conducted which included building demolition, soil excavation, installation of an infiltration basin for surface runoff, and regrading with clean fill. Development of an O&M plan is currently on going (NYSDEC 2000).

The Shenango Steel Mold, site is approximately 18 acres in size and is located approximately 0.25 miles from the Lackawanna site, north of the Union Ship Canal. The site produced iron molds for the steel industry between 1962 and 1982 (NYSDEC 2000). Following site demolition, a spill of transformer oil occurred during salvage operations. In 1994, the NYSDEC removed impacted soils, 55-gallon drums and 5-gallon pails from the site. Toxic Characteristic Leaching Procedure (TCLP) analysis of the drummed material indicated benzene, TCE, PCE, MEK, barium and lead. Some of the materials were identified as toxicity characteristic hazardous waste due to the presence of lead, TCE, and PCE (NYSDEC 2000). Additional sampling of the Shenango Mold sites was conducted as part of a Preliminary Site Assessment of the adjacent Hanna Furnace parcel. Analytical results indicated that PCB (Aroclor 1260) concentrations greater than 500 ppm, remain at the Shenango Steel Mold site (NYSDEC 2000). In addition, numerous exceedances of Class GA Groundwater Quality Standards have been detected at the site.

The Tifft and Hopkins site is located approximately 0.75 acres northeast of the site. The discovery of this site occurred while the City of Buffalo Water Department was repairing a water main on Providence Street. A preliminary site assessment was completed in January 1993 and indicated that chlorobenzene, naphthalene, benzene and toluene were present in the black soil beneath a clay and pavement cap. No remedial action is planned unless the cap is disturbed.

The Ameron site is 1 acre in size and is located approximately 0.5 acres northeast of the BSC site. Ameron operated a protective coating manufacturing operation at this location from 1960 to 1982. Various solvents were stored in underground tanks during plant operations. Investigations by Ameron in 1983 and 1984 discovered solvents in a former drum storage area and under the facility buildings. Under a consent order, Ameron completed construction of a subsurface liquid and vapor collection system in 1988. Operation and Maintenance of the system is ongoing.

The other inactive hazardous waste sites located within a 2-mile radius of the Lackawanna site are in various stages of investigation and are described in NYSDEC's 2000 listing of inactive hazardous waste sites.

2.1.5.2.5 Public

Near the south end of the site, in the area where Blasdell Creek discharges into Lake Erie, effluent from the Erie County Sewage Treatment Plant is directed through an outfall into the lake. As previously noted, Woodlawn Beach, a public park, is located to the south of Blasdell Creek. The Lackawanna site is bounded on the northwest by the USACE's Dredge Disposal Area No. 4 and the Buffalo Outer Harbor.

Two public recreational beaches on Lake Erie are located within 2 miles of the site. The beaches are Woodlawn Beach, located immediately south of the site, and the Niagara Frontier Transportation Authority (NFTA) Lakeside Park (also called Gallagher Beach) located approximately one-half mile north of the site. A beach in the Town of Hamburg Park is located approximately 2.5 miles south of the site. The nearest downstream public beach is on the Niagara River at Beaver Island State Park, Grand Island, New York, approximately 9 miles from the site. Several beaches in Canada on Lake Erie and the Niagara River are nearer to the site than Beaver Island State Park but, because of lake/river flow patterns, would not be contacted by water from the vicinity of the Lackawanna site.

2.1.5.2.6 Fisheries

Commercial fishing within New York waters of Lake Erie is minimal as a result of legislation passed in 1986 that prohibited the use of gill nets. Only one fisherman reported commercial activity during 2000 (NYSDEC 2001). The reported commercial marketable harvest in 2000 totaled 283 kg (624 lbs) of yellow perch, 35 kg (77 lbs) of burbot, and 98 kg (216 lbs) of rockbass.

In order of harvest size, the main sport fishing species on Lake Erie are walleye, smallmouth bass, rock bass, and yellow perch (NYSDEC 2001). Estimates of harvested walleye (28,594) for 2000 represent a 24 percent increase compared to 1999. Conversely, smallmouth bass harvests (15,783) were the third lowest numbers since 1994 and yellow perch harvest (3,021) were the lowest observed in the 13-year survey. Additionally, rock bass have emerged as an abundant nearshore species (7,990 harvested in 2000) and rank fourth in the overall open lake harvest. Round goby populations have also dramatically increased in numbers and were the third-most abundant species encountered in warmwater fisheries.

Bait fish such as Rainbow smelt (age 0 to 1 year) were the most abundant species collected by trawling methods at 30 locations within the open waters of Lake Erie at depths between 15 – 30 meters in October 2000 (NYSDEC 2001). Some shoreline recreational fishing is done downstream of the site from breakwalls and similar structures along Lake Erie, Buffalo Harbor and the Niagara River.

NYSDEC routinely performs chemical contaminant analyses of fish from Lake Erie (The Great Lakes Nearshore Contaminant Monitoring Program). According to Mr. Tim Preddice from NYSDEC Region 5 (personal communication on 2/7/02), a recent study was conducted in 1997. Thirty-five locations were chosen, including a location near a power plant in Dunkirk, New York (approximately 60 miles southwest of BSC), and a location near the mouth of Smokes Creek, within the Woodlawn Beach area. The sample grouping was composed of "Young of Year" fish (47% Bluntnose Minnows, 33% Spottail Shiners and 20% Emerald Shiners). Contaminants evaluated included PCBs, organic chlorinated pesticides, dioxins, furans, mirex and mercury. DDE, DDD, chlorobezene, lindane, cholorodane, PCBs, dioxins, and furan were some of the compounds detected in the fish from all 35 locations. Analyses were compared to criterion established by the "International Joint Commission of Great Lakes" (IJCGL). According to Mr. Preddice no criterion was exceeded in the fish collected from the Dunkirk and Smokes Creek locations (verbal conversation on 2/7/02). The official report of the 1997 sampling has not been released by NYSDEC as of the writing of this document.

2.1.5.2.7 Boating

The nearest boat harbor to the site is the NFTA Small Boat Harbor, approximately 1 mile north of the site. Additional waterfront facilities downstream of the site include a small, private marina just north of the Union Ship Canal at the foot of Tifft Street, the Erie Basin Marina, approximately 3.5 miles north of the site, and a facility at the foot of Ontario Street, over 8 miles from the site. Additional boat launches are located in the Niagara River further downstream.

Harbor facilities are generally open from early May to late October. Boat ramps may be open year-round, although lake ice restricts usage during the winter.

A recreational public area (Woodlawn Beach) operated by the New York State Office of Parks and Recreation Department, is located adjacent to the southern boundary of BSC's property. The northern portion of the park (north of Rush Creek) remains a "wild" area, whereas a swimming beach is located south of Rush Creek. Recreational activities available at the park include swimming, birdwatching, a playground, fishing, boating and windsurfing.

The NFTA Boat Harbor Lakeside Park, constructed in 2002, is located approximately 1,500 feet north of BSC's property boundary. Recreational activities include a sunbathing/wading beach, personalized water-craft (Jet Ski), canoe and kayak launch ramp, a windsurfing access area, a fishing pier, and bicycle/pedestrian path. Currently, the City of Buffalo refers to the area as Gallagher Beach. By mid 2003, New York State plans to make this facility a state park and will add swimming to the available activities.

The marine navigational chart (NOAA Chart 14822) for the area offshore of the site indicates a dumping ground lake-ward of the site located just north of the mouth of Smokes Creek to the USACE Spoils Impoundment No. 4 at the facilities northwest corner. This dumping ground extends a distance of approximately 1/4 to 3/4 mile into the lake. The water levels within the dumping ground average six feet in depth.

There is no specific information available on boating activities directly offshore of the site. However, it is not uncommon to observe small fishing boats offshore and within several hundred feet of the site's shoreline. Windsurfers, jet skis, and small sailboats have also been observed offshore of the site.

2.1.5.2.8 Drinking Water

Numerous telephone contacts were made in 1999 with governmental personnel from communities in the vicinity of the Lackawanna site. Agencies contacted include the Erie County

Department of Health (ECDOH), NYSDEC, as well as two water companies that serve the area (Erie County Water Authority and the Water Division of the Buffalo Department of Public Works). These contacts were made to assess the use of private and commercial water wells. None of these contacts were aware of any private or commercial wells being used within three miles of the site, with the exception of a well used by the Buffalo and Pittsburgh railroad. This well is located at a railroad service building about one and one half miles northeast and upgradient of the site. The well is used for potable and nonpotable uses. Erie County personnel indicated that permission to drill the well was granted because of the long distance (1000 feet) to the nearest water main. Copies of telephone contact sheets, a map showing the location of the Buffalo and Pittsburgh well and a driller's log for the well are presented in Appendix A.4.

According to the contacts mentioned above, none of the communities or Erie County prohibits wells. The ECDOH does require that private residences hook up to municipal water and sewer, if available, whenever a home is sold. All of the area within three miles of the Lackawanna site is served by municipal water companies.

Lake Erie is the primary source of drinking water in the Buffalo area. The major public entities that utilize Lake Erie water are the City of Buffalo, the Town of Tonawanda, and the Erie County Water Authority.

The nearest of these public water supply intakes belongs to the City of Buffalo water system. This intake is located approximately 4 miles north of the site, near the entrance to the Niagara River. The intake is located approximately 8,000 feet from the eastern shore of Lake Erie, in about 20 feet of water. The City of Buffalo water system services a population of about 350,000.

The Town of Tonawanda's water intake is about 1/4 mile upstream of Strawberry Island in the middle of the Niagara River, approximately 9 miles north of the site. This intake services a population of approximately 90,000 people.

The Erie County Water Authority's water intake is just upstream of Motor Island, approximately 10 miles north of the site. Motor Island is located near the entrance of the

Tonawanda Channel of the Niagara River near the south end of Grand Island. This intake services a population of approximately 100,000 people.

Other water authorities drawing water from the Niagara River (East Branch) include the City of Tonawanda (serving approximately 18,000 people), the City of North Tonawanda (serving approximately 40,000 people), the City of Lockport (serving approximately 26,000 people), and the City of Niagara Falls (serving approximately 70,000 people). These water intakes are all at least 14 miles downstream of the Lackawanna site.

2.2 Summary of Phased Site Investigation

2.2.1 Introduction

Constituent characterization at the BSC Lackawanna facility has been one of the major goals of the RFI. Various investigations have been conducted as part of the RFI to determine the nature and extent of potential environmental impacts to groundwater, soil, surface water, and sediment.

As specified in the AOC, the RFI was conducted in phases including Phase I, Phase II-A, Phase II-B, Phase II-C and Phase III. Work plans for each phase were developed with input from and approval by the USEPA and NYSDEC. Draft final reports were submitted to the USEPA and the NYSDEC for Phase I (BSC 1992a), Phase II-A (BSC 1993a), and Phase II-B (BSC 1994a). The results of some portions of the Phase II-C investigation were presented to USEPA in two reports on January 20, 1995 (BSC 1995b) and on April 17, 1995 (BSC 1995c). A full summary of the data collected in Phase II-C was submitted to USEPA on October 21, 1997 (BSC 1997a). The results of the Phase III investigation were submitted to the USEPA in summary form on March 5, 1996 (BSC 1996). A complete summary of the data from Phase III was submitted to USEPA on October 31, 1997 (BSC 1997b).

Summaries of each of the RFI phases are presented below. Further details regarding methodologies used in Phases I, II-A, and, II-B are given in the reports for these phases. Boring logs and construction details for wells, piezometers and test pits are provided in Appendices B through D of this report. Soil, groundwater, and surface water sample records for all phases of the RFI are provided in Appendix E.1. Methodologies for Phases II-C and III are presented in Appendix E.2 of this report. Monitoring well construction data for RFI and HWM wells is summarized on Table 2-1. The sampling dates for RFI and HWM wells are summarized on Table 2-2. The analytical data are discussed in Sections 3.0 through 6.0 of this report. SWMU specific data and sampling records for test pits, surface samples and subsurface borings are presented in the individual SWMU reports in Parts V and VI of this report. Watercourse sampling records for surface water and sediment are presented in the individual watercourse reports in Part VII of this report.

2.2.2 Phase I

Based on the findings of the RFA, the focus of the Phase I RFI was to evaluate potential impacts to human health and the environment via surface water pathways.

Phase I activities were initiated in August 1990 and extended through August of 1992. Major work elements were groundwater monitoring well installation, groundwater monitoring, aquifer testing, installation and monitoring of stilling wells, groundwater modeling, surface water and sediment sampling, surface water modeling, the collection and analysis of climatic data, and the completion of a preliminary risk assessment.

Procedures and results for the various investigation activities are fully described in the Phase I Draft Final Report (BSC 1992a). Table 2-3 lists the 34 wells installed during Phase I and provides a brief description of the purpose of each well. Locations of the wells are shown on Figure 2-5.

2.2.2.1 Groundwater

Five groundwater sampling rounds from a total of 40 wells (Table 2-2) were conducted on a quarterly basis over the period January 1991 to January 1992. This sampling schedule was selected to cover the seasonal variations in weather conditions that might affect water chemistry. Samples were collected from all wells in the groundwater monitoring well network and submitted to the contract laboratory Wadsworth/Alert Laboratories (now named Severn Trent Laboratories, Inc.) of Pittsburgh, Pennsylvania. Water level measurements were taken at each of the monitoring wells on a weekly basis for 13 consecutive months.

The analytical parameters selected for the Phase I investigation were agreed upon by BSC, USEPA, and NYSDEC. The parameters were selected as being representative of constituents typically present in wastes from the coking and iron and steel operations. Analytical parameters for the first and last sampling rounds included the parameters listed on Table 2-4. Analyses of the samples taken in the middle three rounds were limited to the indicator parameters and selected hazardous constituents shown on (Table 2-4). Groundwater sampling records are provided in Appendix E.1.

2.2.2.2 Groundwater Unit Testing

Monitoring well testing to determine groundwater unit hydraulic conductivity was conducted on all wells included within the groundwater monitoring network, except for wells MWS-13, MWS-14, and MWS-15, in December 1990, and June 1991 and August 1991. In addition, groundwater unit testing was conducted at monitoring well MWN-13B and at the piezometers listed in Table 2-3, excluding MW-7B. Groundwater unit testing results were presented in the Phase I report (BSC 1992a). Groundwater unit testing results are discussed in detail in Section 2.5.1.5. Groundwater unit test results for all RFI activities are provided in Appendix E.4

Comments by the USEPA and NYSDEC regarding groundwater unit testing at the Lackawanna site during Phase I were provided to BSC on March 4, 1993 (USEPA 1993a). These comments included concerns about tests performed on wells screened across more than one stratigraphic interval, slug testing procedures, and data reduction and interpretation. BSC has incorporated these comments in later phases of the investigation.

2.2.2.3 Stilling Wells

BSC installed one stilling well into the Ship Canal (SW-1), Smokes Creek (SW-2), and Lake Erie (SW-3) to allow accurate surface water elevation measurements (Figure 2-5A). Each stilling well was "paired" with an existing monitoring well in order to evaluate differences in groundwater and surface water elevations at the stilling well locations. Construction details of the stilling wells are shown in Appendix B. Each stilling well was equipped with a battery-operated continuous water level recorder, installed in onshore weatherproof boxes, and a pressure transducer. Stilling well SW-3 was destroyed by lake ice after less than one year of use and was not replaced.

2.2.2.4 Surface Water and Sediment

Sampling and testing of surface water and sediment from Smokes Creek, the Ship Canal, Blasdell Creek, the South Return Water Trench and the North Return Water Trench was conducted during Phase I. Sampling locations are shown on Figures 2-6 through 2-10. One surface water sample and one sediment sample were collected from each of the three locations in the Ship Canal, and from each of the three locations in Smokes Creek. One surface water sample and one composite sediment sample each were collected from Blasdell Creek, the South Return Water Trench and the North Return Water Trench. The surface water samples were analyzed for the total constituents listed in Table 2-4. The sediment samples were prepared for chemical testing using TCLP. The TCLP extract was then analyzed for the constituents listed in Table 2-4. The results of these investigations were submitted to the USEPA in separate Watercourse Assessment Reports (see Table 1-3).

One other surface water body, the Slabbing Mill Return Trench, was investigated during the Phase I investigation. The results of this investigation were submitted to the USEPA on February 5, 1992 (Table 1-3). The USEPA subsequently determined that no further assessment was required for this watercourse on June 11, 1992.

In EPA's comments on the Phase I Report, the agency stated that the TCLP analysis inadequately characterized contaminants in the sediment samples of the watercourses being investigated. As a result, BSC analyzed sediment samples for total constituents in subsequent watercourse investigations.

2.2.2.5 Groundwater and Surface Water Modeling and Risk Assessment

In the preliminary risk assessment, the mass loading of constituents in groundwater and transport of constituents from groundwater to Lake Erie surface water were calculated and modified. This approach was used because the most probable and significant route of exposure to hazardous waste and/or constituents is through discharge of groundwater to surface water. The predicted surface water constituent concentrations formed the basis of a preliminary assessment of the potential risk to human health from exposure to hazardous constituents as a result of direct contact or ingestion of lake water or fish caught in contaminated water. The groundwater and surface water modeling effort is discussed in detail in the Phase I Report (BSC 1992a).

In comments to the modeling effort provided in the Phase I Draft Report, USEPA and NYSDEC concluded that the use of the target model was inappropriate, given the quantity and quality of the data, which existed at the time. The agencies further concluded that groundwater flow and discharge rates should be based on field data. In response, discharge calculations for the site, provided in later section of the RFI, have been prepared based on field data and not modeling results. The results of the modeling effort in Phase I should be considered only as a point of reference.

2.2.2.6 Meteorological Data

A weather station was located on the roof of a 30-foot-high building (Station "O") located just north of the junction of Smokes Creek and BSC Highway No. 9 (see Figure 2-1). The weather station included an anemometer, rain gauge, and aspirated thermometer. These continuous-recording instruments were used to collect weather data during the one-year monitoring period. The results are presented in Section 3.2 of the Phase I Report and in Appendix A.3 of the RFI.

2.2.3 Phase II-A

The objectives of the Phase II-A investigation were:

- To refine the current understanding of site hydrogeology
- To refine previous estimates of mass loading and transport of hazardous constituents to surface waters bordering the site
- To refine the preliminary risk assessment and,
- To further identify locations of potential sources of hazardous constituents to the groundwater.

Phase II-A field activities were conducted from September 1992 through June 1993. The major elements of the Phase II-A investigation were the construction of 23 monitoring wells and 30 piezometers; groundwater monitoring; the collection of subsurface material samples; groundwater unit testing; a revision of the groundwater and surface water models and the development of preliminary risk assessment. In addition, a surface water investigation of Lake Erie was conducted using mini-piezometers and seepage meters installed into lake bottom sediments in conjunction with the collection and analysis of surface water samples taken from Lake Erie. Lastly, a soil gas survey was performed in the Acid Tar Pits area to investigate the source of potential contamination in Zone 2.

2.2.3.1 Groundwater

Twenty-three new monitoring wells, including five well pairs consisting of a shallow ("A") well screened to intercept the top of the water table within the fill and a deep ("B") well designed to screen the sand unit underlying the fill, as well as 30 piezometers, were installed during the Phase II-A investigation (Table 2-6). Monitoring well and piezometer logs and installation details are included in Appendix B and Appendix C. The rationale for the placement of each of the Phase II-A wells and piezometers is presented in Table 2-6. Monitoring well and piezometer locations are shown on Figure 2-5. Monitoring well and piezometer installation and soil sampling methods were similar to those used in Phase I (BSC 1992a) and are detailed in the

Phase II-A Work Plan (BSC 1992b). Groundwater sampling and analysis was conducted in accordance with procedures specified in the Data Collection Quality Assurance Plan (BSC 1991b). One round of groundwater samples was collected from each of the 23 newly installed wells and from the 40 wells comprising the previously existing Phase I groundwater monitoring well network. The samples were analyzed for the parameters listed on Table 2-4. Groundwater sampling records are provided in Appendix E.1. Groundwater elevations were measured at all wells included in the monitoring program on a monthly basis for three consecutive months. The water level measurements are provided in the Phase II-A Report (BSC 1993a). As part of the Phase II-A Investigation, continuous water level recorders were installed at selected piezometers and well clusters to evaluate vertical hydraulic gradients between the fill and underlying units.

Water level recorders were also installed at locations along the Ship Canal to compare the fluctuations of water levels in the canal with fluctuations in groundwater levels. The data were statistically analyzed to determine lag time, correlation, and attenuation factors. The results of these analyses are discussed in Section 2.7 of this report.

2.2.3.2 Groundwater Unit Testing

Results of the Phase I groundwater model shows that vertical flow (upward or downward) in the slag fill may be an important component influencing groundwater flow and constituent movement. For this reason, in-situ groundwater unit tests (falling-head slug tests) were performed to determine vertical hydraulic conductivity at six of the Phase II-A boreholes prior to their completion as monitoring wells. In addition, step-type pumping tests and/or falling head slug tests were performed to evaluate horizontal hydraulic conductivity at eleven of the wells installed during Phase II-A. Groundwater unit test data, calculations, and results were provided in the Phase II-A report (BSC 1993a). Groundwater Unit testing results are discussed in detail in Section 2.5.1.5. Groundwater unit test result calculations for all wells are provided in Appendix E.4.

Comments by the USEPA and NYSDEC regarding groundwater unit testing at the Lackawanna site during Phase II-A were provided to BSC on October 13, 1993 (USEPA 1993b), following review of the Draft Phase II-A Report. These comments included concerns about tests performed on wells screened across more than one stratigraphic interval, slug testing procedures, and data reduction and interpretation. BSC addressed these comments in later phases of the investigation and the resulting groundwater unit testing changes and results are provided in section 2.5.1.5 of the RFI.

2.2.3.3 Lake Erie Surface Water

The Lake Erie surface water investigation included the installation of five mini-piezometers (Figure 2-11) and three seepage meters (Figure 2-12) into the lake bottom using techniques described by Lee and Cherry (1978). The miniature piezometers and seepage meters were employed to confirm that the lake was a groundwater discharge zone, to measure discharge rates to the lake, to identify the extent of the groundwater discharge zone, to identify hydraulic gradients between groundwater and surface water, and to identify hydraulic conductivities of nearshore lake sediments. These activities are discussed in full in the Phase II-A report (BSC 1993a). In addition, three surface water samples were collected, one from each seepage meter (infiltrometer) location (Figure 2-12). These samples were analyzed for the parameters listed in Table 2-4. Surface water sampling records are provided in Appendix E.1.

2.2.3.4 Soil Gas Survey

During Phase II-A, a passive soil gas survey was performed in the area of the Acid Tar Pits (ATPs) in Zone 2 (Figure 2-13) in order to determine if such a technique was appropriate to investigate potential contaminant source areas at the site. The soil gas survey was limited to an area south and west of the ATPs (SWMUs S-11 and S-22) in Zone 2. The results of the soil gas investigation, including QA/QC installation/retrieval and analysis procedures, are described in detail in the Phase II-A report (BSC 1993a).

2.2.3.5 Modeling and Risk Assessment

The steady-state model developed during Phase I was refined and recalibrated to include additional hydrogeological data gathered during Phase II-A. The model encompassed the entire study area, extending from Blasdell Creek to the Buffalo Harbor (11,500 feet) and from approximately 500 feet east of the Ship Canal to Lake Erie (4,500 feet). A sensitivity analysis was performed in order to assess that the model was functioning properly.

The surface water model was also re-examined using new data gathered during the Phase II-A investigation. The new data included estimates of the groundwater discharge zone and revised estimates of groundwater discharge rates. The purpose of the surface water modeling was to evaluate the dispersion and dilution effects of the Lake Erie and Niagara River flow regimes on hazardous constituents that might be discharged into the lake via groundwater under normal flow conditions, and ultimately, to estimate downstream concentrations.

The Phase I risk findings were re-evaluated using the results of the Phase II-A investigation including data such as the rate of flux of constituents entering surface water and constituent loadings. The risk findings were also re-evaluated using additional information on groundwater quality in the sand layer. The risk assessment was limited to current human health risks due to ingestion of surface water, fish, and shellfish, or dermal contact with the water.

The USEPA and NYSDEC provided comments on the modeling and risk assessment presented in the Phase II-A report (USEPA 1993b). The agencies concluded that the value of the surface water and groundwater model for drawing definitive conclusions about site transport is compromised due to the limited usable data. The agencies further concluded that, in general, the use of simple analytical models and flow net analyses would be more appropriate. BSC agreed and these methods are utilized in later sections of this report.

The agencies also concluded that the surface water risk assessment presented in Phase II-A, while useful in evaluating the potential need for interim measures on a site wide basis, is unacceptable as a final risk estimate due to the limitations of the data used to estimate exposure point concentrations. BSC concurred with the agencies and a new risk assessment has been prepared and is summarized in Part II, Section 5 and presented as Part IV.

2.2.4 Phase II-B

The principal objectives of the Phase II-B investigation were:

- To fill data gaps identified during previous phases of the investigation
- Gather data for the characterization of SWMU/source areas
- Evaluate potential corrective measure technologies.

The Phase II-B investigation occurred between January 1994 and September 1994. Major elements of the Phase II-B investigation were monitoring well construction, groundwater sampling, source characterization activities, hydrological investigations, the collection and analysis of surface water and sediment samples from Blasdell Creek.

The results of the Phase II-B investigation were documented in the Phase II-B Final Draft Report (BSC 1994a).

2.2.4.1 Groundwater

Twenty-two new monitoring wells were installed in Phase II-B, including nine well pairs consisting of shallow ("A") wells screened to intercept the top of the water table within the fill and deep ("B") wells screened in the sand unit underlying the fill; two individual wells screened in the sand unit; and two bedrock ("D") wells. Table 2-7 lists these wells along with their intended purpose. The main objective of these new wells was to evaluate conditions in those areas where constituent plumes were previously detected, namely the Benzol Yard, Coke Oven Area and Acid Tar Pit Area. Boring and monitoring well construction logs are presented in Appendix B. Monitoring well locations are shown on Figure 2-5.

Monitoring well installation procedures followed those employed in previous Phases and specified in Appendix C of the Phase II-B Work Plan (BSC 1994c). Analyses were for parameters listed in Table 2-4. Sampling records are provided in Appendix E.1.

Groundwater levels were measured from selected old and new wells screened in the fill unit. The water level measurements are provided in the Phase II-B Report (BSC 1994a). At the same time, groundwater levels were being measured, groundwater samples were collected from each of the newly installed wells and analyzed for constituents listed in Table 2-4. Split groundwater samples from eight wells (selected by USEPA) were provided to USEPA. Sampling records are provided in Appendix E.1.

2.2.4.2 Groundwater Unit Testing

Groundwater unit testing, utilizing slug testing, was performed in all Phase II-B wells in order to obtain additional data regarding the hydraulic conductivities of the peat, till, and clayey silt units. Results are presented in the Phase II-B report (BSC 1994a).

Comments by the USEPA and NYSDEC regarding groundwater unit testing at the Lackawanna site during Phase II-B were provided to BSC on February 17, 1995 (USEPA 1995), following review of the Draft Phase II-B Report. These comments included concerns about tests performed on wells screened across more than one stratigraphic interval, slug testing procedures (use of falling head tests), and data reduction and interpretation. BSC has addressed these comments in the RFI and the resulting changes are provided in section 2.5.1.5 of this report. Groundwater unit testing results are provided in Appendix E.4.

2.2.4.3 Geophysical and Soil Gas Surveys

A geophysical survey consisting of magnetometry and electromagnetic induction was conducted to identify potential contaminant source areas within Zones 1 and 2 (Figure 2-14). The results of the survey provided the basis for the final design of a soil gas survey conducted over the same area. A total of 47 Petrex soil gas samplers were installed in the two zones. Soil gas probe locations are shown on Figure 2-15. Detailed discussions of the geophysical and soil gas surveys are presented in the Phase II-B Report (BSC 1994a).

2.2.4.4 Smokes Creek Hydrogeology

A hydrogeological investigation was conducted at Smokes Creek in order to provide a better understanding of the relationship between the creek and the groundwater system it traverses. The investigation included the installation of mini-piezometers and seepage meters in the creek bed, following the same techniques used during the Phase I investigation. Results are presented in the Phase II-B report (BSC 1994a) and in the Smokes Creek Watercourse Assessment Report provided in Part VII of the RFI.

2.2.4.5 Ship Canal Hydrogeology

To refine the understanding of groundwater discharge rates to the Ship Canal obtained during Phase I, water level data were collected from the canal itself and also from three adjacent piezometers. The results of this effort were evaluated using the Ferris (1963) method. Results are presented in the Draft Phase II-B report. The applicability of this method and the results obtained from its use were questioned by the Agency. In response to Agency concerns, this method and the results obtained by its use have been omitted from this report.

2.2.4.6 Blasdell Creek Surface Water and Sediment

Surface water and sediment samples were collected from five locations on Blasdell Creek, and analyzed for parameters listed in Table 2-4. The sampling program is discussed in detail in the watercourse assessment for Blasdell Creek (see Part VII). Sample locations are shown on Figure 2-8. Aliquots of water and sediment samples from three of these locations were provided to USEPA for independent analysis per agency request. Sampling records are provided in the Blasdell Creek Assessment Report in Part VII of this report.

2.2.4.7 SWMU Investigations

Twenty SWMUs located in SFA Zones 2, 3, 4, 5, the Tank Farm Area, and the Coke Oven Area were investigated during Phase II-B. Investigation activities included drilling and logging of soil borings, collection and analysis of surface and subsurface soil samples, inspections and a soil gas investigation. Sampling and analytical activities are summarized in Table 2-9. Laboratory analyses for the SWMU assessment samples included total constituent analysis and sample processing by TCLP and the Synthetic Precipitation Leaching Procedure (SPLP) followed by analysis of the resulting extracts. Detailed descriptions of these activities are provided in the Phase II-B Report (BSC 1994a) as well as in the individual SWMU investigation reports provided in Parts V and VI of this report.

2.2.4.8 Preliminary Remedial Technologies Screening

A preliminary screening of remedial technologies was conducted for soils, sludges, and groundwater. The screening process followed applicable USEPA guidance documents. Results of the screening process are presented in the Phase II-B Report (BSC 1994a). Subsequent screening was conducted and incorporated in two workplans submitted to the USEPA: (1) one for SWMUs S-11/S-22 (Acid Tar Pits) (BSC 1995d) and (2) one for SWMU P-11 (Benzol Plant Storage Area) (BSC 1995e).

2.2.5 Phase II-C

The principal objectives of the Phase II-C investigation were:

- Collect additional groundwater, soil, and sediment data for the SWMU and surface water body assessments
- Determine background (off-site) soil and water quality.

BSC completed the Phase II-C field investigation in order to respond to agency comments regarding data gaps following their review of the Draft Phase II-B report.

Phase II-C activities occurred between October 1994 and March 1995. Major work elements included collection and analysis of surface water and sediment samples from on-site locations in Lake Erie, Smokes Creek, the Ship Canal, and Blasdell Creek, and off-site locations upgradient of the site; collection and analysis of seep samples from the south bank of Smokes Creek; and a limited soil gas survey downgradient (north) of SWMU S-22 in the Acid Tar Pits area. Sampling records for these activities are contained in Appendix E.1. Analytical results are provided in the Watercourse Assessments in Part VII of the RFI.

Additional investigations were performed for 25 SWMUs in SFA Zones 2 and 4, plus the Tank Farm and Coke Oven areas. SWMU-related activities included installation of soil borings and monitoring wells; collection and analysis of groundwater samples; and collection and analysis of soil, fill, and waste material samples. Sampling records associated with these activities are provided in Appendix E.1. Analytical results are provided in the individual SWMU assessment reports contained in Parts V and VI of this RFI report.

In order to complete an aggressive Phase II-C field sampling schedule prior to the onset of winter conditions, and a February 28, 1995 agency deadline for field work, much of the Phase II-C field work was conducted prior to submission of the work plan to USEPA which occurred on December 15, 1994. The remaining Phase II-C investigation was conducted during the period when the USEPA was reviewing the work plan. Although the Phase II-C investigation was completed without approval by the agencies, all of the field sampling methods and procedures and data analysis followed agency approved methods and procedures. As a result, the results of the Phase II-C investigation are included in the RFI.

2.2.5.1 <u>Smokes Creek and Acid Tar Pit Area Surface Water, Groundwater and Sediment</u>

Surface water and sediment samples were collected from Smokes Creek, and groundwater samples were collected from ATP area monitoring wells, to determine groundwater quality conditions in the area. A total of five types of sampling were employed:

1. 24 surface water samples were collected from seven locations in Smokes Creek (Figure 2-6). Analytical parameters included those listed in Table 2-4, along

with total and dissolved metals (excluding calcium and sodium) and total dissolved solids. Sixteen additional surface water samples were collected and analyzed for volatile organic compounds (VOCs) only.

2. 16 sediment samples were collected from Smokes Creek. Seven of these samples were analyzed for the parameters in Table 2-4, excluding all but one of the indicator parameters, total organic carbon (TOC). Two of these seven samples also processed by the TCLP method, and the resultant extract was analyzed for the VOCs, semivolatile organic compounds (SVOCs), and metals listed in Table 2-4. Two samples were analyzed for VOCs only. The remaining seven samples were analyzed for selected metals using the Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM) procedure to determine the bioavailability of metals in the sediment (USEPA 1991).

3. Two seep samples (SCS-3 and SCS-4) were collected from two groundwater seepage points in the south bank of Smokes Creek and analyzed for VOCs. Sample locations are shown on Figure 2-6.

4. Groundwater samples were collected from eight monitoring wells to evaluate groundwater conditions in the vicinity of the ATPs. The samples were analyzed for VOCs only.

5. Ten soil gas probes were installed within 50 to 200 feet south of Smokes Creek and approximately 600 feet east and west of monitoring well pair MWS-18A/B (Figure 2-16). Samples from these probes were sent for laboratory analysis for VOCs by thermal desorption-mass spectrometry (TD-MS).

2.2.5.2 Ship Canal Surface Water and Sediment

During Phase II-C, surface water and sediment samples were collected from the Ship Canal to determine if benzene in groundwater, originating from the Coke Oven Area, was migrating through the Ship Canal wall. One surface water sample and one sediment sample each were collected from five locations (Figure 2-7). The six water samples (five samples plus a duplicate sample) were analyzed for the parameters listed in Table 2-4. The six sediment samples (five samples plus a duplicate sample) were analyzed for the parameters listed in Table 2-4, excluding all indicator parameters except TOC. In addition, six additional sediment samples (AV-1, AV-2, AV-3, AV-3DUP, AV-4 and AV-5) were collected from five locations adjacent to the west wall of the canal (Figure 2-7). These six samples were analyzed only for the AVS/SEM selected metals.

2.2.5.3 North and South Return Water Trench Sediment

Seven sediment samples were collected from six locations in the North and South Return Water Trenches (Figures 2-9 and 2-10). The samples were analyzed for the parameters listed in Table 2-4. Also, three surface water samples were collected from the trenches (Figures 2-9 and 2-10) and analyzed for all parameters listed on Table 2-4, including both total and dissolved metals, except carbonate alkalinity and total dissolved solids. Sampling records are provided in Appendix E.1. A complete discussion of groundwater and sediment quality for these water courses is provided in the individual watercourse assessments reports for the North and South Return Water Trenches in Part VII of this report.

2.2.5.4 Lake Erie and Buffalo Outer Harbor Surface Water and Sediment

In order to supplement existing analytical data regarding groundwater discharges to the near-shore portion of the lake, surface water and sediment samples were collected from seven locations in Lake Erie approximately 200 feet from the shore (Figure 2-17). Eight water samples were collected and analyzed for the parameters listed in Table 2-4. A total of seven sediment samples were also collected from six of these locations and were analyzed for the parameters listed in Table 2-4.

To assess Lake Erie and near shore water and sediment quality north of the BSC site, five surface water and five sediment samples were collected from three locations in the Buffalo Outer Harbor and one location in the Union Ship Canal, as shown on Figure 2-18. Five water samples were analyzed for the parameters listed in Table 2-4. Five sediment samples were analyzed for the parameters listed in Table 2-4. Sampling records are provided in Appendix E.1.

2.2.5.5 Background Surface Water and Sediment

Background soil, sediment, and surface water samples were collected from off-site locations and compared with site data to evaluate what concentrations of certain constituents may be indicative of natural conditions existing in the BSC area. One background soil sample was collected from each of following five locations: Humboldt, South, Heacock, and Hamburg Town Parks, and the currently vacant Blasdell School lot. Sampling locations are shown on Figure 2-19. The background soil samples were collected from 0 to 6 inches below ground surface and analyzed for the parameters listed in Table 2-4, excluding all but one indicator parameter, TOC. In addition, surface water and sediment samples were obtained from three upgradient locations in Lake Erie (BK-1, BK-2 and BK-3) (Figure 2-19). Two sediment samples (BC-1 and BC-2) were also collected from Blasdell Creek from a location upstream from the BSC property (Figure 2-19), and were analyzed for the list of parameters in Table 2-4, excluding all but one indicator parameter, TOC, and including AVS/SEM selected metals. No background sediment sample was collected from Smokes Creek, however, because the creek bed consisted of clean course gravel from the area south of Bethlehem Park to just west of South Park Avenue, where the creek bed consisted of shale bedrock. These types of bottom materials are not suitable for sampling.

2.2.5.6 Groundwater

During Phase II-C, groundwater samples were collected from 18 existing monitoring wells. This was done to supplement and confirm groundwater quality data obtained from these wells which had been sampled only once previously. Two new wells installed during Phase II-C (MWN-28A and MWN-29A) were also sampled. A list of the sampled wells is presented in Table 2-8. The groundwater samples were analyzed for the parameters listed in Table 2-4 including total and dissolved metals, calcium and sodium.

2.2.5.7 SWMU Sampling

The Phase II-C SWMU investigation activities included drilling and logging of soil borings, collection and analysis of surface and subsurface soil, fill, sediment, and waste material samples; installation of monitoring wells MWN-28A and MWN-29A in the vicinity of SWMU S-12 (see Figure 2-5); and groundwater sampling. SWMU sampling and analytical activities are summarized in Table 2-9. Rationale for installing MWN-28A and MWN-29A are presented in Table 2-10. Descriptions of these activities, sampling records, and analytical results are provided in the individual SWMU assessment reports presented in Parts V and VI of this RFI report.

2.2.6 Phase III

The principal objectives of the Phase III investigation were to:

- Better document groundwater quality, soil quality, and hydrologic conditions in the Coke Oven and Acid Tar Pits areas
- Better document surface water and sediment quality in the major surface water bodies at the site
- Collect soil/sediment samples at selected SWMUs for completion of SWMU assessment reports
- Conduct human health and ecological risk assessments

Fieldwork tasks were detailed in two Phase III Work Plans: the Groundwater Monitoring Well Installation Work Plan Module (BSC 1995f) and the Sampling, Analysis and Testing Work Plan Module (BSC 1995g), both submitted to and approved by USEPA. Risk assessment tasks were detailed in the approved Human Health Risk Assessment Work Plan (BSC 1997c), and the approved Ecological Risk Assessment Work Plan Module (BSC 1995h).

Major elements of the Phase III investigation were the installation of 25 new monitoring wells and 15 piezometers as well as the collection and analysis of subsurface soil and groundwater samples. Other elements of the Phase III investigation included groundwater unit testing; surface water and sediment sampling in the Ship Canal, Smokes Creek, Blasdell Creek, and Lake Erie; and soil/sediment sampling for selected SWMUs. Groundwater, soil and sediment sampling and analysis was conducted in accordance with procedures specified in the Data Collection Quality Assurance Plan (BSC 1990b, revised 1993) and with specific procedures provided in the above-referenced Phase III Work Plan Modules. Samples were analyzed by Ecology and Environment, Inc., Lancaster, New York. Analytical results are provided in Appendix F. A list of the sampled wells is presented in Table 2-11. Well and piezometer logs, well development, and well construction records are provided in Appendix B. Groundwater and soil boring sampling records associated with these activities are provided in Appendix E.1. Sampling records and analytical results for samples collected for the SWMU and watercourse assessments are contained in Parts V, VI and VII of this RFI report.

2.2.6.1 Groundwater

Groundwater samples were collected from the 25 newly constructed wells and analyzed for the constituents listed in Table 2-4. In addition, water level measurements were taken at all existing on-site monitoring wells and piezometers installed during Phases I, II-A, II-B, II-C, and III to collect data for the development of groundwater elevation contour maps. Groundwater in all wells was observed to identify whether LNAPLs and/or DNAPLs were present in the on-site groundwater. The site-wide groundwater monitoring round was conducted on September 20 and 21, 1995. Results are provided on Table 2-12, along with groundwater levels obtained from other site-wide monitoring rounds.

2.2.6.2 Groundwater Unit Testing

Aquifer testing, consisting of falling and rising head slug tests, was conducted on all 25 Phase III monitoring wells to evaluate the hydraulic properties of the screened units. Representative groundwater unit test data, calculations, and results are provided in Appendix E.4.

2.2.6.3 Ship Canal Surface Water and Sediment

Six designated stations were selected for the collection of surface water and sediment samples in the Ship Canal (Figure 2-7). All samples were split with USEPA Region II. Sampling procedures followed those specified in the Sampling, Analysis and Testing Work Plan (BSC, 1995d). At each station, two locations were sampled for surface water and sediment. Samples were analyzed for the parameters listed on Table 2-4.

2.2.6.4 Smokes Creek Surface Water and Sediment

During Phase III, six stations in Smokes Creek (Figure 2-6) were sampled for surface water and sediment. An additional background sediment sample SC-N (BKG) was also collected to evaluate background sediment conditions (Figure 2-20). All samples were split with technicians from USEPA Region II. Procedures were as outlined in the Sampling, Analysis and Testing Work Plan (BSC 1995g). Water and sediment samples were analyzed for same parameters and by the same methods as samples from the Ship Canal. For Blasdell Creek, sediment samples were collected from nine mid-creek sampling locations, including one upstream location (Figure 2-8 and Figure 2-20). The samples from six Blasdell Creek locations were analyzed for VOCs, SVOCs, total metals and metals using the AVS/SEM procedure. Samples from the remaining Blasdell Creek locations were analyzed for total metals and metals using the AVS/SEM procedure. In addition, four shallow sediment samples were collected from Lake Erie, two at the mouth of Blasdell Creek (BEPA-1 and BEPA-2) and two at the mouth of Smokes Creek (SEPA-1 and SEPA-2)(Figure 2-17). Sediment samples from all four locations were split with the EPA. Three of the four above locations were later resampled for AVS/SEM metals due to a laboratory error. The Lake Erie sampling was requested by EPA in a letter dated July 18, 1995. In this letter, BSC was instructed by EPA to take shallow sediment samples and to attempt to collect sediment core samples. The core samples were attempted but could not be collected because of hard bottom conditions that allowed the core to advance only a couple of inches.

2.2.6.5 Test Pits

Four test pits were excavated in the northeast area of Zone 1 (Figure 2-21) to assess whether buried scrap metal or buried drums were responsible for elevated electromagnetic readings obtained in this area. One grab sample was collected from Test Pit No. 3 (TP-3) at 5 feet below grade and analyzed for total and leachable (SPLP) VOCs, SVOCs, metals, cyanide, and TOC (Table 2-4). Logs of the test pits are provided in Appendix D. Analytical results are provided in Appendix F.

2.2.6.6 SWMU Sampling

Samples were collected from three SWMUs (S-14, S-25 and P-18) to obtain soil and sediment quality data for inclusion in the SWMU Assessment Reports. A composite sample from each of two borings drilled in both SWMU S-14 and S-25 was analyzed for total and leachable (SPLP) constituents including SVOCs, metals, TOC and cyanide (Table 2-4). In addition, the discrete (grab) sample that exhibited the highest headspace reading from each boring was analyzed for total and leachable (SPLP) VOCs (Table 2-4). At SWMU P-18, two sediment samples were collected and analyzed for total and leachable (SPLP) VOCs, SVOCs, metals, and cyanide (Table 2-4). Boring logs, sampling records and the results for Phase III sampling activities are provided in the individual SWMU Assessment Reports provided in Parts V and VI of this report.

2.2.6.7 Human Health and Ecological Risk Assessments

A human health risk assessment and an ecological risk assessment were conducted based on the data collected in all phases of the RFI. Methods and procedures employed in these risk assessments were identical to those described in the work plans previously cited. The results of the risk assessments are provided in Section 4.0 and Section 5.0 of this RFI report.

2.2.7 Comprehensive Groundwater Sampling Event

A site-wide groundwater sampling event was conducted from November 2 through November 11, 1999 of all of the existing onsite pre-RFI and RFI monitoring wells. The primary objective of the sampling event was to provide a "snap shot" of groundwater quality throughout the site at a distinct moment in time. A second objective of the sampling program was to address agency comments regarding the difficulties of interpreting sample data sets that were collected during multiple sampling events. Additionally, the 1999 event was the first of four separate site-wide groundwater elevation monitoring events that were conducted to assess seasonal fluctuations in the groundwater flow. Prior to this sampling round, groundwater quality data had been determined primarily through the sampling of monitoring wells soon after construction.

The work scope for the sampling event was detailed in a Work Plan submitted to USEPA on September 23, 1999 (BSC 1999). Sampling records are provided in Appendix E.1, and a summary of the investigation is provided in Appendix E.3. Analytical results are provided in Appendix F and are discussed in detail in Section 3.0 of the RFI report.

2.2.8 Supplemental SWMU Investigation

- The Supplemental SWMU Investigation was conducted from October 2000 through January of 2001. The principal objectives of the Supplemental SWMU Investigation were to:
- Better document groundwater quality and hydrologic conditions in the Coke Oven area and areas adjacent to the North and South Return Water trenches.
- Collect soil and groundwater samples at selected SWMUs for completion of SWMU assessment reports.
- Fieldwork tasks and procedures were detailed in the Supplemental SWMU Investigation Work Plan submitted to USEPA on September 7, 2000. This work plan generally followed the procedures specified in the Phase III work plan modules (BSC 1995f and BSC 1995g). A detailed summary of the methods and procedures used is provided in Appendix E.3

Major elements of the Supplemental SWMU investigation were the installation of 27 monitoring wells and 17 piezometers (see Table 2-13) and the collection and analysis of subsurface soil samples from seven selected SWMUs. Groundwater, soil and sediment sampling and analysis was conducted in accordance with procedures specified in the Data Collection Quality Assurance Plan (BSC 1990b, revised 1993) as well as specific procedures provided in the above-referenced work plan. Samples were analyzed by Severn Trent Laboratories and Microseeps Laboratories, Inc., of Pittsburgh, PA, and analytical results are provided in Appendix F. Well and piezometer logs, well development, and well construction records are provided in Appendix B. Groundwater and soil boring sampling records associated with these activities are provided in Appendix E.1. Sampling records and analytical results for samples collected for the SWMU assessments are also contained in the individual SWMU Assessment reports contained in Parts V and VI of this RFI report.

2.2.8.1 Groundwater

Groundwater samples were collected from the 27 newly constructed wells and analyzed for the constituents listed in Table 2-4. In addition, water level measurements were taken at all existing on-site monitoring wells and piezometers installed during Phases I, II-A, II-B, II-C, III, the Shoreline Investigation and the Supplemental SWMU Investigation. The water level measurements were subsequently used to collect data for the construction of groundwater elevation contour maps and to also identify whether LNAPLs and/or DNAPLs were present in the on-site groundwater. The site-wide groundwater monitoring round was conducted on November 20, 2001. Water levels in elevations for this monitoring round are provided on Table 2-12.

2.2.8.2 Groundwater Unit Testing

Groundwater unit testing, consisting of falling and rising head slug tests, was conducted on all five of the wells completed in the sand unit ("B" wells) and ten of the twenty-two wells completed in fill ("A" wells) to evaluate the hydraulic properties of the screened units. Representative groundwater unit test data, calculations, and results are provided in Appendix E.4.

2.2.8.3 SWMU Sampling

One surface and one subsurface soil sample was collected from each of four soil borings drilled in the Tank Farm area (SWMU P-74 and P-75). At SWMU P-8, also located in the Tank Farm area, two soil borings were drilled adjacent to the concrete pads of two former aboveground storage tanks that comprise this SWMU. One soil sample each was collected from each boring. Soil samples were also collected from two borings drilled within SWMU S-19. All of the soil samples from these borings were analyzed for total and leachable (TCLP and SPLP) constituents including SVOCs, metals, TOC and cyanide (see Table 2-4). Soil sampling locations for SWMUs S-19, P-74, P-75 and P-8 are provided in the SWMU assessment reports in Part V and Part VI of this RFI report.

Surface samples were collected from the upper 6-inches at five locations in an area used to store soil excavated from SWMU P-73. Soil samples were analyzed for total and leachable (TCLP and SPLP) constituents including VOCs, SVOCs, metals, TOC and cyanide (see Table 2-4). The sampling locations are provided in the SWMU P-73 assessment report in Part VI of this RFI report.

Two test trenches were excavated in SWMU S-17 to assess potential impacts at depths below zones where soil staining had been observed in earlier subsurface investigations. One sample from each trench was collected from what appeared to be clean soil that lay below stained soil. This sample was analyzed for total and leachable (TCLP and SPLP) constituents including VOCs, SVOCs, metals, TOC and cyanide (see Table 2-4). The trench locations and sampling locations are provided in the SWMU S-17 assessment report in Part V of the RFI.

Five test trenches were excavated at SWMU S-28 (Drum Landfill) to assess whether buried drums or other waste had been placed in the area. Although no drums were found, one sample was collected from a layer of stained soil and one sample was collected from below the stained soil. These samples were analyzed for total and leachable (TCLP and SPLP) constituents including VOCs, SVOCs, metals, TOC and cyanide (see Table 2-4). The trench locations and sample locations are provided in the SWMU S-28 assessment report in Part V of the RFI.

Several surface and subsurface samples were collected at SWMU S-18 to better characterize the waste placed in this SWMU. Two borings were advanced in the lime and kish pile area. One kish sample was collected from one boring and a lime and a kish sample were collected from the other boring. In addition, two kish and two lime grab samples were collected from representative waste piles. Two kish and two lime composite samples were also collected from waste piles in the SWMU S-18 area. All of the samples were analyzed for total and leachable (TCLP and SPLP) constituents including VOCs, SVOCs, metals, TOC and cyanide (see Table 2-4). Sample locations are provided in the SWMU S-18 assessment report in Part V of the RFI.

2.2.8.4 Surface Water

Fifteen surface water-measuring locations were established along the North and South Return Water Trenches and Smokes Creek in order to measure the surface water elevations in these water bodies during site wide groundwater monitoring events. Measuring points (Staff Gauges) are SC-1 through SC-3 for Smokes Creek and TBM-1 through TBM-11 and TBM-2006 for the Return Trenches. Staff gauge locations are shown on Figure 2-5.

2.2.9 Shoreline Investigation

An investigation was undertaken to evaluate vertical groundwater gradients and the stratigraphy of subsurface soils along the Lake Erie shoreline and determine the nature of contaminants in the groundwater and sediments along Lake Erie shoreline. Although not an initial objective, dredge spoils encountered during the shoreline investigation were characterized to further evaluate their impact to the sites subsurface conditions.

The Shoreline Investigation Work Plan was presented to USEPA on August 28, 2000 and revised on September 8, 2000. A summary of the methods and procedures used in the investigation is provided in Appendix E.3.

The Shoreline Investigation activities were conducted during September and October of 2000. Work elements included the construction of eight nested (shallow, medium and deep) piezometers (P-25 S/M/D through P-32 S/M/D), two shallow monitoring wells (MWS-27A and MWS-28A), and one deep well (MWS-28B). Seven soil samples were collected from a silty sand unit below slag fill in six of the eight piezometer borings (two samples were collected from P-32). Samples were analyzed for total and leachable (TCLP and SPLP) constituents including VOCs, SVOCs, metals, TOC and cyanide (see Table 2-4). In addition, tentatively identified semi-volatile compounds were also analyzed. Groundwater samples were collected from MWS-27A and the samples split with the NYSDEC. The two remaining monitoring wells were destroyed before they could be sampled. Piezometer and monitoring well locations are shown on Figure 2-5. Boring logs are provided in Appendix B and Appendix C as well as in the "Investigation of Dredge Spoils Dumping" report found in Appendix G; soil sampling records are provided in Appendix E.1. Analytical results and a discussion of the findings of the shoreline investigation are provided in Section 3.0 and Appendix G of this report.

2.2.10 Additional Investigations

2.2.10.1 Fish and Bird Study

As part of an Ecological Risk Assessment, field work was performed from June through August 1996 to assess the completeness of exposure pathways to fish that use Blasdell and Smokes Creeks. The field work also addressed exposure pathway completeness for the birds that may feed on fish found in these water courses.

The Smokes Creek fish community was surveyed by electrofishing on July 23 and August 27, 1996 (Table 2-14). Six segments of Smokes Creek were electrofished along a 3,300 yard segment of the creek extending from the creek mouth at Lake Erie to a point just upstream of the stream fork located above the Hamburg Turnpike Bridge. The Blasdell Creek fish community was surveyed by seining and electrofishing on July 24 and August 28, 1996 (Table 2-14). Two segments of the creek were sampled: one area upstream and one area downstream of the Hamburg Turnpike Bridge. The study and conclusions are presented in the Ecological Risk Assessment report included in Part III of this RFI report.

A limited avian observation was conducted from June 21 to June 28, 1996 at the site. The specific focus of the investigation was to identify birds that used Smokes Creek, Blasdell Creek, or the Ship Canal as a feeding area. The survey technique consisted of traversing the site on foot, pausing frequently to identify birds observed visually or by hearing their calls. The study and conclusions are presented in the Ecological Risk Assessment report included in Part III of this RFI report.

2.2.10.2 Voluntary Natural Attenuation Studies

To assist in addressing fate and transport aspects of on-site groundwater contamination and to support the risk assessment, two voluntary studies were performed to evaluate if natural biological attenuation of organic contaminants was occurring at the site. Natural attenuation is a process by which the mass, concentration or mobility of hazardous and nonhazardous chemicals in groundwater or soil is reduced through physical and/or chemical and/or biological processes.

The study focused on biodegradation because this process can result in the conversion of contaminants to innocuous by-products by virtue of microbial reactions.

The study was conducted in two phases. The first phase was a pilot study to evaluate, through a limited sampling and analysis program, if sufficient evidence was present in contaminated groundwater found within SFA Zone 2 to suggest that natural attenuation was occurring. This phase was followed by a second, more extensive sampling program involving wells located throughout the SFA.

In the pilot study, eleven existing monitoring wells within or near Zone 2 (Table 2-15) were sampled. Groundwater samples were analyzed for three types of parameters that can be used to assess the potential for biodegradation of organic contaminants: dissolved gases (oxygen and carbon dioxide); geochemical parameters (nitrate; dissolved and total manganese; dissolved, total, and ferrous iron; sulfate; and TOC); and benzene. Other useful parameters (dissolved oxygen, oxidation-reduction potential [Eh], and pH) were measured in the field. This phase of the study relied solely on secondary evidence, i.e., the spatial distributions of indicator parameters of biodegradation, to evaluate whether this evidence was sufficient to show that the biodegradation of groundwater found in SFA Zone 2 was occurring.

The second phase of the study involved the sampling of 37 existing monitoring wells (Table 2-15). Groundwater samples were analyzed for a much larger suite of parameters, as well as additional indicator parameters. These data were used, as in the pilot study, to identify secondary evidence of biodegradation. In addition, previously collected RFI data were evaluated to identify the distribution of benzene, phenol, and naphthalene. This evaluation was used to assess primary evidence of natural attenuation at the site. Primary evidence is provided by evaluating the distribution of contaminants in groundwater over time. This evaluation is based on the theory that continued plume growth suggests that natural attenuation is insufficient to limit the plume's downgradient migration, whereas a stable or shrinking plume provides evidence of the ability of natural attenuation processes to limit plume migration.

As a final step in the study, an analytical solute transport model was used to estimate the rate of natural attenuation occurring in groundwater at the Lackawanna site. The model was also used to predict the future fate of benzene distribution in the site groundwater.

The results of the Natural Attenuation investigation were first presented to the USEPA in the First Interim Submittal of the Draft RFI in July 1998. In comments provided to BSC by USEPA on August 14, 1998 (USEPA 1998), USEPA stated that the Natural Attenuation Study was not within the scope of the RFI and was not approved by USEPA. The USEPA further stated that the Natural Attenuation section should be removed from the RFI. BSC agreed and will not discuss further the results of the study. However, the analytical data collected during the study is retained in this report because the sample collection procedures adhered to previously approved work plans.

2.2.10.3 Supplemental Ecological Sampling Program

A supplemental ecological sampling program was conducted from June 5 through June 8, 2001 at the Lackawanna site. The objective of the program was to collect information that was necessary to complete the Ecological Risk Assessment (ERA) for the facility. Details and results of the program are provided in the Ecological Risk Assessment Report in Part III of the RFI.

The Ecological Sampling Program work scope consisted of the following:

- Field reconnaissance of selected terrestrial areas located in the western portion of the site.
- Visual-based habitat assessment of the North and South Return Water Trenches;
- Environmental sediment and surface water sampling in Blasdell Creek and soil sampling in selected SWMU and non-SWMU areas of the site;
- Limited macroinvertibrate biosurveys in Blasdell Creek;
- Delineation of jurisdictional wetland areas adjacent to Smokes Creek, within and adjacent to the BSC Lackawanna site.

An ecological field reconnaissance was conducted in SFA Zones 2, 3, 4 and 5. Work tasks consisted of describing the dominant plant communities and dominant plant species, identifying any obvious signs of distressed vegetation, or signs of wildlife, and documentation and identifying any threatened and endangered species. The survey was qualitative in nature and completed during the growing season.

During the course of the field reconnaissance noted above, a habitat assessment of the North and South Return Water Trenches was completed. The objective of this assessment was to describe the ability of the return trenches to support possible ecological receptors that might be at risk from exposure to potential constituents of concern.

Environmental sampling consisted of collecting soil from selected SWMUs and non-SWMU areas, and surface water and sediment samples from Blasdell Creek. All samples were analyzed for the parameters listed on Table 2-4.

Surface water samples were collected from 5 locations and sediment samples from 8 locations in Blasdell Creek. In addition, one duplicate and one matrix spike and matrix spike duplicate were collected. Indicator parameters of dissolved oxygen, temperature, specific conductivity and pH were measured *in situ* at each sampling location for the water samples.

Two surface soil samples were collected from within each of 9 SWMUs (SWMUs S-3, S-7, S-10, S-11, S-20, S-22, S-23, S-24 and S-27), to better characterize environmental conditions of the soils in these areas. One duplicate and one matrix spike and matrix spike duplicate were also collected. In order to better understand soil conditions outside SWMU areas, surface soil samples were also collected from 10 locations outside of SWMU areas. Six total samples each were collected in SFA Zones 3 and 5 (three in each Zone), and four total samples were collected in Zones 2 and 4 (two in each Zone). One duplicate and one matrix spike and one matrix spike duplicate were also collected. All of the SWMU and non-SWMU soil samples were collected from 0 to 12-inches below the surface with hand augers and/or trowels.

All of the environmental samples collected during the Supplemental Ecological Sampling Program were collected in accordance with the sampling procedures outlined in the Final Work Plan for Phased Site Investigation (BSC, 1990a) and the Data Collection Quality Assurance Plan (BSC, 1990b).

A macroinvertibrate survey was conducted at each of the eight sediment sampling locations in Blasdell Creek. The objective of the survey was to utilize the identification of the benthic macroinvertibrates and their community as an indication of the ecological condition of the sediments within Blasdell Creek. The survey activities consisted of the collection and identification of organisms and the qualitative description of their habitat.

A wetland delineation evaluation was conducted to identify existing baseline ecological concerns indicative of the section of Smokes Creek that flows through the SFA of the BSC site. Wetlands were delineated using U. S. Army Corps of Engineers criteria (COE, 1987).

2.3 Regional Geology and Hydrogeology

2.3.1 Regional Geology

The BSC Lackawanna site is located in the Erie-Ontario Lake Plain physiographic province of Western New York (University of the State of New York, 1976). The geology of the Erie-Niagara basin is described as consisting of unconsolidated deposits (predominantly of glacial origin) overlying Silurian- and Devonian-age sedimentary bedded or layered bedrock (La Sala, 1968). The naturally occurring unconsolidated deposits in the area consist of the following three general types: (1) alluvial silt, sand, and gravel deposited during comparatively recent geologic time; (2) late Pleistocene lacustrine sediments composed primarily of silt, sand, and clay; and (3) Pleistocene glacial till, a heterogeneous mixture of particles (i.e., clay, silt, sand, gravel, and cobbles) deposited directly from glacial ice. Relief in the area is due to pre-glacial erosion of bedrock and subsequent topographic modification by glaciation.

The bedrock formations in the region dip to the south and exhibit only very gentle folding. The average dip is 30 to 40 feet per mile. Because the rocks dip to the south and the land surface rises in that direction, progressively younger rocks are exposed at the surface from north to south. The uppermost bedrock formation within the study area is the Middle Devonian Skaneateles Shale (La Sala, 1968). The upper portion of this formation is generally composed of interbedded marine shales and limestone. Relatively intense erosion near Lake Erie has exposed the rock at lower elevations in western New York than they are farther east in the Appalachian Uplands.

2.3.2 Regional Hydrology

In the Erie-Niagara Basin, the major sources of groundwater are glacial sand and gravel deposits and the Onondaga Limestone, Akron Dolomite, Bertie Limestone, Camillus Shale, and Lockport Dolomite (La Sala, 1968). The Skaneateles and Marcellus Shales overlie the Onondaga Limestone and have a much lower permeability and yield. In some areas, the overlying glacial deposits may be hydraulically connected to the bedrock, particularly where the upper bedrock surface is fractured and the glacial deposits consist of sand and gravel. Recharge to the regional bedrock groundwater unit occurs almost exclusively by percolation from overlying glacial deposits in inter-stream areas. Vertical and bedding joints in the bedrock receive water where they intersect the fracture zone along the top of the rock or intersect the overlying glacial deposits. However, where the bedrock surface is competent and overlain by lacustrine silts, clays, or clayey tills, very little or no hydraulic connection is likely to exist.

Where joints are thin and widely spaced, groundwater flow within and along the bedrock units is controlled by the primary permeability of the unit and by the secondary porosity, which includes fractures, joints, and open bedding plane surfaces. The main sources of groundwater within the bedrock are fractures and solution cavities. The shale at depth has a much lower permeability than the fractured zone at the top of the shale (La Sala, 1968). Yields from wells drilled in the shale are typically less than 10 gallons per minute (gpm), and dry holes or wells with inadequate yields are common.

Shallow peats, lake deposits and tills are commonly considered low-yield units but may contain thin, irregularly distributed discontinuous layers of water-bearing fine sand, sandy clays, or sandy silts. Groundwater recharge to the unconsolidated deposits in the Erie-Niagara basin is variable. More-permeable deposits such as sand and gravel accept infiltration at a much higher rate than low-permeability materials such as till, clay, and silt. Regionally, groundwater recharge ranges from about 500,000 gallons per day (gpd) per square mile (2.4×10^{-3} feet per day [ft/day]) for surficial sand and gravel deposits to about 50,000 gpd per square mile (2.4×10^{-4} ft/day) when the alluvial deposits are overlain by tills (La Sala, 1968).

Groundwater quality in the Erie-Niagara basin as described by La Sala (1968) is generally governed by the concentrations of dissolved solids from soluble minerals. The four most common soluble minerals are calcite ($CaCO_3$), the major constituent of limestone; dolomite ($CaMg\ (CO_3)_2$); gypsum ($CaSO_4 \cdot 2H_2O$); and halite, or common salt ($NaCl$). Calcite and dolomite are distributed throughout the area, not only in the carbonate rocks but also in glacial deposits that contain fragments of carbonate rocks. In addition, most of the shale units are calcareous to some extent. As a result, all of the groundwater in the region is in contact with carbonate minerals. Gypsum is abundant only in the Camillus Shale and present in minor quantities in the Lockport Dolomite. Salt beds, which occur only in the Camillus Shale, are limited to an area approximately 25 miles south and east of the site.

The quality of groundwater in the vicinity of the site is generally fair with moderate levels of hardness (250-500 ppm), sulfate (100-500 ppm) and chloride (100-500 ppm) (LaSala 1968). The concentrations of these dissolved solids in the vicinity of the site increase to the north and decrease to the south and east.

2.4 Site Geology

As noted previously, man-made deposits cover the site, particularly near the lake. While some peat deposits exist, the natural surficial geology of the study area is composed principally of lake sediments consisting of blanket sands and beach ridges that are occasionally underlain by lacustrine silts and clays. Granular deposits frequently act as shallow groundwater units, whereas lacustrine clays and glacial tills often inhibit groundwater flow. Water-laid sediments often contain horizontal laminations and sand seams that facilitate groundwater movement through otherwise low-permeability material. Site-specific hydrogeological conditions are described in Section 2.5.

Available data indicate that the site is underlain by six distinct units. The units in stratigraphic order (top to bottom) include (1) fill, (2) peat, (3) sand, (4) silt and clay, (5) glacial till, and (6) shale or limestone bedrock. The lower unconsolidated deposits are the result of Pleistocene glacial processes. Several cross sections of the site have been prepared using data from previous investigations as well as subsurface data obtained during the RFI. The locations of the cross sections are shown on Figure 2-22. A legend for the cross sections is provided on Figure 2-23. The cross sections are shown on Figures 2-24 through 2-33a. Elevations of the stratigraphic units that underlie the site are presented in Table 2-16. The boring logs used to develop this information are provided in Appendices B and C.

The geologic units are described below in terms of their lithologic characteristics and probable origin.

2.4.1 Fill

The fill unit covers the entire site and consists of iron-making and steel-making slag, cinders, coke, ashes, and brick and steel construction debris generated from BSC plant activities combined with granular fill soils. The thickness of the fill is extremely variable. High ridges of fill with thicknesses greater than 100 feet are present along the Lake Erie shoreline at the northwest corner of the site, whereas in the interior of the site thicknesses are generally much lower (averaging approximately 30 feet). The fill unit gradually thins to the east and is only a few feet thick at Route 5. An Isopach map of the fill is presented in Figure 2-34. Figure 2-31, a cross section through the northern portion of the site, also shows slag thickness in this area. On the boring logs, based on material samples collected from the borings, the fill is described as being dark to light gray or dark brown fine to coarse silty sand with fine to coarse gray gravel.

The composition of the slag is predominantly calcium silicates and oxides, with lesser quantities of elements such as magnesium, iron, phosphorous, carbon, sulfur, and other, minor constituents. Typical iron-making and steel-making slag chemistry expressed in terms of oxides is shown in the table below (slag production is described in the paragraphs following the table).

TYPICAL SLAG CHEMISTRIES
(Weight Percent, Unless Otherwise Specified)

Component	Iron-making Slag	Steel-making Slag
FeO	<1	11
SiO_2	66 - 78	60
Al_2O_3	3 - 8	1
CaO	17 - 37	34
MgO	<3	6
MnO	<1	6

Source: BSC, 1992 (c).

Iron-Making (Blast Furnace) Slag

Iron was produced at BSC in seven blast furnaces situated in a north-south line on the east side of the Ship Canal. Blast furnaces are large, cylindrical, brick-lined structures that are loaded (charged) with coke, iron ores, limestone, and sinter. Process by-products from blast furnace operations include slag as well as particulates removed from exhaust gases. During operation of a blast furnace, the coke is ignited to produce heat to melt the charge. Pre-heated air is blown into the furnace to support the combustion. As the charge melts, molten iron and molten slag form. The slag floats on top of the iron and is drawn off (tapped) through a tapping hole. The molten iron is also tapped, through a hole below the slag tapping hole.

Molten slag was transported by rail to the SFA, where it was dumped and allowed to solidify. The primary disposal area for 40 to 50 years prior to 1983 was in trenches in the southwestern portion of the property (Zones 1 and 2). Slag production in 1974 was estimated to be about 3,100 tons per day. Since about 1940, the slag has been recovered from Zone 1 for use as an aggregate for concrete, granular subgrade of roadways, fill and other commercial uses. A Beneficial Reuse Determination regarding the Blast Furnace Slag was issued to Buffalo Crushed Stone by the NYSDEC on May 31, 1991.

Results of EP Toxicity tests conducted on the slag by BSC in 1981 and 1985 indicated that the slag does not exhibit EP Toxicity (USEPA NEIC, 1988).

Steel-Making Slag

Steel-making slag is a by-product of the production of steel. Steel is an alloy of iron that contains less than 1 percent carbon. Basically, steel-making is a process in which carbon, silicon, phosphorous, manganese, and other impurities present in the raw molten iron or in molten steel scrap (which is also used as a raw material) are oxidized to specific levels. At the Lackawanna Plant, steel was made in both open hearth furnaces and basic oxygen furnaces (BOF).

Molten steel-making slag from the open hearth furnaces was disposed of in the SFA near the blast furnace slag in the area just north of Smokes Creek. Molten steel-making slag from the BOF was disposed of in Zones 2, 3, and 4 along the northwestern portion of the property.

Results of EP Toxicity tests conducted on the steel-making slag by BSC in 1985 indicated that it does not exhibit EP Toxicity (USEPA NEIC, 1988). A Beneficial Reuse Determination regarding the steel-making slag was issued to BSC by the NYSDEC on July 2, 1998.

2.4.2 Peat

One of the unconsolidated geological units identified at the Lackawanna site has been labeled as peat. On the boring logs, it is generally described as a dark-gray or dark-brown clayey silt containing some organic matter. It is dissimilar from true peat, which is a partially decomposed mass of vegetation containing little mineral material. The source of true peat is geologically recent swamp deposits that are formed by the accumulation of decayed plant matter in poorly drained areas (La Sala, 1968). The origin of the so-called peat unit onsite may be similar. The onsite peat is not considered a major stratigraphic unit because it occurs only in relatively thin (less than 10-foot-thick) lenses of small areal extent overlying sand, or silty clay where the sand is absent. The only extensive occurrence of this unit observed on site is in the Coke Oven Area and south towards Smokes Creek (see cross-sections in Figures 2-25, 2-29 and 2-32). This area is presumed to be inshore of the pre-slag fill shoreline. Peat was not encountered in borings south of Smokes Creek. However, this may be the result of the limited number of wells drilled in this portion of the site. An Isopach map of the unit is presented in Figure 2-35.

2.4.3 Sand

A thin, dark gray, fine, silty sand lake deposit is present at the site beneath the fill unit. It may contain traces of fine washed gravel and traces of shell fragments, such as those found during well installations along the existing and former shoreline (Dames & Moore, 1981). The sand unit is not continuous over the entire site, as it generally pinches out to the east side of the site in the vicinity of well MWN-10 and the Coke Oven Area. The sand unit appears to be thickest (> 15 feet) at the southern and northern ends of the site, and just south of Smokes Creek. An Isopach map of the sand unit is presented in Figure 2-36.

There are two sources of the sand in this unit: dredge spoils and proglacial lake deposits that date from pleistocene time and were reworked by the lacustrine environment. Approximately half of the site area in which sand is present, formerly comprised two USACE dumping grounds, shown in Figure 1-2A. Sediments deposited within these areas by the USACE cover an extensive nearshore area and may comprise a significant part of the sand unit in the area between the eastern limit of the dumping grounds and the present day shoreline. Moreover, wave action within the nearshore zone of the lake likely redistributed the USACE dredge spoils shoreward beyond the limits of the dumping grounds. The balance of the sand, present beneath the slag fill, was deposited along the modern (but pre-SFA) shoreline of Lake Erie. It is not possible to differentiate between sand from these two sources, however, because they are derived from essentially the same source areas and hydraulic regime, i.e., nearshore lacustrine sand deposits.

2.4.4 Silt and Clay

Underlying the sand unit is a gray, laminated silt and clay unit that probably formed as a result of slow glacial sedimentation in deeper, low-energy, offshore areas of the lake bottom during Pleistocene time. Occasional thin, fine-to-coarse sand laminae and lenses occur in this unit, probably as a result of storm-generated offshore currents that redeposited sand from near shore areas. The silt and clay unit is generally about 30 feet thick.

Clayey silt lenses are distinguishable (grain size difference) from silty clay lenses and the underlying till unit (see, for example, Figure 2-27). Clayey silt lenses occur throughout the area north of Smokes Creek and are limited (thin) just south of Smokes Creek. An Isopach map of the silt and clay unit is presented in Figure 2-37.

2.4.5 Till

Underlying the silt and clay unit is a typically stiff (hammer blow counts generally greater than 20 blows per foot), reddish-brown to gray silty clay till with some occasional sand, gravel, and limestone boulders. Till characteristically is a compact, non-stratified deposit consisting of materials transported by a glacier as it moves over the land. After deposition of the till, it becomes compacted by the weight of overlying ice during cycles of glacier advance and retreat. At the BSC site, the till is not of uniform thickness and repeatedly thins and thickens across the site. An Isopach map of the till unit is presented in Figure 2-38.

2.4.6 Bedrock

The uppermost bedrock throughout most of the site is composed mostly of dark gray and black fissile shale. This shale comprises the Skaneateles and Marcellus Shales of the Middle Devonian aged Hamilton Group (La Sala 1968). Distinguishing the upper (Skaneateles) shale from the lower (Marcellus) shale is the occurrence of calcareous beds, pyrite, and 10 feet of gray limestone at the base of the Skaneateles shale; these minor strata are identified as the Stafford Limestone. The shale bedrock originated as an accumulation of fine-grained sediments deposited in ancient seas during the Silurian and Devonian periods. The (then) newly formed mountains of the Acadian Orogeny were the source of the sediment debris that was deposited within the warm, shallow sea that covered the area from the present Hudson River to Lake Erie and beyond during this period (University of the State of New York, 1976).

The Stafford limestone is observed to subcrop across the site along a strike trending in a northeast-southwest direction (Rickard and Fisher, 1970), and was identified in the cores from installation of bedrock monitoring wells MWN-02D and MWN-25D. These wells are located in the SFA north of Smokes Creek, west of the Tank Farm Area and the Coke Oven Area, respectively (see Appendices B and C for boring logs and well and piezometer construction records).

Borings drilled into the shale/limestone bedrock indicate that its surface is undulating, with as much as 50 feet of relief. Bedrock surface contours are shown on Figure 2-39. Two east-west trending bedrock valleys are apparent, one in the northern and one in the southern part of the site. These bedrock valleys are filled with unconsolidated deposits of till, silt, clay, and sand topped with industrial fill material.

2.5 Site Groundwater Regime

The Lackawanna site hydrogeology is dominated by its lakeshore setting and the characteristics of the site's subsurface materials. Slag placement in and along Lake Erie and elsewhere on the site created a site-wide man-made fill unit. The thickness of the fill is extremely variable; high ridges of fill more than 100 feet thick are present along the Lake Erie shoreline at the northwest corner of the Site, thinning to a few feet near Route 5. As noted in Section 2.4.3, the fill is underlain by a natural sand unit ranging in thickness from approximately 2 feet to 20 feet. The lower, saturated part of the fill, along with the entire natural sand unit, comprises a low-yield, shallow, unconfined water table groundwater unit. Its saturated thickness ranges from 10 feet to 30 feet. Monitoring wells screened in this groundwater unit typically yield less than 5 gpm. Of the 137 existing RFI groundwater monitoring wells installed onsite, 89 are screened in the slag fill and another 21 screened in both the slag fill and native sands below the fill. Construction details for these wells are provided on Table 2-1.

The water table unit (fill and sand) is underlain by an aquitard consisting of silt, clay and till units that together range in thickness from 2 feet to more than 50 feet. Below this aquitard is a confined and saturated groundwater unit within the uppermost part of the bedrock. This unit is assumed to discharge into Lake Erie. The unconfined water table unit, the confined upper bedrock unit and the aquitard that separates them are described in the following three subsections.

2.5.1 Water Table

The general characteristics of the unconfined water table (groundwater flow patterns, discharge, recharge, hydraulic gradient, hydraulic conductivity, and groundwater flow velocity) are discussed below. The transport and fate of contaminants in this groundwater unit are discussed in later sections of this report.

2.5.1.1 Groundwater Flow Patterns

The first site-wide groundwater measurement round was conducted on September 20 and 21, 1995. Groundwater elevation data is provided Table 2-12 and groundwater contour maps for the fill unit ("A" wells) and for the sand unit ("B" wells) are shown on Figures 2-40 and 2-41, respectively. In order to determine seasonal fluctuations in groundwater levels and groundwater flow directions, four quarterly groundwater measurement rounds were conducted of all site wells and piezometers. Groundwater elevations were measured on October 28, 1999, January 19, 2000, April 3, 2000 and July 12, 2000. Contours of groundwater elevations in wells screened in the fill and sand are presented in Figures 2-42 through 2-49. Groundwater elevation data used to develop these figures are provided in Table 2-12. A review of the four quarterly groundwater contour maps shows no major seasonal difference in the pieziometric surfaces. A final site-wide monitoring round was conducted on November 20, 2001 following the completion of the Supplemental SWMU Investigation. Groundwater elevation data for this round is provided in Table 2-12; groundwater contour maps with flow lines for the fill wells and the sand wells are presented in Figures 2-50 and 2-51, respectively. Groundwater elevations from this round are similar to earlier rounds. Therefore, further discussions of the groundwater flow regimes will be based on the groundwater elevation data collected on November 20, 2001 (most recent data shows the best well coverage).

Local flow patterns indicate several discharge areas in which groundwater flows generally east to west towards Lake Erie and the other onsite surface water bodies: Blasdell Creek, Smokes Creek, the Gateway Metroport Ship Canal, the Union Ship Canal and the North and South Return Water Trenches. The discharge areas are characterized on Table 2-17. Several groundwater divides and flow boundaries exist within the site, based on analysis of the piezometric surface on November 20, 2001(Figure 2-50); these create six distinct discharge areas, shown on Figure 2-52.

BSC developed a groundwater flow model for use in the Corrective Measures phase of site remediation. The computer groundwater flow model TWODAN (Fitz, 1997) is described in a report presented in Appendix E.6.

The model provides a groundwater contour map (Figure 5 of Appendix E-6) for the water table at the site utilizing the October 1999 groundwater elevations measured from the site monitoring well network. Inspection of Figure 5 shows that the groundwater contour lines closely follow those generated during the six site-wide groundwater monitoring events (see Figures 2-40 through 2-51). Additionally, the model provides a groundwater contour map (Figure 6 of Appendix E-6) showing site conditions after the Coke Ovens have been shut down and recharge through leaking surface and subsurface lines has ceased. This figure is also similar to Figures 2-40 through 2-51 but the groundwater mound is slightly less prominent within the Coke Oven operation area.

2.5.1.2 Groundwater Recharge and Discharge

Recharge to the site water table is from rainfall and snowmelt. Most of the site precipitation evaporates or infiltrates to the subsurface. Site runoff is minimal and, if present, is eventually intercepted by one of the surrounding water bodies (Blasdell Creek, Smokes Creek, the Ship Canal, Lake Erie or the Buffalo Outer Harbor).

During the Phase I investigation, a range of site groundwater recharge rates was derived from measured groundwater level fluctuations in two site monitoring wells, MWN-13A and MWS-12A. These wells, installed in the fill unit, are located north and south of Smokes Creek, respectively, within the SFA. Groundwater level fluctuations in these wells were measured by continuous water level recorders and compared to daily precipitation records. Recharge rates were calculated using the method described by La Sala (1968). Because site fill porosity was not measured, a range of porosity values for similar materials (i.e., silty sand) was used. The two recharge rates calculated using the two sets of fluctuations data were similar. The recharge estimates ranged from 2.6×10^{-3} to 3.5×10^{-3} ft/day (0.95 ft/yr to 1.3 ft/yr) (see Appendix H). A value of 1.02 ft/yr provided the best match between predicted and observed heads during groundwater flow modeling during Phase II-A (BSC 1993a). The 0.95 to 1.3 ft/yr estimates agree closely with published regional recharge rates (La Sala, 1968).

USEPA comment # 40 (August 14, 1998) on the First Interim Submittal of the RFI and subsequent comments on January 20, 1999, indicated that without representative information on the porosity of the materials present, analysis of the relationship between precipitation and recharge at the site can only be viewed in a qualitative sense. The USEPA stated further that BSC shall either measure fill porosity or acknowledge within the RFI that uncertainty exists in the recharge values and other values that are dependent on the recharge value.

In response to these comments, BSC is presenting a method by which the porosity of granular material may be estimated from its grain size distribution (Vukovich and Soro 1992). In general, it is well known that the porosity of granular materials depends on a number of factors, primarily grain shape, grain-size uniformity, mineralogical content, and degree of compactness. Of these, the degree of grain-size uniformity, expressed as the coefficient of uniformity η, appears to exert the highest degree of control on the porosity of natural materials (Vukovich and Soro 1992). More specifically, empirical data suggest that porosity increases when the degree of uniformity increases, i.e., when η decreased, according to the following relationship:

$$N \text{ (= porosity)} = 0.255\,(1 + 0.83^{\eta}).$$

Vukovich and Soro (1992) present a plot of this equation, superimposed upon η and n data for natural granular materials, reproduced herein as Figure 2-53.

When this method is applied to grain-size distribution data obtained in 1998 by GZA Environmental for soil grab samples from three locations and two blast oven furnace slag samples obtained by BSC in 1978 from the BSC's Bethlehem, Pennsylvania facility, the estimated porosities of these samples range from 0.26 to 0.31. The raw data and grain-size distribution plots are provided in Appendix E.7. The results of these calculations are summarized in the table below:

Sample	D10 (mm)	d60 (mm)	H	Estimated Porosity
Location A-1	0.0013	2.2	1700	0.26
Location A-2	0.0034	5	1500	0.26
Location B (composite)	0.25	16	64	0.26
Fine Slag – Before Crushing and screening (wet sieve)	0.68	6.1	9.0	0.30
Fine Slag – After Crushing and screening (dry sieve)	0.45	3.9	8.7	0.31

Previous estimates of recharge due to infiltration were based on an observed annual cumulative water table rise of approximately 4.5 feet and assumed porosities of 0.21 to 0.28. These recharge estimates ranged between 0.96 and 1.26 feet/year. BSC believes that the porosity estimates based on grain-size distribution information (presented above) support the use of a recharge value at the higher end of this range, i.e., 1.25 feet/year.

Although a uniform recharge rate for the entire site is unlikely because of the varying surface conditions (i.e., surficial material types, vegetative cover, paved roads, site building and structures, topography, etc.), 1.25ft/yr is a good approximation of the annual average recharge rate for the entire site. This value is used in the groundwater discharge calculations.

To calculate groundwater discharge rates to each surface water body, discharge for an area was assumed to equal recharge for the area. This is reasonable because there are no large-scale, artificial sources of site recharge or discharge. Some artificial recharge to Discharge Area 5 through leaking underground water lines was probable in the Coke Oven Area when the Coke Ovens were active. However, this source of recharge ceased in late 2001 when the Coke Ovens were shut down and any artificial recharge to this area would now be minor. Discharge rates from Discharge Areas 1, 3, 6, and 6A (Figure 2-52) are actually more than the estimated recharge from precipitation, because these areas receive some flow from off-site areas to the east.

Offsite recharge areas A and B (Figure 2-52) were delineated to aid in calculating offsite recharge to Discharge Areas 1 and 6 that flow across large areas of the site. Another recharge area that provides flow to Blasdell Creek from BSC facilities east of Route 5 was designated Recharge Area C. This area was delineated as a result of EPA comment #72 (November 23,

1998) for BSC's First Interim Submittal. Offsite recharge to the other discharge areas of the site were not considered because they are part of large drainage areas that contribute flow to creeks (Smokes Creek and Blasdell Creek) or contribute flow to small discharge areas that are located in areas believed not to be impacted by BSC operations (i.e., Discharge Area 6A).

The area of each discharge area (see Figure 2-52) was measured using Graphic Information System (GIS) software. The results are provided in Table 2-17. Discharge rates were calculated by multiplying the area discharging into each water body by the annual recharge rate. Recharge for Recharge Areas A, B and C were also calculated using the same method. The results are discussed in Section 2.7.2.

2.5.1.3 Horizontal Hydraulic Gradients

The average westward (lakeward) horizontal hydraulic gradient calculated for the water table surface at selected locations along the western perimeter is about 0.0029 ft/ft, based on November 20, 2001 water level measurements in monitoring wells screened in the fill (Figure 2-54). Lower gradients are observed at the northern end of the site; these values decrease to 0.0012 ft/ft and 0.00013 ft/ft in the vicinity of MWN-5A and MWN-6A. Hydraulic gradient calculations for wells screened in the sand unit average 0.0026 ft/ft but decrease to 0.0003 ft/ft near MWN-6A in the northwest corner of the site (Figure 2-55). Localized areas with higher horizontal hydraulic gradients (discussed below) were not used in estimating the sitewide averages.

Localized areas of anomalously high groundwater elevations exist in the Coke Oven Area (Figure 2-50), the ATP area (see Section 2.6), and near SWMU S-23 (Figure 2-50). These areas of groundwater mounding influence the direction of groundwater flow only in their immediate vicinity.

Groundwater mounding in the Coke Oven Area is most likely the result of a non-uniform thickness of groundwater unit materials (fill and sand). A geologic cross section for the area including the Coke Oven Area (Figure 2-25) shows that the saturated thickness of the water table is about 12 feet beneath the Coke Oven Area and increases to 35 feet to the west. The main reason for the thin saturated condition in the Coke Oven Area is a rise in the confining bed (clayey silt and/or peat) in this area. If the average hydraulic conductivity is assumed to be uniform throughout the water table in this area, the groundwater unit transmissivity (hydraulic conductivity times saturated thickness) would be approximately three times lower here than in the western part of the site. In the presence of uniform recharge, lower transmissivity causes a locally steeper hydraulic gradient and mounding of the groundwater table.

Prior to the closure of the Coke Ovens in September 2001, it was believed that artificial recharge could also contribute to the groundwater mound through leaking underground water lines and steam vents that discharged to the ground. Water level measurements in the Coke Oven Area in November 2001 and June 2004, however, continue to show a mound of approximately the same dimensions in the Coke Oven Area several years after the ovens were closed and most of the water lines were disconnected. As a result, it is believed that artificial recharge to this area was minor when the Coke Ovens were active.

In the ATP area, perched water zones are present at depths ranging from 6 to 10 feet below the surface. The perched water elevations appear to be responsive to rainfall events, indicating recharge from precipitation (R.E. Wright, 1997a). In addition, the perched water elevations frequently appear to correlate with the top of coke plant by-product waste in the waste units. In contrast, the surface elevation of the water table in this area is at approximately 20 feet below ground surface. Data collected by R.E. Wright (1997a) indicate that perched groundwater in this area most likely results from reduced hydraulic conductivity associated with waste materials present in the ATPs. A detailed discussion of the hydrogeology of the ATP area is presented in Section 2.6.

The small, somewhat elongate groundwater mound near SWMU S-23 is most likely the result of reduced transmissivity (Figure 2-50).

2.5.1.4 Vertical Hydraulic Gradients

Vertical hydraulic gradients were calculated for all paired monitoring wells and piezometers screened in the fill and sand units. The gradients, along with pertinent well data, are presented in Table 2-18.

Three nested wells/piezometers were installed at some locations. In addition to the wells screened in the overburden ("A" wells and "B" wells), there are wells screened in the underlying bedrock. Hydraulic gradients between the overburden wells ("A" or "B" designations) and the bedrock wells ("D" designations) are also presented in Table 2-18.

Figure 2-56 shows the vertical hydraulic gradients within the overburden between shallower (A) and deeper (B) wells in the water table. These gradients are based on data collected during the November 20, 2001 groundwater monitoring round. Two vertical hydraulic cross sections, Figure 2-57 (normal to Lake Erie) and Figure 2-58 (across Smokes Creek) are also provided. Figure 2-22 shows the locations of the cross sections. Most of the site groundwater exhibits a downward hydraulic gradient (positive values on map); this reflects the occurrence of recharge in these areas. Groundwater in other areas of the site exhibits net upward hydraulic gradient (negative values on map); this indicates discharge of groundwater in these areas. These areas are separated by a line of zero vertical hydraulic gradients. Areas of groundwater recharge appear to exist within the Coke Oven Area, the ATP Area, and Zones 4 and 5. Prominent zones of groundwater discharge occur southwest of the ATPs and west and southwest of the Coke Oven area. A small area of groundwater discharge is also present at the northwest end of the Ship Canal.

USEPA's comment #111 on the Phase I Report indicated that simple monitoring of water level fluctuation was unlikely to provide the information necessary to define the relationship between the fill and sand units. Further, USEPA believed that the use of quantitative pump tests were necessary to improve on the current estimations of hydraulic gradients between the fill and sand units. However, because these units collectively comprise the water table and have no confining layers between them, they are expected to be in close hydraulic communication even though the hydraulic conductivity of the sand unit is up to an order of magnitude greater than that of the fill unit. Therefore, pump testing is unlikely to provide any additional useful data that would augment understanding this relationship.

2.5.1.5 Hydraulic Conductivity

As described in Section 2.2, groundwater unit testing was performed on all Phase I wells, selected wells installed in Phase II-A, all wells installed in Phase II-B and Phase III and selected wells installed during the Supplemental SWMU Investigation. Two types of tests were performed: pumping tests and slug tests. Pumping tests were conducted in several wells screened in highly permeable materials. Slug tests were performed on the remaining wells. Results from Phases I, II-A, and II-B were presented in the reports submitted to USEPA (BSC 1992a, 1993a, and 1994a). Copies of all test results are provided in Appendix E.4, and summarized in Table 2-19.

The Agency has expressed concerns regarding the groundwater unit testing methods and results used during the RFI (USEPA 1998). Specifically, numerous Agency comments (USEPA 1993a, 1993b, 1993c, 1993d, 1994a, 1994b, 1994c, 1994d, 1995, 1998 and 1999) have stated that many of the groundwater tests performed at the site suffered from various shortcomings, most importantly:

- slug and pumping tests performed on wells screened across more than one stratigraphic unit, or in wells whose bentonite seals were not located in the unit of interest, do not give results that can be attributed to a given unit,
- slug tests performed as falling-head tests are not appropriate in wells screened across the water table,
- rising-head slug tests performed for less than sufficient time to allow 90 percent recovery are not valid,
- pumping tests must be performed for longer than 24 hours and at rates of greater than 10 gallons per minute, and
- the Cooper-Jacob and Theis data reduction methods are not appropriate for use with data obtained from single-well tests.

BSC has responded to these concerns by critically reviewing the aquifer testing performed during the RFI and discarding any results from this report that did not satisfy the first three requirements mentioned above. This review included both slug testing and pump testing activities. Specifically, slug testing results were selected for further consideration in cases where the following criteria were met:

- the slug test was a rising-head test,
- the well was screened in only one stratigraphic unit,
- the bentonite seal was located in the screened unit, and
- the test was conducted for more than 10 minutes.

Similarly, pumping testing results were selected in cases where the following criteria were met:

- the tested well was screened in only one stratigraphic unit, and
- an adequate drawdown (0.2 to 10 feet) was obtained.

Longer pumping tests are considered unnecessary because it is often impossible to maintain the rates and duration specified by the USEPA in monitoring wells and because there is adequate piezometric and lithologic control at the site to identify significant boundaries. In addition, the calculations associated with each test were checked for errors and corrected when necessary to obtain updated hydraulic conductivity values. In the case of two of the 4-inch diameter wells (MWN-5A and MWN-6A), review of the pumping test data led to the conclusion that the pumping rates and times were adequate only to yield order of magnitude estimates for the hydraulic conductivity of the fill unit in these wells. Lastly, published texts on groundwater unit testing were also examined to determine if the Cooper-Jacob and Theis data reduction methods are appropriate for use with data obtained from single-well tests. This search led to the conclusion that it is generally accepted that these methods are appropriate to use for single well tests (see, e.g., Kruseman and de Ridder 1976).

Selected groundwater unit testing results based on the above criteria are summarized in Table 2-20. These hydraulic conductivity estimates include data from 13 wells screened in the fill unit, three in the sand unit, one in the peat unit, three in the clayey silt unit, and four screened in bedrock. In addition to the results of groundwater unit testing performed during the RFI, the results from two pumping tests performed in bedrock during a 1981 study (Appendix A.1) are also included in Table 2-20. The groundwater unit testing data and results for the selected slug and pumping tests summarized in Table 2-20 are provided in Appendix E.4. More detailed discussions of the groundwater unit testing methods and of the selection and deselection of the testing results for individual wells are also presented in Appendix E.4.

The hydraulic conductivity of the fill (Table 2-20) was found to range from 1.69 x 10^{-6} centimeters per second (cm/sec) to 4.5 x 10^{-1} cm/sec. This range in values is most likely related to variations in the types of fill and in the methods by which the fill was deposited. The geometric mean of the hydraulic conductivity of the fill was 1.35 x 10^{-3} cm/sec (3.8 ft/day) and the arithmetic mean was 5.07 x 10^{-2} cm/sec (144 ft/day); this is within the range published for silty sand (Freeze and Cherry, 1979).

The hydraulic conductivity of the sand is less variable. The range of values was 6.54 x 10^{-5} cm/sec to 1.11 x 10^{-2} cm/sec, with a geometric mean of 5.99 x 10^{-4} cm/sec (1.7 ft/day) and an arithmetic mean of 3.00 x 10^{-3} cm/sec (8.5 ft/day). This value is typical for silt and silty sand (Freeze and Cherry, 1979).

Despite the different average hydraulic conductivities of the fill and sand indicated by the groundwater unit testing results, these two units act together from a hydrogeological standpoint, and are considered to be hydraulically connected.

The hydraulic conductivity for the clayey silt ranged from 8.63 x 10^{-6} cm/sec to 2.02 x 10^{-5} cm/sec, with a geometric mean of 1.51 x 10^{-5} cm/sec (0.043 ft/day) and an arithmetic mean of 1.62 x 10^{-5} cm/sec (0.046 ft/day). The hydraulic conductivity values for the bedrock from the four RFI bedrock wells ranged from 1.91 x 10^{-6} cm/sec to 1.60 x 10^{-4} cm/sec, with a geometric mean of 1.36 x 10^{-5} cm/sec (0.039 ft/day) and an arithmetic mean of 4.90 x 10^{-5} cm/sec (0.14 ft/day). If the two pre-RFI wells are included (MW-6A and MW-7A), the hydraulic conductivity values ranged from 1.91 x 10^{-6} cm/sec to 6.60 x 10^{-2} cm/sec, with a geometric mean of 6.34 x 10^{-5} cm/sec (0.18 ft/day) and an arithmetic mean of 1.10 x 10^{-2} cm/sec (31 ft/day).

The effect of selecting a subset of the hydraulic conductivity results for the various stratigraphic units (Table 2-20) was examined by comparing the data for all tests of greater than 30 seconds duration and conducted in wells screened in single stratigraphic units (Table 2-20A and Tables 2-21 through 2-24) to those selected data presented on Table 2-20. This comparison was accomplished through the comparison of histograms and geometric and arithmetic means for the data, as shown on Tables 2-21 through 2-24). For the fill unit, the range of the data was not affected but the geometric mean of the data changed slightly from 1.35 x 10^{-3} cm/sec (selected wells) to 2.14 x 10^{-3} cm/sec (tests > 0.5 min./single unit). The arithmetic mean decreased slightly from 5.07 x 10^{-2} cm/sec for the selected wells to 2.04 x 10^{-2} cm/sec (tests > 0.5 min./single unit). For the sand unit, the range of the data was increased slightly and the geometric mean decreased, from 5.99 x 10^{-4} cm/sec for selected wells to 2.04 x 10^{-4} cm/sec (tests > 0.5 min./single unit). The arithmetic mean decreased from 3.00 x 10^{-3} cm/sec to 2.02 x 10^{-3} cm/sec. For the clayey silt unit, the range was increased only slightly, as well as the geometric mean of the data, which increased from 1.51 x 10^{-5} cm/sec for selected wells to 1.91 x 10^{-5} cm/sec (tests > 0.5 min./single unit). The arithmetic mean increased slightly from 1.62 x 10^{-5} cm/sec to 2.18 x 10^{-5} cm/sec. For the bedrock unit, the range of the data was not affected if the two pre-RFI wells were considered, but the geometric mean of the data increased from 6.34 x 10^{-5} cm/sec for selected wells to 2.41 x 10^{-4} cm/sec (tests > 0.5 min./single unit). The arithmetic mean increased slightly from 1.10 x 10^{-2} cm/sec to 1.87 x 10^{-2} cm/sec. In summary, the greatest effects of data selection are the decrease in the geometric mean of hydraulic conductivity values for the sand and bedrock.

The possible geographic bias introduced by selecting a subset (Table 2-20) of the larger groundwater unit testing data set (Table 2-20A) was also examined for each stratigraphic unit at the site. Regarding the fill unit selected tests (Table 2-20), roughly the same number of tests were selected from wells south (six) and north (seven) of Smokes Creek. The only part of the site that the fill groundwater unit testing results may not represent is the Coke Oven area, because no groundwater unit test results from fill in this area were selected. In comparison, well tests for greater than 0.5 minutes and screened in a single unit had 43 well testing results; 26 wells north of Smokes Creek, 17 south of the creek and seven wells located in the Coke Oven Area.

When the geographic distribution of selected sand unit results was examined, the results were less well distributed across the site. Most of the sand unit well tests were not selected because they were actually performed on wells screened in multiple units. Of the three selected tests from the sand unit, all are from the area north of the creek. The part of the site that is not represented by these tests is the areas south of Smokes Creek. Because the screen length for the monitoring wells at the site is typically 10 feet, and the sand unit is less than ten feet thick in these areas, it was not possible to perform valid groundwater unit testing of the sand unit in these areas using existing wells. Test results from Table 2-20A showed an increase from three test results to seven test results with four wells located south of Smokes Creek.

The geographic distribution of the selected clayey silt unit tests was also limited. In fact, all of the selected test results for the clayey silt unit are from three wells in the southern portion of the Coke Oven area. No tests were ever performed on the clayey silt unit south of Smokes Creek. As shown on Figure 2-37, the clayey silt unit is thickest in the area near and west of the Coke Oven area. There are only a few other areas of the site where it is more than 10 feet thick. Data from Table 2-20A also showed test results from the same three wells, but there were two test results for each well.

Selected bedrock groundwater unit testing results came from one well located south of Smokes Creek and three wells located north of the creek. The only area of the site not represented by bedrock groundwater unit testing data is the ATP area. All of the bedrock wells for which hydraulic testing results were selected are screened in shale. Groundwater unit testing results for two pre-RFI wells (MW-6B and MW-7B) were also examined and are provided in Table 2-20. Both are screened in a mixture of limestone and shale. Well testing results from Table 2-20A (tests > 0.5 min./single unit) included eight wells; three south of Smokes Creek and five north of Smokes Creek.

Based on the review of the aquifer testing results presented above, it is concluded that the use of results for aquifer tests greater than 0.5 minutes in duration and for wells screened in a single unit (Table 2-20A) rather than the selected results (Table 2-20) provide the best hydraulic conductivity estimates for the site. The major reasons include:

- The arithmetic mean hydraulic conductivities for the fill and sand are similar for both data sets.

- The number of wells for which there are test results increases significantly (the fill well results goes from 13 to 43 wells, the sand results goes from 3 to 11 wells and the bedrock results go from 6 to 8 wells).
- The geographical distribution of the tests for the sand unit is also better representative of the site with test results increasing from three to seven wells north of Smokes Creek and increasing from no wells to four wells south of Smokes Creek.
- The arithmetic mean for the fill, 2.04×10^{-2} cm/sec (58 ft/day), is similar to the hydraulic conductivity of 2.08×10^{-2} cm/sec (59 ft/day) calculated by the BSC groundwater flow model (Appendix E.6).

Overall, the results of the review of the data and methodologies used to estimate hydraulic conductivity values for the various stratigraphic units present at the site, (see Table 2-20A), provide a reliable representative data set for the hydraulic conductivity values at the site.

2.5.1.6 Groundwater Flow Velocities

Average groundwater velocities in the sand and fill portions of the water table were estimated using a modification of the Darcy equation. This equation gives mean pore velocity (V) as:

$$V = Ki/n$$

where: K = Horizontal hydraulic conductivity
i = Horizontal hydraulic gradient
n = Porosity (0.3 assumed).

Average groundwater velocities in the fill and sand are based on average hydraulic gradient values for the fill (0.0029 ft/ft) and sand (0.0026 ft/ft) units (inferred from groundwater elevations measured in November 2001 (Figures 2-50 and 2-51)) and average (arithmetic mean) hydraulic conductivity values for the hydraulic conductivities of the fill and sand units (Table 2-

20A). The assumed porosity value of 0.30 is consistent with silty sand (Freeze and Cherry, 1979).

The average westward velocity in the fill portion of the water table was 1.97 x 10^{-4} cm/sec (0.6 ft/day). The average westward velocity in the sand is approximately 1.73 x 10^{-5} cm/sec (0.05 ft/day), and reflects its lower hydraulic conductivity. Also, as previously stated, these two units act together from a hydrogeological standpoint, comprising a single groundwater unit.

2.5.2 Peat Layer

A true fibrous peat can be highly permeable with respect to other materials such as sands and silts. However, the soil classified as "peat" present at Lackawanna is not true peat, but instead a silty sediment with lesser amounts of organic materials, which may more accurately be classified as an organic silt (OM on the Unified Soil Classification System). The area underlain by "peat" as shown on Figure 2-35 is approximately 4,200,000 ft^2 (approximately 96 acres) or roughly 8 percent of the total site area west of Route 5. The horizontal hydraulic conductivity of this material is approximately 2.49×10^{-5} cm/sec, based on data from a rising head slug test performed in monitoring well MWN-19B, which is screened in "brown peat with trace of silty clay" (Boring Log – Appendix B and Table 2-20A). This suggests that the peat at Lackawanna has a horizontal conductivity equivalent to that of the silty clay layer that comprises part of the aquitard at the site. The peat largely overlies the silty clay unit in the vicinity of the Coke Oven area and as such represents an additional thickness of aquitard between the fill and sand units and bedrock units. A localized exception to this arrangement occurs in the vicinity of well MWN-26, where the peat overlies a 3 foot thick lens of sand that in turn overlies a silty clay unit. All in all, however, by virtue of its stratigraphic location and hydraulic conductivity, the effect of the "peat" on site hydrology and hazardous constituent migration is likely to be indistinguishable from that of the lower hydraulic conductivity silty clay soils at the site.

2.5.3 Silty Clay and Till Confining Layer

Silty clay and till, or both of these units, are present throughout the majority of the site. Figures 2-37 and 2-38 provide isopachs of the silty clay and till units at the site. The combined presence of these low-conductivity units results in a significant degree of hydraulic separation between the unconfined water table and bedrock groundwater unit. As a result, these units can be considered as behaving as an aquitard.

It is important to note that there are only two areas, i.e., in the vicinity of wells MWN-17A and 17B (just north of Smokes C[illegible] and along the shoreline near the mouth of Smokes Creek, where silt and clay appear to be present (Table 2-15 and Figures 2-37 and 2-38). The size of the area over which the till and silty clay are missing near MWN-17A and 17B is approximately 171,300 sq. ft., whereas the area near the mouth of Smokes Creek is approximately 146,500 sq. ft. Together, these areas represent less than 1 percent of the total site area.

Laboratory based vertical hydraulic conductivity data were obtained during Phase II-B on undisturbed samples collected during Phase I to estimate the degree of hydraulic separation potentially provided by this layer. This information was previously summarized in the Phase II-B report and is also presented in Table 2-25. Although these data could represent artificially low (by perhaps an order of magnitude) values due to problems inherent in laboratory-based methods, they can still be used to indicate that the silty clay and till units provide hydraulic separation between the water table and the bedrock groundwater unit, due to their lower hydraulic conductivity. The laboratory based vertical hydraulic conductivity estimate obtained from one sample analyzed for the 1981 report ($2x10^{-8}$ cm/sec) compares well with data obtained during Phase II-B of the RFI (average $6x10^{-8}$ cm/sec or 2×10^{-4} ft/day) (Table 2-25).

The potentiometric relationship that exists across the aquitard is presented in Table 2-18 that summarizes vertical hydraulic gradients, including that between the bedrock and unconfined (fill/sand) water bearing units.

The use of pumping tests to evaluate the degree to which hydraulic stresses are transmitted across the aquitard was carefully considered. Whether these would be useful and generate meaningful data depends largely upon the capability of site conditions to support sufficiently long-duration pumping tests necessary to this evaluation. The feasibility of such testing is highly dependent on whether the monitoring wells screened in the unconfined water table and/or bedrock groundwater units can support the necessary pumping rates and durations. In general, the bedrock hydraulic conductivity (geometric mean of 2.41 x 10^{-4} cm/sec) is too low to support pumping tests, or to register any drawdown resulting from pumping in a more permeable zone overlying stratigraphic zone. Examination of existing monitoring wells has led to the identification of only two candidate well clusters where bedrock conditions are relatively more permeable and could potentially support pumping rates of five to ten gpm. However, pump testing could potentially result in flow of water from the unconfined water table, with any associated dissolved constituents, down into the bedrock formation. For this reason BSC does not believe it would be appropriate to perform this testing.

Horizontal hydraulic conductivity estimates of the confining layer were determined by groundwater unit testing at three wells screened in the clayey silt confining layer (Table 2-23). Hydraulic conductivity values ranged from 8.63 x 10^{-6} cm/sec to 3.69 x 10^{-5} cm/sec, with an arithmetic mean of 2.18 x 10^{-5} cm/sec (0.06 ft/day). The horizontal hydraulic conductivities are significantly larger than the values calculated for vertical hydraulic conductivity (Table 2-25).

Rates of leakage through the confining layer were calculated using Darcy's Law for three monitoring well pairs (MW-6A/MW-6B, MW-7A/MW-7B, and MW-8A/MW-8B) based on the site-wide average vertical hydraulic conductivity values (Table 2-25). These well pairs were selected because each pair includes a screen above the confining layer and a screen below the confining layer in bedrock. Estimated leakage rates are presented in the table below.

LEAKAGE RATES THROUGH THE CONFINING LAYER

Piezometer Pair	ΔH(ft) on 11/28/01	K_v (ft/day)	Thickness (ft) Of Confining Layer	Leakage Rate (ft/day)
MW-6A/MW-6B	0.07	1.72 x 10^{-4}	10	1.20 x 10^{-6}
MW-7A/MW-7B	5.80	1.72 x 10^{-4}	8	1.25 x 10^{-4}
MW-8A/MW-8B	10.74	1.72 x 10^{-4}	43	4.30 x 10^{-5}

Leakage rates were calculated using the formula:

$L=\Delta HK/b$ where:

ΔH = hydraulic head difference between the two wells

K_v = vertical hydraulic conductivity

b = thickness of confining layer

The leakage rates represent only a small fraction (0.04% to 3.6%) of the precipitation recharge rate of 3.4×10^{-3} ft/day. These leakage rates, together with the continuous nature of the confining layer, indicate that it is an effective aquitard that hydraulically separates the bedrock groundwater unit from the overlying unconfined water table.

2.5.4 Bedrock Unit

In general, rock-coring data collected from the seven bedrock wells completed during the RFI (MWN-2D, MWN-3D, MWN-5D, MWN-15D, MWN-25D, MWS-08D and MW-2D2D) and from three bedrock wells completed during pre-RFI investigations (MW-06B, MW-07B and MW-08B) indicate that the uppermost ten feet or less of the bedrock is moderately to extremely weathered, and that the degree of weathering decreases with depth. Boring data obtained during the RFI show that nearly all of the bedrock identified at the site is shale. Limestone was documented as the uppermost bedrock at only two borings (MWN-2D and MWN-25D), which are located in the northeast and north-central portion of the site, respectively. The conclusion that limestone represents a minor component of the bedrock at the site is also supported by the geotechnical borings generated for the 1981 Dames & Moore report (Dames & Moore 1981). In this report, limestone (or dolomite) was identified as the uppermost bedrock in only two of the five borings drilled to bedrock (MW-6B and MW-8B).

Personal communications with Dr. Robert Jacobi of the University of Buffalo on September 25, 1998 and January 24, 2003 indicate that there are no known faults and no mapped linear features in the immediate area of the site. The nearest mapped fault is the Clarendon-Linden fault system, which lies about 50 miles east of the site.

According to Dr. Jacobi, detailed mapping of structural features such as jointing, fracturing and faulting has not been conducted in the area of the site. Several studies on jointing (Jacobi and Zhao 1996; Engelder and Geiser, 1980) have, however, been conducted in the

Appalachian Plateau region about 60 to 100 miles southwest of the site. Dr. Jacobi also indicated that the findings of these studies can generally be extrapolated to the area of the site.

The above-referenced studies showed that well-developed joint set to the southeast are common to the study area. These joint sets are predominantly oriented northwest to southeast with frequencies of several meters. Orientation of the joints is roughly parallel to the direction of compressive stress, and perpendicular to the formation front, during the Alleghanian orogeny. Development of joint sets potentially occurs in the formations extending down to evaporite units (salts and gypsum) of Silurian age that, at the site, would lie about 500 feet below grade. The different mechanical properties of these evaporite units would be likely to support development of joints.

2.5.4.1 Estimates of Bedrock Hydraulic Conductivity

The hydraulic conductivity values for the testing of wells completed during pre-RFI investigations in 1980/81 ranged from 1.62×10^{-1} cm/sec to 2.90×10^{-5} cm/sec (Table 2-24). The geometric mean is 6.10×10^{-4} cm/sec and the arithmetic mean is 7.50×10^{-2} cm/sec. If this earlier pre-RFI data are considered along with the RFI data, the values range from 1.62×10^{-1} cm/sec to 1.91×10^{-6}, the geometric mean bedrock hydraulic conductivity is 2.41×10^{-4} cm/sec and the arithmetic mean is 1.87×10^{-2} (Table 2-24). The data indicate that the hydraulic conductivity of the bedrock is variable, most likely reflecting the degree of fracturing at a specific location.

2.5.4.2 Installation of Additional Bedrock Monitoring Wells

As part of its comments on the Phase I report (BSC 1992a), the USEPA requested that future work include the installation and sampling of monitoring wells in the bedrock downgradient of identified groundwater contamination source areas, including the Coke Over area, Zone 2, Zone 4, and the Tank Farm Area. These comments indicted that the wells should be paired with existing well clusters so that vertical gradients between the fill/sand groundwater unit and the bedrock groundwater unit could be determined.

As a result of USEPA's request, a total of seven additional bedrock wells were installed downgradient of the Coke Over area, Zone 2, Zone 4, and the Tank Farm Area (see Figures 2-5 and 2-51 and Tables 2-1, 2-11, and 2-12). These wells were paired with existing well clusters, and vertical hydraulic gradients between the fill/sand groundwater unit and the bedrock groundwater unit were estimated during the six site-wide monitoring rounds (see Section 2.5.1.4, Groundwater Flow Patterns). The results are shown in Table 2-18. An upward hydraulic gradient was observed for only two bedrock wells: well MWN-5D for all six monitoring rounds and well MWN-3 during the October 28, 1999 monitoring round. The remaining comparisons between water table wells and bedrock wells showed that a downward hydraulic gradient existed, i.e., that a potential exists for flow from the upper groundwater unit into the bedrock.

Hydraulic unit testing of the bedrock groundwater unit was performed for the seven additional bedrock wells. All of the testing results are provided in Table 2-19, selected test results in Table 2-20 and results for tests greater than 0.5 minutes and wells screened in a single unit are provided in Table 2-20A. It is clear from the data that the significant range of calculated horizontal hydraulic conductivity values may be due to the irregular distribution and development of secondary porosity in the bedrock, which includes fractures (shale and limestone) and solution cavities (limestone), in conjunction with the weathered nature of the bedrock.

Because the bedrock is overlain by a thick layer of low-permeability silty clay and dense till, recharge from overlying deposits is assumed to be very small. This is supported by the leakage rate calculations recorded in Section 2.5.3. The shale is characterized by generally low permeability and, except for outcrop areas, is overlain by relatively low-permeability deposits. These facts lead to the conclusion that the rate of discharge from the shale is low. This is consistent with conditions found regionally (see Section 2.3.2).

Groundwater level data were collected from the ten bedrock unit wells on November 20, 2001, as well as from four quarterly monitoring rounds on October 28, 1999, January 19, 2000, April 3, 2000 and July 12, 2000. The November 2001 data are shown on Figure 2-59. The limited data are insufficient to construct estimated piezometric contours or derive discharge rates for the bedrock unit.

2.5.5 Summary

The primary saturated unit at the site is the unconfined water table, which occupies the sand unit and the saturated portion of the fill unit. Recharge to these units is mainly through infiltration of precipitation and subsequently discharges primarily to Lake Erie and Smokes Creek. The saturated water table is separated from the underlying bedrock groundwater unit by a silty clay and till aquitard, as is seen elsewhere in the region.

Recharge to the site as a whole is estimated to average 1.25 ft/yr. Ten distinct water table discharge areas have been identified; discharge rates for these areas are presented in Section 2.7. The average westward (horizontal) hydraulic gradient for the water table is calculated to be 0.0029 ft/ft. Vertical hydraulic gradients are generally downward, except in an area immediately west of the Coke Ovens and south towards Smokes Creek, and at the western portion of Zone 2.

Using selected groundwater unit testing results to respond to agency concerns (see Table 2-20A), the arithmetic mean hydraulic conductivity is 2.04 x 10^{-2} cm/sec (58 ft/day) for the fill unit and 2.02 x 10^{-3} cm/sec (5.7 ft/day) for the sand unit. These stratigraphic units act together to form a single unconfined saturated water table unit. The arithmetic mean hydraulic conductivity is 2.18 x 10^{-5} cm/sec (0.06 ft/day) for the clayey silt unit. The bedrock groundwater unit was calculated to have an arithmetic mean hydraulic conductivity of 1.25 x 10^{-3} cm/sec (3.5 ft/day) based on data for the RFI wells.

2.6 Acid Tar Pit (ATP) Area Geology and Groundwater

2.6.1 Introduction

The ATP area, located south of Smokes Creek, is approximately 3 acres in size and contains two SWMUs, S-11 and S-22 (Figure 2-60). The hydrogeology of the ATP area differs from that of the rest of the site. This is caused by the presence of SWMU waste materials, which have reduced the permeability of the area, either directly or indirectly or both. This reduced permeability has caused perched water conditions within the area. The geology and groundwater regime of the ATP area are described separately below to allow a clear understanding of the basis of subsequent discussions of contaminant migration from this area. A more thorough description of the ATPs and the waste stored in them is provided in the SWMU reports for SWMUs S-11 and S-22 provided in Part V of this RFI report.

2.6.2 General Characteristics of the ATPs

SWMUs S-11 and S-22 have surface areas of approximately 1.3 acres and 1.6 acres, respectively. Ground surface elevations range from 590 to 620 feet above mean sea level (amsl). The total volume of waste in S-11 and S-22 is approximately 90,000 cubic yards. SWMU S-11 contains one waste pit (ATP-1). In contrast, SWMU S-22 contains three waste pits (ATP-2, ATP-3, and ATP-4) which, according to Electrical Imaging (EI) data collected by R.E. Wright, Inc. (1997a), appear to be connected at depth.

Generally, SWMU S-11 has a gently south-sloping surface with approximately 50-percent vegetative cover, consisting primarily of shrubs, weeds, and small trees. Surficial SWMU material consists of gravel-size slag with minor amounts of stone, bricks and other debris associated with steel manufacturing.

SWMU S-22 is surrounded by a slag berm ranging in height from 3 to 8 feet above the SWMU surface. The surficial SWMU material typically consists of a black to red silt- to sand-size sediment mixed with a large proportion of water. Vegetative cover, which varies from about 20 percent to greater than 80 percent, consists of grasses, small shrubs and trees.

The top of bedrock in this area is at an approximate elevation of 541 to 546 feet above mean sea level (amsl) and slopes gently to the south. As shown on the geologic cross section for the area (Figure 2-33), this bedrock is overlain by 6 to 8 feet of till, followed by 3 to 14 feet of silty clay, 2 to 6 feet of sand, and 24 to 44 feet of slag fill. The ATP area waste materials generally extend one-half to two-thirds through the slag fill, but may extend to the underlying sand layer in localized areas within ATP-4 (within SWMU S-22).

The surface of the water table intersects the lower part of the fill between elevations of about 573 feet to 577 feet amsl. Perched water is found within the upper part of the fill/waste materials, from elevations of about 579 to 595 feet amsl (Figure 2-61).

2.6.3 ATP Area Groundwater Patterns

Groundwater data collected during the RFI indicates the presence of a groundwater mound (elevated groundwater surface) beneath the ATP area. Groundwater elevations observed in well pairs MWS-17A/B and MWS-22A/B, placed within or adjacent to the ATPs, have shown that the deeper wells typically have water elevations of 7 to 15 feet lower than the shallow wells. Piezometers installed within SWMU S-22 by SAIC (formerly R. E. Wright) (R.E. Wright 1992, 1997 and 1998) also have water elevations significantly higher than wells installed outside of the ATPs. The higher water elevations in the shallow wells and piezometers result in the prominent groundwater mound shown on Figure 2-50.

The groundwater mound shown on Figure 2-50 is attributed to multiple water zones within the ATPs that result from the varying hydraulic conductivities of the waste materials and retard the flow of water to the underlying slag. In a 1996 investigation of the ATPs (R.E. Wright (1997), hydraulic conductivities of the ATP waste were reported to range from 2.1 x 10^{-5} cm/sec to 4.13 x 10^{-7} cm/sec. This is significantly lower than the geometric and arithmetic mean hydraulic conductivities of 2.14 x 10^{-3} cm/sec and 5.07 x 10^{-2} cm/sec respectively, calculated for slag fill in the RFI (Table 2-19).

Water-level data from May 23, 1997 (Table 2-26) (R.E. Wright 1997) were used to compare groundwater levels within and around the ATPs. This is the most recent water level data collected from piezometers within the ATPs and wells adjacent to the ATPs (the site-wide water level monitoring rounds conducted in 1999, 2000 and 2001 (see Section 2.5.1.1) did not measure the piezometers installed in the ATPs). Estimated groundwater elevation contours for the ATP area are shown on Figure 2-61. A cross section through the ATPs showing the groundwater table and water levels within the ATPs is provided on Figure 2-62. The water-level data from piezometers constructed inside the ATPs were interpreted as representing perched water, although this water is thought to migrate slowly downward through discontinuous waste of low permeability. Water levels from monitoring well pairs adjacent to the ATPs were interpreted as representing either perched or regional groundwater based on comparisons of water levels in the paired wells. For each pair in which the well water levels differ by more than about one foot on a given date, the higher water level is interpreted as perched water and the lower as regional groundwater. Most well pairs consist of a shallow well screened entirely in fill and a deeper well screened in the sand and fill (sand/fill interface).

In most cases, data from the well pairs over the five most recent site-wide monitoring rounds (Table 2-18) indicate a downward vertical hydraulic gradient between the fill and sand units in the ATP area. Near Smokes Creek, however, well pair MWS-18A/18B typically and MWS-19A/19B occasionally show a neutral or upward vertical hydraulic gradient. This is consistent with expected groundwater flow patterns in an area adjacent to a receiving water body.

In general, the water table beneath the Lackawanna site slopes to the west, toward Lake Erie (Figure 2-50). In the ATP area, however, groundwater flow is radially to the west, south, north and east away from SWMUs S-11 and S-22, the result of water in many perched water zones migrating away from the ATPs. This is based on 1.) comparison of the water table elevations in the ATP area (Figure 2-60) with perched water elevations (Figure 2-61) and 2.) the lack of other known recharge sources in the area.

2.7 Site Surface Water Regime

As shown on Figure 1-2, the site is bounded on three sides by surface waters: on the south by Blasdell Creek, on the west by Lake Erie, and on the north by the Buffalo Outer Harbor (also Lake Erie). In addition, the site is divided into north and south areas by Smokes Creek. The north area also contains three man-made watercourses: the Ship Canal, the North Return Water Trench, and the South Return Water Trench. The following section describes the various water bodies and provides information on their hydraulic and regulatory characteristics. A description of surface water/groundwater interactions follows.

2.7.1 Surface Water Bodies On and Near the Site

2.7.1.1 Lake Erie

The western boundary of the site along Lake Erie is approximately 13,000 feet in length. In the site vicinity, the lake bottom consists of lacustrine silts and clays (Dames & Moore, 1978). The mean lake elevation for the years 1918 to 1996 was 571.30 feet (International Great Lakes Datum [IGLD], 1985). The mean annual lake elevations for the years 1998, 1999, 2000 and 2001 were 572.69 feet, 571.22 feet, 570.85 feet and 570.64 feet, respectively (USACE, 2002).

Water circulation in Lake Erie is wind-driven. The average difference between lake water levels at USACE stations in Cleveland, Ohio, and Buffalo, New York, is extremely small and results in a gradient of approximately 1.36×10^{-7} ft/ft to the north. No difference was measured between water level recorders installed at the BSC site and the USACE station in Buffalo. Average outflow from the lake into the Niagara River is about 200,000 cfs (130 billion gpd)(USACE, 1991). Strong winds form up to 14-foot waves and locally can cause the lake to rise over six feet.

2.7.1.2 Lake Erie Coastal Currents

The complex flow dynamics and turbulent dispersion mechanisms in the coastal area of the Great Lakes have attracted the attention of many investigators. In the coastal area, the surface wind stresses act as the main driving force, coupled with effects due to coriolis force, inertial acceleration, friction, and sometimes stratification (Csanady, 1970). A nearshore band becomes a unique kind of coastal boundary layer in which the offshore mid-lake motions adjust to the shoreline. Field studies of the Great Lakes have shown that coastal currents are predominantly parallel to shore and have typical speeds of 10 to 20 cm/sec (0.33 to 0.66 ft/sec) (USNRC, 1977). The currents are relatively persistent within this boundary layer zone and are in direct response to wind shifts.

Sheng (1975) showed that the effects of horizontal diffusion and advective transport are more important in the narrow coastal boundary layer, where stream-lines generally follow the shorelines, than in the offshore area. The width of the boundary layer is on the order of 1/4-mile for Lake Erie. According to Csandy (1970), constituent dispersion in the coastal zone results in "coastal entrapment" of pollutants, with the formation of a polluted effluent plume that generally follows the shorelines. Observations made in Lake Huron (Murthy, 1972) have shown that a pollutant discharged near the shoreline could form a well-defined plume "hugging" the shoreline. Relatively quick dispersal occurred offshore, followed by reversals in plume direction in response to reversals in wind direction.

Wind-driven circulation in Lake Erie results in a generally west-to-east near-surface flow direction along the shoreline of the site in response to eastward surface wind stress. However, studies indicate that reversal of the coastal current may occur with wind shifts and result in a large-scale mass exchange, during which offshore waters may effectively remove pollutants from the coastal zone (USNRC, 1977).

2.7.1.3 Smokes Creek

The site is roughly divided into north and south areas by Smokes Creek, which flows east to west and discharges into Lake Erie (Figure 1-2). Smokes Creek originates as two branches: the north branch, which drains areas in West Seneca, Lackawanna, and Orchard Park, New York, and the south branch, which drains areas in Lackawanna and Orchard Park. The two branches join in Lackawanna, approximately 1/4 mile east (upgradient) of the BSC property. The creek then flows under the Hamburg Turnpike and through the BSC site. The average cross-sectional dimensions of the creek within the site are 100 feet wide by 10 feet deep. The average width of the channel bottom between the Hamburg Turnpike and Lake Erie is approximately 69 feet. In the SFA and west of BSC Highway 9 (see Figure 1-2), the creek bottom is within the fill. East of BSC Highway 9, where the fill is thinner, the creek penetrates it and the underlying sand unit to the top of the natural clay layer. Local topography is fairly flat, resulting in a low gradient. The slope of the Smokes Creek channel bottom within the site is on the order of 0.001 ft/ft.

In the 1960s, BSC in cooperation with the USACE completed the Smokes Creek Flood Control Project. The project included channelization of the lowermost 5 miles of the stream and the renovation of some 30 bridges for the purpose of flood protection. The project improvements included widening and straightening the channel, regrading the side slopes, placement of rip-rap along the stream bottom and side slopes, installation of cellar jetties (sheet pile walls specially designed to control sediment build-up) along the banks near the mouth of the creek, and placement of sheet piling and stone around the affected bridge abutments. The downstream 2,600 feet of the channel improvements were constructed by BSC, with the USACE performing the rest of the project. The channel improvements resulted in an average channel bottom width of 69 feet for the portion of the creek from the Hamburg Turnpike to the mouth of the creek.

The nominal discharge rate of Smokes Creek is about 49.8 cfs (32.2 mgd) (Table 2-27), as measured at the Route 5 Bridge. Flow is increased below this point by the contribution of three BSC New York State Pollutant Discharge Elimination System (SPDES) outfalls (SPDES Outfalls 216, 217 and 223), the Erie County Sewer District No. 6 Sewage Treatment Plant outfall, and the South Return Water Trench. These outfalls are summarized on Table 2-28 and these discharge locations are shown on Figure 2-63. The combined flow rate is approximately 166 cfs (107 mgd). The capacity of the channel is between 3,600 cfs (approximately 2,400 mgd) where the two branches join and 3,900 cfs (approximately 2,500 mgd) at the mouth (USACE, 1991). Based on the flood frequency curve for this area, this capacity corresponds to a once in 10-year flood event (USACE, 1991). However, such a volume was not reported in the 10-year period of record presented in Table 2-27 when maximum flows were on the order of 300 mgd.

Flow in the creek is highly variable, with long periods of low flow where sewage plant effluent and BSC discharges represent the bulk of the flow. As shown on Table 2-27, average background (upstream of BSC) flow rates of less than 5 mgd can occur in any month of the year, and for up to 6 months at a time. Average background flow rates in Smokes Creek varied between 26 mgd (April through September) and 32 mgd (October through March) during the 10-year period shown on Table 2-27.

The part of Smokes Creek that flows through the BSC site has been dredged periodically during the past 60 years. This was necessary to remove accumulated sediments caused by generally low-velocity flow through the site. In the fall of 1979, approximately 14,000 cubic yards were removed from the downstream 2,600 feet of the creek under a USACE permit and placed in the on-site, NYSDEC-permitted spoils impoundment, SWMU S-4 (see Figure 1-2).

A hydrological study of Smokes Creek was performed in 1995 (BSC, 1995j) at the request of NYSDEC. The purpose of the study was to identify the potential for the creek to flood during a 100-year storm event. The study indicated that, both with and without dredging, the creek was predicted to flood during a 100-year storm event. However, this was found to be inconsistent with actual conditions during two previous 100-year storm events, during which the creek did not flood.

Smokes Creek has received and continues to receive discharges from various plant operations, either directly or via the South Return Water Trench (Section 2.7.1.8). Current discharges are much less than those that occurred when iron- and steel making was at its height. Discharges containing spent pickle liquor, pickling rinse waters, oily and scale-laden waste waters, non-contact cooling water, and Galvanized Products Division process water were discontinued in 1970. Discharges from the Coke Oven operations, which consisted of non-contact cooling water and treated wastewater from a wastewater pretreatment plant, ceased in early 2002. At present, the only BSC discharges into Smokes Creek are treated industrial wastewater from WQCS No. 7 and non-contact cooling water, both resulting from Galvanized Products Division operations. Treated wastewater and non-contact cooling water are discharged to the creek via SPDES Outfalls 216 and 217. In addition to these discharges, water from the Ship Canal or Buffalo Outer Harbor, used for the dilution of the Erie County and BSC discharges, is discharged via SPDES Outfall 223. SPDES outfall locations are shown on Figure 2-63.

2.7.1.4 Blasdell Creek

Blasdell Creek is a natural watercourse that originates east of the site in two branches that drain areas of the Town of Hamburg, New York. These branches subsequently converge near the Hamburg Turnpike (Figure 2-1). From the Hamburg Turnpike, the creek flows adjacent to the southern boundary of the site area before discharging into Lake Erie. Blasdell Creek is approximately 15 feet wide at the Hamburg Turnpike and it widens to approximately 35 feet just east of BSC Highway 9. Near the mouth, the creek splits into 2 channels that are each approximately 12 feet wide. The creek has a depth of approximately 1.5 feet in the northern and southern branches, deepening to approximately 2.5 feet to 5 feet west of Route 5. The surrounding topography is fairly flat, resulting in a low gradient (0.001 ft/ft) between the Hamburg Turnpike and the lake. Flow rates have previously been estimated at less than 50 cfs (32.3 mgd) (Silberman et al., 1969).

Aerial photographs used by USEPA in conducting the RFA (USEPA, 1988) indicate that Blasdell Creek follows the same course that it did in 1938. No evidence of dredging or filling was apparent in the photographs.

Prior to 1970, Blasdell Creek received non-contact cooling water, process water, storm run-off, roof drain discharges, and other miscellaneous flows from the 13-inch Bar Mill, the former Hot Strip Mill (batch pickler), and the Galvanized Products Division Mill. Prior to its shutdown in the 1970's, the Erie County potable water treatment plant discharged filter backwash to Blasdell Creek. In 1970, BSC's process waste streams were directed to the newly constructed WQCS No. 7, which discharges to Smokes Creek. Current discharges to Blasdell Creek include treated process water from WQCS No. 2 for the 13-inch bar mill now owned by Republic Technologies International (Republic), and non-contact cooling water, stormwater and basement sump water from both Republic and BSC's Galvanized Products Division facilities. SPDES outfall discharges to Blasdell Creek for calendar year 2000 averaged 2.75 mgd (see Table 2-29). The locations of SPDES outfalls that discharge to Blasdell Creek are shown on Figure 2-63.

2.7.1.5 Ship Canal

Initially constructed between 1901 and 1903, the Ship Canal is approximately 4,000 feet long and 200 feet wide and is located at the northern end of the site, approximately midway between the Hamburg Turnpike and Lake Erie (Figure 1-2). It provides access to the Buffalo Outer Harbor. The Ship Canal was operated by BSC prior to 1985, when the canal and portions of the adjoining property were sold to the Gateway Trade Center, Inc. The water depth in the canal is approximately 28 feet, and it contains approximately 22.4 million cubic feet of water (ca. 170 million gallons).

Dredging has occurred periodically throughout the history of the canal to maintain adequate depth for ships. The canal was last dredged in 2000.

The southernmost 2,300 feet of the canal are underlain by sandy to clayey silt and gravel, with the upper 5 to 10 feet consisting of fluid mud. These unconsolidated materials, which range in total thickness from 10 to 55 feet, overlie shale bedrock that rises in elevation to the north. The next 500 feet of the canal bottom are cut into rock that was blasted and removed when the canal was constructed. The remaining 1,200 feet are underlain by sandy to clayey silt and gravel that varies in thickness from 10 to 30 feet. In the 1950s, a 2-foot-thick concrete base was constructed along the northerly 1,700 feet of canal to protect utilities present beneath it.

The Ship Canal has been used to off-load cargo from ships to the adjoining storage areas as well as to load cargo. From the early 1920's until 1970, the canal received process wastewaters from the Coke Division operations. In addition, for a short period in the early and late 1970's, blast furnace wastewater was discharged into the south end of the canal. In addition, the canal received discharges of steam condensate and non-contact cooling water through permitted SPDES outfalls.. After the shutdown of the Coke Ovens on September 28, 2001, only one SPDES outfall (No. 410) continued to discharge non-contact cooling water and storm water to the Ship Canal. On November 14, 2001, this outfall was plugged, thereby ending all SPDES outfall discharges to the canal.

Historically, any significant flow within the canal was the result of BSC operations. Prior to the shutdown of the Coke Ovens on September 28, 2001, approximately 75 million gallons of water were withdrawn from the canal daily, and about 8.2 million gallons per day (mgd) were returned to it through four SPDES-permitted outfalls (Table 2-30 and Figure 2-63). In addition, approximately 0.02 mgd was returned to the canal from direct precipitation and from precipitation induced sheet flow, and about 0.20 mgd from groundwater. The remaining water removed from the canal was discharged to Smokes Creek and to the North Return Water Trench via other SPDES-permitted outfalls (see Sections 2.7.1.3 and 2.7.1.7). The resulting net withdrawal from the canal was compensated for by inflow from the Buffalo Outer Harbor (about 67 mgd while the Coke Ovens were still in operation). This approximated a complete exchange of water in the canal every 2.5 days.

After the shutdown of Coke Oven operations, approximately 50 mgd were pumped from the canal through Pump House No. 1 until September 9, 2002. After November 14, 2001, there were no discharges to the canal through SPDES outfalls and the only water that flowed back to the canal were groundwater (about 0.20 mgd), direct precipitation (0.01 mgd) and sheet flow (0.01 mgd). The net withdrawal from the canal was compensated by inflow from the Buffalo Outer Harbor of about 50 mgd. This approximated a complete exchange of water in the canal every 3.4 days. On September 9, 2002, Pump House No. 1 was shut down and water was no longer pumped from the canal. After this date, the only water flowing into the canal is from groundwater flow, precipitation and sheet flow. A water balance for the Ship Canal, including the ultimate use and disposition of all water removed from the canal before and after the shut down of the Coke Ovens, is provided in Appendix E.5.

Table 2-31 gives the estimated water budget for the Ship Canal in 2000 during the period when the Coke Ovens were in full operation. Table 2-32 provides a water budget for the Ship Canal after November 2001 when all of the SPDES outfalls to the canal were closed off.

2.7.1.6 Buffalo Outer Harbor

Part of the northern end of the site is bordered by the Buffalo Outer Harbor, which includes the USACE dredge spoils area (Figure 1-2). The harbor provides a link between the Ship Canal, the Union Ship Canal, and Lake Erie. The water level in the harbor is essentially the same as in the lake. However, because the harbor is protected by breakwalls, wind-induced fluctuations tend to be much smaller than those observed in the lake. Although not measured during this study, the harbor is maintained for navigation at the same approximate depths as the Ship Canal.

2.7.1.7 North Return Water Trench

The North Return Water Trench (NRWT) is a man-made channel that originates in the area formerly occupied by the 32-inch Finishing Mill and flows northwesterly for approximately 3,150 feet to its discharge point in the Union Ship Canal. The trench is approximately square in cross section and averages 8 to 10 feet in width and depth. Moving south to north along the trench, the first 1600 feet of the trench are constructed of brick and concrete. The southernmost 400 feet of this portion are uncovered; the remaining 1200 feet of this portion are covered (roofed) with concrete that contains openings, approximately 8 feet by 12 feet in size, at regular intervals to allow visual inspection. The next 1,400 feet are completely covered by a concrete roof and also lined with bricks and concrete. The final 150 feet of the NRWT (to its discharge point into the Union Ship Canal) are approximately 25 feet wide and formed by a sheet pile bulkhead on each side.

Historically, the NRWT received process water discharges from the blast furnaces and the North Mills Complex, along with non-contact cooling water discharges from the blast furnaces, North Mills Complex and the open hearth furnaces. Discharges to the NRWT just prior to the closing of the Coke Ovens on September 28, 2001 were from the SPDES-permitted outfalls shown on Figure 2-63, all of which were associated with the Coke Oven Division. These outfalls discharged non-contact cooling water, boiler blowdown from Steam Station No. 1 and strainer blowdown from Pump Station No. 1. Table 2-33 presents average daily flow rates for these outfalls during calendar year 2000. After October 18, 2001, all SPDES discharges to the NRWT ceased and the outfalls were plugged.

2.7.1.8 South Return Water Trench

The South Return Water Trench (SRWT) is also a man-made channel (Figure 1-2) originating in the area formerly occupied by the 32-inch Finishing Mill. It flows south approximately 5,000 feet to its point of discharge into Smokes Creek.

The northern portion of the SRWT is constructed of concrete and brick, with an approximate cross section of 8 to 10 feet and an approximate depth below ground level of 8 to 10 feet. At about the mid-portion, the construction changes to brick and sheet piling; at the southern end, where it discharges into Smokes Creek, the trench sides are lined with only sheet piling and the bottom is completed in the fill unit. Although the depth remains fairly constant, the SRWT gradually widens to about 30 feet at its point of discharge into the creek.

Historically, the SRWT carried process water and storm run-off from areas associated with various BSC facilities, and may have helped to drain a marshy area east of the Ship Canal and west of the Hamburg Turnpike. Prior to the early 1970s, effluent from BSC operations typically consisted of storm runoff, non-contact cooling water, and other wastewaters produced by the sinter plant and blast furnaces, hot-forming operations in the South Structural Mills Complex, and the Basic Oxygen Furnace (BOF) scrubber. From approximately 1970 to 1983, WQCS #4 (South Structural Mills) discharged treated wastewater to the SRWT. From approximately 1970 to 1983, WQCS #3 (BOF scrubber water) and #4 (South Structural Mills) discharged treated wastewater to the SRWT. There have been no BSC discharges into the trench since late 1983. The present flow in the SRWT averages approximately 500 gpm (0.72 mgd), based on the measurement of a weir across the south end of the trench (SPDES Outfall No. 226). This flow is attributed to precipitation, groundwater and leaking underground water lines.

2.7.2 Groundwater-Surface Water Relationships

During Phase I of the RFI, BSC undertook to assess the relationship between groundwater and surface water at the site by installing one stilling well in each of the three main surface water bodies on or adjacent to the site (Lake Erie, Smokes Creek, and the Ship Canal) to allow accurate water level measurements (Figure 2-5). These stilling wells were constructed of small-diameter (approximately 1-1/2-inch) perforated, galvanized pipe installed vertically into the surface water. The perforations (1/4-inch-diameter holes spaced on 1/2-inch centers) were designed to permit water to flow into the stilling wells while dampening fluctuations caused by waves. Construction details are shown in Appendix B. Each stilling well was equipped with a battery-operated, continuous water level recorder and a pressure transducer. The recorders were installed in weatherproof boxes located close to the wells. Water level data were collected at one-second intervals and were averaged for each 60-minute period. Water levels were also measured manually on a weekly basis at each stilling well and compared to electronically recorded data. These water levels were provided in the Phase I report (BSC 1992a).

Comparison of water levels in Lake Erie, Smokes Creek, and the Ship Canal with water levels in monitoring wells adjacent to these surface water bodies showed that surface water levels were generally lower than those of the groundwater. This results in a gradient that causes groundwater to flow toward the surface water bodies. Only along the banks of Smokes Creek was the reverse ever observed. Periodic reversals are caused by storm-induced creek level fluctuations that occur infrequently and only for brief time periods (less than one week). Thus, they do not significantly affect the overall flow of groundwater toward Smokes Creek. This conclusion is supported by the observation that water level data from interior wells are not affected by these short-term fluctuations. Consequently, all groundwater associated with the site discharges into the surface water bodies located within or along the site boundaries.

Groundwater recharge and discharge areas for the site are defined on Figure 2-52. These areas were defined through flow net analysis of piezometric contours interpolated from groundwater elevation data obtained on November 20, 2001. The areas are separated by groundwater flow divides (see Section 2.5). All surface water bodies at the Lackawanna site receive groundwater from more than one groundwater discharge area, except for Blasdell Creek. Lake Erie, the Ship Canal and Blasdell Creek also receive groundwater from Recharge Areas A, B, and C, respectfully (see Figure 2-52).

Groundwater discharge into each surface water body at the site was calculated by means of a recharge-based method. In general, this was accomplished by first estimating the areal extent of each individual groundwater discharge area and then multiplying the result by the approximate annual rate of recharge from precipitation at the site. An annual recharge rate of 1.25 ft/yr for the site was used in the groundwater recharge calculations (see Section 2.5). Estimated groundwater flows from each discharge are presented on Table 2-34. Discharge areas are shown on Figure 2-52. Calculated groundwater discharges to Lake Erie, Blasdell Creek, Smokes Creek, and the Ship Canal are presented in Table 2-35. A further discussion of recharge and contaminant loading to surface water bodies is provided in Section 3.3 of this RFI report. The relationships between groundwater and surface water for these waterbodies and the discharge results are discussed in the following subsections.

2.7.2.1 <u>Lake Erie</u>

The investigation of Lake Erie during Phase II-A included the installation of five mini-piezometers (Figure 2-11) and three seepage meters (Figure 2-12) into the lake bottom, using techniques described by Lee and Cherry (1978). The selected locations were considered to be representative of hydrologic conditions at the site boundary. The seepage meters consisted of steel drum end-sections approximately 12 inches high. A small hole was drilled in the top of the section to accept a one-hole rubber stopper through which a sampling tube was connected. Groundwater flow through the lake bottom to the lake was measured and sampled by means of the tube after the drum was driven into the lake bottom. The miniature piezometers and seepage meters were employed to confirm that the lake was a groundwater discharge zone, measure discharge rates to the lake, identify the offshore extent of the groundwater discharge zone, identify hydraulic gradients between groundwater and surface water, and identify the hydraulic conductivity of the nearshore lake sediments. This investigation also provided information on the surface water flow net and the velocity of water moving near and at the lake bottom. These activities are discussed in the Phase II-A report.

Calculated discharge rates and hydraulic conductivities from the seepage meter data are summarized in Table 2-36. The approximate extent of the groundwater discharge zone as a function of measured hydraulic gradient is shown on Figure 2-64. The groundwater discharge rate to Lake Erie south of Smokes Creek (I-1) was found to be greater than the discharge rates estimated from the seepage meters (I-2 and I-3) installed in the lake bottom north of Smokes Creek (Figure 2-12).

Direct groundwater discharge to Lake Erie from the site is derived from onsite Discharge Areas 1, 2A, 4A, and 4B, and offsite recharge Area A located east of Route 5. (Figure 2-52). Indirect discharge to the lake via Smokes and Blasdell Creeks and the Ship Canal were discussed previously. The total direct groundwater discharge to Lake Erie is approximately 1.32 cfs (593 gpm), as estimated from recharged-based calculations (Table 2-35).

The estimated groundwater discharge to the lake based on groundwater flux rates through the lake bottom, as obtained from seepage meter data, is approximately 1.38 cfs. This value is reasonably close to that obtained from recharge-based methods (1.32 cfs; Table 2-35). The seepage estimate was obtained by using the geometric mean of the seepage flux values from the three seepage meters placed in Lake Erie, which is approximately 1.29×10^{-1} µm/s (Table 2-36). When converted to ft^3/ft^2s (equivalent to ft/s), this value is 4.2×10^{-7} ft^3/ft^2s. The total flux of groundwater to the lake is obtained by multiplying this value by the length of the shoreline (12,760 feet) and the width of the shoreline through which 90 percent of the discharge occurs (232 feet; Figure 2-64), and then dividing by 0.9 (to normalize to the total discharge to the lake).

2.7.2.2 Smokes Creek

Evidence collected during the RFI shows that Smokes Creek is a groundwater discharge zone. This conclusion is based in part on the groundwater table contours, and on the observation of seeps along the south bank of Smokes Creek during periods of low flow. In addition, empirical data collected from four mini-piezometers (Table 2-37) installed in the creek bottom during Phase II-B (Figure 2-65) indicate the presence of an upward vertical hydraulic gradient between groundwater and surface water, and thus confirm that Smokes Creek is a groundwater discharge zone. Data from four seepage meters also installed in the creek bottom during Phase II-B (Figure 2-65) were used to calculate hydraulic conductivity values for the creek bottom sediments. These values ranged between 4.5×10^{-5} and 1.8×10^{-3} cm/s (Table 2-37), and are lower than the hydraulic conductivity estimates for the sand and fill units in the ATP area.

Data obtained from the seepage meters were also used to assess whether the creek represents a local groundwater divide, as is suggested by the groundwater table contours. The average measured seepage flow into the creek was estimated as 4.7×10^{-5} cm/s (1.54×10^{-6} ft/s), based on data from the seepage meters (Table 2-37). This value, when multiplied by the average channel bottom width (69 feet) and the total site stream length (6,700 feet), gives an estimated total discharge into Smokes Creek of 0.69 cfs (310 gpm). Given the similarity of this value to the total groundwater discharge to Smokes Creek estimated from recharge-based calculations (0.58 cfs (262 gpm) (Table 2-35), it seems reasonable to conclude that Smokes Creek represents an effective groundwater divide.

As noted above, the bottom channel width (69 feet) was used instead of the average cross sectional width of the creek (100 feet) in calculating seepage flow. The bottom width was used because the seepage meters and mini-piezometers used to obtain seepage rate data were emplaced in the channel bottom. Use of this value gives a conservative estimate of seepage flux into the creek. However, when the average width of the entire channel in the SFA (100 feet) is used, the estimated groundwater seepage rate into the creek is 1.0 cfs. This value exceeds the recharge-based estimate of groundwater flow into the creek (0.58 cfs, see Table 2-35), and implies that even if the recharge-based estimate is too low by a factor of 1.7, the discharge that enters the creek is sufficient to accommodate the groundwater flow toward the creek. This in turn strengthens the conclusion that the creek is an effective groundwater divide.

Direct groundwater discharge to Smokes Creek from the site is derived from Discharge Areas 2B, 3 and 3A (Figure 2-52). The total groundwater discharge to Smokes Creek is approximately 263 gpm, as estimated from recharge-based calculations (Table 2-35). Most of this discharge (204 gpm) comes from Discharge Area 3; only about 24 gpm comes from Discharge Area 2B and about 35 gpm from Discharge Area 3A (Table 2-34). The total groundwater discharge value is small (less than one percent) relative to the total flow in Smokes Creek (approximately 107 mgd), of which approximately 66 percent is derived from BSC SPDES outfalls and the balance from natural surface drainage, the Erie County sewage treatment facility and the South Return Water Trench (see Table 2-28).

2.7.2.3 Blasdell Creek

Groundwater discharge into Blasdell Creek comes from Discharge Area 1A west of Route 5 and Recharge Area C located within the BSC facilities east of Route 5 (Figure 2-52). Discharge Area 1A and Recharge Area C are approximately 1.31×10^6 square feet and 9.36×10^6 square feet in area, respectively. (Table 2-17). Groundwater discharge was calculated by recharge-based methods to be approximately 0.05 cfs (approximately 23 gpm) from Discharge Area 1A and 0.37 cfs (approximately 166 gpm) from Recharge Area C (see Table 2-34). A total discharge to Blasdell Creek from these area amounts to approximately 0.42 cfs or 189 gpm.

2.7.2.4 Ship Canal

During Phase II-A, water level recorders were installed in piezometers at locations along the Ship Canal to allow comparison of water levels fluctuations in the canal with those in nearby groundwater (Figures 2-66 through 2-71). The data were statistically analyzed to determine lag time, correlation, and attenuation factors. The results of these analyses are provided in Table 2-

38 and discussed in Section 5.0 and Appendix B of the Phase II-A Draft Final Report (BSC 1993). Generally, fluctuations in the Ship Canal correlate well with groundwater elevations measured at piezometers at a distance of more than 50 feet from the canal, demonstrating the existence of good hydraulic communication between the groundwater and canal water.

Groundwater discharge into the Ship Canal from Discharge Areas 5 and 6 amounts to approximately 0.26 cfs (approximately 116 gpm) (estimated by means of recharge-based calculations) (Table 2-35). Most of this water flows from the east side of the canal, which is recharged by a much larger area than on the west side of the canal (Figure 2-52). Hence only about 0.04 cfs (19 gpm) is estimated to flow through the western canal sheet-pile wall (Table 2-34).

In addition to onsite recharge to Area 6, an area of approximately 3 million square feet (68 acres) east of Route 5 (Recharge Area B, see Figure 2-52) provides recharge to Area 6. Assuming an annual recharge of 1.25 foot, the estimated recharge from this offsite area is approximately 0.117 cfs or 52.7 gpm. A significant portion of this recharge contribution and the contribution from the eastern portion of Discharge Area 6 would be expected to discharge into the North Return Water Trench and the northern-most portion of the South Return Water Trench.

2.7.2.5 <u>North Return Water Trench</u>

The fluid level in the NRWT is consistently lower than the adjacent groundwater table (see NRWT Watercourse Assessment Report in Part VII of the RFI). This suggests that groundwater from the area around the trench flows into the trench and then to the Union Ship Canal. As a result, there is little likelihood of discharge from the trench to the surrounding groundwater. The trench is believed to intercept most of the flow of groundwater that enters the site from the east of the trench. However, this cannot be verified because of the buried nature of the trench and the general absence of flow data in the trench. Because of this uncertainty, all of the flow from Discharge Area 6 and Recharge Area B is assumed to flow to the Ship Canal and is used in calculating groundwater discharge to the eastern wall of the canal.

The assumption that the trench intercepts much or most of the groundwater flow is supported by the conclusions of the Ground Water Flow Model for the site. This model is provided in Appendix E.6.

2.7.2.6 South Return Water Trench

Although the SRWT is not lined along its entire length, historic groundwater data from areas adjacent to the trench indicate that the flow level in the trench is consistently lower than the surrounding groundwater table (see SRWT Watercourse Assessment Report in Part VII of the RFI). This suggests that groundwater from the area around the trench flows into the trench and then into Smokes Creek. For this reason, discharge from the trench into the groundwater is unlikely. As with the NRWT, this trench is believed to intercept most of the groundwater flow from areas east of the trench, and this assumption is supported by the groundwater flow model. Although the flow in the trench is known (approximately 500 gpm), the flow attributable to groundwater is uncertain because of several leaking water lines adjacent to the trench. This uncertainty does not effect the recharge-based approach used to estimate groundwater discharge to surface water bodies, because groundwater flow through the trench ultimately ends up in Smokes Creek, along with the rest of groundwater flow from Discharge Area 3.

2.7.3 Summary

All groundwater associated with the Lackawanna site discharges into the surface water bodies located within the site or along its boundaries. Groundwater discharge to these surface water bodies was estimated using recharge-based methods and are provided on Table 2-35.

The discharge of surface water runoff to the on- and near-site water bodies is minimal because of the porous nature of surface soils at the site. However, Smokes Creek and Blasdell Creek presently receive process-related discharges directly from ongoing operations at the Lackawanna site. These discharges occur through SPDES-permitted outfalls.

Prior to the shut down of the Coke Ovens in September 2001, approximately 75 mgd were withdrawn from the Ship Canal primarily for use as non-contact cooling water. Before the Coke Ovens were shut down, approximately 11 percent of this amount was returned to the canal from SPDES discharges and the resulting net withdrawal was primarily compensated for by inflow from the Buffalo Outer Harbor. Following the shut down of the Coke Ovens, approximately 50 mgd was withdrawn from the Ship Canal through September 9, 2002 and the Buffalo Outer Harbor thereafter and discharged to SPDES Outfall 223 to meet dilution agreements with Erie County Sewer District No. 6. Water returned to the canal now consists of groundwater, precipitation, and sheetflow.

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3.0 GROUNDWATER, SURFACE WATER AND SEDIMENT QUALITY

3.1 Nature and Extent of Contamination

Chemical constituents present in the groundwater, surface water and sediments at the Lackawanna Facility reflect historical operations at the plant site. In 1988, the U.S. Environmental Protection Agency (EPA) identified the location of Solid Waste Management Units (SWMUs) at the facility that may have contributed chemical constituents to the environment. Subsequent evaluation of these SWMUs, performed as part of the RFI, analyzed the contents of the SWMUs, as well as, the quality of the sites' groundwater, surface water and sediments. The following sections describe the results of the SWMU investigations, their contents and, the nature and extent of site contamination.

3.1.1 Investigation of Potential Source Areas

The location and characteristics of SWMUs identified at the BSC Lackawanna, NY facility were initially presented in the site RFA (NEIC 1988). A total of 104 SWMUs were identified on the east and west sides of Route 5. The SWMUs were categorized as "S" (Slag Fill Area) SWMUs or "P" (Process Area) SWMUs. There were 29 "S" SWMUs found on the west side of Route 5, which were suspected of storing process area wastes. There were 75 "P" SWMUs found on both the east and west sides of Route 5.

Of the 104 SWMUs, 59 were granted a "no further assessment required" (NFA) status by the EPA following submittal of their Preliminary SWMU Assessment Reports (Section 1.0). These preliminary assessments evaluated current and historical SWMU operations and included limited sampling of existing waste material. The NFA status of the initial 59 SWMUs was based on the conclusion that no releases of hazardous constituents occurred from the operation or existence of the respective SWMU and, therefore, no corrective actions were required.

The remaining 45 SWMUs were further investigated during the RFI investigation Phases conducted from 1990 to 2001. The investigation results and final SWMU Assessment Reports are provided as Parts V and VI of this RFI. A summary of the 45 SWMUs is provided in Table 3-1, as well as in Section 6.0. The location and status of site SWMUs, as well as the location of site watercourses, are shown in Figure 3-1.

An additional source of potential concern at the Lackawanna Facility is the presence of dredge spoils that lie beneath slag fill placed along the western portion of the site. These dredge spoils were disposed of offshore between 1936 and 1948 by the USACE. Source areas for the spoils include the Buffalo Harbor area, where the spoils were characterized as "grossly polluted" (USACE 1983). The dredge sediments were subsequently buried by slag fill with the westward extension of the shoreline at the site. The location of the former 'Federal Dumping Grounds' with respect to the 1937 and present shorelines at the site, is shown on Figure 1-2A. A report on the investigation of dredge spoils dumping is provided in Appendix G of this RFI report.

3.1.1.1 SWMU Investigation Approach

As part of the evaluation of potential risk associated with hazardous constituents detected in the RFI investigation, a Tier I Human Health Risk Assessment (HHRA) was performed. The Tier I HHRA was completed for each of the 45 SWMUs included in Table 3-1, as well as, five watercourses: Blasdell Creek, Smokes Creek, North Return Water Trench, South Return Water Trench, and the Gateway Metroport Ship Canal. These SWMUs and watercourses were evaluated based on the concentrations of Chemicals of Potential Interest (COPIs) associated with steel-making operations (USEPA 1991), using Tier 1 screening levels and exposure pathways as defined in *Interim Deliverable #1, Detailed Process for Selection of Chemicals of Potential Concern and Identification of Toxicological Criteria*, dated December 1998 (ID #1).

Each SWMU or watercourse was evaluated in the Tier I HHRA. In some instances, because of location or common waste stream, SWMUs were grouped together for the Tier I HHRA evaluation. The SWMU Groups are summarized below:

SWMU Group PA-1:	SWMUs P-1, P-2, P-3, P-4, and P-5
SWMU Group PA-2:	SWMUs P-6 and P-7
SWMU Group PA-3:	SWMUs P-8 and P-9
SWMU Group PA-4:	SWMUs P-11 and P-12

SWMU Group SFA-1:	SWMUs S-1, S-2, S-4, S-5, S-6, S-7, S-20, and S-27
SWMU Group SFA-2:	SWMUs S-11 and S-22
SWMU Group TF (Tank Farm):	P-8, P-74, and P-75

For each SWMU, SWMU Group or Watercourse, the detected COPIs were screened against EPA criteria. Those values that exceeded the screening levels were identified as Chemicals of Potential Concern (COPCs).

The COPCs were determined by sequentially applying the following criteria to each COPI on a medium by medium basis for each SWMU and watercourse: 1) the chemical was detected in at least 5% of the samples, 2) the chemical was detected in at least one sample at levels above background (*i.e.*, the maximum concentration was above background; for chemicals in surficial SWMU material only), and 3) the chemical was positively detected in at least one sample at levels above applicable screening criteria [*i.e.*, USEPA Region III Risk Based Concentrations (RBCs) EPA Soil Screening Levels (SSLs),]. If there were more than 10 samples collected from a specific matrix (e.g. subsurface soils) for an individual SWMU or SWMU Group, the 95% upper confidence level (UCL) was used, otherwise the maximum concentration was used in the screening evaluation. In some instances the 95% UCL exceeded the maximum concentration. In those instances, the maximum concentration was used.

In addition, in those instances where surface soils were not sampled, the subsurface soil results were evaluated as surface soil results. Conversely, in instances when subsurface soils were not sampled, surface soil data was used for the subsurface soil evaluation.

As part of the SWMU assessment process, the COPC values were further evaluated, based on exposure pathway, in order to determine potential carcinogenic and non-carcinogenic risk to Human Health from the SWMU. The results of the Tier I HHRA are provided in each individual SWMU Assessment and Watercourse Assessment Report (Parts V and VI of this RFI report).

3.1.1.2 SWMU Evaluation- Chemicals of Potential Concern

The COPCs identified for each SWMU were determined based on total constituent analysis and consequently provide a good baseline-screening tool for the identification of elevated chemical concentrations. Therefore, the presence of COPCs provides an indication of whether a particular SWMU has the potential to impact groundwater and, eventually surface water quality at the site.

The COPCs were divided into five constituent classes: metals, chlorinated VOCs, petroleum VOCs, volatile SVOCs, and heavier (carcinogenic) SVOCs. This section summarizes the COPCs identified for each SWMU or SWMU Group. In addition, the following figures show the location of the SWMUs and summarize the COPCs for each constituent class and soil zone (surface or subsurface):

Figure 3-2: COPC Petroleum VOCs in Surface Soils
Figure 3-3: COPC Petroleum VOCs in Subsurface Soils
Figure 3-4: COPC Chlorinated VOCs in Surface Soils
Figure 3-5: COPC Chlorinated VOCs in Subsurface Soils
Figure 3-6: COPC Volatile SVOCs in Surface Soils
Figure 3-7: COPC Volatile SVOCs in Subsurface Soils
Figure 3-8: COPC SVOCs in Surface Soils
Figure 3-9: COPC SVOCs in Subsurface Soils
Figure 3-10: COPC Metals in Surface Soils
Figure 3-11: COPC Metals in Subsurface Soils

As can be seen from these figures, the more prominent and widespread COPCs identified in site SWMU materials consisted primarily of the less mobile and more tightly bound metals and heavier SVOCs. Conversely, considerably fewer volatile and mobile organic compounds (VOC's and volatile SVOCs) were identified as COPCs, particularly in SWMU material exposed at the ground surface.

Zone 2 SWMUs

The SWMU Groups and individual SWMUs within Slag Fill Area Zone 2 are: SFA-1, SFA-2, S-3, S-8, S-21, and S-24. It should be noted that although SWMU S-24 is located north of Smokes Creek and Zone 2, it is adjacent to both and ID #1 established that this SWMU should be evaluated as a Zone 2 SWMU. Based on the phased investigation results and the HHRA COPC screening, the following hazardous constituents were identified as potential environmental concern for Zone 2.

SUMMARY TABLE FOR ZONE 2

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
SFA-1	S-1, S-2, S-4, S-5, S-6, S-7, S-20, and S-27	Metals, chlorinated VOCs, volatile SVOCs and SVOCS	Metals, petroleum VOCs, volatile SVOCs and SVOCS
SFA-2	S-11 and S-22	Metals and SVOCs	Metals, chlorinated VOCs, petroleum VOCs, volatile SVOCs and SVOCS
--	S-3	Metals and SVOCs	Metals and SVOCs
--	S-8	Metals	None
--	S-21	Metals	Metals
--	S-24	None	Metals, petroleum VOCs, volatile SVOCs and SVOCS

Zone 3 SWMUs

There is only one SWMU, SWMU S-10, located within Zone 3. SWMU S-10 is a large pit formerly used to quench slag with either plant water or weak ammonia liquor. The pit is currently inactive and empty. The following hazardous constituents were identified as potential environmental concern for Zone 3.

SUMMARY TABLE FOR ZONE 3

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
--	S-3	None	Metals and SVOCs

Zone 4 SWMUs

The SWMU Groups and individual SWMUs within Slag Fill Area Zone 4 are: S-12, S-13, S-14, S-15, S-16, S-17, S-18, S-23, S-28, and S-29. SWMU S-12 is an asbestos landfill and was not sampled. No chemical analysis was completed for the soil within S-12 and, therefore, a quantitative HHRA was not completed. SWMU S-13 is a NYSDEC-Permitted hazardous waste landfill with a permanent cap. No sampling was completed on S-13 during the RFI, and therefore, a quantitative HHRA was not performed on this SWMU. SWMU S-29 was an area suspected of being used as a drum landfill. Excavations in this area indicated no drums or other waste material was disposed in this area and, therefore, no sampling was conducted. Because there was no sampling data, a HHRA was not completed for this SWMU.

Based on the phased investigation results and the HHRA COPC screening for the remaining SWMUs, the following hazardous constituents were identified as potential environmental concerns for Zone 4.

SUMMARY TABLE FOR ZONE 4

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
--	S-14	Metals	Petroleum VOCs, volatile SVOCs and SVOCS
--	S-15	Metals	None
--	S-16	None	None
--	S-17	Metals and SVOCs	Metals and SVOCs
--	S-18	Metals	Metals, volatile SVOCs, and SVOCs
	S-23	None	Metals, petroleum VOCs, volatile SVOCs and SVOCS
--	S-28	None	Metals and SVOCS

Coal Storage Area (CSA) SWMUs

The two SWMUs within the CSA are: S-19 and S-25. Based on the phased investigation results and the HHRA COPC screening for the SWMUs, the following hazardous constituents were identified as potential environmental concerns for the CSA.

SUMMARY TABLE FOR CSA

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
--	S-19	Metals	Metals, volatile SVOCs and SVOCS
--	S-25	None	Metals and SVOCS

Coke Oven (CO) Area SWMUs

The SWMU Groups and individual SWMUs within the CO area are: SWMU Groups PA-1, PA-2, PA-3, PA-4, and SWMUs P-18, and S-26. SWMU Group PA-1 comprises the former quench pits for the Coke Ovens. SWMU Group PA-2 is the former lime sludge settling basins for the Coke Ovens. SWMU Group PA-3 is the abandoned tar decanter sludge pit (P-9) and the adjacent surface spill near the ball mill (P-10). SWMU Group PA-4 is former Benzol plant storage tanks (P-11) and the adjacent spill cleanup storage area (P-12). SWMU P-18 is the former Hot and Cold wells from the former blast furnace facility and SWMU S-26 is the fill area near Coke Oven battery number 8.

Based on the phased investigation results and the HHRA COPC screening, the following hazardous constituents were identified as potential environmental concern for the CO Area.

SUMMARY TABLE FOR CO AREA

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
PA-1*	P-1, P-2, P-3, P-4, and P-5	Metals	Metals and SVOCS
PA-2	P-6 and P-7	Metals and SVOCs	None
PA-3	P-9 and P-10	None	Metals, volatile SVOCs and SVOCs
PA-4	P-11 and P-12	Metals	Petroleum VOCs and volatile SVOCs
--	P-18**	Metals and SVOCS	Metals and SVOCS
--	S-26	Metals, volatile SVOCs and SVOCS	Metals, volatile SVOCs and SVOCS

* note: Surface water from within several SWMUs (former quench pits) was also analyzed and indicated the presence of two COPCs (benzene and naphthalene) from two constituent classes (petroleum VOCs and volatile SVOCs respectively)

** note: SWMU P-18 was analyzed for sediments present beneath surface water "wells" or containment basins. These sediments were evaluated as "soils" in the HHRA.

Tank Farm (TF) Area SWMUs

There is only one SWMU group, TF Group, located in the TF area. The TF Group is three SWMUs in the former tank farm area. Two SWMUs (P-75 and P-8) are former above ground storage tank (AST) locations. The third SWMU (P-74) is the former surface storage area for the tar tank bottoms. This tar was temporarily stored in the tank farm while many ASTs were being dismantled. Based on the phased investigation results and the HHRA COPC screening, the following hazardous constituents were identified as potential environmental concern for the TF Area.

SUMMARY TABLE FOR TF GROUP

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
TF Group	P-8, P-74, and P-75	Metals. Chlorinated VOCs, volatile SVOCs, and SVOCs	Metals. chlorinated VOCs, petroleum VOCs, volatile SVOCs, and SVOCs

East Plant Area SWMUs

There are two SWMUs (P-73 and P-63) in the East Plant Area. SWMU P-73 contains two subareas, the former drum storage area and a stockpile of surface soil that was removed from the former drum storage area. SWMU P-63 is a former surface storage area for mill scale. Based on the phased investigation results and the HHRA COPC screening, the following hazardous constituents were identified as potential environmental concern for the East Plant Area.

SUMMARY TABLE FOR EAST PLANT GROUP

SWMU Group	SWMU No(s).	Surface Soil COPC Classes	Subsurface Soil COPC Classes
--	P-63	Metals	Metals
--	P-73	Metals	Metals and SVOCs

3.1.1.3 Evaluation of Dredge Spoil Sediments

The near shore area of the BSC property has been used by the United States Army Corps of Engineers (COE) for disposal of dredge spoils from the Buffalo River and Inner Harbor areas from at least 1936 through 1948. The amount of dredge material deposited is stated to be approximately 614,000 cubic yards. The locations of these former disposal areas have been documented and are identified in Appendix G. Historical documents from the 1947 Riparian Survey and obtained through the Freedom of Information Act confirm the presence of dredge spoil placement at the BSC facility. The dredge spoils, once placed, were then covered with slag materials from BSC steel making operations.

In the fall of 2000, BSC conducted an investigation of the near shore hydrogeology and soils as part of the ongoing RFI associated with the Lackawanna Facility. As part of this investigation, eight borings were drilled within 50 feet of the current shoreline. Continuous soil cores were obtained from each boring using a split spoon sampler. The soil cores were described in the field and soil samples were collected from the cores and submitted for chemical testing. After drilling to depth, a series of three clustered piezometer where constructed in the borehole. The piezometers were placed to monitor water levels in the shallow (8 to 12 ft bgs), middle (17 to 22 ft bgs) and deep (25 to 31 ft bgs) groundwater zones. The soils encountered during this study consisted of slag fill (15 to 24 feet thick) underlain by a mixed silt and sand unit (6 to 13 feet thick) that overlies a silty clay unit (17 or more feet thick). The slag unit consists of fine to coarse sand and, fine to coarse gravel consisting of reworked, rounded to well-rounded grains of slag with silt, wood, plastic, metal and cinders. This unit has been interpreted to have been deposited by BSC steel making operations. The mixed silt and sands consist of intermixed sand, silt and clay size particles with rock, glass and wood fragments and leaf matter. The silty clay unit is a till unit and contains some gravel and calcareous shale with occasional sandy lacustrine seams.

The disturbed nature of the mixed silt and sand unit, as well as its depth, thickness, and the presence of angular gravel, leaf litter, coal and other debris confirm that this unit is associated with the historic dredge spoil areas. The physical characteristics of the mixed sand and silts are similar to the sediments described by the COE in characterization studies of sediments from the Buffalo Harbor and of local dredge spoils, which also included evidence of contamination including petroleum odors and sheens (USACE, 1983 and EEI, 1996).

The chemical testing of the sediments collected from the historic dredge spoils at the site detected 23 organic compounds, 13 metals, and 26 tentatively identify compounds (TICs) (see Table 1 in Appendix G). These compounds include VOCs; SVOCs, and metals. All of the 36 identified organics and inorganics detected in the dredge spoils onsite are common to many industrial sites and urban areas including the BSC facility. Additionally these compounds are associated with other offsite hazardous waste sites that may have contributed contaminants to the Buffalo River, Buffalo Harbor, and Black Rock Channel sediments, and are reported to be in the dredged sediments. Thirteen of the 26 TICs (which are not COPIs at the BSC site) are also associated with other offsite hazardous waste sites and area dredge spoil sediments. This includes the presence of aromatic amine compounds (Michlers Base and undefined amines) that are not associated with the BSC facility, but have been associated with dyestuff manufacturing along the Buffalo River and were discharged to the area dredge sediments (Nelson and Nites, 1980). The occurrence of these non-BSC compounds show that the disposal of the dredge spoils in this area have contributed to the presence of regulated compounds at the BSC facility with the potential for offsite migration via groundwater.

In summary it has been shown that dredge spoils have been deposited in the near shore area of the BSC facility beneath significant areas of the SFA, especially north of Smokes Creek. These dredged sediments are present at depths of 15 to 24 feet below ground surface at the shoreline and contain compounds that have contributed to environmental concerns at the site.

3.1.1.4 Summary

The source of chemical constituents found in groundwater, surface water and sediments at Lackawanna site may be attributed to waste materials discharged or stored at the facility, and to the presence of contaminated dredge spoils imported and placed beneath the western portion of the site. The EPA has identified 104 SWMUs at the facility that could have contributed contaminants to the environment. Of these, 59 SWMUs were granted a 'No Further Assessment' status based on the conclusion that no release of contaminants has occurred from these units. The remaining 45 SWMUs were investigated during the phased RFI and the analytical results were subjected to a Tier 1 risk assessment. The results of the risk assessment, which screened detected chemical constituent concentrations against regulatory criteria, identified a number of COPCs that have the potential to impact groundwater and, eventually, surface water quality at the site.

The COPCs identified in the site's SWMU materials included metals, chlorinated VOCs, petroleum VOCs, volatile and heavier molecule weight SVOCs. The more prominent and widely distributed COPCs identified in the SWMU materials consisted primarily of the more tightly bound metals and immobile SVOC compounds. Fewer VOCs were identified as COPCs, particularly in SWMU material exposed at the surface. Of the more mobile COPCs, chlorinated VOCs were limited to SWMU material south of Smokes Creek, while petroleum related (BTEX) and volatile SVOCs compounds were found concentrated in SWMU material associated with several acid tar pits, the Benzol Yard and the Tank Farm area.

3.1.2 General Groundwater Chemistry

Groundwater geochemistry at the site is strongly influenced by the slag matrix in which the upper water-bearing zone has been formed. In contrast to most natural systems, the resulting water exhibits a wide range of values of certain conventional indicator parameters, namely pH and total alkalinity. Both parameters are highly variable across the site in response to the nature of the slag fill and to waste materials storage and disposal. Groundwater pH at the site is a controlling factor in the distribution of certain metal species (e.g., iron and manganese) found at the site, as well as total alkalinity. These relationships are discussed in more detail below.

Figure 3-1 shows the locations of monitoring wells and site features (such as the Benzol Yard, Coke Oven Area, and the site watercourses) that are discussed throughout this section on groundwater quality.

3.1.2.1 pH

A measurement of the acidic or alkaline nature of groundwater, pH at the site is variable (Figure 3-12). In general, the alkaline nature of the slag fill – a material consisting primary of dicalcium silicate, tricalcium silicate, dicalcium ferrite, olivine, calcium-magnesium aluminosilicates, and lime, with lesser amounts of manganese, carbon, chromium, phosphorous, and sulfur – increases the pH of groundwater that comes into contact with it. Interaction between slag fill and groundwater at the site causes pH values of groundwater in the fill unit to rise more or less steadily toward Lake Erie, from background values (7 to 8 S.U.) near the eastern boundary of the site (near Route 5) to values in excess of 12 in the SFA west of the Coke Oven Area. This pattern reflects increasing contact time between groundwater and slag fill as flow occurs across the site toward Lake Erie. Superimposed upon this pattern are localized areas of slightly acidic pH (6 to 7 S.U.), as observed in the vicinity of the ATPs and the Coke Oven Area.

Background pH values were measured in two wells screened in non-slag fill (MW-7A at 7.0 and MW-8A at 7.8) and two wells screened in bedrock and/or the sand unit (MW-7B at 6.8 and MW-8B at 7.3) during the 1999 Comprehensive Groundwater Sampling Event (see Appendix E.1 for groundwater sampling results). These wells are located north of Smokes Creek near the eastern (upgradient) boundary of the property. Average pH values collected from these wells during 13 sampling rounds in 1980 for the fill unit wells ranged from 7.5 to 8.2. Average values for the sand unit wells ranged from 7.2 to 7.9 (Dames & Moore, 1981). These ranges of pH values are consistent with reported regional pH levels in groundwater (LaSala, 1968) and values obtained during the RFI. The pH levels in wells screened in the sand unit show a distribution similar to those in the fill with generally more acidic conditions apparent in wells monitoring the sand unit at the Benzol Yard and the ATPs, and more neutral levels for most sand and bedrock wells bordering Lake Erie.

The slightly lower pHs in the vicinity of the Coke Oven Area and considerably lower pHs in the immediate vicinity of the ATPs (Figure 3-12) are likely due to past activities in these areas. The slightly acidic conditions in the area of the former Coke Oven and Benzol Yard areas may be related to the elevated presence of phenolic compounds observed in the groundwater at that location (Section 3.1.3.2). The presence of phenolics commonly associated with coal is likely associated with former coking operations and the subsequent extraction of coal tar related derivatives from the coke plant off-gases. Acidic conditions in groundwater beneath the ATPs (SWMUs S-11/S-22), MWS-17B and MWS-19B and S-24 (MWN-24A), most likely reflects the past disposal of low pH coal tars, and coke process waste in these areas.

The impact on Lake Erie of the high pH values present in a large portion of the groundwater beneath the western half of the site is likely to be negligible based on the results of sampling within the lake and less alkaline condition observed in the underlying sand unit wells along the Lake Erie shoreline (Figure 3-12). As detailed in Section 3.1.4.1, surface water samples collected during the RFI indicate that pH values for background (7.9±0.2) and offsite (pH = 8.0 ± 0.2) are indistinguishable from lake water (with a pH of 8.0) measured adjacent to the western site boundary. High pH groundwater discharging from the fill unit is apparently neutralized within a relatively short distance by mass dilution enhanced by the inherent buffering capacity of the lake water. This process is further enhanced by the intense mixing of ground and lake waters, which occurs within the nearshore zone due to the influence of breaking waves.

Lake Erie with a pH of 8.0 is a highly buffered and alkaline water body (Great Lakes Commission 1992). The buffering capacity of the lake originates from several sources. Contact with atmospheric carbon dioxide (CO_2), either directly or through precipitation (i.e., rainfall) results in the presence of dissolved CO_2 in the lake. Carbon dioxides in the lake water forms carbonic acid (H_2CO_3) that in turn disassociates into hydrogen ions (H^+), bicarbonate ions (HCO_3), and carbonate ions (CO_3^{2-}) in response to the overall pH of the lake water (WDNR, 1999). Another source of CO_3^{-2} (i.e. carbonate alkalinity) in the lake is weathering of calcareous sediments and the dissolution of limestone bedrock (which consists of Ca and Mg carbonates) (SCS 1986). The relative amounts of these abundant ionic species change in response to the introduction of water having a different pH, and thus act to buffer the pH of the lake.

3.1.2.2 Total Alkalinity

The total alkalinity of a solution may be defined as the capacity of its solutes to react with and neutralize acids. In most natural water, alkalinity is produced largely by the speciation of dissolved carbon dioxide into carbonate and bicarbonate ionic complexes. Noncarbonate contributors can include hydroxide, silicate, borate, and acetate. Carbonate and non-carbonate alkalinity together constitute total alkalinity. Because interaction with slag fill increases groundwater pH, and thus noncarbonate alkalinity, the total alkalinity of groundwater at the site is affected by the presence of the slag.

Total alkalinity concentrations across the site (Figure 3-13) are highly variable, ranging from <1 to 3,520 mg/L in samples obtained during the site-wide sampling event (Table 3-2). This variability is attributable, at least in part, to contact of groundwater with the slag fill. North of Smokes Creek, highest alkalinity concentrations were found along the northwestern perimeter of the site (MWN-06 and MWN-43) and west of the Ship Canal (near MWN-08). Elevated alkalinity at these locations may be associated with the former disposal and processing of high lime steel slag on the northern end of the Slag Fill Area and use of SWMU's P-6 and P-7 as lime settling basins in the Coke Oven Area (Figure 3-13).

South of Smokes Creek, higher alkalinity concentrations in groundwater may be the result of the former disposal of lime dust and high pH sludge from the Blast Oven Furnaces (BOF) at SWMU S-11 (MW-11 and MWS-10B) and further west toward the lake at SWMU S-7/20 (MW-2UIB), respectively. Lower total alkalinity values recorded in the vicinity of SWMUs S-3 and S-16 near Lake Erie, and at SWMU S-22 south of Smokes Creek, may reflect the former disposal of low pH spent pickle liquor (SPL) and treatment sludges from the steel pickling and galvanizing lines.

Unexpectedly high and low values of alkalinity were recorded at MWN-01B (1,050 mg/L) and MWN-05B (non-detect [ND]), which monitor the sand unit near Lake Erie north of Smokes Creek (Figure 3-13). Background values of alkalinity varied from 68.8 mg/L in fill well MW-08A to 363 mg/L in the deeper well MW-07B.

3.1.2.3 Major Ions

The major cations present in groundwater at the site are calcium, magnesium, potassium, sodium, and iron. Major anions present in the groundwater are total alkalinity (largely composed of hydroxyl and carbonate ions), chloride, and sulfate. These ions are common constituents that occur naturally in groundwater and were detected in nearly all site groundwater samples at relatively high concentrations (Table 3-2). Concentrations of these ions were also reported in the site background wells. The areal distribution of the major ions is presented on Figures 3-14 to 3-20. In general, the prevalence of these species is directly related to the interaction between groundwater and onsite materials. The concentration of calcium, magnesium and iron, the basic ingredients in slag, tended to be elevated in the groundwater around the ATPs (Figures 3-14, 3-15, and 3-17). In this area, lime and iron rich precipitator dust were disposed of with SPL, with some probable dissolution of slag material. Higher levels of calcium were also detected in the area of the former lime stabilized SPL sludge impoundment (SWMU S-16) in SFA Zone 4. Throughout SFA Zones 2 and 4, potassium was detected at relatively high concentrations, while magnesium concentrations appeared generally to decrease approaching Lake Erie (Figures 3-15 and 3-16).

Higher than expected sodium and chloride ion concentrations were detected in background monitoring well MW-08A (northeastern margin of site), which may reflect road salt usage in the vicinity of this well (Figures 3-18 and 3-19). Elevated concentrations of sodium were also found in monitoring wells located further west in the Coke Oven Area, which similarly correlated with elevated concentrations of chloride. Concentrations of sodium, chloride, and sulfate were also detected in wells downgradient of the ATPs where sodium rich spent carbonate solution and pickling liquors containing hydrochloric and sulfuric acid were disposed, and SWMU S-21 where wastewater sludges from the BOF operation were stored. Secondary or less prominent concentrations of chlorides and sulfates were observed in the vicinity of former SPL (SWMU S-16) and acid tar (SWMU S-23) disposal areas on the northwestern side of SFA Zone 4 (Figures 3-19 and 3-20).

3.1.2.4 <u>Summary</u>

In summary, the use of slag as fill to extend the Lackawanna site westward into areas originally covered by Lake Erie has resulted in groundwater with distinct chemical properties in comparison to most natural systems. These differences must be understood in order to fully evaluate environmental conditions at the site. In addition, certain aspects of the site-specific groundwater chemistry (i.e., pH) are important with respect to the distribution of constituents that may be related to the occurrence of biodegradation, as will be discussed in Section 3.2, Fate and Transport.

3.1.3 Distribution of Groundwater Constituents

The following assessment of the nature and extent of groundwater contaminants is based upon the occurrence of chemical constituents as observed in the most recent, comprehensive groundwater monitoring data (Appendix F). The comprehensive groundwater sampling event was performed in 1999-2000 on all 144 of the site's existing RFI monitoring wells. This round of groundwater samples was conducted in response to Agency concerns regarding the phased nature of site investigations and subsequent difficulty in interpreting data compiled at different times from multiple sampling events. The groundwater samples were analyzed for the 91 COPIs associated with steel-making operations as defined in the AOC for the Lackawanna facility (USEPA 1990).

A comprehensive review of the data is provided by focusing progressively on the major chemical groups, their subgroups and the individual chemicals of concern as defined in the SWMU materials (Section 3.1.1) and groundwater samples. The major chemical groups include the VOC, SVOC, and inorganic metals. PCBs were analyzed for in groundwater samples containing a sheen or product (see Section 3.1.3.4), however, PCB's were not detected in the dissolve phase of any of the samples analyzed.

The evaluation of groundwater constituents also provides a spatial comparison of COPCs identified in the sites SWMU material (potential source areas) with COPCs identified in the site's groundwater. Groundwater COPCs were determined by sequentially applying the following criteria to the groundwater data: (1) the chemical constituents were detected in at least 5% of the samples and, (2) the maximum detected concentration was greater than the regulatory screening criterion (i.e. USEPA Region III RBC (USEPA 2000) or NYSDEC Ambient Water Quality Standard and guidance value (NYSDEC 1998). For groundwater, applicable COPIs included contaminants with a potential for volatilization, which was identified as the principle exposure pathway for groundwater contaminants at the site (Ref. ID #1). Table 3-2 identifies the groundwater COPCs and list all chemicals detected in the comprehensive groundwater samples.

The location of monitoring wells sampled during the comprehensive groundwater sampling event and the location of SWMUs identified at the site are shown on Figure 3-1. Monitoring wells installed at the site monitor groundwater in the fill and underlying sand and bedrock units. A description of the wells and zones monitored is provided in Section 2.5, which also provides a summary of the construction details (Table 2-1).

3.1.3.1 Volatile Organic Compounds

The distribution of total VOCs and, the BTEX (benzene, toluene, ethylbenzene and xylene) and chlorinated hydrocarbon compound subgroups, is illustrated in Figures 3-21 and 3-22 representing the fill and sand units, respectively. Analytical results from the nine bedrock wells are also represented on Figure 3-22.

The occurrence of total VOCs is widely distributed across the site and is driven by the presence of BTEX compounds, which dominate the elevated VOC concentrations observed in the area of the ATPs and in the Benzol Yard Area (SWMU P-11). In both of these areas: benzene, toluene and xylene, which are groundwater COPCs (Table 3-2), were also identified as COPCs in subsurface SWMU material. Directly across Smokes Creek and northeast of the ATPs, elevated concentrations of BTEX in the vicinity of SWMU S-24 coincide with COPC's detected in SWMU material (Figure 3-3). In the deeper sand unit, BTEX concentrations in groundwater remain high in the area of the ATP's, but decrease significantly from 140,000 µg/L in slag fill well MWS-18A to 65,840 µg/L in MWS-18C screened in the sand.

In monitoring well pairs installed closer to the lake shoreline, BTEX concentrations tended to increase from the shallow to deeper wells. Low levels of BTEX (ND to 12 µg/L) were also detected in bedrock monitoring wells MWN-02D, -03D, -05D, and MWS-08A near the shoreline (Figure 3-22). A higher concentration of BTEX (883 µg/L) was detected in bedrock well MW-2D2D located immediately downgradient of surface impoundment SWMU S-3 in SFA Zone 2. The concentration of BTEX in this well was equivalent to the concentration of BTEX (896 µg/L) reported in the shallower (sand unit) well pair (MW-2D2B) installed at that location. Near the Benzol Yard and Coke Oven Area, a low level of BTEX (7.8 µg/L) was reported in bedrock well MWN-15D (Figure 3-22).

Chlorinated hydrocarbons were detected at much lower concentrations and are present throughout Slag Fill Zone 2, and around SWMUs S-16 and S-23 within Slag Fill Zone 4 (Figure 3-21). Elevated concentrations were reported in wells around the ATPs where chlorinated VOCs have been identified as COPCs in subsurface SWMU material (Figure 3-5). Fewer detections of chlorinated compounds were apparent in the deeper sand unit wells and no chlorinated compounds were detected in the bedrock wells (Figure 3-22).

BTEX Compound Distribution

The distribution and relative proportions of benzene to toluene, ethylbenzene and xylene are shown in Figures 3-23 and 3-24 for the fill and sand units. Not only does the distribution of VOC's closely follow trends in the distribution of BTEX in groundwater, but as seen in these figures, the distribution of BTEX is largely defined by the presence of benzene detected in groundwater samples. In the areas of the ATPs and Benzol Yard, where there are elevated concentrations of BTEX, benzene dominated the sample composition with concentrations typically an order of magnitude or greater than the other BTEX compounds combined (Appendix F). Downgradient of the ATPs and Benzol Yard, in the direction of Lake Erie, BTEX concentrations decrease while the proportion of toluene, ethylbenzene and xylene increase relative to benzene. This pattern suggests progressive downgradient degradation of the more easily degraded benzene, leaving the more persistent BTEX compounds in the near-shore samples.

Highest concentrations of benzene (570,000 µg/L) and toluene (70,000 µg/L) were detected in monitoring well MWN-32A within the Benzol Yard, while the highest concentration of xylene (5,700 µg/L) and ethylbenzene (1,000 µg/L) were detected in monitoring well MW-11 within the ATPs. In deeper (sand unit) groundwater samples, benzene concentrations remained elevated in the vicinity of the ATPs with the highest concentration reported in MWS-18C (65,000 µg/L).

Chlorinated Compound Distribution

Chlorinated hydrocarbon compounds detected at a frequency of greater than 5% in the groundwater samples include trichloroethene (TCE) at a frequency of 7.1% and 1,1 Dichloroethane (1,1 DCA) at a frequency of 15%, with maximum detected concentrations of 64.5 μg/L and 3,100 μg/L, respectively (Table 3-2). Chlorinated compounds detected at a lesser frequency (4 samples or 2.9%) in the comprehensive sampling event samples include chlorobenzene (max 46.0 μg/L), 1,2 dichloroethane (max 10.6 μg/L) and methylene chloride (max 3,700 μg/L). All of these compounds were identified as groundwater COPCs.

TCE and 1,1 DCA were detected in much the same locations, namely Zone 2 of the Slag Fill Area with highs identified in the ATPs and, in the vicinity of SWMUs S-16 and S-23 as previously mentioned (Figure 3-25). 1,1 DCA appeared more widespread and at higher concentrations in these areas, and together with TCE dominated the chlorinated fraction in most groundwater samples (Figure 3-26). Fewer, lower level detections of chlorinated compounds were detected in the deeper groundwater (sand unit) samples, with the exception that the maximum TCE concentration was reported in well MWN-14B, which is immediately downgradient of SWMU S-19 (Landfill AA-Discarded Plant Material). TCE was identified in the HHRA as a COPC in surface soil from SWMU Group SFA-1 (i.e. the Zone 2 Surface Impoundments) and in subsurface material from the ATPs (Figures 3-4 and 3-5).

Other VOC Detections

Figure 3-27 shows the location and distribution of all other VOCs detected in groundwater samples from wells monitoring the fill and sand zones. All of the remaining detected compounds are chlorinated hydrocarbons that include daughter products of the more frequently detected 1,1 DCA (i.e., 1,2 DCA; 1,1,1 TCA; and 1,1,2,2 PCE) and TCE (i.e., Trans-1,2 DCE). Most of these compounds were detected in the area of the ATPs. Concentrations ranged from a low of 1.4 μg/L to a high of 10.6 μg/L 1,2 DCA in monitoring well MWS-10 (Table 3-2). A higher detection of chlorobenzene (46.0 μg/L) was observed in the sample collected at well location MWN-05B monitoring the deeper sand unit.

Methylene chloride, a common laboratory contaminant, was detected at an elevated concentration (3,700 µg/L) in monitoring well MW-11 located within SWMU S-11 of the ATPs. All other detections of methylene chloride ranged between 1.1 µg/L and 12 µg/L.

3.1.3.2 Semi-Volatile Organic Compounds

The next chemical group found in groundwater consists of SVOCs, which are primarily associated with coal tar generated from the processing of coke oven gases, and waste oils from coke by-process and steel finishing operations. These compounds tend to be less soluble and less mobile in groundwater than the VOCs discussed above. Subgroups include phenolic compounds that constitute the acid tars of the middle oil fraction and; polycyclic aromatic hydrocarbons (PAHs) including more volatile tar bases of the middle oil fraction (e.g., naphthalene) and other less soluble semi-volatiles of the heavy and anthracene oil fractions.

The distribution of total SVOCs and the PAH and phenolic subgroups, are shown in Figures 3-28 and 3-29 representing the fill and sand units, respectively. The occurrence of SVOCs is widely distributed across the site in both the fill and underlying sand unit, however, SVOCs were not detected in groundwater samples from the background monitoring wells. Higher concentrations of SVOCs in groundwater were observed in the ATPs and Benzol Yard area with secondary concentrations associated with SWMUs nearer the lake shoreline and the Tank Farm area. With the exception of the Benzol Yard area, higher concentrations of SVOCs (and in particular, phenolic compounds) were detected in the deeper (sand unit) groundwater samples. At monitoring well location MWS-10, downgradient of the ATPs, total phenolic concentrations increased from 51.8 µg/L in slag fill well MWS-10A to 35,380 µg/L in MWS-10B screened in the underlying sand.

In monitoring well pairs installed closer to the lake shoreline, the concentrations of PAHs and phenolics tended to increase from the shallow to deeper monitoring wells. However, in the underlying bedrock unit, only 4 of the 9 bedrock monitoring wells (MW-5B, MWN-15D, MWN-03D and MW-2D2D) detected SVOCs in the groundwater samples (Figure 3-29). The highest concentration of SVOCs (31.1 µg/L) was detected in monitoring well MW-2D2D near the lake shoreline and included several phenolic compounds that were detected at higher concentrations in the sand unit well pair at that location (Figure 3-1).

Base Neutral Compound Distribution

The most prominent base neutral compounds that were detected at the highest concentrations in groundwater samples include naphthalene and pyridine (Table 3-2). Naphthalene was detected in over 60% of the groundwater samples, while pyridine was detected in 15% of the samples with average concentrations of 368 µg/L and 7,698 µg/L, respectively. Naphthalene, which is the most soluble and mobile of the PAH fraction, was typically detected at concentrations greatly exceeding the concentrations of all the other PAH compounds combined (Figures 3-30 and 3-31). Noticeable exceptions include fill unit monitoring location MWN-12 and MWN-44A near acid tar sludge SWMUs S-23 and S-24, and well MWN-33A in the Coke Oven area. At these locations, the combined concentrations of several other volatile SVOCs (i.e., fluorene, fluoranthene, acenaphthylene, and phenanthrene) were equivalent to the detected concentration of naphthalene.

Elevated levels of naphthalene were particularly apparent in the area of the Benzol Plant (SWMU P-11), as well as near the tar pits (SWMUs S-22 and S-24) bordering Smokes Creek (Figure 3-30). Secondary concentrations of naphthalene were observed nearer the lake around the surface impoundments in SFA Zone 2 (SWMU SFA-1); near the Slag Quench Pit (SWMU S-10) in SFA Zone 3; and near coal tar sludge SWMUs S-13 and S-23 in SFA Zone 4. In monitoring well pairs installed near the lake shoreline, naphthalene concentrations tended to increase in the deeper well pairs monitoring the sand unit (Figure 3-31). Naphthalene, which was identified as a groundwater COPC at the site, was also identified as a COPC in soil/fill material at SWMUs where elevated levels of naphthalene occurred in the groundwater samples (Figures 3-6 and 3-7).

Pyridine, which was also identified as a groundwater COPC at the site, was found to be concentrated at the ATPs near Smokes Creek (Figures 3-30 and 3-31). A few, lower level detections of pyridine were observed in the area of the Coke Ovens and Benzol Yard and, near the lake in SFA Zone 4 around SWMUs S-13 and S-28. Near SWMU S-22, an elevated concentration of pyridine (120,000 µg/L) was detected at MWS-17A, which decreased to 1,000 μg/L in the deeper well pair (MWS-17B) monitoring the underlying sand unit. Along Smokes Creek, however, the concentration of pyridine increased in the deeper well pair at monitoring locations MWS-18 A/B/C and MWS-19 A/B, increasing from 150 μg/L to 26,000 μg/L at MWS-18 and from 5.6 μg/L to 3,200 μg/L at MWS-19 (Appendix F). Although pyridine was detected in analyses of the soil/fill at the ATPs, it was not identified as a COPC for the SWMU material.

In addition to naphthalene and pyridine, a number of other PAH compounds were detected in the groundwater samples. These compounds, which have higher molecular weights, are less readily solubilized and were consequently detected at lower concentrations in the samples. Several of the more soluble compounds (anthracene, acenaphthylene, fluorene, and phenanthrene), which like naphthalene are volatile SVOCs, were identified as COPCs in both the groundwater and SWMU materials at the site. In contrast, the least soluble and carcinogenic PAHs, which were found widely distributed in SWMU material (Figures 3-8 and 3-9), were detected in less than 5% of the groundwater samples (i.e., benzo(a)anthracene detected in 4 samples, benzo(a)pyrene detected in 2 samples, and chrysene detected in 2 samples). Maximum concentrations of these compounds were detected in monitoring well MWN-33A located near the Old Benzol Plant in the Coke Oven area (Table 3-2).

In general, the volatile SVOCs were detected at many of the same locations and at similar relative concentrations (Figures 3-32 and 3-33). At well pair locations, concentrations tended to decrease in the deeper (sand unit) well pairs (Appendix F). There also appears to be an association between the detections in the groundwater and locations where COPCs were identified in SWMU material. These locations include the acid tar sludge SWMUs S-23 and S-24; locations within and downgradient of the Tank Farm and Slag Quench Pit (SWMUs P-75 and S-10) in SFA Zone 3; and around the surface impoundments and ATPs in SFA Zone 2 (Figures 3-6 and 3-7). Elevated concentrations were noted at well locations MWN-33A (anthracene at 110 μg/L) and MWN-30A (fluorene at 1700 μg/L) in the Coke Oven area; and at wells MWN-44A (fluoranthene at 310 μg/L; phenanthrene at 760 μg/L and pyrene at 220 μg/L) and MWN-01B (acenaphthylene at 155 μg/L) along the north bank of Smokes Creek.

Phenolic Compound Distribution

Phenolic compounds, which are associated with coal and the manufacture of coke and its by-product wastes, were found widely distributed in the groundwater samples. The most prominent and water soluble of the phenolic compounds, phenol and 3-, and 4- methylphenol were reported at concentrations in the groundwater samples greatly exceeding all other detected phenolic compounds combined (Figures 3-34 and 3-35). Phenol was the most frequently detected compound (52% of samples) with an average concentration of 652 μg/L; while 3-, and 4-methylphenol, 2-methylphenol, and 2, 4- methylphenol were detected in over 30% of the samples (typically at the same locations) with average concentrations of 228 μg/L, 66 μg/L, and 18 μg/L; respectively, (Table 3-2).

The highest concentrations of these compounds were identified in monitoring wells MWS-10B and MW-11 (Phenol at 29,000 μg/L; 3-, and 4- methylphenol at 5,400 μg/L; 2-methylphenol at 980 μg/L; and 2, 4- dimethylphenol at 140 μg/L), which monitor groundwater at and downgradient of SWMU S-11. Elevated levels of phenolic compounds were also detected elsewhere around the ATPs, and at the Benzol Yard (SWMU P-11) and Tank Farm (SWMU S-75) areas north of Smokes Creek. Secondary concentrations of phenolic compounds in groundwater were observed downgradient of the former coal storage yard (i.e., monitoring wells MWN-13, 14 and 20), and at several SWMUs including S-13 (Acid Sludge HWMU 1A) and S-7/S-20 (Ammonia Still Lime Sludge HWMU-2). With the exception of the Benzol Yard, the concentrations of phenolic compounds tended to increase in the deeper (sand unit) monitoring well pairs (Figures 3-34 and 3-35).

Other SVOC Detections

Figure 3-36 shows the location and distribution of all other SVOCs detected in groundwater samples collected during the comprehensive sampling event. The remaining SVOCs consist primarily of chlorinated SVOCs (i.e., bis(2-chloroethyl)ether in two samples; 2-chloronaphthalene in two samples; 2,4-dichlorophenol in one sample; 2,4,6-trichlorophenol in one sample). Many of these compounds were found in one groundwater sample obtained from well MWS-25B that is downgradient of SWMU S-21 (WQCS #3 Sludge Disposal Area) and south of the ATPs. Only one phthalate (bis(2-ethylhexyl)phthalate) was detected in 18 groundwater samples at a maximum concentration of 6.3 µg/L.

3.1.3.3 Heavy Metals Distribution

The distribution of major cations detected in groundwater at the Lackawanna site was discussed in Section 3.1.2.3. This section focuses on the distribution of heavy metals, which are found at lower concentrations and, typically at a lesser frequency in the groundwater samples (Table 3-2). The following discussion focuses on the total dissolved concentration of heavy metals with emphasis on those metals, which were also identified as COPCs based on the analysis of SWMU material samples.

SWMU Related COPC Metals

Of the eleven heavy metals detected in groundwater collected during the comprehensive sampling event (1999-2000), six metals were also identified as COPCs in the sites' SWMU materials. Several of these metals, including arsenic (65% of samples), chromium (96% of samples) and lead (44% of samples), were found to be widely distributed in groundwater samples. Concentrations of these metals were also identified in upgradient monitoring wells (MW-07 and MW-08) located near State Route 5 (Figures 3- 37, 3- 38 and 3- 39).

Higher concentrations of arsenic and lead were generally found in groundwater from wells monitoring the deeper sand unit. Chromium concentrations, however, were typically higher in the shallow fill wells but tended to increase in the sand unit near the Lake Erie shoreline. Elevated concentrations of these metals were observed in the vicinity of SFA Zone 2, where similar metals were identified as COPC's in the ATPs (arsenic in S-11/S-22), at SWMU S-21 (arsenic, chromium and lead), and at the SFA Zone 2 Surface Impoundments (arsenic, chromium and lead in SFA-1 and S-8) (Figures 3-10 and 3-11). Maximum concentrations of arsenic were found in fill wells MWS-10 (at 740 µg/L) and MWS-23A (at 153 µg/L) situated downgradient of SWMU S-11, and in fill and the deeper well pairs MWN-33A (at 662 µg/L) and MWN-26B (at 485 µg/L) in the vicinity of the Old Benzol Yard (Figure 3-37). Maximum chromium and lead concentrations were found in monitoring wells MWS-18B (chromium at 2,000 µg/L) and MW-11 (lead at 1,370 µg/L), downgradient of SWMU S-22 near Smokes Creek and within SWMU S-11 at the ATPs. In the bedrock monitoring wells, the highest concentrations of chromium (max 110 µg/L) and lead (max 11.7 µg/L) were detected in monitoring well MWN-25D in the Coke Oven Area (Figures 3-38, and 3-39. The highest concentration of arsenic in a bedrock monitoring well was 12.3 µg/L in MW-06B.

Less widely distributed heavy metals, which were detected in groundwater and were identified as COPCs in the sites' SWMU material include, antimony, mercury and thallium. Each of these metals was more frequently detected in wells that monitored the slag fill. Highest concentrations of antimony and mercury were detected in SFA Zone 2, whereas, concentrations of thallium were found in SFA Zone 4 (Figures 3-40, 3-41 and 3-42). Maximum concentrations of antimony were detected in monitoring wells MWS-29A (at 10.9 µg/L) downgradient of SWMU S-21, and MWS-01B (at 19.1 µg/L) downgradient of the Slag Fill Area (SFA-1) impoundments. In each of these areas, antimony was identified as a COPC in the SWMU material (Figures 3-10 and 3-11). The maximum concentration of mercury was detected at the ATPs in well MWS-22A (at 0.79 µg/L) with a number of minor detections in the vicinity of SWMUs S-13, S-15 and S-28 in SFA Zone 4 (Figure 3-41). The maximum concentration of thallium was found in monitoring well MWN-04 (at 8.4 µg/L) located in the vicinity of SWMUs S-17, S-18 and S-23 where thallium was identified as a COPC Figures 3-10 and 3-11). Groundwater samples obtained from the bedrock wells did not detect the presence of these metals.

Other Metal Detections

Heavy metals not identified as COPCs in site SWMU material, which were detected in the groundwater samples, include, barium (100% of samples), cadmium (19% of samples), nickel (34% of samples), selenium (55% of samples), and silver (14% of samples). Maximum concentrations of barium (at 33,400 µg/L), cadmium (at 48.2 µg/L) and nickel (at 146 µg/L), were detected in monitoring well MWN-05B that monitors the sand unit downgradient of the Lime Dust and Kish Landfill (SWMU S-18) in SFA Zone 4. Elevated levels of barium were also detected in groundwater samples from monitoring wells MWS-01B, MW-2U1B and bedrock well

MW-2D2D located downgradient of the surface impoundments in SFA Zone 2, and in wells MWN-21B, MWN-26B, MWN-27B, and MWN-49B within the Coke Oven Area (Appendix F). Barium concentrations in these wells ranged from 1,070 µg/L to 22,000 µg/L. Barium was detected at a lesser concentration (23 to 80 µg/L) in the upgradient monitoring wells. Maximum concentrations of selenium (at 27.7 µg/L) and silver (at 91.3 µg/L) were detected in monitoring wells MWN-41A and MWS-18B located downgradient of the SWMU S-10 and SWMU S-22, respectively (Table 3-2).

3.1.3.4 Free Product Occurrence

The occurrence of free product observed as a discrete (floating) layer during the November 20, 2001 groundwater monitoring round is provided in Figure 3-43. During this monitoring event 18 monitoring wells and 11 piezometers recorded product ranging from an observed sheen (on purge water) to a discrete product layer as estimated or measured using an oil/water interface probe. Most recordings of product occurred in the Benzol Yard area (including all the piezometers), where a maximum product thickness of 1.49 feet was measured in piezometer BPP-11. Measurements of free product were recorded in the other piezometers which also monitor the watertable. However, only a sheen of product was observed in monitoring wells that monitor both the shallow and deeper groundwater zones at the Benzol Yard. Further away, free product was not observed in monitoring wells immediately to the east (along the Ship Canal) or to the south of the Benzol Yard (Figure 3-43).

The greatest thickness of floating product (8.51 feet) was measured in shallow well MWN-26C located in the vicinity of the Old Benzol Yard in the Coke Oven Area. Drilling records from this location suggest the boring may have penetrated a buried concrete vault that contained free product at a depth of between 10 and 15 feet. A shallower well (MWN-26A) installed to 7 feet bgs, and a deeper well (MWN-26B) installed to 38 feet, did not, however, produce evidence of free product confirming the probable confined nature of product at this location. Elevated concentrations of BTEX in shallow groundwater from this, and the Benzol Yard area (see Figure 3-21), suggest that the product may be the source of dissolved phase organics, which were derived from the distillation of coke oven gases at the Benzol Plant.

Evidence of free product ranging from a sheen to a thin layer (estimated at 0.01 feet) was observed in other shallow wells (MW-ID7, MWN-44A, MWS-22A, MW-11 and MWS-14) monitoring acid tar pits at SWMUs S-24 and S-11/S-22 near Smokes Creek, and S-23 near Lake Erie in SFA Zone 4 (Figure 3-1). Floating product was also evident in deep sand unit wells MWN-01B (sheen) and MWS-01B (estimated 0.01feet) near the mouth of Smokes Creek. Monitoring wells MWN-01 and MWS-01 which monitor the shallow (fill unit) at these location, curiously, did not show similar evidence of floating product suggesting the product may be confined to the sand unit sediments. At both these locations, the dissolved phase is dominated by PAHs with a noticeable concentration of naphthalene (see Figure 3-31). The chemistry of the dissolved phase at the other locations consisted of a mixture of VOCs and SVOCs dominated by elevated concentrations of PAHs and BTEX compounds with noticeable concentrations of pyridine (MWS-22A), phenol (MW-11) and 1,1 DCA (MW-11) (see Figures 3-21, 3-28 and 3-30).

Previous Reports of Product

The presence of product has also been noted in association with soil and groundwater samples collected during past subsurface investigations and sampling events. Table 3-3 provides a list of monitoring points and observations where product in the form of sheens or discrete films have been identified at the site and the dates the observations were made. These locations are shown on Figure 3-43, along with an indication of whether the product was observed in association with soil, groundwater, or both media.

Most of the locations where product was previously reported correspond with areas of the site where evidence of free product was observed in the November 2001 groundwater samples, including: SWMUs S-11/S-22 and S-23 (HWM-1B); the mouth of Smokes Creek, the northern bank of Smokes Creek upstream of the South Return Water Trench and; the Benzol Yard and Coke Oven Area. Other locations reporting product include the Surface Impoundments in SFA Zone 2; the area of SWMU S-13 (HWM-1A) in SFA Zone 4; and locations around the former coal handling and storage pile (Figure 3-43).

At these locations, evidence of product was typically associated with soil as reported in the boring logs, but was not evident in the development water. This suggests that the product at these locations may be of low solubility and tightly bound by the soil matrix, incapable of forming a discrete phase in groundwater. In many instances, the product observed in the soil is described as a black tar-like or oily substance with a petroleum or naphthalene odor (Table 3-3).

3.1.4 Distribution of Contaminants in Surface Water Bodies

As with the other investigations conducted within the Lackawanna site, the surface water bodies were investigated for the presence of the site specific COPIs. Identification of the COPIs present in the surface water bodies was performed through analysis of the complete set of surface water and sediment data collected in the RFI site investigations. The sampling activity referenced in this section is summarized in Section 2.2 and described in the appropriate watercourse reports provided in Part VII of this RFI report. Complete surface water analytical results for the water bodies and watercourses discussed in this section are provided in Appendix F.

As discussed previously in Section 3.0, both the HHRA and the ERA screened the detected COPIs. Screening of the COPIs in the HHRA and ERA identified constituents that are of most environmental concern. The HHRA screening determined COPCs that may present a potential risk to human health while the ERA determined COPECs that may present a potential risk to the ecology of the site. Tables showing the detected analytes and figures showing detected COPCs and COPECs are provided at the end of Section 3.0.

A Tier I HHRA was performed for each of the watercourses and Lake Erie in accordance with the HHRA ID#1. As part of the Tier I HHRA, for each water body or watercourse, the detected COPIs were screened against EPA criteria. Those values that exceeded the screening levels were identified as COPCs. The COPCs were determined by sequentially applying the following criteria to each detected COPI on a medium-by-medium basis: 1) the chemical was detected in at least 5% of the samples, 2) the chemical was detected in at least one sample at levels above background, and 3) the chemical was positively detected in at least one sample at levels above applicable screening criteria [i.e., EPA Region III Risk Based Concentrations

(RBCs), EPA Soil Screening Levels, or NYSDEC Ambient Water Quality Standards and Guidance Values]. Maximum detected concentrations were used in the screening process.

For each watercourse or water body, the COPCs were evaluated for two media types: sediment and surface water. In addition, a third media type, groundwater discharge, was evaluated for Lake Erie, the Ship Canal and Smokes Creek. The "groundwater discharge" media type evaluates the detected COPIs in each watercourse groundwater discharge area as if the groundwater COPI concentrations remained static once the groundwater discharged into the surface water. The groundwater discharge areas for Lake Erie, the Ship Canal and Smokes Creek were established in HHRA ID#1 and are also presented in Section 2.7.2, Part II of this RFI report. The effects of dilution of the groundwater into the surface water body were considered in the subsequent HHRA evaluations. This approach was used for Lake Erie, the Ship Canal and Smokes Creek because they were determined to be the discharge points for the majority of the groundwater at the Lackawanna site.

The selection of COPCs is presented in detail in each water course assessment report presented in Part VII, Watercourse Assessment Reports, as well as, in Part IV, the HHRA. The COPCs were subsequently evaluated in detail regarding their contribution to risk estimates for a number of receptor scenarios.

A multi-tier ERA was also performed on the watercourses and Lake Erie. In completing the ERA, COPECs were identified by screening detected COPIs with surface water and screening criteria established by the USEPA. These COPECs were identified to be chemicals that may affect the ecology within the watercourses. The COPECs were subsequently evaluated in detail as to their risk to the environment in the ERA. The selection of COPECs is presented in detail in the ERA provided in Part III of the RFI.

The COPCs and COPECs represent the chemicals that are most likely to create an environmental concern on the site and therefore, the use of the COPCs and COPECs provide a good baseline-screening tool for detected hazardous constituents within the water bodies.

Identification of hazardous constituents within the Lackawanna site water bodies and watercourses was performed through analysis of the complete set of surface water and sediment data. Detected analytes identified as COPCs by the HHRA, (Part IV of this RFI) and the COPECs by the ERA (Part III of this RFI) are highlighted in the following discussion.

The sampling activity referenced in this section is summarized in Section 2.2 and described in the appropriate watercourse reports provided in Part VII of the RFI. Complete surface water analytical results for the water bodies and watercourses discussed in this section are provided in Appendix F. Tables showing detected analytes and figures showing detected COPCs and COPECs are provided at the end of Section 3.0.

3.1.4.1 Lake Erie

Background and offsite sampling was performed in three areas: south of the Lackawanna site, within the Buffalo Outer Harbor, and within the Union Ship Canal. The latter two comprise the northern boundary of the site. Samples for the purpose of assessing the potential presence of SWMU-related hazardous constituents within Lake Erie were collected from the shoreline area along the site's western boundary.

3.1.4.1.1 Background Samples

Background and offsite samples were collected to compare with samples collected directly adjacent to the site's western boundary. Samples were collected from an area south of the Lackawanna site (Figure 2-19) and from the Buffalo Outer Harbor and the Union Ship Canal (Figure 2-18).

Surface Water

South of the Lackawanna Site Western Boundary

Surface water samples were collected from three upcurrent areas in Lake Erie. The samples were named BK-1, BK-2, and BK-3 (see Figure 2-19). One grab sample was collected from each location, and one duplicate sample was collected from BK-1 (BK-1 DUP). Samples BK-2 and BK-3 are upstream and south of the site and can be considered to be background samples. Sample BK-1 was collected near the mouth of Blasdell Creek. Because this location could potentially have been impacted from Blasdell Creek, it is best characterized as an offsite sample.

The analytes sampled for include 34 VOCs, 47 SVOCs, 14 metals and additional general chemistry parameters. The minimum and maximum concentrations of the detected analytes are shown in Table 3-4. Two metals, calcium and sodium, were detected. The pH of the samples ranged between 7.7 and 8.1.

Background/offsite samples were compared to Lake Erie on-site surface water COPCs and COPECs. It is important to note that for the human health COPCs, both surface water and groundwater discharge area COPCs were used. Thirty-five analytes were identified as surface water COPCs in the HHRA. None of the analytes were detected in the background/offsite surface samples, as shown in Table 3-4. Twelve analytes were identified as surface water COPECs in the ERA. None of these COPECs were detected in the background/offsite surface water samples, as shown in Table 3-4.

Buffalo Outer Harbor and the Union Ship Canal

Offsite surface water samples were collected from four areas in the Buffalo Outer Harbor and Union Ship Canal area (Figure 2-18). The samples were identified as OH-1, OH-2, OH-3 and OH-5. One duplicate sample was collected (OH-3 DUP).

The analytes sampled for include 34 VOCs, 47 SVOCs, 14 metals and additional general chemistry parameters. The minimum and maximum concentrations of detected analytes are shown in Table 3-5. COPIs detected in the offsite samples included dissolved calcium, sodium and total sodium. Of particular note, one VOC (toluene), one SVOC (phenol), and one additional heavy metal (selenium) were detected. Toluene and selenium were detected at concentrations of 1 µg/L and 5.2 µg/L, respectively in the sample collected from sampling area OH-3, which is located west of the mouth of the Union Ship Canal (Figure 2-18). Phenol was detected in samples from areas OH-3 and OH-5 (2.3 µg/L and 2.8 µg/L, respectively). Sample area OH-5 is located adjacent to the eastern portion of the current COE dumping ground (Figure 2-18). The pH of all samples was 8.

Background/offsite samples were compared to Lake Erie onsite surface water COPCs and COPECs. Thirty-five analytes were identified as surface water COPCs in the HHRA. Of the 35 analytes identified, three COPCs, toluene, phenol and selenium in OH-3 and phenol in OH-5, were detected in the Buffalo Outer Harbor and Union Ship Canal samples, as shown in Table 3-5. Twelve analytes were identified as surface water COPECs in the ERA. Of the 12 COPECs identified for Lake Erie surface water, none were detected in the Buffalo Outer Harbor and Union Ship Canal samples, as shown in Table 3-5.

Sediment

South of the Lackawanna Site Western Boundary

Grab samples were collected from the same three Lake Erie areas used to collect background surface water samples (See Figure 2-19). Sediment samples were named BK-1S, BK-2S and BK-3S. A duplicate sample of sample BK-1S was also collected (BK-1S DUP).

The analytes sampled for include 34 VOCs, 49 SVOCs, 11 metals and additional general chemistry parameters. Minimum and maximum concentrations and frequency of detections are shown on Table 3-6. Five SVOCs (chrysene, fluoranthene, phenanthrene, pyrene, and benzo(a)pyrene), and five heavy metals (arsenic, chromium, lead, nickel and selenium) were detected. Sample area BK-1S, just south of the mouth of Blasdell Creek, contained four of the five SVOCs, and four of the five heavy metals. Sample area BK-2S had one SVOC (benzo(a)pyrene) and all five of the heavy metals. Sample area BK-3S contained three heavy metals. Heavy metal concentrations were similar in the samples from the three areas.

Background/offsite samples were compared to Lake Erie onsite sediment COPCs and COPECs. Three analytes were identified as human health COPCs for Lake Erie sediment in the HHRA. Of the three, two analytes (benzo(a)pyrene and arsenic) were detected in the background/offsite samples, as shown in Table 3-6. The organic COPC benzo(a)pyrene was found in BK-2S; arsenic was found in all three samples. Twenty-six analytes were identified as ecological COPECs for Lake Erie sediment in the ERA. Of the 26 analytes, seven analytes (chrysene, fluoranthene, phenanthrene, pyrene, chromium, lead and nickel) were detected in the background/offsite samples, as shown in Table 3-6.

Buffalo Outer Harbor and the Union Ship Canal

One sediment grab sample was collected from each of three areas in the Buffalo Outer Harbor (OH-2S, OH-3S, and OH-5S) and one in the Union Ship Canal (OH-1S) (Figure 2-18). One duplicate sample was collected from OH-3S (OH-3S DUP).

The analytes sampled for include 34 VOCs, 47 SVOCs, 11 metals and additional general chemistry parameters. The minimum and maximum values and number of detections are provided in Table 3-7. Of the hazardous constituents, nineteen SVOC and eight heavy metals were detected in the samples.

Of these, sample OH-1S consistently had the highest concentrations and the largest number of detected constituents. This sample location is located in the Union Ship Canal. The most commonly detected SVOCs were benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene, as shown in the following table. The most commonly detected heavy metals were arsenic, barium, chromium, lead and nickel.

Analyte (µg/kg)	Sample ID(s)	Maximum Value (Location)
SVOCs		
3-methylphenol & 4-methylphenol	OH-1S, OH-2S	1790 (OH-1S)
Acenaphthene	OH-1S	2770
Acenaphthylene	OH-1S	1050
Anthracene	OH-1S, OH-2S, OH-3S	9830 (OH-1S)
Benzo(a)anthracene	OH-1S, OH-3S, OH-5S	16200 (OH-1S)
Benzo(a)pyrene	OH-1S, OH-2S, OH-3S, OH-5S	12700 (OH-1S)
Benzo(b)fluoranthene	OH-1S, OH-2S, OH-3S, OH-5S	16800 (OH-1S)
Benzo(g,h,i)perylene	OH-1S, OH-2S, OH-3S, OH-5S	10500 (OH-1S)
Benzo(k)fluoranthene	OH-1S, OH-2S, OH-3S, OH-5S	5120 (OH-1S)
bis(2-ethylhexyl)phthalate	OH-2S, OH-3S, OH-5S	658 (OH-3S)
Chrysene	OH-1S, OH-2S, OH-3S, OH-5S	13100 (OH-1S)
Di-n-butyl phthalate	OH-3S	217
Dibenz(a,h)anthracene	OH-1S	1890
Fluoranthene	OH-1S, OH-2S, OH-3S, OH-5S	25300 (OH-1S)
Fluorene	OH-1S, OH-3S	5830 (OH-1S)
Indeno(1,2,3-cd)pyrene	OH-1S, OH-2S, OH-3S, OH-5S	10700 (OH-1S)
Naphthalene	OH-1S, OH-2S, OH-3S, OH-5S	4980 (OH-1S)
Phenanthrene	OH-1S, OH-2S, OH-3S, OH-5S	23700 (OH-1S)
Pyrene	OH-1S, OH-2S, OH-3S, OH-5S	23800 (OH-1S)
Heavy Metals (mg/kg)		
Antimony	OH-1S	17.6
Arsenic	OH-1S, OH-2S, OH-3S, OH-5S	18.1 (OH-1S)
Barium	OH-1S, OH-2S, OH-3S, OH-5S	97.3 (OH-5S)
Chromium	OH-1S, OH-2S, OH-3S, OH-5S	72.8 (OH-1S)
Lead	OH-1S, OH-2S, OH-3S, OH-5S	314 (OH-1S)
Mercury	OH-1S	0.62
Nickel	OH-1S, OH-2S, OH-3S, OH-5S	38.9 (OH-3S)
Selenium	OH-2S, OH-3S	1.7 (OH-3S)

Offsite samples from the Buffalo Outer harbor and the Union Ship Canal were compared to Lake Erie onsite sediment COPCs and COPECs. Three analytes were identified as human health COPCs for Lake Erie sediment in the HHRA. All three were detected in the offsite samples: benzo(a)pyrene, and arsenic were each found in all of the sample locations, and dibenz(a,h)anthracene was found in sample location OH-1. Detected COPCs are shown on Table 3-7. Twenty-six analytes were identified as ecological COPECs for Lake Erie sediment in the ERA. Of the 26 identified, 21 analytes were detected in the Buffalo Outer Harbor and Union Ship Canal samples, as shown in Table 3-7.

3.1.4.1.2 Samples Adjacent to Western Site Boundary in Lake Erie (onsite samples)

Surface Water

Samples were collected from Lake Erie by two methods during the RFI, as described in Section 2.2.3. One sample each was collected from seepage meters (infiltrometers) installed at three separate locations in the lake (see Figure 2-12). Samples were designated I-1, I-2 and I-3. One grab sample each was also collected from an additional seven sampling locations (Figures 2-17). Samples were designated LE-01, LE-02, LE-03, LE-04, LE-05, LE-06 and LE-07. A duplicate sample was also collected at LE-05. In the following discussion, the seepage meter, grab sample and grab sample duplicate locations have been combined, when appropriate, to represent eight sample areas, as follows:

Sample Area Designation	Sample Designation
LE01	LE-1
LE02	LE-2
LE03	LE-3, I-3
LE04	I-2, LE-4
LE05	LE-5, LE-5 DUP
LE06	LE-6
LE07	LE-7
LEI-1	I-1

These sample areas are shown on Figure 2-17. A total of 11 samples plus one duplicate sample were analyzed for the eight areas combined.

The analytes sampled for included 41 VOCs, 48 SVOCs, 14 metals, and additional general chemistry parameters. Of these, only one VOC (toluene), one SVOC (bis[2-ethylhexyl] phthalate), one heavy metal (total lead), and cyanide were detected in the surface water samples collected from Lake Erie during the RFI. The minimum and maximum values and number of detections are provided in Table 3-8.

Toluene and bis(2-ethylhexyl) phthalate were only detected in sampling area LE05 at 0.44 and 37.0 µg/L respectively. Sampling area LE05 is near the mouth of Smokes Creek. Cyanide was detected at a concentration of 0.02 mg/L in one sample collected from the seepage meter located in sampling area LE03, which is located offshore of the northern portion of the site, approximately 2000 feet south of the northern site boundary. The highest total lead concentration, 5.7 µg/L, was detected in one sample from sampling area LE-04, which is located offshore of the northern portion of the site, approximately 1600 feet north of the mouth of Smokes Creek. The pH of the samples ranged from 7.07 to 8.2.

A total of 35 COPCs were identified for Lake Erie surface water in the HHRA. The 35 COPCs were identified based on the concentrations of detected COPIs in both the "on-site" surface water and groundwater within the "Lake Erie groundwater discharge area", (i.e., the groundwater-to-Lake Erie pathway). Only one of the 35 COPCs was identified, based on its concentration, in the on-site surface water. This compound, bis(2-ethylhexyl) phthalate, was detected in sampling area LE-05 at a concentration that exceeded the COPC selected criteria.

The remaining 34 COPCs were identified in the groundwater for the groundwater-to-Lake Erie transport pathway. Of these 34 groundwater-to-surface water transport COPCs, three analytes were detected in Lake Erie surface water:

- Toluene at a concentration of 0.44 µg/L in sample area LE05
- Cyanide at 0.02 mg/L in one sample (seepage meter) from area LE03
- Lead ranging from 3.0 µg/L to 5.7 µg/L in samples from areas LE01, LE03 (seepage meter), LE04, and LE05

Twelve analytes were identified as ecological COPECs for Lake Erie surface water in the ERA. Two COPECs were detected in the water samples; lead in areas LE01, LE03, LE04, LE05, and cyanide in area LE03 (see Table 3-8). Figures 3-44, 3-45, 3-46 and 3-47 show detected COPCs and COPECs for the Lake Erie surface water sampling areas.

Sediment

A total of fourteen grab sediment samples were collected from offshore Lake Erie areas adjacent to the Lackawanna site's western boundary (see Figure 2-17). In the following discussion, the grab sample locations, along with sample duplicates, have been combined, when appropriate, to represent seven sample areas, as follows:

Sample Area Designation	Sample Designation
LE01	LE-1S
LE02	LE-2S
LE03	LE-3S
LE05	LE-5S, LE-5S DUP, SEPA-1 (7/25/95), SEPA-1 (8/28/95), SEPA-2
LE06	LE-6S
LE07	LE-7S
LEBEPA	BEPA-1 (7/27/95), BEPA 2(7/27/95), BEPA-1 (8/28/95), BEPA 2(8/28/95)

The analytes sampled for included 34 VOCs, 47 SVOCs, 11 metals, and additional general chemistry parameters. The minimum and maximum values and number of detections are provided in Table 3-9. Three VOCs, 17 SVOCs, and seven heavy metals were detected. The distribution of the detected contaminants by sample area is as follows:

Sample Area	Parameter Class	Number Detected
LE01	**SVOCs**	5
	Metals (Total)	7
LE02	Metals (Total)	7
LE03	SVOCs	6
	Metals (Total)	5
LE05	VOCs	1
	SVOCs	16
	Metals	7
LE06	VOCs	2

Sample Area	Parameter Class	Number Detected
	SVOCs	6
	Metals	5
LE07	SVOCs	7
	Metals	5
LEBEPA	SVOCs	6
	Metals	6

The sampling area with the most VOCs detected (two) is LE06, which is located approximately 1400 feet south of the mouth of Smokes Creek; the VOCs detected were 1,1,2,2 tetrachloroethane (LE05) and, chloromethane, and toluene (LE06). The largest number of detected SVOCs was in sampling area LE05, which is located near the mouth of Smokes Creek. The most commonly detected SVOCs were chrysene and benzo(b)fluoranthene (detected in five of the seven areas) and fluoranthene, phenanthrene and pyrene, detected in six of the seven sampling areas. Mercury was found at only two sampling areas: LE01 and LE02, which are nearest the northern boundary of the site. Silver was likewise found at only two sampling areas: LE05 and LEBEPA, which is near the mouth of Blasdell Creek. Arsenic, barium, chromium, and lead were detected in all the sampling areas.

Three analytes were identified as COPCs for Lake Erie sediment in the HHRA. All three analytes (benzo(a)pyrene, dibenz(a,h)anthracene, , and arsenic) were detected in sampling area LE05; in addition, arsenic was detected in each sampling location. Detected COPCs are shown on Table 3-9 and Figures 3-44 through 3-47.

Twenty-six analytes were identified as COPECs for Lake Erie sediment in the ERA. Of these 26 analytes, twenty-four analytes (all except acenaphthylene and hexachlorobenzene) were detected in the samples adjacent to the western site boundary. Detected analytes are shown in Table 3-9 and Figures 3-44 through 3-47. Acenaphthalene was detected in offsite sampling location OH-1S only; hexachlorobenzene, although identified as a COPEC because its detection limit exceeded screening criteria, was not detected in any of the samples.

Comparison to Background

The VOC toluene was detected in one Lake Erie surface water sample from area LE05 adjacent to the site; a sample from offsite surface water sample location OH03 in Buffalo Outer Harbor also contained toluene. No other VOCs were detected at any other Lake Erie or Outer Harbor/Union Ship Canal location including background areas BK-2 and BK-3. Only two SVOCs, phenol and bis(2-ethylhexyl)phthalate were detected in both Lake Erie and the Outer Harbor/Union Ship Canal areas. Phenol was detected only in two offsite surface water sample areas (OH03 and OH05). One Lake Erie adjacent surface water sample (LE05) contained the SVOC, bis(2-ethylhexyl)phthalate. Lake Erie adjacent sample areas LE01, LE03, LE04 and LE05 contained some total lead, and cyanide was detected in the seepage meter sample from adjacent area LE03. Total lead and cyanide were not detected in the background and offsite surface water samples.

Comparison of offsite sediment samples from the Outer Harbor and the Union Ship Canal area to samples collected adjacent to the site's western boundary in Lake Erie shows that they contained similar SVOCs and metals. The highest concentrations and the largest number of detected constituents were found in the offsite sample area OH-1S, which is located near the entrance of the Union Ship Canal. Three VOCs were detected in the sediments from Lake Erie; no VOCs were detected in the Buffalo Outer Harbor and Union Ship Canal sediment samples.

Background samples BK-2 and BK-3 contained no VOCs and only one SVOC (benzo(a)pyrene at BK-2). Offsite sample area BK-1, near the mouth of Blasdell Creek had no VOCs but had four SVOCs; with concentrations ranging from 88 to 180 µg/L. Several metals, including arsenic and lead, were found at BK-1, BK-2 and BK-3.

At least one of the offsite and adjacent Lake Erie surface water samples contained the COPC toluene. All of the offsite and adjacent Lake Erie sediment samples contained the COPC arsenic. Arsenic was also found at both Lake Erie background locations BK-2 and BK-3. The ecological COPECs antimony and barium were not found in background samples BK-2 and BK-3. They were, however, found at least one of the offsite and several adjacent Lake Erie sediment samples. The ecological COPEC silver was detected in low levels in two adjacent Lake Erie sediment samples, but was not detected in either background or off site samples.

3.1.4.2 Smokes Creek

Smokes Creek is a natural water body that crosses the site prior to draining into Lake Erie. Smokes Creek originates as two branches, the north and south branch (Figure 1-1). For the purpose of this discussion, Smokes Creek includes the section of the creek that flows through the site, and the north branch along which the background samples were collected (Figure 2-20).

3.1.4.2.1 Background Samples

Background samples of water and sediment were collected from off-site and site boundary locations in Smokes Creek to compare with samples collected from on-site locations within the creek.

Surface Water

One background surface water sampling area for Smokes Creek, SC05, was sampled during the RFI (Figure 2-6). This area is situated near the point where Smokes Creek enters the project site, just west of Route 5. Two surface water samples, SC-5(94) and SC-5(95), were collected at this point: one in 1994 and one in 1995. The chemicals analyzed included 34 VOCs, 48 SVOCs, 14 metals, and additional general chemistry parameters. Of the analyzed constituents, one VOC (chloroform at 5.5 μg/L), five SVOCs (bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, diethyl phthalate, di-n-butyl phthalate, fluoranthene, and naphthalene), and five metals (barium, calcium, chromium, potassium and sodium) were detected in the samples. Minimum and maximum concentrations and detection frequencies are shown in Table 3-10. The surface water pH at the sample point was 7.8.

Background samples were compared to Smokes Creek onsite surface water COPCs and COPECs. A total of 37 surface water COPCs were identified for Smokes Creek in the HHRA and were detected in either the Smokes Creek surface water samples or in the groundwater within the Smokes Creek groundwater discharge area. Of the 37 COPCs, six analytes, chloroform, bis(2-ethylhexyl)phthalate, fluoranthene, naphthalene, barium and chromium were detected in the background samples, as shown in Table 3-10. Twenty-four analytes were identified as COPECs for Smokes Creek surface water in the ERA. Five of the detected analytes in the background samples (chloroform, butyl benzyl phthalate, diethyl phthalate, barium, and chromium) are COPECs, as shown in Table 3-10. Detected COPCs and COPECs in Smokes Creek background surface water samples are shown on Figures 3-48 through 3-51.

3.1.4.2.2 **Sediment**

Two background sediment sampling areas were sampled during the RFI: One area, SC05, is the same as that from which the background surface water sample was collected (Figure 2-6). The second area, SC(N)BKG, is located approximately 1.8 miles east of the site (Figure 2-20). Two sediment samples were collected at location SC05, one in 1994 and one in 1995, and two sediment samples were collected at location SC(N)BKG in 1995 (one of the samples in 1995 was analyzed for AVS/SEM only).

Sample Area Designation	Sample Designation
SC05	SC-5(1994), SC-5 (1995)
SC(N)BKG	SC(N)BKG

The analytes sampled for included 34 VOCs, 48 SVOCs, 23 metals, and additional general chemistry parameters. Minimum and maximum concentrations and detection frequencies are shown in Table 3-11.

Two VOCs were detected in the background samples from area SC05: chloromethane at 12 μg/kg and methylene chloride at 18 μg/kg. Fourteen SVOCs were detected in the background samples (see Table 3-11); eleven of these were detected at both locations. The upstream location (SCNBK) consistently had lower SVOC concentrations compared to the samples obtained from location SC05. Twenty-one metals were detected in the sediments with the majority of the metals found in area SC(N)BKG, though at lower concentrations.

Background samples were compared to Smokes Creek onsite sediment COPCs and COPECs. Eight sediment COPCs were identified for Smokes Creek in the HHRA. All eight analytes were detected in the background samples, as shown in Table 3-11. Forty-three analytes were identified as ecological COPECs for Smokes Creek sediment in the ERA. Of the 43 COPECs, 26 were detected in the background samples, as shown in Table 3-11. Detected COPCs and COPECs in Smokes Creek sample area SC05 are shown on Figures 3-48 through 3-51.

3.1.4.2.3 On-site Samples from Smokes Creek

Surface Water

Six surface water locations (sampling areas) (not including background samples) were sampled in Smokes Creek during the RFI, and 34 surface water samples were collected at these locations (See Figure 2-6). The samples were assigned to the six sampling areas as follows:

Sample Area Designation	Sample Designation
SC01	SS-1, SC-1, SC-1V, SC-1N, SC-1S
SC02	SC-2, SC-2.3, SC-2.6, SC-2N, SC-2S, SC-2S DUP
SC03	SS-2, SC-3 (10/28/94), SC-3 DUP (10/28/94), SC-3.3, SC-3.3 DUP, SC-3.6, SC-3.6 DUP, SC-2V, SC-3 (7/27/95)
SC04	SS-3, SS-3 (DUP) , SC-4, SC-4.3, SC-4.6, SC-3V
SC06	SC-6.3, SC-6.6, SC-6N, SC-6S
SC07	SC-7.3, SC-7.6, SCS-3, SCS-4

The analytes tested for included 34 VOCs, 47 SVOCs, 14 metals, and additional general chemistry parameters. The maximum values, detection frequencies and comparison to COPCs and COPECs for these analytes are provided in Table 3-12.

Sampling areas SC01 had the largest numbers of detected VOCs (eight VOCs detected). SC01 is located near the confluence with Lake Erie. The most commonly detected VOCs were as follows:

- Benzene in all sampling areas at concentrations ranging from 0.4 to 4 µg/L

- Bromoform in all but area SC07 at concentrations ranging from 0.9 to 5 µg/L
- Dibromochloromethane in all but area SC07 at concentrations ranging from 0.4 to 1 µg/L
- Methylene chloride in three areas at concentrations ranging from 6.8 to 14 µg/L
- Chloroform in four of the six areas at concentrations ranging from 0.4 to 8.8 µg/L.

SC01, SC02, SC03, and SC06 had the largest number of detected SVOCs (four, six, six, and seven, respectively). These areas are within the western half of the course of Smokes Creek through the site. The most commonly detected SVOCs were as follows:

- bis(2-ethylhexyl) phthalate in three sampling areas at concentrations ranging from 2.5 to 17 µg/L
- diethyl phthalate in four sampling areas at concentrations ranging from 0.2 to 0.5 µg/L
- di-n-butyl phthalate in three sampling areas at concentrations ranging from 0.4 to 1.2 µg/L
- Butyl benzyl phthalate in three sampling areas at concentrations ranging from 0.1 to 0.2 µg/L
- Naphthalene in three sampling areas at concentrations ranging from 0.4 to 1.3 µg/L.

Sampling areas SC01 and SC02 has the largest number of detected total metals. The most commonly detected heavy metals were as follows:

- Total arsenic in three sampling areas at concentrations ranging from 0.0054 to 0.0074 mg/L
- Total barium in four sampling areas ranging from 0.026 to 0.030 mg/L and dissolved barium in the same sampling areas at concentrations ranging from 0.025 to 0.027 mg/L.
- Total selenium in five sampling areas ranging from 0.0038 to 0.0073 mg/L, and dissolved selenium in three sampling areas ranging from 0.0031 to 0.0073 mg/L.

- Total chromium in three sampling areas ranging from 0.001 to 0.021 mg/L, and dissolved chromium in three sampling areas at concentrations from 0.033 to 0.058 mg/L.

Cyanide was detected in four sampling areas (SC01, SC02, SC03, and SC04) at concentrations ranging from 0.022 to 0.044 mg/L.

Surface water pH varied between 7.6 and 7.7 in the sampling areas.

Thirty-seven analytes were identified as Smokes Creek surface water COPCs in the HHRA. Eighteen of the analytes were detected in the surface water samples, as shown in Table 3-12. The remaining COPCs were detected in the groundwater within the Smokes Creek groundwater discharge area. Twenty-four analytes were identified as surface water COPECs in the ERA. Twenty of the analytes were detected, as shown in Table 3-12. Detected COPCs and COPECs are also shown on Figures 3-48 through 3-51.

Sediment

A total of 20 grab sediment samples (not including the background samples) were collected from six sediment sampling areas during the RFI (See Figure 2-6). Seven additional grab samples were collected and analyzed for metals via the AVS/SEM method. The results of the AVS/SEM analyses are discussed subsequently in the ERA Report (Part IV of this RFI Report). The 20 regular (non-AVS/SEM) samples were assigned to the following sampling areas:

Sample Area Designation	Sample Designation
SC01	SED-2 (TCLP only), SC-1, SC-1N, SC-1S
SC02	SC-2-CORE, SC-2-DREDGE, SC-2N, , SC-2S, SC-2S DUP
SC03	SED-3 (TCLP only), SC-3 (94), SC-3 (95)
SC04	SED-4 (TCLP only), SED-5 (SED-4 DUP-TCLP only), SC-4, SC-4 DUP
SC06	SC-6, SC-6N, SC-6S
SC07	SC-7

These sampling areas are shown on Figure 2-6. The analytes tested for included 34 VOCs, 47 SVOCs, 11 metals, and additional general chemistry parameters. Eight VOCs, 22 SVOCs, 14 metals and cyanide were detected. The minimum and maximum value detected and detection frequencies are summarized in Table 3-13.

Samples SED-2, SED-3, SED-4, and SED-5 were tested for the same analytes after application of the Toxicity Characteristic Leaching Procedure (TCLP). The results of the TCLP analyses are summarized in Table 3-14. For the purpose of the following discussion, these results are not considered; instead, they are addressed in the Watercourse Assessment Report for Smokes Creek, which is presented in Part VII of this RFI Report.

Detected analytes were distributed in Smokes Creek sediment as illustrated by the following table.

Sample Area	Parameter Class	Number Detected
SC01	VOCs	6
	SVOCs	15
	Metals	12
SC02	VOCs	4
	SVOCs	17
	Metals	13
SC03	VOCs	3
	SVOCs	16
	Metals	13
SC04	VOCs	3
	SVOCs	15
	Metals	10
SC06	SVOCs	19
	Metals	8
SC07	VOCs	2
	SVOCs	1

The most commonly detected VOCs are the following:

- Carbon disulfide in three of the sampling areas (SC02, SC03, SC04) at concentrations ranging from 4.6 to 37 µg/kg
- Toluene in three of the sampling areas (SC01, SC03, SC04) at concentrations ranging from 10 to 270 µg/kg
- Trichlorofluoromethane in three of the sampling areas (SC01, SC03, SC04) at concentrations ranging from 7.8 to 130 µg/kg.

Of the six sampling areas, SC01 had the most VOCs (six of the eight detected in Smokes Creek sediment).

The following 12 SVOCs were detected in all of the Smokes Creek sediment sampling areas except SC07:

- Anthracene at concentrations ranging from 130 µg/kg at SC02 to 46,000 µg/kg at SC06
- Benzo(a)anthracene at concentrations ranging from 370 µg/kg at SC02 to 85,000 µg/kg at SC06
- Benzo(a)pyrene at concentrations ranging from 400 µg/kg at SC02 to 61,000 µg/kg at SC06
- Benzo(b)fluoranthene at concentrations ranging from 510 µg/kg at SC02 to 62,000 µg/kg at SC06
- Benzo(g,h,i)perylene at concentrations ranging from 300 µg/kg at SC02 to 35,000 µg/kg at SC06
- bis(2-ethylhexyl)phthalate at concentrations ranging from 740 µg/kg at SC01 to 5900 µg/kg at SC03
- Chrysene at concentrations ranging from 510 µg/kg at SC01 to 83,000 µg/kg at SC06
- Fluoranthene at concentrations from 990 µg/kg at SC02 to 180,000 µg/kg at SC06
- Fluorene at concentrations ranging from 85 µg/kg at SC01 to 33,000 µg/kg at SC06
- Indeno(1,2,3-cd)pyrene at concentrations ranging from 280 µg/kg at SC02 to 38,000 µg/kg at SC06
- Phenanthrene at concentrations ranging from 530 µg/kg at SC02 to 170,000 µg/kg at SC06
- Pyrene at concentrations ranging from 820 µg/kg at SC02 to 190,000 µg/kg at SC06

With the exception of bis(2-ethylhexyl)phthalate, chrysene and fluorene, the minimum concentrations of the above SVOCs were found at sampling area SC02 and the maximum concentrations were found at sampling area SC06.

Of the 14 metals detected in Smokes Creek sediments, six (antimony, arsenic, chromium, lead, nickel, and selenium were detected in all of the areas except SC07 and three (barium, cadmium, and silver) were detected in four of the five areas. Mercury was detected in only one sampling area (SC03). The range of maximum concentrations for the nine commonly detected heavy metals was as follows:

- Antimony at concentrations ranging from 1 to 23.4 mg/kg
- Arsenic at concentrations ranging from 5.9 to 34.7 mg/kg
- Barium at concentrations ranging from 52.1 to 215 mg/kg
- Cadmium at concentrations ranging from 2.4 to 8.6 mg/kg
- Chromium concentrations ranging from 22.2 to 197 mg/kg
- Lead at concentrations ranging from 26.5 to 465 mg/kg
- Nickel at concentrations ranging from 20.2 to 63.5 mg/kg
- Selenium at concentrations ranging from 3.1 to 13 mg/kg
- Silver at concentrations ranging from 3.7 to 8 mg/kg.

Cyanide was detected in four sampling areas (SC01, SC02, SC03, and SC04) at concentrations ranging from 4.9 to 43.5 mg/kg.

Some of the differences in analyte distribution were associated with different sample collection methods. Location SC02 includes a sample that was collected from an 8-foot core; 25 analytes were detected in this core sample. For location SC02, grab samples taken from 0-6 inches had higher concentrations than core samples for all but four hazardous constituent analytes detected in both sample types (benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, antimony and cadmium).

Eight analytes were identified as COPCs for Smokes Creek sediment in the HHRA (see Table 3-10). These included six SVOCs and two metals. Forty-three analytes were identified as COPECs in the ERA. Of the 43 analytes, 40 were detected, including 8 VOCs, 20 SVOCs, and 12 inorganics (see Table 3-13). Hexachlorobenzene, although identified as a COPEC because its detection limit exceeded screening criteria, was not detected in any of the samples. Detected COPCs and COPECs are shown on Figures 3-48 through 3-51.

Comparison to Background

In Smokes Creek, background surface water concentrations for one heavy metal (barium) and three SVOCs (bis[2-ethylhexyl]phthalate, diethyl phthalate, and butyl benzyl phthalate) were higher than, or the same as, the concentrations for these constituents in the onsite surface water for the creek. Only chromium (which was not detected in all on-site sampling locations) had concentrations that were noticeably higher in on-site surface water than in background surface water. Concentrations of other analytes detected in both background and on-site locations were similar.

In the Smokes Creek sediment samples, the highest concentrations for chloromethane, aluminum, arsenic, beryllium, cobalt, copper, iron, lead, magnesium, manganese, potassium, selenium, and vanadium were found in a background sampling area. Of the heavy metals, only barium and chromium were noticeably higher in the on-site sediments, and only at one location (SC03).

Background sediment SVOC concentrations were slightly higher than concentrations found at onsite locations SC01 and SC02, but lower than concentrations at locations SC03, SC04 and SC06. Concentrations of SVOCs in the sediment at onsite sampling area SC06 were significantly higher than concentrations at the background and other onsite sampling locations.

3.1.4.3 Blasdell Creek

Blasdell Creek is a natural water body on the Lackawanna site that originates east of the site in two branches (north and south) that drain areas of the Town of Hamburg, New York. These branches converge near the Route 5, forming the creek that passes through the Lackawanna site.

3.1.4.3.1 Background Samples

Three background locations [BC-01(BKG), BC-02(BKG) and BC-13S] (see Figures 2-19 and 2-20) were sampled in Blasdell Creek during the RFI; a total of three grab sediment samples were collected at these locations. No surface water samples were collected. Sample BC01 (BKG) and a duplicate were collected from the South Branch of Blasdell Creek and samples BC02 (BKG) and BC13 were collected from the North Branch of Blasdell Creek. The analytes tested for included 34 VOCs, 48 SVOCs, 23 metals, and additional general chemistry parameters. Of these, 3 VOCs (1,1,2,2 tetrachloroethane, benzene, and methyl ethyl ketone), 12 SVOCs, and 19 inorganics were detected in the background sediment samples. The minimum and maximum values detected and detection frequencies are summarized in Table 3-15.

The largest number of VOCs (2) was detected in sample BC-01 (BKG) (South Branch of Blasdell Creek). One VOC was detected in the BC02 (BKG) sample (North Branch of Blasdell Creek). Between 8 to 11 SVOCs were detected in each of the three sample locations. Seven heavy metals were detected in locations BC01 (BKG) and BC02 (BKG). Five heavy metals were detected in the remaining sample (BC13).

Background samples were compared to Blasdell Creek on-site sediment COPCs and COPECs. Nine sediment COPCs for Blasdell Creek were identified in the HHRA. All nine COPCs were also detected in the background samples, as shown in Table 3-15. Twenty-four analytes were identified as sediment COPECs in the ERA. Of these 24 analytes, fourteen were detected in the background samples, as shown in Table 3-15.

3.1.4.3.2 Onsite Surface Water

Samples were collected from ten surface water sampling areas in Blasdell Creek (see Figure 2-8) during the RFI, and a total of eighteen surface water samples were analyzed. In the following discussion, the sample locations have been combined, when appropriate, to represent ten sampling areas as follows:

Sample Area Designation	Sample Designation
BC01	AMEC-BC-SW-5
BC02	BC-01, AMEC-BC-SW4, AMEC-BC-SW6, AMEC-BC-SW99
BC04	BC-02, AMEC-BC-SW7, AMEC-BC-SW8
BC05	AMEC-BC-SW3
BC06	BC-03, BC-03 DUP
BC09	BC-05
BC11	AMEC-BC-SW2, AMEC-BC-SW9 (DUP OF AMEC-BC-SW2)
BC12	BC-04
BC13	AMEC-BC-SW1
BCSW	SW-1

The analytes sampled for included 33 VOCs, 41 SVOCs, 15 metals, and additional general chemistry parameters. One VOC was detected, 1,1-dichloroethane, at a concentration of 6.2 µg/L in area BC09. The SVOC bis(2-ethylhexyl)phthalate was detected in area BC12 at a concentration of 2.2 µg/L. Areas BC09 and BC12 are located in the South Branch and North Branch of Blasdell Creek, respectively, to the east of Route 5 but on the Lackawanna site. No other VOCs or SVOCs were detected. Fourteen metals were detected in the areas above. Some of the most common heavy metals detected in the samples were arsenic, barium, chromium, iron, and lead. The minimum and maximum concentrations detected and detection frequencies are summarized on Table 3-16. The pH of the samples ranged from 7.6 to 8.3.

Three analytes were identified as surface water COPCs (one VOC, and two metals) for Blasdell Creek in the HHRA. These COPCs were 1,1-dichloroethane at a maximum concentration of 6.2 µg/L and two metals, arsenic and lead at maximum concentrations of 6.9 µg/L and 19.6 µg/L respectively. Detected COPCs are shown on Table 3-16. Twelve analytes were identified as COPECs for Blasdell Creek surface water in the ERA. Three of the twelve analytes (barium, lead and mercury) were detected, as shown on Table 3-16. The remaining COPECs were not detected but were identified as COPECs because their detection limits were higher than the screening criteria. Detected surface water COPCs and COPECs are shown on Figures 3-52 through 3-55.

3.1.4.3.3 On-site Sediment

Thirteen areas were sampled in Blasdell Creek during the RFI, and 25 grab sediment samples were collected from these locations (see Figure 2-8). Three additional sediment samples were collected and analyzed via the AVS/SEM method. These sample results are discussed in the ERA Report (Part IV of the RFI Report). In the following discussion, the sample locations have been combined, when appropriate, to represent thirteen sampling areas as follows:

Sample Area Designation	Sample Designation
BC01	AMEC-BC-SED5
BC02	BC-01, BC-05S, AMEC-BC-SED7
BC03	AMEC-BC-SED6
BC04	BC-02, BC-06S, AMEC-BC-SED8
BC05	AMEC-BC-SED4
BC06	BC-03, BC-03 DUP, BC-07S (7/26/95), BC-07S (8/28/95), AMEC-BC-SED3
BC07	BC-08S (7/26/95)
BC08	BC-10S (7/26/95)
BC09	BC-05, BC-11S
BC10	BC-12S (7/26/95), BC-12S DUP (7/26/95) BC-12S (8/28/95) BC-12S DUP (8/28/95)
BC11	AMEC-BC-SED2
BC12	BC-04, BC-09S (7/26/95)
BC13	AMEC-BC-SED1, AMEC-BC-SED99 (DUP of AMEC-BC-SED1)

The analytes sampled for included 35 VOCs, 49 SVOCs, 23 metals, and additional general chemistry parameters. Of these, a total of 2 VOCs, 18 SVOCs, and 28 inorganics were detected in the samples collected from the creek. The minimum and maximum concentrations detected and the detection frequencies are summarized on Table 3-17. The distribution of the detected contaminants by sample area is as follows:

Sample Area	Parameter Class	Number Detected
BC01	SVOCs	9
	Metals	11
BC02	VOCs	2
	SVOCs	11
	Metals	21
BC03	SVOCs	10
	Metals	13
BC04	VOCs	1
	SVOCs	13
	Metals	22
BC05	SVOCs	7
	Metals	13
BC06	VOCs	2
	SVOCs	16
	Metals	22
BC07	SVOCs	13
	Metals	18
BC08	SVOCs	15
	Metals	20
BC09	VOCs	1
	SVOCs	16
	Metals	23
BC10	SVOCs	13
	Metals	20
BC11	SVOCs	9
	Metals	14
BC12	SVOCs	10
	Metals	23
BC13	SVOCs	10
	Metals	13

From seven to sixteen SVOCs were detected in each of the thirteen sampling areas. The highest concentrations of SVOCs were detected in location BC09, which is in the North Branch of Blasdell Creek east of, but near Route 5. The next highest concentrations were detected at locations BC04, BC06 (both located west of Route 5), and BC11 (located in the North Branch near BSC's eastern property line). The largest number of metals detected was found in sample areas BC09 and BC12 (located in the South Branch just east of Route 5). The highest concentrations of metals were found in sample area BC06.

One additional sample (BCSED-1) was a composite from three separate locations in the creek (see Figure 2-8). The three locations are designated BCSED-1, BCSED-2 and BCSED-3. This sample was tested for the same analytes after application of the TCLP. The results are presented in Appendix F. In addition, samples from areas BC01 through BC05 were also analyzed after application of the TCLP. The results of these analyses are summarized on Table 3-18. In this section these results are not considered; they are addressed in the Watercourse Assessment Report for Blasdell Creek, which is presented as Part VII of this RFI Report.

Nine sediment COPCs were identified for Blasdell Creek in the HHRA and twenty-four sediment COPECs were identified for Blasdell Creek in the ERA. Detected sediment COPCs and COPECs are shown in Table 3-17 and on Figures 3-52 through 3-55.

3.1.4.3.4 Comparison to Background

In general, both background and on-site sediment samples contained similar SVOCs and metals. In the majority of cases, concentrations of SVOCs were higher in the on-site areas of Blasdell Creek than those found in the background samples. Only two VOCs (dichlorodifluoromethane and trichloroethene) were detected in the on-site sediment samples; neither was detected in the background sample areas. Three VOCs were detected in the background samples (1,1,2,2-tetrachloroethane, benzene and methyl ethyl ketone), none of which were detected in the on-site sample areas. On-site metals concentrations were generally higher than background concentrations with one exception; location BC01 had slightly lower metals concentrations.

3.1.4.4 Gateway Metroport Ship Canal

The Gateway Metroport Ship Canal (Ship Canal) is located at the northern end of the site, approximately midway between the Route 5 and Lake Erie. Water from the Ship Canal was used for various Lackawanna site operations. Prior to the cessation of operations at the Coke Ovens, approximately 75 mgd were removed from the canal. After the Coke Ovens were shut down, all pumping from the canal ceased.

3.1.4.4.1 Surface Water

A total of 38 surface water samples were collected from the Ship Canal during the RFI from a total of six sampling areas (see Figure 2-7). In the following discussion, the samples have been combined, when appropriate, into six sample areas, as follows:

Sample Area Designation	Sample Designation
GM01	GM-1, GM-1E, GM-1W
GM01A	GM-1AV-COMP, GM-1AV.25, GM-1AV.5, GM-1AV.75, GM-1AE, GM-1AW
GM02	GM-2, GM-2COMP, GM-2E, GM-2V.25, GM-2V.5, GM-2V.75, GM-2W, SS-5
GM03	GM-3, GM-3E, GM-3W, SS-6
GM04	SS-7, SS-7 DUP, GM-4, GM-4E (7/19/95), GM-4W, GM-4 0.25, GM-4 0.50, GM-4 0.75, GM-4 COMP, GM-4E (8/22/95), GM-4W
GM05	GM-5, GM-5 DUP, GM-5E (7/19/95), GM-5W (7/19/95), GM-5E (8/22/95), GM-5W (8/22/95)

The analytes sampled for included 34 VOCs, 47 SVOCs, 14 metals, and additional general chemistry parameters. Of these, one VOC (benzene), six SVOCs, and eleven metals were detected in the surface water samples. The minimum and maximum concentrations detected for each analyte and the detection frequency are shown on Table 3-19. The pH of the samples ranged from 8 to 8.1. The distribution of the detected constituents by sample area is as follows:

Sample Area	Parameter Class	Number Detected
GM01	VOCs	1
	SVOCs	2
	Metals (total and dissolved)	5
GM01A	SVOCs	3
	Metals (total and dissolved)	6
GM02	VOCs	1
	SVOCs	4
	Metals (total and dissolved)	8
GM03	VOCs	0
	SVOCs	1
	Metals (total and dissolved)	7
GM04	VOCs	0
	SVOCs	1
	Metals (total and dissolved)	5
GM05	SVOCs	1
	Metals	5

Only one VOC, benzene, was detected in sampling areas GM01 and GM02 at concentrations of 0.7 and 1 µg/L , respectively.

The sampling area with the most SVOCs detected (four) is GM02, located approximately 1,000 feet to the north of the southern end of the canal. The most commonly detected SVOCs were as follows:

- bis(2-ethylhexyl) phthalate in four sampling areas at concentrations ranging from 0.4 to 20 µg/L
- di-n-butyl phthalate in three sampling areas at a maximum concentration of 0.2 µg/L.

Of the eleven heavy metals detected, the most commonly detected was dissolved barium at all six sampling areas at concentrations ranging from approximately 18.3 µg/L to 24.5 µg/L. Total lead (GM04 and GM03) and dissolved lead (GM03) were detected at only two sampling areas located in the northern half of the canal at concentrations ranging from 3.1 µg/L to 5.2 µg/L. Total mercury (GM04) and dissolved mercury (GM05) were detected at only two sampling areas (GM04 and GM05) located in the northern half of the canal at concentrations ranging from 1.0 to 1.1 µg/L. Dissolved cadmium was detected in sampling area GM01A and total cadmium was detected in sampling areas GM02 and GM04 at concentrations of 4.1 µg/L, 3.3 µg/L and 3.3 µg/L, respectively.

Seven analytes were identified as surface water COPCs for the Ship Canal in the HHRA (arsenic, benzene, bis(2-ethylhexyl)phthalate, naphthalene, phenol, trichloroethene and total xylenes. Four were detected in surface water samples; arsenic, benzene, bis(2-ethylhexyl)phthalate, and naphthalene. The remaining three analytes that were not detected were identified as COPCs for the groundwater-to Ship Canal - transport pathway.

Detected COPCs are shown on Table 3-19 and on Figures 3-56 through 3-59. Because of the recent dredging of sediment in the Ship Canal it was concluded that there were no completed exposure pathways to populations of ecological receptors in the watercourse as stated in the ERA (Part IV) (AMEC 2002). Therefore, no COPECs were identified for Ship Canal surface water.

3.1.4.4.2 Sediment

A total of nineteen sediment samples were collected from the Ship Canal during the RFI from a total of six sampling areas (see Figure 2-7). Five additional sediment samples and a duplicate were collected from the Ship Canal during Phase II-C and analyzed for metals via the AVS/SEM method; The results for these samples are addressed in the ERA Report, Part IV of this RFI Report. As with surface water, the sample locations have been combined, when appropriate, to represent six sample areas, as follows:

Sample Area Designation	Sample Designation
GM01	GMS-1, GMS-1 DUP, GM-1SE (7/24/95), GM-1SW, GM-1SE (8/22/95)
GM01A	GM-1ASE, GM-1ASW
GM02	GMS-2, GM-2SE, GM-2SW
GM03	GMS-3, GM-3SE, GM-3SW
GM04	GM-4, GM-4SE, GM-4SW
GM05	GM-5, GM-5SE, GM-5SW

The analytes sampled for included 34 VOCs, 47 SVOCs, 11 metals, and additional general chemistry parameters. Of these, 7 VOCs, 22 SVOCs, and 11 metals were detected. The maximum concentration detected for each sampling area is shown on Table 3-20. The distribution of the detected constituents by sample area is as follows.

Sample Area	Parameter Class	Number Detected
GM01	VOCs	1
	SVOCs	20
	Metals	10
GM01A	VOCs	1
	SVOCs	18
	Metals	6
GM02	VOCs	3
	SVOCs	17
	Metals	8
GM03	VOCs	3
	SVOCs	18
	Metals	7
GM04	VOCs	2
	SVOCs	17
	Metals	9
GM05	VOCs	4
	SVOCs	19
	Metals	9

The sampling area with the most VOCs detected (four) is GM05, which is the northernmost sample location in the canal and closest to the Buffalo Outer Harbor. Sixteen of the 22 SVOCs were detected at all six sampling areas. The highest concentrations of the majority of SVOCs detected were consistently found at location GM03 (see Table 3-20).

Methyl ethyl ketone was the most commonly detected VOC. It was detected in all but sampling area GM03 at concentrations ranging from 9 to 120 µg/kg.

- Methylene chloride was detected in sampling area GM02 at a concentration of 3 µg/kg
- Benzene was detected at GM05 with a concentration of 7.7 µg/kg
- Toluene was detected in sampling areas GM02 and GM03 at a concentration of 2 µg/kg and 13 µg/kg, respectively.
- Ethylbenzene was detected in sampling area GM-03 at a concentration of 9 µg/kg
- Total xylenes were detected in sampling areas GM03 and GM05 at concentrations of 12 µg/kg and 15 µg/kg , respectively
- Carbon disulfide was detected in sampling areas GM04 and GM05, both at concentrations of 2 µg/kg

A total of eleven heavy metals were detected in the sediment samples. The most commonly detected were as follows:

- Arsenic in all six sampling areas at concentrations ranging from 7.0 to 15.9 mg/kg
- Barium in all six sampling areas at concentrations ranging from 45.8 to 120 mg/kg
- Chromium in all six sampling areas at concentrations ranging from 22.8 to 68.3 mg/kg
- Mercury in all six sampling areas at concentrations ranging from 0.35 to 7.3 mg/kg
- Nickel in all six sampling areas at concentrations ranging from 20.3 to 65 mg/kg

In addition, lead was detected in all six sampling areas at concentrations ranging from 29.9 to 842 mg/kg. The highest concentrations (ranging from 245 to 842 mg/kg) were detected in sampling area GM01, located at the southern end of the canal. In the remaining five sampling areas, concentrations ranged from 29.9 to 125 mg/L.

During Phase I (see Figure 2-7), three sediment samples (SED-6, SED-7, and SED-8) were collected from three separate locations in the canal these samples were tested for the same analytes after application of the TCLP. The results of the analyses are summarized on Table 3-21. For the purpose of this discussion, these results are not considered; they are addressed in the Watercourse Assessment Report for the Ship Canal, which is presented as Part VII of this RFI Report.

Seven analytes were identified as sediment COPCs for the Ship Canal in the HHRA. All seven were detected in the samples, as shown in Table 3-20. Detected COPCs are shown on Figures 3-56 through 3-59. Due to the recent dredging of sediment in the Ship Canal it was concluded that there were no completed exposure pathways to populations of ecological receptors in the watercourse as stated in the ERA (Part IV) (AMEC 2002) (page 40, Section 3). Therefore, no COPECs were identified for Ship Canal sediment.

3.1.4.5 North Return Water Trench

The North Return Water Trench (NRWT) is a man-made channel that originates in the area formerly occupied by the 32-inch Finishing Mill and flows northwesterly for approximately 3,300 feet to its point of discharge into the Union Ship Canal.

3.1.4.5.1 Surface Water

Three surface water samples (NRW-1, NRW-1 DUP, and SW-3) were collected from two locations in the northern portion of the NRWT (see Figure 2-10). The analytes sampled for included 34 VOCs, 47 SVOCs, 14 metals, and additional general chemistry parameters. Two VOCs were detected in both of the samples collected from NRW-1, the southernmost sample location: benzene at a concentration of 0.2 µg/L and methylene chloride at concentrations of 0.8 and 0.9 µg/L. Two heavy metals (including lead) at a concentration of 3.2µg/L) were detected in one sample collected from the northernmost sample location, SW-3. Lead was detected, in the southernmost location (NRW-1) also at a range of 5.0 µg/L to 6.2 µg/L. The minimum and maximum concentrations detected and detection frequencies are summarized on Table 3-22.

Although completed exposure pathways to potential human receptors were identified for the NRWT in the HHRA, ID No. 1 (BSC 1998a), no COPCs were identified for surface water based on the concentrations of detected analytes. Thirteen analytes were identified as surface water COPECs in the ERA. Of the 13 identified, three analytes, chromium, lead and methylene chloride, were detected in the samples, as shown on Table 3-22. The remaining COPECs were not detected but were identified as COPECs because their detection limits were higher than the screening criteria. Detected COPECs are shown on Figures 3-60 through 3-63.

3.1.4.5.2 Sediment

A total of two grab sediment samples (NRS-2 and NRS-3) were collected from locations in the central and northern portion of the NRWT, respectively (see Figure 2-10). The analytes sampled for included 34 VOCs, 47 SVOCs, 11 metals, and additional general chemistry parameters. Of these, a total of 1 VOC, 16 SVOCs, and 6 heavy metals were detected in the samples collected from the trench. The concentrations detected and the detection frequencies are summarized on Table 3-23.

The distribution of analytes was the same for the two sampling locations, with the following two exceptions:

- The only detected VOC, total xylenes at 5.5 µg/kg, was present in the sample from NRS-2 but not NRS-3
- Acenaphthene, acenaphthylene and naphthalene were detected in NRS-2 but not NRS-3.

The concentrations of those analytes detected in both locations generally were approximately seven to eighteen times higher in the sample from NRS-2 as compared with NRS-3, with the exception of fluorene, which was approximately thirty eight times higher in the sample from NRS-2.

One additional sample (NRSED-3) consisted of a composite from three separate locations in the trench (see Figures 2-9 and 2-10); this sample was tested for the same analytes after application of the TCLP. It should be noted that one composite of sample NRSED-3 was, in error, collected from the north end of the SRWT (see Figures 2-9 and 2-10). The results of the analyses are summarized on Table 3-24. These results are not included in this discussion; they are discussed in the Watercourse Assessment Report for the NRWT, which is presented as Part VII of this RFI Report.

Eight analytes were identified as sediment COPCs for the NRWT in the HHRA, as shown on Table 3-23. All eight analytes were detected. The highest concentrations of detected COPCs were detected in NRS-2. The only heavy metal identified as a COPC (arsenic) was detected in both samples (NRS-2 and NRS-3) at similar concentrations. Twenty-three analytes were identified as sediment COPECs for the NRWT in the ERA. Twenty of the 23 analytes were detected in the samples, as shown on Table 3-23. The remaining COPECs were not detected but were identified as COPECs because their detection limits were higher than the screening criteria. Detected COPCs and COPECs are shown on Figures 3-60 through 3-63.

3.1.4.6 South Return Water Trench

The South Return Water Trench (SRWT) is also a man-made channel originating in the area formerly occupied by the 32-inch Finishing Mill. It flows south approximately 5,000 feet to its point of discharge into Smokes Creek.

3.1.4.6.1 Surface Water

Two surface water samples (SRW-1 and SW-2) were collected from the southern portion of the SRWT (see Figure 2-9). The sample locations have been assigned into the following sample areas to match areas where sediment samples were collected.

Sample Area Designation	Sample Designation
ST01	SRW-1
ST02	SW-2

The analytes sampled for included 34 VOCs, 47 SVOCs, 14 metals, and additional general chemistry parameters. Two VOCs (benzene at a concentration of 0.2 µg/L and 1,1,1-trichloroethane at a concentration of 0.3 µg/L) were found in the sample collected in sample area ST01. Six metals were detected including dissolved selenium at a concentration of 7.5 µg/L in ST01 and total lead at 8.3 µg/L in ST02. The concentrations detected and the detection frequencies are summarized on Table 3-25. The distribution of the detected constituents by sample area is as follows:

Sample Area	Parameter Class	Number Detected
ST01	VOCs	2
	Metals	4
ST02	Metals	2

The two VOCs detected in sample area ST01 were 1,1,1-trichloroethane and benzene at 0.3 and 0.2 µg/L, respectively. Calcium, potassium, selenium and sodium were detected in sample ST01. Lead and mercury were the only metals detected in ST02.

Although completed exposure pathways to potential human receptors were identified for the SRWT in the HHRA, ID No. 1 (BSC 1998a), no surface water COPCs were identified based on the concentrations of detected analytes. Ten analytes were identified as surface water COPECs in the ERA. Of the ten analytes, two analytes, lead and mercury were detected in the sample collected from ST02, shown on Table 3-25. The remaining COPECs were not detected but were identified as COPECs because their detection limits were higher than the screening criteria. Detected COPECs are shown on Figures 3-64 through 3-66. It should be noted that no volatile COPECs were detected in the sediment samples from the SRWT.

3.1.4.6.2 Sediment

A total of five sediment samples were collected from the SRWT during the RFI from a total of three sampling locations (see Figure 2-9). In the following discussion, the sample locations have been combined, when appropriate, into three sample areas, as follows:

Sample Area Designation	Sample Designation
ST01	SRS-3
ST02	SRS-1, SRS-1 DUP
ST03	NRS-1, SRS-2

The analytes sampled for included 34 VOCs, 47 SVOCs, 11 metals, and additional general chemistry parameters. Of these, a total of one VOC, 13 SVOCs and 11 metals were detected in the samples collected from the trench. The maximum value detected and the detection frequencies are summarized on Table 3-26. The distribution of the detected constituents by sample area is as follows:

Sample Area	Parameter Class	Number Detected
ST01	SVOCs	11
	Metals	6
ST02	SVOCs	11
	Metals	8
ST03	VOCs	1
	SVOCs	12
	Metals	11

The VOC detected was tetrachloroethene from sampling area ST03 at a concentration of 5.2 µg/kg.

The same SVOCs were detected at the three sampling areas, with the following exceptions:

- Bis(2-ethylhexyl) phthalate was detected in the samples from areas ST01 and ST02 but not in the two samples from area ST03
- Anthracene and dibenz(a,h)anthracene were detected in the two samples from area ST03 but not in the samples from areas ST01 and ST02

Concentrations in sampling area ST03 were higher than concentrations in sampling area ST01 for those analytes detected in both areas; likewise, concentrations were similar for most analytes detected in both areas ST02 and ST03.

Six heavy metals, arsenic, barium, chromium, lead, nickel and selenium were detected in all three areas. In addition, mercury and antimony were detected in areas ST02 and ST03 but not ST01. Silver, cadmium and thallium were detected in area ST03 only. Area ST03 typically had the highest concentrations for analytes also detected in the other sampling areas, particularly for lead.

One additional sample (SRSED-2) consisted of a composite from three separate locations in the trench (see Figure 2-9); this sample was tested for the same analytes after application of the TCLP. The results of the analyses are summarized on Table 3-27. These results are not included in this discussion; they are addressed in the Watercourse Assessment Report for the SRWT, which is presented as Part VII of this RFI Report.

Three analytes, antimony, arsenic and lead, were identified as sediment COPCs for the SRWT in the HHRA. All three were detected in at least two of the sediment samples from the SRWT, as shown on Table 3-26. Twenty-nine analytes were identified as sediment COPECs for the SRWT in the ERA. Twenty-two of the 29 were detected in the samples collected, as shown on Table 3-26. The remaining COPECs were not detected but were identified as COPECs because their detection limits were higher than the screening criteria. Detected COPC's and COPECs are shown on Figures 3-64, 3-65 and 3-66.

3.2 Contaminant Fate and Transport

3.2.1 Background

This section describes the fate and transport processes influencing the behavior of contaminants detected at the Bethlehem Steel site. The discussion emphasizes the processes that are essential in evaluating potential exposure of human and environmental receptors to the site contaminants. The following items are presented:

- general description of fate and transport processes occurring in the water-bearing formation (soil/ground water system) and in surface water bodies (surface water/sediment system),
- identification and description of properties of contaminants detected at the site in excess of the COPC RBC criteria, and
- media-specific and contaminant-specific evaluation of fate and transport occurring at the site.

Information used in this section is based on text, figures and tables of Section 2.4 (Site Geology) and Section 3.1 (Nature and Extent of Contamination).

3.2.2 General Description of Fate and Transport Mechanisms

3.2.2.1 Transport Processes

Water-Bearing Formation

The water-bearing formation at the site can be described as a relatively shallow, unconfined aquifer. The groundwater table occurs typically from 5 to 20 feet below the ground surface. The system consists of an unsaturated zone, comprising the soil matrix, air and moisture and a saturated zone where only the soil matrix and water are present.

In the unsaturated zone, the total mass of a contaminant is partitioned between the dissolved phase (soil moisture), the gas phase (soil gas) and the solid phase (soil matrix). In the saturated zone, the soil gas is absent as a result of full water saturation and the partitioning occurs only between the soil matrix and water. Under equilibrium conditions, each phase contains a certain fraction of the total contaminant mass present in the system. The relative mass fractions are determined by the properties of each contaminant and by the nature of the soil matrix. The equilibrium conditions may be disturbed by such phenomena as migration of the more or less contaminated water or soil gas into the area, or removal of mass from one of the media through degradation processes. Under these circumstances, concentration gradients are created resulting in the occurrence of mass transfer between the media.

The mass sorbed onto the soil matrix is essentially immobile. The exception is the mass in the topmost soil layer, which can be transported by processes capable of moving soil particles (wind, surface runoff). Sorbed mass generally acts as a source for the dissolved (water) and/or gas phases.

Transport of contaminants dissolved in the soil moisture in the unsaturated zone is generally limited as a result of very low flow rates in the absence of full saturation. The only significant mechanism may be a gravity-driven, downward flow during wet-weather periods when the soil moisture exceeds field capacity. Such vertical transport of contaminants acts as a source for the saturated zone below.

The mass contained within the soil gas and within water in the saturated zone is more mobile. Soil gas can flow in response to pressure gradients, migrating in both vertical and horizontal directions. The migration can create a surface discharge of contaminants into the atmosphere or act as a source of contamination for the groundwater in the saturated zone. The migrating soil gas may transfer mass into the soil matrix and soil moisture in previously uncontaminated areas, thus increasing the areal extent of soil contamination in the unsaturated zone. The primary transport mechanisms of contaminants dissolved in groundwater are advection and dispersion. Advection is the movement of the dissolved contaminants carried by the flow of groundwater. At the Bethlehem Steel site, saturated zone lies within sand and slag units, both of which are relatively permeable. Hydraulic gradients are moderate. Therefore, the migration of dissolved contaminants takes place relatively rapidly. Dispersion refers to dissolved contaminants spreading due to the presence of nonuniformities in the groundwater flow field. It results in a general widening of the plume, as well as in smearing of the plume boundaries. The magnitude of dispersion is site-specific and, generally, difficult to measure. In the process similar to that occurring in the soil gas, contaminants migrating within groundwater may reach previously uncontaminated area and enter other environmental media.

Contamination migrating with soil gas or groundwater constantly interacts with the soil matrix. The driving forces behind this process are created by concentration gradients between different phases. Mass may either adsorb from the mobile phase of soil gas or groundwater onto the soil particle, or it may undergo a reverse process of desorption.

In the case of adsorption, the contaminant mass is transferred from the mobile medium into the immobile soil medium. This phenomenon tends to decrease the velocity of contaminant migration. The process is called retardation. The magnitude of the retardation depends on the properties of each contaminant and the soil matrix. The key indicator parameter for the retardation properties of the soil is the organic carbon content. Soils with high organic carbon content adsorb dissolved contaminants more readily and create a more significant retardation effect than soils poor with organic carbon. Desorption is the reverse process. Contamination is transferred from the soil matrix into the groundwater or soil gas. As a result, soils containing contaminant mass may act as a source if exposed to the less contaminated soil gas or groundwater. The desorption from soil into the soil gas or groundwater would be inhibited by the high content of organic carbon in the soil.

The organic carbon content of the onsite soils has been found to be high to very high. Therefore, both the retardation of contaminant migration and the mass storage of contaminants within the soil matrix are likely to be significant.

Surface Water Bodies

The site is bordered by Lake Erie to the west. A major natural surface water body located within the site's boundaries is Smokes Creek, which discharges into Lake Erie. The site also contains the Ship Canal, the NRWT and SRWT, all of which are man-made. The Ship Canal and the NRWT discharge to the Buffalo Outer Harbor. The SRWT discharges into the Smokes Creek approximately 3,000 feet from the creek mouth.

Surface water bodies receive contaminant loadings from the groundwater discharge as well as from the surface discharges caused by wind erosion and runoff from contaminated soils. Therefore, contaminants enter the system both in the dissolved form and adsorbed on solid particles. Within surface water bodies, both dissolved and particulate contaminants are subjected to the transport processes of advection, dispersion and interaction with suspended sediments and bottom sediment. Flow velocities in surface water bodies are typically significant, and advection is often the dominant transport process. Likewise, due to the wave action and the turbulent nature of the flow, dispersion may be considerable. As a result, transport and spread of contaminants in surface water is typically rapid.

Within the water column, contaminants partition between the aqueous phase and the suspended solids. In the bottom sediment layer, the same partitioning process takes place between the sediment and the relatively immobile water contained in the interstitial space. Exchange of mass between the water column and the sediment layer occurs as a result of the settlement and resuspension of solids as well as through the processes of diffusion.

Surface waters are directly exposed to the atmosphere. Therefore, for volatile compounds, volatilization takes place rapidly and may be the dominant transport process. The process is most pronounced especially in shallow streams, such as Smokes Creek, and under intense wave action, such as that occurring frequently in Lake Erie.

3.2.2.2 Mass Destruction Processes

Water-Bearing Formation

Most contaminant mass contained within the water-bearing formation is located far from the influence of sunlight and the atmosphere. Therefore, mass destruction processes within the water-bearing zone that relies on the presence of air or exposure to sunlight, such as photolysis, are of little importance and will not be discussed. The exception is mass concentrated at the ground surface. This however, is typically low relative to the mass contained in the subsurface.

For organic compounds, the most significant mass destruction process that takes place in the subsurface environment is microbial degradation. During degradation, organic compounds may be transformed into daughter forms, which may be recalcitrant or degradable. Daughter compounds can be either more or less toxic than the parent compounds. If a contaminant degrades into a sequence of degradable daughter compounds, it is ultimately fully metabolized into such compounds as carbon dioxide, methane, water, and chloride.

The most significant microbial degradation processes operating in groundwater systems are aerobic respiration, denitrification, iron reduction, sulfate reduction, and methanogenesis. There are also abiotic mechanisms that result in the destruction or transformation of the mass of organic contaminants, such as hydrolysis and photolysis. However, under normal temperature and light conditions prevailing in subsurface environments, rates of abiotic reactions are relatively low. Typically, the importance of these processes in the overall rate of mass destruction is low.

Surface Water Bodies

Mass destruction processes acting on contaminants within the surface water system are essentially the same as those described above: biodegradation, hydrolysis, and photolysis. However, their rates are typically much greater. This is due to the increased availability of oxygen and sunlight in the surface environment, as well as to higher temperatures during the summer season.

At the site, contaminant loadings act on the near-shore zone of Lake Erie and on two relatively small creeks. Therefore, the environment can be classified as shallow water. The availability of oxygen and sunlight is significant, and temperatures during summer season are high. The mass destruction processes operating in the water column are likely to take place at significant rates.

Conditions within the bottom sediment layer are different. There is no direct exposure to the atmosphere or sunlight. Therefore, mass destruction processes operate more slowly and accumulation of contaminants is more likely than within the water column.

3.2.3 Contaminants of Potential Concern

Criteria for defining COPCs are outlined in Section 3.1 (Nature and Extent of Contamination). The following types of compounds are represented among COPCs: VOCs, SVOCs and inorganics. Table 3-28 shows some of the physical properties of organic COPCs relevant to their fate and transport.

3.2.3.1 Volatile Organic Compounds (VOCs)

Major groups of VOCs identified as COPCs are chlorinated hydrocarbons and BTEX compounds. The distribution of VOC compounds in the sampled environmental media are shown in Figures 3-2 through 3-5 (soils), Figures 3-21 through 3-27 (groundwater) and Figures 3-44, 3-48, 3-52, 3-56 and 3-60 (surface water and sediment).

VOCs generally are moderately to highly soluble in water, and readily enter both the surface and subsurface environments. They readily volatilize into the atmosphere or the soil gas. Their ability to partition into the soil or sediment is generally low to moderate, making them relatively mobile. In the subsurface environment or bottom sediments, chlorinated hydrocarbons are typically recalcitrant, except under anaerobic conditions, while BTEX compounds are relatively degradable. At the surface, VOCs generally decay under the action of sunlight and upon the exposure to the atmosphere. Dissolved VOCs are transported by advection and dispersion in both surface waters and groundwater. The same processes of advection and dispersion are responsible for the migration of VOCs in the atmosphere or the soil gas.

3.2.3.2 Semivolatile Organic Compounds (SVOCs)

Major groups of SVOCs identified as COPCs are PAHs, phenols and phthalates. Pyridine was also detected. For the purpose of presentation, SVOCs were divided into volatile semivolatile compounds, and semivolatile compounds, based on their ability to volatilize. The distribution of SVOC compounds in the sampled environmental media are shown in Figures 3-6 through 3-9 (soils), Figures 3-28 through 3-36 (groundwater) and Figures 3-45, 3-46, 3-49, 3-50, 3-53, 3-54, 3-57, 3-58, 3-61, 3-62, 3-64 and 3-65 (surface water and sediments). Table 3-28 shows some of the physical properties of the SVOCs relevant to their fate and transport.

Both the solubility of SVOCs in water and their ability to volatilize into the atmosphere or soil gas are generally low. Their ability to partition into soil or sediment is high to very high. Upon entering the environment, SVOCs typically partition into soil or sediment, with only a very minor portion of their mass present in the dissolved or gas phases. As a result, they generally do not migrate in groundwater, soil gas or atmosphere. They can be transported when carried by the motion of soil particles (such as wind-driven fugitive dust or sediment in surface runoff and surface water). The exception among SVOCs detected here are naphthalene, phenol and pyridine, which are moderately to highly volatile and/or soluble in water (note: pyridine is miscible). As a result, they will migrate in the dissolved phase and gas phase.

Biodegradation rates of SVOCs are typically low to very low, except for some phenols, which readily degrade, in aerobic environments. Dissolved SVOCs, such as naphthalene, phenol and pyridine, are transported by advection and dispersion in both surface waters and groundwater. The same processes of advection and dispersion are responsible for the migration of some SVOCs, such as naphthalene and pyridine in the atmosphere or the soil gas.

3.2.3.3 Inorganic Compounds

Inorganic compounds identified as COPCs are heavy metals. Other parameters, such as certain non-heavy metals, alkalinity, sulfate, nitrate, etc, were also analyzed for; however, they are all naturally occurring. Their presence in groundwater is to be expected and does not constitute an indicator of contamination. They will be discussed only in connection with their influence on the fate and transport of organic and inorganic COPC and COPEC compounds.

The distribution of COPC and COPEC metals in the sampled environmental media are shown in Figures 3-10 through 3-11 (soils), 3-37 through 3-42 (groundwater) and 3-47, 3-51, 3-55, 3-59, 3-63 and 3-66 (surface water and sediment).

Metals detected above the COPC RBC criteria are antimony, arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver and thallium. Metals dissolve in groundwater and are transported by advection and dispersion. They also enter the soil matrix through adsorption on certain minerals, especially those present in clays. There are no mass destruction processes affecting metals. The content of metals in dissolved and adsorbed phases may change as a result of precipitation/dissolution or complexation (i.e., binding of metal ions to other inorganic ions, or to organic compounds). These reactions are governed by such groundwater characteristics as pH, Eh (oxidation-reduction potential), presence of organics, etc.

Cyanide generally occurs in the subsurface environment as part of such compounds as hydrogen cyanide, sodium cyanide or potassium cyanide. It can be present as a gas, liquid or solid. In dissolved phase it is transported through advection and dispersion. It is generally moderately amenable to biodegradation.

3.2.4 Site-Specific Fate and Transport – Organic Compounds

3.2.4.1 Unsaturated Zone

Source of Contamination

Typical mechanisms of contamination of unsaturated zone soils include land disposal, surface spills and leaks from piping. Numerous instances of these mechanisms have likely taken place over the decades-long operational period of the site. As a result, the site contains multiple potential sources that may have contributed to the contamination of unsaturated zone soils. Some of the major source areas are: a group of SWMUs south of the Smokes Creek in SFA Zone 2, the Tank Farm north of Smokes Creek, a group of SWMUs along the Lake Erie shoreline at the northwest end of the site, and a group of SWMUs west of the Ship Canal in the Coke Oven Area.

The unsaturated zone is typically contaminated from the land surface. Therefore, the surficial soil contamination can be considered indicative of the contamination in the unsaturated zone. Figures 3-2, 3-4, 3-6, 3-8 and 3-10 show COPC compounds detected in the surface soils.

Migration

Areas mentioned in the preceding section are likely to create sources of migration of the soluble portion of contamination. Contaminants present in the unsaturated zone soils undergo dissolution in the precipitation percolating through the unsaturated zone. This occurs during wet weather periods, when the water content in the unsaturated zone exceeds the field capacity of the soil matrix. The flow is mostly gravity-driven, directed downward. Such downward migration through the unsaturated zone may constitute a source of contamination of the saturated zone below. The lateral extent of migration of the contaminated soil moisture in the unsaturated zone is very limited due to the general absence of the lateral flow.

The volatile compounds also migrate with the soil gas. The site is generally unpaved, and the thickness of the unsaturated zone is small. Therefore, the sources of unsaturated zone contamination are in close contact with the atmosphere, which would significantly reduce the potential extent of lateral migration by soil gas. Most likely, the bulk of the contamination contained in the soil gas is vented into the atmosphere.

Large areas of the site are either unvegetated or sparsely vegetated. Therefore, contamination adsorbed into soils from the top-most layer of the unsaturated zone migrates as wind-driven fugitive dust or as the solid content of the surface runoff. The possible extent of such migration is significant. The receptors for the surface runoff are mainly Smokes Creek and the near-shore zone of Lake Erie. The fugitive dust can migrate in any direction, depending on the wind direction. Generally, the mass loadings of fugitive dust and the particulate fraction of surface runoff decrease with time. This is because the "reservoir" of fine, mobile particles in the surficial layer is limited. As fine particles are flushed out of the surface soils, the remaining surface becomes less prone to wind or water driven erosion. The surficial soils at the site have remained mostly undisturbed for a significant length of time, following the cessation of the plant operations. Therefore, the magnitude of fugitive dust and runoff loading is likely to be small. The exceptions are areas of unpaved roads, which are still in use.

Degradation

Relatively little is known about the degradation of contaminants in the unsaturated zone at the site. Generally, unsaturated zone degradation rates have to be estimated by means of field testing, such as respiration tests. Such data is not available. Therefore, only a qualitative assessment can be performed.

In the top-most layer of surface soil, contaminants are exposed to the action of sunlight and high temperatures in the summer, and may undergo a significant amount of abiotic degradation. In the remaining portion, where the temperature is moderate to low and there is no exposure to sunlight, the abiotic processes are likely to be limited. Rates of biological degradation depend largely on the presence of water. In the unsaturated zone, sufficient water may not be present continuously, thus limiting the potential for the growth of microorganisms.

This is likely to occur at this site because of the nature of the overburden (slag is generally coarse, permeable and characterized by low water holding capacity).

In general, rates of contaminant degradation in the unsaturated zone are expected to be relatively low.

3.2.4.2 Groundwater

Source of Contamination

Major sources of groundwater contamination appear to be SWMU facilities located in two general areas: immediately south of the Smokes Creek in SFA Zone 2, and along the Ship Canal (especially in the Benzol Plant Area.). In both of these areas widespread free product and soil contamination has been found (see Figure 3-43). Groundwater becomes contaminated through a direct contact with soil and free product (dissolution) and by receiving infiltration percolating downward through contaminated soils. Most likely an additional transfer into groundwater occurs through the mass exchange with the contaminated soil gas, albeit the mass loading from this source is probably much lower than direct dissolution or contaminated precipitation.

Other likely sources of groundwater contamination are the SWMUs P-74 and P-75 areas located between the Smokes Creek and the Ship Canal, and a group of SWMUs in the northwest corner of the site, along the shore of Lake Erie.

Migration

In the source area along the Ship Canal, the potentiometric surface map (Figures 2-50 and 2-51) indicates the existence of a groundwater divide parallel to the canal. The flow from that source takes place both towards the Ship Canal and towards Lake Erie. The plume migrating towards the canal is almost immediately intercepted as a result of the close proximity of the water divide and the canal. The plume migrating towards Lake Erie travels through relatively permeable sand and fill units, where hydraulic gradients are on the order of 1/1,000 $^{ft/ft}$ to 5/1,000 $^{ft/ft}$. The velocity of migration is probably moderate to high for contaminants that do not readily adsorb on organic carbon. For more adsorbent contaminants, significant retardation is expected, caused by the high organic carbon content of the onsite soils. The plume appears to have spread throughout the region between the source and Lake Erie. Additional sources are located along Lake Erie. Most likely, there are other, smaller plumes emanating from these sources and mingling with the plume migrating from the area along the canal. Because of the overlap, relative contributions of each source as well as plume migration distances are difficult to distinguish. Likewise, the question of whether the total plume is still expanding or has already reached stability is not easily answered with available data. However, the combined effect of all sources has already created an area of groundwater contamination extending from the Ship Canal to Lake Erie and south partially towards the Smokes Creek. Both Lake Erie and the Ship Canal appear to receive discharges of contaminated groundwater.

The above discussion pertains to the plume of dissolved BTEX compounds, PAHs and phenolics (Figures 3-21, 3-22, 3-28 and 3-29). The dissolved contamination from chlorinated hydrocarbons appears to be limited to a very small region just downgradient of the group of SWMU areas in the northwest corner of the site (Figure 3-21). This small plume appears to be discharging into Lake Erie.

The flow pattern in the vicinity of the other major source SWMU areas just south of the Smokes Creek appears to be relatively complex. A mounding effect and radial flow are present around SWMUs S-11 and S-22. Downgradient SWMU areas are located both within the tributary region of Smokes Creek and Lake Erie. Hydraulic gradients are very high in the mound and gradually decrease towards Lake Erie. See Figures 2-50 and 2-51. Groundwater is contaminated throughout the entire area. Some "fingering" effect is present, most likely a result of the complex flow regime and the overlap of plumes migrating from sources located in very close proximity. Plumes of all major contaminants of concern are present – BTEX, PAHs, phenolics and chlorinated hydrocarbons (Figures 3-21, 3-22, 3-28 and 3-29). The contaminated groundwater discharges to the lower reach of Smokes Creek and Lake Erie immediately south of the creek mouth. Because of the close proximity of sources to discharge locations, the plume south of the Smokes Creek has most probably reached a stable condition.

Degradation

Many of the compounds detected at the site are potentially degradable in groundwater. Degradation potential can be analyzed using the following indicators:

- pH – The pH of groundwater has an effect on the presence and activity of microbial populations. Generally, microorganisms that are the most efficient biodegraders prefer neutral pH values (6 to 8). Figure 3-12 shows the pH maps for the fill and sand units. Values are generally high to very high, with the majority being in the range of 8 to 14. Such high values generally do not occur in natural aquifers. The water-bearing zone at the site consists of man-made slag, which is characterized by a very high pH. The high pH of groundwater is, therefore, most likely a result of human activities. The range of 6 to 8, optimal for the biodegrading microorganisms, occurs locally along the Ship Canal and SWMUs S-11 and S-22 (in both sand and fill) as well as along the Lake Erie shoreline (sand unit only). Therefore, it may be anticipated that these locations experience significant biodegradation rates. In the remainder of the site, the degradation rates would be expected to be relatively low. However, because the high pH and high food conditions have been present for several decades, microbial communities capable of metabolizing hydrocarbons in a high pH environment may have evolved. However, before proposal of a remedial method which takes advantage of these communities, verification of their existence, extent and efficacy would be necessary. Verification of the existence of these specialized microbial communities would require additional future CMS investigations coupled with bench scale and pilot studies to determine effectiveness.
- Alkalinity - Elevated alkalinity can be an indicator of aerobic respiration, denitrification, iron reduction, and sulfate reduction. Maps of alkalinity in the sand and fill layers are presented in Figure 3-13. Generally, at the large scale, the alkalinity is elevated in the plume area as compared to the samples taken at the upgradient and sidegradient limits of the site (along Route 5 and Blasdell Creek). However, some alkalinity values in regions of high concentration of organics in groundwater are very low, especially near the Ship Canal and SWMUs S-11 and S-22. It is possible that this pattern is an indicator of biodegradation through aerobic respiration, denitrification, iron reduction, and sulfate reduction occurring at the site-

wide scale. More study would be necessary to determine whether this occurs, and, if so, whether satisfactory rates of biodegradation of contaminants are possible.

- Nitrate - A decrease in the concentrations of nitrate can be indicative of denitrification. Concentrations of nitrate inside the plume area are very low site-wide (see Figure 3-67). However, equally low concentrations have been detected in upgradient and sidegradient areas. Therefore, it appears that there is no decreasing trend that might be interpreted as a clear indicator of the occurrence of denitrification. This may be partially caused by the human influences, such as post-industrial contamination. The unusually high pH of the groundwater may also influence the nitrate distribution.

- Sulfate - The concentration of sulfate in groundwater decreases as a result of sulfate reduction processes. A map of sulfate concentrations (Figure 3-20) does not show any discernible trends. As in the case of nitrate, this may be due to the influence of human activities or the high pH of the groundwater. Therefore, it is not certain whether sulfate reduction is occurring within the aquifer.

- Oxygen and Methane – Dissolved oxygen is the most favored electron acceptor in the biodegradation of hydrocarbons. Dissolved oxygen levels of less than 1 mg/L indicate that aerobic degradation may have occurred, that available oxygen has been largely utilized and a shift to anaerobic process may be taking place.

  Methane normally is not found in uncontaminated subsurface environments. The presence of methane suggests that methanogenesis, an anaerobic degradation process, is occurring in the system. This process typically takes place once the oxygen is removed from groundwater by the initial stage of biodegradation (aerobic respiration).

  Maps of dissolved oxygen and methane concentrations are presented on Figures 3-68 and 3-69, respectively, and from these maps, it can be seen that, as the concentration of dissolved oxygen increases, the concentration of methane decreases.

Significant concentrations of methane, coupled with low concentrations of oxygen, occur throughout the entire site in the sand unit. The sand layer appears to be under anaerobic or close to anaerobic degradation conditions. However, the only upgradient sample, taken along Route 5, also indicated the absence of dissolved oxygen. Before being filled, the entire area was within the limits of Lake Erie. Therefore, it is not clear whether the low oxygen/high methane environment in the sand unit is the result of degradation, production of methane by former lake bottom sediments (typically rich in organic material) or the combination of both processes.

In the fill unit, site-wide concentrations of dissolved oxygen (DO) are also relatively low. Here, however, a trend may be distinguished. There are 94 sampling points. With the exception of four data points, the trend is as follows: low DO levels of less than 0.8 mg/L correspond to methane concentrations of up to 23 mg/L, moderate DO levels of 0.8 to 2.5 mg/L correspond to methane concentrations of up to 2 mg/L, and methane is virtually absent where the DO concentration is above 2.5 mg/L. This progression of increasing methane and decreasing oxygen concentrations shows the areal transition from aerobic to anaerobic conditions, which is a characteristic feature of the process of biodegradation. Sampling points with high methane and low oxygen concentrations occur mainly near the Ship Canal and SWMUs S-11 and S-2. This also corresponds to the location of areas of low alkalinity. Such a trend may be indicative of the occurrence of anaerobic based degradation.

- Oxidation/Reduction Potential – The oxidation/reduction potential is an indicator of the relative tendency of a solution to transfer electrons. It depends upon and influences rates of biodegradation. Maps of the redox potential for the fill and sand units are shown on Figure 3-70. There is a very wide range of values; however, most of them are low and all but one are less than 400 milivolts. This indicates that if biodegradation were occurring, anaerobic reactions would dominate. This supports results obtained from the analysis of the dissolved oxygen/methane correlation. However, because similar results are observed in upgradient and sidegradient samples, this may also indicate that low redox potential may be a regional characteristic of the groundwater in the area. Also, the redox potential is known to be influenced by the pH. The unusually high pH values at the site make the interpretation of the redox values difficult.

It appears that the intensity of the biodegradation near major source areas near the Ship Canal and SWMU S-22/S-11 is significant. The process is constantly utilizing and depleting available "preferred" electron acceptors (ie. available oxygen) and has progressed to the stage of anaerobic biodegradation. Most likely, varying amounts of dissolved hydrocarbons are being biodegraded.

Biodegradation may be occurring throughout the remainder of the site. However, the rates are difficult to deduce from the data. The presence of both methane and oxygen seems to indicate that the system is in the transitional state between aerobic and anaerobic processes. There are no clear trends regarding sulfate and nitrate reduction. A very high pH of the groundwater may be adversely influencing the biodegradation chemistry. Also, upgradient and sidegradient samples may not fully represent "undisturbed" conditions, as the entire region has a long history of industrial use.

Overall Plume Behavior

The following is a brief discussion of the current state and behavior of the plume, based on the synthesis of the migration and degradation data.

There appear to be two major sources feeding the plume of dissolved contamination: the area along the Ship Canal and the area of SWMUs S-11 and S-22. Numerous smaller sources also exist throughout the site. Plumes migrating from the various sources display overlapping, and are difficult to distinguish.

Biodegradation appears to be occurring at the site in various areas. Degradation rates are believed to be significant in the vicinity of the two main sources. At these locations, it is believed the biodegradation process has progressed to where anaerobic bacteria are controlling degradation. In the remainder of the site, the intensity of degradation is difficult to estimate.

Groundwater in many areas of the site displays high pH, which is known to adversely affect biodegradation chemistry.

Groundwater contamination north of the Smokes Creek appears to have spread within the area between the Ship Canal and Lake Erie. A groundwater divide exists along the Ship Canal. As a result, it appears that both the Ship Canal and Lake Erie serve as discharge locations for the plume. Based on aquifer characteristics (high conductivity, moderate gradients) the plume migration in that region most likely occurs at moderate to high rates. In the region between the divide and the Ship Canal, the migration distance is short and the plume appears to have achieved stability. The distance of the westward migration towards the lake is considerable. Plumes from small sources mingle with the plume migrating from the area along the Ship Canal. The stability of the combined plume is difficult to ascertain.

South of Smokes Creek, the major source is the area of SWMUs S-11 and S-22. A groundwater mound with a high radial gradients exists in that region. The flow is both towards Smokes Creek and westwards towards Lake Erie. Part of the plume discharges immediately to Smokes Creek, with the remainder migrating west towards Lake Erie. The westward plume mingles with plumes from smaller sources located along the lake shore. Migration distances are relatively short, and the combined plume has most likely achieved a stable condition. The contaminated groundwater in the area south of Smokes Creek discharges to the lower reaches of the Smokes Creek and to Lake Erie immediately south of the creek mouth.

3.2.4.3 Surface Water and Sediment

Source of Contamination

Current sources of surface water/sediment contamination related to the site include contaminated surface soil particles carried by fugitive dust and surface runoff as well as the discharge of contaminated groundwater and free product. In the past, industrial discharges may have occurred directly into the surface waters.

Large portions of the site are sparsely vegetated. Contamination has been detected in the surface soils on a site-wide basis, especially SVOCs and metals. Therefore, surface soils may constitute a source of contaminated fugitive dust and surface runoff.

The fugitive dust can be carried by wind in any direction and probably reaches all surface water bodies in the vicinity of the site. The accumulation of fugitive dust is directly proportional to the surface area of the receiving water body. Surface areas of Smokes and Blasdell Creeks are insignificant compared to the area of Lake Erie adjacent to the site. However, since both Creeks discharge to Lake Erie, the bulk of loading associated with the fugitive dust is received by Lake Erie.

The topography of the site is very complex. The area contains numerous mounds and surface depressions. However, the general trend is the slope towards Lake Erie and Smokes Creek. These surface water bodies are also the receptors of the bulk of the contamination associated with the contaminated soil particles carried by runoff.

Generally, the mass loadings of fugitive dust and the particulate fraction of surface runoff decrease with time. This is because the "reservoir" of fine, mobile particles in the surficial layer is limited. As fine particles are flushed out of the surface soils, the remaining surface becomes less prone to wind or water driven erosion. The surficial soils at the site have remained mostly undisturbed for a significant length of time, following the cessation of plant operations. Therefore, the magnitude of fugitive dust and runoff loading is likely to be small. The exceptions are areas of unpaved roads, which are still in use.

Groundwater contamination has been described in the previous section. Dissolved plumes have reached Smokes Creek, Lake Erie and the Ship Canal. Therefore, all of these surface water bodies receive contaminant loading via the groundwater pathway.

Free product has been detected in the water bearing zone at several locations. However, product areas are mostly far from the potential receiving water bodies. The exceptions are SWMU S-24, located immediately north of the Smokes Creek, and a hydraulic oil spill just east of the mouth of the SRWT, where free product has been observed to enter the creek.

Migration

There are two distinct surface water environments at the site: Lake Erie and small creeks, trenches and the Ship Canal. Smokes Creek and Blasdell Creek are natural streams, although they flow through the man-made fill area. The streams formed by the return water trenches and the Ship Canal are entirely man-made.

In Lake Erie, the area impacted by the site is the near-shore zone. This region is dominated by longshore currents and by wave action. Contaminants reaching the near-shore zone are likely to be rapidly mixed throughout the water column. They will partition between the dissolved phase, the phase adsorbed onto solid particles within the water column, and the phase associated with the bottom sediment. Volatile organics will volatilize rapidly into the atmosphere under the action of the waves, and some will be broken down by photolysis and biodegradation.

Waters of Lake Erie contain a high volume of suspended solids (much higher than, for example, nearby Lake Ontario). Therefore, the fraction of contamination directly dissolved in water is reduced through contaminant adsorption onto the suspended solids. Also, the contaminated water will be rapidly mixed with the ambient water of the lake. The volume of water being contaminated by the combined action of all site-related sources is negligible compared to the volume available in the lake, resulting in a significant dilution. As a result, the concentration of contaminants in the water is generally low or "not detected" (see Figures 3-44 through 3-47). Contamination within the water column (both dissolved and adsorbed onto suspended solids) will be transported rapidly within the lake by the longshore currents, which are predominantly northward.

Migration of bottom sediments does occur as a result of resuspension. This pertains mostly to the sediment in the shallow zone, where the wave action is felt throughout the entire water column. The overall mass of sediments, and the associated mass of contaminants transported within the shallow zone, can be significant, especially during storms. In the deeper region, the sediment transport is likely to be minor, and contaminants trapped within the bottom sediments tend to be relatively immobile.

The Ship Canal is a man-made feature, functionally resembling a fiord connected to the lake. Hydraulic conditions in the canal are different than in the open lake. The exchange of water is much slower, the depth is relatively high and uniform; and the wave action is generally suppressed. Therefore, the contaminants are much more likely to stay within the confines of the canal, or settle to the bottom. Re-suspension of bottom sediments is unlikely; therefore, contaminants associated with the sediment are generally immobile. Figures 3-56 through 3-59 show results of sediment and surface water sampling in the Ship Canal. Concentrations of contaminants in water are generally low; however, the frequency of detections is greater than in the open lake.

In the onsite streams, the migration regime is significantly different than in Lake Erie. The volume of water receiving the contaminant loading is low. The streambed slopes are very flat. The resulting flow velocities are generally low, except during very high water conditions. The streams lack the significant capacity to dilute and disperse the loading of contamination. Also, the turbulence facilitating rapid volatilization of volatile compounds is generally absent. As a result, contaminants are detected in the surface water of these streams with a much greater frequency than in Lake Erie, and generally at higher concentrations (see Figures 3-48 through 3-51 for Smokes Creek and Figures 3-52 through 3-55 for Blasdell Creek). The contamination is transported by advection into the Lake Erie, which is the receiving water body for both of the creeks.

The contamination contained in the bottom sediments of the creeks is relatively immobile. The downstream reaches of the creeks, adjacent to the site, are mostly depositional in nature and resuspension is likely to be insignificant, excepting occasions where sediment is dredged from either the creek, or the mouth of the creek to prevent upstream flooding.

The North and South Return Water Trenches were used to carry process water from plant operations. Currently, discharges to the trenches are minor and the flow they convey is very low. Even though the trenches are man-made, their current hydrologic regime is similar to that of the Smokes and Blasdell Creeks: low flow velocities and generally shallow depths. Therefore, the migration of contaminants within the trenches is similar to that described above for the creeks.

Degradation

Little site-specific data is available to assess degradation rates in surface water and sediments. Degradation is probably relatively rapid in the surf zone of Lake Erie, where high levels of dissolved oxygen are likely to occur as a result of wave-induced oxygen transfer from the atmosphere. In the Ship Canal, onsite creeks and water return trenches, where the wave action and turbulence are generally low or absent, the degradation rates are likely to be slow. In the bottom sediments of all of the surface water bodies affected by the site's contamination, the environment is likely to be low in oxygen, and degradation rates are probably slow.

3.2.5 Site-Specific Fate and Transport – Metals

Fate and transport of metals in the environment are governed by very complex mechanisms. They are not only affected by the aquifer chemistry, but also are a strong function of the interactions between different metals present. The determination of the workings of these mechanisms requires copious amount of data, most of which are not available for this site. The studies that would have to be undertaken to acquire and interpret the data are beyond the scope of this project. As a result, the description of site-specific fate and transport processes operating at the site can only be given in very general terms.

Sources

The site has a long history of industrial use, predominantly related to steel making. Therefore, metals were used extensively and for various purposes. Figures 3-10 and 3-11 show a wide distribution of soil contamination. The concentrations tend to be somewhat higher south of Smokes Creek, along the Ship Canal and along Lake Erie. However, the differences do not appear to be significant enough to point to major, localized sources. Most likely, there are numerous sources of metals contamination distributed throughout the entire site.

Migration

Various processes governing the migration behavior of metals in the subsurface environment can be expressed macroscopically through the notion of the partition coefficient, defining the ratio of the mass of metals associated with soil to that associated with groundwater. The partitioning coefficient is a function of the pH, metal concentration, as well as properties of the groundwater and the aquifer matrix. Generally, this coefficient has been found to be strongly influenced by the nature of the aquifer matrix and by the pH. Its value increases with the clay content and the organic carbon content of the aquifer, and increases with the pH. In other words, in high clay/carbon content aquifers with high pH, most of the metal mass is adsorbed onto the soil, while under opposite conditions, more of the metals' mass tends to occur in the dissolved form.

Results of pH testing of the aquifer at the site are shown on Figure 3-12. Values range from neutral (pH of 6 to 8) to very high (pH over 12). Under these conditions, metals tend to adsorb onto soils, and remain essentially immobile. This process is likely aided by the relatively high organic carbon content of the onsite soils. Figures 3-10 and 3-11 show metal concentrations in soils, while concentrations in groundwater are presented on Figures 3-37 to 3-42. Soil concentrations tend to be high, often reaching values on the order of 100 to 1,000 mg/kg. Concentrations in groundwater, on the other hand, are mostly low, on the order of up to 10 μg/L. The only areas where metals concentrations in groundwater tend to be high (up to the order of 1,000 μg/L) are the vicinity of S-11, S-21 and S-22 (south side of Smokes Creek) and some locations along the Ship Canal. Based on Figure 3-12, those areas also display the lowest values of pH detected at the site. Therefore, the higher dissolved-phase concentrations of metals in those regions may not be the result of strong sources, but rather of the partitioning of metals being more favorable to the dissolved mass fraction.

It appears that the bulk of the mass of metals at the site is present in the soil-adsorbed form. This mass is essentially immobile, with the exception of the portion present in surficial soils that can migrate with surface runoff or as fugitive dust. The relatively smaller mass fraction associated with groundwater is migrating through advection and dispersion processes, and is reaching the receiving onsite surface water bodies (Lake Erie, Smokes Creek, etc). The concentrations in groundwater are relatively uniform, with exception of areas where the pH values are relatively low and higher concentrations occur. Particular plumes emanating from different sources are difficult to distinguish. The migration via groundwater, as well as the metals carried with the surface runoff and fugitive dust, has contaminated the surface water and sediment of the water bodies present at the site and those bordering the site (see Figures 3-47, 3-51, 3-55,3-63 and 3-66). However, given the long history of the industrial use in the entire region, the rapidity of migration within surface water bodies and the persistence of metals, it is difficult to ascertain what portion of the surface water/sediment contamination can be attributed to the site.

The pH within surface water bodies and their sediments can be expected to be much lower than the pH within the onsite aquifer, creating an environment where the metals are less attracted to the soil particles and more readily dissolve in water. Therefore, the nature of partitioning between the water and sediment is likely to be different than the water/soil partitioning in the aquifer. The mobile portion of the metals' mass, migrating with the flow of surface water, is expected to be more significant.

Degradation

There are no significant processes of degradation of metals in the natural environment. Therefore, the sources of metal loading as well as the migration of metal contamination at the site are expected to persist.

3.2.6 Mann-Kendall Trend Analysis of Groundwater Monitoring Locations

In response to EPA comments (USEPA 2002) on a draft of Section 3.0 of the RFI, a Mann-Kendall groundwater trend analysis, for a range of the most recent available 40 observations, was done for wells and other groundwater sampling locations where COPI's were detected. The method used is described by Gilbert (1987). The lookup table for probability calculation from 4 (minimum allowed) to 40 observations was obtained from Hollander (1999). For many of these locations, there was insufficient information (less than 4 observations) to determine a trend (this is shown as Insufficient Data). For others, a trend was found but didn't meet the Mann-Kendall statistical test of confidence. The cut off point was 90% probability that the trend was statistically significant. In other words, there had to be a probability of less than 1 in ten (0.1 or less as calculated in the probabilities column) that the trend reported was statistically insignificant.

For other locations, the calculated Mann-Kendall Statistic was outside of the boundary limits of the Statistical test, and are labeled "No Value." For the "No Value" cases, in general the S statistic exceeds the values in the lookup table for the number of detections used, meaning, in general, that the trend is either excessively positive (up), or excessively negative (down), depending on the sign of the Mann-Kendall Statistic shown. Because the probability can't be calculated from the lookup table, it shows "No Value."

The trend analyses described above are presented in Table 3-29.

3.3 Constituent Loadings to Surface Waters

3.3.1 Approach

Estimates of groundwater loadings to surface water bodies were performed using recharge-based groundwater discharge rates (Section 2.7.2 and Appendix J). The rate of discharge for each discharge area was multiplied by the concentration of constituents detected during the most recent, comprehensive groundwater sampling event (1999-2000) to derive loading rates. Since the concentration of a given constituent in groundwater differed in wells monitoring the fill and sand units, separate estimates of constituent loadings were determined for these units.

In response to Agency comments on the Draft RFI (March 23, 1999), which questioned the validity of loading estimates that did not take into account the difference in flow rates between the fill and sand units, loadings were recalculated to take into account the apparent 10-fold difference in hydraulic conductivity (hence flow volume) between the fill and sand units. Also questioned by the Agency was the accuracy of, and consistency in, extrapolation of isoconcentration contours used to project constituent concentrations at the point of discharge. As isoconcentration contours used to project constituent concentrations at the point of discharge. As a result, a less interpretative and more conservative method was applied utilizing measured concentrations of constituents in wells located nearest the point of discharge. To accomplish this, the groundwater discharge areas (see Appendix J) were subdivided into shoreline segments each represented by a monitoring well with close proximity to the respective discharge section.

The methodology and location of wells, discharge areas and shoreline segments used to derive loading values is presented in Appendix J. Tables 3-30 to 3-40 provide the calculated estimates of loadings for the various chemical groups by discharge area and shoreline segment for the fill and sand units. The chemical constituents presented include compounds identified as COPCs in groundwater and surface water at the site and, other frequently detected groundwater constituents. Figures 3-71 to 3-76 show the relative areal distribution of estimated surface water loads for the major chemical groups. Since over 90 percent of the site groundwater discharges through the fill unit, based on a 10-fold difference in hydraulic conductivity between the fill and sand units, a similar proportion of chemical constituents that discharge to surface water are predicted to flow from the fill unit (see Appendix J).

In general, the loadings presented can be viewed as conservative estimates since the loading concentrations are taken from monitoring wells located, on average, 200 to 300 feet from the point of surface water discharge. As a result, the estimated loading may overestimate the actual constituent concentration entering the water body by not taking into account further degradation, dilution or retardation which may occur as the flow from the site approaches and enters the near shore zone. The calculated loading of dissolved constituents may, however, in some instances also underestimate actual loadings due to the occurrence of LNAPL sheens. This could be anticipated at locations where LNAPL sheens have been reported in wells in close proximity to the point of groundwater discharge. In particular, this would include shoreline segments along Smokes Creek and along the Ship Canal near the Benzol Yard as discussed below and identified in Section 3.1.3.4.

3.3.2 Loading to Lake Erie

The loading of constituents to Lake Erie has been recognized as occurring through four discharge areas; two south of Smokes Creek (Areas 1+A and 2A), and two north of Smokes Creek (Areas 4A and 4B) (Figure 2-52). Discharge Area 1+A includes SFA Zone 1 and recharge provided by offsite Area A east of NYS Route 5. Loadings to Lake Erie from Area 1+A were based on the discharge occurring through the slag fill since the sand unit was not recently monitored at that location. Further north along the lake shoreline, Area 2A includes discharge occurring from SFA Zone 2, while Area 4A receives flow from SFA Zones 3, 4 and 5 and includes flow originating from the groundwater mound along the Coke Oven Area (Figure 2-52). Discharge Area 4B along the northern boundary of the site receives flow from the Coke Oven Area and discharges in the direction of the USACE Dredge Spoil Containment Area No. 4 and Lake Erie. As in the case of Area 1+A, loadings from Area 4B are based on discharge occurring only through the fill since the sand unit in that area does not have representative data. The saturated thicknesses and discharge rates of the sand and fill units and the lengths of the shoreline segments are provided in Appendix J.

Constituent loadings to Lake Erie are dominated by the discharge of metals, particularly in the area north of Smokes Creek (Table 3-30). In general, the discharge of organic compounds to Lake Erie is dominated by SVOCs with the more volatile SVOCs accounting for over 70 percent of the loading, (principally in the form of naphthalene). Although a lesser quantity of chemical constituents are discharged from the lower conductivity sands, the relatively high loading rates reflect higher overall groundwater concentrations in the sand unit near the lake. This is particularly apparent for Discharge Area 4A north of Smokes Creek, where dredge spoil sediments were previously disposed in the former shoreline area by the USACE (see Section 3.1.1.3).

3.3.2.1 Volatile Organic Loadings

It is predicated that Lake Erie receives 43.3 pounds per year (lbs/yr) of volatile organics of which 41.4 lbs/yr are BTEX compounds. Over 70 percent of the BTEX loading is released from the slag fill in Discharge Areas 2A and 4A (Table 3-30), where the principal compound discharged is xylene. The estimated annual loading rate for benzene to Lake Erie is approximately 11.4 lbs/yr from all four discharge areas.

South of Smokes Creek, VOCs were not detected in groundwater representing Discharge Area 1+A (Table 3-33). The greatest loading of BTEX (7.0 lbs/yr) occurs further north along discharge segment MW-2D4 (Discharge Area 2A) located just south of Smokes Creek near surface impoundment SWMU S-3 (HWM-2) (see Figure 3-71). The only volatile compound reported in an RFI sample obtained from Lake Erie near this vicinity was toluene, which was detected at a concentration of 0.44 µg/L (Figure 3-44). In addition to the BTEX compounds, trace amounts of chlorinated compounds including 1,1 DCA and TCE are predicted to be discharged from segments MW-2D4 and MW-2D3 in Discharge Area 2A (Table 3- 34).

North of Smokes Creek the greatest loadings of BTEX are predicted to occur from the fill along shoreline segment MWN-03 (8.7 lbs/yr) and from the fill and sand units of segments MWN-05A and MWN-05B (7.0lbs/yr). Shoreline segment MWN-03 is located downgradient of the Coal Tar Sludge Pit (SWMU S-13), while MWN-05 is located downgradient of the Lime Dust and Kish Landfill (SWMU S-18). Besides the BTEX compounds, chlorinated hydrocarbons in the form of chlorobenzene (1.8 lbs/yr) are estimated to be released from segments MWN-05A and MWN-05B (Table 3-35). Nearer the Coke Oven Area, loadings from Discharge Area 4B includes the BTEX compounds (2.7 lbs/yr), of which, benzene is the dominant compound released (Table 3-36).

3.3.2.2 Semi-Volatile Organic Loadings

The loading of SVOCs to Lake Erie is predicted to occur at a rate of 210 lbs/yr and is represented mostly by the more volatile SVOCs with naphthalene accounting for 57 percent of the loading. The greater proportion of SVOCs released (86 lbs/yr) is projected to occur from Discharge Area 4A, and the least from Area 1 + A where SVOCs were not detected in the nearshore groundwater sample (Table 3-30).

South of Smokes Creek along Discharge Area 2A, most of the SVOC loading (28 lbs/yr) is predicted to occur from the fill along segment MW-2D4 near the mouth of Smokes Creek

(Table 3-34 and Figure 3-73). Here the estimated loading includes 23 lbs/yr of naphthalene and 2.4 lbs/yr of phenolics. Only 5.7 lbs/yr or about 20 percent of the areas total load of SVOCs takes place through the sand unit.

North of Smokes Creek the greatest loadings occur along segment MWN-02 and MWN-02B (46 lbs/yr) downgradient of the Slag Quench Pit (SWMU S-10) and Tank Farm Area (SWMU P-75), and along segments MWN-05A and MWN-05B (76 lbs/yr). In the vicinity of segment MWN-05, the sand unit is predicted to carry a greater load of semi-volatiles, reflecting the presence of high concentrations of naphthalene in the underlying sands (Table 3-35). In addition to 108 lbs/yr of volatile SVOCs (mostly naphthalene), Discharge Area 4A is also predicted to release 38 lbs/yr of phenolics (mostly 3-4 methylphenol and phenol) with the greatest release of phenolics occurring from the sand unit of segment MWN-05B (Figure 3-74). It appears from the loading estimates that the slag fill generally releases a wider array of constituents, including pyridine, at typically higher concentrations (Table 3-30).

Surface water samples collected from the lake during the RFI did not report the presence of SVOCs. Semi-volatile organics were, however, detected in the lake sediments especially in the vicinity of Smokes Creek where higher groundwater loadings are predicted (Figures 3-45 and 3-46).

3.3.2.3 Metal Loadings

Total metals and cyanide loadings to Lake Erie are estimated at around 1,727,093 lbs/yr and 21 lbs/yr respectively. Most of the loading occurs through the fill unit with less than 0.01 percent of the total loading represented by heavy metals (Table 3-30).

The loading of metals, particularly heavy metals, to Lake Erie north of Smokes Creek greatly exceeds the predicted loading south of Smokes Creek (Figure 3-75). High levels of total (590,156 lbs/yr) and heavy (976 lbs/yr) metals are projected to be released to Lake Erie from the sand unit along discharge segment MWN-05B (Table 3-35). Calcium and iron, along with lesser quantities of magnesium, potassium and sodium, are the principal major ions released down-gradient of the Lime Dust and Kish Landfill (SWMU S-18). In addition, approximately two-thirds of the barium (estimated to account for over 98 percent of the heavy metals loading) is projected to be released from segment MWN-05B. Other discharge segments with estimated high heavy metal loadings include segment MWN-02 located near Smokes Creek and segments MWN-18A and MWN 43A, which border the northern portion of the site down-gradient of the former Coal Storage Pile and Landfill SWMU S-25, where metals were reclaimed from slag (Figure 3-76).

Other heavy metals contributing to the loading of Lake Erie includes arsenic (6.4 lbs/yr); chromium (41.8 lbs/yr), lead (3.5 lbs/yr); nickel (13.5 lbs/yr) and selenium (17.5 lbs/yr). With the exception of selenium, these metals are COPCs in the lake sediments with noticeably higher concentrations reported in the vicinity of Smokes Creek. Lead (3.0 to 5.7μg/L) and cyanide (0.02μg/L) were also detected in lake water samples obtain north of Smokes Creek (Figure 3-47).

3.3.3 Loadings to Blasdell Creek

Groundwater discharge from the site to Blasdell Creek from Discharge Area 1A was estimated from the discharge-based calculations to be approximately 0.05 cfs. Loadings to Blasdell Creek (see Table 3-30 and 3-37) were based on groundwater results obtained from monitoring well MWS-06, which monitors the fill unit. In this area, the sand unit was found to be absent, with slag fill directly overlying silty clay sediments.

Groundwater samples collected from monitoring well MWS-06 near Blasdell Creek did not detect any organic compounds. Total metals loading is estimated at 16,864 lbs/yr, of which, 15 lbs/yr are heavy metals. Heavy metals detected in the groundwater included arsenic, barium and chromium. Of these metals, arsenic and barium were identified as a COPC or COPEC in the surface water of Blasdell Creek (Figure 3-55). Estimated annual loading rates of these metals varied between 0.12 lbs/yr and 14.0 lbs/yr (Table 3-37). The highest loading rate was associated with barium, which accounted for approximately 94 percent of the total estimated heavy metals loading to Blasdell Creek. A similar predominance of barium was observed in the heavy metal loadings for the other discharge areas at the site.

3.3.4 Loading to Smokes Creek

Groundwater loadings to Smokes Creek were estimated for Discharge Areas 2B (southern bank) and Area 3A (northern bank) which are located west of BSC Highway #9 and border SFA Zones 2 and 3, respectively (Figure 2-52). In general, constituent loading along the south bank of Smokes Creek is dominated by the presence of volatile organics (mainly BTEX compounds), whereas loading along the north bank is characterized more by the discharge of semi-volatile compounds (Table 3-30). For both discharge areas, the greatest loadings to surface water are associated with the slag fill unit, which tends to have higher groundwater constituent concentrations and discharge rates.

3.3.4.1 Volatile Organic Loadings

Loadings of volatile organics from Discharge Areas 2B and 3A consists primarily of BTEX compounds and, in particular, benzene, which accounts for approximately 99 percent (1,418 lbs/yr) and 66 percent (7.3 lbs/yr) of the estimated annual loading of volatile organics from these discharge areas, respectively (Table 3-30). By far, the largest estimated loading rates of benzene are predicted to occur from shoreline segments MWS-18A and MWS-19A located adjacent to the ATPs, and from segment MWN-44A near the Acid Tar Sludge Landfill north of Smokes Creek (Tables 3-38 and 3-39). Within this same section of Smokes Creek, the highest concentrations of benzene have been reported in surface water (4 µg/L) and sediment (25µg/kg) samples (Figure 3-48).

In addition to benzene, it is estimated that lesser quantities of xylene (12.0 lbs/yr) and toluene (5.3 lbs/yr), both identified in Smokes Creek surface water and sediment samples, as well as minor accounts of ethylbenzene (0.7 lbs/yrs) and chlorinated hydrocarbon (0.4 lbs/yr as 1,1 DCA) are discharged to Smokes Creek.

3.3.4.2 Semi-Volatile Organic Loadings

Estimated annual loading rates of SVOCs range from 55 lbs/yr along the south side of Smokes Creek (Area 2B) to 146 lbs/yr along the northern bank (Area 3A). Most of the loadings to Smokes Creek consist of PAHs and, in particular, the more volatile PAHs including naphthalene (100 lbs/yr) and phenanthrene (26.5 lbs/yr). Greatest loadings of SVOCs (90 percent) are predicted to occur from the slag fill, which on average has a saturated thickness approximately twice that of the sand unit and a much greater hydraulic conductivity (Table 3-30).

The high loading of naphthalene along this stretch of Smokes Creek is reflected in the presence of naphthalene in surface water samples at concentrations of between 0.4 μg/L and 1.3 μg/L (Figure 3-49). Naphthalene and other PAHs detected in groundwater (i. e. acenaphthylene, anthracene, fluorene, phenanthrene, fluoranthene and pyrene) is also reported to be present in sediment samples (Figures 3-49 and 3-50). Elevated levels of these constituents were detected downstream of discharge segment MWN-44A, which provided the highest estimate of groundwater loadings of PAHs (84 lbs/yr). Significant loadings of SVOCs are also predicted near the mouth of Smokes Creek (shoreline segments MWS-01 at 33 lbs/yr and MWN-01 at 56 lbs/yr), where product has been detected in the near shore wells (see Section 3.1.3.4 and Figure 3-73).

In addition to PAH's, phenolic compounds (14.4 lbs/yr) and pyridine (16.4 lbs/yr) are estimated to discharge from Areas 2B and 3A. The majority of the loading along the south side of Smokes Creek (phenol at 3.6 lbs/yr and pyridine at 12.6 lbs/yr) is predicted to occur from the sand unit downgradient of the ATPs (segments MWS-18A/C). Along the north bank, maximum loadings of phenolics (3-4 methylphenol at 6.0 lbs/yr) and pyridine (at 2.2 lbs/yr) are projected to occur from the fill unit downgradient of the Tank Farm Area (segments MWN-01 and MWN-44A [Figure 3-74]).

3.3.4.3 Metal Loadings

Total metals and cyanide loadings to Smokes Creek are estimated at around 114,900 lbs/yr and 66.9 lbs/yr, respectively. Approximately 93 percent of the loading is contributed by the slag fill unit. Of the total metals loading, less than 0.1 percent is represented by heavy metals (Table 3-30).

The greatest contribution to loading along the south bank of Smokes Creek occurs downgradient of the ATPs along shoreline segment MWS-02 (total and heavy metals at 15,991 lbs/yr and 1.3 lbs/yr, respectively; cyanide at 29 lbs/yr) (Table 3-38), whereas on the north side the greatest loading occurs along segment MWN-44A (total and heavy metals at 15,811 lbs/yr and 7.1 lbs/yr, cyanide at 5.1 lbs/yr) near SWMU S-24 (Table 3-39). Of the estimated 31 lbs/yr of heavy metals discharged to Smokes Creek, nearly two-thirds is represented by the metal barium. Many of the heavy metals identified in groundwater bordering Smokes Creek (including arsenic, barium, chromium, lead, nickel and selenium) have been reported in surface water and sediment samples (Figures 3-51).

3.3.5 Loadings to the Gateway Metroport Ship Canal

Groundwater loadings to the Ship Canal were based on estimates of discharge originating from the Coke Oven Area and from the Benzol Plant on the west side of the canal. East of the canal, preliminary assessment of former SWMUs in that area received a "no further action assessment" from USEPA (1991) and it was concluded that the groundwater was not significantly impacted.

Constituent loading to the Ship Canal were limited to groundwater discharges from the fill unit only. Although sand deposits were identified at a few locations bordering the canal, the sand unit does not form a discernable unit in this area (i.e., located landward of the former shoreline). As a result, only constituent concentrations monitored in shallow wells installed along the canal were used to calculate groundwater loadings (Figure 2-52).

3.3.5.1 Volatile Organic Loadings

The loading of volatile organics consists primarily of the BTEX compounds (81 lbs/yr) with benzene (75 lbs/yr) accounting for about 90 percent of the volatile loading to the canal. In addition, a few chlorinated hydrocarbons (1,1,2,2 TCA and TCE) were identified, but provide only a trace contribution to the surface water loading (Table 3-30). Most of the benzene discharged to the canal is projected to occur along segments MWN-26A and MWN-09 (Table 3-40), which are situated downgradient of the Benzol Yard and Old Benzol Plant at locations where product has been historically identified (see Section 3.1.3.4 and Figure 3-71). Surface water samples collected during the RFI from the Ship Canal recorded benzene concentrations of 0.7μg/L and 1.0μg/L near this location (Figure 3-56).

3.3.5.2 Semi-Volatile Organic Loadings

The loading of SVOCs to the Ship Canal is estimated to consist mostly of naphthalene (5.0 lbs/yr) and phenol (1.6 lbs/yr), accounting for approximately 63% and 20%, respectively of the annual loading of SVOCs (Table 3-30). Other SVOCs contributing minor quantities to surface water include acenaphthylene, bis(2-Ethylhexyl) phthalate, fluorene and pyridine. The majority of the naphthalene loading is predicated to occur from discharge segment MWN-07 located along the northern end of the canal downgradient of Coke Oven Battery No. 8, while the majority of phenol is predicted from segment MWN-09 near the Benzol Yard (Figures 3-73 and 3-74). Naphthalene was detected in RFI surface water samples at concentrations of 0.5 μg/L and 0.6μg/L (Figure 3-57). The only other SVOC detected in the canal water was bis(2-Ethylhexyl)phthalate at concentrations of between 0.7 μg/L and 20.0 μg/L (Figure 3-58).

3.3.5.3 Metal Loadings

Total metals and cyanide loadings to the Ship Canal are estimated at 112,043 lbs/yr and 12 lbs/yr, respectively. Over two-thirds of all metals and cyanide loadings are predicted to occur from discharge segment MWN-07 at the north end of the canal (Table 3-40). Of the total heavy metals loading (18 lbs/yr), barium (13 lbs/yr) and chromium (4.0 lbs/yr) account for over 90 percent of the loading to the canal. Barium was detected in most surface water samples at concentrations of between 19.6 μg/L and 25.6 μg/L, while chromium was detected in a single RFI water sample at 40.4 μg/L (Figure 3-59).

3.3.6 Summary

Groundwater flow at the site occurs primarily through fill materials, which were incrementally placed as the site was developed. Over 90 percent of the groundwater flow takes place through the fill unit, which is typically several times thicker and an order of magnitude more permeable than the underlying sand unit. As a result, most of the chemical constituents entering area waterbodies is predicted to flow from the sites' fill material.

The yearly load of chemical constituents discharged to surface water bodies includes 2,051 pounds of organic compounds and 1,970,900 pounds of inorganics including cyanide (see Table 3-30). The majority of the organics discharged include the more readily transported and soluble volatile organics (1,632 lbs/yr) consisting primarily of BTEX compounds (1,630 lbs/yr) and dominated by the presence of benzene (1,577 lbs/yr). Nearly 97 percent of the volatile compounds are released from the fill unit, particularly to Smokes Creek (1,432 lbs/yr) and the Ship Canal (81 lbs/yr) in the vicinity of the ATPs (SWMUs 11 and 22) and the Benzol Yard (P-11), respectively. In both of these areas, benzene was detected in the RFI surface water samples. In contrast, minor amounts of chlorinated hydrocarbons (2.3 lbs/yr) are predicted to be released from the site to surrounding waterbodies.

Semivolatile organics most subject to groundwater loading are the more volatile PAH compounds. Of the 419 pounds of SVOCs predicted to be released, naphthalene accounts for over half (225 lbs/yr) of the load, while the more soluble of the phenolic compounds (i.e. phenol and 3-4 methylphenols) provide an additional 12 percent or 49 pounds of the yearly SVOC load. Most of the release of SVOCs is predicted to occur along Smokes Creek and the Lake Erie shoreline north of Smokes Creek. The greatest loading of PAHs is projected to occur from the north bank of Smokes Creek in the vicinity of SWMU S-24, and near the confluence of Smokes Creek with Lake Erie. As a result of this discharge, and the subsequent transport of SVOCs into Lake Erie, significant concentrations of PAHs have been detected in RFI sediment samples collected from Smokes Creek (including upstream locations) and Lake Erie near its junction with Smokes Creek. Although 77 percent of the SVOC load is predicted to occur from the fill unit at the site, 73 percent (i.e. 70 lbs/yr) of the SVOC load discharged by the underlying sand unit, is projected to be released along the northwestern shoreline of Lake Erie (Discharge Area 4A).

The inorganic contribution to surface water loading at the site consists primarily of major ions (e.g. calcium, iron and magnesium) commonly associated with the composition of the slag fill. Consequently, the greatest loadings of inorganics occur from the fill unit bordering Lake Erie, especially north of Smokes Creek from SFA Zones 3, 4 and 5. This includes the release of heavy metals (primarily barium), which contributes 1395 pounds (less than 0.1%) of the yearly load of metals. Although 69 percent of the total metals load takes place through the slag fill, 72 percent of the heavy metals load is predicted to occur from the sand unit, most notably in the vicinity of SWMU S-18. The release of metals to surface water from the Slag Fill Area is reflected in the widespread detection of heavy metals in RFI sediment and surface water samples from Lake Erie and Smokes Creek.

3.4 References

Gilbert, R., 1987. Statistical Methods for Environmental Pollution Monitoring, Section 16.4. Van Nostrand Reinhold, New York.

Hollander, M. and Wolfe, D., 1999. Nonparametric Statistical Methods, Second Edition, Table A-30. John Wiley and Sons, Inc. New York.

United States Environmental Protection Agency, 2002. Letter from Mr. Dale Carpenter of USEPA Region II to Mr. Leo Kaercher of BSC transmitting USEPA comments to BSC's June 29, 1999 responses to USEPA comments originally dated June 18, 2002.

4.0 SUMMARY OF THE ECOLOGICAL RISK ASSESSMENT

A Tier 1 and Tier 2 Ecological Risk Assessment (ERA) was conducted for the site as part of the RFI. The ERA was conducted to determine the potential for adverse effects posed to wildlife and community receptors from site-related constituents in soil, sediment, and surface water.

The ERA discussed the ecological investigation that was conducted as part of the RFI. It focused on the potential impacts to the terrestrial ecosystem within the SFA and the aquatic ecosystem of the six water bodies that may have been impacted by BSC operations: Lake Erie, the Gateway Metroport Ship Canal (Ship Canal), Smokes Creek, Blasdell Creek, and the north and south return water trenches (NRWT, SRWT).

The SFA forms the 13,000-foot western boundary of the site along Lake Erie. The SFA material consists primarily of slag from iron and steel production, but it also contains other materials. SWMUs were used for the management of waste materials, including construction and demolition debris, sludges, dusts, and liquids from iron, steel, and coke manufacturing operations, sludges from wastewater operations, and dredged sediments from Smokes Creek. The SFA has also been the site of oil storage tanks, coal storage piles, and management areas for various types of materials (*e.g.*, machinery) from Plant operations. The SFA is arbitrarily divided into five zones for planning purposes:

- Zone 1 – the southernmost zone, currently undergoing slag reclamation;
- Zone 2 – used as a waste management area;
- Zone 3 – portions of this zone were used as waste management areas; slated for future reclamation;
- Zone 4 – used as a waste management area; and
- Zones 5 – the northernmost zone, which is slated for future reclamation.

The site is characterized by low topographic relief, except within the SFA where slag piles are characterized by steep slopes, some of which rise to approximately 60 feet before dropping off sharply at the lakeshore. Because the slag fill is so porous, precipitation runoff generally does not leave the site via a surface runoff pathway. Exceptions include precipitation that falls on the shoreline embankments that slope toward Lake Erie.

A state-regulated wetland area is located approximately one mile northeast of the site boundary and represents a remnant of a much larger wetland associated with the Buffalo River that most likely existed before industrialization of the area. A narrow band of riparian wetlands is present along Smokes Creek, from Hamburg Turnpike to its mouth.

In 1988, an RFA was conducted by the USEPA. The RFA identified 104 SWMUs that may have received hazardous constituents and/or wastes and five watercourses within and around the site that may have been impacted by hazardous constituent releases from the SWMUs. In 1990, BSC and USEPA Region II negotiated and entered into an AOC that directed BSC to perform a phased, site-wide RFI. The objective of the RFI was to determine the nature and extent of any hazardous constituents released from SWMUs into soils, air, groundwater, sediment, and surface water at or near the site and their potential human health and environmental impacts. The RFI was performed under the direction and approval of USEPA Region II and the NYSDEC and is documented in this RFI Report.

4.1 Terrestrial Habitat

A habitat characterization of the SFA was performed that identified on site fauna and flora and evaluated the viability of habitats at the site. The results of this characterization indicated that recent and ongoing physical disturbances in Zones 1 and 5 preclude vegetative growth within those areas. However, many areas in Zones 2, 3, and 4 have been substantially undisturbed since the cessation of steel making in 1983. Soil formation and the slow rate of plant community development in the SFA are somewhat characteristic of primary succession, but true primary succession is typified by rapid colonization by opportunistic plant species. The slow vegetative development at the site is attributable to the slag substrate, which was devoid of nutrients and which lacked an existing seed reservoir at the time of its placement in the SFA.

Only a thin veneer of soil has developed since slag deposition, ranging from one to more than four inches deep.

Large areas in Zones 3 and 4 appear to have been colonized by just a few plant species, which do not provide sufficient cover for most wildlife taxa. The relative scarcity of trees and shrubs indicates a lack of vertical complexity in community structure over most of the SFA, precluding biological diversity. A developed canopy and understory are present in the northwest section of Zone 2 and the western portion of Zone 3, where the greatest abundance and diversity of wildlife has been observed.

Based on field observations, over half of the SWMUs investigated in the SFA have fewer than 50% vegetation cover. Overt effects of SWMU-related wastes on vegetation were obvious in those SWMUs (such as SWMU S-1 and SWMU S-22) where oil and/or tar-like substances cover the SWMU surface. Plants in physical contact and at least partially covered with these substances are chlorotic and withered, while plants just beyond the edge of these materials appear healthy. Forbs and small saplings growing outside SWMU perimeters are without apparent stress.

In order to characterize potential adverse effects from SWMU-related materials to the terrestrial ecosystem, soil samples were collected from the surface horizon (generally to six inches below ground surface). Analytical results of these samples were screened against ecotoxicological benchmarks to develop a list of constituents of potential ecological concern (COPECs). Average daily doses (ADDs) of COPECs were estimated for selected wildlife receptors (representing species observed or potentially dwelling on the site) by applying receptor-specific exposure factors to maximum and average concentrations of COPECs in soils. Terrestrial wildlife receptors evaluated in the ERA were as follows:

- Deer mouse;
- Short-tailed shrew;
- American robin; and
- Red-tailed hawk.

Complete exposure pathways quantitatively evaluated for the wildlife receptors included ingestion of potentially impacted soil and ingestion of potentially impacted food. Food chain ADDs were modeled for the ingestion of vegetation by the deer mouse, ingestion of earthworms by the short-tailed shrew and American robin, and ingestion of deer mice by red-tailed hawks.

ADDs were then compared to receptor-specific toxicity reference values corresponding to literature-derived doses at which no adverse effects were observed (NOAEL) and at which adverse effects were observed at the lowest tested concentration (LOAEL).

COPEC-specific hazard quotients (HQs) at a given location were then summed to provide a hazard index (HI). The results indicated that, with the exception of the deer mouse in SWMU S-5, terrestrial receptor HIs based on maximum concentrations of detected compounds exceeded 1.0 in every SWMU and background location. In all cases, SWMU S-5 had the lowest HIs and SWMU S-6 had the highest HIs. Deer mouse NOAEL HIs ranged from one in SWMU S-5 to 131 in SWMU S-6. Shrew NOAEL HIs ranged from 3.3 to 1.3E+03, robin NOAEL HIs ranged from 24 to 1.3E+04, and red-tailed hawk NOAEL HIs ranged from 7.5 to 770. COPECs contributing to the terrestrial wildlife risks were antimony, arsenic, chromium, lead, selenium, thallium, and polycyclic aromatic hydrocarbons (PAHs).

In conclusion, the terrestrial ecosystem at the site (*e.g.*, areas other than obviously impacted SWMUs such as S-1, S-22 and S-24) is influenced primarily by the physical characteristics of the habitat subjected to continued disturbance from industrial operations and traffic associated with the slag reclamation operations. The plant community in the SFA is one of low diversity and is comprised of pioneering species because of physical factors such as the man-made substrate (slag and other non-native fill), which essentially precludes the development of a mature terrestrial community. Despite the elevated HIs for many SWMUs, toxicological effects from site COPECs are not overt, as the fauna and flora observed at the Site generally appeared healthy. However, the potential for adverse effects to all four receptors is likely at the obviously contaminated SWMUs (*i.e.*, S-1, S-6, S-22, S-24), where the physical presence of tars and oils may result in acute physical effects, as well as, toxicological effects.

4.2 Aquatic Habitat

Water bodies potentially affected by the site include Smokes Creek, Blasdell Creek, Lake Erie, the SRWT, the NRWT, and the Ship Canal. Analytical results from surface water and sediment samples collected during the RFI were used to characterize potential effects from site COPECs to selected semi-aquatic receptors. The analytical results of the upstream and downstream surface water and sediment sampling effort were used to estimate exposure and risks for five receptors:

- Mallard;
- Great blue heron;
- Raccoon;
- Spotted sandpiper; and
- Red-tailed hawk.

Complete exposure pathways quantitatively evaluated for the semi-aquatic wildlife receptors included ingestion of potentially impacted sediment and surface water, and ingestion of potentially impacted food. Food chain ADDs were modeled for the mallard ingesting benthic invertebrates from sediments, the great blue heron ingesting fish, the raccoon and spotted sandpiper ingesting benthic invertebrates, and the red-tailed hawk ingesting raccoons.

4.2.1 Gateway Metroport Ship Canal

The Ship Canal is a man-made watercourse designed to provide access from the former site to the Buffalo Outer Harbor. Previous sampling of surface water and sediments were conducted as part of the RFI; however, sediments from the entire length of the Canal were dredged by the USACE in October 2001 effectively removing all contaminants. For this reason, the Ship Canal area was eliminated from consideration in the ERA.

4.2.2 Blasdell Creek

Blasdell Creek was recently channelized and dredged by the USACE. The section running through the site from NY State Route 5 to Former BSC Highway 9 contains a rock wall along its southern bank and a grass- and shrub-covered northern bank. Vegetation from Hamburg Turnpike to west of Former BSC Highway is generally sparse. A small, vegetated wetland area is present west of the BSC highway, but vegetation thins for the last 200 feet to the creek's discharge into Lake Erie. Blasdell Creek historically received BSC discharges as well as discharges from the Erie County potable water treatment plant filter backwash. It also receives surface runoff from NY State Route 5.

As part of the RFI, benthic invertebrate and fish surveys were conducted in Blasdell Creek. The results of the quantitative benthic survey were inconclusive, as community metrics showed that both upstream and downstream locations were impacted. This result may be a consequence of the recent changes in physical habitat (channelization and dredging) rather than from chemical stressors. The fish survey, conducted in 1996 (prior to dredging), demonstrated that the Blasdell Creek has similar fish abundance, species diversity, and numbers of pollution-intolerant species compared to other Lake Erie tributaries. The limits of the fish community are also most likely a consequence of recent change in the physical habitat rather than chemical stressors.

Quantitative risks to the mallard, great blue heron, raccoon, and red-tailed hawk indicated that the potential for adverse effects to these receptors is insignificant for all exposure pathways evaluated. The HI for the spotted sandpiper suggested the potential for adverse ecotoxicological effects from sediment ingestion exposure and benthic invertebrate ingestion exposure to metals, including arsenic, antimony, chromium, and lead.

4.2.3 Smokes Creek

Smokes Creek historically received discharges from BSC and City of Lackawanna Sewage Treatment Plant (STP), and currently receives discharges from the City STP. NY State Route 5 also crosses Smokes Creek upstream of the BSC facility and runoff from Route 5 may enter the stream at this point. The Creek has been channelized since the 1960s and dredged periodically, the last time in 1979. An analysis of historical fishery surveys showed improving fish abundance and diversity, as well as an increasing number of pollution-intolerant species, signifying improving water quality. NYSDEC has substantiated this condition by upgrading the Smokes Creek stream classification from D to C.

The analytical results of the upstream and downstream surface water and sediment sampling effort were used to estimate doses and risks for the five semi-aquatic receptors. Food web modeling results indicate no unacceptable risks from the ingestion route to mallards (benthic invertebrates), raccoons (fish and benthic invertebrates), and red-tailed hawks (raccoons). Although the upstream and downstream HIs for the great blue heron are approximately equivalent, the individual HQs for cadmium and selenium are greater downstream than upstream. The HI for mallards is only slightly greater than one for ingestion of benthic invertebrates.

4.2.4 North Return Water Trench

The NRWT originates from the area formerly occupied by the 32-inch finishing mill. It discharges to the Ship Canal and ultimately, Lake Erie. It is a mostly covered, man-made brick and concrete channel that, at times, runs beneath buildings. It does not contain habitat for wildlife. Observations of the NRWT revealed a mixed population of dead and live forage fish amongst algae and floating garbage. It is likely that these fish were present in the NRWT as a result of being entrained into water intakes rather than from a viable resident community.

The analytical results of surface water sampling from the NRWT were used to calculate doses and risks for mallards from direct ingestion of NRWT surface water. The resulting HIs were at least seven orders of magnitude less than one, indicating that there are no significant risks to the mallard as a consequence of exposure to COPECs in NRWT surface water.

4.2.5 South Return Water Trench

The SRWT originates from the area formerly occupied by the 32-inch finishing mill and discharges to Smokes Creek and ultimately, Lake Erie. Like the NRWT, it is a partially covered, man-made brick and concrete channel. Unlike the NRWT, portions of the SRWT serve as wildlife habitat for a variety of organisms, including aquatic plants, forage fish, predatory fish, reptiles, carnivorous birds, and omnivorous mammals. Results of surface water and sediment sampling from the trench were used to calculate exposures and risks for four receptors: mallard (direct contact with surface water and ingestion of benthic invertebrates), spotted sandpiper (ingestion of benthic invertebrates), raccoons (ingestion of benthic invertebrates), and red-tailed hawks (ingestion of raccoons).

Hazard indices for the mallard, raccoon, and red-tailed hawk were less than one, indicating no unacceptable risks are posed to these receptors from exposure to SRWT media. The spotted sandpiper HI was 504, based on exposure to antimony, arsenic, chromium, lead, selenium, and cyanide.

4.2.6 Lake Erie

Surface runoff from SFA, Smokes Creek, Blasdell Creek, the NRWT, and the SRWT ultimately discharge to Lake Erie. The analytical results of surface water and sediment samples collected in 1992 and 1994 were used to estimate ADDs for the mallard exposed to Lake Erie surface water. The resulting surface water HIs were at least four orders-of-magnitude less than one, indicating that 1) no ecotoxicological effects are predicted for the mallard from exposure to Lake Erie surface water, and 2) discharges from other BSC-related water bodies (Smokes Creek, Blasdell Creek, and both water return trenches) are not adversely affecting Lake Erie.

4.3 Uncertainty

An uncertainty analysis determined that the majority of the HQs and HIs are most likely overestimated for the following reasons. ADDs were estimated using modeled vegetation/prey concentrations. Uptake factors used to estimate a concentration in vegetation or prey species are generally conservative and do not take into account metabolism, attenuation, and excretion of a chemical. Conservatism was also inherent in the estimation of exposure (assuming 100% bioavailability of all COPECs, upper bound ingestion rates, soil samples biased toward impacted areas), in the inclusion of non-detected compounds as COPECs, and in the disregard for natural attenuation processes (*e.g.*, biodegradation, sorption, volatilization), natural species variability, and avoidance behavior in the ADD calculations.

4.4 Recommendations

Based on the conclusions of the ERA, a Tier 3 ecological risk assessment is not recommended. The information provided in this ERA in conjunction with other information provided in the RFI is adequate for risk management decision-making to determine which SWMUs should be evaluated for remediation and in what order. The calculated risk estimates suggest the potential for unacceptable hazards in several of the SWMUs evaluated in the SFA; however, risk managers should take into account the habitat quality on a SWMU by SWMU basis, as well as constituent bioavailability and attenuation prior to making decisions regarding the necessity for and extent of remediation to be performed at the SWMUs.

5.0 SUMMARY OF THE HUMAN HEALTH RISK ASSESSMENT

This section summarizes the conceptual approach and methodology for evaluating potential human health risks due to releases from solid waste management units (SWMUs) to soil, air, groundwater, sediment, and surface water at or near the Lackawanna facility. The approach and methodologies presented follow the standard steps prescribed in USEPA's guidance, i.e., 1) data evaluation/selection of chemicals of potential concern (COPCs), 2) exposure assessment, 3) toxicity assessment, and 4) risk characterization and uncertainty analysis (USEPA 1989). Part IV of this RFI report provides the technical details of each step summarized in this section. The risk assessment approach adopted for the Lackawanna Facility was initially provided in the HHRA Work Plan (BSC 1997) and subsequent interim deliverables to that Work Plan (BSC 1998, 1999).

Based on the approach and methodologies contained in Part IV, individual risk assessments were completed for each SWMU, SWMU group, or watercourse. These risk assessments are documented in Parts V, VI, and VII of the RFI report. An individual HHRA for Lake Erie receptors and an HHRA for site-wide groundwater exposures are included in Appendices D and E of Part IV. This section of the RFI report summarizes each risk assessment step and the results of the HHRA.

5.1 Data Evaluation and the Selection of Chemicals of Potential Concern

The selection of COPCs is an initial step in the risk assessment process. The selection of COPCs is designed to reduce the number of detected chemicals for quantitative risk evaluation, to those that dominate or provide the major contribution to overall risk estimates. This is accomplished by first developing a dataset of appropriate analytical information for use in both screening and, ultimately, in determining representative concentrations in site media. Elimination of some chemicals was then accomplished during the screening step by applying several criteria.

The sequential application of the selection criteria included:

- The chemical was detected in at least 5% of the samples in the dataset,
- The chemical was detected at a level above the medium-specific maximum background value in at least one sample, and
- The chemical was detected in at least one sample in the dataset above the applicable screening level (or criterion).

The maximum detected concentrations of organic and inorganic chemicals present in surficial and SWMU material, and sediment were compared to maximum concentrations measured in background samples (or obtained from scientific literature). Background data were not available for the other media.

The selected screening criteria were as follows:

- USEPA Region III risk-based concentrations (RBCs) for surficial SWMU material, subsurface SWMU material (nonvolatile chemicals), and sediment (USEPA 2000a),
- USEPA Soil Screening Levels (SSLs) based on inhalation for volatile chemicals in subsurface SWMU material (USEPA 1996a),
- For water (groundwater, surface water, pit water), the lower of the New York State Ambient Water Quality Standard or Guidance Value (NYSDEC 1998) and the USEPA Region III residential tap water RBC (USEPA 2000b).

Because there is no RBC for lead in soil, a screening level of 400 mg/kg was used. This value represents a soil concentration that the integrated exposure uptake biokinetic (IEUBK) model predicts would result in an acceptable blood lead level in children assuming residential exposures (USEPA 1994). Similarly, because there is no screening level for lead in water, the drinking water lead action level of 15 µg/L was used (USEPA 1991c).

Table 5-1 summarizes the chemicals of potential interest initially derived for the facility and the COPCs ultimately selected in at least one medium within a SWMU, SWMU group or watercourse risk assessment.

5.2 Exposure Assessment

The objective of an exposure assessment is the estimation of the type and magnitude of exposures to the COPCs for the site. The types of relevant exposures are identified by determining what complete exposure pathways are or could foreseeably become complete for either the entire site or portions of it. Determining the magnitude of exposures is accomplished by quantifying the intensity, duration, and frequency of exposure events for those complete exposure pathways.

5.2.1 Complete Exposure Pathway Evaluation

The human health risk assessment for the Lackawanna Facility is a conservative, baseline risk assessment of potential health effects caused by releases, in the absence of any actions to control or mitigate those releases. Potential exposure pathways are evaluated with both current and future time frames in mind along with the four components that define an exposure pathway. These are:

- A source and mechanism of constituent release to the environment,
- A mechanism to transport that constituent to an exposure medium,
- A point of potential human contact with the affected medium, and
- A route of entry into humans.

If any of these elements are missing, the pathway was considered incomplete and did not require quantification, or inclusion in the HHRA.

The receptor scenarios evaluated are associated with current use patterns and unrestricted future commercial/industrial development of all areas of the site, as well as recreational development in the area of SFA Zone 1. These populations and a description of their activity patterns that could result in exposure include:

- Current non-BSC Commercial/Industrial Workers – these workers in general are not located in areas where SWMUs are located. Limited exposure to releases to ambient air from nearby sources (i.e., uncovered SWMUs, subsurface SWMU material or from groundwater/pit water).

- Future Commercial/Industrial Workers – these workers are a future population that could come in direct contact with SWMU material, if those areas are redeveloped for some industrial or commercial land use. Inhalation of both ambient and indoor air affected by SWMU releases are also considered relevant exposures.

- Future Construction Workers—this population is possible under future development of the site. Because of excavation-type activities, this population could come in direct contact with both surface and subsurface SWMU material, and well as vapors or particulates released to ambient air from these SWMUs. In some areas of the site, groundwater is sufficiently shallow, resulting in potential direct contact exposures by this population. Similar exposures could occur in site areas where pits are located.

- Future Utility/Maintenance Workers – once the Lackawanna site is redeveloped there is some potential for contact with SWMU material for this type of population, either directly or through inhalation of releases from the SWMUs, groundwater or pit water.

- Future Ship Canal Maintenance Worker –Although the historical activity patterns for workers at this site location is minimal, this population is included. This population could be exposed to both surface water and sediment in the Ship Canal.

- Current and Future Trespassers – This population could bypass site security and freely wander around the site. This population could come in limited contact with surficial SWMU material, as well as vapors and particulates emanating from either the SWMU material, or groundwater and pit water affected by SWMU releases.

- Future Marina Workers – This population could be relevant dependent on recreational development within SFA Zone 1. Although direct contact with SWMU material is not relevant for this population, inhalation of releases from other SWMUs (including groundwater and standing water in pits), are potential exposures.

- Future Greenway Users – Greenway users are assumed to be adults and children residing in the area who would regularly use a proposed greenway area for recreational purposes. As with the marina workers, direct contact with SWMU material is not relevant, but inhalation of releases is a potential exposure.

- Current and Future Recreational Bathers – Recreational bathers are adults and children who regularly wade or swim in Blasdell Creek, Smokes Creek, and along nearshore Lake Erie in the vicinity of the Lackawanna site. Exposures could occur to surface water and sediment in these waterbodies affected by site releases.
- Current and Future Fish Consumers – This population consists of adults and children residing in the area who regularly catch and eat fish from Smokes Creek and nearshore Lake Erie.
- Current and Future Off-Site Residents – These populations consist of adults and children living on the fenceline of the Lackawanna boundary who could be exposed to particulate or vapor releases from SWMU material, including groundwater and pit water affected by releases.
- Present and Future Off-Site Water Consumer: The off-site water consumer population includes adults and children whose drinking water supply is surface water from intakes downstream of the mouth of the Niagara River.

The SWMUs and watercourses described in previous sections are the sources of COPCs that include metals, cyanide, VOCs, PAHs, and other SVOCs. The exposure media relevant for the human receptor populations described earlier include:

- Surficial and subsurface materials within the SWMUs
- Groundwater
- Standing water in Coke Oven Area pits
- Airborne particles and vapors released from SWMU material, groundwater or pit water
- Surface water in Lake Erie, Smokes Creek, Blasdell Creek, the Return Water Trenches (North and South) and the Ship Canal.
- Sediment in Lake Erie, Smokes Creek, Blasdell Creek, the Return Water Trenches (North and South) and the Ship Canal.

- Fish from Lake Erie, Smokes Creek, and Blasdell Creek.

The concentrations and distributions of COPCs can be affected by the following fate and transport mechanisms:

- Leaching from SWMU material to underlying groundwater
- Migration of dissolved COPCs in groundwater to surface water bodies
- Volatilization from SWMU material, groundwater, and pit water to ambient or indoor air,
- Suspension and transport of COPCs in particulate form to ambient air,
- Transport of COPCs adsorbed to soil particles via surface water runoff,
- Biological or chemical transformation,
- Trophic transfer of COPCs in aquatic or terrestrial systems.

The following information was considered in developing the complete exposure pathway determination for the Lackawanna site. On-site groundwater consumption was not considered a complete pathway since potable water supplies at the Site and in the vicinity are provided by surface water intakes in Lake Erie and the southern end of the Niagara River, areas unaffected by Site releases. Residential development is not expected to occur and was not considered a foreseeable future land use. It was assumed that commercial/industrial workers (and buildings to house them) could be present anywhere on the site regardless of the feasibility of this actually happening. Each Part V, VI, and VII SWMU or watercourse report includes more specific information regarding complete exposures evaluated in the risk assessment as well as providing information as to why certain pathways are considered incomplete and, therefore, not evaluated. Table 5-2 summarizes the potential receptor scenarios evaluated at the SWMUs and watercourses.

5.2.2 Quantification of Exposure

In order to develop Risk-Based Screening Levels (RBSLs) and complete the comparison to site concentrations in a risk characterization, two steps were necessary to quantify exposure: 1) the development of population-specific exposure factors as inputs to the RBSL equations and 2) the calculation of representative exposure concentrations for use in the RBSL comparisons.

Several assumptions were made in developing the exposure scenarios that affect the RBSL calculations:

- The conditions at each SWMU were assumed to remain unchanged (except for the scenarios that include intrusive activities). Therefore, no contact with surface material is assumed at covered SWMUs.
- Where surface data were unavailable at uncovered SWMUs, subsurface analytical results were considered representative of surface material.
- For inhalation of airborne particles released from uncovered SWMUs, the receptor was assumed to be actually present on the SWMU.
- For on-site receptors, "direct contact" was defined as total exposure via ingestion, dermal contact, and inhalation of either volatiles or particulates.
- On-site receptors were assumed to spend their entire exposure duration on or in a building at each SWMU.

The human physiological or activity attributes that result in exposure are collectively referred to as exposure factors. These factors are used to define general population behavior, and are conservative estimates derived from scientific studies, observations, or professional judgment. Many are USEPA-recommended default values (USEPA 1991a,b; 1996a). The selections of the exposure factors for all the assumed populations at the Lackawanna Facility are detailed in ID No. 2 and Part IV.

In order to determine if RBSLs are exceeded, it was necessary to develop a representative concentration for each chemical at each SWMU or watercourse undergoing evaluation. These concentrations, referred to as exposure point concentrations, are based on site-specific sampling results described in earlier sections of this RFI report. The available useable analytical data were combined into a dataset and representative concentrations were derived based on guidance in USEPA (1992 and 2002). In general, if the dataset contained 10 or more samples the 95% upper confidence limit (95UCL) of the arithmetic mean was used as the representative concentration. If the 95UCL was greater than the maximum detected concentration, the maximum concentration was considered the representative concentration. If the dataset contained less than 10 samples, the maximum detected concentration was used in the comparison to RBSLs.

In order to estimate intermedia transfers (i.e., SWMU material releases to air, vapor releases from groundwater, etc.) several fate and transport models were used. They included:

- Dispersion modeling to calculate area source emissions using the USEPA Industrial Source Complex Short-Term model,
- Calculation of indoor and ambient air concentrations from modeled volatilization and particulate emission factors,
- Estimation of future surface water concentrations using total mass flux calculations and dilution factors.

Representative concentrations for each COPC, for each SWMU/SWMU Group or Watercourse and for each relevant exposure medium are summarized in Tables 2.4 through 2.10 in the HHRA (Part IV).

5.3 Toxicity Assessment

The toxicity assessment step in the risk assessment process characterizes the relationship between the magnitude of exposure and nature and magnitude of the resulting adverse health effect. In general, chemical toxicity is divided into two broad categories for risk assessment purposes: noncancer and cancer. The USEPA has developed toxicity criteria derived from available toxicological and epidemiological information for one or both categories for most chemicals detected at the Lackawanna Site. Noncancer effects were evaluated using USEPA-derived reference doses (RfDs) and reference concentrations (RfCs). Cancer risks were evaluated using USEPA-derived slope factors (SFs).

The toxicity criteria used in the SWMU/Watercourse risk assessments were selected from a hierarchy including:

- The Risk Information System (IRIS) (USEPA 2000b)
- Health Effects Assessment Summary Tables (HEAST) (USEPA 1997)
- NCEA Provisional Values, as noted in Region III RBC tables (USEPA 2000a)

The toxicity criteria used in the HHRA are summarized in Table 5-3.

Lead, because of its unique toxicological properties was evaluated differently. Lead produces noncarcinogenic effects, but does not appear to have a threshold. The USEPA generally evaluates lead by estimating blood lead levels through pharmacokinetic modeling and comparing them to target blood lead levels. For adult populations, USEPA has developed an Adult Lead Model that predicts an acceptable level of lead in the soil that would be protective of a developing fetus (USEPA 1996b). This model is applicable to the occupational and trespasser receptors at this facility and was used to calculate an RBSL for lead in soil and sediment.

Toxicity values are not available for all chemicals for all routes of exposure. Where appropriate, surrogate chemicals were used both in the screening process and in the risk characterization. For other chemicals, oral toxicity values, but not inhalation are available; dermal toxicity values are not available for any chemical. Route-to-route extrapolations were utilized in these cases. For each extrapolation, the toxicity value was assumed to be the same for each route. This assumption, therefore, assumes that the chemical is equitoxic by both routes (i.e., oral to inhalation, or oral to dermal).

5.4 Risk Characterization

Risk characterization involves estimating the magnitude of the potential adverse health effects of the COPCs and summarizing the nature of the health impact to the assumed receptor populations. Risk characterization for this HHRA was accomplished in two steps. In the first step, RBSLs were calculated for each exposure medium – receptor population combination, and a comparison was done with the representative concentrations calculated for that medium. In the second step, RBSLs exceedances were further evaluated with regard to Tier 1 cancer and noncancer benchmarks.

Risk-based screening levels are chemical concentrations that are not expected to produce adverse health effects under the assumed exposure conditions. Inputs to the screening level calculations are the previously described exposure factors, toxicity values, and any intermedia modeling factors (e.g., the volatilization factors for releases from groundwater or subsurface SWMU material). In addition, the equations require a target hazard index (THI, assumed to be 1) and a target cancer risk level (TR, assumed to be 1×10^{-6}).

The RBSL equations are described in detail in Part IV and the calculated RBSLs for each chemical and receptor combination for each SWMU or watercourse are included in the Part V, VI, VII reports as well as summarized in tables within Section 5 of Part IV. Comparisons of the RBSLs to the representative concentrations are also summarized in those tables.

The comparison of the representative COPC concentration to the RBSL for each receptor population provides a preliminary screening of potential risk. If there were no exceedances of RBSLs, then the conclusion was that no further evaluation with regard to risk is warranted. If there were exceedances of RBSLs, a further evaluation was done that included multiple chemicals, pathways, and calculated total risk estimates.

The further characterization, or Tier 1 HHRA, was accomplished by calculating either (or both) a screening-level hazard index (SLHI) or a total screening-level cancer risk ($\mathrm{SLCR}_{\mathrm{total}}$). These values were then compared with the Tier 1 noncancer benchmark (1) or the Tier 1 cancer benchmark (1×10^{-4}), as established in the work plan (BSC 1997).

For those chemicals that exceed RBSLs based on noncancer hazards, a screening-level hazard quotient (SLHQ) was calculated based on the following equation:

$$\mathrm{SLHQ} = \frac{\text{Representative concentration}_{\mathrm{COPC/medium}}}{\mathrm{RBSL}_{\mathrm{COPC/medium/receptor/pathway}}}$$

The SLHQs for each medium, receptor, and COPC combination were added to derive a noncarcinogenic SLHI.

A further evaluation was done by developing target organ-specific SLHIs. This segregation of effects acknowledges that not all chemicals have the same toxicological endpoints or mechanisms of toxicity. It is, therefore, appropriate to add only those chemicals that have similar effects. Any endpoint-specific SLHQs greater than 1 indicate that noncancer health hazards are unacceptable.

Carcinogenic risks are defined in terms of the probability of an individual developing cancer over a lifetime as the result of exposure to a chemical at a given concentration (USEPA 1989). The incremental probability of developing cancer over a lifetime is referred to as an excess cancer risk, i.e., it is the additional risk above and beyond the risk in the absence of the assumed exposures. The SLCR was calculated by the following equation:

$$\mathrm{SLCR} = \frac{\text{Representative concentration}_{\text{COPC/medium}}}{\mathrm{RBSL}_{\text{COPC/medium/receptor/pathway}}} \; x \; \text{Target Risk Level}$$

An SLCR was calculated for each chemical-specific RBSL exceedance. Cancer risks (i.e., SLCRs) were then summed regardless of target organ differences, weight of evidence categories, or potential antagonistic or synergistic effects. Based on USEPA guidance (USEPA 1989, 1991d) total cancer risks for a given population equal to or less than 1×10^{-4} were considered negligible and further actions to reduce this risk are not warranted.

The second risk characterization step is documented in each SWMU or watercourse report in Parts V, VI, and VII of this RFI report. Tables 5-4 and 5-5 provide a summary of the risk and hazard estimates for each population evaluated in each SWMU, SWMU group, or watercourse. In addition, a Tier 1 HHRA was done for some exposures that are not SWMU-specific. These included exposures to Lake Erie and site-wide exposures to groundwater. The results of these risk assessments are also included in Table 5-5.

The results of the Tier 1 HHRAs conducted for SWMUs, SWMU groups, watercourses and site-wide groundwater, at the Lackawanna Facility, indicate that levels of benzene, naphthalene, pyridine, carcinogenic PAHs, and some metals (notably lead, arsenic, chromium, and thallium) exceed either (or both) noncarcinogenic RBSLs and carcinogenic RBSLs resulting in risk and hazard levels above the Tier 1 benchmarks of 1.0 (for hazard) and 1 x 10^{-4} (for excess cancer risk).

Table 5-4 summarizes the Tier 1 HHRA results for SWMUs and SWMU groups. Risks and hazards are the highest for the future commercial/industrial receptor scenario, which is the population that represents the greatest potential exposure, via multiple pathways, to the COPCs. Since this worker cannot be exposed to ambient air and indoor air simultaneously, risk and hazard estimates were developed separately for ambient air exposures and indoor air exposures as shown on Table 5-4. The $\mathrm{SLCR}_{\mathrm{totals}}$ above the Tier 1 cancer benchmark range from 2 x 10^{-4} to 8 x 10^{-3}. These exceedances are generally attributable to indoor air exposures; benzene is the primary chemical contributor with PAHs contributing at some SWMUs. The $\mathrm{SLHI}_{\mathrm{totals}}$ for the future commercial/industrial worker that exceed the Tier 1 noncancer benchmark range from 1.1 to 1,859. Again, the indoor air pathway is the significant pathway contributor, with benzene and naphthalene the primary chemical contributors. At five SWMUs, the lead RBSL is exceeded, indicating an unacceptable hazard attributable to this chemical.

For the other occupational scenarios exceedances of the risk or hazard benchmarks were not as frequent nor as great. For the future construction workers, $\mathrm{SLCR}_{\mathrm{totals}}$ exceed the Tier 1 benchmark at five SWMUs; risk estimates range from 2 x 10^{-4} to 5 x 10^{-4}. The $\mathrm{SLHI}_{\mathrm{totals}}$ for this population range from 2.5 to 964; benzene is the primary contributor. The lead RBSL is exceeded at five SWMUs for this population as well as the utility/maintenance worker and the trespasser population, thus indicating an unacceptable hazard attributable to this chemical.

For the future utility/maintenance worker, the risk benchmark is met at all SWMUs, however the hazard benchmark is not. The $\mathrm{SLHI}_{\mathrm{totals}}$ for this population range from 2.6 to 119 (benzene). Exceedances of the hazard benchmark for the non-BSC commercial/industrial worker are limited to five SWMUs. The $\mathrm{SLHI}_{\mathrm{totals}}$ range from 1.1 to 5.1 (benzene). Risk benchmarks are not exceeded at any SWMU for this receptor scenario.

For the trespasser receptor scenario, all risk and hazard benchmarks are met, except for lead at five SWMUs. For the future marina worker, the only benchmark exceedance occurs at SFA-2, where the $\mathrm{SLHI}_{\mathrm{total}}$ is 4.9 (benzene).

There are no exceedances of either risk or hazard benchmarks at any SWMU location for either the future greenway user or present/future fenceline resident population.

Table 5-5 summarizes the SLHI and SLCR values for populations evaluated for the watercourses and site-wide groundwater exposures. Benchmark exceedances occur only at Smokes Creek and the South Return Water Trench. The only exceedance of the risk benchmark (5×10^{-4}) is associated with the indoor air pathway for a future commercial/industrial worker encountering groundwater in the area of Smokes Creek. This exceedance is attributable to benzene in the groundwater in this area. The $SLHI_{total}$ for this population at this location ranges from 10 (ambient air) to 218 (indoor air). Both benzene and pyridine contribute to these exceedances. Other hazard exceedances are noted for the utility/maintenance worker at the South Return Water Trench (1.1, attributable to arsenic). For the future construction worker at Smokes Creek, a SLHI of 4.0 was calculated. This exceedance is attributable to pyridine.

For all other receptor scenarios at the other watercourses, and for site-wide groundwater, there are no exceedances of risk or hazard benchmarks. In some locations and for some populations, not even RBSLs are exceeded, indicating that a Tier 1 HHRA (i.e., the calculation of SLCR and SLHI values) was not needed. Tables 5-4 and 5-5 indicate these receptor/location combinations.

Based on the above information, most SWMUs require some evaluation as part of the Corrective Measures Study. The risk assessment concludes, however, that three SWMUs (S-15, S-16, and S-25), as well as Blasdell Creek, the Ship Canal, the North Return Water Trench, and Lake Erie do not warrant evaluation of remedial activities for the protection of human health. Further evaluation of the results of the SWMU, SWMU Group and Watercourse Assessments is provided in Section 6.0 of the RFI.

5.5 Uncertainty Analysis

There are multiple sources of uncertainty in any exposure and risk estimate. Each time a single assumption is used to describe a dynamic parameter, some level of uncertainty is introduced. Some assumptions have some or significant scientific basis, others do not. The selection of multiple, conservative assumptions, especially in the exposure assessment, generally results in an overestimation of potential health risks posed by the site. The key factors and assumptions that are primary contributors to uncertainty in the risk assessments for the SWMUs and watercourses are discussed in detail in Part IV of this RFI report and are summarized below. Each SWMU/watercourse risk assessment provides additional uncertainties specific to, or applicable, to the area. The major sources of uncertainty include:

- Use of biased sampling locations to represent average chemical concentrations for a receptor scenario,
- Use of multiple, conservative exposure factors to quantify the level of exposure for each receptor scenario,
- The inclusion of receptor scenarios that are not part of the foreseeable plan for the development of the Lackawanna Facility,
- The use of fate and transport modeling to predict a protective level of lead in SWMU material; as well as the magnitude of releases from SWMU material and groundwater to either ambient or indoor air.
- The accuracy of toxicological criteria based on animals studies
- The toxicological model of cancer potency using the Linearized Multistage Model,

The net effect of the uncertainties in these risk assessments is the generation of excess cancer risks and hazards that probably far exceed any likely exposure conditions either now or in the future at the Lackawanna site.

5.6 References

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6.0 SUMMARY OF SWMU/WATERCOURSE RESULTS

As discussed in Section 3.1, 104 SWMUs and six watercourses were investigated as required in the AOC. Between 1988 and 1992, 59 SWMUs and one watercourse were determined to require "No Further Assessment" by the USEPA and as such are no longer a regulatory concern. Documentation of the BSC submittal letters to the USEPA regarding each of these 60 reports and the respective letters from the USEPA granting no "further assessment designation" is provided in Part V of the RFI. A summary of the remaining 45 SWMUs and five watercourses that were evaluated in the phased RFI investigations is provided below.

6.1 SWMU/SWMU Group Results

As summarized in Section 3.1, SWMUs at BSCs Lackawanna site were designated as either "P" or "S" SWMUs. "P" SWMUs are located within former process areas of the plant. "S" SWMUs are located within the SFA. Each SWMU was investigated as required by the AOC. In some instances, where locations and waste types were similar, multiple SWMUs were evaluated as part of a SWMU Group. For each SWMU or SWMU Group, chemical analysis of SWMU material (when available) was evaluated and compared to local groundwater conditions. The material was often evaluated for hazardous waste characteristics and its potential to leach (SPLP extraction analysis). Total constituent results, when available, were also evaluated in a Tier I Human Health Risk Assessment. Details of how the SWMUs and SWMU Groups were investigated are summarized in Section 3.1. Parts V and VI of the RFI also include the complete final Assessment Report for each SWMU or SWMU Group.

6.1.1 SWMU Group PA-1

SWMU Group PA-1 includes SWMUs P-1, P-2, P-3, P-4, and P-5 which, because of similar waste streams and processes, are grouped together for the Human Health Risk Assessment (HHRA). SWMU Group PA-1 consists of the following Coke Oven Quench Water Pits: North Station (P-1), Arctic Station (P-2), Central Station (P-3), "A" Station (P-4), and "B" Station (P-5). These Coke Oven Quench Water Pits were concrete pits used to receive and recycle quench water from the coke-making operations. Coke fines ("breeze") that were collected in the pits were periodically removed for recycling.

VOCs, SVOCs, metals, and cyanide were detected in the material around these SWMUs. However, SPLP analysis indicates that the SWMU materials have a low potential to leach. Groundwater analytical results indicate the presence of several VOCs, SVOCs, cyanide, and numerous metals in the groundwater beneath SWMU Group PA-1. Because a groundwater mound has historically been present beneath the Coke Ovens it is possible that these groundwater constituents may be sourced from other Coke Oven operations (upgradient of the pits) rather than being related to SWMU Group PA-1.

The results of the Tier 1 HHRA show that certain compounds in Coke Oven groundwater exceed carcinogenic and/or noncarcinogenic RBSLs, producing either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the carcinogenic benchmark of 1×10^{-4} for certain scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the Corrective Measures Study (CMS).

6.1.2 SWMU Group PA-2

SWMU Group PA-2 includes SWMUs P-6 and P-7. Group PA-2 consists of two adjacent concrete pits: the former Lime Sludge Settling Basin (P-6) and the Abandoned Lime Sludge Settling Basin (P-7).

TCLP analytical results for both SWMU units indicate that the materials adjacent to SWMU P-6 and within SWMU P-7 do not exceed the toxicity characteristic criteria of a RCRA Hazardous Waste. Total constituent analysis of SWMUs P-6 and P-7 material detected VOCs, SVOCs and metals, with the highest SVOCs concentrations in the SWMU P-7 sample. SPLP analysis of SWMUs P-6 and P-7 material shows only trace levels of polycyclic aromatic hydrocarbons (PAHs), a subset of SVOCs, in the SWMU P-7 material.

The results of the Tier 1 HHRA show that levels of benzene and naphthalene in groundwater and benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h) anthracene and indeno(1,2,3-c,d)pyrene in surficial SWMU material exceed noncarcinogenic and/or carcinogenic RBSLs, and produce either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the Tier 1 carcinogenic benchmark of 1×10^{-4} for some receptor scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.3 SWMU Group PA-3

SWMU Group PA-3 includes SWMUs P-9 and P-10, and consists of the "Abandoned Tar Decanter Sludge Pit" (P-9) and the adjacent "Contaminated Soil Area near the Ball Mill" (P-10).

TCLP analysis of SWMU P-9 material indicates that benzene concentrations exceed the toxicity characteristic criterion for a RCRA characteristic hazardous waste. TCLP analysis of SWMU P-10 indicates that the material did not exceed the toxicity characteristic criteria for a RCRA Hazardous Waste. Total constituent analysis of SWMU P-10 material detected several VOCs, SVOCs, and metals. In particular, several PAH compounds were detected at elevated levels.

Groundwater analytical results indicate that metals in the SWMUs may be affecting the underlying groundwater. However, because SWMUs P-9 and P-10 are located in the former Coke Oven Area, the groundwater results may also reflect contributions from other Coke Oven Area operations.

The results of the Tier 1 HHRA show that levels of benzene and naphthalene in Coke Oven groundwater exceed noncarcinogenic and/or carcinogenic RBSLs, and produce either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the Tier 1 carcinogenic benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation may be completed during the CMS.

6.1.4 SWMU P-11

SWMU P-11 consists of the former Benzol Plant Tank Storage Area at the southern end of the former Benzol Plant.

TCLP analysis indicated that the material in SWMU P-11 does not exceed the toxicity characteristic criteria for a RCRA Hazardous Waste. Total constituent analysis of SWMU P-11 material indicated the presence of VOCs (including benzene, toluene, ethylbenzene and xylenes) and metals. SPLP results of SWMU P-11 material showed only one VOC.

Groundwater results indicated VOCs, SVOCs, metals, and cyanide were present in the groundwater wells immediately surrounding SWMU P-11. LNAPL (0.02 feet to 2 feet thick) was present in groundwater wells at the former Benzol Plant Area. Analysis of the LNAPL indicated that it contained BTEX compounds, SVOCs, metals, and PCBs. Additionally, groundwater beneath and around the Benzol Plant has historically contained BTEX and several SVOCs also found in the LNAPL samples.

The results of the Tier 1 HHRA show that levels of benzene, naphthalene and toluene in subsurface SWMU material, benzene and naphthalene in groundwater, and benzene in #17 Pit water exceed noncarcinogenic RBSLs, producing a hazard index greater that the Tier 1 noncarcinogenic benchmark of 1.0 for certain scenarios. Also, levels of benzene in subsurface SWMU material, and benzene in groundwater exceed carcinogenic RBSLs, and produce carcinogenic risk levels greater than the Tier 1 carcinogenic risk benchmark of 1×10^{-4}. The SWMU P-11 area is adjacent to the former Spill Cleanup Soil Storage Area (SWMU P-12) and because of this and the common waste history of the two SWMUs, the HHRA also included data from SWMU P-12.

Based on these results, further evaluation may be completed during the CMS.

6.1.5 SWMU P-12

SWMU P-12 is identified as the Spill Cleanup Soil Storage Area due to its one-time use, starting in 1987, as a storage area for material contaminated with oil as the result of a spill at the former Benzol Plant. The material was removed from SWMU P-12 in 1992.

Results of TCLP analysis of oil-contaminated material (1989) and the remaining surface soil samples, following removal of the oily material, indicate that neither oil contaminated material or the underlying surface soils exceeds the toxicity characteristic criteria for a RCRA hazardous waste. For the remaining surface soils, VOCs, several SVOCs and metals were detected in the total constituent analysis while only metals were detected in the SPLP analysis. This indicates that the compounds in SWMU P-12 materials have a low potential to leach. No subsurface soil samples were collected.

Groundwater analytical results from both upgradient and downgradient wells indicate the highest concentrations of VOCs and SVOCs are present in the upgradient well with no apparent additive effect attributable to the former storage of oil-contaminated material in SWMU P-12. Groundwater is likely impacted by the adjacent upgradient Benzol Plant Area (SWMU P-11).

The results of the Tier 1 HHRA show that levels of benzene, naphthalene and toluene in subsurface SWMU material and benzene and naphthalene in groundwater exceed noncarcinogenic RBSLs, producing a hazard index greater that the Tier 1 noncarcinogenic benchmark of 1.0 for certain scenarios. Also, levels of benzene in subsurface SWMU material, and in groundwater exceed carcinogenic RBSLs, and produce carcinogenic risk levels greater than the Tier 1 carcinogenic risk benchmark of 1×10^{-4}. The area is adjacent to the former Benzol Plant (SWMU P-11) and because of this and the common waste history; the HHRA also included data from SWMU P-11.

Based on these results and in accordance with the Work Plan, further evaluation may be completed during the CMS.

6.1.6 SWMU P-18

SWMU P-18 consists of two water filled, steel lined basins (Hot and Cold Wells) related to the former Blast Furnace Cooling Towers. These cooling towers served as the wastewater treatment system for the blast furnace operations' gas cleaning system.

TCLP results indicate that lead detected in SWMU P-18 material sediment exceeds the toxicity characteristic criteria for a RCRA Hazardous Waste. However, the Blast Furnace sludge in the Hot and Cold Wells is explicitly excluded from hazardous waste regulations under RCRA Subtitle C and is codified in 40 CFR Part 261.4(b)7(ii)(L). VOCs, SVOCs, and metals were detected in the total constituent and SPLP analyses of the sediment samples.

Groundwater analytical data indicates that the majority of VOCs, SVOCs, and metals were detected at higher concentrations in the upgradient wells than in the respective downgradient wells. Based on this data, it is unlikely that the materials stored in SWMU P-18 have had an additive effect on the groundwater beneath the SWMU.

The results of the Tier 1 HHRA show that levels of benzene and naphthalene in Coke Oven groundwater are greater than carcinogenic and noncarcinogenic RBSLs and produce either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the carcinogenic benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation may be completed during the CMS.

6.1.7 SWMU P-63

SWMU P-63, located in the East Plant area, is identified as "Mill Scale Storage Area No. 2" because oily mill scale was stored in the area prior to 1992.

TCLP analysis of oily mill scale prior to its removal for recycling shows that this material did not meet the criteria of a RCRA characteristic hazardous waste. Total constituent analysis indicates that VOCs, SVOCs, and metals are present in the surface and subsurface soils. However, the SPLP analysis indicates that only one SVOC and three metals appear to have the potential to leach from the surface and subsurface soils. No groundwater data is available for the East Plant area.

The results of the HHRA are that none of the chemicals in the SWMU material exceeds Tier 1 noncarcinogenic or carcinogenic benchmarks for any of the scenarios.

Based on these results and in accordance with the work plan, further evaluation is not warranted during the CMS.

6.1.8 SWMU P-73

SWMU P-73 is located at both the Former Drum Storage Area east of the Cold Strip Mill and Flander's Field, both in the East Plant area. The Former Drum Storage Area was used to store drums prior to construction of a gas compressor station in the area. Flander's Field is the area where excavated soil from the Former Drum Storage Area was placed in order to facilitate the construction the gas compressor station in the Former Drum Storage Area.

TCLP analysis indicates that the SWMU materials do not exceed toxicity characteristic criteria for a RCRA Hazardous Waste. Total constituent analytical results, when compared to subsequent SPLP results, indicate that hazardous constituents within both the subsurface materials in the Former Drum Storage Area and the stockpiles on Flander's Field, have a low potential to leach. No groundwater data is available for the East Plant Area.

The results of the Tier 1 HHRA show that arsenic and chromium in surface SWMU material produce noncarcinogenic hazard levels that are greater than the Tier 1 noncarcinogenic benchmark of 1.0 for some receptor scenarios.

Based on these results and in accordance with the Work Plan, further evaluation will be completed during the CMS.

6.1.9 SWMU Tank Farm Group

The SWMU Tank Farm Group includes SWMUs P-74, P-75, and P8, which, because of common waste histories and locations, are grouped together. SWMU P-75 is the Tank Farm area and encompasses SWMU P-74 (the former tank-bottom "Waste Piles in Tank Farm" areas) and SWMU P-8 (the two former "Waste Oil Storage Tanks").

TCLP analyses of Tank Farm materials do not exceed toxicity characteristic criteria for a RCRA Hazardous Waste, except for benzene in one SWMU P-75 sample. Total constituent and SPLP analyses of the Tank Farm boring samples detected several VOCs, SVOCs, and metals. The compounds detected in SPLP soil analysis were also detected in groundwater analysis, indicating that the Tank Farm materials may be contributing to groundwater contamination. In addition, VOCs and SVOCs detected in the downgradient wells were not detected in the upgradient wells.

The results of the Tier 1 HHRA show that levels of arsenic and antimony in surface soil, and benzene and naphthalene in subsurface SWMU material exceed noncarcinogenic RBSL, and produce a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0 for certain receptor scenarios. Additionally, the levels of arsenic, benzene, benzo(a)anthracene, and benzo(a)pyrene in subsurface SWMU material and arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene in surficial SWMU material exceed carcinogenic RBSLs and produce carcinogenic risk levels greater than the Tier 1 carcinogenic risk benchmark of 1 x 10^{-4} for some receptor scenarios.

Based on these results, further evaluation may be completed during the CMS.

6.1.10 SWMU Group SFA-1

SWMU Group SFA-1, the Zone 2 SWMUs, consists of adjacent SWMUs S-1, S-2, S-4, S-5, S-6, S-7/S-20, and S-27, which are grouped together for the HHRA. SWMU Group SFA-1 is located in the western end of Zone 2 within the Slag Fill Area (SFA) in an area known as "the impoundments."

SWMUs S-1 and S-5 in Group SFA-1 were observed to have exposed liquids and at times oil on the surface of the impoundments. RFI and non-RFI investigations found no samples which exceeded TCLP criteria for a RCRA characteristic hazardous waste.

Historic documents obtained from regulatory agencies, including the COE show that the dredge spoils were deposited off the BSC Lackawanna facility shoreline from at least 1937 to 1948. These spoils underlie a significant portion of the SFA, including the area immediately adjacent and potentially under several SWMUs in the SWMU Group SFA-1. The potential impact to groundwater in the sand unit beneath the site in the northern portion of SFA-1 is further assessed in this RFI report.

Total constituent and SPLP analyses indicate the presence of several VOCs, SVOCs, metals, and cyanide in the SWMU material. Similar compounds are also noted in the groundwater samples collected from the wells surrounding the SWMUs. However, the contribution of these particular SWMUs to the groundwater contamination is not known, as groundwater constituents have also been detected in upgradient wells.

The results of the Tier 1 HHRA indicate that levels of antimony, arsenic, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-c,d)pyrene in surficial SWMU material, and benzene and naphthalene in subsurface SWMU material exceed carcinogenic and/or non-carcinogenic RBSLs, producing either a hazard index greater than the Tier 1 non-carcinogenic benchmark of 1.0, or a carcinogenic risk greater than the carcinogenic benchmark of 1×10^{-4}.

Levels of lead in surficial material exceed direct contact RBSLs for all populations evaluated.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.11 SWMU S-3

SWMU S-3 is the Ammonia Still Lime Sludge (ASLS) impoundment that received ammonia still lime sludge and sludges from BSC's Basic Oxygen Furnace and from Blast Furnace Final Thickeners. This SWMU is also located in the area known as the "impoundments" and is adjacent to SWMUs S-2, S-4 and S-7/20.

SWMU S-3 is a de-listed Hazardous Waste Management Unit, based on waste sampling results from the non-RFI 1985, 1988 and 1992 investigations. Numerous SVOCs and metals were detected in subsurface soil samples collected in the earlier de-listing investigations and in the surface soils collected in the 2001 Ecological Risk Assessment Investigation. As part of the Contingency Closure Plan and Post-Closure Plan for SWMU S-3, groundwater sampling has been conducted for one upgradient well and three downgradient wells monthly during 1985 and quarterly or semiannually thereafter.

The November 1999 RFI facility-wide sampling event indicated that in general, concentrations of VOCs were greater in downgradient fill unit wells compared to the upgradient fill unit well. Most SVOCs and metals detected were at similar concentrations between upgradient and downgradient fill wells. In general, VOC and SVOC concentrations were higher in the downgradient sand well, when compared to the upgradient sand well.

Because semi-annual groundwater data is available since 1995, a Mann-Kendal trend analysis was conducted for the fill unit wells. Several VOCs and SVOCs detected in November 1999 exhibited either an upward or downward trend scenario for the downgradient wells. Several metals (total and dissolved) detected in November 1999 showed an upward trend in both the upgradient and downgradient wells, suggesting that those particular metals may not be sourced from SWMU S-3.

Historical documents indicate that the USACE deposited dredge spoils off the BSC Lackawanna facility shoreline from at least 1937 to 1948. Because of these USACE dredge spoils that underlie a significant portion of SWMU S-3, the contribution of this particular SWMU to groundwater contamination within the sand unit is not known.

The results of the Tier 1 HHRA show that the concentration of lead in surface and/or subsurface SWMU material is greater than the RBSL for some scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.12 SWMU S-8

SWMU S-8 was constructed as an impoundment to be used for waste storage but was never put into use. SWMU S-8 is known as Surface Impoundment H and was declared a SWMU because of the unknown nature of the fill material used to construct the impoundment. .

TCLP analysis of the SWMU material (i.e. impoundment walls and floor) in 1992 indicates that the material does not exceed the criteria of a RCRA Characteristic Hazardous Waste. Total constituent analysis indicates the presence of one VOC, several SVOCs and metals in the floor of the SWMU. Metals were also detected in the wall material. No compounds were detected in the SPLP analysis of either material.

The results of the Tier 1 HHRA show that levels of arsenic, chromium and thallium in surficial SWMU material are greater than RBSLs and produce a noncarcinogenic hazard index greater than Tier 1 the noncarcinogenic benchmark of 1.0 for some scenarios.

For some scenarios, concentrations of cresols and zinc in groundwater contribute to a noncarcinogenic hazard index greater than 1.0. For some receptor scenarios lead levels exceed the calculated RBSL.

Based on these results and in accordance with the work plan, further evaluation may be completed during the CMS.

6.1.13 SWMU S-10

SWMU S-10 is known as Slag Quench Area J. The SWMU was originally used to quench slag with weak ammonia liquor from the 1960's to the 1980's. The SWMU has been inactive since the 1980's and consists of an empty pit. No waste is stored in this pit.

TCLP analysis of the SWMU material indicates that the material does not exceed the criteria of a RCRA Characteristic Hazardous Waste. Total constituent analysis indicates the presence of VOCs, SVOCs, metals and cyanide.

The 1999 and 2000 groundwater analytical results indicate that the low levels of organics and metals are present in the groundwater beneath the SWMU. Most SVOCs and metals were present in slightly higher concentrations in the downgradient wells. The downgradient wells are located within areas determined to be historical USACE dredge spoils disposal grounds. As such, the contribution of SWMU S-10 to groundwater contamination cannot be fully determined.

The results of the Tier I HHRA indicate that thallium and chromium in surface SWMU material exceed noncarcinogenic RBSLs and produce calculated hazard indices that are greater than the Tier 1 benchmark of 1.0.

Based on these results, further evaluation may be completed during the CMS.

6.1.14 SWMU S-11

SWMU S-11 consists of Landfill K (Acid Tar Pit South), which received waste materials from steel and coke making at the BSC facility. Due to the nature of the materials within the Acid Tar Pits (ATPs), a groundwater mound exists in the area of SWMU S S-11 as well as SWMU S-22. Because SWMU S-11 is adjacent to SWMU S-22 and due to the presence of common waste types in both SWMUs, the Tier I HHRA used data from both SWMU S-22 and SWMU S-11 in the evaluation.

The investigations identified three waste types within SWMU S-11: coal tar, waste lime, and iron precipitator dust. Numerous hazardous constituents (VOCs, SVOCs, and metals) and materials of high pH (>11 s.u.) are present in the SWMU material. The concentrations of hazardous constituents and pH levels vary within each waste type.

RFI sampling indicates that materials stored within SWMU S-11 do not exceed TCLP criteria for a RCRA characteristic hazardous waste. However, the non-RFI sampling indicates that the SWMU material contains benzene at a concentration that exceeds RCRA TCLP criteria.

SVOCs, VOCs, and metals were present in both the upgradient and downgradient wells. In general, reported concentrations of VOCs and SVOCs in downgradient wells were significantly less than their respective concentrations in the wells in and near SWMU S-11.

The results of the Tier 1 HHRA reveal that levels of arsenic in surface SWMU material and benzene, naphthalene and toluene in subsurface SWMU material exceed noncarcinogenic RBSLs, and produce hazard indices greater than the noncarcinogenic benchmark of 1.0 for certain receptor scenarios. Also, levels of benzene, 1,1,2,2-tetrachloroethane and trichloroethene in subsurface SWMU material exceed carcinogenic RBSLs, and producing carcinogenic risk levels greater than the Tier carcinogenic risk benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.15 SWMU S-12

SWMU S-12 is known as Asbestos Landfill L because it received bagged asbestos material and possibly other waste materials. SWMU S-12 is currently maintained as a NYSDEC-permitted landfill.

Because of the nature of the landfilled material (sealed bags of asbestos) SWMU materials were not collected for analysis.

Groundwater sampling results from the events conducted in 1995 and 1999 indicate that asbestos wastes placed in the landfill have not contributed to the COPIs detected in the groundwater. The hazardous compounds identified in upgradient and downgradient wells are not associated with the asbestos or asbestos-related materials placed in the landfill.

Since the asbestos material was disposed in sealed plastic bags, the downward migration of insoluble asbestos to the groundwater table is unlikely. The landfill construction methods and the slag cover prevent exposure pathways via ingestion, inhalation, and dermal contact.

In accordance with ID No. 1, SWMU S-12 has been eliminated from quantitative analysis in the risk assessment. This landfill has not experienced a release of hazardous constituents and is not likely to experience a release in the future. There is no available exposure pathway to direct human contact, nor to groundwater, surface water or air. Therefore, further evaluation during the CMS is not warranted.

6.1.16 SWMU S-13

SWMU S-13 is known as the Tar Sludge Surface Impoundment because it contains tar decanter sludge material generated during the coking process at the BSC facility. Prior to 1982, solid wastes including iron-making slag, coke fines, coal tar tank bottoms, and ammonia absorber acid oil were co-disposed with tar decanter sludge in SWMU S-13.

SWMU S-13 was closed in the fall of 1988 in accordance with the Consent Agreement and applicable New York and federal closure requirements for a landfill containing RCRA hazardous wastes. The surface impoundment was covered with a polyethylene geomembrane cap, clay, topsoil and grass. Runoff and diversion ditches were also installed around the surface impoundment. Groundwater monitoring in support of the impoundment closure requirements is currently conducted on a semi-annual basis.

The RFI 1999 facility-wide sampling event indicated VOC concentrations were higher in the upgradient well compared to the four downgradient wells. The SVOC concentrations were generally higher in the downgradient wells. The total metals concentrations were generally higher in the upgradient wells.

Although VOCs and SVOCs were detected in the downgradient wells, and SVOC concentrations were generally higher in the downgradient wells, statistical trend analysis of the semiannual groundwater sampling program shows that a majority of the VOC and SVOC concentrations have remained static or trended downward. This indicates the construction of the impermeable cap in the late 1980s is preventing further leaching of the waste material.

In accordance with ID No. 1 (BSC, 1998b), SWMU S-13 (also known as HWMU 1A) has been eliminated from quantitative analysis in the risk assessment. Under a NYSDEC-approved closure plan, in 1987, SWMU S-13 was closed and capped as a hazardous waste impoundment, and deed restrictions were implemented to restrict future use on and around the site. This SWMU is currently monitored under a NYSDEC-approved post-closure plan.

From 1978 to 1982, SWMU S-13 was used to dispose of several non-hazardous wastes including iron-making slag, coke fines, coal tar tank bottoms and ammonia absorber acid-oil. Coal tar sludge, or decanter sludge, is the only listed hazardous waste disposed of in S-13. BSC does not have data from S-13 that meet the criteria established for use in a risk assessment. In addition, the available waste characterization data relevant to S-13 are for coal tar sludge (primarily Toxicity Characteristic Leaching Procedure analyses); however, less than 1% of the material in S-13 is believed to be coal tar sludge. Because data are not available for the SWMU itself, COPC selection could not be performed for this unit.

The potential for exposure to constituents in groundwater (e.g., inhalation of volatiles) are not specifically applicable to this SWMU, as potential receptor populations are restricted access to and near this SWMU.

It is unlikely that the material in S-13 is capable of posing a substantial present or future hazard to human health. With such a small amount of the waste in S-13 being derived from hazardous waste, completed closure (including the installation of a permanent non-permeable cap under the close supervision of NYSDEC), and deed restrictions on future use, potential threat associated with human health (e.g.,, direct contact with SWMU material) has been removed (to the extent such a threat ever existed). Further, BSC continues to comply with post-closure care requirements for S-13. Therefore, as BSC continues to comply with these requirements, it is not believed that S-13 poses a current or future threat to human health and no further assessment is warranted.

6.1.17 SWMU S-14

SWMU S-14 is General Rubble Landfill N, an area used to dispose of discarded material from plant operations at the BSC facility.

TCLP results demonstrate that the material within SWMU S-14 does not exceed the criteria for a RCRA characteristic hazardous waste. Total constituent analysis shows that the VOCs, SVOC, and metals are present, while the SPLP data indicates only SVOCs have the potential to leach from the material. Groundwater within Zone 4 contains concentrations of VOCs, SVOCs, and metals. Because there is no groundwater data downgradient of SWMU S-14 the contribution of this particular SWMU to groundwater is not known.

The results of the Tier I HHRA indicate that benzene and naphthalene in subsurface SWMU material exceed noncarcinogenic RBSLs and result in calculated hazard indices greater than the Tier 1 benchmark of 1.0.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.18 SWMU S-15

SWMU S-15 is identified as General Rubble Landfill O.

TCLP analysis of SWMU S-15 material indicates that the material did not exceed TCLP toxicity characteristic criteria for a RCRA hazardous waste. Total constituent analysis shows the presence of SVOCs and metals in the SWMU material, while SPLP analysis indicates only a few metals have the potential to leach.

Groundwater results indicate constituents of concern generally are found at higher concentrations in the upgradient well than in the downgradient well. Comparison of SPLP and groundwater results indicates that the SWMU material has not had an additive on the underlying groundwater quality.

The results of the HHRA are that none of the chemicals in surface SWMU material or Zone 4 groundwater exceeds Tier 1 noncarcinogenic or carcinogenic RBSLs for any of the scenarios.

Based on these results and in accordance with the work plan, further evaluation is not warranted during the CMS.

6.1.19 SWMU S-16

SWMU S-16 is known as the Lime Stabilized Pickle Liquor Sludge Landfill, because it received spent pickle liquor (SPL) sludge. The landfill, which is covered with a geomembrane cover, has been closed on an interim basis pending a final decision on the 1985 De-listing petition.

TCLP metals analysis of SWMU S-16 material prior to placement of the geomembrane cover indicates that the material did not exceed TCLP toxicity characteristic criteria for a RCRA hazardous waste. No TCLP, VOC or SVOC analysis was conducted. The presence of several metals within the downgradient groundwater may be related to SWMU S-16.

Groundwater lies approximately 9 feet below the floor of the landfill. The landfill construction methods and the geomembrane cover prevent exposure pathways via ingestion, inhalation, and dermal contact.

The results of the Tier 1 HHRA show that no chemicals in subsurface SWMU material or Zone 4 groundwater exceed any of the calculated RBSLs.

Based on these results and in accordance with the work plan, further evaluation is not warranted during the CMS.

6.1.20 SWMU S-17

SWMU S-17 is known as the former Vacuum Carbonate Blowdown Landfill Q. The site consists of two parallel, northwest-southeast oriented trenches that are approximately 300 feet long. The two trenches were reportedly used as a disposal area for "vacuum carbonate blowdown solution". This solution was a liquid waste from a coke oven gas desulfurization process.

TCLP analysis of the SWMU S-17 material indicates that the material does not exceed the toxicity characteristic criteria for a RCRA hazardous waste. Total constituent analysis shows that several VOCs, SVOCs, and metals are present in the SWMU material. SPLP analysis indicates that the analytes present in the SWMU material are not likely to leach at significant concentrations.

The results of the Tier 1 HHRA indicate that levels of mercury and chromium in surface SWMU material are greater than noncarcinogenic RBSLs and the calculated hazard indices are greater than the Tier 1 noncarcinogenic benchmark of 1.0 for some scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.21 SWMU S-18

SWMU S-18 is identified as the Lime Dust and Kish Landfill R, because it received two waste products of the basic oxygen furnace process—lime dust (calcium oxide) and kish (consisting principally of carbon fines).

In the 1992 TCLP analysis, metals in the SWMU material (lime dust and kish) did not exceed the toxicity characteristic criteria for a RCRA hazardous waste. In the 2000 TCLP analysis, lime dust was determined to be non-hazardous, however lead in the kish material exceeded the toxicity characteristic criterion for a RCRA hazardous waste. Total constituent analysis of the kish material in 2000 detected four PAHs at low concentrations and eight metals. The 2000 total constituent analysis and SPLP analysis indicated that, in general, the metals detected have the potential to leach.

Groundwater results indicate that SWMU S-18 has not impacted the shallow fill unit groundwater beneath the SWMU. The analytical results from the deeper "B" wells indicate that the sand unit may have been impacted by an on-site source. However, because this SWMU is located within areas determined to be historical USACE dredge spoils disposal grounds, the contribution of SWMU S-18 to groundwater contamination is not known.

The results of the HHRA indicate that antimony, arsenic, and thallium in surficial SWMU exceed noncarcinogenic RBSLs and produce a hazard index greater than the Tier 1 acceptable noncarcinogenic benchmark of 1.0 for certain scenarios. Additionally, lead in surficial SWMU material is found at a level higher than the Tier 1 RBSLs for some scenarios. And in subsurface SWMU material, the representative concentration of lead exceeds RBSLs for certain scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.22 SWMU S-19

SWMU S-19 is identified as Landfill AA (Murphy's Mountain). This unit was constructed out of site rubble for the use as a "wind-break" for the coal pile storage area to the east.

TCLP analysis indicated that SWMU S-19 material does not exceed TCLP criteria for a RCRA characteristic hazardous waste. Total constituent and SPLP analysis for soil samples detected VOCs, SVOCs, and metals.

Groundwater monitoring results indicate several VOCs, SVOCs, and metals in adjacent/downgradient fill wells. In general, higher concentrations of analytes were detected in the fill wells downgradient from SWMU S-19. No VOCs or SVOCs were detected in upgradient sand unit well, although numerous VOCs, SVOCs and metals were detected in downgradient sand unit well. The effect of the previously mentioned USACE dredge spoils on the sand unit groundwater quality in this area is not known.

The results of the HHRA are that none of the chemicals in SWMU exceed Tier 1 noncarcinogenic or carcinogenic benchmarks for any of the scenarios.

Based on these results and in accordance with the work plan, further evaluation is not warranted during the CMS.

6.1.23 SWMU S-21

SWMU S-21, known as the Scrap Melter Dust Storage Area, was used to store precipitator dust that resulted from the operation of the scrap melter.

Total constituent analysis indicated the presence of several metals in the SWMU S-21 waste material. TCLP results demonstrate that the waste material does not exceed the criteria of a RCRA characteristic hazardous waste. SPLP analysis indicated that lead has the potential to leach from the SWMU material, although analytical results from downgradient monitoring wells reveal that the wells were not significantly impacted by lead. No VOCs or SVOCs were detected in the total, TCLP, and SPLP analyses.

The presence of organic compounds and inorganic analytes in upgradient and downgradient/crossgradient monitoring wells likely can be attributed to the Acid Tar Pits (SWMUs S-11 and S-22). These units are known to contain constituents (VOCs, SVOCs, metals, and cyanide) that are impacting groundwater in this area.

The results of the Tier 1 HHRA indicate that levels of antimony and arsenic in surficial SWMU material are greater the noncarcinogenic RBSLs and generate a calculated hazard index that is greater than the Tier 1 noncarcinogenic benchmark of 1.0 for certain scenarios. Additionally, the maximum concentrations of lead exceed RBSLs for certain scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.24 SWMU S-22

SWMU S-22 is identified as the Vacuum Carbonate Blowdown Impoundment (Acid Tar Pit North) and was used to store acid tar from the cokemaking and off-gas operations. Due to the nature of the materials within Acid Tar Pits (ATPs), a groundwater mound exists in the area of SWMU S-22 and S-11. Because SWMU S-11 is adjacent to SWMU S-22 and the presence of common waste types, the Tier I HHRA used data from both SWMU S-22 and SWMU S-11 in the evaluation.

The investigations identified five waste types within SWMU S-22: spent pickle liquor, coal tar, coke oven gas condensate, waste lime, and iron precipitator dust. Numerous hazardous constituents (VOCs, SVOCs, and metals) and materials of low pH (<2 s.u.) and high pH (>11 s.u.) are present in the SWMU material. The concentrations of hazardous constituents and pH levels vary within each waste type.

Non-RFI sampling indicates that benzene and pyridine detected in the SWMU materials exceed the TCLP criteria of a RCRA characteristic hazardous waste.

Hazardous constituents found in the groundwater (both the fill and sand units) have migrated horizontally from SWMU S-22. A low permeability clay layer underlying SWMU S-22 inhibits the downward migration of the hazardous constituents.

The results of the Tier 1 HHRA show that levels of arsenic in surface SWMU material and benzene, naphthalene and toluene in subsurface SWMU material exceed noncarcinogenic RBSLs. The levels produce hazard indices greater than the Tier I noncarcinogenic benchmark of 1.0 for certain receptor scenarios. Also, levels of benzene, benzo(a)pyrene, 1,1,2,2-tetrachloroethane and trichloroethene in subsurface SWMU material exceed carcinogenic RBSLs, and produce carcinogenic risk levels greater than the Tier I carcinogenic risk benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.25 <u>SWMU S-23</u>

SWMU S-23 is the Sludge Landfill area used to dispose of coal tar material from coking operations, tar tank cleaning, and coke breeze.

Total constituent and SPLP analysis of boring samples from SWMU S-23 detected several VOCs and SVOCs. TCLP analysis of SWMU S-23 waste samples demonstrated that the SWMU materials exceed the toxicity characteristic criteria for a RCRA hazardous waste.

Although no upgradient wells are present near SWMU S-23 due to a groundwater mound in the area, groundwater sampling shows that most of the VOCs and SVOCs detected in the SPLP analysis are also present in the groundwater downgradient of the SWMU in the fill unit groundwater. SWMU S-23 is located within areas determined to be historical dredge spoils disposal grounds and is adjacent to the Spent Pickle Liquor Landfill (SWMU S-16). As such, the contribution of SWMU S-23 to groundwater contamination in the sand unit cannot be fully determined.

The results of the Tier 1 HHRA indicate that levels of benzene, naphthalene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-c,d)pyrene in subsurface SWMU material exceed noncarcinogenic and/or carcinogenic RBSLs and produce calculated hazard indices greater than the Tier 1 hazard benchmark of 1.0 or risk levels greater than the Tier 1 carcinogenic benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.26 SWMU S-24

SWMU S-24 is identified as the Tar Pit North of the Lime Plant, an area used for the disposal of tar waste from the coking operations.

TCLP analysis of the soil samples collected in 1993 and 1995 and excavated waste material sampled in 1994 showed that the material in S-24 exceeds the criteria of a RCRA characteristic hazardous waste. Total constituent analyses of samples collected from S-24 show concentrations of VOCs (benzene, toluene, and xylenes), and SVOCs.

Groundwater monitoring results indicate that several VOCs, SVOCs, and metals were detected in downgradient well MWN-44A. Analytes do not appear to be present in high concentrations in the other downgradient wells. This may indicate that the area around MWN-

44A requires additional investigation. Additionally, several of the compounds detected in the groundwater were also detected in the TCLP analysis of the soil samples.

The results of the Tier 1 HHRA indicate that levels of arsenic, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, naphthalene and toluene in subsurface SWMU material and cresols and zinc in groundwater exceed carcinogenic and/or noncarcinogenic RBSLs, producing either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the carcinogenic benchmark of 1×10^{-4}.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.27 SWMU S-25

SWMU S-25 is identified as the Landfill/Impoundment under North End of Coal Pile. Review of records and photos within BSC files indicate that the nearby area was occupied by a large a pile of slag. During the 1940s, 1950s, and 1960s, the pile was systematically excavated for reclamation of metallics, resulting in the creation of a pile or piles of excavated and/or reclaimed material in the SWMU S-25 area.

SPLP analytical results of subsurface material in the SWMU indicate that no SVOCs were detected. Of the four VOCs detected by SPLP analysis, only one compound (total xylenes) was also detected in two of the groundwater samples (MWN-18A and MWN-43A). However, the concentrations of the extract were lower than the concentrations found in the groundwater samples. Only two metals, barium and chromium, were detected in the SPLP analysis.

Although VOCs and SVOCs are present within the groundwater downgradient of SWMU S-25, the data from the SPLP soil sampling as well as data received from the sampling of groundwater from crossgradient well MWN-18A, does not further support the contention that SWMU S-25 has had an additive effect on the underlying groundwater.

The results of the Tier 1 HHRA indicate that there are no chemicals in subsurface SWMU material that generate calculated hazard or risk levels that are greater than the Tier 1 benchmarks of 1.0 for noncarcinogens, or exceed the risk benchmark of 1 x 10^{-4} for carcinogens.

Based on the data collected in the SWMU investigation and the results of the Tier I HHRA, no further evaluation of this SWMU is required.

6.1.28 SWMU S-26

SWMU S-26 is the Fill Area near Coke Battery Number 8, a portion of the Buffalo Outer Harbor that was filled during construction of the northwester portion of the Ship Canal. The area was filled in to form the northwest corner of the canal. In addition, this area also appears to be the former discharge point for an open drainage channel that may have carried process water or surface water runoff from the coke oven areas.

TCLP results from the soil/fill material demonstrate that the materials in the SWMU do not exceed the criteria for a RCRA characteristic hazardous waste. Analytical results indicate that VOCs, SVOCs, and metals detected in the groundwater are similar to the organic compounds and inorganic analytes detected in the 1992 composite subsurface soil samples (including total constituent, TCLP, and SPLP analyses). Because the composite samples included saturated material, it is unclear if groundwater is being impacted by the fill or by upgradient sources in the Coke Oven area.

Analytical results from monitoring wells located at the southern end of the SWMU did not show any VOC or SVOCs above detection limits. These results suggest that the soils in this area of the SWMU are not impacting groundwater.

The results of the Tier I HHRA indicate that benzene and naphthalene in groundwater and chromium in surficial SWMU material exceed RBSLs and produce hazard indices greater than the Tier 1 acceptable noncarcinogenic benchmark of 1.0. The Tier 1 HHRA also concludes that cancer risks do not exceed the cancer risk benchmark of 1 x 10^{-4} for any receptor population.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.29 SWMU S-28

SWMU S-28 is known as the Drum Landfill, identified from an aerial photograph as a pit, south of the Tar Decanter Sludge Landfill (SWMU S-13). According to the USEPA, it appeared from an aerial photograph taken on September 30, 1982 showed that drums were present in the southern portion a pit adjacent to SWMU S-13.

Test pits throughout the SWMU S-28 area did not encounter drums or evidence of drums disposal. However a blue colored layer of slag was observed. This blue layer was sampled prior to backfilling the test pits. TCLP results from soil samples obtained from SWMU S-28 demonstrate that the material in the SWMU does not exceed the TCLP criteria for a characteristic hazardous waste. Total constituent analysis and SPLP analysis of the SWMU materials detected several SVOCS and metals. Because there are no downgradient monitoring wells, the effect of these materials on the underlying groundwater quality is unknown.

The results of the Tier 1 HHRA indicate that the level of chromium in subsurface SWMU material exceeds the noncarcinogenic RBSL, and produces a calculated hazard index that is greater than the Tier 1 noncarcinogenic benchmark of 1.0 for certain scenarios.

Based on these results and in accordance with the work plan, further evaluation will be completed during the CMS.

6.1.30 SWMU S-29

SWMU S-29 is the Drum Landfill, an excavation adjacent to the southern end of Asbestos Landfill L (SWMU S-12). The unit was designated as a SWMU because the USEPA reported that, based on review of a September 1982 aerial photograph, it appeared as if drums were present in the a pit adjacent to SWMU S-12.

As part of the RFI, the SWMU location was excavated to determine if drums were disposed in this area during past operations. No evidence of past waste disposal was encountered during the investigation of SWMU S-29. No record or other information regarding disposal of wastes in this unit has been found by BSC. Therefore, no further assessment of this unit is required because it is not a source of potential releases of contaminants to the environment.

6.2 Watercourse Results

As summarized in Section 3.1, five watercourses currently exist on the Lackawanna property and have been investigated as required by the AOC. The results of the investigations are summarized below. Both sediment and surface water were evaluated for each watercourse. Details of how the watercourses were investigated are summarized in Section 3.1. Part VII of the RFI also includes the complete final Assessment Report for each watercourse.

6.2.1 North Return Water Trench

The North Return Water Trench (NRWT) is a man-made drainage channel, which received process water and storm run-off from various BSC facilities at the site and carried these wastewaters to the Union Ship Canal and Buffalo Outer Harbor. The NRWT is approximately 3,150 feet long with an average width of 8 to 10 feet and an average depth of 8 to 10 feet. The southernmost 400 feet of the trench is open and constructed of brick and concrete. The next 1,200 feet of trench to the north is covered with a concrete roof and has sides that are lined with brick and reinforced concrete with access pits/manways at regular intervals. The next 1,400 feet of the trench is completely covered by a concrete roof. The northernmost 150 feet of the NRWT, near where it discharges, is uncovered, approximately 25 feet wide and lined with sheet piling.

TCLP analysis indicated that the materials in the NRWT do not exceed toxicity characteristic criteria as a RCRA hazardous waste. No SVOCs and only a few VOCs and metals were detected in two rounds of surface water sampling. Total constituent analysis of sediment samples indicated the presence of one VOC, several SVOCs, and metals. No SVOCs were detected in the sediment TCLP analysis.

Based on November 20, 2001 monitoring data, surface water levels within the trench are below the surrounding groundwater table. This indicates that the surface water within the trench is not leaking into the surrounding groundwater.

The Tier 1 HHRA indicates that no chemicals in the sediment or surface water generated elevated carcinogenic risks or noncarcinogenic hazards. Based on these results no further assessment will be completed.

6.2.2 South Return Water Trench

The South Return Water Trench (SRWT) is an approximate 5,000-foot long man-made drainage channel. The SRWT received process water and storm run-off from various BSC facilities at the site and carried these wastewaters to Smokes Creek. The northern portion of the trench is constructed primarily of concrete and brick, with an average cross section of 8 to 10 feet and an average depth of 8 to 10 feet. Further down the trench, construction initially consists of sheet piling with an open bottom. Eventually the trench widens to about 30 feet across and is an open channel with sections of unsupported soil banks and sections occasionally supported by concrete rip/rap or sheet piling. This portion constitutes the majority of the trench. At the southern most end of the channel (where it discharges into Smokes Creek), it is lined with sheet piling in order to maintain flow.

Free product has been observed in the SRWT both as sheen on the surface of the water and oil droplets rising from depth near the junction with Smokes Creek. This may be due to the presence of the Linde Spill site, currently being remediated, adjacent to the southern terminus of the trench where it meets Smokes Creek.

TCLP analysis indicated that sediment in the SRWT does not exceed toxicity characteristic criteria as a RCRA hazardous waste. Total constituent analysis detected only a few analytes at low concentrations in the surface water samples and one VOC, several SVOCs, and metals in the sediment samples.

Based on November 20, 2001 monitoring data, nearby groundwater and SRWT surface water elevations show that this watercourse is located within a groundwater depression. This indicates that the surface water within the trench is not leaking into the surrounding groundwater.

The results of the HHRA are that none of the chemicals in surface SWMU material or Zone 4 groundwater exceeds Tier 1 noncarcinogenic or carcinogenic RBSLs for any of the scenarios.

Based on the presence of sheens on the surface water of the trench and in accordance with the Work Plan, further evaluation of the SRWT will be completed in the CMS and may include a Tier 2 assessment or an evaluation of corrective measures.

6.2.3 Smokes Creek

Smokes Creek flows from east to west, bisecting the BSC, Lackawanna New York facility and draining into Lake Erie.

Both in Smokes Creek and in the adjacent SRWT, oil-like globules and sheen have been noted on the banks and surface water, as well as rising from depth. This may be due to the presence of the Linde Spill site, which is adjacent to the intersection of Smokes and the SRWT.

TCLP analysis indicates that the materials in Smokes Creek do not exceed TCLP criteria for a RCRA characteristic hazardous waste. Total constituent analysis of the surface water and sediment samples detected a few VOCs, several SVOCs, and metals in Smokes Creek. In general, constituents detected in the sediment samples were consistent with the background sample. The Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM) analysis indicates that bivalent metals in the sediment may be available for consumption or absorption by organisms in the creek.

The results of the Tier 1 HHRA indicate that levels of benzene, vinyl chloride, and pyridine in the Smokes Creek groundwater exceed noncarcinogenic and carcinogenic RBSLs, and produce either a hazard index greater than the Tier 1 noncarcinogenic benchmark of 1.0, or a carcinogenic risk greater than the carcinogenic benchmark of 1 x 10^{-4}.

Based on these results and in accordance with the work plan, further evaluation may be completed during the CMS.

6.2.4 Blasdell Creek

Blasdell Creek is a natural watercourse, which flows in two branches across the East Plant area and then converges into a single waterway along the southwestern portion of BSC property before emptying into Lake Erie.

TCLP analysis indicates that the sediments in Blasdell Creek do not exceed the toxicity characteristic criteria of a RCRA Hazardous Waste. Total constituent analysis shows low levels of VOCs, SVOCs and metals in the surface water and SVOCs and metals in the sediment. In 1994, SVOCs and metals were detected at higher concentrations and in greater number in the sediment samples than in the background sample. In 1995, SVOCs and metals were detected at similar concentrations in both background and sediment samples. In addition, AVS/SEM analysis indicates that bi-valent metals in the sediment may be available for consumption or absorption by organisms.

The Tier 1 HHRA indicates that none of the chemicals detected in sediment or surface water generate cancer risks or noncancer hazards above acceptable risk benchmarks (i.e., cancer risk of 1 x 10^{-4}; hazard quotient of 1).

Based on these results and in accordance with the work plan, further evaluation is not warranted during the CMS.

6.2.5 Ship Canal

The Ship Canal is located in the north central portion of the BSC site and opens to the Buffalo Harbor at its northern end.

TCLP analysis indicates that the materials in the Ship Canal do not exceed the toxicity characteristic criteria of a RCRA Hazardous Waste. Total constituent analysis of the surface water and sediment samples detected SVOCs and metals that may be impacting the Ship Canal. In addition, AVS/SEM analysis indicates that bi-valent metals in the sediment may be available for consumption or absorption by organisms.

The results of the Tier 1 HHRA are that that none of the COPCs for which RBSLs were calculated produce hazard indices greater than the Tier 1 noncarcinogenic benchmark of 1.0, or risk levels greater than the Tier 1 carcinogenic benchmark of 1×10^{-4}.

Maintenance dredging of the canal was conducted during July and September 2000. The permitted volume of dredged was not to exceed 20,000 cubic yards. The sediments were placed in USACE Disposal Area No. 4.

Based on these results, further evaluation is not warranted during the CMS.

6.3 Results of SWMU and Watercourse Assessments

Conclusions for the SWMUs and Watercourses presented in this section are further evaluated with the results of the ERA. The summary of the SWMU and Watercourse status based on this combined evaluation is presented in Section 7.0 as well as Table 7-1 and Figure 7-1.

6.4 References

Bethlehem Steel Corporation (BSC), 1998. Human Health Risk Assessment for Bethlehem Steel Corporation's Lackawanna, New York Site. Revised Final Interim Deliverable Number 1: Detailed Process for Selection of Chemicals of Potential Concern and Identification of Toxicological Criteria. Bethlehem Steel Corporation, Lackawanna, NY. December.

7.0 SUMMARY AND CONCLUSIONS

The BSC site has been used for the making of steel and related products for almost a century. As a result of these activities, environmental impacts to the site's soil and groundwater and the sediment and surface water of adjacent surface water bodies have occurred.

The source of chemical constituents found in groundwater, soil, surface water and sediments at Lackawanna site may be attributed to by-products and waste materials spilled, discharged or stored at the facility (primarily in SWMUs), and to the presence of contaminated dredge spoils imported and placed beneath the western portion of the site.

7.1 Groundwater

Investigations of the groundwater at the site show that VOCs are widely distributed and driven by BTEX compounds (primarily benzene) that dominate the elevated VOC compounds in the ATPs and Benzol Yard areas. The sources of these chemicals are primarily associated with by-products and wastes generated by coke-making operations. Chlorinated hydrocarbons were detected at much lower concentrations and are present throughout Slag Fill Zone 2, and around SWMUs S-16 (HWM-1A/Lime Sludge Landfill) and S-23 (Sludge Tar Pit) within Slag Fill Zone 4. Sources of these compounds are not known. The SVOCs are primarily associated with coal tar generated from the processing of Coke Oven gases and waste oils from coke by-process and steel finishing operations. The occurrence of SVOCs is widely distributed across the site in both the fill and underlying sand unit with naphthalene being the most commonly detected SVOC. Of the eleven heavy metals detected in groundwater, only six were found in SWMU materials. Several of these metals, (arsenic, chromium and lead) are widely distributed in the sites groundwater but at low concentrations. Sources are assumed to be the storage and landfilling of steel-and coke-making wastes.

7.2 Surface Water and Sediment

Surface water and sediment impacts have occurred in Lake Erie, Smokes Creek, Blasdell Creek, the North and South Return Water Trenches and the Ship Canal. Samples collected from Lake Erie adjacent to the site showed one VOC, in surface water near the mouth of Smokes Creek, and several SVOCs and metals with concentrations highest near the mouth of Smokes Creek. VOCs, SVOCs and heavy metals were also detected in the remaining surface water bodies with the largest number of compounds and the highest concentrations detected in Smokes Creek adjacent to, and downstream of, the ATPs.

7.3 Constituent Loading

Constituent loading to the surface water bodies was estimated using recharge-based groundwater discharge rates and concentrations of constituents detected during the most recent sampling events. Total loading to all of the surface water bodies was estimated at 1,632 pounds per year for VOCs, 419 lbs/yr for SVOCs and 1,395 lbs/yr for heavy metals. The majority of VOCs are discharged to Smokes Creek, while the majority of SVOCs and metals are discharged to Lake Erie.

7.4 Ecological Risk Assessment

The ERA was conducted at the Site to assess potential impacts to ecological receptors from identified releases of hazardous constituents and to provide a characterization of the ecological populations, communities and ecosystems at the site. COPECs were also identified using Tier 1 and Tier 2 assessments of the sites COPIs. The ERA did not recommend a Tier 3 ecological risk assessment, as information provided in this ERA is adequate for risk management decision-making.

7.5 Human Health Risk Assessment

The HHRA was performed to evaluate potential human health risks due to chemical releases from SWMUs to soil, air, groundwater, sediment and surface water. Fifty-three chemicals were selected as COPCs and 12 receptor scenarios were evaluated with respect to current and future development of the site. The HHRA concluded that 39 of the 42 SWMUs and 2 of the 6 watercourses evaluated could pose a risk to human health under certain exposure scenarios. and require further assessment. Three of the 45 SWMUs were not evaluated for Human Health Risk.

7.6 SWMUs and Watercourses

The SWMUs and Watercourses were evaluated in the assessment reports, human health risk assessment and ecological risk assessments. Using the results of these studies, 38 SWMUs of the 45 SWMUS and 3 watercourses of the six watercourses are recommended for further evaluation using either a Corrective Measures Study. The remaining seven SWMUs and three watercourses require no further assessment. Table 7-1 lists both the SWMUs and Watercourses recommended for CMS and those that require no further action. Figure 7-1 shows the location and status of all SWMU and Watercourses.