

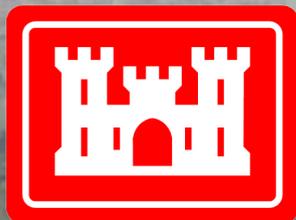
Final

3 AOCs Comprehensive Remedial Investigation Report

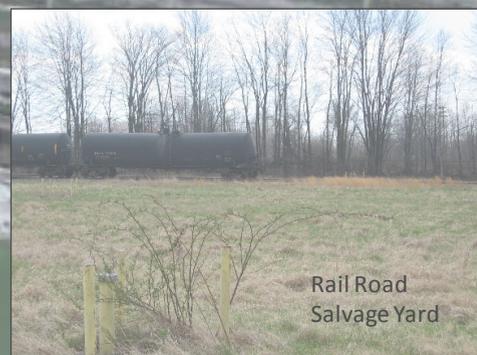
Former Lordstown Ordnance Depot
Formerly Used Defense Site No. G05OH0149
Lordstown, Ohio

Prepared for

U.S. Army Corps of Engineers



July 2014



CH2MHILL®

Final

3 AOCs Comprehensive Remedial Investigation Report

Former Lordstown Ordnance Depot
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Executive Summary

This comprehensive remedial investigation report (CRI) presents the results of the numerous investigative activities conducted at 3 Areas of Concern (AOCs) at the Former Lordstown Ordnance Depot in Lordstown, Ohio. The 3 AOCs that are the subject of this report are the former Railroad Salvage Yard (RSY), the former Burn Pit Area (BPA), and the former Waste Oil Pit. The three AOCs are collectively known as the “3 AOCs Site.”

The specific nature of operations at the RSY is unknown. The area is small, approximately 0.25 to 0.50 acre in size, and is located in a triangular-shaped area formed by the service road to the northwest and the auxiliary railroad tracks to the south. During site investigations, the RSY exhibited bare patches and stressed vegetation, which prompted further evaluations of potential contaminant.

The BPA were used by the Department of Defense (DoD) for disposal of non-inventoried, combustible materials such as waste paper, wood, cardboard, and building demolition debris, as well as non-flammable materials such as junk vehicles, asbestos-containing demolition debris, and miscellaneous glass and metal materials. Burning pits within the BPA were used to dispose waste during the 1950s. The working locations of the pits changed with time. The BPA are estimated to cover approximately 5 acres. Currently, the ground surface of the BPA provides very little evidence of its existence, portions of the area have been reforested, and the remainder of the area is covered by native grasses.

The former Waste Oil Pit was used by the DoD during the 1950s for disposal of petroleum products (such as waste motor oil and waste gasoline), waste paints, and spent solvents. The pit was circular in shape with an approximate diameter of 30 feet. Disposal consisted of dumping liquid waste into the pit and allowing the waste to soak into the ground. Burning of liquid wastes occurred periodically. Some soil in the immediate vicinity of the pit was excavated and removed in November 1998 by the U.S. Army Corps of Engineers–Louisville District as a time-critical removal action. The Waste Oil Pit investigation area includes the former location of the disposal pit as well as the surrounding area.

The investigations of the 3 AOCs were performed to define the nature and extent of contamination posing unacceptable risk to human health and the environment, relative to the U.S. Environmental Protection Agency’s (USEPA’s) target risk range and non-cancer hazard target. Investigations were performed from 1995 through 2009 for media that may have been contaminated as a result of past activities at each of the 3 AOCs. Samples of the following media were collected at some or all of the sites: surface soil, subsurface soil, bedrock, and groundwater. The samples were analyzed for parameters including: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), dioxins/furans, and metals. All samples were collected and validated in accordance with work plans that followed Louisville Chemistry Guidance and were approved by the Ohio Environmental Protection Agency (EPA).

The physical setting at the site consists of glacially derived fine-grained soils overlying sandstone and shale bedrock. The soils range from 2 to 6 feet thick. The upper portion of bedrock is weathered and fractured; the frequency of fractures decreases with depth. Groundwater at the site flows primarily through the bedrock. The depth to groundwater ranges from 1 to 5 feet below ground surface (bgs) across the site and fluctuates 1 to 2 feet seasonally. Generally, groundwater flows from south to north across the area. Beaver Creek is an ephemeral creek that originates at the railroad tracks on the southern edge of the site and flows north to northwest towards Beaver Pond.

To assess the nature and extent of contamination, analytical results were evaluated to demonstrate each of the AOCs has been adequately characterized for risk assessment and to move forward in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process to a feasibility study to define remedial alternatives.

At the former Waste Oil Pit, a time-critical removal action removed much of the source in soil; however, residual soil contamination remains in the vicinity of the former Waste Oil Pit, most notably at and near the

bedrock interface. The sandstone bedrock underlying the former Waste Oil Pit and its vicinity contains a concentrated source to groundwater, in the form of residual nonaqueous phase liquid (NAPL). The NAPL has been delineated at nearly 20 feet into bedrock, up to 50 feet from the Waste Oil Pit side- and upgradient, and over 100 feet downgradient. Soil contaminants were also detected in the vicinity of the former RSY and BPA, but the concentrations are more sporadic and much lower than at the Waste Oil Pit. VOCs comprise the largest and most concentrated groundwater contaminant plume at the site. The source of the VOC plume is the Waste Oil Pit; the plume extends approximately 500 feet to the north-northwest of the Waste Oil Pit in the direction of groundwater flow. Although other VOCs are present in the groundwater plume near the Waste Oil Pit, most of the plume can be characterized by trichloroethene and its degradation products cis-1,2-dichloroethene and vinyl chloride. Groundwater in the vicinity of the former BPA also shows low concentrations of VOCs.

Based on observed site conditions and properties of site-related preliminary constituents of concern identified, an assessment of contaminant fate and transport was completed. The results of the RI show that the nature and extent of contamination has been delineated at each of the three AOCs and the investigations have obtained the information needed to define the conceptual site model to assess the fate and transport of site-related contaminants, and to assess potential risks to human health. By mutual agreement between Ohio EPA and the U.S. Army Corps of Engineers, an ecological risk assessment was not included in the CRI report because the intended reuse of the property is commercial/industrial and, following development, no significant ecological habitats will remain. In addition, given the minimal size of the site, the AOCs would not support a sufficient number or type of ecological receptors to conclude the existence of an unacceptable risk.

A human health risk assessment (HHRA) was performed to evaluate potential current and future risks associated with each of the three AOCs and for sitewide groundwater. Risks estimates presented in this report represent potential current or future risks to human health based on exposure assumptions and assumed chemical toxicities and are hereinafter referred to as “current risk” or “future risk”. Surface soil, subsurface soil, and recent groundwater analytical data were evaluated in the HHRA. While the 3 AOCs are part of a property that is used as an industrial park, and land use at the 3 AOCs is not anticipated to change in the future, the HHRA included an evaluation of future residential land use exposures to provide information regarding hypothetical unlimited use/unrestricted exposure (UU/UE). Risks were evaluated for exposure to the following:

- Surface soil for future industrial workers, current trespassers/visitors (adult, youth, child), and hypothetical residents
- Total soil (that is, combined surface and subsurface soil) for future construction workers, future industrial workers, and hypothetical residents
- Groundwater for future construction workers, future industrial workers, and hypothetical residents

For the RSY AOC, current land use is not associated with human health risks above USEPA’s target risk range of 1×10^{-6} to 1×10^{-4} and target hazard index (HI) of 1 for the receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in excess lifetime cancer risks (ELCRs) less than or within USEPA’s target risk range and noncarcinogenic hazards less than USEPA’s target level. For future land use, ELCRs for all receptors evaluated are less than USEPA target risk range. Noncarcinogenic hazards for all receptors evaluated, except the hypothetical residential child, are less than USEPA’s target HI. Hazard estimates for hypothetical residential child use of the RSY AOC exceed the target HI.

For the BPA AOC, current land use is not associated with human health risks above USEPA’s target risk range and target HI for receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in ELCRs within or less than USEPA’s target risk range or target HI. The construction worker HI for total soil is 1.

Therefore, there are no noncarcinogenic human health risks above USEPA's target level for the construction worker. For future land use, ELCRs for all receptors evaluated are less than or within USEPA's target risk range. Noncarcinogenic hazards for all receptors evaluated, except the hypothetical residential child, are less than USEPA's target hazard level. Hazard estimates for hypothetical residential child use of the BPA AOC exceed the target hazard level. Lead in both surface and total soil exceeded the residential soil screening level (400 milligrams per kilogram).

For the Waste Oil Pit AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for receptors evaluated in the HHRA. For future land uses, risks were estimated for adult and child residents, industrial workers, and construction workers exceeding USEPA target risk range and/or target HI.

For sitewide groundwater, potential exposures by future adult and child residents and industrial workers exceed USEPA's target risk level and/or HI. Risk estimates for construction workers were below USEPA's target risk range and target HI.

Volatile constituents in soil and groundwater have the potential to migrate into indoor air spaces. Therefore, inhalation of indoor air at future buildings potentially impacted by volatiles detected in soil and groundwater is considered a potential pathway at the 3 AOCs. Because of site conditions (that is, shallow groundwater depth and shallow bedrock), vapor intrusion cannot be eliminated as a potential exposure pathway. The vapor intrusion pathway may be complete for potential future indoor air exposures and has the potential to exceed target risk levels for both residential and industrial land uses at the 3 AOCs Site.

In accordance with USEPA guidance, a feasibility study will be performed to evaluate remedial alternatives for the final Chemicals of Concern identified in soil and groundwater. The feasibility study will consider the vapor intrusion pathway.

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Acronyms and Abbreviations

ALM	adult lead model
amsl	above mean sea level
AOC	area of concern
atm-m ³ /mole	atmospheres-cubic meter per mole
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BLL	blood lead level
BPA	Burn Pit Area
BTEX	benzene, ethylbenzene, toluene, and xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
COPC	constituent of potential concern
CRI	comprehensive remedial investigation
CSF	cancer slope factor
CSM	conceptual site model
DABS	dermal absorption fraction
DCA	dichloroethane
DCE	dichloroethene
DDD	dichlorodiphenyldichloroethane
DDT	dichlorodiphenyltrichloroethane
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DPT	direct-push technology
EDB	ethylene dibromide
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
ERA	ecological risk assessment
°F	degrees Fahrenheit
FLOD	Former Lordstown Ordnance Depot
FS	feasibility study
FUDS	Formerly Used Defense Site
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment

HI	hazard index
HQ	hazard quotient
HSA	hollow-stem auger
IDW	investigation-derived waste
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
ITC	International Technology Corporation
IUR	inhalation unit risk
JEM	Johnson and Ettinger Model
K_d	distribution coefficient
K_{oc}	organic carbon adsorption coefficient
K_{ow}	octanol-water partition coefficient
$\mu\text{g}/\text{dL}$	micrograms per deciliter
$\mu\text{g}/\text{L}$	microgram per liter
$\mu\text{g}/\text{kg}$	micrograms per kilogram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MMOA	mutagenic mode of action
NAPL	nonaqueous phase liquid
OCC	Ohio Commerce Center
OCDD	octachlorodibenzo-p-dioxin
Ohio EPA	Ohio Environmental Protection Agency
PA	preliminary assessment
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PID	photoionization detector
ppb	parts per billion
PPRTV	Provisional Peer Reviewed Toxicity Value
PRG	Preliminary Remediation Goal
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act

redox	reduction-oxidation
RfC	reference concentrations
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RSL	Regional Screening Level
RSY	Railroad Salvage Yard
SI	site investigation
SRI	supplemental remedial investigation
SVOC	semivolatile organic compound
TAL	target analyte list
TAMPEEL	Trumbull Area Multi-Purpose Environmental Education Laboratory
TCDD	tetrachlorodibenzo-p-dioxin
TCE	trichloroethene
TCRA	time-critical removal action
TCT	Twin City Testing
TEQ	toxicity equivalent
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
UTL	upper tolerance level
UU/UE	unlimited use and unrestricted exposure
VF	volatilization factor
VOC	volatile organic compound

Introduction

Remedial investigation (RI) activities have been ongoing for 3 Areas of Concern (AOCs) at the Former Lordstown Ordnance Depot (FLOD) since 1997. This RI report presents the findings of the RI in a comprehensive manner to support decision making to move forward in the site remediation process. The 3 AOCs that are the subject of this report are the former Railroad Salvage Yard (RSY), the former Burn Pit Area (BPA), and the former Waste Oil Pit. The 3 AOCs are collectively known as the “3 AOCs Site.” The report was prepared for the U.S. Army Corps of Engineers (USACE)—Louisville District under Contract Number W912QR-04-D-0020, between USACE and CH2M HILL.

1.1 Purpose

The purpose of this comprehensive remedial investigation (CRI) report is to consolidate and present information collected on the 3 AOCs Site since 1995 in a comprehensive manner to support decisions related to moving forward in the site remediation process, including a current, detailed presentation of the site setting and investigative activities performed to define the nature and extent of contamination at the 3 AOCs Site, and the current or future risk it poses to human health. By mutual agreement between the Ohio Environmental Protection Agency (Ohio EPA) and USACE, an ecological risk assessment was not included in the CRI report because the intended reuse of the property is commercial/industrial and, following development, no significant ecological habitats will remain. In addition, given the minimal size of the site, the AOCs would not support a sufficient number or type of ecological receptors to conclude the existence of an unacceptable risk.

1.2 FLOD Background

The FLOD is a Defense Environmental Restoration Program (DERP)/Formerly Used Defense Site (FUDS) facility. It was an active military installation operated by the United States Department of Defense (DoD) from 1943 until 1963 for transportation, storage, and reconditioning of military combat-related equipment, material, and supplies.

1.3 FLOD Description

The FLOD is located in a mixed industrial/commercial/residential area of the Township of Lordstown, Ohio, in Trumbull County (Figure 1-1) and is zoned commercial/industrial. The FLOD was bordered on the east by Ohio State Route 45, on the south by the Baltimore and Ohio Railroads, on the west by residential properties located on the east side of Ellsworth-Bailey Road, and on the north by a mixture of residential and agricultural properties. Figure 1-2 shows the FLOD boundary and surrounding area. Within the FLOD boundary are 2 parcels covering approximately 520 acres. The majority of the property, approximately 480 acres, is currently known as the Ohio Commerce Center (OCC). The remaining approximately 39 acres located on the northwest corner of the FLOD are owned by the Lordstown School District and known as the Trumble Area Multipurpose Environmental Education Laboratory (TAMPEEL). Figure 1-3 shows the FLOD property boundaries, site features, and the 3 AOCs, which are located on the southwest corner of the OCC.

1.3.1 FLOD History

The DoD acquired approximately 565 acres in Lordstown, Ohio, in 1942. Construction of the military facility began immediately and was completed in January 1943. During the period of 1943 through 1945, the facility was used for the transportation, storage, and reconditioning, of military combat-related equipment, material, and supplies. On August 29, 1943, the facility was transferred from an Ordnance Depot Installation to contractor management under a subsidiary of Sears, Roebuck and Company, known as the Lordstown Depot Management, Inc. On November 5, 1945, it reverted to the Army (USACE 1998). The facility continued to be used for the storage, repair, and maintenance of industrial and military equipment and vehicles after World

War II. In 1945, approximately 45 acres along the western edge of the facility were declared surplus by the General Services Administration and were turned over to private citizens for residential development. The FLOD boundary presented in this CRI report excludes the 45 acres.

In 1956, ordnance missions at the facility were terminated, and the facility was reassigned to provide administrative and logistical support for the regional Nike Anti-Aircraft Activities, and logistical support for the United States Army Reserve. In 1963, the facility was placed on inactive status, and in 1967, a majority of the property was transferred to the Community Improvement Corporation of Warren and Trumbull County and deeded to OCC in 1976. The TAMPEEL was established in 1973 (Twin City Testing [TCT], 1995).

1.3.2 3 AOCs History

The following subsections summarize the site's history.

1.3.2.1 Railroad Salvage Yard

The specific nature of operations at the RSY is unknown. The area is small, approximately 0.25 to 0.50 acre in size, and is located in a triangular-shaped area formed by the service road to the northwest and the auxiliary railroad tracks to the south. During site investigations, the RSY exhibited bare patches and stressed vegetation, which prompted further evaluations of potential contaminant conditions.

1.3.2.2 Burn Pit Area

The BPA was used by the DoD for disposal of non-inventoried, combustible materials such as waste paper, wood, cardboard, and building demolition debris, as well as non-flammable materials such as junk vehicles, asbestos-containing demolition debris, and miscellaneous glass and metal materials. The working locations of the pits changed with time. The BPA are estimated to cover approximately 5 acres. Currently, the ground surface of the BPA provides very little evidence of their existence. Portions of the area have been reforested, and the remainder of the area is covered by native grasses.

1.3.2.3 Waste Oil Pit

The former Waste Oil Pit was used by the DoD during the 1950s for disposal of petroleum products (such as waste motor oil and waste gasoline), waste paints, and spent solvents. The pit was circular in shape with an approximate diameter of 30 feet. The pit area was still visible in 1998. An interim removal action was conducted by USACE in November 1998 to remove visibly stained soil. The Waste Oil Pit area includes the former location of the disposal pit as well as the surrounding area.

The approximate locations of the 3 AOCs are shown in Figure 1-4. Historical aerial photographs illustrating surface conditions at the 3 AOCs in 1951, 1959, and 2006 are shown in Figures 1-5 through 1-7.

1.3.3 Regulatory Framework

Environmental response actions at DERP/FUDS sites conform to the requirements of the National Oil and Hazardous Substance Pollution Contingency Plan and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) under 40 *Code of Federal Regulations* Part 300. Under the FUDS program, DoD is responsible for investigating, evaluating and, if required based on investigation findings, cleaning up DoD-generated environmental contamination at FUDS property, in accordance with the Environmental Quality FUDS Program Policy of May 2004 (U.S. Army, 2004). The U.S. Army oversees the FUDS program for DoD, and USACE manages the investigation, evaluation, and cleanup of such properties. USACE is the lead regulatory agency for the TAMPEEL site under the FUDS program, while Ohio EPA has provided input throughout the RI process.

1.3.4 Chronology of Investigations

The following subsections summarize the chronology of investigations performed at the site. Table 1-1 summarizes the project timeline.

1.3.4.1 Preliminary Assessment

The preliminary assessment (PA) conducted at the site was a limited-scope investigation that required the collection of readily available historical information and a site reconnaissance. The PA was performed on behalf of the OCC to distinguish between AOCs that pose little or no threat to human health and the environment and AOCs that required further investigation. The PA was documented in the *Level I Environmental Site Assessment of the OCC* (R & R International, 1990). The PA was later supplemented by an additional site assessment in 1994 (CH2M HILL, 1994). Both documents were prepared for the OCC.

1.3.4.2 Site Investigation

The 3 AOCs Site investigation (SI) was a limited-scope investigation that required the collection of environmental media samples and the review of historical site documents. The SI was designed to identify potential environmental concerns related to DoD activities, determine, through a records search, the type of materials disposed of at the AOCs, and to collect environmental media samples to determine if DoD-related contamination is present and is being released to the environment. The SI is documented in the *Site Investigation, Preliminary Summary of Analytical Data with Conclusion and Recommendations* (TCT, 1995) and the *Final Site Investigation Report* (Maxim, 1997).

Conclusions from the SI indicated that contaminants were present in three AOCs at concentrations that exceeded the preliminary risk screening criteria and that these AOCs needed additional evaluation. The USACE—Louisville District continued the CERCLA process based on the SI results and conducted an RI to delineate the nature and extent of the contamination at the 3 AOCs.

1.3.4.3 Remedial Investigation

The RI began in 1997 to determine the source, nature, and extent of contamination in groundwater and soils resulting from past activities at the site. The 1997 RI activities were performed by IT Corporation, Inc. In accordance with the DERP/FUDS program, only DoD-related activities were addressed. The RI activities were conducted to achieve the following objectives:

- Characterize the site geological and surface features to assist in evaluating contaminant fate and transport
- Characterize the nature and extent of contamination at the 3 AOCs to determine the impact of past activities and provide data for human health and ecological risk assessments
- Determine background conditions for the site to assist in the evaluation of the analytical results

Seven soil borings were completed at the RSY, 10 soil borings and 3 monitoring wells were completed in the vicinity of the BPA, 10 soil borings and 4 monitoring wells were completed in the vicinity of the Waste Oil Pit, 2 downgradient and 2 upgradient monitoring wells were completed, and 3 background soil borings were completed.

1.3.4.4 Time-critical Removal Action

Analysis of RI results from media samples collected in the vicinity of the former Waste Oil Pit initiated the time-critical removal action (TCRA) of the Waste Oil Pit by the USACE—Louisville District in 1998. The interim action was intended to remove, as much as feasible, the source of groundwater contamination. The Waste Oil Pit was excavated in November 1998 when the groundwater table was low so that the pit was relatively dry (International Technology Corporation [ITC], 2000a). The limit of the excavation was based on visually targeting contaminated soils (stained soils) that were believed to act as a source of groundwater contamination. Analyses of post-excavation soil samples collected from the excavation walls indicated that residual contaminated soil remained in the vicinity of the pit (ITC, 2000a). The vertical extent of soil excavation was limited by bedrock, which is approximately 5 feet below ground surface (bgs) in the vicinity of the Waste Oil Pit. The excavation was later backfilled with compacted clay.

1.3.4.5 Supplemental Remedial Investigation

A supplemental RI (SRI) was conducted in 2000 and 2001 to further evaluate the source, nature, and extent of contamination in groundwater and soils resulting from past activities at the site. The SRI activities were performed by Shaw Environmental, Inc. The SRI activities were conducted to achieve the following objectives:

- Better delineate the nature and extent of soil contamination
- Better delineate the nature and extent of groundwater contamination
- Investigate subsurface anomalies detected in geophysical surveys of the former RSY and BPA
- Investigate aquifer hydraulic conductivity

Eleven soil borings were completed in BPA where geophysical surveys showed anomalies, 9 monitoring wells were completed downgradient of the former Waste Oil Pit, groundwater sampling of 11 existing and 9 new monitoring wells was completed, and a slug test of 11 existing and 9 new monitoring wells was completed.

1.3.4.6 Data Gap Investigations

Based on findings through the RI and SRI work, several data gaps were identified, and additional investigative work was conducted to address the data gaps. The data gaps were filled by the investigative work conducted under the TAMPEEL Landfill and 3 AOCs Investigation Work Plan (CH2M HILL, 2007) and the TAMPEEL Landfill and 3 AOCs Investigation Work Plan Addendum (CH2M HILL, 2009a), as follows:

- Installed two monitoring wells, conducted four quarterly groundwater monitoring events from December 2007 through October 2008 at all existing site wells to evaluate seasonal effects, and used improved analytical detection levels
- Completed soil borings around the Waste Oil Pit in 2007 to evaluate residual contamination
- Sampled bedrock in the vicinity of the Waste Oil Pit in 2009 to delineate bedrock contamination at depth and laterally around the former Waste Oil Pit
- Installed 2 additional monitoring wells downgradient of the Waste Oil Pit in 2009 to improve plume delineation

The data and information obtained from the above investigations is presented comprehensively for the 3 AOCs in this CRI report.

1.4 Report Organization

The CRI report consists of the following sections:

- Section 1—Introduction
- Section 2—Study Area Investigations
- Section 3—Physical Characteristics of the Study Area
- Section 4—Nature and Extent of Contamination
- Section 5—Contaminant Fate and Transport
- Section 6—Human Health Risk Assessment
- Section 7—Summary and Conclusions
- Section 8—References

Section 1 presents the purpose of this report, the history of the FLOD, and provides the basis for and summary of the investigation conducted at the 3 AOCs.

Section 2 provides a detailed description of the data collection activities conducted during investigations. It also includes a breakdown of sample collection locations, a description of field activities and field procedures followed during the collection of environmental media samples, and a description of data validation activities.

Section 3 discusses the physical characteristics of the site and the surrounding investigation area. It also includes a brief description of the topography and surface water features, soils, geology, hydrogeology, meteorology, demography and land use, and ecological conditions associated with the site and surrounding investigation area.

Section 4 discusses the nature and extent of contaminants based on the analytical results obtained from the data collected during investigation activities. It also identifies site contaminants and discusses the distribution of the contaminants across the site.

Section 5 discusses the contaminants' potential fate when released to environmental media and ability to migrate through environmental media. It also identifies the physical and chemical nature of the contaminants, the fate and transport of contaminants, and identifies potential contamination migration routes.

Section 6 presents the human health risk assessment (HHRA).

Section 7 provides a summary of the report and the conclusions of the CRI.

Section 8 is a list of references cited in this report.

Study Area Investigations

Multiple field investigations were conducted at the 3 AOCs over a period of 14 years from 1995 to 2009. (Refer to Table 1-1 for a summary of the project timeline.) Information collected during the investigations has resulted in the generation of environmental data that has been used to define the physical characteristics of the study area (Section 3), delineate the nature and extent of contamination associated with each AOC (Section 4), and assess current and future risks to human health (Section 6). Section 2 summarizes the field investigation activities and identifies the sampling methods and analytical analysis associated with the media samples collected from each AOC. The sampling rationale for each media sample collected is defined in Table 2-1. All field investigation activities were conducted in accordance with Ohio EPA-approved work plans and standard operating procedures.

2.1 Contaminant Source Investigation—Railroad Salvage Yard

Soil borings were advanced and surface and subsurface soil samples were collected at the RSY during SI activities in 1995 and 1996 and RI activities in 1997. The sample collection included one soil boring using a hollow-stem auger (HSA) drill rig in both 1995 and 1996 and sample collection using a split spoon sampler. Then in 1997, seven soil borings were advanced using a direct-push technology (DPT) drill rig and samples were collected using disposable sample liners. The nine boring locations are shown on Figure 2-1. Boring logs are provided in Appendix A.

2.1.1 Surface Soil Investigation

A sample was collected from the 0- to-2-foot depth interval from nine soil borings to identify potential surface soil contamination and to characterize nature and extent of contamination. The samples collected in 1995 and 1996 were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticide/polychlorinated biphenyls (PCBs), and Resource Conservation and Recovery Act (RCRA) metals. The samples collected in 1997 were analyzed for VOCs, SVOCs, and target analyte list (TAL) metals as well as one sample (SB-126) analyzed for total organic carbon (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.1.2 Subsurface Soil Investigation

A sample was collected from between 2 feet bgs and above the bedrock surface from 9 soil borings to identify potential subsurface soil contamination and to characterize nature and extent of contamination. The sample depth interval was selected based on the highest photoionization detector (PID) reading and/or visual contamination. If none of the material recovered from the boring had elevated PID readings and/or visual contamination, a sample from the 2-foot interval directly above bedrock was collected to determine if contamination had reached the till and bedrock interface. The samples collected in 1995 and 1996 were analyzed for VOCs, SVOCs, pesticide/ PCBs, and RCRA metals. The samples collected in 1997 were analyzed for VOCs, SVOCs, and TAL metals, as well as one sample (SB-126) analyzed for total organic carbon (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.2 Contaminant Source Investigation—Burn Pit Area

Soil borings were advanced and surface and subsurface soil samples were collected at the BPA during SI activities in 1995 and 1996, RI activities in 1997, and SRI activities in 2000. Eleven soil borings were advanced in 1995, 4 soil borings were advanced in 1996, 15 soil borings were advanced in 1997, and 20 soil borings were advanced in 2000. The 50 boring locations are shown on Figure 2-1. (Refer to Figure 2-2 for greater detail on the Waste Oil Pit area.) In 1995, 1996, and 2000, soil borings were advanced using an HSA drill rig and samples were collected using a split-spoon sampler. In 1997, soil borings were advanced using an HSA

drill rig and split-spoon samplers and a DPT drill rig and disposable sample liners. Boring logs are provided in Appendix A.

2.2.1 Surface Soil Investigation

A sample was collected from the 0- to-2-foot depth interval from 48 soil borings to identify potential surface soil contamination and to characterize nature and extent of contamination. The samples collected in 1995 and 1996 were analyzed for VOCs, SVOCs, pesticide/PCBs, and RCRA metals. The samples collected in 1997 were analyzed for VOCs, SVOCs, and TAL metals. Samples collected from soil borings that were later converted into monitoring wells were analyzed for RCRA metals too. The samples collected in 2000 were analyzed for VOCs, SVOCs, pesticide/PCBs, and TAL metals. Samples collected from soil borings that were later converted into monitoring wells were also analyzed for RCRA metals (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.2.2 Subsurface Soil Investigation

A sample was collected from between 2 feet bgs and above the bedrock surface from 47 soil borings to identify potential subsurface soil contamination and to characterize nature and extent of contamination. At sample location SB-16, no sample was collected due to poor recovery. No samples were collected from sample locations SB-202 or SB-204. It is uncertain why subsurface samples were not collected at SB-202 or SB-204; however, the depth to bedrock is 4.2 feet bgs at SB-202 and 1.8 feet bgs at SB-204.

The sample depth interval was selected based on the highest PID reading and/or visual contamination. If none of the material recovered from the boring had elevated PID readings and/or visual contamination, a sample from the 2-foot interval directly above bedrock was collected to determine if contamination had reached the till and bedrock interface. The samples collected in 1995 and 1996 were analyzed for VOCs, SVOCs, pesticide/PCBs, and RCRA metals. The samples collected in 1997 were analyzed for VOCs, SVOCs, and TAL metals. Samples collected from soil borings that were later converted into monitoring wells were also analyzed for RCRA metals. The samples collected in 2000 were analyzed for VOCs, SVOCs, pesticide/PCBs, and TAL metals. Samples collected from soil borings that were later converted into monitoring wells were also analyzed for RCRA metals (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.3 Contaminant Source Investigation—Waste Oil Pit

Soil borings were advanced and surface soil, subsurface soil, and bedrock samples were collected at the Waste Oil Pit during SI activities in 1995 and RI activities in 1997, TCRA activities in 1998, and SRI activities in 2007 and 2009. Ten soil borings were advanced in 1995, 14 soil borings were advanced in 1997, 21 soil borings were advanced in 2007, and 9 bedrock borings were advanced in 2009. The 54 boring locations are shown in Figure 2-2. Eight confirmation subsurface soil samples were also collected from the Waste Oil Pit in 1998 during the TCRA of the disposal pit. In 1995, soil borings were advanced using an HSA drill rig, and samples were collected using a split spoon sampler. In 1997 and 2007, soil borings were advanced using both a DPT drill rig and disposable sample liners. In 2009, bedrock borings were advanced using a combined Rotasonic and wire-line rock coring methods to prevent downward migration of contaminants. Boring logs are provided in Appendix A.

2.3.1 Surface Soil Investigation

A sample was collected from the 0- to-2-foot depth interval from each boring advanced in 1995 and 1997 to identify potential surface soil contamination and to characterize nature and extent of contamination. Two samples were collected from SB-07 due to the shallow depth of bedrock at the sample location. Samples were analyzed for VOCs, SVOCs, pesticide/PCBs, and metals (either TAL or RCRA). Samples collected from SB-01 and SB-02 were also analyzed for dioxin (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.3.2 Subsurface Soil Investigation

A sample was collected from between 2 feet bgs and above the bedrock surface from each boring advanced in 1995, 1997, and 2007 to identify potential subsurface soil contamination and to characterize nature and extent of contamination. Three soil borings were completed at SB-11 because of high levels of VOCs detected at the location. No samples were collected from SB-01, SB-101, SB-105, SB-106, or SB-108 due to poor recovery. The sample depth interval was selected based on the highest PID reading and/or visual contamination. If none of the material recovered had elevated PID readings and/or visual contamination, a sample from the 2-foot interval directly above bedrock was collected to determine if contamination had reached the till and bedrock interface. The samples were analyzed for VOCs, SVOCs, pesticide/PCBs, metals (either TAL or RCRA). Samples collected during the TCRA in 1998 were analyzed for dioxin as well (Table 2-2). The analytical methods used to analyze samples collected during each investigation are defined in Table 2-3.

2.3.3 Bedrock Investigation

Samples were collected from the bedrock at each boring advanced in 2009 to evaluate potential bedrock contamination. The investigation was conducted per the TAMPEEL Landfill and 3 Areas of Concern Investigation Work Plan Addendum (CH2M HILL, 2009a). Borings were advanced into bedrock at depths varying from 5 feet bgs at BB-08 to 46 feet bgs at BB-06. Figure 2-2 depicts the locations of the 2009 bedrock borings relative to the former Waste Oil Pit. Bedrock boring (BB-01) located near the center of the former Waste Oil Pit was drilled and sampled first, and additional step-out borings were completed around BB-01 until the extent of contamination was established by field screening. Because the objective of the investigation was to delineate the extent of source material in bedrock, two borings (BB-03 and BB-08) were abandoned after confirming source material was present in bedrock at these locations, so that additional borings could be performed and samples collected further out in order to still meet project objectives with the available resources.

The nine bedrock borings were drilled using the wire-line rock-coring method, which uses a rotary cutting motion to core into bedrock while at the same time advancing an outer casing to prevent downward migration of contaminants during drilling. At the end of each core run (the cored interval), the core barrel and rock core were retrieved from the borehole using a wire-line system, leaving the outer casing in place.

During the coring, potable water was circulated in the borehole to bring the rock cuttings to the surface and to cool the drill bit. At locations where evidence of contamination was not observed in the core samples during a core run, the drilling water was recirculated back into the borehole for use during the next core run. To avoid carrying contaminants down with the drill water during recirculation, the drill water was not recirculated in the borehole at locations where evidence of contamination was observed in the core samples.

Each boring (except in BB-03 and BB-08) was drilled and screened for evidence of contamination (staining on rock cores, odors, and PID readings) from the ground surface to the depth where evidence of contamination was no longer observed. Samples were collected from two intervals in each boring. The first sample was collected from the interval exhibiting the greatest evidence of contamination, and the second sample was collected from the bottom of the borehole where evidence of contamination was not observed. Bedrock samples were collected from three depth intervals at BB-01 at the request of the onsite USACE representative. Bedrock boring advancement was terminated in BB-03 and BB-08 before the bottom of contaminated interval was established in each boring, and no samples were collected from these locations. Additional step-out borings (BB-09 and BB-04) were completed and sampled beyond BB-03 and BB-08, respectively, because these borings were not meeting the investigation objective of bounding the lateral extent of the contamination in their respective locations.

Non-standard sample collection methods were required for bedrock sample collection and analysis. Bedrock coring and sampling were conducted in accordance with the approved work plan. (Refer to Section 2.3 of the Final Work Plan, including Attachment 1, QAPP Addendum, dated October 2009.) The sample collection and analytical methods were developed to qualitatively evaluate the concentration and extent of VOCs in bedrock that could still be acting as a source of contamination.

Because the bedrock was too hard to collect by EnCore or sleeve, sample collection techniques were developed in conjunction with the laboratory to minimize potential loss of VOCs. The borings were drilled without adding water to the maximum extent possible, and short coring runs (approximately 2 to 4 feet) were drilled to minimize sample disturbance (for example, frictional heating and disaggregation). The procedures also included driving an outer casing as the hole is advanced, and an inner casing for retrieval of samples using as little water as possible during drilling to preserve the integrity of the samples and to minimize the chance that constituents of concern (COC) will be carried downward from the borehole. The bedrock samples were disaggregated by placing pieces of bedrock into a resealable plastic bag and hitting the bag with a hammer against a firm, hard surface. For VOC analysis, approximately 50 grams of the disaggregated rock no larger than 0.75 inch in diameter were placed in a pre-tared (with 50 milliliters of methanol) 4-ounce jar provided by the laboratory. The analytical methods used to analyze samples collected during the investigation are defined in Table 2-3.

2.4 Groundwater Investigations—Sitewide

Monitoring wells were installed within and around the 3 AOCs in 1997, 2000, 2007, and 2009 (Figures 2-1 and 2-2). The monitoring wells were installed to identify potential groundwater contamination associated with the 3 AOCs and to characterize nature and extent of contamination, if present (Table 2-1). A total of 11 monitoring wells were installed in 1997, 9 monitoring wells were installed in 2000, and 2 monitoring wells were installed in 2007, and 2 monitoring wells were installed in 2009 (Table 2-4). Groundwater samples collected from the wells in 1997, 2000, 2007, and 2008 were analyzed for VOCs, SVOCs, and TAL metals. Samples collected in 1997 and 2000 were also analyzed for pesticides/PCBs (Table 2-5). The analytical methods used to analyze samples collected during the investigation are defined in Table 2-3.

2.4.1 Drilling and Monitoring Well Installation

Monitoring wells within and around the 3 AOCs were installed in accordance with local, state, and federal guidelines. Monitoring well boreholes were drilled using either an HSA drill rig, a rotary drill rig, or a Rotasonic drill rig. Some monitoring well boreholes were drilled using multiple drill rigs. Monitoring well construction diagrams are provided in Appendix A.

Monitoring well installation began within 48 hours of borehole completion using decontaminated equipment and supplies. The monitoring wells were constructed using flush-threaded 2-inch-diameter Schedule 40 polyvinyl chloride casing and screen. Monitoring well screens are 10 feet in length with 0.010-inch continuous slots, and placed to screen-specific saturated zones depending upon the monitoring well. The annulus space between the well screen and the borehole was backed with clean silica sand to a minimum depth of 1 foot above the top of the well screen. Following the verification of the top of the filter pack, a bentonite pellet seal was placed immediately above each filter pack. The bentonite seals are approximately 2 to 4 feet thick depending upon the monitoring well. The remaining open annulus space was backfilled with a grout mix that consisted of Portland cement, potable water, and bentonite powder.

All monitoring wells were fitted with aboveground surface completions. The protective well casings extend 2 to 3 feet above land surface. A 4-inch-diameter steel protective casing with a lockable, hinged cap was set in neat cement, with the bottom below the frost line, approximately 3 to 4 feet below grade. Four concrete-filled steel guard posts 5 feet in total length were set 3 feet below ground around the monitoring well to protect the surface casing. The guard posts were set in neat cement around the outside of the concrete pad that was placed around the base of the protective casing. The monitoring well pads were sloped to promote drainage away from the well. The well identification was permanently marked on the casing cap and the protective casing. All monitoring wells were relocked and well identification remarked in fall 2007.

2.4.2 Monitoring Well Development

Development of monitoring wells began no sooner than 48 hours after installation. The monitoring wells were developed so that groundwater samples collected from the well were representative of actual groundwater conditions. Well development was accomplished using a decontaminated submersible pump,

surge block, and bailers. During development, discharge rates were measured using a graduated container (such as a plastic bucket) prior to containerization. A minimum of five well volumes were removed from each monitoring well during development. Development continued until groundwater parameters (that is, pH, temperature, turbidity, and specific conductivity) stabilized. Monitoring wells that produce insufficient yield for standard well development were purged dry three times. All monitoring wells were also redeveloped in fall 2007, prior to the first quarterly monitoring event. Monitoring well development logs were completed for each monitoring well (Appendix B).

2.4.3 Groundwater-level Measurements

Groundwater levels were collected prior to sampling of each monitoring well in 1997, 2000, 2007, and 2008. The water levels were recorded in order to ascertain the local groundwater flow direction. A water level indicator was used to measure depth-to-groundwater to the nearest 0.01 foot. During each event, all groundwater levels were measured within a 24-hour period. Recorded groundwater levels are provided in Table 2-6.

2.4.4 Groundwater Sampling

Groundwater wells were sampled during the RI, SRI, and the quarterly groundwater sampling events. Monitoring wells MW-127 and MW-130 were sampled after installation in 2009. The monitoring wells were sampled using low-flow purge techniques. Pumping rates and groundwater levels were measured and monitored to minimize drawdown and to ensure adherence to low-flow sampling technique. A minimum of three well volumes were removed from each monitoring well prior to sampling.

The temperature, pH, specific conductance, and turbidity of the purge water were measured and recorded periodically during purging to provide representative parameter values. Samples were collected only after a minimum of three well volumes had been removed and the physical parameters of temperature, pH, and specific conductance had stabilized and turbidity was less than 5 nephelometric turbidity units. If a well was purged dry before three well bore volumes had been removed or field parameters had stabilized, then sampling was conducted as soon as sufficient recharge had occurred.

Groundwater samples were collected in 1997 and 2000 and analyzed for VOCs, SVOCs, pesticides/PCBs, and TAL metals. In 2007, 2008, and 2009 groundwater samples were collected and analyzed for VOCs, SVOCs, and TAL metals. Samples were collected directly from the disposable, Teflon-lined polyethylene tubing. When collecting VOC samples, the pumping rate was lowered to minimize turbulence and aeration of the sample. Unfiltered and filtered groundwater samples were collected and analyzed for TAL metals. Samples requiring filtration were filtered using a disposable 0.45-micrometer membrane inline filter attached to the discharge line of the sample pump. Samples were preserved in the field, capped, labeled, and immediately placed on ice before being packaged and shipped to the designated laboratory.

2.4.5 Slug Tests

Rising head and falling head slug tests were performed on 20 monitoring wells in 2000. The slug tests were performed to determine the hydraulic conductivity of the geologic formation in the vicinity of the monitoring well. Groundwater measurements and response times were recorded on electronic data loggers and are provided in Appendix C. The data collected from the slug tests were later analyzed using the Bouwer and Rice Method (Bouwer and Rice, 1976) and the Hvorslev Method (Hvorslev, 1951) to produce estimated hydraulic conductivity values.

2.5 Surveying

Surveying activities were performed as part of the field investigation activities to establish the horizontal and vertical locations for each soil boring and monitoring well. A registered professional surveyor licensed in the state of Ohio (Shaw, Weiss, and DeNaples in 1997; Lynn, Kittinger & Noble, Inc., in 2000; and Hammontree and Associates in 2007 and 2009) was used to survey the locations. At each soil boring location the northing, easting, and ground surface elevation was recorded, and at each monitoring well location the

northing, easting, ground surface elevation, and the top of casing of the monitoring well was recorded. Horizontal control was referenced to the North American Datum of 1927 Ohio State Plane Coordinate System, and vertical control was referenced to the National Geodetic Vertical Datum of 1929. Soil boring and monitoring well coordinates and elevations are provided in Table 2-7.

2.6 Field Quality Control Sampling

To evaluate the reliability of field sampling procedures, field quality control (QC) samples were collected for each media sampled in accordance with the quality assurance project plan (QAPP) and/or work plans for each investigation. QC samples collected included matrix spikes and matrix spike duplicates at a frequency of 1 per 20 (5 percent) samples, and field duplicates at a frequency of 1 per 10 samples (10 percent).

In addition to the aforementioned field QC samples, field split quality assurance (QA) samples were collected for soil and groundwater during the RI. Split QA samples were collected at a frequency of 5 percent of total soil and total groundwater samples collected (half of the field duplicate samples per media). Field split QA samples were collected by dividing an aliquot of the media sampled into three equal portions. One portion was for the original sample, one for a field duplicate, and one for the split QA sample. Collected QA samples were submitted for analysis to the Missouri River Division laboratory. QA/QC samples for soil analysis are presented in Table 2-2.

2.7 Equipment Decontamination

Prior to commencement of field investigation activities, a decontamination area was established and sampling equipment that was either directly or indirectly in contact with media samples was decontaminated before use. Sampling equipment (that is, stainless steel bowls, and trowels or spoons, core barrels, split spoons, etc.) were decontaminated in the following sequential steps:

- Washed and scrubbed equipment with a solution of potable water and laboratory-grade nonphosphate detergent
- Rinsed several times with potable water
- Rinsed with a 10 percent hydrochloric acid solution
- Rinsed with deionized water
- Rinsed with pesticide-grade isopropanol
- Rinsed with deionized water
- Equipment allowed to air dry
- Equipment wrapped in aluminum foil, shiny side out

Drilling equipment was steam-cleaned prior to drilling each boring, installation of each monitoring well, and prior to leaving the site. Monitoring well casing materials that arrived onsite sealed in factory-supplied packaging was not decontaminated prior to use. Any monitoring well casing materials or well screens that were not sealed when they arrived at the wellhead were steam-cleaned and allowed to air dry prior to use in the monitoring well.

Potable water used during the field investigation was obtained from an onsite source. One potable water sample was collected during the RI for offsite chemical analysis.

2.8 Investigation-derived Waste Management

Field investigation activities generated both solid and aqueous investigation-derived waste (IDW) and miscellaneous trash. Management of IDW was performed in a manner consistent with the *Guide to*

Management of Investigation—Derived Wastes, 9345.3-03FS (U.S. Environmental Protection Agency [USEPA], 1992a).

Excavated soil and rock generated from soil borings and monitoring well installations were placed into steel, 55-gallon drums approved by the Department of Transportation and staged onsite. Water generated from drilling, decontaminating drilling and sampling equipment, well development, and groundwater sampling was placed into Department of Transportation approved, 55-gallon steel drums and a polyethylene storage tank and staged onsite. The IDW drums and polyethylene storage tank were properly labeled and staged in a central location onsite for temporary storage until they were removed for disposal.

At the conclusion of each field investigation, soil and liquid samples were collected from the IDW drums and polyethylene storage tank to characterize the waste. The IDW, both soil and water, was later removed from the site and properly disposed of in accordance with applicable local, state, and federal regulations.

Disposable sampling equipment, personal protective equipment, and miscellaneous trash were disposed of in solid waste containers at the conclusion field investigation activities.

Physical Characteristics of the Study Area

Information on the site's physical characteristics was observed and recorded as part of the CRI. The information was used in conjunction with the environmental sampling data presented in Section 4, in order to understand the nature and extent of contamination within and around the 3 AOCs. Section 3 summarizes the physical characteristics of the study area.

3.1 Surface Features

The site and surrounding area consist of gently rolling hills, small gullies, and ravines. Predominant vegetation includes native grasses and trees, such as maple, birch, beech, and hemlock.

The topography of the site and surrounding area is relatively flat, with an elevation range between 940 to 945 feet above mean sea level (amsl) around the 3 AOCs (Figure 3-1). Within a 1-mile radius of the site, the elevations range from approximately 900 to 980 feet amsl. Prior to the existence of the FLOD, much of the land surface consisted of wetlands and swamp forests. The land surface was altered during construction of the FLOD to suit the needs of the facility. During construction, some of the low-lying areas and wetlands were filled and graded and, therefore, removed some of the pre-existing topographic relief. In general, the land surface slopes gently from south to north with a localized high point near the former Waste Oil Pit.

3.2 Meteorology

Located in northeast Ohio, Lordstown primarily has a continental climate, with pronounced daily and seasonal temperature changes. Summers are relatively warm and moderately humid, with average high temperatures in July and August above 80 degrees Fahrenheit (°F) and average low temperatures slightly below 60°F during these months. Winters are generally cool to cold, with January typically being the coldest month of the year. The average high temperature in January is 34.2°F, and the average low temperature is 16.1°F. The average growing season for the region is 156 days. The last frost before spring usually occurs in late April or early May, and the first frost in fall usually occurs in early October. The prevailing winds are generally from the south but also from the southwest, north, and northwest directions. The average wind speed is highest, around 12 miles per hour, from November to April (U.S. Department of Agriculture [USDA], 2011a).

Severe spring storms with strong winds, hail, thunder, and lightning occur between the months of April and June, and winter ice and snow storms develop between the months of November and March. Since 1971, the average annual rainfall for the area is 37.82 inches, with low variability between years. July is typically the wettest month of the year, with average monthly rainfall of 4.21 inches. Snowfall is typical for northeastern Ohio. Significant snowstorms are common due to lake-enhanced snowfall. The highest monthly average snowfall of 12.1 inches occurs in January (USDA, 2011a).

3.3 Surface Water Hydrology

Surface water features in the vicinity of the site consists of Beaver Creek, TAMPEEL Spring, Aspen Creek, and two small ponds: Beaver Pond and Study Pond. Beaver Creek is an ephemeral creek that originates at the railroad tracks on the southern edge of the site and flows north to northwest towards Beaver Pond (Figure 3-1). The water present in Beaver Creek is a combination of surface water runoff and groundwater discharge. Over the years, the development of multiple beaver lodges and dams along the creek has created Beaver Pond. Beaver Pond is approximately 1 to 2 acres in size. The extent of the Beaver Pond has been larger at times; its size changes depending on activity of the beavers, surface water runoff, and groundwater discharge. From Beaver Pond, Beaver Creek flows north and feeds into Duck Creek approximately 1.5 miles north of the site. Duck Creek continues to flow north another 2 miles before discharging into Mahoning River just west of downtown Warren, Ohio. Duck Creek is one of several tributaries of Mahoning River (Figure 1-1).

Study Pond is located northwest of the investigation area on the northern portion of the TAMPEEL Nature Center property. The pond was formed after a borrow pit was created for building the adjacent roadway around 1985. Study Pond is presumed to be recharged by groundwater and has no surface water outlet. The pond is approximately 20 feet deep and is bordered on the east and west sides by white pine timber.

A small spring known as TAMPEEL Spring is located approximately 200 feet south-southwest of Study Pond. TAMPEEL Spring is the headwater for a small drainage that flows northeast to the unnamed tributary that flows north to Duck Creek.

Aspen Creek originates near the TAMPEEL parking area and runs north-northeast, eventually discharging into Beaver Creek. Water in Aspen Creek is a combination of runoff from the TAMPEEL and groundwater discharge.

3.4 Surface Soils

Unconsolidated overburden overlies bedrock at the site. The unconsolidated overburden in the vicinity of the site is relatively thin, between 2 to 6 feet bgs, and consists of USDA-classified Udorthent and Wadsworth soils at the surface (USDA, 2011b).

Surface soils on the western side of the service road (area encompassing the BPA) are classified as Udorthent loamy soil. This type of soil is common for areas that have been previously cut or filled. Historical documents and soil boring logs verified that the area was once cut and filled. The origin of the fill material encountered is unknown, but due to similar characteristics of the fill and native soils, it appears to have been cut from other areas of the site or surrounding vicinity.

Soils of the Udorthent complex are typically acidic to neutral, made up of predominantly fine sandy loam, and can be found on slopes that are inclined between 15 to 25 percent but are more commonly found on slopes that are inclined between 0 to 5 percent. Udorthent soils commonly occur in areas of recently exposed soil, in areas of weakly cemented rocks, such as shale, or in areas of thin soil over hard rocks. Udorthent soils are typically moderately dark to dark in the uppermost 6 to 10 inches and resemble topsoil. Depending upon the percentage of coarse material present, Udorthents have a highly variable permeability, varying from moderate to slow at the surface to rapid to very slow at depths below 10 inches. Udorthent soils are typically covered by grassy vegetation (USDA, 1999).

Surface soils on the eastern side of the service road (area encompassing the former RSY and Waste Oil Pit) are classified as Wadsworth soils. Wadsworth soils commonly form in glacial till on flat plains and are strongly influenced by sandstone and clay shale. Soils of the Wadsworth complex are typically highly acidic, made up of predominately fine sandy loam, and can be found on slopes that are inclined between 0 to 12 percent. Wadsworth soils are also commonly friable and dark grayish-brown to light brownish-gray in the uppermost 0 to 8 inches. Depending upon the percentage of coarse material present, permeability is generally moderate to slow at the surface to slow to very slow at depth. Wadsworth soils are typically covered by grassy vegetation or deciduous timber, such as maple, beech, or red oak (USDA, 2005).

3.5 Geology

3.5.1 Regional Geology

Northeastern Ohio is part of the Glaciated Allegheny Plateau physiographic region. The Glaciated Allegheny Plateau has relatively very little topographic relief when compared to the non-glaciated Allegheny Plateau located to the south. The Glaciated Allegheny Plateau physiographic region is dominated by mixed glacial deposits and landforms deposited by either the Grand River sub-glacial Lobe or the Killbuck sub-glacial lobe. North-central and northwestern Trumbull County is covered by glacial deposits associated with the Grand River Lobe, which developed during the Wisconsinian glacial stage (14,000 to 24,000 years ago). Central and southern Trumbull County is covered by remnant glacial outwash deposits and landforms developed during the Pre-Illionian (older than 300,000 years ago) and the Illionian (130,000 to 300,000 years ago) glacial

stages. The unconsolidated overburden overlies bedrock. The bedrock ranges in age from Late Devonian (385 to 359 million years ago) to Early Pennsylvanian (322 to 307 million years ago). The geologic bedrock units of Trumbull County are generally composed of Paleozoic sandstone, shale, and limestone. The bedrock was later modified by Mesozoic and Tertiary erosion (Back et al., 1988).

3.5.2 Site Geology

The geology across the site consists of unconsolidated glacial deposits overlying shallow bedrock. Thickness of the unconsolidated glacial deposits is generally between 2 to 6 feet; however, thicker deposits, up to 10 feet, are present along the western portion of the investigation area. The unconsolidated glacial deposits present in the subsurface consist of brown to grayish-brown clayey silts or silty clays that contain varying percentage of sand grains. Soil boring logs indicate that a 15- to 25-foot-thick sandstone bedrock unit lies directly beneath the glacial deposits in the southern and central portions of the investigation area. In north-central portions of the investigation area, the sandstone unit thins to about 1 to 5 feet thick. The sandstone unit eventually pinches out north of the investigation area. Soil boring logs also indicate that a shale unit of undetermined thickness underlies the sandstone unit. Where the sandstone unit is absent, the shale unit lies directly beneath the overburden.

The interpretation of the top of bedrock is complicated by the weathered nature of the sandstone bedrock and the different drilling technologies used to support the subsurface investigations. Each technique that was used (HSA, DPT, rotasonic, and wire-line coring) penetrates rock differently, and results in varying degrees of intact cores. To make the interpretation as consistent as possible, all available soil borings and monitoring wells logs installed during site investigations were reviewed to support interpretation for this report. The interpreted elevation of the top of bedrock at the 3 AOCs area ranges between 942 and 932 feet amsl (Figure 3-2). Due to the large number of borings installed in and around the Waste Oil Pit, only a portion of the borings and their bedrock depth elevations were identified in Figure 3-2. The borings that were not displayed on the figure have comparable top of bedrock elevations and conform to the bedrock contour lines.

Lithology taken from soil boring and monitoring well installation logs drilled during site investigations was used to construct geologic cross sections to determine geologic trends across the 3 AOCs. Figure 3-3 identifies the geologic cross section lines: A-A' (Figure 3-4), B-B' (Figure 3-5), and C-C' (Figure 3-6). As shown on the bedrock contour map and geologic cross sections, bedrock across the 3 AOCs occurs at an average depth of 4.4 feet bgs at the former Waste Oil Pit area, 4.9 feet bgs at the former BPA, and 5.4 feet bgs at the former RSY (Table 3-1). Within the investigation area, the highest bedrock elevation appears in the vicinity of monitoring well MW-118 at an elevation of 941.70 feet amsl, and the lowest bedrock elevation appears in the vicinity of soil boring SB-112 at an elevation of 932.84 feet amsl.

Analysis of the bedrock contour map and geologic cross sections indicates that the top of the bedrock varies several feet within the 3 AOCs and that lower top of bedrock elevations are generally found to the north and west of the investigation area. Geologic cross section A-A' (Figure 3-4) illustrates how the bedrock surface elevations within the investigation area decrease from south to north, and geologic cross section B-B' (Figure 3-5) illustrates how the bedrock surface elevations decrease from east to west. Soil borings and well installation logs indicate that the top of the sandstone unit is highly weathered. Fractures within the sandstone unit are highly weathered to a depth of 10 feet bgs and moderately weathered to a depth of 14 feet bgs. The sandstone unit is typically composed of fine- to medium-grained cemented sand, which is light gray to white and thinly bedded to massive at depth. Sandstone hardness generally corresponds to structure and depth, with soft to moderately hard sandstone near the top of the unit and moderately hard to hard sandstone at depths approximately 12 to 20 feet bgs. Soil boring logs indicate that the sandstone unit exhibits a high degree of predominantly horizontal fracturing in some locations. Thin discontinuous lenses of dark gray and black shale are present within the sandstone unit, with shale lenses being more prevalent near the sandstone and shale contact. The base of the sandstone bedrock unit is poorly defined in

the southern portion of the investigation area, due to the fact that few soil borings have been advanced to the depths necessary to define its total thickness.

The shale bedrock unit beneath the investigation area is typically fine-grained, light to dark gray to black and thinly bedded. Discontinuous lenses of fine-grained, lightly colored sandstone and claystone are present within the shale unit, with sandstone lenses being more prevalent near the sandstone and shale contact. Soil boring logs generally indicate that the number of fractures per foot of core is less in the shale than in the overlying sandstone. Like the overlying sandstone unit, the base of the shale bedrock unit is poorly defined in the investigation area, due to the fact that no soil borings have been advanced to the depths necessary to define its total thickness.

3.6 Hydrogeology

Groundwater flows in through interconnected pore spaces between unconsolidated grains and through pores, fractures, and weathered zones within bedrock. The depth to groundwater across the investigation area is typically between 1 to 5 feet bgs (Table 2-6). Analysis of groundwater levels measured at site monitoring wells indicates that the water table fluctuates between 1 to 2 feet, above and below the bedrock surface, throughout the year in response to seasonal variations in precipitation. The potentiometric surface within the 3 AOCs Site is typically at its highest elevations in early spring, between 944 and 936 feet amsl, and at its lowest elevation in late summer, between 943 and 935 feet amsl.

Groundwater levels measured at the site monitoring wells during site investigations were used to construct potentiometric maps for June 2001 (Figure 3-7), December 2007 (Figure 3-8), March 2008 (Figure 3-9), June 2008 (Figure 10), and September 2008 (Figure 3-11). Analysis of the potentiometric surface maps indicates that groundwater flow is influenced by bedrock topography and that the groundwater flow directions are consistent throughout the seasons and over the years. Groundwater flows in three different directions across the investigation area. Groundwater flows south to north from the Waste Oil Pit to Beaver Pond, southeast to northwest from the RSY to Beaver Creek, and south to north-northeast from the Waste Oil Pit to the northeastern sections of the Service Road. In general, groundwater flows from south to north across the investigation area.

Hydraulic conductivity values were estimated using data resulting from slug tests performed at 20 of the site monitoring wells. Of the 20 site monitoring wells tested, useable data were available from only 11 of the monitoring wells. Slug tests that generated unusable data sets showed that the aquifer's response was too rapid to calculate realistic hydraulic conductivity values. The hydraulic conductivity values for the eleven useable data sets ranged from 0.14 to 22 feet per day using the Bouwer and Rice Method and from 0.20 to 31 feet per day using the Hvorslev Method (Table 3-2). The two-order-of-magnitude range in hydraulic conductivity values may be attributed to the localized fracturing in the upper zone of the sandstone bedrock. Data logger output from the 20 monitoring wells tested is provided in Appendix C.

The hydraulic gradients at the site ranged from 4×10^{-3} foot per foot just downgradient (north-northwest) of the Waste Oil Pit (September 2008, Figure 3-9) to 3×10^{-2} foot per foot near MW-125 (March 2008, Figure 3-8).

The mobile porosity (effective porosity) is assumed to be 15 percent. Using the hydraulic conductivity, hydraulic gradient, and assumed mobile porosity values, the estimated average linear groundwater flow rate ranged from 0.004 to 0.8 feet per day in the area just downgradient of the Waste Oil Pit, and from 0.03 to 6 feet per day near MW-125. According to the Groundwater Resources Map of Trumbull County, groundwater at the investigation area is obtained from the saturated sandstone and sandy shale bedrock. Although occasional well yields of up to 75 gallons per minute are possible, maximum sustained well yields are typically closer to 25 gallons per minute (Haiker, 1996). During well development and sampling, all site monitoring wells produced sufficiently to keep the monitoring wells from going dry with the exception of well MW-105, which repeatedly went dry.

3.7 Demography and Land Use

The FLOD is located in the north-central segment of the Lordstown Township. The site resides just outside of the city limits of Warren, Ohio, in Trumbull County, approximately 4 miles southwest of downtown Warren. According to the 2000 Census, Trumbull County had a population of 225,116. Lordstown Township had a population of 3,633, of which 24 percent were under age 18, 65 percent were age 18 to 65, and 11.0 percent were over the age of 65. Lordstown has a total area of approximately 23 square miles, predominantly occupied by a mixture of residential and commercial properties. The population density is about 157 people per square mile.

The investigation area is currently within the OCC, zoned as commercial, and encompasses 480 acres. Approximately 40 percent of the property is used for storage, while the remaining 60 percent is used for light manufacturing or assembly. Approximately 25 tenants use the space through leases of one month or longer; others lease parking spots on a temporary or month-to-month basis. The FLOD is bounded to the east by Ohio State Route 45 and to the south by the Baltimore and Ohio Railroads. Tracts near the southwest are zoned commercial and are occupied by trucking/transportation companies. The property (39 acres) along the northwestern edge of OCC is owned by the Trumbull County Board of Education and is occupied by the TAMPEEL. Property along the northern property boundary is residential and agricultural.

Water supplies for Lordstown Township are derived from Meander Lake, which is located approximately 3 miles to the southeast of the investigation area. The Lordstown Water Commissioner indicated that all residents in the investigation area are supplied with city water.

A water well search of Ohio Department of Natural Resources records conducted in 2011 (EDR, 2011), indicates that 30 water wells have been recorded in the vicinity of the 3 AOCs (within 1 mile). Figure 3-10 shows the locations of the water wells, and the information compiled from the boring logs is presented in Table 3-3. The water well logs are in Appendix D. The wells were either completed in sandstone, shale, or limestone at depths ranging from 43 to 118 feet bgs. Static groundwater levels from the water wells vary from 6 to 37 feet below ground surface, and pump tests indicated that the wells yield 2 to 30 gallons per minute. Any current use of the water wells, including their abandonment status is unknown. For example, the well identified as "1" on Figure 3-10 is within the 3 AOCs Site, though there is no evidence or available record of its existence. Because all residents in the area are on public supply, the wells, if still in existence, are likely unused or are for non-potable use. Regardless, the proximity of the offsite water wells will be considered relative to the nature and extent of contamination in Section 4.5.

3.8 Ecology

The site is located within the western Erie/Ontario Lake Plain EcoRegion (Omernik, 1986), which is generally characterized as containing irregular plains as the predominant land surface form and having a dominant natural vegetation of the beech/maple and northern hardwood communities (such as maple, birch, beech, and hemlock) in undisturbed areas. The predominant soil order for the ecoregion is Alfisols, which form in semiarid to humid areas, typically under a hardwood forest cover (the Wadsworth soil series present within the investigation area is a subset of the Alfisols soil order). The investigation area itself consists of small ravines and lowlands with deciduous trees and open fields with grasses and low shrubs.

Mammals that are likely to be present in the area include the white-tailed deer, badger, mink, raccoon, red and gray foxes, coyote, beaver, eastern cottontail, woodchuck, least shrew, and opossum. Common birds include the eastern great blue heron, green-winged teal, mourning dove, eastern belted kingfisher, eastern horned lark, blue-gray gnatcatcher, eastern cowbird, and a large variety of ducks, woodpeckers, and warblers. Reptiles and amphibians, found throughout the state include the snapping, midland painted, and spiny soft-shelled turtles, five-lined skink, northern water snake, midland brown snake, eastern hognose, and eastern milk snake. Fish common to lakes and streams in the area include bass, perch, carp, pike, muskies, trout, catfish, and suckers.

SECTION 4

Nature and Extent of Contamination

This section presents the nature and extent of contamination observed based on the investigative activities discussed in Section 2. The nature of contamination refers the type of contamination present and how concentrated it is, as well as the physical properties of the contamination in environmental media. The extent means how widespread the contamination is. Understanding nature and extent supports an evaluation of what has or will happen to contaminants in the environment (that is, fate and transport, as discussed in Section 5). Ultimately, the information is also needed to assess current and future risks that the contamination may pose to human health and the environment (that is, risk assessment, as discussed in Section 6). Section 4 is organized first by AOC, then by the environmental media associated with each, to enhance understanding of the unique conditions associated with each AOC.

A first step in evaluation of nature and extent is to consider the constituents detected at the site. However, just because a constituent is detected does not mean it is attributable to a site-related release. Metals are naturally occurring in the environment (refer to Section 4.1), and several other constituent groups (for example, polynuclear aromatic hydrocarbons [PAHs]) are found nearly ubiquitously in the environment due to “anthropogenic” (meaning, human-related) activities, such as atmospheric deposition. Background concentrations are considered in the discussion of uncertainties of the risk assessment in Section 6 for any risks calculated at concentrations exceeding the target risk thresholds, in order to support risk management decisions.

The data used to determine nature and extent were generated using standard protocol to ensure they are accurate and representative. Laboratory-generated data from the investigations were developed using standard methods consistent with Data Quality Objective Level III or IV criteria and may be used with confidence in assessing the nature and extent of contamination and risk assessment. The Laboratory Data Tables and Data Validation Summary Reports are in Appendix E.

Data flags were assigned to results according to the QAPP and/or work plans for each investigation. Multiple flags are routinely applied to specific sample method/matrix/analyte combinations, but there will be only one final flag. A final flag is applied to the data and is the most conservative of the applied validation flags. The final flag also includes matrix and blank sample impacts.

The data flags are defined below, and should be referenced throughout review of this section to aid in interpretation of the analytical data presented:

"=" = The analyte of concern was detected at the concentration level reported

B = Qualifier indicates the presence of the qualified target compound in the method or procedure blank

E = Indicates that the compound's reported concentration exceeds the upper calibration standard (exceeds the linearity of the curve)

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample

N = Spiked sample recovery was not within control limits

M = Duplicate injection precision >20%D

R = The sample results were rejected because of serious deficiencies in the ability to analyze the sample and meet QC criteria; The presence or absence of the analyte cannot be verified

U = The analyte was analyzed for, but was not detected above, the reported sample quantitation limit

UJ = The analyte was not detected above the reported sample quantitation limit; however, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample

W = Post-digestion spike is outside control limits (85 to 115%), where sample absorbance is <50% of spike absorbance

"*" = Duplicate relative percent difference was not within control limits

"+" = Correlation coefficient for Method of Standard Additions was <0.995

4.1 Determination of Background

Understanding the site background conditions is an important step to establishing nature and extent of site-related contamination. A number of potentially site-related contaminants occur naturally in the environment (that is, metals), or due to more regional or non-site-specific anthropogenic activities. Defining the background concentrations allows for distinguishing what contamination is truly site-related, to support remedy decision making. This subsection presents the approach used to define site background, along with the resulting background concentrations considered in defining nature and extent. While several contamination groups were analyzed to assess background, site background levels were only calculated for metals.

4.1.1 Soil

During the RI, three soil borings (SB-128A, SB-129, and SB-130) were performed to collect background soil data to supplement background data collected during the SI (SB-21 and SB-39). Soil samples were also collected from two monitoring wells (MW-103 and MW-110) for inclusion in the background data set. Background soil sample locations are depicted in Figure 2-1, with the exceptions of SB-128A and SB-130, which are located approximately 300 feet to the west outside the boundaries of the figure.

At the RI sample locations, background soil samples were collected from both the 0- to 2-foot depth interval and the 2-foot depth interval above the soil bedrock interface.

The background soil samples collected during the RI were analyzed for VOCs, SVOCs, pesticides/PCBs, and TAL metals while SI background samples were analyzed for VOCs, SVOCs, pesticides/PCBs, and RCRA metals. Since the metals are naturally occurring, background concentrations were established only for metals. The results for the remaining constituents detected in the background soil samples are used for general comparison only.

VOCs, SVOCs, and pesticides/PCBs were either not detected, or the detected values were less than the method detection limit for the samples (for example, bis(2-ethylhexyl)phthalate was detected at 0.075 and 0.2 micrograms per kilogram ($\mu\text{g}/\text{kg}$) while detection limits ranged from 0.38 to 0.42 $\mu\text{g}/\text{kg}$). The organics that were detected are either common laboratory contaminants¹ (for example, bis(2-ethylhexyl)phthalate maximum detection 0.21 milligrams per kilogram (mg/kg) and methylene chloride (maximum detection 0.003 mg/kg) or PAHs (fluoranthene with a maximum detection of 0.076 mg/kg and pyrene with a maximum detection of 0.076 mg/kg).

Anthropogenic background constituents are defined by USEPA as constituents that are present in the environment due to human-made, non-site sources (for example, industry, automobiles). Background can range from localized to ubiquitous. For example, pesticides—most of which are not naturally occurring (anthropogenic)—may be ubiquitous in certain areas (for example, agricultural areas), and salt runoff from

¹ Common Laboratory Contaminants. Certain organic chemicals (considered by USEPA to be acetone, 2-butanone, methylene chloride, toluene, and the phthalate esters) are commonly used in the laboratory and therefore may be introduced into the sample from laboratory cross-contamination, not from the site. A list of the common laboratory contaminants can be found at the following link: http://www.epa.gov/oswer/riskassessment/datause/pdf/parta_14.pdf

roads during periods of snow may contribute high ubiquitous levels of sodium. PAHs and lead are other examples of anthropogenic, ubiquitous constituents, although these constituents also may be present at naturally occurring levels in the environment due to natural sources (for example, forest fires may be a source of PAHs, and lead is a natural component of soils in some areas) (USEPA, 1989). In addition to burning in the BPA, the low levels of PAHs may also be due to anthropogenic sources such as locomotive exhaust from the rail line on the south side of the property (Figure 1-3), or runoff or leaching from asphalt-bitumen. The objective for calculating background values for the metals was to compile a single background data set for the entire site. However, background soil samples were collected from both surface and subsurface depth intervals and from areas underlain by different bedrock compositions (sandstone and shale). Prior to calculating background values, the background data were evaluated to determine whether there is a statistically significant variation in metals concentrations between sample depth intervals.

The metals soil data was segregated into four groups that include surface and subsurface soil underlain by sandstone and surface and subsurface soil underlain by shale. Two commonly accepted statistical methodologies, the Student's T-test and the F-test, were used to determine if there is a statistically significant difference (alpha = 0.05) between soil data sets. If no difference between groups was determined, the data sets were combined. The Student's T-test and the F-test methodologies are shown below.

The T-test is conducted to test whether there is no difference between two population means with equal variances from a combined data set that is normally distributed. The null hypothesis to be tested is:

H_0 : The populations have equal means
versus

The alternative hypothesis

H_A : $\mu_1 > \mu_2$
 H_A : $\mu_1 < \mu_2$
 H_A : $\mu_1 \neq \mu_2$ either

Rejection Region for a Level 0.05 Test

$T_{test} \geq T_{0.95, n_1 + n_2 - 2}$
 $T_{test} \leq -T_{0.95, n_1 + n_2 - 2}$
 $T_{test} \geq T_{0.975, n_1 + n_2 - 2}$ or
 $T_{test} \leq -T_{0.975, n_1 + n_2 - 2}$

The sample means the sample variance of the two groups are calculated, followed by the calculation of the estimated pooled standard deviation:

$$s = \left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \right]^{0.5}$$

The test statistic is then calculated:

$$T_{test} = \frac{\bar{x}_1 - \bar{x}_2}{s \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

The critical values ($T_{critical}$) are determined from a T-test table and the T_{test} values are compared to the $T_{critical}$ values. Based on the rejection table, when the T_{test} statistic is between the two critical values, there is insufficient information to conclude that the means are from two different populations.

The F-test is conducted to test whether there is no difference between two population variances from a combined data set that is normally distributed. The null hypothesis to be tested is:

H_0 : The populations have equivalent variances ($\sigma_1^2 = \sigma_2^2$)
versus

The alternative hypothesis

Rejection Region for a Level 0.05 Test

$$\begin{array}{ll}
 H_A: & \sigma_1^2 > \sigma_2^2 & F_{\text{test}} \geq F_{0.05, n1-1, n2-1} \\
 H_A: & \sigma_1^2 < \sigma_2^2 & F_{\text{test}} \leq F_{0.95, n1-1, n2-1} \\
 H_A: & \sigma_1^2 \neq \sigma_2^2 & \text{either } F_{\text{test}} \geq F_{0.025, n1-1, n2-1} \text{ OR} \\
 & & F_{\text{test}} \leq F_{0.975, n1-1, n2-1}
 \end{array}$$

The sample variances of the two groups are calculated and the test statistic is calculated:

$$F_{\text{test}} = \frac{s_1^2}{s_2^2}$$

The two F_{critical} values are determined from an F table, and the F_{test} value is compared to the F_{critical} values. Based on the rejection table, when F_{test} is between the two F_{critical} values, there is insufficient information to conclude that the sample variances are from two different populations.

The soil metals background data sets were then evaluated to determine whether they are distributed normally. The W test developed by Shapiro and Wilk (Gilbert, 1987; Equations 12.3 and 12.4) were used to determine whether or not a data set has been drawn from a population that is normally distributed for sample size of 50 or less. By conducting this test on the natural logarithm of each data value, the W test is used to determine whether or not the sample was drawn from an underlying lognormal distribution.

The null hypothesis tested is:

H_0 : The population has a normal (lognormal when the data is transformed) distribution.

versus

H_A : The population does not have a normal (that is, lognormal when the data is transformed) distribution.

If H_0 is rejected, then H_A is accepted.

The equation for calculating W is:

$$W = \frac{1}{d} \left[\sum_{i=1}^k a_i (x_{[n-i+1]} - x_{[i]}) \right]^2$$

where:

$$d = \sum_{i=1}^n x_i^2 - \frac{1}{n} \left(\sum_{i=1}^n x_i \right)^2$$

$$k = \frac{n}{2} \text{ if } n \text{ is even}$$

$$= \frac{n-1}{2} \text{ if } n \text{ is odd}$$

- a_i = Shapiro-Wilk coefficient (Gilbert, 1987; Table A-6)
- x_i = i^{th} data value in the ordered data set
- x_i^2 = square of the i^{th} data value in the ordered data set
- n = number of data points

W = Shapiro-Wilk test statistic (Gilbert, 1987; Table A-7)

H_0 is rejected at the α significance level if W is less than the quantile given in Gilbert, 1987.

To test the null hypothesis that the population has a lognormal distribution, the observed data, y_1, y_2, \dots, y_n where $y_i = \ln x_i$, is transformed.

Once the data have been transformed, the following calculations were used to determine if onsite constituent concentrations are statistically greater than background. This step is accomplished by calculating the upper 95 percent upper tolerance limit (UTL) (Ohio EPA, 1991; Gilbert, 1987).

For normally distributed data:

The upper 95 percent tolerance limit ($UTL_{0.95}$) is actually the upper 95 percent confidence limit for the 95th quantile. Its purpose is to define that concentration of a constituent below which, with 95 percent certainty, all values in a population will fall. The $UTL_{0.95}$ is calculated using the following equation:

$$UTL_{0.95} = \bar{x} + sK_{0.95,0.95}$$

where:

\bar{x}	=	mean of background concentration
s	=	relative standard deviation
$K_{0.95,0.95}$	=	factor for estimating the 95 percent confidence limit for the 95th quantile (Gilbert, 1987; Table A-3)

For lognormally distributed data:

The upper 95 percent tolerance limit for data with an underlying lognormal distribution is calculated by:

$$UTL_{0.95} = \exp [\bar{y} + sK_{(0.95,0.95)}]$$

where:

\bar{y}	=	$\Sigma y/n$ = sample arithmetic mean of the log-transformed data, $y = \ln x$
s	=	relative standard deviation
$K_{0.95,0.95}$	=	factor for estimating the 95 percent confidence limit for the 95th quantile (Gilbert, 1987, Table A-3)

The statistical tests that are described in this section are parametric procedures and are intended for use in cases where the percentage of nondetects in a particular data set is less than 50 percent. In the event that the percentage of nondetects for a particular constituent is greater than 50 percent, non-parametric procedures were applied as appropriate. Procedures for evaluating and applying non-parametric statistics are described in the guidance document *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance* (USEPA, 1992b).

Evaluation of the background data consisted of reviewing the data set distribution and variance for each constituent analyzed. Results of this evaluation indicate that the surface soil (ending depth ≤ 2 feet) and subsurface soil (ending depth > 2 feet) data were from the same population for 15 of the 16 parameters based on the ANOVA test assuming a Normal distribution; however, based on a Wilcoxin Rank Sum Test, 6 of the 16 parameters were from the same population assuming from the same distribution (nonparametric). Based on the analysis, it was decided to have a single background value for soil. Ohio EPA recommended the generation of a single background data set after it was determined there was no statistical difference between the data sets. The background soil values calculated for comparison to AOC data are presented in Table 4-1.

4.1.2 Groundwater

Monitoring wells MW-103, MW-109, and MW-110 were installed at locations upgradient of the three AOCs. Groundwater samples were collected from the wells to assess groundwater conditions prior to any potential impact from the facility operations. Rigorous statistical evaluation of background cannot be completed with three data points since the data set is too small to achieve statistically valid background values. Therefore, the background concentrations for metals are defined as the maximum concentration detected in samples from these three wells. The background groundwater values for comparison to sitewide groundwater data are presented in Table 4-1.

4.2 Sources

The following potential sources of soil contamination were identified and investigated:

- **Railroad Salvage Yard**—During site investigations, the RSY exhibited bare patches and stressed vegetation, which prompted further evaluations of potential contaminant conditions.
- **Burn Pit Area**—The BPA consists of multiple burn areas used for disposal of non-inventoried, combustible materials, non-flammable materials, and miscellaneous glass and metal materials.
- **Waste Oil Pit**—The Waste Oil Pit was used to dispose petroleum products, waste paints, and spent solvents.

Groundwater was identified as a media of concern and a sitewide approach was taken to investigate groundwater because of the close proximity of the AOCs and the interconnectivity of the groundwater beneath them.

4.3 Surface Soil

The following subsections describe the nature and extent of contamination observed in surface soil at the RSY, BPA, and Waste Oil Pit.

4.3.1 Railroad Salvage Yard

Section 2.1 described the surface soil samples collected and analyzed at the RSY. Surface soil samples were collected in the vicinity of the RSY during the SI conducted in 1995 and 1996 and the RI conducted in 1997. Surface soil samples were not collected from the vicinity of the RSY during the SRI conducted in 2000 and 2001 and data gap investigations conducted in 2007 through 2009 since the SI and RI data adequately characterized surface soil. Table 4-2 summarizes the constituents detected in surface soil at the RSY.

4.3.1.1 VOCs

Figure 4-1 shows the magnitude and extent of total VOC concentrations in surface soil at the RSY. The highest total VOC concentrations were detected in surface soil collected from borings SB-122, SB-123, and SB-124. Detected VOCs consisted primarily of chlorinated aliphatic compounds. Trans-1,2-dichloroethene (trans-1,2-DCE) was detected in two samples with the maximum concentration occurring in the sample from SB-123 (4.9 J µg/kg); cis-1,2-dichloroethene (cis-1,2-DCE) and methylene chloride were each detected in three samples with the maximum detected concentrations occurring in samples from SB-123 (77 J µg/kg) and SB-10 (13 B µg/kg) respectively; and trichloroethene (TCE) was detected in four samples with the maximum concentration occurring in the sample from SB-124 (60 J µg/kg).

Acetone was detected in three samples with the maximum concentration occurring in the sample from SB-122 (67 µg/kg). At SB-126, acetone was detected in the normal sample (12 J µg/kg) but was not detected in the duplicate sample. Toluene was detected in the sample from SB-10 (1 µg/kg) and 2-butanone was detected in the sample from SB-122 (13 J µg/kg).

4.3.1.2 SVOCs

Figure 4-2 shows the magnitude and extent of total SVOC concentrations in surface soil at the RSY. SVOC concentrations were detected in surface soil collected from borings SB-37 and SB-126, whereas SVOCs were not detected in the other seven samples collected from the RSY. SVOCs detected predominantly consisted of PAHs. One exception was that di-n-butylphthalate was detected in the sample from SB-37 and the duplicate sample from SB-126. The highest total SVOC concentrations were in the sample from SB-37 (24,540 µg/kg) and total PAH concentrations were 24,469 µg/kg. The detected concentrations were more than an order of magnitude greater than those detected in the sample from SB-126.

4.3.1.3 Pesticides/PCBs

The pesticides delta-BHC (6.3 µg/kg) and endosulfan sulfate (16 µg/kg) were detected in the sample from SB-10. At SB-37, 4,4'-dichlorodiphenyltrichloroethane (4,4'-DDT) was detected at 11 µg/kg. Samples collected during the RI conducted in 1997 were not analyzed for pesticides or PCBs.

4.3.1.4 Metals

Figure 4-3 shows the magnitude and extent of metals concentrations in surface soil exceeding site-specific background values at the RSY. Detected concentrations of aluminum, arsenic, beryllium, chromium, cobalt, cyanide, iron, magnesium, nickel, potassium, silver, sodium, and vanadium were below background values. One or more metals were detected above background concentrations in 5 of 9 surface soil samples collected from the RSY. The following metals (followed by the maximum detected concentration) were detected above background in at least one sample: barium (254 mg/kg), cadmium (4.3 mg/kg), copper (46.8 mg/kg), lead (863 mg/kg), manganese (2,690 mg/kg), mercury (0.61 mg/kg), selenium (2.6 mg/kg), and zinc (155 mg/kg). The only metal consistently detected above background in all five samples was barium. It is possible that the metals may have leached from the railroad tracks and migrated to the RSY by surface water runoff based on its proximity.

4.3.2 Burn Pit Area

Section 2.2 describes the surface soil samples collected and analyzed at the BPA. Surface soil samples were collected in the vicinity of the BPA during the SI conducted in 1995 and 1996, the RI conducted in 1997, and the SRI conducted in 2000 and 2001. Surface soil samples were not collected in the vicinity of the BPA during the data gap investigations conducted from 2007 through 2009 since the SI, RI, and SRI data adequately characterized surface soil. Table 4-3 summarizes the constituents detected in surface soil at the BPA.

4.3.2.1 VOCs

Figure 4-1 shows the magnitude and extent of total VOC concentrations in surface soil in the vicinity of the BPA. The highest total VOC concentration was detected in surface soil collected from boring SB-112. The other total VOC concentrations were more than an order of magnitude lower than the total VOC concentration detected at SB-112.

In samples collected during the SI and RI, acetone accounts for the majority of VOC detections, as it was detected in 9 samples with concentrations ranging up to 220,000 µg/kg (SB-112). Methylene chloride was detected in 6 samples and detected concentrations ranged up to 6 µg/kg (SB-19). Acetone and methylene chloride are common laboratory contaminants. No other VOCs were detected during the SI and RI.

During the SRI, VOCs were detected in 17 of the 20 surface soil samples. VOCs were not detected in surface soil samples from MW-124, SB-203, and SB-210. Total VOC concentrations ranged up to 81.29 µg/kg (SB-201). Methylene chloride, a common laboratory contaminant, was detected in 10 samples and concentrations ranged up to 9.1 µg/kg (MW-118). Benzene, ethylbenzene, toluene, and xylenes (BTEX) compounds were detected in 14 samples and with a maximum detection of 89.3 µg/kg (SB-204).

4.3.2.2 SVOCs

Figure 4-2 shows the magnitude and extent of total SVOC concentrations in surface soil in the vicinity of the BPA. As SVOCs detected in samples collected during the SI and RI in the vicinity of the BPA consisted predominantly of PAHs. In addition to PAHs, several phthalate compounds were also detected. SVOCs were detected in all samples with the exception of samples from MW-107 and SB-113. In samples from SB-13, SB-15, SB-17, SB-18, and SB-34, total SVOC concentrations ranged up to 12,270 µg/kg; however, PAHs were not detected. In the remaining samples, total SVOC concentrations ranged up to 52,980 µg/kg (SB-111), while total PAH concentrations ranged up to 52,980 µg/kg (SB-111). In samples collected during the SRI, SVOCs were only detected in surface soil samples from MW-124, SB-203, and SB-212. Detected SVOCs consisted of PAHs. Total SVOC concentrations in samples MW-124, SB-203, and SB-212 were 3,250 µg/kg, 540 µg/kg and 5,960 µg/kg, respectively.

4.3.2.3 Pesticides/PCBs

In samples collected during the SI and RI, pesticides were detected only in samples from SB-12, SB-13, SB-14, and SB-33. 4,4-Dichlorodiphenyldichloroethane (4,4'-DDD) and 4,4'-DDE were detected in samples from SB-14 and SB-33 with maximum concentrations of 170 and 120 µg/kg, respectively, both in the sample from SB-33. 4,4'-DDT was detected in the sample from SB-14 (94 µg/kg), delta-BHC was detected in the sample from SB-12 (6.6 µg/kg), and heptachlor was detected in the sample from SB-13 (28 µg/kg). PCBs were not detected in the surface soil samples collected in the vicinity of the BPA.

In samples collected during the SRI, pesticides were detected in surface soil samples from two locations. PCBs were not detected in any samples. Endosulfan II and dieldrin were detected in SB-214 at concentrations of 7.3 and 20 µg/kg, respectively. Both the above constituents and endrin aldehyde were detected in SB-203 at concentrations of 71, 66, and 39 µg/kg, respectively.

Pesticides are not known to be related to materials handled or disposed at the 3 AOCs Site, and the results suggest the pesticide concentrations in surface soil are attributed to historical activities related to their intended use. If pesticides are present as a result of their intended use, they are not regulated by CERCLA.

4.3.2.4 Metals

Figure 4-4 shows the magnitude and extent of metals concentrations in surface soil exceeding site-specific background values in the vicinity of the BPA.

In samples collected during the SI and RI, the following metals, followed by the maximum detected concentration, were detected above background in at least one sample: barium (1,520 mg/kg), cadmium (7.1 mg/kg), copper (253 mg/kg), iron (88,200 mg/kg), lead (21,800 mg/kg), magnesium (10,300 mg/kg), manganese (2,230 mg/kg), mercury (0.60 mg/kg), nickel (85.4 mg/kg), selenium (3.0 mg/kg), silver (2 mg/kg), sodium (637 mg/kg), and zinc (1,680 mg/kg). Of the metals listed above, cadmium, iron, magnesium, mercury, nickel, selenium, silver, and sodium were detected above background in four or fewer samples.

In samples collected during the SRI, metals were detected above background in 10 of the 13 surface soil samples. The following metals, followed by their maximum detected concentration, were detected above background in at least one sample: antimony (49.8 mg/kg), arsenic (43.6 mg/kg), barium (466 mg/kg), calcium (146,000 mg/kg), chromium (35.3 mg/kg), copper (162 mg/kg), iron (72,600 mg/kg), lead (277 mg/kg), magnesium (9,340 mg/kg), manganese (2,790 mg/kg), mercury (0.31 mg/kg), and zinc (697 mg/kg).

4.3.3 Waste Oil Pit

Section 2.3 described the surface soil samples collected and analyzed in the vicinity of the Waste Oil Pit. Surface soil samples were collected in the vicinity of the Waste Oil Pit during the SI conducted in 1995 and the RI conducted in 1997. Surface soil samples were not collected in the vicinity of the Waste Oil Pit during the SI conducted in 1996, the SRI conducted in 2000 and 2001, or the data gap investigations conducted from 2007 through 2009. Table 4-4 summarizes the constituents detected in surface soil in the vicinity of the Waste Oil Pit.

4.3.3.1 VOCs

Figure 4-1 shows the magnitude and extent of total VOC concentrations in surface soil in the vicinity of the Waste Oil Pit. One or more VOC was detected in 17 of 23 samples and total VOC concentrations ranged from nondetects to 95,700 µg/kg (duplicate sample from SB-107). It should be noted that the highest detected total VOC concentration (all individual constituents were qualified as estimated) occurred in the duplicate sample from SB-107, while VOCs were not detected in the original sample from SB-107. This difference may be attributed to sample variation between the original and duplicate samples since VOC samples are not homogenized. Detected VOCs consisted primarily of chlorinated VOCs and petroleum hydrocarbons (BTEX compounds, including toluene, ethylbenzene, and xylenes).

One or more chlorinated VOCs, including TCE, tetrachloroethene (PCE), total 1,2-dichloroethene (1,2-DCE), and cis-1,2-DCE were detected in 12 samples. Total VOC concentrations ranged from nondetect to 44,000 µg/kg (duplicate sample from SB-107). The distribution and magnitude of TCE concentrations detected in surface soil is shown in Figure 4-5.

Toluene, ethylbenzene, and xylenes were detected in four samples at concentrations ranging up to 5,800 J µg/kg, 6,900 J µg/kg, and 39,000 J µg/kg, respectively (duplicate sample from SB-107). It should be noted that the highest detected total VOC concentration (all individual constituents were qualified as estimated) occurred in the duplicate sample from SB-107, while VOCs were not detected in the original sample from SB-107. This difference may be attributed to sample variation between the original and duplicate samples since VOC samples are not homogenized. Other VOCs detected (followed by their maximum detected concentration) include 2-hexanone (4 µg/kg), acetone (2,200 µg/kg), bromomethane (410 J µg/kg), chloromethane (1,000 BJ µg/kg), methylene chloride (12,000 µg/kg), and naphthalene (190 J µg/kg). The maximum detected concentration of each of these constituents was detected in SB-1.

4.3.3.2 SVOCs

Figure 4-2 shows the magnitude and extent of total SVOC concentrations in surface soil in the vicinity of the Waste Oil Pit. Total SVOC concentrations in samples from SB-2, SB-4, SB-5, SB-6, SB-102, SB-105, SB-107, MW-101, and MW-111 ranged from 150 µg/kg (SB-105) to 163,630 µg/kg (SB-01), while total PAH concentrations ranged from 87 µg/kg (SB-105) to 158,100 µg/kg (SB-01). Total SVOC concentrations in samples from SB-3, SB-7, SB-8, SB-9, SB-104, and SB-108 ranged from 49 to 2,800 µg/kg; however, PAH compounds were not detected in these samples. SVOCs were not detected in samples from SB-101, SB-103, SB-106, SB-109, SB-110, and MW-102. Total SVOC concentrations in the background sample collected from MW-109 were 116,049 µg/kg. At most locations, SVOC concentrations were within the same order of magnitude or less than those detected in the background sample.

4.3.3.3 Pesticides/PCBs

Pesticides were detected in samples from 10 locations. 4,4'-DDD was detected in 8 samples and concentrations ranged from 12 µg/kg (SB-4) to 10,000 D µg/kg (SB-1); 4,4'-DDE was detected in 3 samples and concentrations ranged from 7.4 µg/kg (SB-5) to 160 µg/kg (SB-1); 4,4'-DDT was detected in 5 samples and concentrations ranged from 13 µg/kg (SB-5 and SB-6) to 1,300 µg/kg (SB-110). Delta-BHC, endosulfan sulfate, and methoxychlor were each detected in a single sample, at concentrations of 2.2 J µg/kg (SB-9), 22 µg/kg (SB-6), and 290 µg/kg (SB-1), respectively.

Agency for Toxic Substances and Disease Registry (ATSDR) reports typical agricultural soil levels to range between 200 to 6,000 µg/kg (ATSDR, 1994), which was substantiated in a study reported by Ohio State University (Willett, et al., 1994) where levels averaging 2,000 µg/kg DDT in surface soil were observed in land previously farmed. The researchers found this level of DDT despite the occurrence of plowing of these fields since the last DDT application. The data support the conclusion that DDT detections may be a result of former agricultural application of DDT for its intended use, and not AOC-related activity. If the pesticides are present from agricultural activities, they are not regulated by CERCLA.

No PCBs were detected in surface soil samples collected in the vicinity of the Waste Oil Pit.

4.3.3.4 Dioxins/Furans

Surface soil samples collected from SB-1 and SB-2 in 1995 were analyzed for dioxins/furans. Constituents detected in surface soil, followed by the maximum detected concentration, include octachlorodibenzo-p-dioxin (OCDD) (21.27 µg/kg) and 2,3,7,8-TCDD (0.021 µg/kg).

4.3.3.5 Metals

Figure 4-6 shows the magnitude and extent of metals concentrations in surface soil exceeding site-specific background values in the vicinity of the Waste Oil Pit. The following metals, followed by their maximum detected concentration, were detected above background in at least one sample: arsenic (24.3 N mg/kg), barium (172 mg/kg), calcium (10,700 J mg/kg), lead (85 mg/kg), manganese (1,550 mg/kg), nickel (51.8 mg/kg), sodium (92.5 E mg/kg), and zinc (131 N mg/kg). Metals were not detected above background in samples from MW-102, MW-111, SB-03, SB-05, SB-09, SB-102, SB-104, SB-106, SB-108, and SB-110.

4.4 Subsurface Soil and Bedrock

The following subsections describe the nature and extent of contamination observed in subsurface soil and bedrock at the RSY, BPA, and Waste Oil Pit.

4.4.1 Railroad Salvage Yard

Section 2.1.2 describes the subsurface soil samples collected and analyzed at the RSY. Subsurface soil samples were collected in the vicinity of the RSY during the SI conducted in 1995 and 1996 and the RI conducted in 1997. Subsurface soil samples were not collected from the vicinity of the RSY during the SRI conducted in 2000 and 2001 and data gap investigations conducted in 2007 through 2009 since the SI and RI data adequately characterized subsurface soil. Table 4-5 summarizes the constituents detected in subsurface soil at the RSY.

4.4.1.1 VOCs

Figure 4-7 shows the magnitude and extent of total VOC concentrations in subsurface soil at the RSY. The majority of detected VOCs consisted of chlorinated aliphatic compounds. Trans-1,2-DCE was detected in the sample from SB-123 (1.8 µg/kg), cis-1,2-DCE was detected in two samples with the maximum detected concentration occurring in sample from SB-123 (39 µg/kg), methylene chloride was detected in the sample from SB-123 (3.6 µg/kg), and TCE was detected in 3 samples with the maximum concentration occurring in the sample from SB-123 (9.7 µg/kg). Acetone was detected in 2 samples with the maximum concentration occurring in the sample from SB-122 (19 µg/kg).

4.4.1.2 SVOCs

Figure 4-8 shows the magnitude and extent of total SVOC concentrations in subsurface soil at the RSY. SVOCs were not detected in subsurface samples from SB-122, SB-124, SB-125, SB-126, and SB-127. Total SVOCs were detected in samples from SB-10, SB-121, SB-123, and SB-37, with the maximum total detected concentration occurring in the sample from SB-121 (8,648 µg/kg). PAHs were detected only in the samples from SB-121 (8,368 µg/kg) and SB-123 (836 µg/kg).

4.4.1.3 Pesticides/PCBs

Pesticides and PCBs were not detected in subsurface samples collected at the RSY.

4.4.1.4 Metals

Figure 4-3 shows the magnitude and extent of metals concentrations in subsurface soil exceeding site-specific background values at the RSY. Detected metals concentrations were below background for all metals in samples from SB-10, SB-122, SB-125, and SB-37. The following metals (followed by the maximum detected concentration) were detected above background in at least 1 sample: aluminum (19,700 mg/kg),

barium (216 mg/kg), beryllium (1.8 J mg/kg), cobalt (28.9 mg/kg), copper (39.1 mg/kg), lead (85.6 mg/kg), magnesium (7,640 mg/kg), manganese (2,170 mg/kg), nickel (53.5 mg/kg), and zinc (120 J mg/kg).

4.4.2 Burn Pit Area

Section 2.2.2 describes the subsurface soil samples collected and analyzed at the BPA. Subsurface soil samples were collected in the vicinity of the BPA during the SI conducted in 1995 and 1996, the RI conducted in 1997, and the SRI conducted in 2000 and 2001. Subsurface soil samples were not collected in the vicinity of the BPA during the data gap investigations conducted from 2007 through 2009 since the SI, RI, and SRI data adequately characterized subsurface soil. Table 4-6 summarizes the constituents detected in subsurface soil at the BPA.

4.4.2.1 VOCs

Figure 4-7 shows the magnitude and extent of total VOC concentrations in subsurface soil in the vicinity of the BPA.

In samples collected during the SI and RI, acetone was detected in 12 samples with concentrations ranging up to 25,000 µg/kg (SB-120). Methylene chloride was detected in three samples with concentrations ranging up to 4 µg/kg (SB-20). Benzene was detected in the sample from MW-104 (11 µg/kg) and chloromethane was detected in the sample from SB-116 (360 µg/kg).

In samples collected during the SRI, VOCs were detected in 15 of 18 subsurface soil samples and total VOC concentrations ranged up to 35.9 µg/kg (SB-214). VOCs were not detected in samples from MW-117, MW-118, and MW-119. Methylene chloride was detected in 6 samples and concentrations ranged up to 7.7 µg/kg (MW-120). Petroleum hydrocarbons (BTEX compounds) were detected in 10 samples and concentrations ranged up to 34.3 µg/kg (SB-214). The constituent not included in these categories, followed by the maximum detected concentration, is acetone (5.4 µg/kg), which was detected in 5 samples.

4.4.2.2 SVOCs

Figure 4-8 shows the magnitude and extent of total SVOC concentrations in subsurface soil in the vicinity of the BPA.

In samples collected during the SI and RI, SVOCs were detected at 14 locations, with total concentrations ranging from 110 µg/kg (SB-38) to 54,240 µg/kg (SB-11). Constituents contributing to total SVOC concentrations included bis(2-ethylhexyl)phthalate, di-n-butylphthalate, di-n-octylphthalate, and diethylphthalate. At 11 of these locations, the results were qualified to indicate the detected constituent(s) were also detected in associated blank samples. SVOCs were not detected in samples from MW-104, MW-105, MW-106, MW-107, MW-108, SB-112, SB-113, SB-117, SB-118, and SB-120.

In contrast with SVOC data for surface soils, concentrations in subsurface soil were generally less extensive than in surface soil. PAHs were detected only in samples from SB-111 (511 µg/kg), SB-115 (484 µg/kg), and SB-116 (864 µg/kg). In samples collected during the SRI, SVOCs were not detected in any of the subsurface soil samples. Although not widespread as seen in surface soils, the SVOCs in subsurface soil are also likely related to the past burning activities at the BPA.

4.4.2.3 Pesticides/PCBs

Pesticides/PCBs were not detected in subsurface soil samples collected during the SI. The RI samples were not analyzed for pesticides/PCBs. In samples collected during the SRI, pesticides were detected in only one subsurface soil sample location. PCBs were not detected in any samples. The pesticide dieldrin was detected in SB-203, at a concentration of 13 µg/kg.

4.4.2.4 Metals

Figure 4-4 shows the magnitude and extent of metals concentrations in subsurface soil exceeding site-specific background values in the vicinity of the BPA.

During the SI and RI, the following metals, followed by the maximum detected concentration, were detected above background in at least one sample: antimony (58.5 mg/kg), arsenic (30 mg/kg), barium (2,510 mg/kg), cadmium (9.1 mg/kg), chromium (705 mg/kg), copper (946 mg/kg), iron (175,000 mg/kg), lead (11,900 mg/kg), magnesium (10,800 mg/kg), manganese (2,760 mg/kg), mercury (3.1 mg/kg), nickel (142 mg/kg), selenium (3.9 mg/kg), sodium (1,010 mg/kg), and zinc (4,620 mg/kg). The maximum detected concentration for each metal occurred in the sample from MW-104 with the exception of mercury, which was detected above background only in the sample from SB-38. Lead was detected above background in six samples, and the remaining metals listed above were detected above background in three or fewer samples.

In samples collected during the SRI, metals were detected above background in four subsurface soil samples. The following metals, followed by their maximum detected concentration, were detected above background in at least one of the four samples: barium (99.7 mg/kg), iron (42,800 mg/kg), lead (27.3 mg/kg), and manganese (1,190 mg/kg).

4.4.3 Waste Oil Pit

Sections 2.3.2 and 2.3.3 describe the subsurface soil and bedrock samples collected and analyzed in the vicinity of the Waste Oil Pit. Subsurface soil samples were collected in the vicinity of the Waste Oil Pit during the SI conducted in 1995, the RI conducted in 1997, after the TCRA conducted in 1998, and the data gap investigation conducted in 2007. Subsurface soil samples were not collected in the vicinity of the Waste Oil Pit during the SI conducted in 1996, the SRI conducted in 2000 and 2001, or the data gap investigation conducted in 2009. Bedrock samples were only collected during the data gap investigations conducted in 2007 and 2009. Table 4-7 summarizes the constituents detected in subsurface soil and bedrock in the vicinity of the Waste Oil Pit.

4.4.3.1 VOCs

Sixty-four samples were collected in subsurface soil and bedrock, 47 samples were collected from subsurface soil, and 17 samples were collected from bedrock material.

Figure 4-7 shows the total VOC concentrations in subsurface soil in the vicinity of the Waste Oil Pit. One or more VOC was detected in 38 of 47 samples and total VOC concentrations ranged from nondetect to 232,317 µg/kg (SB-11). While many VOCs were detected in one or more samples collected from subsurface soil, the most prevalent were those also detected in surface soil in the vicinity of the Waste Oil Pit (chlorinated VOCs, petroleum hydrocarbons, and other VOCs found in solvents). In many instances, the detected concentrations are similar or higher in subsurface soil than they were at the collocated location collected for surface soil, including the confirmation samples collected after the TCRA was completed in 1998 when the waste/soil in the Waste Oil Pit was removed. Specific details of the removal action are detailed in a separate report, the *"Time Critical Removal Action, Remedial Investigation, Former Lordstown Ordnance Depot."*

Figure 4-5 shows concentrations of TCE in soil and bedrock. It is likely that the presence of TCE and other chlorinated VOCs are a result of site-related contamination since these constituents are commonly present in solvents or are a degradation product of solvents.

While the horizontal extent of contamination in the soil in the vicinity of the Waste Oil Pit was characterized for VOCs upon completion of the 2007 data gap investigation, the vertical extent of contamination had not been fully characterized, as evident by the elevated concentrations of VOCs at the bottom of the Waste Oil Pit, indicating that VOCs have migrated downward to bedrock. The 2009 data gap investigation was conducted to characterize the vertical extent of contamination by further investigating contamination migration from the waste pit to bedrock.

The highest concentration of TCE (1,300 µg/kg) in bedrock was detected in the sample collected from 7 to 8 feet at BB05, which is 25 feet downgradient of the center of the former Waste Oil Pit (Figure 4-5). TCE was also detected from three intervals in BB01 (8 to 9 feet bgs, 23 to 24 feet bgs, and 25 to 26 feet bgs) at the center of the former Waste Oil Pit. The vertical extent of the downgradient edge of TCE was characterized

with samples collected from deeper bedrock in BB04 (from 9 to 10 feet bgs) and BB07 (from 19 to 20 feet bgs). The deepest bedrock samples downgradient of the Waste Oil Pit were nondetect.

Material that appeared to be nonaqueous phase liquid (NAPL), or residual free-phase product, was observed in some sections of bedrock cores and drill water from borings located within the former Waste Oil Pit and borings close to the pit. Based on observations of floating material in the Waste Oil Pit during drilling, the material appears to be light nonaqueous phase liquid. This would be consistent with the understood source (weathered waste oil). It had a petroleum-like odor and exhibited elevated PID readings. The NAPL was observed in bedrock beneath the footprint of the former Waste Oil Pit and in bedrock surrounding the former Waste Oil Pit footprint. Of note, the volume of recoverable NAPL was insufficient to generate a sample for laboratory analysis.

The horizontal extent of the NAPL in the area around the former Waste Oil Pit was delineated during the bedrock investigation. North of the former Waste Oil Pit, NAPL was observed in core samples recovered from BB06, which was located 75 feet north of the former Waste Oil Pit; however, NAPL was not observed in rock samples recovered from BB07 located approximately 140 feet north of the former Waste Oil Pit. The absence of NAPL in the core from BB07 indicates the horizontal extent of NAPL contamination north of the former Waste Oil Pit lies between BB06 and BB07. Similarly, NAPL was observed in rock cores from BB03, located 25 feet south of the center of the former Waste Oil Pit, but not in BB09 located 100 feet south of the former Waste Oil Pit. The absence of NAPL in rock cores from BB09 indicates the horizontal extent of NAPL contamination south of the former Waste Oil Pit lies between BB03 and BB09.

BB08 and BB04 were similarly used to determine the extent of NAPL west of the former Waste Oil Pit, because NAPL was observed in BB08 and not in BB04. In addition, BB01 and BB02 were used to define the extent of NAPL east of the former Waste Oil Pit because NAPL was observed in BB-01 from the overburden/bedrock interface to the bottom of borehole at 26 feet bgs. NAPL was observed in the core samples from BB02 to 8 feet bgs. Only 2 feet (6 to 8 feet bgs) of bedrock section was observed to be contaminated with NAPL at BB02. This indicated that BB02 is close to the edge of the extent of NAPL contamination in bedrock in this area; therefore, BB02 defined the extent of NAPL east of the former Waste Oil Pit.

The vertical extent of NAPL in bedrock was established at the borings where NAPL was observed in core samples. In BB01, which was located at the center of the former Waste Oil Pit, an oily substance similar to the NAPL described above was observed to 24 feet bgs. In the fracture surfaces of the black shale, NAPL also was encountered from 24 feet bgs to the bottom of the borehole at 26 feet bgs. The oily material encountered from 17 to 26 feet bgs at BB01 did not indicate elevated PID readings compared to NAPL material encountered at shallower depths (5 to 17 feet bgs). In BB06, NAPL was observed to a depth of 14 feet bgs, and was not observed from 14 feet bgs to the total depth of the borehole (46 feet bgs). In BB-2, NAPL was observed up to 8 feet bgs, and was not observed from 8 feet bgs to the end of borehole (21 feet bgs). Figure 4-9 shows a cross-section view of the delineated extent of NAPL in bedrock.

4.4.3.2 SVOCs

Figure 4-8 shows the magnitude and extent of total SVOC concentrations in subsurface soil in the vicinity of the Waste Oil Pit. Total SVOC concentrations ranged from nondetect to 163,630 µg/kg (SB-1), while total PAH concentrations ranged from nondetect to 158,100 µg/kg (SB-1). There was some variability in the SVOC concentrations between the duplicate and the native sample collected at location SB-107 (0 to 2 feet bgs). This variability is likely due to the samples not being homogenized before placing in jars. The remaining total SVOC and PAH concentrations were at least 10 times less than the concentrations detected in SB-1. Several SVOCs were detected in bedrock samples, but most of the detections were “J” flag as estimated values. Some of the detections were rejected for project during data validation use and flagged “R.” The results were rejected because they did not meet the QAPP criteria for the project. Additional information on findings and conclusions during data validation are provided in the Data Summary Reports in Appendix E.

4.4.3.3 Pesticides/PCBs

Pesticides were detected in 19 subsurface soil samples. The following pesticides were detected: 4,4-DDD, 4,4-DDE, 4,4-DDT, alpha-chlordane, alpha-endosulfan, beta-BHC, beta-chlordane, beta-endosulfan, delta-BHC, dieldrin, endrin, endrin ketone, gamma-BHC, heptachlor epoxide, and methoxychlor.

4.4.3.4 Dioxins/Furans

Subsurface soil samples collected from WOP-S01 through WOP-S08 in 1998 were analyzed for dioxins/furans. Constituents detected in subsurface soil, followed by the maximum detected concentration, include 1,2,3,4,6,7,8-HpCDD (0.54 µg/kg), 2, 3, 4, 7, 8-PeCDF (0.087 J µg/kg), OCDD (160 µg/kg), Total HpCDD (1.1 µg/kg), Total HpCDF (0.47 J µg/kg), Total PeCDD (0.46 J µg/kg), Total PeCDF (1.3 µg/kg), and Total TCDF (0.0071 J µg/kg).

4.4.3.5 Metals

Figure 4-6 shows the magnitude and extent of metals concentrations in subsurface soil exceeding site-specific background values in the vicinity of the Waste Oil Pit. The following metals were detected above background concentrations: aluminum, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, thallium, vanadium, and zinc.

4.5 Sitewide Groundwater

Section 2.4.4 described the sitewide groundwater samples collected. Groundwater wells were sampled during the RI conducted in 1997, SRI conducted in 2000, and the quarterly groundwater sampling events conducted in 2007 and 2008. Monitoring wells MW-127 and MW-130 were sampled after installation in 2009. Table 4-8 summarizes the constituents detected in sitewide groundwater.

4.5.1 VOCs

Groundwater was analyzed for samples collected from MW-101 through MW-111 during the RI. VOCs were not detected in samples collected during the RI from wells MW-102, MW-103, MW-105, MW-107, and MW-111. Only chlorinated aliphatic hydrocarbons were detected in the samples from MW-101 and MW-108. The detected chlorinated aliphatics, and their maximum detections, include TCE (420 micrograms per liter [µg/L]), cis-1,2-DCE (13,000 µg/L), and vinyl chloride (2,300 µg/L). Maximum concentrations were detected in groundwater at MW-101. Acetone was detected in the samples collected from MW-104 (150 µg/L) and MW-106 (38 µg/L). Chloroform was detected at 2.8 µg/L in the sample collected from MW-106.

Monitoring wells MW-117 through MW-125 were installed during the SRI to further delineate the VOC groundwater plume. VOCs were not detected in samples collected during the SRI from wells MW-103, MW-105, MW-107, MW-109, MW-110, MW-111, MW-117, MW-120, MW-124, and MW-125. Detected VOCs consisted of chlorinated aliphatics and petroleum hydrocarbons (BTEX compounds). The detected chlorinated aliphatics and the maximum detections include TCE (98 µg/L), cis-1,2-DCE (5,600 µg/L), and vinyl chloride (1,000 µg/L). The detected BTEX compounds and the maximum detections include benzene (66 µg/L) and toluene (40 µg/L). Toluene was only detected in the sample from MW-101. A comparison of the RI and SRI groundwater results for MW-101 shows that VOC concentrations decreased over time, which may be a result of the removal of the Waste Oil Pit.

Two additional wells (MW-128 and MW-129) were installed in 2007 to provide additional delineation information on the VOC groundwater plume and each of the existing and new wells were sampled for four quarters spanning 2007 and 2008. TCE, cis-1,2-DCE, and vinyl chloride are the most elevated and widespread VOCs in groundwater. Isoconcentration maps for these constituents detected in September 2008 compared to isoconcentrations from 2000 groundwater results are shown in Figures 4-10 through 4-12. The isoconcentrations show that the VOC plume has not migrated from 2000 to 2008. The differences seen in the isoconcentration maps from 2000 to 2008 are primarily a result of new wells that were installed

between the 2000 and 2008 sampling events. TCE and cis-1,2-DCE concentrations downgradient of the source in MW-118 and MW-119 have decreased and vinyl chloride concentrations have increased. VOCs such as TCE, 1,1-DCE, cis-1,2-DCE, and 1,2-trans-DCE detected in samples collected from MW-104 during the four quarters shows a detection in the vicinity of the former BPA. In review of the associated soil VOC results (Figures 4-1 and 4-1), there is no apparent source area identified, and if one is present, it is highly localized.

Monitoring wells MW-127 and MW-130 were installed and sampled in fall 2009 to delineate vertical and horizontal nature and extent of the source of contamination related to the former Waste Oil Pit and further delineate the vertical extent of the groundwater plume associated with the former Waste Oil Pit. TCE and vinyl chloride were not detected in samples collected from MW-127 and MW-130. Cis-1,2-DCE was also not detected in MW-130 and only low-level detections were found in MW-129 (3.1 µg/L). The results show the downgradient vertical extent has been defined.

The September 2008 and fall 2009 results indicate that groundwater contamination resulting from the residual source associated with the former Waste Oil Pit is limited to groundwater in the shallow zone (that is, shallower than 36 feet bgs) in the vicinity of the Waste Oil Pit. Results from MW-121 and MW-129 indicate that groundwater contamination may exist down to 36 feet bgs downgradient of the former Waste Oil Pit. The groundwater plume appears to be delineated well within the FLOD boundary, and presents no potential of reaching the offsite water wells (refer to Section 3.7 and Figure 3-10).

4.5.2 SVOCs

During the RI, SVOCs were detected at concentrations less than 4.5 µg/L in the original and duplicate samples collected from MW-101. Detected constituents included 1,2-dichlorobenzene, 4-methylphenol, bis(2-chloroethyl)ether, bis(2-ethylhexyl)phthalate, and naphthalene. Bis(2-ethylhexyl)phthalate was also detected in the ground water samples collected from MW-105 and MW-107. SVOCs were not detected in the samples from MW-102, MW-103, MW-104, MW-106, MW-108, and MW-111.

During the SRI, SVOCs were detected at concentrations less than 5.5 µg/L in the original and duplicate samples collected from MW-101 and in the sample collected from MW-102. Detected constituents included 1,2-dichlorobenzene, bis(2-ethylhexyl)phthalate, and naphthalene. SVOCs were not detected in any other samples. SVOCs were also only present at low levels similar to the RI and SRI during data gap investigations conducted from 2007 through 2009.

4.5.3 Pesticides/PCBs

Pesticides and PCBs were not detected in any of the groundwater samples during the RI. During the SRI, pesticides were detected in only one sample location (MW-111). The detected constituents were aldrin (0.053 µg/L), alpha-BHC (0.029 µg/L), and beta-BHC (0.025J µg/L). PCBs were not detected in any groundwater samples during the SRI. Pesticides and PCBs were not analyzed during data gap investigations.

4.5.4 Metals

Total concentrations for each metal analyzed except zinc were detected above background in one or more groundwater samples collected during RI, SRI, and data gap investigations. In general, total metals concentrations above background concentrations are widespread in sitewide groundwater. However, the upgradient wells (MW-109 and MW-110) had similar concentrations of total metals and most of the metals results were only marginally above background concentrations. In addition, the presence of dissolved-phase metals in groundwater was much less prevalent. Aside from the detections of dissolved metals in the upgradient well, MW-109 and MW-110, only iron, manganese, and potassium were detected in the dissolved phase in groundwater. This suggests that most total metals concentrations detected were biased high from suspended solids present in the groundwater.

Metals in groundwater often are biased high as a result of sampling methods that entrain suspended solids in groundwater samples. Elevated suspended solids in groundwater samples may cause metals to be biased high. Suspended solids contribute metals to the water sample because metals typically are present naturally

in soil at concentrations several orders of magnitude greater than groundwater concentrations. Metals in the suspended solids are dissolved when the sample is acidified for preservation. One of the goals of purging wells prior to sampling was to reduce turbidity to less than 10 nephelometric turbidity units. This was not achieved in all cases; therefore, suspended solids in the samples may have affected metals results. In many cases, filtered samples were collected concurrently with unfiltered samples in order to evaluate potential effects of suspended solids in the unfiltered samples. Results are generally similar, as shown in Table 4-8.

Contaminant Fate and Transport

This section presents the fate and transport of contaminants in each medium. The physical characteristics of the study area and distribution of contaminants presented in Sections 3 and 4 were used as the basis for defining the fate and transport of contaminants identified at the 3 AOCs and the groundwater conceptual site model (CSM) for the 3 AOCs Site (Figure 5-1) and the CSM from ground surface to bedrock for the Waste Oil Pit (Figure 5-2). The section consists of three parts:

- Potential routes of migration are discussed for each medium (Section 5.1), including an overview of potential source areas and a synopsis of possible exposure pathways. This discussion is expanded upon in Section 6.
- Contaminant persistence in soils and groundwater is considered (Section 5.2). For each class of compounds, the general fate and transport characteristics of the relevant contaminants are summarized since their chemical and physical properties affect contaminant migration and fate.
- Contaminant migration is presented (Section 5.3) with an overview of factors affecting contaminant migration.

5.1 Potential Routes of Migration

This section delineates the potential routes of migration for contaminants both within the AOCs and from the AOCs. Potential migration pathways in the AOCs are considered for each of the following three available media:

- Air emissions, specifically the dispersion of VOCs from soil (Section 5.1.1)
- Soil and bedrock, primarily the potential leaching of contaminants from soil and bedrock to groundwater and nearby surface water, and the potential erosion of surface soil into adjacent surface water (Section 5.1.2)
- Groundwater and potential transport of contaminants to surface water by discharge of groundwater to surface water (Section 5.1.3)

Primary and secondary sources of contaminants and release mechanisms for chemical migration are presented in Table 5-1. Primary sources and release mechanisms are noted for soil, surface water/sediment, and groundwater. Secondary sources are noted for potential migration from a primary source to a second primary source before potential exposures may occur. A potential exposure medium is noted for each pathway.

5.1.1 Air Emissions

Volatile chemicals in near-surface soil and surface water have the potential for migration to the air by volatilization. Individual chemical rates of volatilization are a function of their vapor pressure, Henry's Law Constant, relative concentration in the two media, temperature, and other factors such as wind conditions. As discussed in more detail later in this section, VOCs, relative to other classes of chemicals, have a tendency to volatilize to the atmosphere because of their relatively high vapor pressures and air/water partitioning.

Air monitoring was conducted at each boring location during soil boring and well installation work using a PID. With the exception of one boring in the former Waste Oil Pit (SB-11), no significant concentrations of organic vapors were detected during the field investigation program. No significant concentrations of organic vapors were detected during the field investigation program. Because of the generally low levels of air measurements, the air emissions pathway is not considered further in this discussion of contaminant fate and transport. Since migration of contaminants by volatilization could occur under varying conditions and could be a potential pathway, potential exposure scenarios by volatilization and subsequent inhalation are considered in Chapter 6.

5.1.2 Soil

Potential contaminant AOCs in the vadose zone have been previously summarized (Section 4), and include the following:

- RSY—Some locations with low concentrations of PAHs and halogenated hydrocarbon compounds.
- BPA—Surface soils predominantly contain PAHs, some locations have acetone in both the surface and subsurface soils.
- Waste Oil Pit Area—In general, shallow subsurface (0 to 2 feet bgs) and subsurface soils contain the following: VOCs, including aromatic hydrocarbon compounds (toluene, ethylbenzene, and xylenes [total]) and halogenated aliphatic compounds (TCE, PCE, cis-1,2-DCE). Generally, low concentrations of metals (with the exception of lead) and SVOCs (particularly PAHs) were also detected. There are some locations with low concentrations of pesticides.

Contaminants found in surface and subsurface soils at the three AOCs of the investigation area may be released to the environment by one of the following three potential pathways listed in Table 5-1:

- Volatilization:
 - As indicated in Section 5.1.1, volatilization from surface soils is discussed in Section 6.
- Erosion and Surface Runoff:
 - Contaminants could be transported by erosion of surficial materials during precipitation events to the tributary to Duck Creek and the ditches paralleling the roadway. During periods of extensive precipitation, eroded soil and runoff could also be expected to reach Duck Creek. Figure 3-1 presents a map of the land surface topography and of surface drainage at the investigation area.
- Leaching:
 - The principal processes that control contaminant migration by leaching are sorption and solubility. Leaching of soil contaminants into groundwater can occur from any depth in the vadose zone, and in the case where NAPL is present below the water, from the saturated zone.

5.1.3 Groundwater

Groundwater at the investigation area is contaminated with VOCs downgradient of the Waste Oil Pit and in the vicinity of the BPA. The nature and extent of contamination are discussed in Section 4.

Potential pathways for migration of contaminants from groundwater include groundwater flow into surface water in the tributary to Duck Creek and the Beaver Pond. However, if VOCs discharge to surface water, they would rapidly volatilize to air and would not persist in sediment or surface water.

The potential fate and migration of contaminants by the identified pathways are discussed in detail in Section 5.3.

5.2 Contaminant Persistence

Persistence is a measure of how long a given chemical will exist in a specific medium. Mobility describes the relative potential of a chemical to be transported in environmental media. Contaminant persistence and mobility in environmental media is a function of physical and chemical properties of a given class of compounds, the specific chemicals within each class found in the environment, and properties of the media of concern (including tendencies of each class of compounds to transfer among available media).

Persistence and mobility of compounds detected in FLOD soil and groundwater are discussed below by compound class. For purposes of this discussion, relevant classes of compounds are VOCs, SVOCs, metals, and pesticides.

5.2.1 Chemical and Physical Properties

The persistence, transport, and fate of chemicals in the environment depend on individual chemical and physical properties. A brief discussion of the physical and chemical properties of constituents is provided in the following paragraphs, along with a description of the significance of each property to volatilization, sorption, diffusion, dispersion, biodegradation, and other attenuation processes.

Chemical and physical properties relevant to the evaluation of transport and fate of detected chemicals include water solubility, vapor pressure, log octanol-water partition coefficient, organic carbon partition coefficient, Henry's Law Constant, density, and water solubility. Table 5-2 presents a summary of the physical and chemical properties for the constituents detected at the 3 AOCs Site. Other properties to be considered in the evaluation of transport and fate of detected chemicals include distribution coefficient, vapor pressure, Eh and pH, and half-life. The impact on each of the relevant classes of compounds is discussed after the introduction of each physical property.

5.2.1.1 Water Solubility

The solubility of a chemical in water is the maximum amount of the chemical that will dissolve in pure water at a specified temperature. Chemicals with high solubility are relatively mobile in water and are likely to leach from wastes and soils. When dissolved in water, these chemicals tend to have low volatilization potential and are generally biodegradable. Conversely, chemicals with low solubility tend to adsorb on soils and are not readily biodegraded. They also have a greater tendency to volatilize (see vapor pressure and Henry's Law discussions).

5.2.1.2 Vapor Pressure

Vapor pressure is a measure of the tendency of a substance to pass from a solid or a liquid to a vapor state. It is measured as the pressure of the gas in equilibrium with the pure liquid or solid at a given temperature. From dry soils, the vapor pressure indicates the volatilization potential of a given chemical to the atmosphere. From moist soils, volatilization is dependent on vapor pressure and the Henry's Law Constant (see discussion below). A chemical with a vapor pressure less than 10^{-6} millimeters of mercury tends to associate with particulate matter; a chemical with a higher vapor pressure tends to associate with the vapor phase. Highly water-soluble compounds generally show little volatilization from water or moist soils unless they also have a high vapor pressure.

5.2.1.3 Log Octanol-Water Partition Coefficient

The octanol-water partition coefficient (K_{ow}) is a coefficient representing the ratio of the solubility of a compound in octanol (a nonpolar solvent) to its solubility in water (a polar solvent). The higher K_{ow} , the more nonpolar the compound. Log K_{ow} is generally used as a relative indicator of the tendency of an organic compound to adsorb to soil. Log K_{ow} values are generally inversely related to aqueous solubility and directly proportional to molecular weight.

5.2.1.4 Organic Carbon Partition Coefficient

The organic carbon adsorption coefficient (K_{oc}) is a measure of the degree to which an organic substance will preferentially dissolve in water or adsorb to organic carbon in soil. Higher K_{oc} values indicating a greater tendency to remain sorbed. Organic chemicals moving through the subsurface will alternately adsorb or desorb from available organic matter in soil matrix. The higher the K_{oc} values, the greater the tendency of a chemical to be attracted to the organic fraction of the soil and the lower its mobility in the subsurface environment.

5.2.1.5 Henry's Law Constant

The Henry's Law Constant describes a linear relation between vapor pressure and water solubility, providing a measure of a chemical's ability to move from water or moist soils to air. Compounds with Henry's Law Constants greater than 10^{-3} atmospheres-cubic meter per mole ($\text{atm}\cdot\text{m}^3/\text{mole}$) can be expected to readily volatilize from water. Compounds with values ranging from 10^{-3} to 10^{-5} $\text{atm}\cdot\text{m}^3/\text{mole}$ exhibit moderate

volatilization. Compounds with values less than 10^{-5} atm-m³/mole show limited ability to volatilize from water or moist soils.

5.2.1.6 Density

The density of a substance is defined as an object's mass per unit volume; it is an absolute quantity. Compounds with a density greater than 1 will tend to sink in water in their free phase, while those with a density less than one will tend to float on water in their free phase.

5.2.1.7 Distribution Coefficient

The distribution coefficient (K_d) is a measure of the concentration of a chemical sorbed onto a solid relative to the concentration of the same chemical in the associated liquid phase. The K_d is the slope of a linear sorption isotherm relating the concentrations in the two media. The larger the K_d , the greater sorption to the solid phase and the less in solution for a given solute. As with K_{oc} , the distribution coefficient measures the relative mobility of a chemical in the environment; a larger K_d corresponds to a lower mobility. A K_d value may be estimated from the K_{oc} of the chemical in question and the fraction of organic carbon in the soil.

5.2.1.8 Eh and pH

Eh is referred to as the reduction-oxidation (redox) potential and is a measure of the oxidizing potential of water. Elevated Eh levels tend to facilitate dissolution of inorganic compounds. Additionally, the presence of oxidizing or reducing conditions will influence the microorganism population in the subsurface, which will affect the processes and rates governing biodegradation of organic compounds. The effects of Eh on biodegradation are compound, media, and site-specific. The parameter pH is a measure of the hydrogen ion activity in water. Values of pH below the neutral value of 7 indicate acidic conditions. Water with low pH values would promote dissolution of inorganic compounds.

5.2.1.9 Attenuation Half-life

A half-life is the time required for the concentration of a substance to decrease from its initial level to one-half its initial level. Various attenuation processes including, but not limited to, biodegradation, reactions with other substances, or mass removal from the media in question may cause the apparent decrease.

5.2.2 Volatile Organic Compounds

VOCs can be expected to be mobile in the environment, with potential to volatilize to the atmosphere, leach to groundwater, erode to surface water, and to move with groundwater flow. VOCs tend to exhibit high water solubility, vapor pressure, and Henry's Law Constants, along with a corresponding low K_{oc} . The properties all enhance the potential for attenuation of VOCs. Many VOCs also tend to have relatively short half-lives in groundwater, on the order of days to months.

VOCs have a limited tendency to adsorb to solids and can be expected to be moderately to highly mobile in the environment. Especially in surficial soils, VOCs can migrate by diffusion through soil-air pore spaces to the ground surface, where they can be transported by wind.

VOCs were found in soil and groundwater in the vicinity of the 3 AOCs. These compounds fall into three general VOC classes: halogenated hydrocarbons, aromatic hydrocarbons, and ketones. VOCs detected by media for each AOC are presented in Section 4. The relevant physical and chemical properties of each of these general VOC classes are discussed below.

5.2.2.1 Halogenated Hydrocarbons

Halogenated hydrocarbons detected at the 3 AOCs Site include, TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, 1,1,2-trichloroethane, 1,1-DCE, 1,2-dichloroethane (DCA), 1,1-DCA, 1,2-dichloropropane, chloroform, chloromethane, chloroethane, methylene chloride, vinyl chloride, bromomethane, bromodichloromethane, dibromochloromethane, and trichlorofluoromethane. Many of the compounds are used in industrial settings

as solvents or as raw products in manufacturing. Most are liquids at standard temperature and pressure, while some (vinyl chloride and chloromethane) are present as gasses.

Relative to the other aromatic hydrocarbons, the halogenated hydrocarbons have high solubilities and little tendency to partition onto organic carbon or other soil solids. They have relatively high vapor pressures and high Henry's Law Constants. Therefore, volatilization from soils and groundwater is a significant mobility process for most halogenated hydrocarbons. The high specific gravity of these compounds causes them to tend to sink when present as NAPL.

Halogenated hydrocarbons are subject to degradation under both aerobic and anaerobic conditions. Under aerobic conditions, a cometabolite such as methane, propane, toluene, or cresol is required to induce the degradation. Most halogenated hydrocarbons are, however, highly oxidized compounds and are resistant to degradation by this mechanism. In general, more reduced daughter products (dichlorinated and single chloride compounds) are easier to degrade under aerobic conditions than the trichlorinated and tetrachlorinated compounds (Murray and Richardson, 1993).

Halogenated compounds can also be degraded under anaerobic conditions. There are several mechanisms involved, including reductive dehalogenation and dehydrohalogenation (Sims, 1990). Reduction of halogenated hydrocarbons by biological mediated reductive dehalogenation generally requires the presence of a methanogenic (bacteria that produce methane), sulfate-reducing, or nitrate-reducing bacterial population. This type of bacterial population is encouraged by the presence of an anaerobic environment with a low or negative Eh. Because the bacterial population involved in this process does not typically use halogenated hydrocarbons as a carbon or energy sources, degradation is more rapid if a substrate such as acetate, formate, glucose or methanol is provided (Freedman, 1989).

The presence of transition metal complexes (iron, cobalt, and nickel) can act as catalyst in the biodegradation of halogenated hydrocarbons as these complexes serve as electron donors during the reduction process. The use of transition metals alone can also induce abiotic (non-biological) reductive dehalogenation.

The classic reductive halogenated hydrocarbon degradation pathway is provided in Figure 5-3 (Dragun, 1988). This pathway follows the reduction from the most halogenated compounds (1,1,1-TCA and PCE) to chloroethane. In general, PCE can undergo reductive dehalogenation and form TCE. TCE can undergo reductive dehalogenation and form 1,1-DCE and the cis- and trans-1,2-DCE isomers. These three compounds can also undergo reductive dehalogenation and form vinyl chloride; or the carbon-carbon double bond can be reduced to form 1,1-DCA and 1,2-DCA, respectively. 1,1-DCA and 1,2-DCA can undergo reductive dehalogenation and form chloroethane, or dehydrohalogenation and form vinyl chloride. Vinyl chloride can undergo reductive dehalogenation and form ethylene, or the carbon-carbon double bond in vinyl chloride can be reduced to form chloromethane.

In general, the greater the degree of halogenation, the greater the likelihood that a compound will be reduced, rather than oxidized and vice versa. The complete reduction of PCE and TCE to ethylene, which requires the reductive dehalogenation of vinyl chloride to ethylene, is fairly uncommon in natural settings.

5.2.2.2 Aromatic Hydrocarbons

Aromatic hydrocarbons detected at the 3 AOCs Site include chlorinated aromatics (1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, cumene, and styrene) and BTEX compounds. Discussions of the persistence and mobility of these follow.

BTEX compounds are used extensively in chemical manufacturing, and are found in percent concentrations in gasolines. BTEX compounds are relatively easily degraded in an aerobic environment. Published BTEX half-lives are typically short, in the range of 1 week to 1 year. Although degradation under anaerobic conditions can occur, degradation under aerobic conditions is much more prevalent.

Compared to other VOCs, the halogenated aromatics compounds display low solubilities, low vapor pressures, and high organic partitioning coefficients. Based on these properties, they are less mobile than other VOCs. Because of the halogenated nature of these compounds, they are less susceptible to biologic reduction than BTEX compounds. Reported half-lives range from a few weeks to 2 years.

5.2.2.3 Ketones

Ketones detected at the AOCs include acetone and 2-butanone. Ketones are used as high quality solvents and as carriers in chemical manufacturing. They have relatively high vapor pressures and tend to volatilize quickly at standard temperature and pressure. Ketones are very highly soluble (acetone is miscible) and have relatively low Henry's Law Constants. Because of these properties, once dissolved they tend not to volatilize easily. They have very low partitioning coefficients and tend to be very mobile in groundwater. Ketones are amenable to biologic and abiotic decay.

5.2.2.4 Soil

The persistence of VOCs in the subsurface is compound and concentration specific. The nature and concentrations of VOCs in soil and bedrock varies significantly between the East Side and West Side of the access road. Migration of VOCs from soil and bedrock is typically limited to volatilization to the atmosphere and leaching to groundwater. The high vapor pressure of many VOCs detected at the AOCs would cause near-surface VOCs in soils to vaporize quickly. VOCs in deeper soils and bedrock would be less likely to vaporize. VOCs might also be migrating from the groundwater or deeper soils to downgradient soils. A smear zone is evident immediately downgradient of the former Waste Oil Pit in the zone where the top of water table fluctuates seasonally. VOCs can leach to water percolating through the unsaturated zone. The rate of leaching is limited by the rate of recharge through the low permeability tills.

5.2.2.5 Groundwater

Degradation and migration of contaminants primarily govern the persistence of primary VOC contaminants in groundwater at the AOCs. The magnitude of contaminant loss by groundwater discharge to the surface water bodies is unknown. The presence of several daughter products from reduction of PCE and TCE (TCE, cis- and trans-1,2-DCE, and vinyl chloride) and the relatively higher concentrations of the daughter products indicate that degradation of higher end halogenated hydrocarbons is occurring. Part of the degradation process also includes the cometabolism of petroleum constituents with the chlorinated compounds.

5.2.2.6 Semivolatile Organic Compounds

SVOCs are, as the name implies, less volatile compounds (with respect to VOCs). Because of their lower solubilities, vapor pressures, and Henry's Law Constants, the mobility of SVOCs is generally poor and they tend to adsorb to solids within the environment. The preferential mode of transport is through suspension with the solids to which they are adsorbed rather than dissolution into the aqueous media. These characteristics tend toward low mobility and moderate to extensive persistence within the environment.

SVOCs were detected in every media. Of the detected SVOCs, the majority belong to the PAH group. PAHs were predominantly detected in soil samples. The remaining groups of SVOCs only had two or three compounds detected. Chlorinated SVOCs were present in groundwater only.

In general, PAHs are associated with the combustion of fuels (coal/gasoline/wood), runoff or leaching from asphalt-bitumen, or separation from coal-tar products (Kirk-Othmer). PAHs as a class portray low solubility in water and therefore limited mobility exists through passage with the solids to which they are adsorbed. The higher the carbon content of the soil, the stronger the affinity of the compound to the soil. The persistence of PAHs in the environment is enhanced by their low volatility in part due to the high molecular weight. Generally, only the PAHs anthracene, naphthalene, benzo(a) anthracene, and benzo(a) pyrene are considered to be found in asphalt or bitumen products. The remaining PAHs, in addition to the previously mentioned compounds, are present within the exhaust condensate of gasoline engines and combustion products of the previously mentioned fuels (*Handbook of Environmental Data on Organic Chemicals*,

Verschueren, 2001). The phthalates (dicarboxylic acid esters) are generally more soluble than the PAHs and are somewhat ubiquitous within the natural environment due to their use in the manufacture of plastics. Bis(2-ethylhexyl)phthalate is used in the manufacture of plastics to maintain softness and flexibility. Plasticizers, such as bis(2-ethylhexyl)phthalate and the other phthalates, do not become a permanent part of the plastic and can find their way in the air, water, and soil. Although not very soluble in water, they are highly soluble in fats.

The chlorinated SVOCs group exhibits moderate solubility's in water and vapor pressures and Henry's Law Constants, which indicate greater association with the vapor phase, thus comparatively, higher volatilities.

The general SVOC category consists of compounds that are more soluble and possess higher vapor pressures than compounds from the three preceding categories. The characteristics tend to allow more avenues of mobility through both dissolution and volatilization (moderate Henry's Law Constants).

5.2.2.7 Surface Soils

SVOCs detected in the surface soil samples collected at the AOCs were mostly PAHs. PAHs were ubiquitous in almost all surface samples collected in the vicinity of the BPA and Waste Oil Pit. The only surface soil sample from the RSY that had PAHs detected was from SB-126.

5.2.2.8 Subsurface Soils

SVOCs detected in the subsurface soil samples were also comprised mainly of PAHs. Dibenzofuran (general SVOC) and three phthalates were the only non-PAH SVOCs detected in subsurface soils.

5.2.2.9 Groundwater

Twenty-five SVOCs were detected in the groundwater samples collected from the AOC monitoring wells. The detections were at low concentrations typical of PAHs, which have the characteristics of low mobility and persistence in the upper soil layers. The solubility of PAHs in water is moderate to poor.

5.2.3 Metals

Unlike organic compounds, metals do not degrade in the environment, but they may change chemical form or speciation. They are generally considered to be indefinitely persistent. Dissolved metals in groundwater may interact with soil or other solids through sorption processes (that is, ion exchange, adsorption, and precipitation), through complexation, and can act as catalysts in biodegradation processes. The physical and chemical processes are sensitive to pH, groundwater composition, redox conditions, and the type and amount of organic matter, clay minerals, and oxyhydroxide minerals. In general, the solubility of metal compounds (amorphous solids or minerals) in potable groundwater is low (for example, oxide and hydroxide minerals) to moderate.

Given the limited solubility of most metals under ambient conditions and their affinity for ion exchange and adsorption reactions, most metal compounds have low mobility in the environment. However, groundwater containing elevated levels of chloride, bicarbonate, sulfate, or phosphate can enhance the solubility and mobility of metal compounds by the formation of aqueous complexes (for example, lead chloride⁺, manganese sulfate, etc.). Additionally, extreme pH and Eh (that is, the redox potential) conditions can significantly increase the solubility and mobility of metals in the environment. Therefore, the quantity of the metal in the source, metal compound solubilities, the composition of groundwater, and the adsorption capacity of the soils determine the migration potential of the metal element in the environment. Relevant physical and chemical properties of the AOC-related metals and their persistence in the environment are discussed below. Additional information can be found in Brookins (1988).

Aluminum (Al) is an abundant, naturally occurring element that is found in hundreds of alumino-silicate and oxyhydroxide minerals. It is the most abundant metal in the earth's crust, but is never found in the native state as metal. Bauxite, an impure oxide ore of aluminum, is the chief commercial deposit exploited for aluminum, with the pure metal recovered by electrolysis. Aluminum is extensively used for kitchen utensils,

building materials, in the canning industry, and in thousands of industrial applications where a strong, light, easily constructed material is needed. Pure aluminum is soft and lacks strength, but it is alloyed with small amounts of copper, magnesium, silicon, manganese, and other elements to impart useful properties of vital importance in the construction of aircraft. Aluminum has excellent corrosion resistance, due to the formation of a nearly insoluble thin protective oxide layer on the metal.

In the natural environment, aluminum is not redox sensitive, as it exists solely in the +3 valence state. The concentration of dissolved aluminum in most surface and ground waters (that is, pH of 4 to 10) is commonly on the order of parts per billion (ppb) or less. Dissolved aluminum concentrations on the order of ppb or less are generally controlled by the dissolution of aluminosilicate minerals (mainly clay minerals) and/or the precipitation of $\text{Al}(\text{OH})_3$ (gibbsite), whereas aluminum concentrations above about 10 ppb generally indicate the presence of colloidal aluminum species. Under acidic conditions (pH less than 4), aluminum is solubilized as the Al^{+3} or $\text{Al}(\text{OH})_2^+$ ions, while above pH 10 it is mobilized by the formation of the AlO_2^- specie. In general, aluminum has very limited mobility under the near neutral pH conditions of potable groundwater.

Antimony (Sb) is a naturally occurring element that is found in over 100 minerals. The metal is sometimes found in the elemental state, but more frequently occurs as stibnite (Sb_2S_3), as antimonides of the heavy metals, and as oxides. It is extracted from the sulfide by roasting to the oxide, which in turn is reduced by salt and scrap iron. It is also prepared from its oxides by reduction with carbon. The high-purity form of antimony is used in semiconductor technology, while the commercial grade is widely used in alloys (for example, to increase the hardness and mechanical strength of lead). Antimony oxides and sulfides are used in manufacturing flame-proofing compounds, paints, ceramic enamels, glasses, and pottery. Antimony and most of its compounds are toxic to animals.

Antimony is a multivalent element with -3, 0, +3, and +5 valence states. At neutral pH, the Sb(III) species $[\text{Sb}(\text{OH})_3^0]$ is dominant under reducing and transitional Eh conditions, while the Sb(V) species $[\text{Sb}(\text{OH})_6^-]$ is dominant under oxidizing conditions. In the presence of sulfur, under reducing conditions, Sb_2S_3^0 and $\text{Sb}_2\text{S}_4^{2-}$ become dominant species, while under transitional redox conditions, $\text{Sb}(\text{OH})_3^0$ and Sb_2O_3 become the dominant species. All of the Sb(V) compounds are very soluble; therefore, antimony concentrations are not expected to be solubility limited under oxidizing conditions. Natural concentrations are probably controlled by adsorption/desorption reactions rather than precipitation/dissolution reactions. Antimony concentrations in natural groundwater are typically very low (a few ppb), although hot springs and waters impacted by acid mine drainage may contain much higher levels. Very little is known about the sorptive behavior of antimony. Limited studies appear to indicate that antimony is highly mobile due to that fact that it exists primarily as neutral or negatively charged species. Because it exists as an anionic complex under oxidizing conditions, adsorption by hydrous oxides at low pH may be significant. Otherwise, antimony species are believed to be a highly mobile.

Arsenic (As) is naturally occurring element that forms several common minerals. The metal is sometimes found in its elemental form, which is either a yellow or metallic-gray modification. It is also found in sulfides such as realgar (AsS) and orpiment (As_2S_3), as the oxide, arsenates and arsenides, and sulfoarsenides of heavy metals. Arsenopyrite (FeAsS) is the most ubiquitous mineral found in nature, and upon heating, sublimes to ferrous sulfide. Arsenic is used in agricultural insecticides, poisoning agents, pyrotechny, bronzing, and for hardening and rounding lead shot. High-purity arsenic is also used as a doping agent in solid-state devices such as transistors. Arsenic is released to the environment through the burning of coal and the smelting of ores. Arsenic and its compounds are highly toxic.

Arsenic is a multivalent element with -3, 0, +3 and +5 valence states. In natural groundwater, however, arsenic exists in the +3 and +5 oxidation states and forms a variety of species. The As(V) species H_3AsO_4^0 , H_2AsO_4^- , HAsO_4^{2-} , and AsO_4^{3-} dominate in oxidizing conditions. The As(III) species H_3AsO_3^0 , H_2AsO_3^- , HASO_3^{2-} , and AsO_3^{3-} dominate under strongly reducing conditions. At neutral pH, in the presence of sulfur, the oxidation of As(III) to As(V) occurs at Eh values above about -110 millivolts. Arsenic species are generally

present in the aqueous environment in low concentrations (a few ppb), and correlate strongly with iron, which scavenges most of the available arsenic in the system. Under oxidizing conditions, the neutral and negatively charged As(V) species are quite mobile. Arsenic complexes have a strong affinity for iron/manganese oxyhydroxide minerals. Arsenic is also attenuated in groundwater through coprecipitation and scavenging by metal sulfides.

Barium (Ba) is a naturally occurring element that exists chiefly in the sulfate (barite) or carbonate (witherite) form. It is ubiquitous trace element in carbonate rocks and Portland cement, substituting for calcium in the calcite and lime mineral structures. Barite is used in paint, X-ray imaging work, glassmaking, and extensively as a weighting agent in oil well drilling muds. Witherite has found some commercial application as a rat poison.

Barium is not redox sensitive in the natural environment, and it occurs only in the +2 valence state. The concentration of dissolved Ba in surface and ground waters is generally kept below 100 ppb, and is controlled by the solubility of barite and adsorption of the Ba^{2+} ion on clay mineral surfaces. The formation of witherite ($BaCO_3$) becomes important above a pH of 10, and Ba can be mobilized as the Ba^{2+} ion below a pH of about 2. Barium does not form strong aqueous complexes with bicarbonate, sulfate, nitrate, or phosphate ions. This characteristic, along with the low solubility of barite and high adsorption affinity of Ba^{2+} , results in limited mobility of Ba under the near neutral pH conditions of potable groundwater.

Beryllium (Be) is a naturally occurring element that is found in approximately 30 minerals, none of which is common. The most important beryllium minerals are bertrandite, beryl, chrysoberyl, and phenacite, with beryl and bertrandite being the most important sources for the element and its compounds. Aquamarine and emerald are precious forms of beryl. Beryllium metal is prepared by reducing Be fluoride with magnesium metal. Beryllium is the lightest of all metals and finds applications in nuclear reactors as a neutron moderator, as structural materials for high-speed aircraft, missiles, and spacecraft, and as a copper alloy for the production of springs and nonsparking tools. Beryllium and its compounds are toxic.

Beryllium occurs only in the +2 valence state in nature. The most common Be minerals, beryl and bertrandite, are quite insoluble in nature. Bromellite (BeO) is soluble under acidic conditions, dissolving to form the Be^{2+} ion. Under neutral pH conditions, Be is generally not detected in groundwater samples due to the insoluble nature of Be minerals.

Cadmium (Cd) is a naturally occurring element that most often occurs in trace quantities with zinc ores, such as sphalerite (ZnS). Almost all Cd is recovered as a byproduct during the processing of zinc, copper, and lead ores. Cadmium is used most extensively in the electroplating industry, and also finds use in solder, batteries, and as a barrier to control fission reactions. Silver solder contains Cd, and workers using this material must exercise caution to avoid exposure to dangerous fumes. Cadmium and solutions of its compounds (for example, $CdSO_4$) are toxic.

Cadmium is not redox sensitive in the natural environment, and it occurs only in the +2 valence state. The concentration of dissolved Cd in surface and ground waters is generally kept below 10 ppb, and is controlled by the substitution of Cd for zinc and/or lead in carbonate and sulfide minerals and by the adsorption of the Cd^{2+} ion on clay mineral surfaces. Under oxidizing conditions, the formation of otavite ($CdCO_3$) is possible above a pH of 8 and $Cd(OH)_2$ above a pH of 11. In the presence of sulfide (reducing conditions), greenockite (CdS) may form. However, the substitution of Cd for zinc and/or lead in carbonate and sulfide minerals generally prevents the formation of pure otavite or greenockite. Cadmium does not form strong aqueous complexes with bicarbonate, sulfate, nitrate, or phosphate ions. This characteristic, along with the partitioning of Cd into zinc and lead minerals and the high adsorption affinity of Cd^{2+} , results in limited mobility of Cd under the near neutral pH conditions of potable groundwater.

Calcium (Ca) is the fifth most abundant metal in the earth's crust. It is an essential constituent for plant and animal life forms and is found in leaves, bones, teeth, and shells. The pure metal is never found in nature, as Ca readily combines with carbonate, sulfate, fluoride, or phosphate to form calcite ($CaCO_3$), gypsum

($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), fluorite (CaF_2), or apatite ($\text{Ca}_5[\text{PO}_4]_3\text{F}$, $\text{Ca}_5[\text{PO}_4]_3\text{Cl}$, or $\text{Ca}_5[\text{PO}_4]_3\text{OH}$). At higher temperature, Ca combines with aluminum and silicon to form hundreds of minerals (for example, pyroxene, feldspar, and clay phases). Calcium finds wide use and application as lime (CaO) and Portland cement.

Calcium exists solely in the +2 valence state in nature. The ubiquitous distribution of Ca in limestone, shale, and granite ensures that Ca will be present in groundwater. The solubility of limestone in water containing carbon dioxide (for example, rain) creates distinct groundwater compositions that can be identified by their pH (near neutral) and elevated Ca and carbonate concentrations (that is, FLOD groundwater's). Once in solution, the Ca^{2+} ion is the most important aqueous specie, with carbonate and sulfate complexes forming in the presence of these ligands.

Chromium, Total (Cr) is a naturally occurring element that mainly occurs in the oxide state, principally as chromite (FeCr_2O_4). Chromium metal is usually produced by reducing the oxide with aluminum. Chromium is used in the manufacturing of stainless steel and other alloys, and as a catalyst in many chemical processes. All chromium compounds are colored; the most important being sodium chromate (Na_2CrO_4) and potassium chromate (K_2CrO_4), the dichromates (for example, $\text{K}_2\text{Cr}_2\text{O}_7$), and the chrome alums (for example, $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$). Dichromates are used as oxidizing agents in quantitative analysis and in the tanning industry.

Chromium exists in the +3 and +6 valence states in nature. The oxidation of Cr(III) to Cr(VI) occurs at Eh values above 500 millivolts at a pH of approximately 7. Cr(III) forms sparingly soluble oxide and hydroxide minerals under moderate to low redox conditions over the pH interval of 5 to 12. However, Cr(VI) is quite mobile under oxidizing conditions, primarily as the CrO_4^{2-} specie above a pH of 6, and Cr(VI) species are known carcinogens. Negatively charged chromium complexes (for example, CrO_4^{2-} and CrO_2^-) can effectively adsorb onto iron and manganese oxyhydroxide minerals.

Cobalt (Co) is a naturally occurring element that is often associated with nickel, silver, lead, copper, and iron ores, from which it is recovered as a byproduct. The relatively pure cobalt minerals, cobaltite (CoAsS), sphaerocobaltite (CoCO_3), bieberite ($\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$), and sycoporite (CoS) are uncommon. Cobalt is alloyed with iron, nickel, chromium, tungsten, and other metals to make magnet steels, stainless steels, and specialty alloys for cutting tools, dies, and jet turbines. The salts (for example, CoSO_4) have been used for centuries to produce brilliant and permanent blue colors in glass, pottery, tiles, and porcelain. Cobalt-60, a man-made isotope, is an important gamma-ray source that has found wide application in the medical profession.

The most important valence state for Co is the +2 state, although Co possesses a +3 valence state under strong oxidizing conditions when pH is above 8. Under moderate oxidizing conditions, the formation of sphaerocobaltite (CoCO_3) is possible above a pH of 8 and $\text{Co}(\text{OH})_2$ above a pH of 11. In the presence of sulfide (reducing conditions), sycoporite (CoS) may form. However, the substitution of Co for nickel and/or lead in carbonate and/or sulfide minerals generally prevents the formation of pure sphaerocobaltite or sycoporite and keeps aqueous lead concentrations under 10 ppb. Cobalt readily forms aqueous complexes with hydroxide ion and also exists in solution as the Co^{2+} ion.

Copper (Cu) is a naturally occurring element that can occur in native form, but is chiefly found and extracted from cuprite (Cu_2O), malachite ($\text{Cu}_2\text{CO}_3[\text{OH}]_2$), azurite ($\text{Cu}_3[\text{CO}_3]_2[\text{OH}]_2$), chalcopyrite (CuFeS_2), and bornite (Cu_5FeS_4). The discovery of Cu dates back to prehistoric times, and it remains one of our most important metals. Copper is obtained by smelting, leaching, and electrolysis. The most important application of the metal is in the electrical industry, with numerous other applications employed for its alloys, brass, and bronze.

Copper may exist in nature with a valence of 0, +1, or +2. Under reducing conditions, native Cu is the stable form in the absence of sulfide, with Cu sulfide minerals becoming important as sulfur is added to the system. Above neutral pH and under oxidizing conditions, native copper and Cu sulfides are oxidized to cuprite and, at high Eh, tenorite (CuO). In the presence of carbonate and above a pH of 7, malachite and azurite are the stable Cu minerals. Below a pH of 6 and under oxidizing conditions, Cu minerals oxidize to form cupric ion (Cu^{2+}) and hydroxide species. In carbonate groundwaters, Cu carbonate species will be the dominant aqueous form.

Iron (Fe) is the fourth most abundant metal, by weight, in the earth's crust, and it is the most abundant, useful, and important metal. It is a vital constituent of plant and animal life, the most notable component being hemoglobin. The most common ore is hematite (Fe_2O_3), which is reduced with carbon to produce the metal. Iron is also found widely distributed in minerals such as magnetite (Fe_3O_4), goethite (FeOOH), hydroxide phases (for example, $\text{Fe}(\text{OH})_3$), siderite (FeCO_3), and pyrite (FeS). Nearly all Fe is used to produce carbon steel and special alloy steels that contain nickel, chromium, vanadium, and tungsten.

Iron occurs in the +2 and +3 valence states under ambient conditions. Under reducing conditions and below a pH of 8, Fe can be mobilized as the Fe^{2+} specie in the absence of carbonate. Addition of carbonate to the system results in the stabilization of siderite between a pH of about 5 and 9. Under oxidizing conditions, $\text{Fe}(\text{OH})_3$ is stable above a pH of 4 and dissolved Fe concentrations are driven very low (for example, 50 ppb or less) as the pH rises above 7. In the presence of oxygen, precipitation of $\text{Fe}(\text{OH})_3$ is followed by aging of the hydroxide to goethite and eventually hematite (although the kinetics for this aging is very slow under ambient temperature). Dissolved Fe readily complexes with hydroxide, carbonate, and chloride ions when available.

Lead (Pb) is a naturally occurring element that rarely occurs in elemental form. Lead is obtained chiefly from galena (PbS) through roasting. Other common minerals that contain lead in appreciable quantities are anglesite (PbSO_4), cerrusite (PbCO_3) and minim (Pb_3O_4). Lead is a poor conductor, is a blueish-white metal of bright luster, is very resistant to corrosion, and is very soft, malleable, and ductile. The metal is used as a shield against radiation and sound vibration and in a variety of manufacturing processes, which includes the production of plumbing pipes, ammunition, and cable coverings. Lead has been introduced into the environment in large quantities through prior use of leaded gasoline, lead solder in electronics, and past use of insecticides containing Pb arsenide salts. As Pb is cumulative toxin, it is of significant environmental concern. Lead is a multivalent element with 0, +2, and +4 valence states. In natural environments, lead exists primarily as Pb(II) and rarely as native lead. Pb(IV) only exists in extremely oxidizing conditions generally not found in the environment. The dominant aqueous species are Pb^{2+} under acidic conditions, and Pb^{2+} - carbonate complexes under alkaline conditions. When chloride ion is present in appreciable concentration (for example, 100 ppm or greater), Pb chloride complexes become important. Cerrusite and anglesite are the solubility controlling phases in carbonate systems containing sulfur (for example, FLOD groundwaters). At a pH of approximately 7 and in the presence of carbonate, Pb concentrations in natural groundwater are typically below 30 $\mu\text{g}/\text{L}$. Both adsorption/desorption and ion-exchange reactions also serve to lower aqueous Pb concentrations

Magnesium (Mg) is the eighth most abundant metal in the earth's crust. It is an essential constituent for plant and animal life. The pure metal is never found in nature, as Mg readily combines with carbonate and sulfate to form dolomite ($\text{MgCa}[\text{CO}_3]_2$), magnesite (MgCO_3), kieserite ($\text{MgSO}_4 \cdot \text{H}_2\text{O}$), and epsomite ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$). At higher temperature, Mg combines with aluminum and silicon to form hundreds of minerals (for example, pyroxenes, zeolites, and clay phases). Magnesium is used in flashlight photography, flares, pyrotechnics, and aluminum alloys. Its hydroxide, chloride, sulfate, and citrate compounds are used in medicine.

Magnesium exists solely in the +2 valence state in nature. The ubiquitous distribution of Mg in dolomite, shale, metamorphic, and igneous rocks ensures that Mg will be present in groundwater. The solubility of dolomite in water containing carbon dioxide (for example, rain) creates distinct groundwater compositions that can be identified by their pH (near neutral) and elevated Mg and carbonate concentrations (that is, FLOD groundwaters). Once in solution, the Mg^{2+} ion is the most important aqueous specie, with carbonate and sulfate complexes forming in the presence of these ligands.

Manganese (Mn) is a ubiquitous naturally occurring element that is an essential nutrient in animals for utilization of vitamin B₁. It is found in a variety of minerals including oxides, sulfides, silicate and carbonates, with pyrolusite (MnO_2) and rhodochrosite (MnCO_3) being the most common Mn-bearing minerals. Manganese substitutes for iron, magnesium, and calcium in mineral structures. The metal is obtained by electrolysis, or by reduction of the oxide in the presence of sodium, magnesium, and aluminum. Manganese is chemically reactive, and decomposes

in cold water at a slow rate. It is used in the manufacturing of several steel alloys. Pyrolusite is used as a depolarizer in dry cells, and to decolorize glass tinted by iron impurities. Permanganate is a strong oxidizing agent used widely in quantitative analysis and in medicine. Manganese oxyhydroxide compounds can form in low temperature systems, and act as strong adsorbing agents for inorganic ions and ligands.

Manganese is a multivalent element with +2, +3, +4, and +7 oxidation states. All oxidation states except the +7 state form environmentally important solid phases. Mn(II) is the stable and dominant oxidation state in most natural waters below pH of 8. Its oxides and hydroxides form under basic conditions (pH greater than 8) or at neutral pH under high oxidizing conditions. In natural groundwaters, Mn concentrations are typically about 50 times less than those for dissolved iron. Iron/manganese oxyhydroxide particles in unfiltered groundwater samples typically inflate the total Mn concentrations up to several orders of magnitude above dissolved values.

Mercury (Hg) is a naturally occurring element and is the only common metal liquid at ambient temperature. The dominant ore is cinnabar (HgS), which is heated in air and the vapor condensed to yield mercury liquid. The liquid is widely used in laboratory work for making thermometers, barometers, diffusion pumps, and many other instruments. It is also used in pesticides, batteries, dental amalgams, and as a catalyst. Other naturally occurring salts of Hg include mercuric chloride (HgCl₂, a corrosive sublimate), mercurous chloride (Hg₂Cl₂, calomel, occasionally used in medicine), and mercuric sulfide (HgS, vermilion, a high-grade paint pigment). Mercury is also present in coal and can be released from coal combustion or leached from coal piles. Mercury is a cumulative poison that is readily absorbed through the respiratory tract, gastrointestinal tract, or through broken skin.

Mercury occurs as native Hg, Hg(I), and Hg(II) over the Eh-pH space of observed surface and ground waters. Native Hg is stable under moderate oxidizing to reducing conditions over the pH range of 0 to 8, with calomel becoming the stable phase under oxidizing conditions when chloride ion is present. Over the pH interval of 8 to 11, montroydite (HgO) is the stable oxide under oxidizing conditions. Under reducing conditions in the presence of sulfide, vermilion or cinnabar is stabilized. The sulfide, chloride, and oxide minerals are nearly insoluble, resulting in Hg concentrations in groundwater that are well below detection limits. However, native Hg can readily form organic compounds (for example, methyl mercury) that are widely found in groundwater and streams.

Nickel (Ni) is a scarce, naturally occurring element that is chiefly found in the sulfide ores pentlandite ((Fe,Ni)₉S₈) and pyrrhotite (Fe_{1-x}[Ni,Co,Mn,Cu]_xS). Nickel is primarily used in the steel alloys Invar, Monel, Inconel, and the Hastelloys. It is also used extensively for currency, as a catalyst for hydrogenating vegetable oils, magnets, and batteries. Nickel sulfide fumes and dusts are recognized as potential carcinogens.

In the natural environment, Ni occurs in the Ni(II) valence state and is mobile as the Ni⁺² ion above the sulfide/sulfate redox join. Nickel hydroxide (Ni[OH]₂) is the stable phase between pH 8 and 10 and bunsenite (NiO) is the stable, nearly insoluble Ni phase above a pH of about 10. Nickel minerals are not common and Ni concentrations in groundwater are generally below detection due to its scarce occurrence.

Potassium (K) is the seventh most abundant metal in the earth's crust and it is an essential nutrient for plant life. The metal is obtained by electrolysis of the hydroxide, which is produced from the mining of the evaporite minerals sylvite, carnallite (KMgCl₃•6H₂O), langbeinite (K₂Mg₂[SO₄]₃), and polyhalite (K₂Ca₂Mg[SO₄]₄•2H₂O). At high temperature, K combines with oxygen, aluminum, and silicon to form hundreds of minerals (for example, feldspars, micas, and clay minerals). The chief use of K is as a fertilizer, with numerous other uses provided by its hydroxide, nitrate, chloride, bromide, cyanide, chromate, and dichromate salts.

Potassium exists in nature only in the +1 valence state. The K⁺ ion is the only specie found in most groundwaters. Most K concentrations in groundwater are controlled by ion-exchange reactions with clay minerals. Potassium concentrations in groundwater are generally less than 10 milligrams per liter (mg/L), unless evaporite deposits with soluble K salts are present.

Selenium (Se) is a naturally occurring element that is found in a few scarce minerals, such as crooksite and clausthalite. It is recovered from the flue dusts remaining from processing copper ores or the anode muds from electrolytic copper refineries. Selenium is a member of the sulfur family and resembles sulfur both in its various forms and compounds. It is used in the production of photocells, solar cells, and solid-state devices. Elemental Se is practically nontoxic, but its compounds are extremely toxic and resemble arsenic in their physiological reactions. Selenium can exist in the -2, 0, +4, or +6 valence states under natural conditions. Under strong reducing conditions, Se can substitute for sulfur in sulfide minerals (for example, FeSe and ferroselite), while mild reducing to oxidizing conditions can produce native Se, especially at low pH. Oxidized forms of Se are not stable as solids, and a variety of Se(IV) and Se(VI) aqueous species are formed. The aqueous Se species are especially important, as they have been linked to adverse health effects.

Silver (Ag) is a naturally occurring element that is found in its native form and in ores such as argentite (Ag_2S), chlorargyrite (AgCl); although lead, lead-zinc, copper, gold, and copper-nickel ores are principal sources. About 30 percent of the U.S. industrial consumption of Ag goes into photographic film, with much of the remainder used for making jewelry, solder, electrical contacts, and dental alloys. Although native silver is not considered toxic, its compounds are poisonous. Silver compounds can be absorbed by tissue through the circulatory system and when reduced they accumulate in the tissue.

Silver occurs in the natural environment in its native form and in the +1 and +2 valence state, although the +2 valence state is only obtained under highly oxidized conditions at low pH. Under reducing conditions in the presence of sulfide, Ag is stable as argentite, or as native Ag in the absence of sulfide. Under oxidizing groundwater conditions, the sulfide and native phases are dissolved and Ag can be mobilized if chloride is absent. As most groundwaters contain 10 to 50 mg/L chloride and chlorargyrite is relatively insoluble, Ag concentrations in groundwater will commonly remain below 20 ppb.

Sodium (Na) is the sixth most abundant element in the earth's crust. It is never found as the free metal, and the most common sodium compound is halite (NaCl), a salt that is important to animal nutrition. Sodium metal is obtained commercially by electrolysis of dry, fused NaCl . The compounds most important to industry are common salt (NaCl), soda ash (Na_2CO_3), baking soda (NaHCO_3), caustic soda (NaOH), Chile saltpeter (NaNO_3), di- and tri-sodium phosphates, sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$), and borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$). Sodium compounds are important to the paper, glass, soap, textile, petroleum, chemical, and metal industries.

Sodium occurs in nature only in the +1 valence state. The Na^+ ion is the only specie found in most groundwaters. Most Na concentrations in groundwater are controlled by ion-exchange reactions with clay minerals. Sodium concentrations in groundwater are generally less than 30 mg/L, unless evaporite deposits with soluble Na salts are present.

Thallium (Tl) is a scarce, naturally occurring element that is primarily found in trace concentrations in iron, zinc, and lead ores. Thallium sulfate has been produced and widely employed as a rodenticide and ant killer, although its use has been prohibited in the U.S. since 1975 as a household insecticide and rodenticide. It is also used in photo cells, low melting glasses, and some medicinal applications. However, the element and its compounds are toxic and therapeutic benefits are limited.

Thallium exists in nature in the +1 and +3 valence states, but mobility in the aqueous environment is limited to the +1 valence state. Under mild to strong oxidizing conditions, thallium is predicted to be stabilized as Tl_2O , Tl_2O_3 , or Tl_2O_4 . The Tl^+ ion is stable under reducing conditions below a pH of 9, with Tl_2S stable above a pH of 9. Tl^+ may be present in very low concentrations (a few ppb) under reducing conditions.

Vanadium (V) is a naturally occurring element that is found in over 65 minerals, the most important sources for the metal being carnotite ($\text{K}_2[\text{UO}_2]_2[\text{VO}_4]_2 \cdot 3\text{H}_2\text{O}$), roscoelite ($\text{KV}_2\text{AlSi}_3\text{O}_{10}[\text{OH}]_2$), vanadinite ($\text{Pb}_5[\text{VO}_4]_3\text{Cl}$), and patronite (VS_4). About 80 percent of the V produced is used as ferrovanadium or as a steel additive, with the remainder finding application in dyeing, printing, and superconductor industries. Vanadium and its compounds are considered to be mild toxins.

Vanadium can occur in the +2, +3, +4, and +5 valence states, although the +2 state is uncommon. Under mild oxidizing to reducing conditions and neutral pH of common groundwaters, V is immobilized as the solid phases V_2O_4 and V_2O_3 . However, where groundwaters move across redox fronts in mineralized regions of the earth's crust, V will be immobilized as carnotite, vanadinite, and patronite. Under oxidizing conditions, V is mobilized as VO^{2+} below a pH of 5, $H_2VO_4^-$ between a pH of about 5 and 8, and as HVO_4^{2-} above a pH of 8. Where a source of V exists and oxidizing conditions prevail, V tends to be a mobile constituent in groundwater environments.

Zinc (Zn) is a naturally occurring element that is an essential nutrient for the growth of humans and animals. Its principal ores are sphalerite (ZnS), smithsonite ($ZnCO_3$), calamine ($Zn_4Si_2O_7[OH] \cdot H_2O$), and franklinite ($ZnFeMnO_4$). Zinc metal is obtained by roasting the ores to the oxide and reducing the oxide with coal or carbon. The metal is used to form a number of alloys, the most important being brass, nickel silver, bronze, German silver, soft solder, and aluminum solder. Zinc is also used extensively to galvanize other metals such as iron to prevent corrosion. Zinc is not considered toxic, but the freshly formed oxide (ZnO) is known to cause the Aoxide shakes when inhaled.

Zinc occurs in the natural environment solely in the +2 oxidation state. Under reducing conditions and the presence of sulfide, Zn is immobilized as sphalerite. Under oxidizing conditions, Zn is mobile below a pH of 7 and immobile above a pH of 9 as ZnO . Between a pH of 7 and 9, smithsonite is stable when carbonate groundwater is present (for example, FLOD groundwaters). Zn concentrations in groundwater are generally kept below 50 ppb when carbonate minerals are present in the groundwater/soil system.

5.2.3.1 Soils

Most metals were detected in soil at each of the AOCs, some of which exceeded site-specific background concentrations. The elevated levels of metals relative to background are assumed to have two causes: (1) human activity, and (2) varying geochemical composition between background and AOC soils.

The metals are persistent over time in the environment, with possible migration related to sediment transport in streams, airborne transport of surface particulates, leaching and dissolution of source materials, or desorption of metals into the liquid phase.

5.2.3.2 Groundwater

Total concentrations for each metal analyzed except zinc were detected above background in one or more groundwater samples. However, the presence of dissolved phase metals in groundwater was much less prevalent. This suggests that metals found in total concentrations were biased high from suspended solids present in the groundwater.

5.2.4 Chlorinated Pesticides and PCBs

Chlorinated pesticides were the principal class of pesticides determined by Method 8080 in SW-846 during the analytical program at the AOCs. PCBs were not detected in any media. Table 5-2 presents a summary of selected physical and chemical properties. As a group, pesticides are intended to kill insects, plants, weeds, molds, and rodents. DDT and other chlorinated hydrocarbons like lindane (γ -BHC), aldrin/dieldrin, and heptachlor have gained notoriety because of their persistence in the environment, their tendency to accumulate in living tissue, and their adverse effects upon non-target species. Their chemical stability prevents their breakdown within the environment and promotes accumulation within animal or plant tissue.

DDT is nearly immobile in soils and the hydrophobic nature of the molecule results in evaporation with water at a much greater rate than its vapor pressure would predict. DDT persistence in soils extends years after application. Microbial metabolism and photodecomposition can cause degradation of DDT. However, the processes are poorly understood. Dehydrohalogenation to DDE can be accomplished by resistant strains of insects and catalytically by iron. Under anaerobic conditions, microbial activity can convert DDT to DDD. Pesticides were not detected in groundwater. DDD, DDT, and DDE were detected in surface and subsurface soils.

Generally, the pesticides at the AOCs are of low water solubility. These compounds exhibit low to moderate volatilization according to the Henry's Law constants. Additionally, the three pesticides detected, report vapor pressures in the range of 10^{-6} millimeters of mercury to 10^{-7} millimeters of mercury, indicative of the tendency to associate with particulate matter.

5.3 Contaminant Migration

Primary potential routes of contaminant migration at the 3 AOCs include the following:

- Erosion of surface soil to sediments
- Movement of contaminants from the soil and bedrock into groundwater
- Movement of groundwater north-northwest from the AOCs

The majority of detected VOCs were chlorinated aliphatics and, to a lesser extent, BTEX chemicals. This indicates that leaching from surficial to subsurface soils may be an important transport mechanism for VOCs. The presence of NAPL in the bedrock in the vicinity of the Waste Oil Pit indicates that VOCs have migrated into bedrock as a component of disposed waste oil.

Chlorinated VOCs and BTEX chemicals were also detected in groundwater samples downgradient of the Waste Oil Pit, which indicates leaching to groundwater and advective transport has occurred.

SVOCs were detected in surface and subsurface soil samples from these AOCs and, to a limited extent, in groundwater. Detected SVOCs were predominantly PAHs. PAHs were typically detected either in surface soils or subsurface soils, but seldom in both samples from each boring. This suggests that leaching is not a significant transport mechanism for SVOCs. As with VOCs, subsurface contamination may be attributed to past grading and filling activities. Very low concentrations of SVOCs were detected in groundwater, which suggests that vertical movement of SVOCs is limited, and that dissolution and movement by groundwater transport appears to be minimal. This is expected given the discussion of SVOC transport provided in Section 5.2.

Pesticides were detected at low concentrations in two surface soil samples from the RSY and in 11 surface soil samples from the Waste Oil Pit. Pesticides were also present in several subsurface soil samples in the vicinity of the Waste Oil Pit. Pesticides were detected in only one groundwater sample at very low concentrations, which suggests that leaching of pesticides is limited and subsurface detections may be attributed to past grading and filling activities.

With the exception of barium, different sets of metals detected above background occurred in surface and subsurface soils. Detected metals were generally isolated occurrences with no discernible pattern. Leaching of metals does not appear to be a significant transport mechanism. Metals (dissolved) detected above background in groundwater included arsenic, barium, cadmium, iron, lead, manganese, nickel, and potassium.

Baseline Human Health Risk Assessment

This section presents the results of the HHRA, which evaluates current and future risks to human health from residual constituents detected in soil at the 3 AOCs and groundwater at the 3 AOCs (termed “sitewide groundwater”). A baseline HHRA for the 3 AOCs and sitewide groundwater was previously completed in 2006 in accordance with the approved work plan (ITC, 2000b). The HHRA for the Waste Oil Pit AOC soil and sitewide groundwater were updated in this HHRA because additional soil and groundwater data were collected subsequent to 2006. The HHRA for the RSY and BPA AOCs have not been updated. The updated Waste Oil Pit AOC and sitewide groundwater HHRA was prepared in accordance with the approach and methodology presented in the *Human Health Risk Assessment Work Plan for Lordstown 3 AOCs* (CH2M HILL, 2011). The objective of the HHRA is to evaluate and document the current and future risks to human health associated with potential current and future exposures to constituents if no further remedial action is taken. The HHRA incorporates the general methodology described in the following guidance sources:

- *Risk Assessment Guidance for Superfund [RAGS], Volume 1, Human Health Evaluation Manual, Part A* (USEPA, 1989)
- *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors* (USEPA, 1991a)
- *Soil Screening Guidance: User’s Guide* (USEPA, 1996)
- *Exposure Factors Handbook* (USEPA, 1997a)
- *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part D* (USEPA, 2001a)
- *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part E* (USEPA, 2004a)
- *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part F* (USEPA, 2009a)
- *Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment* (Ohio EPA, 2005)

The supporting tables for this HHRA are presented in Appendix F.1 (RSY and BPA AOCs) and Appendix F.2 (Waste Oil Pit AOC and sitewide groundwater). The data presented in the tables were collected and validated (following Louisville Chemistry Guidance) in accordance with the work plans approved by the USACE-Louisville District’s subject matter expert (chemist) and the Ohio EPA.

An ecological risk assessment (ERA) has not been included in this RI report. An ERA was performed for the 3 AOCs Site, and results documented in the "Remedial Investigation Report for the Former Lordstown Ordnance Depot, Project No. 77528," dated April 2000. Subsequently, the OCC presented a property management plan that indicated commercial/industrial development in the area of the 3 AOCs. As a result, additional consideration of terrestrial ecological risk was not necessary. Further, given the minimal size of the AOCs, the AOCs would not support a sufficient number or type of ecological receptors to conclude the existence of an unacceptable risk.

While the ERA did not look at aquatic risk, the groundwater plume does not appear to present a potentially unacceptable risk by cross-media impacts to ecological receptors in Beaver Creek or Beaver Pond. The USEPA Region 5 Ecological Screening Level for TCE, 1,2-DCE, and vinyl chloride (the only VOCs found at the leading edge of the plume) are 47 µg/L, 970 µg/L, and 930 µg/L, respectively. The constituents were of nondetected concentrations at the sub-parts per billion level in the wells closest to Beaver Creek or Beaver Pond (MW-107 and MW-125; as shown in Figures 4-10 through 4-12).

6.1 Human Health Exposure Conceptual Site Model

The purpose of the CSM is to present an overview of site conditions, potential constituent migration pathways, and exposure pathways to potential receptors. Figures 6-1 through 6-4 present the human health CSM for potential exposure for the site associated with soil at each AOC and sitewide groundwater, respectively. The CSMs present the potential exposure media, exposure routes, and receptors to be evaluated in the HHRA. Table 1 in Appendix F.1 summarizes the potential exposure pathways and scenarios considered for the RSY and BPA AOCs, and Table 1 in Appendix F.2 summarizes the potential exposure pathways and scenarios considered for the Waste Oil Pit AOC and sitewide groundwater, respectively. The CSM is described in more detail in Section 6.5.1.

6.2 Scope of the HHRA

The HHRA consists of the following components:

- **Identification of Constituents of Potential Concern (COPCs)**—Identification of the appropriate HHRA data set and selection of the COPCs. COPCs identified in this screening are the focus of the subsequent steps of the HHRA.
- **Exposure Assessment**—Identification of the potential pathways of human exposure, characterization of the potentially exposed populations, and estimation of the magnitude, frequency, and duration of exposures.
- **Toxicity Assessment**—Assessment of the potential adverse effects of the COPCs and compilation of the toxicity values used for developing numerical risk estimates.
- **Risk Characterization**—Integration of the results of the exposure assessment and toxicity assessment to develop numerical estimates of health risks.
- **Uncertainty Assessment**—Identification and discussion of sources of uncertainty associated with the data, methodology, and values used in the HHRA.

These components are described in the following sections.

6.3 Identification of Constituents of Potential Concern

The data evaluated in the HHRA consist of soil and groundwater samples collected during the PA (TCT, 1995), SI (Maxim, 1997), TCRA (ITC, 2000), and soil and groundwater samples collected for the post-RI data gap investigation under the TAMPEEL Landfill and 3 AOCs Investigation Work Plan (CH2M HILL, 2007). The investigations are summarized in Section 1 and further detailed in Section 2. Sample analyses for VOCs, SVOCs, pesticides/PCBs, explosives, dioxin/furans, and metals were used in the HHRA.

The results of analyses of the bedrock samples collected in the vicinity of the Waste Oil Pit are not included in this HHRA. The purpose of the bedrock samples was to evaluate the extent of VOCs that migrated into bedrock and could be a source of groundwater contamination. For this objective, a non-standard analytical method for analyzing VOCs in bedrock was developed as a semi-quantitative way to evaluate bedrock. The results cannot be quantitatively evaluated in a HHRA.

Screening against human health risk-based levels to identify COPCs further reduced the data set for each environmental medium.

6.3.1 Data Summary and Evaluation

Section 6.3.1 describes the data evaluation activities that were performed for the 3 AOCs and sitewide groundwater. The data evaluation was performed to define a set of chemical data suitable for use in the HHRA.

Analytical results for the 3 AOCs and sitewide groundwater are presented in Section 4. The soil data was grouped and evaluated as two exposure groups: (1) surface soil (0 to 2 foot interval based on the approved work plan [ITC, 2000b], and (2) total soil (0 to 6 foot interval for Waste Oil Pit and RSY and 0-to-12-foot interval for BPA; intervals based on depth to bedrock). The analytical parameters for soil samples consist of VOCs, SVOCs, pesticides/PCBs, dioxins/furans, explosives, and metals, while groundwater samples were analyzed for VOCs, SVOCs, explosives, and metals (total and dissolved). Groundwater data collected before 2007 were not included in the data set for sitewide groundwater since more recent groundwater data (from 2007 to 2009) are more comprehensive and more accurately represent current groundwater concentrations at the site.

The list of samples used in the HHRA for the 3 AOCs and sitewide groundwater is presented in Table 6-1. Appendix I contains the analytical data set used in the HHRA for the Waste Oil Pit AOC and sitewide groundwater since the data represent samples collected after the 2006 HHRA.

All data selected for inclusion in the HHRA were initially evaluated to determine their reliability for use in the quantitative HHRA based on the following criteria:

- Data qualified with a J (estimated) were treated as detected concentrations.
- Data qualified with an R (rejected) and Z (other data available) were excluded from the HHRA.
- Data qualified with a B, E, D, +, and N were treated as detected concentrations.
- For duplicate samples, the higher of the two concentrations were used when both values were detects or when both values were nondetect. In cases where one result was a detect and the other a nondetect, the detected value was used.

Details of the data quality evaluation for the samples collected at the 3 AOCs and sitewide groundwater can be found in the following documents:

- Soil samples collected in 1995—*Summary of Findings at Lordstown* (TCT, 1995)
- Soil samples collected in 1997 and 2000—Section 2
- Soil samples collected in 2000—*Final Waste Oil Pit Time Critical Removal Action Former Lordstown Ordnance Depot* (ITC, 2000a)
- Soil samples collected in 2007—*Draft Former Lordstown Ordnance Depot Waste Oil Pit Soil and Bedrock Investigation* (CH2M HILL, 2010)
- Groundwater samples collected in 2007 and 2008—*Final Annual Monitoring Data Summary Report for the TAMPEEL and 3 Areas of Concern Sites* (CH2M HILL, 2009b)
- Groundwater samples collected in 2009—*Draft Former Lordstown Ordnance Depot Waste Oil Pit Soil and Bedrock Investigation* (CH2M HILL, 2010)

6.3.2 Selection of Constituents of Potential Concern

The maximum detected concentration of each analyte in each medium was compared to its screening level as defined below to select the COPCs for the medium. If the maximum detected concentration exceeded its screening level, the constituent was selected as a COPC. The COPC screening tables for the RSY AOC surface soil and total soil are presented in Appendix F.1, Tables 2 and 3, respectively. The COPC screening tables for the BPA AOC surface soil and total soil are presented in Appendix F.1, Tables 4 and 5, respectively. The COPC screening tables for the Waste Oil Pit AOC surface soil and total soil, and sitewide groundwater are presented in Appendix F.2, Tables 2.1 through Table 2.3, respectively. If no screening level was available for an analyte, a surrogate constituent was selected and its screening level was used for the COPC selection process.

- **Soil (Risk-Based Screening):** The maximum detected concentrations in the Waste Oil Pit AOC surface soil and total soil were compared to USEPA Regional Screening Levels (RSLs; USEPA, 2011a) for residential contact with soil. Additionally, total soil was also compared to USEPA RSLs for industrial contact with soil to select COPCs for industrial workers and construction workers. The maximum detected concentrations in the RSY and BPA AOC surface soil and total soil were compared to USEPA Region 9 Preliminary Remediation Goals (PRGs) (USEPA, 2004b) for residential contact with soil because it was the accepted, standard screening level at the time that this risk assessment was performed. PRGs and RSLs based on noncarcinogenic effects were adjusted (divided by 10) to account for exposure to multiple constituents. RSLs based on carcinogenic effects were used as presented in the RSL table (that is, based on an excess lifetime cancer risk [ELCR] of 1×10^{-6}). PRGs based on carcinogenic effects were adjusted by 10 (that is, based on an ELCR of 1×10^{-7}).
- **Groundwater:** The maximum detected concentrations in groundwater were compared with the RSLs for tap water (USEPA, 2011a), adjusted as described above for soil.
- **Lead:** USEPA considers lead to be a special case because of the difficulty in identifying the classic “threshold” needed to develop a reference dose (RfD). The residential soil PRG for lead (400 mg/kg) is based on the Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children and, therefore, was not adjusted downward by a factor of 10. For the RSY and BPA AOCs, lead in soil was compared with the adult screening level of 1,414 mg/kg for industrial, commercial, and trespasser exposures. Lead concentrations in groundwater were compared to the lead Federal Action Level for drinking water (15 µg/L; USEPA, 2009b).
- **Chromium:** The RSL or PRG (depending on the year the risk assessments were performed) for hexavalent chromium was used in screening total chromium data as a conservative approach consistent with the USACE- and Ohio EPA-approved HHRA Work Plan. However, there is no site history information to connect the use of hexavalent chromium to former DoD operations.
- **Dioxins/Furans:** For dioxin data, the toxic equivalency factors recommended by USEPA (2010a) were used to calculate 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent (TEQ) concentrations for each sample in which dioxins were detected, and the calculated concentrations were used in the COPC screening process. Appendix F.2, Table 2.1.RME Supplement A, presents the calculation of the 2,3,7,8-TCDD TEQ concentrations for Waste Oil Pit AOC soil.
- **Background Screening:** Detected metals may be naturally occurring concentrations and not related to historical site activities. Therefore, the maximum detected concentrations in soil and groundwater were compared to background upper tolerance limit concentrations of metals based on site-specific background samples. The results are presented in Table 4.1 for soil and groundwater. Figure 4-1 presents the background soil sampling locations, and Figure 4-2 presents the background monitoring well locations. Background samples were also collected and analyzed for dioxins. 2,3,7,8-TCDD equivalent concentrations for background samples are presented in Appendix F.2, Table 2.1.RME Supplement A, and were compared to Waste Oil Pit AOC dioxin concentrations. During preparation of the RSY and BPA AOCs HHRA in 2006, chemicals were eliminated as COPCs if the maximum detected concentration was less than background. For the Waste Oil Pit AOC and sitewide groundwater, chemicals were not eliminated as COPCs on the basis of background in accordance with the HHRA work plan (CH2M HILL, 2011). However, the maximum detected concentrations of metals in soil and groundwater were compared to site-specific background concentrations. Background concentrations comparisons were used to identify COCs in Section 6.8.
- **Essential Human Nutrients:** Constituents considered essential nutrients, present at low concentrations (that is, within or slightly above naturally occurring levels), and toxic only at very high doses were not selected as COPCs. The constituents include calcium, magnesium, potassium, and sodium. Although iron

is considered an essential nutrient and is toxic at only very high doses, iron was included in the HHRA because a screening level is available.

- **Nondetected Constituents:** A separate COPC screening was conducted for chemicals that were not detected in Waste Oil Pit AOC soil or sitewide groundwater, in accordance with the HHRA work plan (CH2M HILL, 2011). If the maximum reporting limit for a nondetected constituent exceeded the screening level, the constituent was included for quantitative evaluation. The risk evaluation and supporting tables for nondetected constituents are provided in Appendix G. The uncertainty associated with nondetected constituents with elevated reporting limits is included in Section 6.9.

6.3.3 Summary of Constituents of Potential Concern

6.3.3.1 Railroad Salvage Yard AOC

Constituent identified as COPCs in the RSY AOC surface soil and total soil are presented in Appendix F.1, Tables 2 and 3, respectively. In both surface soil and total soil, six metals (arsenic, cadmium, chromium, iron, lead, and manganese), one VOC (TCE), five PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene), and one pesticide (delta-BHC) were detected at maximum concentrations greater than the screening levels and were selected as COPCs. Aluminum was also detected at maximum concentrations greater than the screening levels; however, it was not selected as a COPC because it was less than background concentrations.

6.3.3.2 Burn Pit Area AOC

Constituents identified as COPCs in the BPA AOC surface soil and total soil are presented in Appendix F.1, Tables 4 and 5, respectively. In both surface soil and total soil, nine metals (aluminum, antimony, arsenic, barium, cadmium, chromium, iron, lead, and manganese), two VOCs (2-hexanone and acetone), six PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene), and one phthalate (bis(2-ethylhexyl)phthalate), and three pesticides (delta-BHC, dieldrin, and heptachlor) were detected at maximum concentrations greater than the screening levels and were selected as COPCs. In total soil, three additional metals (copper, mercury, and zinc) and one VOC (chloromethane) were also detected at maximum concentrations greater than the screening levels and were selected as COPCs.

6.3.3.3 Waste Oil Pit AOC

Detected constituents identified as COPCs in the Waste Oil Pit AOC surface soil and total soil for trespasser and residential exposures are presented in Appendix F.2, Tables 2.1.RME and 2.2.RME, respectively. In surface soil, 2,3,7,8-TCDD TEQ, seven metals (aluminum, antimony, arsenic, chromium, cobalt, iron, and manganese), one pesticide (4,4-DDD), seven SVOCs (2-methylnaphthalene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene, naphthalene), and one VOC (TCE) were detected at maximum concentrations greater than the screening levels and were selected as COPCs. The detected concentrations of aluminum and chromium were less than background concentrations; however, comparison to background was not used to eliminate analytes as COPCs.

In total soil, 2,3,7,8-TCDD TEQ, nine metals (aluminum, antimony, arsenic, cadmium, chromium, cobalt, iron, manganese, and thallium), one pesticide (4,4-DDD), eight SVOCs (2-methylnaphthalene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, and indeno(1,2,3-cd)pyrene), and six VOCs (cis-1,2-dichloroethene, ethylbenzene, naphthalene, total xylenes, TCE, and vinyl chloride) were detected at maximum concentrations greater than the screening levels and were selected as COPCs. The detected concentrations of chromium were less than background concentrations; however, comparison to background was not used to eliminate analytes as COPCs.

Detected constituents identified as COPCs in the Waste Oil Pit AOC total soil for industrial worker and construction worker exposures are presented in Appendix F.2, Table 2.2.b.RME. Three metals (arsenic, chromium, thallium), one pesticide (4,4-DDD), four SVOCs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene) and two VOCs (TCE, vinyl chloride) were detected at maximum

concentrations greater than the screening levels and were selected as COPCs. The detected concentrations of chromium were less than background concentrations; however, comparison to background was not used to eliminate analytes as COPCs.

6.3.3.4 Sitewide Groundwater

Detected constituents identified as COPCs in sitewide groundwater are presented in Appendix F.2, Table 2.3.RME. Ten metals (aluminum, antimony, arsenic, chromium, cobalt, iron, lead, manganese, nickel, and silver), five SVOCs (benzo(a)pyrene, benzo(b)fluoranthene, bis(2-chloroethyl)ether, bis(2-ethylhexyl)phthalate, and indeno(1,2,3-cd)pyrene), and 16 VOCs (1,1,2-trichloroethane, 1,1-dichloroethene, 1,4-dichlorobenzene, benzene, bromodichloromethane, chloroform, cis-1,2-dichloroethene, dibromochloromethane, ethylbenzene, m&p-xylene, naphthalene, o-xylene, PCE, total xylenes, TCE, and vinyl chloride) were detected at maximum concentrations greater than the screening levels and were selected as COPCs.

6.4 Vapor Intrusion

Volatile chemicals in soil and groundwater can volatilize, migrate through soil gas and subsequently, into indoor spaces. Therefore, inhalation of indoor air at hypothetical future buildings potentially impacted by volatiles detected in soil and groundwater is considered a potential pathway at the 3 AOCs. The DoD Vapor Intrusion Guidance document (DoD, 2009), vapor intrusion guidance from USEPA (2002a), Interstate Technology & Regulatory Council (2007), and Ohio EPA's *Sample Collection and Evaluation of Vapor Intrusion to Indoor Air for Remedial Response and Voluntary Action Programs—Guidance Document* (2010) were consulted when evaluating the potential vapor intrusion exposure pathway at the 3 AOCs.

Chemicals detected in soil and groundwater that are sufficiently toxic and volatile require an evaluation of the vapor intrusion pathway. Following the identification of toxic and volatile chemicals in groundwater, analytical data for these constituents are typically screened against target groundwater concentrations for vapor intrusion to identify indoor air COPCs; since screening target concentrations are not available for soil, all sufficiently toxic and volatile chemicals detected in soil are selected as COPCs. Subsequently, indoor air concentrations are typically calculated using the Johnson and Ettinger Model (JEM).

However, at the 3 AOCs, use of screening levels and modeling (the JEM) to evaluate site data and calculate indoor air EPCs is not applicable because the JEM is applicable only when there is a distance of at least 5 feet between the ground surface and either the groundwater table or the bedrock. The average depth to groundwater at the 3 AOCs is less than 5 feet bgs, NAPL is present in groundwater, and bedrock is shallow, ranging between 2 and 6 feet bgs (CH2M HILL, 2010).

Based on this site-specific information, vapor intrusion cannot be eliminated as a potential exposure pathway. Since indoor air concentrations cannot be modeled using the JEM due to subsurface conditions, risks from vapor intrusion cannot be quantified. Because of the presence of volatile compounds in both groundwater and soil, the vapor intrusion pathway may be complete for potential future indoor air exposures and has the potential to exceed target risk levels for both residential and industrial land uses.

6.5 Exposure Assessment

Exposure assessment is the estimation of the likelihood, magnitude, frequency, duration, and routes of exposure to a constituent. Exposure refers to the potential contact with a constituent based on standard exposure assumptions and chemical toxicities. Exposure can occur when constituents migrate from a source to an exposure point, or when a receptor comes into direct contact with contaminated media.

The following are the three components of exposure assessment:

- Characterization of exposure setting
- Identification of exposure pathways
- Quantification of exposure

6.5.1 Characterization of Exposure Setting

Characterization of exposure setting consists of two parts: (1) characterization of the site with respect to the physical characteristics, and (2) characterization of the site with respect to human populations at or near the site.

6.5.1.1 Physical Characteristics

The 3 AOCs are open, level areas that are mostly vegetated with native grasses and weeds. There are no buildings in the immediate vicinity of the 3 AOCs. A description of the 3 AOCs is included Section 1.1.2. A description of the site demography, land use and physical setting, including the surface water hydrology, topography, geology, and hydrogeology is provided in Section 3.

6.5.1.2 Potentially Exposed Populations

The 480 acres encompassed by OCC are zoned commercial. Approximately 40 percent of the property is used for storage while the remaining 60 percent is used for light manufacturing or assembly. Approximately 25 tenants use space through leases of 1 month or longer, others lease parking spots on a temporary or month-to-month basis. The 3 AOCs are undeveloped and unoccupied. While the 3 AOCs are part of a property that is used as an industrial park and land use at the 3 AOCs is not anticipated to change in the future, the HHRA included an evaluation of future residential land use exposures to provide information regarding hypothetical unrestricted land use at the site.

The site and surrounding area are serviced by the municipal water supply, which is derived from Meander Lake. Groundwater at the site is not currently used for potable purposes, but a local groundwater ordinance does not exist that prevents current or future use of site groundwater. The Lordstown Water Commissioner (EDR, 2011) indicated that all residents in the area are supplied with city water; however, Ohio Department of Natural Resources records indicate that 30 water wells are present within 1 mile of the site (Figure 3-10). The end use of these wells is unknown at this time, although they may be used for drinking water currently or in the future. However, based on currently available data, there is no indication that site-related, impacted groundwater is present offsite. Therefore, the offsite groundwater exposure pathways were considered to be incomplete and were not evaluated in this HHRA. The following are onsite populations potentially exposed to groundwater at the 3 AOCs:

- Current trespassers/site visitors (adult, youth, and child)
- Future industrial workers (adult); under the future industrial land use scenario, it is assumed that there is no locally grown produce or other food sources
- Future construction workers (adult)
- Future hypothetical residents (adult and child); Although current and future land use at the 3 AOCs is anticipated to be commercial, evaluation of residential land use exposures was included in the HHRA to provide information regarding hypothetical unrestricted land use at the site. However, consistent with USEPA guidance (2001b), remedial goals can be based on reasonably foreseeable land uses (rather than hypothetical unrealistic land uses).

Table 1 in Appendix F.1 summarizes the potentially exposed populations at the RRSY and BPA AOCs, and Table 1 in Appendix F.2 summarizes the potentially exposed populations at the Waste Oil Pit AOC and sitewide groundwater. The risks estimates presented in this HHRA represent potential current or future risks to human health based on assumed exposures and chemical toxicities and are referred to as “current risk” or “future risk” for the receptor groups.

6.5.2 Identification of Exposure Pathways

An exposure pathway can be described as the physical course that a COPC takes from the point of release (or source) to a receptor. To be complete, an exposure pathway must have all of the following components:

- A source (such as constituent residues in soil)
- A mechanism for chemical release and migration (such as leaching)

- An environmental transport medium (such as groundwater)
- A point of potential human contact (exposure point, such as a potable well)
- A route of intake (for example, ingestion of groundwater from a potable well)

In the absence of any one of the components, an exposure pathway is considered incomplete, and, by definition, there is no risk or hazard. In some cases, a receptor may contact a source directly, eliminating the release and transport pathways.

The potential exposure pathways for the site were identified in the CSM (Figures 6-1 through 6-4) and are listed in Table 1 in Appendix F.1 and Table 1 in Appendix F.2. The following subsections discuss the elements of the exposure pathways for the site.

6.5.2.1 Constituent Sources

As shown on Figures 6-1 through 6-4, the initial source of contamination for the BPA and Waste Oil Pit AOCs is historical dumping and burning activities at the site. The specific nature of former operations at the Railroad Salvage Yard is unknown. During site inspections, the RSY exhibited bare patches and stressed vegetation, which prompted investigation of site conditions.

The BPA was used for disposal of non-inventoried, combustible materials such as waste paper, wood, cardboard, and building demolition debris, as well as non-flammable materials such as junk vehicles, asbestos-containing demolition debris, and miscellaneous glass and metal materials. Burning pits were used for incineration and disposal during the 1950s. The working locations of the pits changed with time.

The Waste Oil Pit was used during the 1950s for disposal of petroleum products such as waste motor oil, waste gasoline, waste paints, and spent cleaning solvents. Wastes were generated at an estimated rate of approximately 25 gallons per day. Liquid wastes were disposed at the pit and were allowed to soak into the ground. Burning of the wastes occurred periodically.

6.5.2.2 Release and Transport Mechanisms

Constituent fate and transport, including constituent mobility and persistence, and the potential constituent migration pathways and release mechanisms at the site are discussed in Sections 4 and 5.

6.5.2.3 Exposure Points and Exposure Routes

Exposure points are the locations where humans could contact site-related contamination. Onsite exposure points include soil in the 0- to 6-foot interval (RSY AOC and Waste Oil Pit AOC), soil in the 0- to 12-foot interval (BPA AOC), and groundwater beneath the site. Table 1 in Appendixes F.1 and F.2 describes the exposure pathways that were considered for evaluation and presents the rationale for evaluation of the exposure pathway.

Section 6.1 identifies the potential receptors and exposure pathways. In summary, the current land use exposure routes for quantitative evaluation include the following:

- Trespassers/visitors (adult, youth, and child)—Incidental ingestion of, dermal contact with, and inhalation of volatile and particulate emissions from surface soil (3 AOCs; youth only for RSY and BPA AOCs).

The future land use exposure routes include the current pathways and the following:

- Residents (adult and child)—Incidental ingestion of, dermal contact with, and inhalation of volatile and particulate emissions from surface soil (RSY and BPA AOCs) and total soil (all 3 AOCs) and ingestion of tap water and dermal contact through showering (adult) or bathing (child) and inhalation of volatile constituents in bathroom air.
- Industrial Workers—Ingestion of, dermal contact with, and inhalation of volatile and particulate emissions from surface soil (RSY and BPA AOCs) and total soil (Waste Oil Pit AOC) and ingestion of tap water and dermal contact with tap water while washing hands.

- Construction Workers—Incidental ingestion of, dermal contact with, and inhalation of particulate and volatile emissions from total soil (all 3 AOCs), and dermal contact with and inhalation of volatile emissions from shallow groundwater.

As discussed previously, the 3 AOCs are part of a property that is used as an industrial park. Although land use at the 3 AOCs is not anticipated to change in the future, evaluation of residential land use exposures was included in the HHRA to provide information regarding hypothetical unrestricted land use at the site, and serve as baseline conditions.

6.5.3 Quantification of Exposure

Potential exposure is quantified by estimating the exposure point concentrations (EPCs) of COPCs in environmental media and COPC intake by the receptor.

6.5.3.1 Exposure Concentrations

EPCs are estimated constituent concentrations that a receptor may contact and are specific to each exposure medium. EPCs may be directly measured or estimated using environmental fate and transport models. Constituent concentrations in soil and groundwater were measured for this assessment.

For the RSY and BPA AOCs, fate and transport modeling conducted for the HHRA included estimating fugitive dust and volatile emissions from soil following the methods in USEPA's *RAGS Part B: Development of Risk-based Preliminary Remediation Goals* (USEPA, 1991b).

For the Waste Oil Pit AOC, fate and transport modeling included estimating fugitive dust and volatile emissions from soil following the methods in USEPA's *Soil Screening Guidance: User Guide* (USEPA, 2002b), as listed in Appendix F.2, Tables 4 RME Supplement C-1 and C-2, and Table 4.RME Supplement E. For sitewide groundwater, fate and transport modeling was used to estimate concentrations in shower air and bathroom air by the Andelman model (1990; modified by Schaum et al., 1994) as listed in Appendix F.2, Table 3.3.RME Supplement A, and estimate volatile emissions from groundwater in an open excavation for a construction scenario using a Two-Film Volatilization Model (Appendix F.2, Table 3.3.RME Supplement B).

For the Waste Oil Pit AOC surface soil and total soil and sitewide groundwater, the ProUCL software Version 4.1. (USEPA, 2011b) was used to assess the data distribution and to calculate the 95 percent upper confidence limit (UCL) for each COPC. ProUCL identifies the UCL calculation method based on the data distribution (that is, normal, lognormal, gamma, or nonparametric if the data do not fit any of the distributions). The recommendations outlined in the ProUCL software documentation were followed to select the appropriate UCL for each COPC (USEPA, 2011b). The maximum detected concentration was used as the EPC in cases where the estimated 95 percent UCL was greater than the maximum detected concentration. Appendix F.2, Tables 3.1.RME through Table 3.3.RME, present the EPCs for the COPCs and the rationale for the selected EPCs for the Waste Oil Pit AOC surface soil and total soil, and sitewide groundwater.

At the time the HHRA was prepared for the RSY and BPA AOCs, the ProUCL software was not available. The W-test (Gilbert, 1987) was used to determine the appropriate distribution describing each soil data set. The equation used to calculate the UCL for the lognormal distribution is shown below:

$$UCL = e^{\bar{x} + 0.5s^2 + sH/\sqrt{n-1}} \text{ where:}$$

UCL	=	95 percent upper confidence limit
e	=	constant (base of the natural log, equal to 2.718)
\bar{x}	=	arithmetic mean of transformed data
s	=	standard deviation of the transformed data
H	=	H-statistic (Gilbert, 1987)
n	=	number of samples

The equation used to calculate the UCL for the normal distribution is:

$$UCL = \bar{x} + t(s/\sqrt{n})$$

where:

UCL	=	95 percent upper confidence limit
\bar{x}	=	arithmetic mean of the untransformed data
s	=	standard deviation of the untransformed data
t	=	Student-t statistic (Gilbert, 1987)
n	=	number of samples

The statistical tests used for the RSY and BPA AOCs were parametric procedures intended for use in cases where the percentage of nondetects in a particular data set is less than 50 percent. In the event that the percentage of nondetects for a particular chemical was greater than 50 percent, non-parametric procedures were applied as appropriate. Procedures for evaluating and applying non-parametric statistics are described in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance* (USEPA, 1992b). Appendix F.1, Tables 2 through 5, present the EPCs and rationale for the selected EPCs for the RSY and BPA AOCs surface soil and total soil.

6.5.3.2 Estimation of Constituent Intakes

Intake is the amount of a constituent entering the exposed receptor's body. Intakes of COPCs through contact with exposure media, such as incidental ingestion and dermal contact with soil, are expressed using algorithms provided in USEPA guidance (1989, 2004a). The generalized equation for calculating constituent intakes is as follows:

$$I (\text{mg/kg} - \text{day}) = \frac{C \times CR \times EF \times ED}{BW \times AT}$$

Where:

<i>I</i>	=	intake (milligrams per kilogram per day [mg/kg-day])
<i>C</i>	=	constituent concentration at exposure point (the EPC; mg/L or mg/kg)
<i>CR</i>	=	contact rate, or amount of contaminated medium contacted per unit time or event (L/day or mg/event)
<i>EF</i>	=	exposure frequency (days/year)
<i>ED</i>	=	exposure duration (years)
<i>BW</i>	=	body weight (kg)
<i>AT</i>	=	averaging time, or period over which exposure is averaged (days)

The intake equation requires exposure parameters specific to each exposure pathway. Many of the exposure parameters have default values, which were used for this assessment. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and duration, are provided in USEPA guidance. Appendix F.1, Table 6, identifies the exposure parameters for each scenario evaluated for the RSY and BPA AOCs. Appendix F.1, Tables 7 through 54, identify the intake equations for each of the scenarios evaluated for RSY and BPA AOCs. Appendix F.2, Tables 4.1.RME through 4.8.RME, identify the exposure parameters and intake equations for each scenario evaluated for the Waste Oil Pit AOC and sitewide groundwater. The values used for the exposure parameters were sufficiently conservative so that a reasonable maximum exposure (RME) scenario could be evaluated for site receptors.

The algorithms for estimating intakes of COPCs for individual exposure pathways are provided below.

6.5.3.3 Incidental Ingestion of Soil

The equation to calculate intake from the incidental ingestion of soil can be expressed as:

$$CDI (mg/kg - day) = \frac{CS \times IR_{soil} \times EF \times ED \times CF}{BW \times AT}$$

Where:

<i>CDI</i>	=	chronic daily intake (mg/kg-day)
<i>CS</i>	=	constituent concentration in soil at exposure point (mg/kg)
<i>IR_{soil}</i>	=	ingestion rate of soil (mg/day)
<i>EF</i>	=	exposure frequency (days/year)
<i>ED</i>	=	exposure duration (years)
<i>CF</i>	=	conversion factor (1×10^{-6} kg/mg)
<i>BW</i>	=	body weight (kg)
<i>AT</i>	=	averaging time, or period over which exposure is averaged (days)

6.5.3.4 Dermal Contact with Soil

The dose from dermal contact with soil can be estimated from the following equation:

$$DAD (mg/kg - day) = \frac{DA_{event} \times SA \times EV \times EF \times ED}{BW \times AT}$$

Where:

<i>DAD</i>	=	dermal absorbed dose (mg/kg-day)
<i>DA_{event}</i>	=	dermally absorbed dose per event (mg/cm ² -event)
<i>SA</i>	=	skin surface area available for contact (cm ²)
<i>EV</i>	=	event frequency (events/day)
<i>EF</i>	=	exposure frequency (days/year)
<i>ED</i>	=	exposure duration (years)
<i>BW</i>	=	body weight (kg)
<i>AT</i>	=	averaging time, or period over which exposure is averaged (days)

The dermally absorbed dose per event can be estimated using the following equation:

$$DA_{event} (mg/cm^2 - event) = CS \times CF \times SSAF \times DABS$$

Where:

<i>DA_{event}</i>	=	dermally absorbed dose per event (mg/cm ² -event)
<i>CS</i>	=	constituent concentration in soil at exposure point (mg/kg)
<i>CF</i>	=	conversion factor (1×10^{-6} kg/mg)
<i>SSAF</i>	=	soil to skin adherence factor (unitless)
<i>DABS</i>	=	dermal absorption factor (days/year)

To estimate exposure through dermal contact with soil, two additional parameters are necessary. The first parameter, the dermal absorption fraction (DABS), estimates the amount of a constituent in soil that would be absorbed by the skin. The DABS values used for the RSY and BPA AOCs are presented in Appendix F.1, Table 55. For the Waste Oil Pit AOC, the DABS values are presented in Appendix F.2, Table 4 Supplement D.

The second additional parameter necessary to estimate dermal exposure to constituents in soil is the adherence factor. The adherence factor estimates the amount of soil that adheres to the skin per unit of surface area. For the RSY and BPA AOCs, the adherence factors were obtained from USEPA Dermal Exposure Manual (USEPA, 1998) and are included in the Appendix F.1, Table 6. For the Waste Oil Pit AOC, the

adherence factors were obtained from USEPA RAGS Part E (USEPA, 2004a) and are included in Tables 4.1.RME through 4.8.RME in Appendix F.2.

6.5.3.5 Inhalation of Volatiles and Particulates from Soil

Railroad Salvage Yard and BPA AOCs. Inhalation intakes of volatile COPCs in soils at the RSY and BPA AOCs were estimated using the following equation (USEPA, 1991b):

$$I_s = \frac{C_s \cdot (1/VF) \cdot IR \cdot FI \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_s	=	intake from soil for contaminant (mg/kg-day)
C_s	=	concentration of contaminant in soil (mg/kg)
VF	=	volatilization factor (m^3/kg)
IR	=	inhalation rate (m^3/day)
FI	=	fraction inhaled from contaminated source (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days); for noncarcinogens, AT equals [(ED)(365 days/year)]; for chemical carcinogens, AT equals [(70 years)(365 days/year)]

and where:

$$VF = (Q/C) \times \frac{[3.14 \cdot a \cdot T]^{1/2}}{2 \cdot D_{ei} \cdot K_{as} \cdot \theta_a} \times 10^{-4} \text{ m}^2 / \text{cm}^2$$

and:

$$\alpha = \frac{D_{ei} \cdot \theta_a}{\theta_a + (p_s \cdot 1 - \theta_a) / K_{as}}$$

where:

Q/C	=	inverse of the mean concentration at the center of a 0.5-acre source ($g/m^2\text{-s}$ per kg/m^3)
T	=	exposure interval (7.9×10^8 s)
D_{ei}	=	effective diffusivity (cm^2/s); equal to $[(D_i)(E^{0.33})]$, where D_i is the chemical specific molecular diffusivity (cm^2/s)
θ_a	=	air filled porosity (L_{air}/L_{soil})
D_i	=	diffusivity in air (cm^2/s)
p_s	=	soil or particulate density (2.65 g/cm^3)
E	=	default soil porosity (0.35)(unitless)
K_{as}	=	soil to air partition coefficient ($g \text{ soil/cm}^3 \text{ air}$); equal to $[(\text{chemical specific Henry's law constant (atm}\cdot\text{m}^3/\text{mol}) / K_d (\text{chemical specific soil to water partition coefficient (unitless)}))(41)]$. K_d can be estimated as $K_{oc} [(\text{organic carbon partition coefficient})(OC)\{\text{soil organic carbon content}\}]$ estimated at 0.02.

Specific values for these exposure parameters are listed in Appendix F.1, Table 6.

Inhalation intakes of particulates from soils as a result of outdoor activities by industrial and construction workers, trespassers, and residents were estimated using the following equation.

$$I_s = \frac{C_s \cdot IR \cdot RF \cdot CF \cdot EF \cdot ED}{BW \cdot AT \cdot TCF \cdot PEF}$$

where:

I_s	=	intake from soil from contaminant (mg/kg-day)
C_s	=	concentration of contaminant in soil (mg/kg)
IR	=	inhalation rate (m ³ /day)
RF	=	respirable fraction (unitless)
CF	=	conversion factor (10 ⁻⁶ kg/mg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days); for non-carcinogens AT equals [(ED)(365 days/year)]; for chemical carcinogens, AT equals [(70 years)(365 days/year)]
TCF	=	time conversion factor (days/year)
PEF	=	particulate emission factor (m ³ /kg) [4.63x10 ⁹ (USEPA, 1991b)]

Specific values for these parameters are listed in Appendix F.1, Table 6.

Waste Oil Pit AOC. The methods presented in USEPA's RAGS, Part F (USEPA, 2009a), were used to estimate inhalation exposures for the Waste Oil Pit AOC. The intakes associated with inhalation of constituents in air involves five steps as described in the following equations:

1. Calculation of Inhalation Exposure Concentration

$$EC = \frac{CA \times ET \times EF \times ED}{AT}$$

Where:

EC	=	exposure concentration in air (milligrams per cubic meter [mg/m ³])
CA	=	constituent concentration in air (mg/m ³)
ET	=	exposure time (hrs/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AT	=	averaging time, or period over which exposure is averaged (years × 365 days/year × 24 hours/day)

2. Calculation of Constituent Concentration in Air

$$CA = CS \times \left(\frac{1}{PEF} + \frac{1}{VF} \right)$$

Where:

CA	=	constituent concentration in air (mg/m ³)
CS	=	constituent concentration in soil (mg/kg)
PEF	=	particulate emission factor (m ³ /kg)

VF = volatilization factor (m^3/kg)

3. Calculation of Particulate Emission Factor for Trespassers, Residents, and Industrial Workers

$$PEF = \frac{Q}{C} \times \frac{3600}{0.036 \times (1-V) \times \left(\frac{U_m}{U_t}\right)^3 \times F_x}$$

Where:

PEF = particulate emission factor (m^3/kg)
 Q/C = inverse of the mean concentration at center of square source (g/m^2-s per kg/m^3) (85.63178)
 V = fraction of vegetative cover (unitless) (0.5)
 U_m = mean annual wind speed (m/s) (4.33)
 U_t = equivalent threshold value of wind speed at 7 meters (m/s) (11.32)
 F_x = function dependent on U_m/U_t (unitless)

This PEF value was calculated using Equation 4-5 and Exhibit D-2 from the *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002b) assuming values for 0.5-acre source area exposed and the Cleveland, Ohio, climatic zone.

4. Calculation of Particulate Emission Factor for Construction Workers

$$PEF_{SC} = \frac{Q}{C_{Sr}} \times \frac{1}{F_D} \times \frac{T \times A_R}{556 \times \left(\frac{W}{3}\right)^{0.4} \times \left(\frac{365 \text{ d/yr} - p}{365 \text{ d/yr}}\right) \times \sum VKT}$$

Where:

PEF = particulate emission factor (m^3/kg)
 Q/C_{Sr} = inverse of the mean concentration at center of square source (g/m^2-s per kg/m^3) (23.01785)
 F_D = Dispersion Correction Factor (unitless)(0.188)
 T = Total time over which construction occurs (seconds)(7,200,000)
 A_R = Areal extent of site contamination (acres)(0.5)
 W = Mean weight of vehicle (tons)(14)
 p = number of days with at least 0.01 inches of precipitation (days/yr)(140)
 VKT = sum of fleet vehicle kilometers traveled during the exposure duration (km)(33.7)

A PEF value was calculated to reflect construction activities. This PEF value was calculated using Equations-5-5 and 5-6 of the aforementioned USEPA document (USEPA, 2002b). It was assumed that the daily unpaved road traffic consists of three vehicles (one 2-ton car and two 20-ton trucks) generating particulates in the vicinity of construction workers.

5. Calculation of Volatilization Factor

$$VF = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{1/2} \times 10^{-4} \left(\frac{m^2}{cm^2}\right)}{2 \times \rho_b \times D_A}$$

Where:

VF = volatilization factor (m^3/kg)
 Q/C = inverse of the mean concentration at center of square source (g/m^2-s per kg/m^3) (68.18)
 D_A = apparent diffusivity (cm^2/s)
 T = exposure interval (s) (9.5×10^8)

ρ_b = dry soil bulk density (g/cm³) (1.5)

6. Calculation of Apparent Diffusivity

$$D_A = \frac{\left(\left(\theta_a^{10/3} \times D_i \times H' \right) + \left(\theta_w^{10/3} \times D_w \right) \right)}{\rho_b K_d + \theta_w + \theta_a H'} \times n^2$$

Where:

D_A = apparent diffusivity (cm²/s)
 θ_a = air-filled soil porosity (L_{air}/L_{soil}) ($n - \theta_w$)
 θ_w = water-filled soil porosity (L_{water}/L_{soil}) (0.15)
 n = total soil porosity (L_{pore}/L_{soil}) (0.43)
 D_i = diffusivity in air (cm²/s; chemical-specific)
 D_w = diffusivity in water (cm²/s; chemical-specific)
 H' = Henry's Law Constant (dimensionless; chemical-specific)
 ρ_b = dry soil bulk density (g/cm³) (1.5)
 ρ_s = soil particle density (g/cm³) (2.65)
 K_d = soil to water partition coefficient (cm³/g) ($K_{oc} \times f_{oc}$)
 K_{oc} = soil organic carbon partition coefficient (cm³/g; chemical-specific)
 f_{oc} = fraction organic carbon in soil (g/g) (0.006)

Note that the chemical-specific volatilization factor (VF) for soil is considered applicable only for soil COPCs that are volatile (with a Henry's Law Constant of 1×10^{-5} atm·m³/mole or greater and with a molecular weight of less than 200 grams per mole). Appendix F.2, Table 4.RME Supplement E, provides chemical-specific VFs and their associated input parameters for soil COPCs.

6.5.3.6 Ingestion of Groundwater

The methods presented in USEPA's RAGS, Part A (USEPA, 1989) were used to evaluate ingestion exposure to groundwater for residents and industrial workers.

The dose from ingestion of groundwater (tap water) can be estimated from the following equations:

$$CDI = \frac{CW \times IR_w \times EF \times ED \times CF_1}{BW \times AT}$$

Where:

CDI = chronic daily intake (mg/kg-day)
 IR_w = ingestion rate of water (L/day)
 EF = exposure frequency (days/year)
 ED = exposure duration (years)
 CF_1 = conversion factor (mg/ μ g)
 BW = body weight (kg)
 AT = averaging time, or period over which exposure is averaged (days)

Inhalation of Shower and Bathroom Air. The methods presented in USEPA's RAGS, Part F (USEPA, 2009a) were used to estimate inhalation exposures to shower and bathroom air from 3 AOCs groundwater.

1. Calculation of Inhalation Intake Factor

$$EC = \frac{CA \times ET \times EF \times ED}{AT}$$

Where:

<i>EC</i>	=	exposure concentration in air (milligrams per cubic meter [mg/m ³])
<i>CA</i>	=	constituent concentration in air (mg/m ³)
<i>ET</i>	=	exposure time (hrs/day)
<i>EF</i>	=	exposure frequency (days/year)
<i>ED</i>	=	exposure duration (years)
<i>AT</i>	=	averaging time, or period over which exposure is averaged (years × 365 days/year × 24 hours/day)

2. Calculation of Constituent Concentration in Air. Shower and bathroom air concentrations were calculated using the following equations from the Andelman model (1990; modified by Schaum et al., 1994).

$$C_a = \frac{\left(\frac{C_{a \max}}{2} \times t_1 + C_{a \max} \times t_2 \right)}{t_1 + t_2}$$

$$C_{a \max} = \frac{C_w \times f \times F_w \times t_1}{V_a}$$

Where:

<i>CA</i>	=	concentration of chemical in air (mg/m ³)
<i>CA_{Max}</i>	=	maximum concentration of chemical in air (mg/m ³)
<i>t₁</i>	=	time in shower (hr)
<i>t₂</i>	=	time in bathroom after shower (hr)
<i>f</i>	=	fraction volatilized for chemical
<i>F_w</i>	=	shower water flow rate (L/hr)
<i>V_a</i>	=	bathroom volume (m ³)

6.5.3.7 Dermal Contact with Groundwater

The methods presented in USEPA's RAGS, Part E (USEPA, 2004a), were used to evaluate dermal exposure to groundwater for resident, industrial worker, and construction worker receptors.

The dose from dermal contact with groundwater can be estimated from the following equations:

$$DAD = \frac{DA_{event} \times SA \times EV \times EF \times ED}{BW \times AT}$$

Where:

<i>DAD</i>	=	dermal absorbed dose (mg/kg-day)
<i>DA_{event}</i>	=	dermally absorbed dose per event (mg/cm ² -event)
<i>SA</i>	=	skin surface area available for contact (cm ²)
<i>EV</i>	=	event frequency (events/year)
<i>EF</i>	=	exposure frequency (days/year)
<i>ED</i>	=	exposure duration (years)
<i>BW</i>	=	body weight (kg)
<i>AT</i>	=	averaging time, or period over which exposure is averaged (days)

1. DA_{event} for Metals:

$$DA_{event} = CW \times K_p \times t_{event} \times 0.001 \frac{mg}{\mu g} \times 0.001 \frac{L}{cm^3}$$

Where:

DA_{event}	=	dermally absorbed dose per event (mg/cm ² -event)
CW	=	constituent concentration in groundwater (μg/L)
K_p	=	permeability coefficient (cm/hr; chemical-specific)
t_{event}	=	event duration (hr/event)

2. DA_{event} for Organics:For $t_{event} \leq t^*$:

$$DA_{event} = 2 \times FA \times CW \times K_p \sqrt{\frac{6 \tau_{event} \times t_{event}}{\pi}}$$

Where:

DA_{event}	=	dermally absorbed dose per event (mg/cm ² -event)
CW	=	constituent concentration in groundwater (μg/L)
FA	=	fraction absorbed water (dimensionless; chemical-specific)
K_p	=	permeability coefficient (cm/hr; chemical-specific)
τ_{event}	=	lag time per event (hr/event; chemical-specific)
t_{event}	=	event duration (hr/event)

For $t_{event} > t^*$:

$$DA_{event} = FA \times CW \times K_p \left[\frac{t_{event}}{1+B} + 2 \tau_{event} \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

Where:

DA_{event}	=	dermally absorbed dose per event (mg/cm ² -event)
CW	=	constituent concentration in groundwater (μg/L)
FA	=	fraction absorbed water (dimensionless; chemical-specific)
K_p	=	permeability coefficient (cm/hr; chemical-specific)
B	=	ratio of permeability coefficient of compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless; chemical-specific)
τ_{event}	=	lag time per event (hr/event; chemical-specific)
t_{event}	=	event duration (hr/event)

The models used to estimate potential dermal exposures to groundwater are shown in Tables 4.5.RME and 4.6.RME in Appendix F.2. Values for the chemical-specific parameters used in the models were obtained from USEPA's RAGS Part E (USEPA, 2004a) and are presented in Table 7.4.RME Supplement A, 7.7.RME Supplement A, and 7.8.RME Supplement A in Appendix F.2.

6.5.3.8 Approach for Potential Mutagenic Effects

COPCs with a mutagenic mode of action (MMOA) require separate exposure evaluations for age ranges 0 to less than 2, 2 to less than 16, and 16 and older (USEPA, 2005) due to toxicity adjustments required for these age ranges. The age-group-specific exposure factors are provided in Appendix F.2, Table 4.1.RME Supplement A through Table 4.8.RME Supplement A and Table 4 RME Supplement B. Since age-specific

toxicity factors (exposure from birth and exposure through adulthood) are available for vinyl chloride, the exposure factors for two specific age groups (0 to less than 6 years and 6 to less than 30 years) were used in the calculation of ELCR estimates for vinyl chloride. Guidance for evaluation of COPCs with MMOA was not available at the time the HHRA for the RSY and BPA AOCs was prepared. Therefore, the MMOA exposure evaluation was not conducted for these two AOCs.

6.6 Toxicity Assessment

The toxicity assessment describes the relationship between the magnitude of exposure to a constituent and possible severity of adverse effects, and weighs the quality of available toxicological evidence. This assessment provides, where possible, a numerical estimate of the increased likelihood and/or severity of adverse effects associated with constituent exposure (USEPA, 1989). The toxicity assessment identifies the toxicity values for the COPCs used to estimate potential health effects. Health effects are divided into two broad groups: noncarcinogenic and carcinogenic. This division of classification is used because health risks are calculated quite differently for carcinogenic and noncarcinogenic effects, and separate toxicity values are often available for carcinogenic and noncarcinogenic effects of a specific COPC.

For the RSY and BPA AOCs, slope factors were obtained from the Integrated Risk Information System (IRIS) (USEPA, 2004c), an online database, and Health Effects Assessment Summary Tables (HEAST; USEPA, 1997b), a compilation of non-verified toxicity data, as well as other USEPA sources. One exception is PAH toxicity where the relative potency factor approach (USEPA, 1993) was used for oral exposures. RfDs were also obtained from IRIS (USEPA, 2004c) and HEAST (USEPA, 1997b). Carcinogenic and noncarcinogenic toxicity values used in the RSY and BPA AOCs are provided in Appendix F.1, Table 56.

For the Waste Oil Pit AOC and sitewide groundwater, toxicity values used in the HHRA are based on the USEPA recommendation that a tiered approach be used to obtain the toxicity values (that is, the RfDs and cancer slope factors [CSFs]), used to calculate noncarcinogenic and carcinogenic risks (USEPA, 2003a). The hierarchy of toxicity value sources is as follows:

- Tier 1: USEPA's IRIS database (USEPA, 2011c)
- Tier 2: Provisional Peer Reviewed Toxicity Value (PPRTV) database maintained by the USEPA's National Center for Environmental Assessment and the Superfund Health Risk Technical Support Center
- Tier 3: Other USEPA and non-USEPA sources including National Center for Environmental Assessment (USEPA, 2001c); Agency for Toxic Substances and Disease Registry, HEAST (USEPA, 1997b); California Environmental Protection Agency Toxicity Criteria Database (2011); USEPA's Office of Water, World Health Organization, Environmental Criteria and Assessment Office, New Jersey Department of Environmental Protection Chromium Workgroup (2009), and the New York State Department of Health

The use of provisional toxicity values, such as those from the PPRTV database, increases the uncertainty in the quantitative risk estimates.

Carcinogenic and noncarcinogenic toxicity values used to evaluate the Waste Oil Pit AOC and the sitewide groundwater are provided in Appendix F.2, Tables 5.1, 5.2, 6.1, and 6.2.

6.6.1 Toxicity Information for Noncarcinogenic Effects

Noncarcinogenic effects are quantified by comparing intake or exposure to either RfDs or reference concentrations (RfCs). The RfD is a health-based dose, expressed as constituent intake rate in units of mg/kg-day, used in evaluating noncarcinogenic effects. The RfD is based on the assumption that thresholds exist for certain toxic effects such as liver or kidney damage, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure (USEPA, 1989). The oral RfD

is used to estimate adverse effects from the oral route of exposure. The RfC is used to estimate adverse effects from inhalation exposure.

Chronic RfDs and RfCs are developed to evaluate potential toxicity for long-term exposure (more than 7 years of exposure). Subchronic RfDs and RfCs are used to evaluate exposure durations ranging from 2 weeks to 7 years for adults (for example, construction workers) exposure durations. Subchronic values are less available than chronic toxicity values. Sometimes in toxicity sources, like IRIS (USEPA, 2011c), chronic value estimates are from subchronic data. If the original data were multiplied by an uncertainty factor of 10 to account for the transformation from a subchronic value to a chronic value, then the chronic value can be divided by 10 to obtain a subchronic value. In the absence of an acceptable subchronic toxicity value, chronic values were used conservatively in the HHRA to evaluate subchronic exposures.

6.6.2 Toxicity Information for Carcinogenic Effects

Potential carcinogenic effects are quantified using oral CSFs and inhalation unit risk factors. The CSF is defined as a plausible upper-bound estimate of the probability of a cancer effect per unit intake of a constituent over a lifetime (USEPA, 1989). CSFs and unit risk factors may be derived from the results of chronic animal bioassays, human epidemiological studies, or both. For carcinogens, risks are estimated as the probability that an individual will develop cancer over a lifetime because of exposure to the carcinogen. Cancer risk from exposure to contamination represents the anticipated excess or incremental cancer risk, which is cancer occurrence in addition to normally expected rates of cancer development over the average adult lifetime of 70 years.

6.6.3 Estimated Toxicity Values for Dermal Exposure

Toxicity values have not been developed for the dermal absorption pathway. In general, the oral CSFs and oral RfDs are expressed as administered doses (that is, the amount of a constituent administered per unit time and weight). Conversely, exposures resulting from the dermal pathway are expressed as absorbed doses. Therefore, it is necessary to adjust the oral toxicity value to account for the chemical-specific absorption efficiency. Dermal RfDs and CSFs were estimated from oral toxicity values using chemical-specific gastrointestinal absorption factors (ABS_{GI}) to calculate total absorbed dose, as described in USEPA dermal risk assessment guidance (USEPA, 2004a) using the equations shown below.

The dermal reference dose (RfD_d) is derived by multiplying the oral RfD by the ABS_{GI} :

$$RfD_d = RfD_o \times ABS_{GI}$$

Where:

RfD_d	=	Dermal reference dose (mg/kg-day)
RfD_o	=	Oral reference dose (mg/kg-day)
ABS_{GI}	=	Fraction of constituent absorbed in the gastrointestinal tract (unitless)

The dermal CSF (CSF_d) is derived by dividing the oral CSF by the ABS_{GI} :

$$CSF_d = \frac{CSF_o}{ABS_{GI}}$$

Where:

CSF_d	=	Dermal cancer slope factor (mg/kg-day) ⁻¹
CSF_o	=	Oral cancer slope factor (mg/kg-day) ⁻¹
ABS_{GI}	=	Fraction of constituent absorbed in the gastrointestinal tract (unitless)

The ABS_{GI} values used for the RSY and BPA AOCs HHRA are provided in Appendix F.1, Table 57. The ABS_{GI} values used in the Waste Oil Pit AOC and the sitewide groundwater HHRA were obtained from USEPA's

RAGS, *Volume I: Human Health Evaluation Manual, Part E* (USEPA, 2004a). When chemical-specific ABS_{GI} values are unavailable, a default ABS_{GI} value of 1 for organic and inorganic chemicals (USEPA, 2004a) was used. The dermal RfDs are included in Appendix F.2, Table 5.1. The dermal CSFs are presented in Appendix F.2, Table 6.1.

6.6.4 Constituents without Available USEPA Toxicity Values

Some COPCs at the site do not have RfDs or CSFs because the noncarcinogenic and/or carcinogenic effects of these constituents are not yet determined. In these cases, toxicity values from a constituent with similar toxicological properties and approved toxicity values may be used as a surrogate. Surrogates were selected based on previous recommendations from USEPA on other projects. The surrogates used in the Waste Oil Pit AOC and the sitewide groundwater HHRA are identified in Appendix F.2, Tables 2.1 through 2.3.

Potential exposures to carcinogenic PAHs were evaluated using the relative potency approach for oral exposures (USEPA, 1993). The toxicity of benzo(a)pyrene was used as a surrogate for other carcinogenic PAHs, and the CSF of benzo(a)pyrene was scaled using factors of 1, 0.1, 0.01, and 0.001 to estimate CSFs for other carcinogenic PAHs.

Lead, which was retained as a COPC for groundwater, does not have published toxicity factors. Lead is assessed based on blood-lead uptake using physiologically based pharmacokinetic models called the IEUBK Model and the Adult Lead Methodology. As a screening tool, lead was screened using 400 mg/kg in soil for trespassing and residential scenarios, and screening using 800 mg/kg for worker scenarios. Lead concentrations in groundwater were screened using the Federal Action Level (15 $\mu\text{g}/\text{L}$). Potential exposures to lead were quantitatively evaluated based on blood-lead uptake modeling using USEPA tools and guidance (USEPA, 1994, 2003b, 2009c, 2010b) that recommends evaluating average soil lead concentration across the exposure area. Lead was identified as a COPC in both surface soil and total soil for the RSY AOC and BPA AOC, and in sitewide groundwater. Results of the lead evaluation for each area are summarized below and the lead models are presented in Appendix H. For lead, if the exposure model (either adult lead model [ALM] or IEUBK model) predicted more than 5 percent of the exposed population exceeding a blood lead level (BLL) of 10 micrograms per deciliter ($\mu\text{g}/\text{dL}$), lead was identified as a preliminary OC for that potential receptor/exposure area combination.

6.6.4.1 Railroad Salvage Yard AOC

Based on the average lead concentration (119.7 mg/kg) in surface soil (0 to 2 feet), the ALM predicts that up to 1.6 percent of the adult worker population will have BLLs exceeding 10 $\mu\text{g}/\text{dL}$ (Table 1 of Appendix H), which is below the target level. Therefore, lead was not identified as a preliminary COC in surface soil for adult workers.

Based on the average lead concentration (69.9 mg/kg) in subsurface soil (0 to 5 feet), the ALM predicts that 1.4 percent of the future indoor/outdoor worker population will have BLLs exceeding 10 $\mu\text{g}/\text{dL}$ (Table 2 of Appendix H), which is below the target level. Therefore, lead was not identified as a preliminary COC in surface soil for future indoor/outdoor workers.

6.6.4.2 Burn Pit Area AOC

Based on the average lead concentration (737.7 mg/kg) in surface soil (0 to 2 feet), the ALM predicts that 4.7 percent of the future indoor/outdoor worker population will have BLLs exceeding 10 $\mu\text{g}/\text{dL}$ (Table 3 of Appendix H), which is below the target level. Therefore, lead was not identified as a preliminary COC in surface soil for future indoor/outdoor workers.

Based on the average lead concentration (501.5 mg/kg) in subsurface soil (0 to 12 feet), the ALM predicts that 3.4 percent of the future indoor/outdoor worker population will have BLLs exceeding 10 $\mu\text{g}/\text{dL}$ (Table 4 of Appendix H), which is below the target level. Therefore, lead was not identified as a preliminary COC in surface soil for future indoor/outdoor workers.

The average lead concentrations in surface soil (737.7 mg/kg) and total soil (501.5 mg/kg) exceed the residential screening level of 400 mg/kg. Therefore, lead was identified as a preliminary COC in surface soil for future residents.

6.6.4.3 Sitewide Groundwater

For the sitewide groundwater, based on the average detected lead concentration in groundwater (13.25 µg/L) and the average total soil concentration (275.25 mg/kg) for all 3 AOCs, the IEUBK model predicts that 2.787 percent of the future child resident population will have BLLs exceeding 10 µg/dL (Table 5 of Appendix H), which is below the target level. Therefore, lead was not identified as a preliminary COC for future child residents.

6.7 Risk Characterization

Risk characterization combines the results of the previous elements of the HHRA to evaluate the potential health risks associated with exposure to the COPCs.

6.7.1 Noncarcinogenic and Carcinogenic Risk Estimation Methods

Potential human health risks are discussed independently for carcinogenic and noncarcinogenic constituents because of the different toxicological endpoints, relevant exposure duration, and methods used to characterize risk. Some constituents may produce both noncarcinogenic and carcinogenic effects, and were evaluated in both groups. The methodology used to estimate noncarcinogenic hazards and carcinogenic risks are described below. Following the description of the methodology, the noncarcinogenic hazards and carcinogenic risks for the site are discussed.

6.7.1.1 Noncarcinogenic Hazard Estimation

Noncarcinogenic health risks are estimated by comparing the calculated intake or exposure concentration to the RfD or RfC, respectively. The calculated intake or exposure concentration divided by the RfD or RfC, respectively, is equal to the hazard quotient (HQ):

$$HQ = \text{Intake} / \text{RfD}$$

or

$$HQ = \text{Exposure Concentration} / \text{RfC}$$

The intake or exposure concentration and RfD or RfC represent the same exposure period (that is, chronic or subchronic) and the same exposure route (that is, oral intakes are divided by oral RfDs while inhalation exposure concentrations are divided by RfCs). An HQ that exceeds 1 (that is, the intake or exposure concentration exceeds the RfD or RfC, respectively) indicates there is a potential for adverse health effects associated with exposure to that COPC.

To assess the potential for noncarcinogenic health effects posed by exposure to multiple COPCs, a hazard index (HI) approach is used (USEPA, 1989). This approach assumes that noncarcinogenic hazards associated with exposure to more than one COPC are additive. Synergistic or antagonistic interactions between COPCs are not considered. The HI may exceed 1 even if all of the individual HQs are less than 1. HIs also are added across exposure routes and media to estimate the total noncarcinogenic health effects to a receptor posed by exposure through multiple routes and media. An HI greater than 1 indicates there is some potential for adverse noncarcinogenic health effects associated with exposure to the COPCs. However, if the HI is greater than 1, the HI is evaluated by target organ/critical effect, to determine if the HI for a specific target organ/effect is greater than 1. If the HI for each target organ/effect is 1 or less, it can be assumed that there are no human health risks above USEPA's target level. Consistent with USEPA guidance (USEPA, 1991a,b), estimated HIs are presented with one significant figure for comparison with the target HI (1), and the HHRA conclusions are based on comparison of these two values.

6.7.1.2 Carcinogenic Risk Estimation

The potential for carcinogenic effects due to exposure to COPCs is evaluated by estimating the ELCR. ELCR is the excess incremental increase in the probability of developing cancer during a lifetime because of the assumed exposures to the site over the baseline risk without exposure to the site.

ELCR is calculated by multiplying the intake or exposure concentration by the CSF or inhalation unit risk (IUR), respectively.

$$ELCR = Intake \times CSF$$

or

$$ELCR = Exposure\ Concentration \times IUR$$

The combined risk from exposure to multiple COPCs was evaluated by adding the risks from individual COPCs. Risks also were added across the exposure routes and media if a receptor group would be exposed through multiple routes and to multiple media.

For COPCs with a MMOA, the ELCR was calculated using age-dependent adjustment factors (USEPA, 2005) for each applicable COPC/receptor/exposure pathway combination using one of the equations below (USEPA, 1989, 2004a, 2011a):

For oral exposures:

$$ELCR = (10 \times CDI_{0-2\text{yrs}} + 3 \times CDI_{2-6\text{yrs}} + 3 \times CDI_{6-16\text{yrs}} + CDI_{16-30\text{yrs}}) \times CSF_{oral}$$

For inhalation exposures:

$$ELCR = (10 \times EC_{0-2\text{yrs}} + 3 \times EC_{2-6\text{yrs}} + 3 \times EC_{6-16\text{yrs}} + EC_{16-30\text{yrs}}) \times IUR$$

For dermal exposures:

$$ELCR = (10 \times DAD_{0-2\text{yrs}} + 3 \times DAD_{2-6\text{yrs}} + 3 \times DAD_{6-16\text{yrs}} + DAD_{16-30\text{yrs}}) \times CSF_{dermal}$$

Where:

CDI(i-jyrs)	=	Chronic daily intake (mg/kg-d) from i to j yrs;
DAD(i-jyrs)	=	Dermal absorbed dose (mg/kg-d) from i to j yrs;
EC(i-jyrs)	=	Inhalation exposure concentration (mg/m ³) from i to j yrs;
CSF _{oral}	=	Oral cancer slope factor (mg/kg-d) ⁻¹ ;
IUR	=	Inhalation unit risk (mg/m ³) ⁻¹ ;
CSF _{dermal}	=	Dermal cancer slope factor (mg/kg-d) ⁻¹

Among various COPCs identified at the site, vinyl chloride is the only COPC that is categorized by USEPA as having an MMOA and age-specific toxicity factors have been established for two exposure scenarios (exposure from birth and exposure through adulthood). In accordance with the approach used in the calculation of RSLs for vinyl chloride, the following equations were used to estimate ELCR for vinyl chloride.

$$ELCR = CDI_{0-6\text{yrs}} \times CSF_{from\ birth} + CDI_{6-30\text{yrs}} \times CSF_{adulthood}$$

or

$$ELCR = EC_{0-6\text{yrs}} \times IUR_{from\ birth} + EC_{6-30\text{yrs}} \times IUR_{adulthood}$$

where:

$CSF_{\text{from birth}}$ = cancer slope factor (exposure from birth)

$CSF_{\text{adulthood}}$ = cancer slope factor (exposure through adulthood)

$IUR_{\text{from birth}}$ = inhalation unit risk (exposure from birth)

$IUR_{\text{adulthood}}$ = inhalation unit risk (exposure through adulthood)

The calculations of ELCR for vinyl chloride are presented in Table 7.6 RME Supplement A of Appendix F.2 for future residential soil and groundwater use scenarios.

USEPA Superfund guidance generally considers the site ELCR target range to be within 1 to 100 in a million (1×10^{-6} to 1×10^{-4}) (USEPA, 1991). When a cumulative ELCR to a receptor group under the assumed exposure conditions at the site exceeds 100 in a million (that is, 10^{-4} ELCR), CERCLA generally requires remedial action to reduce risks at the site (USEPA, 1991b). If the cumulative risk is 10^{-4} or less, action generally is not required, but may be warranted if a risk-based chemical-specific standard (for example, Maximum Contaminant Level) is exceeded. Therefore, the total estimated ELCR for each area receptor group was compared to the target ELCR range of 1×10^{-6} to 1×10^{-4} . Consistent with USEPA guidance (USEPA, 1991a,b), estimated ELCRs are presented with one significant figure for comparison with USEPA's target range (1×10^{-6} to 1×10^{-4}), and the HHRA conclusions are based on comparison of these two values.

6.7.2 HHRA Results

6.7.2.1 Railroad Salvage Yard AOC

The results of the risk characterization for the RSY AOC surface soil and total soil are presented below by receptor and compared to USEPA's target ELCR range of 1×10^{-6} to 1×10^{-4} and target HI of 1 per target organ. It should be noted that noncarcinogenic hazards were summed across all COPCs in the 2006 HHRA rather than evaluating HIs on a target organ-specific basis. The risk estimates are provided in Appendix F.1, Tables 7 through 30. A summary of the risk drivers for each receptor is presented in Table 6-2.

Adult Residents. At 2×10^{-5} , the ELCR estimate for adult residents exposed to surface soil is within USEPA's target risk range. ELCR is primarily driven by arsenic through ingestion (1×10^{-5}) and dermal absorption (2×10^{-6}). The noncarcinogenic hazard (0.6) for exposures to surface soil is less than USEPA's target HI.

At 1×10^{-5} , the ELCR estimate for adult residents exposed to total soil is within USEPA's target risk range. The noncarcinogenic hazard (0.4) for exposures to surface soil is less than USEPA's target HI.

Child Residents. At 4×10^{-5} , the ELCR estimate for child residents exposed to surface soil is within USEPA's target risk range. ELCR is primarily driven by arsenic through ingestion (3×10^{-5}) and dermal absorption (3×10^{-6}). The maximum target organ-specific HI (2) for exposures to surface soil exceeds USEPA's target HI, primarily due to manganese through ingestion).

At 3×10^{-5} , the ELCR estimate for child residents exposed to total soil is within USEPA's target risk range. ELCR is primarily driven by arsenic through ingestion (3×10^{-5}) and dermal absorption (2×10^{-6}). The maximum target organ-specific HI for total soil does not exceed USEPA's target HI.

Trespassers. The ELCR estimate (4×10^{-7}) for trespassers exposed to surface soil is less than USEPA's target risk range. The cumulative noncarcinogenic hazard (0.05) for exposures to surface soil is less than USEPA's target HI.

Construction Workers. At 2×10^{-6} , the ELCR estimate for construction workers exposed to total soil is within USEPA's target risk range. The total noncarcinogenic hazard (1) for exposures to total soil is equal to USEPA's target HI. No individual chemical HQ exceeds 1.

Industrial Workers. At 6×10^{-6} , the ELCR estimate for industrial workers exposed to surface soil is within USEPA's target risk level. The total noncarcinogenic hazard (0.2) for exposures to surface soil is less than USEPA's target HI.

Exposure to Soil Lead. The representative concentrations of lead in surface soil (120 mg/kg) and total soil (16 mg/kg) are less than the residential screening level of 400 mg/kg and the industrial screening level of 1,414 mg/kg, indicating that the soil lead concentrations are associated with acceptable blood lead levels, relative to USEPA's risk goals.

6.7.2.2 Burn Pit Area AOC Soil

The results of the risk characterization for the BPA AOC surface soil and total soil are presented below by receptor and compared to USEPA's target risk range and target HI. It should be noted that noncarcinogenic hazards were summed in the 2006 HHRA rather than evaluating on a target organ/system basis. The risk estimates are provided in Appendix F.1, Tables 31 through 54. A summary of the risk drivers for each receptor is presented in Table 6-3.

Adult Residents. At 2×10^{-5} , the ELCR estimate for adult residents exposed to surface soil is within USEPA's target risk range. ELCR is primarily driven by arsenic through ingestion (1×10^{-5}) and dermal absorption (2×10^{-6}). The noncarcinogenic hazard (0.5) for exposures to surface soil is less than USEPA's target HI.

At 1×10^{-5} , the ELCR estimate for adult residents exposed to total soil is within USEPA's target risk range. The noncarcinogenic hazard (0.4) for exposures to total soil is less than USEPA's target HI.

Child Residents. At 3×10^{-5} , the ELCR estimate for child residents exposed to surface soil is within USEPA's target risk range. ELCR is primarily driven by arsenic and benzo(a)pyrene through ingestion (3×10^{-5} and 3×10^{-6} , respectively) and dermal absorption (2×10^{-6} and 1×10^{-6} , respectively). The maximum target organ-specific HI for exposures to surface soil does not exceed USEPA's target HI.

At 3×10^{-5} , the ELCR estimate for child residents exposed to total soil is within USEPA's target risk range. ELCR is primarily driven by arsenic through ingestion (2×10^{-5}) and dermal absorption (2×10^{-6}). The maximum target organ-specific HI for exposures to total soil does not exceed USEPA's target HI.

Trespassers. The ELCR estimate (3×10^{-7}) for trespassers exposed to surface soil is less than USEPA's target risk range. The total noncarcinogenic hazard (0.04) for exposures to surface soil is less than USEPA's target HI.

Construction Workers. At 2×10^{-6} , the ELCR estimate for construction workers exposed to total soil is within USEPA's target risk range. The total noncarcinogenic HI is 1, equal to USEPA's target HI.

Industrial Workers. At 6×10^{-6} , the ELCR estimate for industrial workers exposed to surface soil is within USEPA's target risk range. The total noncarcinogenic hazard (0.2) for exposures to surface soil is less than USEPA's target HI.

Exposure to Soil Lead. The representative concentration of lead in surface soil is 1,100 mg/kg, which is greater than the residential screening level of 400 mg/kg but below the industrial screening level of 1,414 mg/kg, indicating that the soil lead concentrations may be associated with blood lead levels above USEPA target risk levels for a residential scenario. The representative concentration of lead in total soil is 23 mg/kg, which is less than the residential and industrial screening levels.

6.7.2.3 Waste Oil Pit AOC and Sitewide Groundwater

The results of the risk characterization for the Waste Oil Pit AOC and sitewide groundwater are presented below by receptor and compared to USEPA's target risk range and target HI. The risk estimates for detected COPCs are provided in Appendix F.2, Tables 7.1.RME through 7.8.RME and are summarized in Appendix F.2, Tables 9.1.RME through 9.8.RME. Tables 10.1.RME through 10.6.RME provide the receptor scenarios with a total target organ HI greater than 1 and/or ELCRs greater than 1×10^{-4} . For receptors with risk estimates exceeding USEPA's targets, the COPCs contributing HIs greater than 0.1 for that target organ or ELCRs greater than 1×10^{-6} are included in the tables. A summary of the risk contributions for each receptor is presented in Table 6-4.

Current/Future Adult Trespassers/Site Visitors. The HHRA assumed that current/future adult trespassers/visitors could be exposed to surface soil through incidental ingestion and dermal contact and to

particulate and volatile emissions from surface soil through inhalation. Table 9.1.RME, Appendix F.2 summarizes the hazard and ELCR estimates to the current/future adult trespassers/visitors from exposures to detected COPCs. The noncarcinogenic hazard (0.07) is less than USEPA's target HI. The ELCR estimate (2×10^{-6}) is within USEPA's target risk range.

Current/Future Youth Trespassers/Site Visitors. The HHRA assumed that current/future youth trespassers/visitors could be exposed to surface soil through incidental ingestion and dermal contact and to particulate and volatile emissions from surface soil through inhalation. Table 9.2.RME, Appendix F.2, summarizes the hazard and ELCR to current/future youth trespassers/visitors from exposures to detected COPCs. The noncarcinogenic hazard (0.2) is less than USEPA's target HI and the ELCR (8×10^{-6}) is within USEPA's target risk range.

Current/Future Child Trespassers/Site Visitors. The HHRA assumed that current/future child trespassers/visitors could be exposed to surface soil through incidental ingestion and dermal contact and to particulate and volatile emissions from surface soil through inhalation. Table 9.3.RME, Appendix F.2, summarizes the hazard and ELCR to current/future youth trespassers/visitors from exposures to detected COPCs. The noncarcinogenic hazard (0.4) is less than USEPA's target HI. The ELCR (3×10^{-5}) is within USEPA's target risk range. ELCR is driven primarily by arsenic, chromium, benzo(a)pyrene, and benzo(b)fluoranthene.

Future Adult Residents (Noncarcinogenic Hazard). The HHRA assumed that future adult residents could be exposed to total soil through incidental ingestion and dermal contact and to particulate and volatile emissions from total soil through inhalation and exposure to groundwater through ingestion of tap water and dermal contact and inhalation of volatile chemicals in bathroom air while showering. Table 9.4.RME, Appendix F.2, summarizes the hazard to future adult residents from exposures to detected COPCs.

For detects in total soil, the noncarcinogenic hazard (30) exceeds USEPA's target HI. The primary contributor to hazard is thallium (HI = 30), which is also related to the single target organ (hair) exceeding the target HI of 1.

For detects in groundwater, the noncarcinogenic hazard (30) exceeds USEPA's target HI. The primary contributors to hazard are arsenic (HI = 1), manganese (HI = 2), silver (HI = 2), cis-1,2-DCE (HI = 20), vinyl chloride (HI = 1), TCE (HI = 1), and total xylenes (HI = 0.2). Target organs exceeding the target HI of 1 include the liver (HI = 2), nervous system (HI = 3), skin (HI = 3), and kidney (HI = 20).

ELCRs were not calculated for adult residents but were calculated for lifetime residents following USEPA guidance.

Future Child Residents (Noncarcinogenic Hazard). The HHRA assumed that future child residents could be exposed to total soil through incidental ingestion and dermal contact and to particulate and volatile emissions from surface soil through inhalation and exposure to groundwater through ingestion of tap water and dermal contact and inhalation of volatile chemicals in bathroom air while showering. Table 9.5.RME, Appendix F.2, summarizes the hazard to future child residents from exposures to detected COPCs.

For detects in total soil, the noncarcinogenic hazard (300) exceeds USEPA's target HI. The primary contributors to hazard are thallium (HI = 300), aluminum (HI = 0.2), manganese (HI = 0.3), cis-1,2-DCE (HI = 0.2), and TCE (HI = 0.7). Target organs/critical effects exceeding the target HI of 1 include developmental effects (HI = 2), kidney (HI = 2), and hair (HI = 30).

For detects in groundwater, the noncarcinogenic hazard (80) exceeds USEPA's target HI. The primary contributors to hazard are aluminum (HI = 0.1), arsenic (HI = 3), cobalt (HI = 1), manganese (HI = 5), silver (HI = 3), cis-1,2-dichloroethene (HI = 50), TCE (HI = 2), vinyl chloride (HI = 2), 1,1,2-trichloroethane (HI = 2), m&p-xylene (HI = 0.1), naphthalene (HI = 0.3), and total xylenes (HI = 0.5). Target organs/critical effects exceeding the target HI of 1 include the liver (HI = 6), respiratory (HI = 3), development (HI = 3), nervous system (HI = 6), vascular (HI = 3), skin (HI = 6), and kidney (HI = 60).

ELCRs were not calculated for child residents but were calculated for lifetime residents, following USEPA guidance.

Future Lifetime Residents (ELCR). The HHRA assumed that future lifetime residents could be exposed to total soil through incidental ingestion and dermal contact, and to particulate and volatile emissions from total soil through inhalation and exposure to groundwater through ingestion of tap water and dermal contact and inhalation of volatile chemicals in bathroom air while showering. Table 9.6.RME, Appendix F.2, summarizes the ELCR for future lifetime residents from exposures to detected COPCs.

For detected COPCs in total soil, the ELCR (2×10^{-4}) exceeds USEPA's target risk range. ELCR is driven primarily by dioxins (2,3,7,8-TCDD EQ), arsenic, chromium, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno (1,2,3-cd)pyrene, TCE, and vinyl chloride.

For detected COPCs in groundwater, the RME ELCR (1×10^{-3}) exceeds USEPA's target risk rang. ELCR is driven primarily by arsenic, chromium, benzo(a)pyrene, benzo(b)fluoranthene, indeno (1,2,3-cd)pyrene, bis(2-chloroethyl)ether, benzene, bromodichloromethane, chloroform, dibromochloromethane, ethylbenzene, PCE, vinyl chloride, 1,1,2-trichloroethane, naphthalene, and TCE.

Future Industrial Workers. The HHRA assumed that future industrial workers could be exposed to total soil through incidental ingestion and dermal contact and to particulate and volatile emissions from surface soil through inhalation and exposure to groundwater through ingestion of tap water and dermal contact with groundwater through hand washing. Table 9.7.RME, Appendix F.2, summarizes the hazard and risk to future industrial workers from exposures to detected COPCs.

For detected COPCs in total soil, the noncarcinogenic hazard (20) exceeds USEPA's target HI. The primary contributor to hazard is thallium (HI = 20), which is also related to the single target organ (hair) exceeding the target HI of 1. The ELCR (2×10^{-5}) is within USEPA's target risk range. ELCR is driven primarily by arsenic, chromium, benzo(a)pyrene, TCE, and vinyl chloride.

For detected COPCs in groundwater, the noncarcinogenic hazard (10) is greater than USEPA's target HI. The primary contributor to hazard is cis-1,2-DCE (HI = 8) and TCE (HI = 0.3) through ingestion, which are also related to the single target organ (kidney) exceeding the target HI of 1. The ELCR (1×10^{-3}) exceeds USEPA's target risk range. ELCR is driven primarily by arsenic, chromium, benzo(a)pyrene, bromodichloromethane, chloroform, dibromochloromethane, and vinyl chloride through ingestion.

Future Construction Workers. The HHRA assumed that future construction workers could be exposed to shallow groundwater in excavations through dermal contact and inhalation, to total soil through incidental ingestion and dermal contact, and to particulate and volatile emissions from total soil through inhalation during excavation and construction activities. Table 9.8.RME, Appendix F.2 summarizes the hazard and risk to future construction workers from exposures to detected COPCs.

For detected COPCs in total soil, the noncarcinogenic hazard (80) exceeds USEPA's target HI. The primary contributor to hazard is thallium (HI = 80). The ELCR (2×10^{-6}) is within USEPA's target risk range.

For detected COPCs in groundwater, the noncarcinogenic hazard (0.06) is less than USEPA's target HI. The ELCR (5×10^{-7}) is less than USEPA's target risk range.

6.8 Summary of Constituents of Concern

To support the remedial alternative selection process, risk-based remedial goals for industrial/commercial land use will be developed in the Feasibility Study (FS) for COCs identified for the 3 AOCs and sitewide groundwater. This section describes how the COCs are identified and summarizes the COCs for the 3 AOCs and sitewide groundwater. Preliminary COCs for soil and sitewide groundwater were identified based on the results of the risk characterization for detected COPCs and were identified where the potential ELCR or HI for a receptor group exceeded USEPA threshold values (a total ELCR of 1×10^{-4} or a target organ-specific HI of 1). When a target ELCR of 1×10^{-4} was exceeded for an environmental medium for a receptor group, the COPCs posing an individual ELCR greater than 1×10^{-6} in the environmental medium responsible for the human health risks above USEPA's target range were identified as preliminary COCs. When a potential target

organ-specific HI exceeded 1 for an exposure medium for a receptor group, the COPCs posing a HQ greater than 0.1 for that target organ in the environmental medium responsible for the HI greater than 1 were identified as preliminary COCs. For lead, if the exposure model (either ALM or IEUBK model) predicted more than 5 percent of the exposed population exceeding a BLL of 10 µg/dL, lead was identified as a preliminary COC for that potential receptor/exposure area combination.

Final COCs take into consideration whether the metals identified as preliminary COCs are attributable to background levels, and are identified for the realistic future site use (industrial/commercial) only; a future residential land use scenario is not realistic. If the maximum detected concentrations of a metal in a given medium do not exceed its corresponding background level it can be concluded that risk estimates associated with that metal may be attributable to background levels. Therefore, that metal is not selected as a final COC.

6.8.1 Railroad Salvage Yard AOC

The preliminary COCs identified for receptors evaluated for the RSY AOC are summarized in Table 6-2.

- **Resident (Child)—Future Scenario**
 - Surface soil (0-2 foot)
 - Manganese (HI = 2) (Table 12 of Appendix F.1)

Lead was not identified as a preliminary COC in the RSY AOC (presented in Section 6.6.4 and summarized in Tables 1 and 2 of Appendix H).

Background concentrations were taken into consideration when identifying COPCs (that is, chemicals within background concentrations were not selected as COPCs). In addition, analytes that were 100 percent nondetected in an environmental medium were not identified as COPCs. Because a residential scenario is not realistic for the Railroad Salvage Yard, no final COCs were identified.

6.8.2 Burn Pit Area AOC

With the exception of lead, no COCs were identified for receptors evaluated for the BPA AOC.

Lead was not identified as a COC for workers in the BPA AOC (presented in Section 6.6.4 and summarized in Tables 3 and 4 of Appendix H). However, the average lead concentrations in surface soil (737.7 mg/kg) and total soil (501.5 mg/kg) exceed the residential screening level of 400 mg/kg. Therefore, lead was identified as a preliminary COC in surface soil for future residents.

Background concentrations were taken into consideration when identifying COPCs (that is, chemicals within background concentrations were not selected as COPCs). In addition, analytes that were 100 percent non-detected in an environmental medium were not identified as COPCs. Because a residential scenario is not realistic for the BPA, no final COCs were identified.

6.8.3 Waste Oil Pit AOC

The following are the preliminary COCs identified for receptors at the Waste Oil Pit AOC:

- **Resident (child, child/adult aggregate)—Future Scenario**
 - Total soil (0-6 foot)
 - Hair HI = 300 (due to thallium)
 - Kidney HI = 2 (due to cis-1,2-DCE and TCE)
 - Arsenic (ELCR = 4E-05), chromium (ELCR = 7E-05), benzo(a)anthracene (ELCR = 5E-06), benzo(a)pyrene (ELCR = 2E-05), benzo(b)fluoranthene (ELCR = 4E-06), indeno(1,2,3-cd)pyrene (ELCR = 2E-06), TCE (ELCR = 6E-06), and vinyl chloride (ELCR = 1E-05)

- **Industrial Worker (adult)—Future Scenario**
 - Total soil (0-6 foot)
 - Hair HI = 23 (due to thallium)
- **Construction Worker (adult)—Future Scenario**
 - Total soil (0-6 foot)
 - Hair HI = 70 (due to thallium)

To evaluate whether the metals identified as preliminary COCs are attributable to background levels, the detected concentrations of metals were compared to the background concentrations established in Table 4-1. It was observed that the maximum detected concentrations of chromium in total soil did not exceed its corresponding background level. Therefore, it was concluded that risk estimates associated with chromium may be attributable to background levels. Therefore, chromium was not selected as a final COC in total soil. However, for other metals identified as preliminary COCs, the risk estimates may be associated with historical site activities.

The final COCs identified for industrial workers and construction workers are presented in Table 10.1 RME and 10.2 RME of Appendix F.2 and are summarized in Table 6-4.

- **Industrial Worker (adult)—Future Scenario**
 - Total soil (0-6 foot)
 - Thallium (Table 10.1.RME of Appendix F.2)
- **Construction Worker (adult)—Future Scenario**
 - Total soil (0-6 foot)
 - Thallium (Table 10.2.RME of Appendix F.2)

It is important to note that thallium was only detected in 1 of 53 samples over a very small area. Typically, if a chemical's frequency of detection is less than 5 percent (which is the case here), it is screened out consistent with Section 5.9.3 of USEPA's Risk Assessment Guidance for Superfund, Part A (1989). Additionally, there is no known military use for thallium, except possibly as an applied rodenticide (which may also be a non-military use), which would be an intended use rather than a release. This outlier does not warrant focus in the future FS and should not drive site action.

6.8.4 Sitewide Groundwater

The preliminary COCs identified for sitewide groundwater are presented in Table 10.2.RME through 10.5.RME of Appendix F.2 and are summarized in Table 6-4.

- **Resident (child, child/adult aggregate)—Future Scenario**
 - Skin HI = 6 (due to arsenic and silver)
 - Vascular HI = 3 (due to arsenic)
 - Nervous system HI = 6 (due to manganese, xylenes, and TCE)
 - Kidney HI = 50 (due to cis-1,2-DCE and TCE)
 - Liver HI = 5 (due to TCE and vinyl chloride)
 - Development HI = 3 (due to TCE)
 - Respiratory HI = 3 (due to 1,1,2-TCA and naphthalene)
 - Arsenic (ELCR = 3E-04), chromium (ELCR = 3E-04), benzo(a)pyrene (ELCR = 9E-05),

benzo(b)fluoranthene (ELCR = 1E-05), bis(2-chloroethyl)ether (ELCR = 1E-05), indeno (1,2,3-cd)pyrene (ELCR = 1E-05), benzene (ELCR = 8E-06), bromodichloromethane (ELCR = 7E-05), chloroform (ELCR = 3E-05), dibromochloromethane (ELCR = 7E-05), ethylbenzene (ELCR = 3E-06), PCE (ELCR = 5E-06), vinyl chloride (ELCR = 7E-04), naphthalene (ELCR = 5E-06), and TCE (ELCR = 3E-06) (Table 10.4.RME of Appendix F.2)

- **Industrial Worker (adult)—Future Scenario**

- Kidney HI = 8 (due to cis-1,2-DCE) through ingestion and dermal contact (Table 10.5.RME of Appendix F.2)
- Arsenic (ELCR = 8E-05), chromium (ELCR = 1E-05), bromodichloromethane (ELCR = 3E-06), dibromochloromethane (ELCR = 5E-06), and vinyl chloride (ELCR = 6E-04) through ingestion and dermal contact (Table 10.5.RME of Appendix F.2)

Lead was not identified as a preliminary COC in sitewide groundwater (presented in Section 6.6.4 and summarized in Table 5 of Appendix H).

To evaluate whether the metals identified as preliminary COCs are attributable to background levels, detected concentrations were compared to background concentrations established in Table 4-1. It was observed that the maximum detected concentrations of all metals identified as preliminary COCs exceeded their corresponding background levels. Therefore, it was concluded that risk estimates associated with groundwater may be attributable to historical site activities, and all preliminary COCs for the industrial scenario were identified as final COCs.

6.9 Uncertainty Associated with Human Health Assessment

The risk measures used in HHRAs are not fully probabilistic estimates of risk, but are conditional estimates given that a set of assumptions about exposure and toxicity are valid. Thus, it is important to specify the assumptions and uncertainties inherent in the HHRA to place the risk estimates in proper perspective (USEPA, 1989).

6.9.1 Uncertainty in Constituent of Potential Concern Selection

The data sets for soil at the 3 AOCs represent a compilation of several sampling events. These subsets consist of samples that were collected at various times for different investigations and were analyzed by different laboratories. Combining these data sets involves some uncertainty in the HHRA. The degree of potential overestimation or underestimation of risk resulting from combining all of the data is unknown but is not expected to be significant since all data were validated prior to use.

The age of the analytical data contributes some uncertainty to the HHRA. Historical data collected in 1995, 1997, 1998, and 2000 were included in the data sets. These data may no longer be representative of site conditions since volatilization and degradation most likely has occurred over time. The degree of potential overestimation of site concentrations, and risks, is unknown.

The HHRA uses soil samples collected from 0.5 to 1 foot, 0.5 to 1.5 feet, and 0 to 2 feet to represent surface soil, whereas Ohio EPA defines surface soil as 0 to 1 foot. The impact on the EPCs and risk estimates from using soil samples collected at slightly deeper intervals than 1 foot is not known but is not expected to be significant since the samples contain a portion of the 0 to 1 foot interval.

The sampling that was conducted at the site generally focused on areas of known or suspected impact from historic site use, based on previous sampling information and observations during previous construction activities. Therefore, the uncertainty in sampling and the possibility of missing a location impacted by site constituents is expected to be minimal. The uncertainty associated with the data analysis is minimal, as the data were fully validated before use in the HHRA.

As discussed in Section 4.1, a railroad line is located on the south side of the property (Figure 1-3) and is a potential PAH and metals source for the RSY. It is possible that the locomotive exhaust from the rail line could contribute to the presence of PAHs in soil at the 3 AOCs.

The general assumptions used in the COPC selection process were conservative so that compounds that should be considered COPCs were not eliminated from the quantitative HHRA.

Constituents that were not detected in any sample within a medium were evaluated separately in the HHRA, based on Ohio EPA's interest in determining whether there were significant risks associated with the elevated reporting limits in the HHRA data set. The risk evaluation for the nondetected constituents is provided in Appendix G. If the maximum reporting limit of a nondetected constituent exceeded the screening level, the nondetected constituent was included for quantitative evaluation. For soil, a number of SVOCs, VOCs, and pesticides/PCBs were 100 percent nondetect but had maximum reporting limits exceeding screening levels. For groundwater, a number of SVOCs, VOCs, and a metal were 100 percent nondetect but had reporting limits exceeding screening levels. As provided in Appendix G, the estimated HIs and ELCRs were within USEPA-acceptable levels for potential trespassers/site visitors and construction/utility workers; however, the estimated risks exceeded USEPA-acceptable levels for potential industrial workers and hypothetical residents. There is uncertainty associated with the quantitative evaluation of nondetected constituents with maximum reporting limits above screening levels. The EPCs for 100 percent nondetected chemicals were calculated using ProUCL, based on the range of reporting limits provided by the laboratory, and it was assumed that all nondetected chemicals are present at the site, which is expected to overstate current and future risks.

6.9.1.1 Chromium Screening Levels

Chromium was detected in soil and groundwater sample populations evaluated in this HHRA. As discussed in Section 6.3.2, per the approved HHRA Work Plan, the RSLs or PRG (depending on the year the risk assessments were performed as noted above) for hexavalent chromium were used in screening total chromium data as a conservative approach consistent with the HHRA Work Plan that was approved by one of the Army's elements (USACE) and Ohio EPA due to the fact that it is not standard practice at the time the samples were collected to speciate chromium forms. Additionally, it was assumed that all measured concentrations of chromium in these exposure media are present as hexavalent chromium in the subsequent intake estimates and risk characterizations. There is a large degree of uncertainty associated with the risk estimates for chromium. It is unlikely that 100 percent of the chromium detected in soil and groundwater is present in the hexavalent form, and there is no site history information to connect the use of hexavalent chromium to former DoD operations. Therefore, the assumption that 100 percent is in the hexavalent form results in an overestimate of risk. The forms of chromium expected to be present in site media based on the environmental setting and site-specific conditions will be further evaluated and discussed in the FS.

6.9.1.2 Chemicals Missing Screening Levels

Di-n-octyl phthalate was the only chemical detected in site soil and groundwater that has no screening levels or toxicity values that could be used to calculate a screening level. No RfD, RfC, or carcinogenicity assessment are currently available on IRIS (USEPA, 2011c). Di-n-octyl phthalate was detected in site soil and groundwater at an extremely low frequency and at a concentration lower than other detected phthalates that were not identified as COPCs in soil and one phthalate (bis(2-ethylhexyl)phthalate) which was identified as a COPC in groundwater. The di-n-octyl phthalate detection was co-located with other phthalates such as bis(2-ethylhexyl)phthalate in both soil and groundwater. Although potential health effects associated with exposure to di-n-octyl phthalate in soil could not be quantified due to the lack of toxicity values, it is unlikely that di-n-octyl phthalate would be identified as a COC in soil or groundwater because other phthalates detected at greater frequency and higher concentrations were not identified as COPCs during the conservative residential screening process for soil and bis(2-ethylhexyl)phthalate was not identified as a COC in groundwater.

6.9.2 Uncertainty Associated with Exposure Assessment

The HHRA assumed that concentrations remain constant throughout the exposure period and that these concentrations occur everywhere throughout the site. This assumption results in an over-estimation of risk since concentrations of VOCs and SVOCs will decrease over the exposure durations used in the HHRA.

Uncertainty in the exposure assessment generally was treated with conservative decision rules and assumptions, and therefore likely resulted in overestimates of actual exposures. Several exposure scenarios evaluated by this HHRA, such as future residential site use, are hypothetical and are not anticipated to exist in the future; residential assumptions for soil exposure likely overestimate potential site risks because this area is currently zoned commercial.

The exposure factors used for quantifying potential exposures were conservative and reflect upper-bound assumptions on the exposure. The reliability of the values chosen for the exposure factors also contributes substantially to the uncertainty of the resulting risk estimates. Because most of the exposure factors are upperbound assumptions, the resulting risks likely overestimate the actual risk.

The future soil exposure scenario adds additional conservatism by assuming that the subsurface soil will become surface soil during future construction activities, and that future receptors may come in contact with what is the current surface soil and current subsurface soil in the future. During many construction projects, clean fill material such as topsoil is placed over the soil that is disturbed during excavation. The topsoil material generally is needed to support growth of grass and other landscape plants. This would decrease the possibility of future exposure to both the current surface and subsurface soil after construction activities.

The HHRA included a hypothetical groundwater potable use scenario even though the Lordstown Township uses municipal water as their source for drinking water. Therefore, the groundwater risk estimates likely overstate potential future groundwater risk.

6.9.3 Uncertainty Associated with Toxicity Assessment

Uncertainty associated with the noncarcinogenic toxicity values is included in Appendix F.2, Tables 5.1 and 5.2. Several uncertainty factors were applied by USEPA to extrapolate doses from animal studies to humans. These uncertainty factors range between 1 and 3,000. Therefore, a high degree of uncertainty exists in the noncarcinogenic toxicity values, and varies based on the available scientific data for each COPC. The noncarcinogenic toxicity values are expected to overestimate actual toxicity.

The uncertainty associated with CSFs is mostly associated with the low-dose extrapolation, where carcinogenicity at low doses is assumed to be a linear response with higher doses in laboratory studies. This is a conservative assumption, introducing a high degree of uncertainty into CSFs extrapolated from higher areas of the dose-response curve. The CSFs are based on the assumption that there is no threshold level for carcinogenicity; however, most of the experimental studies indicate the existence of a threshold level. Therefore, CSFs developed by USEPA represent upper-bound estimates. ELCRs generated in this HHRA should be regarded as upper-bound estimates of the potential ELCRs, rather than an accurate representation of ELCR. The true ELCR is likely to be less than the predicted value (USEPA, 1989).

Additional uncertainty is inherent in the prediction of relative sensitivities of different species of animals and the applicability of animal data to humans.

There is a large degree of uncertainty associated with the oral-to-dermal adjustment factors (based on constituent-specific ABS_{GI}) used to transform the oral RfDs and CSFs based on administered doses to dermal RfDs and CSFs based on absorbed doses. It is not known if the adjustment factor results in an underestimation or overestimation of the actual toxicity associated with dermal exposure.

Surrogate constituents were used for detected constituents without screening levels and toxicity values. The use of surrogate constituents may underestimate or overestimate the risks or hazards.

6.9.4 Uncertainty in Risk Characterization

The uncertainties identified in each component of the HHRA ultimately contribute to uncertainty in risk characterization. The addition of ELCRs and HIs across pathways and COPCs contributes to uncertainty based on the interactions of COPCs such as additivity, synergism, potentiation, and susceptibility of exposed receptors. The simple assumption of additivity used for this site may or may not be accurate and may over- or underestimate risk; however, very little information on chemical mixtures is currently available and a better alternative is not available at this time.

Thallium was identified as a COC in Waste Oil Pit soil. However, thallium was only detected in 1 of 53 samples over a very small area and this outlier should not drive site action. Further, the magnitude of the lone thallium detection should have no bearing on it being retained in the FS. If a chemical's frequency of detection is less than 5 percent (which is the case here), it is screened out consistent with Section 5.9.3 of USEPA's Risk Assessment Guidance for Superfund, Part A (1989). Additionally, there is no known military use for thallium, except possibly as an applied rodenticide (which may also be a non-military use), which would be the intended use rather than a release.

6.10 Human Health Risk Summary

This HHRA was performed to evaluate potential current and future risks associated with detected constituents at the 3 AOCs and sitewide groundwater. Surface soil, subsurface soil, and groundwater analytical data were evaluated in the HHRA. Risks were evaluated for exposure to the following:

- Surface soil for industrial workers, trespassers/visitors (adult, youth, child), and hypothetical residents
- Total soil (that is, combined surface and subsurface soil) for construction workers, industrial workers, and hypothetical residents
- Groundwater for construction workers, industrial workers, and hypothetical residents

The future land use scenarios evaluated in this HHRA were conservative since it is likely that land use will not change from commercial use. Additionally, groundwater at the site is not a current potable source, and it is not expected or reasonable to assume that it will be used for potable use in the future.

Tables 6-2, 6-3, and 6-4 summarize the ELCRs and HIs and identify the Final COCs for the RSY AOC, BPA AOC, Waste Oil Pit AOC, and sitewide groundwater, respectively. The risk estimates for the RSY AOC are presented in Appendix F.1, Tables 7 through 30. The risk estimates for the BPA AOC are presented in Appendix F.1, Tables 31 through 56. The risk estimates for the Waste Oil Pit AOC and sitewide groundwater are presented in Appendix F.2, Tables 7.1.RME through 7.8.RME; Appendix F.2, Tables 9.1.RME through 9.8.RME, summarize the ELCRs and HIs. Appendix F.2, Tables 10.1.RME through 10.8.RME present the constituents that contributed HIs above 0.1 to total target organ HIs greater than 1 in a medium or ELCRs greater than 10^{-6} that contributed to total cumulative receptor ELCRs greater than 10^{-4} in a medium.

For the RSY AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for the receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in ELCRs less than or within USEPA's target risk range and noncarcinogenic hazards less than USEPA's target level. For future land use, ELCRs for all receptors evaluated are less than USEPA target risk range. Noncarcinogenic hazards for all receptors evaluated, except the hypothetical residential child, are less than USEPA's target HI; hazard estimates for hypothetical residential child use of the RSY AOC exceed the target HI.

For the BPA AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in ELCRs within or less than USEPA's target risk range or target HI. The construction worker HI for total soil is 1.

Therefore, there are no noncarcinogenic human health risks above USEPA's target levels for the construction worker. For future land use, ELCRs for all receptors evaluated are less than or within USEPA's target risk range. Noncarcinogenic hazards for all receptors evaluated are less than USEPA's target hazard level. Lead in both surface and total soil exceeded the residential soil screening level (400 mg/kg).

For the Waste Oil Pit AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for receptors evaluated in the HHRA. For future land uses, estimated risks for adult and child residents, industrial workers, and construction workers exceed USEPA's target range for ELCR and/or HI target.

For sitewide groundwater, potential groundwater exposures by future adult and child residents and industrial workers exceed USEPA's target risk level and HI. Risk estimates for construction workers were below USEPA's target risk range and target HI.

Volatile chemicals in soil and groundwater have the potential to migrate into indoor air spaces. Therefore, inhalation of indoor air at future buildings potentially impacted by volatiles detected in soil and groundwater is considered a potential pathway at the 3 AOCs. Because of site conditions (that is, shallow groundwater depth and shallow bedrock), vapor intrusion cannot be eliminated as a potential exposure pathway. The vapor intrusion pathway may be complete for potential future indoor air exposures and has the potential to exceed target risk levels for both residential and industrial land uses at the 3 AOCs.

Summary and Conclusions

This CRI report presents a detailed and comprehensive summary of the site setting and investigative activities performed to define the nature and extent of contamination at the 3 AOCs Site, and the current and future risk it poses to human health. Investigations were performed from 1995 through 2009 for media that may have been contaminated as a result of past activities at the 3 AOCs. Samples of the following media were collected at one or more of the 3 AOCs: surface soil, subsurface soil/bedrock, and groundwater. The samples were analyzed for parameters that included one or more of the following: VOCs, SVOCs, pesticides, PCBs, dioxins/furans, metals, total organic carbon, percent solids, and total solids.

To assess the nature and extent of contamination, analytical results were evaluated to confirm that each of the AOCs has been adequately characterized for risk assessment and to move forward in the CERCLA process. Based on observed site conditions and properties of site-related preliminary COCs identified, an assessment of contaminant fate and transport was completed. The results of the RI show that the nature and extent of contamination has been delineated at each of the 3 AOCs, and the investigations have obtained the information needed to define the conceptual site model and to assess the fate and transport of site-related contaminants.

The physical setting at the site consists of glacially derived fine-grained soils overlying sandstone and shale bedrock. The soils range from 2 to 6 feet thick. The upper portion of bedrock is weathered and fractured; the frequency of fractures decreases with depth. Groundwater at the site flows primarily through the bedrock. The depth to groundwater ranges from 1 to 5 feet bgs across the site and fluctuates 1 to 2 feet seasonally above and below the bedrock surface. In general, groundwater flows from south to north across the area. Beaver Creek is an ephemeral creek that originates at the railroad tracks on the southern edge of the site and flows north to northwest towards Beaver Pond.

At the former Waste Oil Pit, a TCRA removed much of the source in soil; however, residual contamination remains in the vicinity of the former Waste Oil Pit, most notably at and near the bedrock interface, and in sandstone bedrock underlying the former Waste Oil Pit. Soil contaminants were also detected in the vicinity of the former RSY and BPA, but the concentrations are more sporadic and much lower than at the Waste Oil Pit. VOCs comprise the principle contaminant in the plume extending from the Waste Oil Pit, 500 feet to the north-northwest in the direction of groundwater flow. Although other VOCs are present in the groundwater plume near the Waste Oil Pit, most of the plume can be characterized by trichloroethene and its degradation products, cis-1,2-dichloroethene and vinyl chloride. One groundwater sample in the vicinity of the former BPA also showed low parts per billion concentrations of VOCs.

An HHRA was performed using the data collected for soil at each of the 3 AOCs, and the most recent groundwater data for the 3 AOCs. The HHRA for the BPA and RSY is presented as completed in 2007. Because additional data was collected for the Waste Oil Pit and site groundwater after 2007, the HHRA for those two areas was redone in this RI. Surface soil, subsurface soil, and groundwater analytical data were evaluated in the HHRA. Risks were evaluated for exposure to:

- Surface soil for industrial workers, trespassers/visitors (adult, youth, child), and hypothetical residents
- Total soil (that is, combined surface and subsurface soil) for construction workers, industrial workers, and hypothetical residents
- Groundwater for construction workers, industrial workers, and hypothetical residents

For the RSY AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for the receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in ELCRs less

than or within USEPA's target risk range and noncarcinogenic hazards less than USEPA's target level. For future potential land use, ELCRs for all receptors evaluated are less than USEPA target risk range. Noncarcinogenic hazards for all receptors evaluated, except the hypothetical residential child, are less than USEPA's target HI.

For the BPA AOC, current land use is not associated with human health risks above USEPA's target risk range and HI threshold for receptors evaluated in the HHRA. Contact with surface soil by trespassers (youth) and industrial workers and contact with total soil by construction workers were estimated to result in ELCRs within or less than USEPA's target risk range or threshold HI. The construction worker HI for total soil is 1. Therefore, there are no noncarcinogenic human health risks above USEPA's target levels for the construction worker. For future land use, ELCRs for all receptors evaluated are less than or within USEPA's target risk range. Noncarcinogenic hazards for all receptors evaluated are less than USEPA's target hazard level. Lead in both surface and total soil exceeded the residential soil screening level (400 mg/kg).

For the Waste Oil Pit AOC, current land use is not associated with human health risks above USEPA's target risk range and target HI for receptors evaluated in the HHRA. For future land uses, risks were estimated for adult and child residents, industrial workers, and construction workers exceeding USEPA target range for ELCR and/or HI target.

For sitewide groundwater, potential groundwater exposures by future adult and child residents and industrial workers exceed USEPA's target risk level and HI. Risk estimates for construction workers were below USEPA's target risk range and target HI.

Volatile chemicals in soil and groundwater have the potential to migrate into indoor air spaces. Therefore, inhalation of indoor air at future buildings potentially impacted by volatiles detected in soil and groundwater is considered a potential pathway at the 3 AOCs. Because of site conditions (that is, shallow groundwater depth, shallow bedrock, and the presence of NAPL in groundwater), vapor intrusion cannot be eliminated as a potential exposure pathway. The vapor intrusion pathway may be complete for potential future indoor air exposures and has the potential to exceed target risk levels for both residential and industrial land uses at the 3 AOCs. Based on the findings of the RI, human health risk estimates associated with the former disposal activities at the former Waste Oil Pit, the Railroad Salvage Yard, the Burn Pit Area (for residential land use), and site groundwater exceed the USEPA-acceptable risk range and HI threshold. Therefore, USACE proposes to proceed to prepare an FS to identify and evaluate remedial options, including the option for the unlimited use and unrestricted exposure (UU/UE) condition. The vapor intrusion pathway will also be considered.

SECTION 8

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