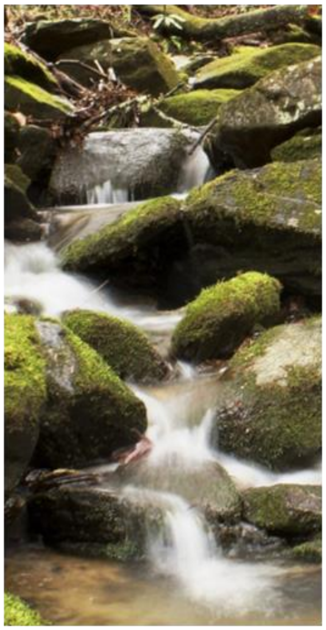

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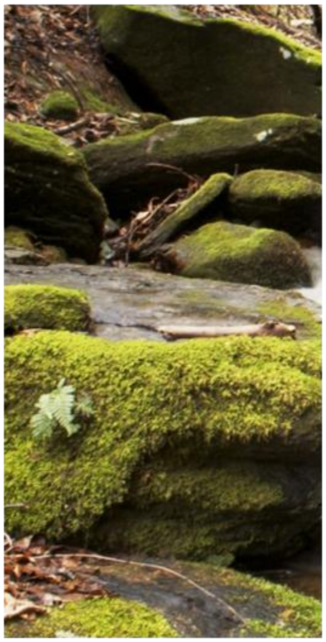
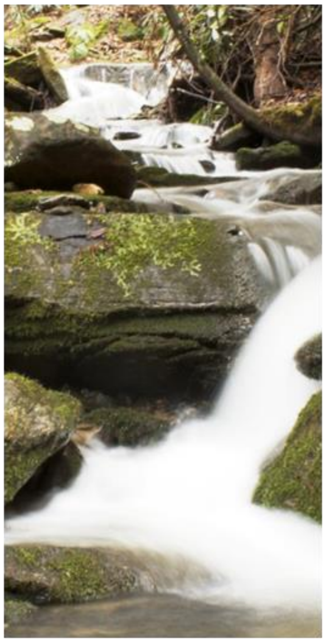


Final Remedial Investigation Report

December 21, 2015

Chemtronics Superfund Site
Swannanoa, Buncombe County
North Carolina
EPA ID: NCD 095 459 392



Prepared for
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and CNA Holdings, LLC
Project Number 2115.182

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Chemtronics Superfund Site
Swannanoa, Buncombe County
North Carolina
EPA ID: NCD 095 459 392

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LIST of ACRONYMS

1,2-DCA	1,2-dichloroethane
2,4,6-TNT	2,4,6-trinitrotoluene
ACM	Asbestos Containing Material
ADD	Average Daily Dose
AOC	Settlement Agreement and Order on Consent for Remedial Investigation/ Feasibility Study
AP	Acid Pits
ARAR	Applicable or Relevant and Appropriate Requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	Area Use Factor
BAF	Bioaccumulation Factor
BERA	Baseline Ecological Risk Assessment
BRA	Baseline Risk Assessment
BSAF	Biota-Sediment Accumulation Factor
BZ	3-Quinuclidinyl Benzilate
C_{air}	Chemical Concentration in Air
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	Centimeter
COC	Chemical of Concern
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CRA	Conestoga-Rovers and Associates
CS	Ortho-Chlorobenzylidene Malononitrile
CSM	Conceptual Site Model
CWM	Chemical Waste Management
DA	Disposal Area
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethene
DDT	Dichlorodiphenyltrichloroethane
DENR	North Carolina Department of Environment and Natural Resources
DEQ	North Carolina Department of Environmental Quality
EDD	Electronic Data Deliverable
EPA	United States Environmental Protection Agency
EPC	Exposure Point Concentration

EPT	Ephemeroptera, Plecoptera, Tricoptera
EqP	Equilibrium Partition
ERA	Ecological Risk Assessment
ESB	Equilibrium Partitioning Sediment Benchmark
ESV	Ecotoxicity Screening Value
FS	Feasibility Study
FSAP	Field Sampling and Analysis Plan
ft	Feet/Foot
ft-bgs	Feet Below Ground Surface
ft/day	Feet per Day
ft-msl	Feet Above Mean Sea Level
GEAE	Generic Ecological Assessment Endpoint
GIS	Geographic Information System
gpm	Gallons Per Minute
HASP	Health and Safety Plan
HBL	Health-Based Limit
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW	High Molecular Weight
HMX	Octahydro-1,3,7,5-tetranitro-1,3,7,5-tetrazocine
HQ	Hazard Quotient
HSA	Hollow-Stem Auger
HSMP	Holistic Site Management Plan
ID	Inside-Diameter
IDW	Investigation-Derived Waste
IMAC	Interim Maximum Allowable Concentration
in-bgs	Inches Below Ground Surface
IRIS	Integrated Risk Information System
K_{oc}	Organic Carbon-Water Partition Coefficient
K_p	Permeability Coefficient
kg	Kilogram
L	Liter
LADD	Lifetime Average Daily Dose
LCV	Lowest Chronic Value
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observable Effect Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg	Milligrams
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
MS/MSD	Matrix Spike/Matrix Spike Duplicates
MSCC	Maximum Soil Contaminant Concentration
MSD	Metropolitan Sewerage District
NAAQS	National Ambient Air Quality Standards
NC NHP	North Carolina Natural Heritage Program

NCAC	North Carolina Administrative Code
NCGS	North Carolina Geological Survey
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NPL	National Priorities List
NRWQC	National Recommended Water Quality Criteria
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response
OVA	Organic Vapor Analyzer
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCE	Tetrachloroethylene
PPRTV	Provisional Peer Reviewed Toxicity Values
PVC	Polyvinyl Chloride
PWR	Partially Weathered Rock
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
ROI	Receptor of Interest
SF	Slope Factor
SLERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific Management Decision Point
SMS	Site Management Strategy
SOW	Scope of Work
SSL	Soil Screening Level
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
T&E	Threatened and Endangered
TAL	Target Analyte List
TBA	Tert-Butyl Alcohol
TCE	Trichloroethylene
TDI	Total Daily Intake
TLM	Target Lipid Model
TNT	Trinitrotoluene
TOC	Total Organic Carbon
TRV	Toxicity Reference Values
TU	Toxic Unit

UCL	Upper Confidence Limit
URF	Unit Risk Factor
USFWS	United States Fish and Wildlife Service
UST	Underground Storage Tank
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
WNC	Western North Carolina
WQB	Water Quality Benchmark
WWC	Warren Wilson College
µg/L	Micrograms per Liter
µg/m	Micrograms per Meter

Executive Summary

A site-wide remedial investigation (RI) was performed at the Chemtronics Superfund Site (Site) located at 180 Old Bee Tree Road in Buncombe County, North Carolina, in the community of Swannanoa. The RI was completed in accordance with a Settlement Agreement and Order on Consent (AOC) for a Remedial Investigation/Feasibility Study (RI/FS) for the Site pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA 2008b). The AOC was signed by the United States Environmental Protection Agency (EPA) and the Companies (Chemtronics, Inc., Northrop Grumman Systems Corporation [Northrop], and CNA Holdings, LLC [CNA]) (together, the Companies) on October 24, 2008. The objectives of the RI/FS activities are:

> *(a) To determine the nature and extent of contamination and any threat to the public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a Remedial Investigation as more specifically set forth in the Statement of Work…*
>
> *(b) To identify and evaluate remedial alternatives to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a Feasibility Study as more specifically set forth in the Statement of Work…*

SITE BACKGROUND

The Site occupies approximately 1,065 acres of rural land in Buncombe County, North Carolina. The Site is divided into two distinctly separate geographic areas commonly referred to as the Front Valley and the Back Valley. A prominent ridge separates the Front and Back Valley areas.

The majority of the Site is situated within one of two local watersheds, the Unnamed Branch in the Front Valley and Gregg Branch in the Back Valley, both of which are part of a larger watershed (Bee Tree Creek) and a regional watershed (Swannanoa River). Both the Unnamed Branch and Gregg Branch discharge to Bee Tree Creek. All surface water from the Site drains to these tributaries of Bee Tree Creek or directly to Bee Tree Creek, which then discharges into the Swannanoa River approximately 4,500 feet (ft) downstream of the Site. The Swannanoa River is a significant regional drainage.

The property was first developed and operated as an industrial facility in 1952. Prior to 1952, the Site was rural farm and dairy land. The primary products manufactured on-Site were explosives, propellants, incapacitating agents, and a variety of specialty chemicals. Manufacturing activities occurred primarily in the Front Valley, and material testing and waste disposal occurred primarily in the Back Valley. Manufacturing and related activities occurred on less than 200 acres of the Site and were primarily located in the southern portion of the Site. Most of the manufacturing activities were discontinued by the late 1980s, and all manufacturing activities ceased in 1994.

Various waste products and byproducts associated with the manufacturing of explosives, flares, military incapacitating agents (e.g., ortho-chlorobenzylidene malononitrile [CS] and 3-quinuclidinyl benzilate [BZ]), and various chemical intermediates were disposed of on-Site. The primary waste products included chlorinated and non-chlorinated solvents, acidic solutions, byproducts of the manufacturing processes, and solid waste such as gloves and coveralls.

The Site was first included on the National Priorities List (NPL) in December 1982. The Site was historically regulated by both the EPA CERCLA/Superfund program and the North Carolina

Department of Environment and Natural Resources (DENR), which is now called the North Carolina Department of Environmental Quality (DEQ), Resource Conservation and Recovery Act (RCRA) program. The historical CERCLA investigations focused primarily on waste disposal sites associated with the former Site operations. RCRA investigations focused on other areas of the Site that involved historical manufacturing operations. In 2007, DENR requested that EPA consolidate oversight of all Site environmental remediation activities under EPA's Superfund/CERCLA authority. The only ongoing authorized Site activities at present are CERCLA-related remedial activities, occasional utility maintenance and repair work, and security guard patrols.

SITE GEOLOGY

The Site is underlain by regolith overlying metamorphic rocks, including metagraywacke, schistose metagraywacke, and amphibolite. Foliation within these rocks trends in a northeast-southwest direction. Fractures are oriented in both northeast-southwest and northwest-southeast directions. The orientation of the foliation and the fractures control Site topography and drainage features as well as groundwater flow in the underlying bedrock. Differential weathering rates of the bedrock result in an uneven top of bedrock topography.

Groundwater at the Site exists in a three-part aquifer consisting of a Surficial Aquifer System, a Transition Zone Aquifer System, and a Bedrock Aquifer System. These three aquifer systems are interconnected but have different characteristics that influence groundwater flow and potential transport mechanisms for chemicals of potential concern (COPCs) within them. The three aquifer systems are interconnected with a predominantly downward vertical gradient between the various systems. Groundwater flow is predominantly toward the southeast in all of the aquifer systems. Locally, groundwater in the Surficial Aquifer System, the Transition Zone Aquifer System, and the Bedrock Aquifer System may discharge to the Unnamed Branch, Gregg Branch, or Bee Tree Creek.

SITE COPCs

COPCs were selected for each media (soil, groundwater, surface water, and sediment) based on a review of known Site chemical usage, results of previous sampling activities, and readily available analytical methods. Site COPCs detected in soil consisted primarily of volatile organic compounds (VOCs), nitroaromatic compounds, and perchlorate. Semivolatile organic compounds (SVOCs) and pesticides were also detected at a lesser frequency or concentration. Site COPCs detected in groundwater consisted primarily of VOCs, nitroaromatic compounds, and perchlorate. The primary COPCs detected in surface water were VOCs and perchlorate. SVOCs and pesticides were the primary Site COPCs detected in sediment.

SUMMARY OF RI FIELDWORK

To meet the stated objectives for the RI/FS, the Companies developed an *RI/FS Work Plan* (Work Plan) (Altamont 2009b) to describe an RI/FS process designed to meet the requirements of the AOC and its attached Scope of Work (SOW). RI tasks included selecting medium-specific COPCs, sampling various on-Site environmental media (soil, groundwater, surface water, and sediment), updating the survey of off-Site potential groundwater receptors, sampling off-Site water supply wells, performing a baseline risk assessment (BRA), and preparing this RI report.

The RI fieldwork was completed in three phases performed between December 2009 and July 2012. RI sampling activities consisted of:

- Collection and analyses of a total of 541 soil samples from 290 soil sampling locations within 45 areas
- Installation of 56 monitoring wells to supplement the existing Site monitoring well network
- Collection and analyses of groundwater samples one time or more from 175 on-Site monitoring wells
- Collection and analyses of surface water and sediment samples from 53 locations
- Updating of the potential groundwater receptor survey
- Sampling of eight off-Site potential groundwater receptor wells and analysis for Site COPCs

BASELINE RISK ASSESSMENT

To quantify the potential risks to human health and ecological receptors from Site COPCs, soil, groundwater, sediment, and surface water, data collected during the RI were evaluated in the BRA. The BRA included both a human health risk assessment (HHRA) and an ecological risk assessment (ERA). The BRA was performed in an iterative manner using data collected during each phase of the RI to refine subsequent data collection activities.

The HHRA evaluated the following potentially exposed populations at and around the Site under current and reasonably expected future land use:

On-Site:

- Industrial workers
- Maintenance workers
- Construction workers
- Recreational users
- Trespassers

Off-Site:

- Residents
- Maintenance workers
- Recreational users

Although not considered a likely potential exposure scenario, the HHRA also considered risks to future on-Site residential receptors.

A comprehensive ERA was conducted, and the results are presented in this Remedial Investigation Report (RI Report). The ERA evaluated various aquatic and terrestrial receptors. Terrestrial receptors include invertebrates (from earthworms to insects), small vertebrates such as passerine birds and small herbivorous mammals, predatory birds, and mammals. Aquatic receptors include benthic invertebrates (worms, some crustaceans, some insects), fish and amphibians, birds, and piscivorous mammals.

CONCLUSIONS

Results of the HHRA indicate that overall there are no unacceptable risks to human health at the Site when considering current receptors and exposure pathways. The HHRA did identify a potential for unacceptable risk to limited on-Site receptors under assumed future exposures, including potential future industrial worker exposure to COPCs in soil at two locations and several areas where potential unacceptable future industrial worker exposure via vapor intrusion or potable/nonpotable groundwater use, and maintenance worker/construction worker exposure via direct contact with groundwater risks may exist.

The ERA concluded that conditions at the Site do not pose unacceptable risks to aquatic and terrestrial populations. However, some risks to individual soil invertebrates, plants, mammals, or birds cannot be definitively ruled out by the risk assessment alone. The ERA provides a summary of key issues as they may relate to risk management decisions for the Site.

The groundwater data do not indicate off-Site migration of VOCs, nitroaromatics, or perchlorate at concentrations exceeding applicable groundwater criteria. The off-Site water well survey and water well sampling activities found no COPCs attributable to the Site in off-Site groundwater at concentrations that exceed the Title 15A, North Carolina Administrative Code (NCAC), Subchapter 2L standard (2L standard). With the exception of potential future off-Site potable/nonpotable groundwater use, there are no potential future unacceptable risks to off-Site receptors from hazardous substances at the Site.

Site COPC concentrations in surface water samples collected from Bee Tree Creek downstream of its confluence with on-Site streams are either non-detectable or below the Title 15A, NCAC, Subchapter 2B standard (2B standard) and/or EPA National Criteria.

Based on the results of the BRA, three soil areas and 11 groundwater areas have been identified as warranting further evaluation in the Feasibility Study (FS). These areas are summarized in Section 9. Although not a current or expected future exposure scenario, an additional 16 soil areas have also been retained for further evaluation in the FS, including evaluating the elimination of potential future residential exposure via institutional controls.

SITE REDEFINITION

Based on the results of the RI, an evaluation was performed to identify those portions of the Site that should be retained as part of the CERCLA Site and those portions that may be excluded from the redefined Site based on the absence of evidence suggesting adverse impacts from Site-related COPCs or past manufacturing operations. The proposed redefinition of the Site boundary will be considered by the EPA with the decision documented in the Record of Decision for the Site.

1.0 Introduction and Objectives

The Chemtronics Superfund Site (Site) is located at 180 Old Bee Tree Road in Buncombe County, North Carolina, in the community of Swannanoa (Figures 1-1 and 1-2). On October 24, 2008, the United States Environmental Protection Agency (EPA) and the Companies (Chemtronics, Inc., Northrop Grumman Systems Corporation [Northrop], and CNA Holdings, LLC [CNA]) (together, the Companies) signed a Settlement Agreement and Order on Consent (AOC) for a Remedial Investigation/Feasibility Study (RI/FS) for the Site pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA 2008b). The AOC stated (at Section III, paragraphs 9.a and 9.b) that the objectives of the RI/FS activities are:

> *(a) To determine the nature and extent of contamination and any threat to the public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a Remedial Investigation as more specifically set forth in the Statement of Work…*
>
> *(b) To identify and evaluate remedial alternatives to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a Feasibility Study as more specifically set forth in the Statement of Work…*

To meet these stated objectives for the RI/FS, the Companies developed a detailed, five-volume *RI/FS Work Plan* (Work Plan) (Altamont 2009b) to describe an RI/FS process designed to meet the requirements of the AOC and its attached Scope of Work (SOW). The five volumes of the Work Plan include the following:

- Volume 1—Work Plan Overview
- Volume 2—Field Sampling and Analysis Plan (FSAP)
- Volume 3—Quality Assurance Project Plan (QAPP)
- Volume 4—Ecological Risk Assessment Work Plan
- Volume 5—Health and Safety Plan

The Work Plan described the holistic, comprehensive approach to be used in conjunction with a Conceptual Site Model (CSM) to investigate the Site. The Work Plan specified an iterative approach to updating the CSM and identifying data gaps based upon data gained from evaluation of the Site. The Work Plan included a preliminary CSM that was developed following a review of the entire Site operational history and previous investigations performed prior to its preparation. The preliminary CSM identified areas of potential impacts from Site-related chemicals of potential concern (COPCs), potential COPC migration pathways, and potential receptors (see Section 1.5 for how COPCs were determined). Risk-based remedial action objectives (RAOs), designed to protect potential on-Site and off-Site receptors, were developed for soil, groundwater, surface water, and sediment and were described in the Work Plan.

The Work Plan included a detailed description of the baseline risk assessment (BRA) process for the Site, which consists of the human health risk assessment (HHRA) and the ecological risk assessment (ERA). The Work Plan specified that the human health component of the BRA would be used to determine whether any area of the Site poses an unacceptable risk to potential receptors based on the reasonable maximum exposures (RMEs) to hazardous substances and other pollutants or contaminants under current and reasonably expected future land use at the Site in accordance with EPA's CERCLA risk management policy (i.e., remedial action is warranted if cumulative carcinogenic site risks for current or future land use are greater than 1 x 10^{-4} or the Hazard Index (HI) for non-carcinogens is greater than 1 [EPA 1991]). The Work Plan further specified that if the human health portion of the BRA determines that an unacceptable RME risk exists, remedial action alternatives will be evaluated in a subsequent Feasibility Study (FS) phase to determine the appropriate methods for mitigating the risk. The Work Plan also specified that the ERA will be used to evaluate quantitatively and qualitatively whether any area of the Site poses an unacceptable risk to ecological receptors from Site COPCs in soil, surface water, or sediment and whether such risk warrants further evaluation or remedial action.

The Work Plan described a phased, step-by-step process for collecting the data necessary to support the BRA, determining whether and where remedial action is warranted and evaluating remedial alternatives, including an evaluation of the existing remedy. The Work Plan specified that Remedial Investigation (RI) data collection would be considered complete when SOW requirements for the RI are satisfied and sufficient data have been collected to support a reliable determination of whether and where remedial action is warranted. The Work Plan indicated that a FS will be performed after the RI to evaluate remedial alternatives that can be used to mitigate unacceptable human health or ecological risks and a Site-wide remedy will be recommended. Supplemental data collection and pilot testing of potentially applicable remedial technologies will be performed during the FS, as necessary, to support evaluation of specific alternatives.

The Work Plan summarized the overall RI/FS process as follows:

- Prepare a preliminary CSM based upon available data and update as appropriate using new data
- Compile Applicable or Relevant and Appropriate Requirements (ARARs) to be used in the FS
- Define RAOs for each media (soil, groundwater, surface water, and sediment)
- Collect sufficient Site characterization data using a phased, step-by-step process to evaluate the nature and extent of Site COPCs in each media as necessary to support a BRA
- Complete the BRA to determine whether and where remedial action is warranted
- Evaluate remedial action alternatives to mitigate unacceptable RME risks
- Recommend a Site-wide remedy

The EPA and the North Carolina Department of Environment and Natural Resources (DENR), which is now called the North Carolina Department of Environmental Quality (DEQ), approved the five-volume Work Plan on November 19, 2009.

1.1 Purpose of this Report

The purpose of this Remedial Investigation Report (RI Report) is to document the RI data collection, evaluation, and risk assessment activities that were completed to meet the objectives defined in the Work Plan.

The investigation activities and data evaluation were performed by Altamont Environmental, Inc. (Altamont) and ENVIRON International Corporation (ENVIRON) in accordance with the Work Plan (Altamont 2009) and the following documents prepared during the course of this RI work that provided interim data evaluation and recommendations for additional Site investigation activities, including: *Site Characterization Technical Memorandum* (Phase I Technical Memorandum) dated August 27, 2010 (revised April 27, 2011) (Altamont 2010 and 2011a, respectively) and the *Phase II Site Characterization Technical Memorandum* (Phase II Technical Memorandum) dated October 20, 2011 (Altamont 2011b). These reports are located in Appendix A. A Draft RI Report was submitted to the EPA and DENR on March 1, 2013. Several iterations of comments on the Draft RI Report were received from EPA and DENR between June 2013 and August 2015. These comments were addressed in written responses and during several meetings and teleconferences. Approval of the resolution of all comments and items regarding finalization of the RI was received via e-mail from EPA and DEQ on October 14, 2015 This Final RI Report forms the basis for proceeding with the FS portion of the RI/FS process for the Site.

1.2 Site Background

1.2.1 Site Description

The Site occupies approximately 1,065 acres of rural land in Buncombe County, North Carolina. The Site is located at 180 Old Bee Tree Road, approximately 8 miles east of Asheville, in the community of Swannanoa (Figure 1-1). The Site is situated within the southern Appalachian mountains with the approximate center of the Site lying at latitude 35 degrees, 38 minutes, 18 seconds north and longitude 82 degrees, 26 minutes, 8 seconds west. The topography of the Site is moderately sloping to steep, with elevation ranging from 2,200 to 3,400 feet above mean sea level (ft-msl). The Site lies on the southeast side of Bartlett Mountain and is moderately to heavily vegetated with mixed forest types including hardwoods and conifers. The Site is divided into two distinctly separate geographic areas commonly referred to as the Front Valley and the Back Valley. A prominent ridge separates the Front and Back Valley areas (Figure 1-2).

The majority of the Site is situated within one of two local watersheds, the Unnamed Branch in the Front Valley and Gregg Branch in the Back Valley, both of which are part of a larger watershed (Bee Tree Creek) and a regional watershed (Swannanoa River) (Figures 1-1,1-2, and 1-3). Both the Unnamed Branch and Gregg Branch discharge to Bee Tree Creek. All surface water from the Site drains to these tributaries of Bee Tree Creek, or directly to Bee Tree Creek, which then discharges into the Swannanoa River approximately 4,500 feet (ft) downstream of the Site. The Swannanoa River is a significant regional drainage.

To effectively manage, record, and communicate information regarding the Site, a 250-by-250-foot grid system was developed and overlain on the Site map(s). Individual grids were assigned a combined letter and numerical code as depicted in the attached figures (in which a letter code [A through Z] was assigned to grids along the west to east axis and a numerical code [1 through 47] was assigned along the north to south axis). For example, as shown in Figure 1-3, Pond 1 is found within grid O-43. Given the large size (approximately 1,065 acres) of the Site, this grid-based numbering system has been used to assist with mapping features such as historical building locations and monitoring well locations and providing reference points for Site sampling.

1.2.2 Site History and Current Use

The property was first developed and operated as an industrial facility in 1952. Prior to 1952, the Site was rural farm and dairy land. The Site has been owned and operated by Oerlikon Tool and Arms Corporation of America (1952 to 1959), Celanese Corporation of America (1959 to 1965), Northrop Carolina, Inc. (1965 to 1978), and Chemtronics, Inc. (1978 to present). The primary products manufactured on-Site were explosives, propellants, incapacitating agents, and a variety of specialty chemicals.

Manufacturing activities occurred primarily in the Front Valley, and material testing and waste disposal occurred primarily in the Back Valley. Manufacturing and related activities occurred on less than 200 acres of the 1,065 acre Site and were primarily located in the southern portion of the Site. Most of the manufacturing activities were discontinued by the late 1980s, and all manufacturing activities ceased in 1994. Various waste products and byproducts associated with the manufacturing of explosives, flares, military incapacitating agents (e.g., ortho-chlorobenzylidene malononitrile [CS] and 3-quinuclidinyl benzilate [BZ]), and various chemical intermediates were disposed of on-Site. The primary waste products included chlorinated and non-chlorinated solvents, acidic solutions, byproducts of the manufacturing processes, and solid waste such as gloves and coveralls.

The Site was historically regulated by both the EPA CERCLA/Superfund program and the DENR Resource Conservation and Recovery Act (RCRA) program.

CERCLA investigations and remediation activities were performed on-Site prior to the RI described in this Site-wide RI Report. The Site was first included on the National Priorities List (NPL) in December 1982. The historical CERCLA investigations focused primarily on waste disposal sites associated with former Site operations. The prior CERCLA investigations included investigations of all the known historical waste disposal areas on the Site and included 23 individual disposal areas which were grouped into six discrete waste disposal areas (DAs). These areas are designated as DA10/11 and DA23 (located in the Front Valley) and DA6, DA7/8, DA9 and the Acid Pits (AP) (located in the Back Valley). Together, these DAs occupy less than 10 acres of the Site. Solid waste material and possibly solvents were reportedly incinerated in the AP. Chemical waste and spent acid were also disposed in trenches in the AP. Chemical wastes from the manufacturing of CS and BZ were reportedly placed in 55-gallon drums and were neutralized with a kill solution. These drums were buried in DA6, DA7/8, DA9, and DA10/11 along with other process wastes and solid wastes. DA23 is a former wastewater treatment biolagoon associated with Building 113, which was built on top of an abandoned leach field also associated with Building 113. Figure 1-3 identifies the former locations of buildings and other operational areas as well as the DAs.

Historically, CERCLA Site remedial activities, as specified in the 1988 Record of Decision (ROD) and the 1989 ROD Amendment (EPA, 1988 and 1989a), focused primarily on the DAs. A series of CERCLA investigation efforts were performed (Camp Dresser & McKee, Inc. 1985, and Metcalf & Eddy, 1987a and b). Activities included drilling and excavating soil borings and test pits into and through the DAs to characterize the waste materials remaining in place. The characterization included estimates of the number and description of the type and condition of the containers remaining in place. Remedial activities included capping and fencing of the DAs and installing and operating groundwater extraction and treatment systems in both the Front Valley and the Back Valley. The Front Valley extraction system utilizes two extraction wells, and the Back Valley system utilizes 12 extraction wells (Figure 1-4).

The RCRA investigations at the Site focused on areas of the Site historically used for manufacturing operations. These areas were designated as RCRA solid waste management units (SWMUs) and included wastewater sumps and waste material accumulation, handling, and storage areas.

As part of the activities completed under the RCRA program, sumps and other SWMUs at the Site were, in most cases, inspected, cleaned, and backfilled with soil. These activities are described in detail in the following reports:

- *Confirmation Sampling Study*, Environmental Investigations, 1998
- *Site Investigation*, Environmental Investigations, 2000
- *Phase II Site Investigations*, Environmental Investigations, 2002
- *Building 111 Sump Closure Evaluation*, Altamont Environmental, Inc., 2005
- *Building 155 Sump System Closure Evaluation*, Chemtronics Inc., 2006
- *Confirmatory Soil Sampling—Building 111 Sump Area*, Altamont Environmental, Inc., 2006a

Section 2 of the Work Plan included a detailed discussion of previous investigations. Table 1-1 provides a list of reports from previous investigation activities. Those investigations documented that the constituents used or produced in the manufacturing processes include various volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), explosive compounds, perchlorate, metals, organic acids, and specialty chemicals.

The Site has been inactive since 1994. Between 2004 and 2006, all buildings and other structures, except those associated with ongoing environmental assessment and remediation activities, were demolished down to the building slab, and the resulting debris was disposed of off-Site. These activities were documented in the Building Demolition and Waste Removal Report prepared by Chemtronics in December 2009. Table 1 from that report provides details on debris and waste material disposal and recycling. A summary of the material disposed or recycled is as follows:

- Building debris—11,960 tons of debris was disposed of at the Republic Services Union County Landfill in Enoree, South Carolina
- Metal debris—79 tons of metal debris was recycled at the Biltmore Iron and Metal Co. in Asheville, North Carolina
- Asbestos-containing material (ACM)—630 cubic yards of ACM was disposed of at the H.A.M. Landfill in Peterstown, West Virginia
- Various non-hazardous materials—26 drums of non-hazardous liquids were disposed of at the GARCO, Inc. facility in Asheboro, North Carolina and 22 drums at the Chemical Waste Management (CWM) facility in Emelle, Alabama
- Hazardous liquids and solids—2,300 pounds of hazardous liquids and solids were disposed of at the SCS facility in Sumter, South Carolina; 550 pounds were disposed of at the Ecoflo facility in Greensboro, North Carolina; and 265 pounds were disposed of at the OES facility in Creedmoor, North Carolina
- Various universal waste, fluorescent bulbs, ballasts, etc.—various wastes were recycled at Cleanlite Recycling in Spartanburg, South Carolina

During the building demolition and waste removal activities in 2004, GARCO, Inc. was retained to investigate an area in the Back Valley known as the Target Area. During Site operations flares and rockets were launched from a concrete pad located near Building 124 and directed toward the lower half of a south, southeast facing slope approximately 1,000 meters distant from the launch site (an area known as the Trajectory Path). The Target Area was the impact zone resulting from the launch of flares and rockets along the Trajectory Path. The Target Area was gridded, and a sweep of the area for metallic objects was performed by unexploded ordnance (UXO) qualified personnel. Objects recovered during this sweep appeared to be fragments of possible ordnance items, including rocket components such as nose cone pieces and tail fins. No UXO was identified during the sweep of the Target Area. Metallic debris located during this sweep was collected and disposed of off-Site as appropriate.

In a letter dated March 9, 2007 DENR requested that EPA consolidate oversight of all Site environmental remediation activities under EPA's CERCLA authority. The only ongoing authorized Site activities at present are CERCLA-related remedial activities, occasional utility maintenance/repair work, and security guard patrols.

1.2.3 **Adjacent Land Use**

The Site is bordered to the north, northeast, and northwest by sparsely populated woodlands, primarily national forests or state game lands. Unincorporated residential neighborhoods are located immediately east, west, and south of the Site (Bee Tree community, Dillingham Circle, and Old Bee Tree/Rainbow Ridge community, respectively). An inactive industrial facility (Tandy Electronics) is located immediately south of the Site and is currently being investigated/remediated under the North Carolina Registered Environmental Consultant Program. Several more industrial facilities are located further to the south. Warren Wilson College (WWC) is located approximately 0.75 miles south of the Site.

1.3 Site Management Strategy

As described in the Work Plan, the Site Management Strategy (SMS) is focused on the long-term management of potential risks within the Site and protection of potential off-Site receptors. The components of the strategy include the following activities:

- Monitoring and management of on-Site areas where unacceptable risks were identified during the RI under current and future on-Site land use and groundwater use scenarios
- Identification/assessment of on-Site sources of groundwater and/or surface-water contamination that may warrant response actions (including possible active remedial measures, engineering or institutional controls, or further controls in the case of the DAs) to adequately protect on-Site and off-Site receptors
- Evaluation of potential remedial alternatives to address on-Site conditions that the BRA determined may present unacceptable human health and/or ecological risks under current and future use of the Site

The SMS provides the overall framework to guide the investigation and characterization of Site conditions. The RI work was designed to address the Site as a whole, with an emphasis on evaluating groundwater conditions at the Site boundary and working back toward potential source areas. The RI was designed to identify the sources of Site COPCs and define the nature and extent of Site COPCs, including physical characteristics and chemical constituents in soil, groundwater, surface water, and sediment at the Site, in sufficient detail to support the BRA and holistic Site remedial strategy. In addition, the RI/FS was designed to provide a comprehensive, Site-wide assessment of (1) the potential human health and ecological risks associated with these conditions under current and reasonably expected future uses and exposure scenarios for the Site, and (2) both the existing CERCLA remedy and other potential remedial alternatives for the Site as a whole.

Another important element of the Site strategy is a Site-specific CSM based on current and reasonably expected future Site use. As discussed above, the Site has been inactive since 1994 and, currently, the only activities at the Site are CERCLA remediation activities, utility maintenance and repair work, and security guard patrols. Workers at the Site are limited to those performing environmental investigation or remediation, security personnel, and those performing occasional maintenance or construction (including utility workers). All such workers are aware of the presence of potential chemical hazards at the Site and take appropriate precautions to ensure that they do not have unacceptable exposures. Their activities are governed by a health and safety plan (HASP) for the Site. Fencing along portions of the Site boundary, warning signs, security guard patrols of on-Site roads, and rough terrain discourage trespassers. Although occasional trespassers have been observed on the Site, the potential for current human exposure to on-Site contamination is relatively low. The preliminary CSM was based on the expectation that institutional controls may be implemented as necessary to limit future on-Site land use to commercial/industrial uses for impacted portions of the Site, although certain other portions of the Site where no historical manufacturing, testing, or waste disposal activities occurred may be suitable for unrestricted use. The preliminary CSM was also based on the expectation that institutional controls will be established to prohibit potable use of groundwater on-Site within impacted portions of the Site. In addition, institutional controls will be necessary to ensure the long-term protectiveness of caps and fencing associated with the DAs.

Specific long-term land use has not been determined but any Site use will be consistent with the limitations described above. A Site redefinition is currently under review by EPA and DENR. The “Existing Site” (the Site as it is currently defined) consists of approximately 1,065 acres. The “Redefined Site” is the portion of the Site to be retained as part of the newly defined CERCLA Site and consists of approximately 535 acres and is inclusive of affected areas of the Site and an additional buffer. The “Excluded” portion of the site, defined as the unaffected portion of the Existing Site to be removed or excluded from the redefined CERCLA Site, consists of approximately 530 acres. In consideration of the Site Redefinition, Chemtronics, Inc., the property owner, proposes to include a restriction in the deed as follows:

- The Redefined Site and the Excluded portion of the Site will be used only for non-residential purposes
- Groundwater beneath both the Redefined Site and the Excluded portion of the Site will not be used for potable purposes

These deed restrictions will apply to the Site, regardless of ownership, and are intended to eliminate potential future residential exposure pathways. In accordance with the 2008 AOC, the subject deed restrictions, as described above, will be submitted to EPA within 90 days after approval of the RI and be recorded within 90 days after EPA approval of the deed restrictions.

Finally, the preliminary CSM was based on the expectation that off-Site land use and groundwater use around the Site would remain unrestricted. Consistent with these assumptions, the SMS is focused on preventing off-Site migration of groundwater plumes, preventing exposure of off-Site receptors to contaminated groundwater and surface water, and evaluating the practicability and appropriateness of additional measures to ensure long-term protection of off-Site receptors.

1.4 Remedial Action Objectives

Preliminary RAOs identified in the Work Plan provide medium-specific goals for protecting human health and the environment. Preliminary RAOs developed in the Work Plan are listed below:

1.4.1 **Soil**

1. Prevent ingestion, dermal contact, and inhalation by human receptors of carcinogenic and non-carcinogenic contaminants from surface and subsurface soil at concentrations that pose an unacceptable risk
2. Prevent soil contaminants from leaching to groundwater at concentrations that result in ongoing groundwater concentrations above the remedial standards established for the Site
3. Prevent terrestrial ecological contaminant exposures to surface soil that result in adverse impact to the survival and reproductive abilities of mammal and bird populations

1.4.2 **Groundwater**

1. Restore the quality of degraded groundwater, where feasible and necessary, to protect human health and the environment, meet the North Carolina groundwater quality standard (Title 15A, North Carolina Administrative Code [NCAC], Subchapter 2L standard [2L standard]), and permit beneficial use of groundwater (including use as a future source of drinking water)
2. Prevent ingestion, dermal contact, and inhalation by human receptors of carcinogenic and non-carcinogenic contaminants in groundwater at concentrations that pose an unacceptable risk
3. Prevent migration of contaminated groundwater to on-Site surface water and sediments at concentrations that pose an unacceptable human health or ecological risk
4. Prevent migration of contaminated groundwater to off-Site surface water at concentrations causing an exceedance of the North Carolina surface-water quality standard (Title 15A, NCAC, Subchapter 2B standard [2B standard])
5. Prevent migration of contaminated groundwater to surface water and sediments at concentrations that pose an unacceptable human health or ecological risk

1.4.3 **Surface Water and Sediment**

1. Prevent inhalation, ingestion, or dermal contact of carcinogenic and non-carcinogenic contaminants by on-Site industrial workers, maintenance workers, construction workers, recreational users, and trespassers in surface water at concentrations that pose an unacceptable risk
2. Prevent ingestion or dermal contact of carcinogenic and non-carcinogenic contaminants by on-Site industrial workers, maintenance workers, construction workers, recreational users, and trespassers in sediment at concentrations that pose an unacceptable risk

3. Prevent on-Site surface water/sediment concentrations from causing on-Site or off-Site recreational users and trespassers to ingest fish containing carcinogenic and non-carcinogenic contaminants at concentrations that pose an unacceptable risk
4. Prevent inhalation, ingestion, or dermal contact of carcinogenic and non-carcinogenic contaminants by off-Site maintenance workers and recreational users in surface water at concentrations that pose an unacceptable risk
5. Prevent ingestion or dermal contact of carcinogenic and non-carcinogenic contaminants by off-Site maintenance workers and recreational users in sediment at concentrations that pose an unacceptable risk
6. Prevent contaminant exposures in aquatic systems that adversely impact aquatic organism diversity and community function or result in adverse impact to the survival and reproductive abilities of mammal and bird populations

1.5 Technical Approach

The technical approach for performing the RI was described in detail in the Work Plan. RI tasks included selecting medium-specific COPCs, sampling various on-Site environmental media (soil, groundwater, surface water, and sediment), updating the survey of off-Site potential groundwater receptors, sampling off-Site water supply wells, performing a BRA, and preparing this RI report.

1.5.1 **Selection of Site COPCs**

Section 4 of Volume 1 of the Work Plan described the detailed evaluation process that was used to develop an initial list of COPCs for each media (soil, groundwater, surface water, and sediment).

Soil COPCs were selected based on available manufacturing process knowledge, chemical usage information, and historical Site investigation data. Specific soil COPCs selected for analyses varied by area but consisted of VOCs, SVOCs, nitroaromatics, perchlorate, pesticides/herbicides, metals, CS, BZ, and cyanide.

Groundwater COPCs were selected based on a review of known Site chemical usage, results of previous sampling activities, and readily available analytical methods. Groundwater COPCs selected for analyses included VOCs, SVOCs, nitroaromatics, and perchlorate, as well as CS, BZ, metals, pesticides/herbicides, methanol, ethanol, organic acids, ammonia, chloride, cyanide, nitrate, nitrite, sulfate, and sulfide.

Surface water COPCs were selected based on a review of the results of previous sampling activities. Surface water COPCs selected for analyses included VOCs, nitroaromatics, perchlorate, metals, pesticides, chloride, and hardness.

Because sediment had not been comprehensively sampled during previous investigation activities, a broad suite of sediment COPCs including VOCs, SVOCs, nitroaromatics, perchlorate, pesticides, CS, BZ, and metals was selected for analyses.

1.5.2 **Update of Potential Groundwater Receptor Survey and Sampling of Off-Site Wells**

The various hydrogeologic evaluations performed at the Site have identified that the downgradient direction for aquifer systems underlying the Site is toward the south-southeast. In 2003 and 2004, consistent with DENR guidance, a groundwater receptor survey was performed to identify wells and springs within one-quarter mile (1,320 feet) of the southern half of the Site. To be conservative, the survey was extended to a distance of 1,500 feet. Thirty-four potable wells and three springs were identified and sampled. Results from that sampling event did not detect any Site-related compound in the wells or springs sampled. The survey of potential groundwater receptors was updated during the RI consistent with the methodology described in the approved Work Plan. The survey identified four new potable wells in use within 1,500 feet of the downgradient (south-southeast) property boundary. Those wells were sampled for VOCs, nitroaromatics, and perchlorate as specified in Section 2.1.1 of the Work Plan (Volume 2, Field Sampling and Analysis Plan). No nitroaromatic compounds or perchlorate were detected. One VOC, chloroform, was detected in three of the private wells at concentrations significantly below the 2L standard. As discussed in Section 6.4 of the Phase I Technical Memorandum, chloroform is commonly formed during water treatment as a degradation product of chlorine, which is commonly used to disinfect water supply wells. The private wells were completed in fractured bedrock to depths equivalent to on-Site bedrock monitoring wells. The bedrock zones are monitored as part of the Site groundwater monitoring network.

The potable wells that were sampled during the RI are listed on Table 1-2 and shown on Figure 1-5. A similar groundwater receptor survey was performed in 2009 by MACTEC for the Radio Shack Corporation facility located to the south of the Site. The MACTEC groundwater survey identified no additional groundwater receptor wells in the area 1,500 feet to the southeast of the Site.

1.5.3 **On-Site Sampling**

Soil, groundwater, surface water, and sediment sampling was performed on-Site during the RI. The criteria for selecting sample locations for each media were presented in Section 4.1 of Volume 2 of the Work Plan.

The sampling scope of work for soil utilized a biased-sampling program (as described in Section 4 of Volume 2 of the Work Plan and the materials provided in Appendix A of Volume 2 of the Work Plan) in which samples were collected from locations where Site COPC concentrations were expected to be highest.

The sampling scope of work for groundwater used an iterative approach to evaluate data collected during the RI and to refine the understanding of the distribution of Site COPCs in groundwater. The primary objectives were to identify potential source areas where Site COPCs were entering the groundwater system and to delineate the extent of Site COPCs sufficient to support the BRA.

Surface water and sediment sampling was performed to confirm the results of previous investigations and to support the BRA.

1.5.4 **BRA**

To quantify the potential risks to human health and ecological receptors from Site COPCs, a BRA was performed. Potential exposures to soil, groundwater, sediment, surface water, and air were evaluated in the BRA in accordance with the process specified in Section 9.5 of Volume 1 and Volume 4

("Ecological Risk Assessment Work Plan") of the Work Plan. The BRA was performed in an iterative manner using data collected during each phase of the RI to refine subsequent data collection activities.

1.6 Summary of RI Activities

The RI fieldwork was completed in three phases which were performed between December 2009 and September 2012. Following each phase, data objectives were evaluated for completeness, and the understanding of Site conditions was updated. Data gained from the phased RI activities were used iteratively to identify data gaps and develop the scope of subsequent investigation phases. A detailed description of the methods and results of each phase of work is included in Section 3 of this RI Report. A substantial amount of assessment and characterization work was completed during multiple phases of the RI, including:

- An off-Site potential receptor survey was completed, and eight potable wells were sampled (the wells are identified on Figure 1-5).
- A total of 541 soil samples were collected from 290 soil sampling locations within 45 areas (locations of the soil samples are shown on Figure 1-6).
- Fifty-six monitoring wells were installed to supplement the existing Site monitoring well network (the locations of all the Site groundwater monitoring wells are shown on Figure 1-4).
- Groundwater samples were collected one time or more from 175 on-Site monitoring wells.
- Surface water and sediment samples were collected from 53 locations (the locations of surface water and sediment samples are shown on Figure 1-7).
- Laboratory analyses were performed on soil, groundwater, surface water, and sediment samples.
- Data verification and validation were performed on the laboratory analytical results.
- The BRA was prepared and is included in this RI Report.
- This RI report was prepared.

1.7 Report Organization

This RI Report is organized as follows:

Executive Summary—Provides an overview of the RI process, findings, and conclusions

Section 1—Introduction—Provides a description of the project objectives, Site history, Site RAOs, SMS, and the technical approach that was utilized to complete the RI

Section 2—Geologic and Hydrologic Framework—Describes the regional and Site geology and hydrology

Section 3—Field Investigation—Provides a detailed description of each phase of fieldwork, including a summary of recommendations for the subsequent phase

Section 4—Nature and Extent of Site COPCs—Summarizes the RI data per media (soil, groundwater, surface water, and sediment) and describes the nature and extent of Site COPCs in each media

Section 5— Routes of COPC Migration and Transport—Provides a description of the sources of Site COPCs, migration and transport pathways, and a brief introduction to the potential human and ecological receptors evaluated in the BRA

Section 6—Human Health Risk Assessment—Describes the methodology and results of an HHRA performed as part of the BRA

Section 7—Ecological Risk Assessment—Describes the methodology and results of an ERA performed as part of the BRA

Section 8—Site Redefinition – Provides a discussion of the proposed redefinition of the CERCLA Site boundary

Section 9—Summary and Conclusions

Section 10—References

2.0 Geologic and Hydrologic Framework

This section describes the regional and Site-specific geologic and hydrologic framework. This description is based on published literature and geologic maps for the region, as well as Site-specific data developed during numerous field investigation activities performed from 1983 to the present.

2.1 Regional Geologic Setting

The Site lies within the Blue Ridge Physiographic Province (Horton and Zullo 1991). This Province extends northeast to southwest from Pennsylvania to Alabama, but reaches its greatest width in the segment of the southern Appalachians encompassing Tennessee, the Carolinas, and northern Georgia. The Blue Ridge Province is predominantly composed of igneous and metamorphic rocks that were formed between 360 and 1,600 million years ago. The rocks have been complexly folded and faulted in a northeasterly direction, parallel to the regional trend of the mountains. The major rock units occur as northeast trending belts with northeast and northwest tectonically derived fractures. These structural imprints are reflected in the topographic and drainage patterns within the region.

2.1.1 Regional Lithology

The predominant rock types in the area are high-grade metamorphic rock of the Ashe Metamorphic Suite. These rocks were initially deposited as mudstones and sandstones and, to a lesser extent, mafic volcanic rocks, which were subsequently metamorphosed during the late Proterozoic Era approximately 570 million years ago. The sandstones and mudstones were metamorphosed resulting in the following metamorphic rock types, including:

- Metagraywacke: a gray to dark gray, medium- to coarse-grained gneissic rock with bands of the minerals plagioclase and quartz alternating with bands of the platy minerals biotite and muscovite
- Schistose metagraywacke: a gray to dark gray garnet-muscovite schist with a medium- to coarse-grained texture consisting of muscovite, quartz, chlorite, plagioclase, biotite, and garnet, arranged in a sub-parallel orientation

Interlayering occurs at a scale from several inches to miles, with areas of predominantly metagraywacke and other areas of predominantly schistose metagraywacke.

Amphibolite, a metamorphic mafic volcanic rock, occurs as a very minor rock type throughout the region. Amphibolite is a dark green to black, strongly foliated rock consisting of predominately hornblende and plagioclase, with minor amounts of garnet and epidote (North Carolina Geologic Survey [NCGS] 2005).

2.1.2 Regional Structural Geology

All three of the rock types described in Section 2.1.1 exhibit foliation, which is a planar structure produced by alignment or compositional banding of minerals that make up the rock. On both a regional and local basis the foliation is generally parallel to the northeasterly orientation of the Blue Ridge Province. The foliation strike, or compass bearing, is predominantly to the northeast, whereas the foliation dip, or the angle and direction of inclination relative to a horizontal plane, varies throughout the area. Folds within the rock formations are the primary influence on foliation dip direction and angle.

Joints and fractures strike either northeasterly, which is parallel to the regional orientation of the major folds and foliation, or northwesterly, which is sub-perpendicular to the regional orientation of the foliation and fold axis. This directionality reflects the tectonic history of the region. The direction of dip angle of the joints is highly variable due to the complex regional folding and faulting. Major lineations, including large-scale features (such as stream and ridge alignments), which are controlled by rock type or zones of structural weakness (such as joints or fractures), also trend along two primary directions: northeast and northwest.

There are no known major geologic faults or shear zones exposed at the surface within 2 miles of the Site. The Brevard Fault Zone, a major geologic boundary separating the Blue Ridge Province from the Piedmont Province, lies about 7 miles south of the Site.

2.1.3 Regional Hydrology

Groundwater in the Blue Ridge Province occurs primarily in complex hydrogeologic terranes that consist of metamorphosed igneous, sedimentary, and volcanic rocks. Rocks within these terranes have undergone multiple deformations and often are interlayered at varying scales (inches to miles) (DENR, Groundwater Bulletin 2011-01). Many researchers have described groundwater within the Blue Ridge Province as occurring in a two-part flow system consisting of: (1) relatively shallow flow through alluvium and regolith, and (2) flow through deeper bedrock fractures. However, some researchers have referred to a three-part flow system in which a highly permeable transition zone between the regolith and the underlying bedrock is defined as a separate unit.

In the three-part system, the uppermost groundwater generally occurs in regolith, which consists of soil and saprolite (soft, highly weathered, decomposed bedrock) with localized areas of alluvium (material deposited by streams or rivers) or colluvium (materials deposited by gravity-induced downslope movement). Saprolite is generally the most prevalent component of the regolith and is formed through processes of chemical and mechanical weathering of the underlying bedrock. It is typically composed of clay and coarser granular material up to boulder size and often contains texture reflecting relic structures of the parent rock from which it was formed (LeGrand 2004). The thickness of the uppermost groundwater system varies according to the type of underlying rock, slope, and geologic history.

The transition zone between the regolith and the underlying competent, fractured bedrock is typically composed of partially weathered rock (PWR) and is a zone of relatively high permeability. The PWR is formed as a result of incomplete mechanical and chemical weathering of the parent bedrock and may be composed of rock fragments of varying size. Generally the PWR contains less clay than the overlying regolith (LeGrand 2004). The transition zone has a relatively high permeability resulting from the incomplete mechanical and chemical alteration of the underlying bedrock. The thickness of the transition zone is highly variable depending on underlying rock type, geochemical, and tectonic processes. Locally the boundary between the transition zone and the underlying bedrock may be gradational.

Groundwater in the bedrock system occurs primarily within fractures or, to a much lesser extent, foliation. The bedrock system has little or no primary porosity and, consequently, little storage. In the bedrock system, groundwater flow is dependent on the number, size, and orientation of fracture openings and the interconnectedness between the fracture network and the overlying transition zone and regolith. Generally, the size and frequency of bedrock fractures decrease with depth.

Groundwater recharge is from precipitation infiltrating into the regolith. Groundwater held in storage in the regolith or transition zone provides recharge to the underlying bedrock fracture system. Vertical hydraulic gradients are generally downward in recharge areas and upward in discharge areas. Typically, recharge occurs in upland areas and discharge occurs in lowland areas, resulting in surface water discharge at springs and seeps and along stream banks or surface ponds.

LeGrand (2004) describes the groundwater and surface water flow patterns in the Blue Ridge Province as interconnected and strongly influenced by local topography. This hydrogeologic system has been described as a Slope-Aquifer System where both surface water and the interconnected groundwater system are constrained by topographic divides (LeGrand 2004). This model depicts discrete groundwater basins essentially mimicking the local watershed basins.

According to LeGrand, groundwater discharge constitutes the majority of annual stream flow. Under natural flow conditions, groundwater in the regolith, the transition zone, and the underlying bedrock eventually discharges to surface water. Some groundwater moves laterally in the regolith and discharges directly to local surface water bodies. Other flow paths may include recharge of the underlying fractured bedrock in upland zones and eventual discharge to surface water in local or remote lowland zones. In other words, groundwater flows from zones of recharge (high head pressure) to zones of discharge (low head pressure). Seasonally, evapotranspiration may have a significant influence on total groundwater discharge.

2.2 Site Geology

The geology of the Site is typical of that found in the Blue Ridge Province and consists of regolith (primarily soil, alluvium, and saprolite) overlying a partially weathered and fractured bedrock transition zone (i.e., the PWR), which grades into competent bedrock with depth. A typical stratigraphic column for the Site was developed based on the review of the geologic logs from borings drilled at the Site (see Figure 2-1). Detail on the location and thickness of the lithologic units at the Site are included on the cross-sections included in this report (Figures 2-4 through 2-12). Figures 2-2 and 2-3 show the locations of the cross-sections for the Front Valley and Back Valley, respectively.

2.2.1 **Site Lithology**

2.2.1.1 Regolith

In Western North Carolina (WNC) and other parts of the southern Appalachians, most of the regolith is composed of saprolite, derived from in-place weathering of bedrock, with some localized alluvium or colluvium present in the regolith. Components of regolith on-Site are described below.

2.2.1.1.1 Soil

Soil at the Site is primarily the result of final in-place weathering of underlying bedrock and the decomposition of organic matter. The majority of the soil at the Site was formed by decomposition, disintegration, and mixing of the underlying saprolite with decomposing organic matter.

Site soil grades downward from dark brown organic rich material to soil that is typically red-orange in color as a result of the weathering and oxidation of ferro-magnesium minerals such as biotite and garnet. Silicate minerals that are resistant to weathering and chemical alterations, such as quartz and muscovite, are represented as very fine to medium sand and silt-sized grains. Relic structures of the parent rock, such as foliation, are absent in soil, although highly weather-resistant quartz veins are sometimes present. The high percentage of clay, silt, and fine sand-sized particles suggests that the permeability of the soil is relatively low. The thickness of soil at the Site is generally less than 3 feet and, as a result, soil is not specifically identified on the cross-sections.

2.2.1.1.2 Alluvium and Colluvium

Locally, alluvium or colluvium exists along stream channels or as isolated deposits on low angle slopes, respectively. Areas of alluvium are identified on the cross-sections shown on Figures 2-5, 2-6, and 2-7. In general, alluvium at the Site is gray and consists primarily of fine to coarse sand with varying amounts of silt and gravel. Alluvium has a relatively high permeability and hydraulic conductivity. Colluvium exhibits many of the characteristics of the parent material(s) but may have less internal cohesion and a higher relative permeability. Colluvium is not identified as a separate unit on the geologic cross-sections prepared for this report.

2.2.1.1.3 Saprolite

Saprolite is a highly weathered and thoroughly decomposed rock formed by in-place chemical weathering of igneous or metamorphic rocks. The material is unconsolidated and soil-like but still retains the relic structure present in the parent rock. Saprolite was observed in nearly all of the borings at the Site with a thickness generally ranging from 2 to 65 ft. However, saprolite approaching 100 feet in thickness was documented at several locations at the Site. The grain size in saprolite is a function of the composition and proximity to the underlying parent rock. In general, saprolite becomes coarser-grained and less clay-rich with depth. Furthermore, the grain size is coarser in quartzitic bands and finer in micaceous bands. The high percentage of clay, silt, and fine sand-sized particles, along with the relict structure, results in variable horizontal and vertical permeability within the saprolite.

2.2.1.2 Transition Zone

The transition zone underlies the regolith at the Site and comprises the PWR. The transition zone is generally about 5 to 30 feet thick, but locally may be as thick as 65 ft. PWR overlies the highly fractured uppermost bedrock and varies in thickness depending on the parent rock type and the degree of localized fracturing in the parent rock. The PWR at the Site resembles the parent rock (e.g., metagraywacke or amphibolite) in grain size and color, but is generally more friable. Locally, thin layers of more resistant bedrock are occasionally found within the transition zone.

The primary minerals within the PWR are quartz, feldspar, and biotite. Iron staining of the grains is sometimes present, and foliation is apparent. Clay mineral development is minimal, and the unit is thought to be moderately permeable. The transition zone formed from weathering of the amphibolite is darker in color and tends to be thicker than the transition zone formed from metagraywacke or schistose metagraywacke. This thickening of the transition zone in association with amphibolite is illustrated on the cross-sections shown on Figures 2-4 and 2-6.

2.2.1.3 Bedrock

As discussed in Section 2.1.1, the predominant bedrock types underlying the Site are metagraywacke and schistose metagraywacke. These rock types have alternatively been identified as muscovite-biotite gneiss and garnet-muscovite schist during previous Site investigation activities (Metcalf & Eddy 1987b). Lesser amounts of amphibolite are locally present on-Site.

The weathering of the bedrock at the Site is dependent on the mineralogy of the parent rock in addition to other geochemical conditions and tectonic processes. Amphibolite weathers more easily than the metagraywacke or the schistose metagraywacke, and as a result amphibolite weathers to a greater depth. In addition, the schistose metagraywacke weathers more easily than the metagraywacke and so weathers to a greater depth. This results in an uneven bedrock topographic surface and a variable thickness of the transition zone. The uneven top of bedrock topography is illustrated on the cross-sections shown on Figures 2-2 through 2-10 and on the top of bedrock topographic maps prepared for portions of the Front Valley and Back Valley and included as Figure 2-13 and Figure 2-14, respectively.

As shown on Figure 2-13, top of bedrock in the Front Valley generally decreases in elevation from the upper (northwest) portion to the lower (southeast) portion of the Front Valley. However, a prominent bedrock ridge separates the upper Front Valley from the lower Front Valley. In addition, a top of bedrock depression is present in the upper Front Valley. This depression, and the adjacent ridge, may restrict groundwater flow in the transition zone between the upper and lower Front Valley. The top of bedrock topography in the lower Front Valley is characterized by several localized mounds and depressions. These mounds and depressions also may locally influence groundwater flow in the transition zone.

The top of bedrock topographic map for the Back Valley is shown on Figure 2-14. The top of bedrock contours for the Back Valley map are limited to those areas where borings were drilled that intercepted the top of bedrock with a reasonable level of confidence in the geologic interpretation. In the area shown, the top of bedrock elevation generally decreases down-valley. However, a localized bedrock depression is apparent in the area directly south of the AP. This depression may locally influence groundwater flow in the transition zone.

2.2.2 **Site Structural Geology**

The structural characteristics of the bedrock include foliation and jointing (i.e., fracturing). The foliation, as measured in outcrops, ranges from north 25 degrees east to north 45 degrees east in strike and dips from 25 degrees to 65 degrees northwest (Metcalf & Eddy 1987b). These orientations are consistent with regional and local data (NCGS 2005).

Most of the fractures observed in bedrock outcrops do not extend far into the rock. Metcalf & Eddy (1987b) concluded that the data implied that fractures exist primarily near the top of bedrock and, consequently, the irregular and poorly defined fracturing and massive appearance of outcrops observed suggest that the capacity to store and transmit groundwater within the bedrock is limited by the infrequent occurrence and shallow extent of the fractures. Fracture trace mapping presented in the 1985 Draft RI/FS Work Plan (Camp, Dresser, McKee 1985) indicate surface fracture orientations are generally coincident with the major Site lineation directions, northeast and northwest.

Geophysical logging of select bedrock wells was completed on three occasions: (1) in 2003 (*Data Summary Report*, December 2006b), (2) in 2006 during the installation of bedrock wells (*Bedrock Well Installation Report*, April 2007, and (3) during this RI as described in Section 2 (Altamont 2006 and 2007, respectively). Bedrock drilling is described in detail in Section 3, and geophysical logs for bedrock wells drilled during this RI are included in Appendix B. Review of the geophysical logs, specifically video, caliper, and acoustic televiewer logs, indicates that generally fracture density decreases with borehole depth. However, some wells did encounter significant fractures at depth as described in Section 2.2.2.1.

Figures 2-15 and 2-16 present rose diagrams prepared using data from acoustic televiewer logs for the Front Valley and the Back Valley, respectively. The diagrams illustrate fractures in only the screened portion of screened bedrock wells and in the entire open-hole portion of a well completed with an open borehole. On a rose diagram, the direction of the pie-shaped bar represents the fracture dip direction. The width of the pie-shaped bar represents the frequency of fractures (i.e., the wider the bar the more frequent the fractures in the direction indicated). The fracture strike is 90 degrees to the dip direction. On a regional scale, bedrock fractures tend to strike in two primary directions, northeast and northwest. However, on a local scale, bedrock fracture strike is more variable as illustrated on Figures 2-15 and 2-16.

2.2.2.1 Front Valley

Examination of Figure 2-15 suggests that the fracture patterns in the Front Valley bedrock wells fall into two categories. Well borings along the eastern property boundary, southern property boundary, and in the southeast portion of the Site consistently encountered fractures that strike predominantly northeast/southwest and dip to the northwest. These fracture patterns correlate with the primary regional trends. Conversely, the fracture patterns in well borings in the upper, northwest portion of the Front Valley are more variable, and the predominant fracture orientations do not correlate with those encountered in the southeast portion of the Front Valley and generally do not correlate well with regional trends. Fractures in the southeast (lower) portion of the Front Valley dip generally to the northwest while strike and dip of fractures in the northwest (upper) portion of the Front Valley are more variable.

More specifically, wells located in the southeast portion of the Front Valley (wells MW175-Q40F, MW177-M44F, MW202-P45EF, and MW204-L45EF) show relatively similar fracture strike orientations (Figure 2-15). In addition, each of these wells encountered a prominent, nearly horizontal water-bearing fracture at about 2,000 ft-msl elevation which is about 250 ft below ground surface (ft-bgs) in that portion of the Site. As described in Section 3, water level monitoring during Phase II well drilling activities documented significant responses to aquifer stresses during drilling and packer testing in the wells screened across the fracture at 2,000 ft-msl (see Section 3.12 and Appendix A of the Phase II Technical Memorandum). The consistent orientation of the fractures in the screened portion of these boreholes and the response to pumping stresses suggest an interconnected water-bearing fracture system exists in the lower Front Valley at approximately 2,000 ft-msl.

The fracture orientations are much more variable in both depth and orientation in the upper, northwest portion of the Front Valley (Figure 2-15). Deeper fractures in the upper portion of the Front Valley are either absent or do not appear to be directly interconnected with those in the lower portion of the Front Valley. For example, during drilling of MW227-J39EF, water-bearing fractures were encountered at depths to 138 ft-bgs (elevation 2,124 ft-msl) but no water-bearing fractures were encountered below 138 ft to a total depth of 283 ft (elevation 1,979 ft-msl). A nearby well, MW229-L41EF, installed to the southeast of MW227-J39EF, did encounter a water-bearing fracture at around the 2,000-ft-msl elevation. However, the wells in the southeast portion of the Site that are screened across the prominent fracture encountered at 2,000 ft-msl (described above) did not respond to the aquifer stresses that were induced during the drilling of MW229-L41EF. This suggests that the prominent water-bearing fractures identified in the lower Front Valley do not extend to the northeast up the Front Valley to the location of MW229-L41EF.

A surface seismic refraction study performed in 2002 by ECS Mid-Atlantic, LLC *(Data Summary Report*, December 2006) identified a possible geologic discontinuity at a location between the lower, southeast Front Valley and the upper, northwest Front Valley in the vicinity of monitoring well DW152-2 (Altamont 2006). This possible geologic discontinuity appears to be coincident with the western margin of the pronounced lineament that controls the orientation of Bee Tree Creek in the proximity of the Site and the western extent of the 2,000 ft-msl fracture network. However, the referenced geophysical report noted that there was a low correlation between the seismic methods utilized for this survey and known borehole data. Therefore, the actual presence of the possible geologic discontinuity is uncertain.

2.2.2.2 Back Valley

Beneath the Back Valley, the primary fracture strike directions, which are perpendicular to the dip directions shown on Figure 2-16, also tend to group with the primary regional trends. However, numerous fractures also show orientations not concordant with the regional primary directions.

2.2.3 **Site Hydrology**

2.2.3.1 Surface Water

As discussed in Section 1.2.1, the majority of the Site is situated within two local watersheds (Unnamed Branch and Gregg Branch), and these watersheds are referred to as the Front Valley and Back Valley, respectively. The Unnamed Branch and Gregg Branch are both part of a larger, local watershed (Bee Tree Creek) and a regional watershed (Swannanoa River, Figure 1-2). Gregg Branch discharges to Bee Tree Creek on-Site, and the Unnamed Branch discharges to Bee Tree Creek off-Site (Figure 1-3).

Three ponds are situated on-Site. Two of the ponds (Ponds 1 and 2) are manmade and one (Pond 3) appears to be natural (Figure 1-3).

2.2.3.2 Aquifer Systems

Hydrogeologic conditions in the vicinity of the Site are consistent with the three-part flow system previously described for the Blue Ridge Province in Section 2.1.3. The components of this system are the regolith, the transition zone, and the underlying bedrock, all of which may locally discharge to nearby surface water bodies.

Three primary aquifer systems have been identified at the Site: the Surficial Aquifer System (which occurs in the regolith), the Transition Zone Aquifer System, and the Bedrock Aquifer System. The three aquifer systems are shown on the stratigraphic column (Figure 2-1). These three aquifer systems are interconnected but have distinctly different characteristics that influence groundwater flow and, potentially, Site COPC transport mechanisms within them.

The Surficial Aquifer System exists in the regolith and extends from the capillary fringe above the water table to the top of the transition zone. Generally, the Surficial Aquifer System behaves as an unconfined water-bearing unit. Locally however, semi-confined conditions may exist within the Surficial Aquifer System. There are numerous areas on Site where a water-bearing zone, usually defined by relict structure or lithologic variation, has exhibited confined or semi-confined characteristics. For example, in some borings completed in the Surficial Aquifer System, the groundwater rose to a higher level than where it was first encountered. Borings drilled only a few ft away did not exhibit the same characteristics. Therefore, the areal extent of these zones may be small and disconnected.

The Transition Zone Aquifer System represents the gradational shift from the bottom of the regolith, through the partially weathered rock (PWR), and into the top of the fractured competent rock. As this shift is gradational, many Site monitoring wells have been installed approximately 6 ft into the fractured bedrock to ensure that the well is screened across the lower transition zone and into the upper highly fractured bedrock. The well screens, which are typically 15 ft in length, were installed into the upper part of the fractured bedrock to intersect the zone considered to be the most transmissive and, consequently, to have the highest flow rate within the Transition Zone Aquifer System.

The Bedrock Aquifer System extends below the PWR and exists within a system of fractures in the underlying bedrock.

Previous Site documents used various aquifer and well naming conventions. Beginning in 2002, a Site-specific aquifer and well naming nomenclature was adopted which included six discrete aquifer zones (A through F) as defined in the Holistic Site Management Plan (HSMP) (Altamont 2003). This nomenclature was refined in the Work Plan to consolidate zones with similar characteristics into three predominant aquifer systems each consisting of two aquifer zones. In the current hydrogeologic framework, the Surficial Aquifer System includes Zones A and B, the Transition Zone Aquifer System includes Zones C and D, and the Bedrock Aquifer System includes Zones E and F. Figure 2-1 identifies the aquifer zones within each aquifer system.

Various well naming conventions were applied to wells installed prior to 2002 (e.g., M85L-9 or BW-14). Wells installed after 2002 use a well naming nomenclature that includes the well identification number, the Site grid location and the aquifer zone in which the well screen is installed. Wells installed after 2002 but prior to this RI (2009) have a well name that includes the discrete zone in the name (such as MW144-M44C where well MW144 is located in Site grid M44 and is screened in Zone C). The current well nomenclature uses the combined aquifer zone designation to indicate which aquifer system the well is screened in. Using the current naming convention, well MW220-L37CD is located in Site grid L37 and is screened in the Transition Zone Aquifer System (Zones C and D). Site figures prepared for this report use a color code to identify which zone or combination of zones each well is screened in.

2.2.3.3 Groundwater Flow Patterns

The Slope-Aquifer System model (see description in Section 2.1.3) developed by LeGrand was applied at the Site and utilized during historical Site investigations. The presence of discrete groundwater basins at the Site was initially presented in the *Remedial Investigation Report* (Metcalf & Eddy 1987b). Subsequent groundwater-level measurement and flow-direction analyses have refined this model for the Site. Figures 2-17 and 2-18 present generalized potentiometric-level drawings for the Surficial Aquifer System (Zone AB) and the Transition Zone Aquifer System (Zone CD) for the Front Valley. Figures 2-19 and 2-20 present similar drawings for the Back Valley. Review of these drawings suggests that groundwater flow in these aquifer systems is separate and discrete between the groundwater basins within the Front Valley (Unnamed Branch) and the Back Valley (Gregg Branch). Groundwater beneath both the Front Valley and the Back Valley flows generally down-valley toward the southeast with discharge from the Surficial Aquifer System into the Unnamed Branch, Gregg Branch, and Bee Tree Creek.

A generalized potentiometric-level surface map for groundwater in the Bedrock Aquifer System is shown on Figure 2-21. Groundwater in this system also flows toward the southeast in both the Front Valley and the Back Valley but trends to a more southerly direction and begins to parallel Bee Tree Creek as flow approaches the Bee Tree Creek watershed. This suggests that, in the area of the Site, Bee Tree Creek may not be a significant discharge point for groundwater in the lower bedrock system.

The complexity of groundwater flow within the fractured bedrock makes it difficult to support mapping of the potentiometric gradient below the ridge separating the Front and Back Valleys. Thus, the Front Valley and Back Valley contour lines shown on Figure 2-21 are not connected. However, the mapped data suggests that the deeper portion of the Bedrock Aquifer Systems in the Front Valley and the Back Valley behave similarly and may be interconnected within deeper intervals.

Monitoring of water levels in bedrock wells during drilling actively demonstrated that the degree of interconnectedness is variable. For example, well MW225-T32F was monitored during drilling of MW228-O27EF, which is located approximately 1,600 ft away (Figure 2-16). Well MW225-T32F did not show any response to drilling, which indicates that a hydraulically efficient interconnected fracture system in the bedrock system in the Back Valley does not extend to the northeast up the Back Valley to the location of MW228-O27EF.

However, BW-14, which is a flowing artesian well located about midway between MW225-T32F and MW228-O27EF, did respond during drilling of each of these wells (see Appendix C and Appendix A of the *Phase II Technical Memorandum*). During Phase II drilling of MW225-T32F, the water level in BW-14 dropped approximately 10 feet and remained at that elevation. During Phase III drilling of MW228-O27EF, the water level returned to approximately the same elevation as it was prior to the drilling of MW225-T32F. This indicates that there is some degree of hydraulic connectivity in the bedrock system between the upper and lower Back Valley.

2.2.3.4 Vertical Gradients

Potentiometric groundwater levels measured in adjacent wells screened in different aquifer systems were used to calculate vertical groundwater gradients between aquifer systems. These data were used to determine if there is the potential for vertical movement of groundwater between systems. An upward gradient indicates that groundwater could flow from a deeper aquifer system to a shallower aquifer system. Conversely, a downward gradient indicates that groundwater could flow from a shallow aquifer system to a deeper aquifer system.

Groundwater potentiometric elevations established during the groundwater-level gauging event performed between April 19 and 23, 2012, are summarized on Table 2-1 and posted on the cross-sections shown in Figures 2-2 through 2-10. As shown on these figures, groundwater elevations in adjacent well sets show differences in potentiometric groundwater elevations. Vertical gradients were calculated for select well sets by dividing the difference in measured groundwater elevations in adjacent wells by the difference in the elevations of the midpoint of the respective well screens. These vertical gradients are illustrated on Figure 2-22. The calculated vertical gradients are represented by circles of varying diameters. The circles that represent the vertical gradients are color-coded as either upward gradient (red) or downward gradient (blue). The relative diameters of the circles indicate the magnitude of the vertical gradient (i.e., the larger the diameter, the greater the magnitude).

As shown on Figure 2-22, an overall downward vertical gradient exists between all aquifer systems throughout the Site. However, there are locations where upward vertical gradients exist between some of the aquifer systems. In the Front Valley, an upward vertical gradient was measured between the

Transition Zone Aquifer System and the Surficial Aquifer System in the vicinity of wells MW180-H38AB and MW200-H38CD. In the Back Valley, upward vertical gradients were measured between the Transition Zone Aquifer System and the Surficial Aquifer System in the vicinity of wells MW149-O28C and MW168-O28B and between the Bedrock Aquifer System and the Transition Zone Aquifer System in the vicinity of wells MW172-T32E and MW172-T35D. Additionally, flowing artesian conditions exist in well BW-14 (Figure 1-4) located in the mid reach of the Back Valley. (Note: Vertical gradients in the upper part of the Back Valley were measured while the Back Valley groundwater extraction system was in operation. This may have had a localized effect on the measured vertical gradients.)

The general trend of downward vertical gradients beneath the Site, especially in the lower reaches of the Front Valley, indicates that groundwater in the Bedrock Aquifer System in the Front Valley may not completely discharge to Bee Tree Creek. Locally, upward flow from the Bedrock Aquifer System in the Back Valley may be discharging to Bee Tree Creek. Overall, however, groundwater on-Site flows down-valley toward the southeast in all of the aquifer systems and there is a predominant downward vertical gradient between aquifer systems.

2.2.3.5 Groundwater Level Fluctuations

Groundwater level measurements have been recorded in select Site wells located near the Front Valley and Back Valley groundwater extraction systems since 1992. Review of the data from well sets outside the zone of influence of the extraction systems in both the Front Valley and Back Valley indicates that generally the various aquifer systems respond similarly to seasonal and annual changes in precipitation.

As discussed in the Work Plan, the total measured water-level fluctuation during the 2000 to 2008 time period varied with a range of a few feet in the Front Valley Surficial Aquifer System wells to as much as 6 feet in the Bedrock Aquifer System wells. In the Back Valley, wells in all of the aquifer systems exhibit fluctuations of 5 to 10 ft. Review of water level data collected from 2008 to September 2012 indicates more recent groundwater level fluctuations are consistent with the previous data.

2.2.3.6 Aquifer Properties

Activities to determine various aquifer properties such as hydraulic conductivity (or permeability), transmissivity, and storage coefficients were performed during the 1987 RI (Metcalf & Eddy 1987b), in 1991 for the *Final Design Analysis* (Sirrine Environmental Consultants 1991), and during Phase III of this RI. Further discussion summarizing the aquifer testing performed for this RI is included in Section 3.3.2.3. Aquifer testing during the 1987 RI consisted of slug tests on wells screened in the Surficial Aquifer System and straddle packer tests on open-hole bedrock wells. Aquifer testing during the 1991 *Final Design Analysis* consisted of stressing a bedrock well in the Back Valley and recording responses in nearby Bedrock Aquifer System and Surficial Aquifer System wells, and in the Front Valley stressing both a Bedrock Aquifer System and a Surficial Aquifer System well and recording responses in nearby Bedrock Aquifer System and Surficial Aquifer System wells. Aquifer testing performed during the current RI consisted of both step drawdown testing and a constant rate pumping and recovery test performed in a Front Valley Bedrock Aquifer System well (MW227-J39EF) and recording responses in nearby Surficial Aquifer System, Transition Zone Aquifer System, and Bedrock Aquifer System wells.

Review of results from aquifer testing indicates that locally, and to varying degrees, the three aquifer systems on-Site are hydraulically interconnected and show measurable response to stress from one aquifer system to another. The response to stress between aquifer systems was also noted during the drilling and packer testing performed during Phase II and Phase III of this RI as described in Section 3.3.2.3.

The hydraulic conductivities derived from the various aquifer test methods are summarized as follows:

- Hydraulic conductivities derived from slug test data collected from the Surficial Aquifer System ranged from 0.16 to 1.5 feet per day (ft/day) with a mean of 0.5 ft/day. Hydraulic conductivities for the Surficial Aquifer System derived from step drawdown and constant rate tests ranged from 1.1 to 2.5 ft/day (Metcalf & Eddy 1987b).
- Bedrock Aquifer System hydraulic conductivities from packer testing in bedrock wells ranged from 1 x 10^{-3} ft/day to 4 ft/day. Hydraulic conductivities derived from a constant rate pumping test for the Bedrock Aquifer System ranged from 9.4 x 10^{-7} ft/day to 2.8 x 10^{-4} ft/day with an average of 1.55 x 10^{-4} ft/day for the bedrock matrix and 0.14 to 1.36 ft/day for the fractures with an average of 0.88 ft/day.

2.2.3.7 Groundwater Flow Velocities

Average groundwater flow velocity can be estimated for the aquifer units for which sufficient hydraulic conductivity data are available. Using aquifer system specific-groundwater gradients derived from the potentiometric level maps included as Figures 2-17 through 2-21 and the average hydraulic conductivities discussed above, estimates of groundwater velocity can be derived using the following relationship:

$$V=Ki/n^e$$

where K is hydraulic conductivity, i is the local groundwater gradient, and n^e is the effective porosity of the material through which the groundwater is flowing (Driscoll 1986).

Groundwater velocities for the Surficial Aquifer System in the Front Valley are estimated to be 0.24 ft/day in the upper Front Valley and 0.1 ft/day in the lower Front Valley. These estimates were derived using an average hydraulic conductivity of 1 ft/day, gradients of 0.026 and 0.05 respectively, and a value of 0.21 for the effective porosity. This effective porosity value was obtained from a published value for fine sand in *Applied Hydrogeology* (Fetter 1994).

Groundwater velocities for the Surficial Aquifer System in the Back Valley are estimated to be 0.19 ft/day in the upper Back Valley and 0.14 ft/day in the lower Back Valley. These estimates were derived using an average hydraulic conductivity of 1 ft/day, gradients of 0.03 and 0.04 respectively, and a value of 0.21 for the effective porosity.

The estimated groundwater velocities for the Surficial Aquifer System are within the range of groundwater velocities calculated at the nearby Bent Creek Research Station (DENR, Groundwater Bulletin 2011-01), which has similar hydrogeologic conditions. Groundwater velocities at the Bent Creek Research Station range from 0.01 to 1 ft/day with a median value of 0.1 ft/day.

Previous aquifer testing results included in the Metcalf and Eddy (1987) and SEC (1991) reports provide some estimates for Site-specific aquifer properties for the Transition Zone and Bedrock Aquifer systems. However, these values are highly variable and do not allow a reliable estimate of Site specific groundwater flow velocities. Hydrogeologic investigation at the Bent Creek Research Station indicated a groundwater flow velocity for the Transition Zone Aquifer system of 0.2 to 20 ft/day, with a median of approximately 2 ft/day. However, as noted in the hydrological investigation report, actual velocities at any given location will depend on local geology and topography.

Groundwater velocities for the Bedrock Aquifer System are dependent on the number and interconnectedness of the bedrock fractures, and, as such, standard groundwater flow equations cannot be used to estimate groundwater velocity for fractured bedrock systems.

3.0 Field Investigation

The RI Field Investigation activities were completed in general accordance with the Work Plan. The Companies, Altamont, and ENVIRON jointly developed the Work Plan to achieve all requirements of the AOC and its associated SOW. The Work Plan describes the holistic, comprehensive approach that was used to investigate the Site. A preliminary understanding of Site conditions was developed at the Work Plan stage, and data gaps were identified based on a review of the entire Site operational history as well as data collected during investigations performed prior to the preparation of the Work Plan. The Work Plan defined a phased, iterative approach to identify data gaps and refine the understanding of the Site. The scope of work for each subsequent investigative phase of the RI was designed to address residual data gaps.

The Work Plan described the methods to: (1) collect soil, groundwater, surface water, sediment, and potential receptor data, and (2) perform the BRA, which includes an ERA.

The Site investigation approach presented in the Work Plan was premised on the need to obtain sufficient data to characterize the nature and extent of the COPCs found at the Site in sufficient detail to support the BRA as required under the SOW and to investigate the Site on a holistic, comprehensive basis.

During the RI, the primary focus was on the collection of data necessary to verify that no potentially unacceptable Site-related risks or adverse environmental impacts exist off-Site and to identify on-Site locations where Site COPCs would pose a potential unacceptable risk based on RME under current or future land use or where an adverse environmental impact exists that would warrant developing and evaluating remedial alternatives. The collection of data to support these RI objectives was performed in phases of field investigation in order to focus sampling efforts and increase the efficiency of the investigation. The SMS described in detail in the Work Plan and summarized in Section 2 envisioned that Site characterization activities would be fully integrated with the identification of potential risks and environmental impacts that warrant remedial action and that estimates of exposures and associated impacts on human and ecological receptors would be refined throughout the phases of the RI as more data were obtained (40 Code of Federal Regulations [CFR] 300.430[d]).

To focus sampling efforts and increase efficiency, Site characterization activities in each phase of the field investigation were designed to collect data so that reliable management decisions could be made as early in the RI as possible. For example, after each round of soil sampling, the data were analyzed using a screening-level risk assessment process, in which upper-bound estimates of the RME for each relevant exposure pathway and receptor at a particular exposure unit were calculated using the highest concentrations of detected COPCs within the exposure unit. Similar screening evaluations were also performed for ecological receptors.

The soil sampling program described in the Work Plan was designed to address known and potential release mechanisms at the Site, including the following:

- Potential leaks, releases, and/or discharges from sumps formerly used to manage manufacturing process wastewaters to the adjacent surface or subsurface soils
- Possible discharges from building drains and trenches directly to surface or subsurface soils
- The historical discharge of Site COPCs into wastewater ditches and other conveyances that led to surface waters at the Site, including the Unnamed Branch

- Possible releases and spills of Site COPCs at or near former buildings, manufacturing locations, and testing sites
- Potential releases to surface and subsurface soil from areas previously used to store or dispose of process equipment and/or various types of waste

The Phase I soil sampling scope of work was designed using a biased-sampling program (as described in Section 4 of Volume 2 of the Work Plan and the materials provided in Appendix A of Volume 2 of the Work Plan) in which soil samples were collected from locations where Site COPC concentrations were expected to be highest (e.g., likely discharge points from sumps, collection points in ditches that formerly carried industrial wastewater, etc.). Soil COPCs selected for analyses were based on available manufacturing process knowledge, chemical usage information, and historical Site investigation data. Specific soil COPCs selected for analyses varied by area but consisted of all or a subset of VOCs, SVOCs, nitroaromatics, perchlorate, pesticides/herbicides, metals, CS, BZ, and cyanide.

Extensive information on the operational history of each area was provided in Volume 2 of the approved Work Plan (Field Sampling and Analysis Plan) and was used as a basis for selection of specific sampling locations and thus to support the development of the overall RI sampling activities. The area-specific information is organized with tab dividers labeled with each area’s identifier and includes the operational history of the area, descriptions of buildings and waste management areas contained in previous investigation reports, historic photographs of the area, and building slab penetration maps that were prepared prior to building demolition activities.

Soil data collected during each phase of the RI were evaluated both qualitatively and quantitatively to determine whether the data were sufficient to support the BRA. Soil data were assessed qualitatively by examining features of the data that are less amenable to a quantitative assessment. For example, the sampling data were evaluated based on key qualitative criteria, such as (1) unexpected trends in the vertical or horizontal distribution of Site COPCs, (2) unusual or inconsistent field screening measurements, (3) unusually high quantitation limits or large variances in the data from duplicate pairs, and (4) data that were inconsistent with the known historical operations and/or chemical usage in a particular sampling area, among others. The results of the qualitative data assessment were used in conjunction with the results of the screening-level risk assessment to reach decisions about the need for additional data collection at the conclusion of each phase of the RI.

In the quantitative data assessment, the highest COPC concentrations from the biased sampling data for each area were used in a screening-level risk assessment to calculate upper-bound risk estimates to conservatively predict whether the BRA would ultimately determine that the area warrants remedial action if no additional data were collected. The upper-bound risk estimates for each area were then compared to EPA’s acceptable risk limits for carcinogens and non-carcinogens as described, for example, in the April 22, 1991 memorandum by Mr. Don Clay (former Assistant Administrator of EPA) (EPA 1991a), to determine whether additional sampling in a particular operational area was warranted. If this conservative simulation of the HHRA showed that an area did not warrant remedial action (i.e., the upper-bound cumulative cancer risk and HI did not exceed 1×10^{-4} and 1, respectively), then it was concluded that further sampling of the area was not necessary and the area was not included in the next phase of field investigation. Conversely, if the simulation showed that remedial action would be warranted (i.e., the upper-bound cumulative cancer risk and/or HI exceeded 1×10^{-4} or 1, respectively), then additional sampling was proposed for the next phase of field investigation to further evaluate the area. Similar simulations were performed for ecological receptors in the screening-level ecological risk assessment (SLERA) in which the need for additional sampling in areas with Hazard Quotients (HQs) greater than 1 was evaluated. In addition, such results were used in assessing whether the development of remedial alternatives in the FS should be initiated. In some cases, interim actions were performed to achieve significant risk reduction quickly or to expedite progress toward completing remediation of that area (e.g., soil excavation at Area B122).

The Site groundwater investigation focused on collecting data to evaluate the potential on-Site exposures, off-Site exposures, impacts to surface water, and to support remedial alternatives evaluation. Well locations were selected to improve the understanding of groundwater quality, flow characteristics, groundwater/surface-water interactions, or vapor intrusion potential, as appropriate. Monitoring well installation and groundwater sampling were performed in each phase of the RI. The results of these activities were used to guide subsequent phases of the RI until sufficient data had been collected to identify source areas of groundwater impacts and support the BRA. A chronological summary of sampling activities performed in each well during various sampling events is included in Table 3-1.

As discussed in Section 4.2.1 of Volume 1 of the Work Plan, the first set of groundwater samples collected from each monitoring well installed during each phase of the RI was analyzed for a comprehensive suite of groundwater analytes (VOCs, SVOCs, nitroaromatics, and perchlorate, as well as CS, BZ, metals, pesticides, herbicides, methanol, ethanol, organic acids, ammonia, chloride, cyanide, nitrate, nitrite, sulfate, and sulfide). As described in Section 1, these analytes were selected based on a review of known Site chemical usage, results of previous sampling activities, and readily available analytical methods. This suite of analyses was used to confirm the appropriate COPCs in groundwater and to locate any previously unidentified potential COPCs.

Groundwater data collected during each phase of the RI were evaluated both qualitatively (as described above) and quantitatively to determine whether the data were sufficient to support the BRA. In the quantitative data assessment, groundwater results for each of the 175 monitoring wells sampled during the RI were evaluated in the BRA (Section 6). The evaluation conservatively used the highest detected concentration for each Site COPC for each well from the entire set of RI and recent pre-RI data (since June 2007).

Surface water sampling during the RI was performed to confirm the surface water sampling results presented in the *2008 Site-Wide Groundwater and Surface Water Sampling Data Summary Report* (Altamont 2009a). Surface water sampling performed during the RI included sampling at 53 locations throughout the Site during both high-flow and low-flow conditions during Phase I and collection of two samples during Phase III to refine the distribution of COPCs in nearby shallow groundwater. Surface water samples were submitted for analyses for VOCs, nitroaromatics, perchlorate, metals, pesticides, chloride, and hardness. As described in Section 4.2.2 of Volume 1 of the Work Plan, these analytes were selected based on the results of previous sampling activities.

Surface water data collected during the RI were evaluated both qualitatively (as described above) and quantitatively to determine whether the data were sufficient to support the BRA. In the quantitative data assessment, surface water results for each surface water location sampled during the RI were evaluated in the BRA (Section 6). The evaluation conservatively used the highest detected concentration for each Site COPC at each location among the entire set of RI data (since June 2007).

As discussed in Section 3.4.1, results from groundwater and surface water sampling were used to develop a Site-wide monitoring program. This program includes annual sampling of groundwater and surface water for a selected suite of analytes including VOCs, nitroaromatics, and perchlorate.

Sediment sampling was performed concurrently with surface water sampling at each surface water sampling location. As discussed in the Work Plan, since sediment was not comprehensively sampled during previous investigation activities, a suite of analytes including VOCs, SVOCs, nitroaromatics, perchlorate, pesticides, CS, BZ, and metals was selected. Sediment data collected during the RI were evaluated both qualitatively (as described above) and quantitatively to determine whether the data were sufficient to support the BRA. In the quantitative data assessment, results for each sediment location sampled during the RI were evaluated in the BRA (Section 6). The evaluation conservatively used the highest detected concentration for each Site COPC at each location among the entire set of RI data.

The RI fieldwork was completed in three phases which were performed between December 2009 and September 2012. The scope of work for Phase I was described in detail in the Work Plan along with the data collection methodologies that were utilized throughout for the entire RI. The Phase I field activities, laboratory analyses, data evaluation, and data gap analyses and recommendations for Phase II investigation activities were documented in the *Phase I Technical Memorandum* dated August 27, 2010. Comments were received from EPA and DENR on September 20, 2010. Responses to the agency comments were provided in correspondence dated November 3, 2010. These responses were accepted by EPA and DENR on November 17, 2010 and a Revised Phase I Technical Memorandum was submitted on April 27, 2011. Phase II field activities, laboratory analyses, data evaluation, and data gap analyses were presented in the *Phase II Technical Memorandum* dated October 21, 2011 along with recommendations for Phase III. Comments and concurrence with the Phase II Technical Memorandum and proposed Phase III scope of work were received from EPA and DENR on November 30, 2011. Responses to the agency comments were provided on January 20, 2012. The Phase I and Phase II Technical Memoranda are included in Appendix A. The Phase III field activities, laboratory analyses, and data evaluation are presented in this RI Report. Field records, including records of soil borings, well construction details, field sampling sheets, calibration records, and survey reports are included in Appendix B.

The following sections summarize the work completed in each phase, the resultant data gaps, and the recommendations for additional investigation.

3.1 Phase I Fieldwork, Analysis, and Data Evaluation

Phase I addressed the sampling, analysis, and data evaluation procedures prescribed in the Work Plan. Deviations from the procedures defined in the Work Plan were documented in the Phase I Technical Memorandum.

Phase I fieldwork began in December 2009 and was completed in April 2010. Phase I drilling services were provided by AE Drilling Services, LLC (AE Drilling) of Greenville, South Carolina. All Phase I soil, groundwater, and investigation derived waste (IDW) samples were shipped overnight to Lancaster Laboratories Inc. (Lancaster) located in Lancaster, Pennsylvania, where they were analyzed consistent with the methods specified in Table A.4 of the Work Plan, Volume 3—QAPP. A technical review of the analytical data was performed by Lancaster as specified in Section 2.1 of the QAPP. Upon completion of the technical review, analytical data were transmitted as electronic data deliverables (EDDs) to Conestoga-Rovers & Associates (CRA) located in Niagara Falls, New York for further validation/verification using the criteria specified in Section 2.2 of the QAPP. Laboratory analytical reports for Phase I are included in Appendix C. Data verification and validation results for Phase I are included in Appendix D.

Additionally, field audits were performed to evaluate health and safety procedures and to ensure quality control. Field audit reports are included as Appendix E.

A summary of the Phase I scope and findings follows.

3.1.1 **Soil**

The Phase I soil sampling scope of work was designed using a biased-sampling program in which soil samples were collected from locations where Site COPC concentrations were expected to be highest. Phase I surface and subsurface soil sampling was completed at 45 former "operational areas" where there was reasonable potential for soil impacts. These 45 areas were defined to correspond to individual buildings or groups of buildings and related areas that had common historical processes/operations and/or were located in nearby, contiguous areas. These areas included all 14 of the SWMUs and the one area of contamination listed in Paragraph 11.z of the AOC (which are located within 9 of the 45 total operational areas). The 45 areas chosen for soil sampling were based on a comprehensive review of the available information on former chemical handling and storage practices, former operations and processes, and known or suspected past releases. If data from a previous investigation of the area were available, such data were also considered in biasing the sampling locations.

Both surface and subsurface soil samples were collected from each biased sampling location where Site COPCs were suspected to have been able to enter the subsurface. At such locations, one subsurface soil sample was collected from each boring at a depth where COPCs were likely to be found at the greatest concentrations based on field observations and/or screening measurements. For locations where field screening/observations did not identify a preferential sampling depth, the subsurface sample was collected from a depth of 5 to 6 ft-bgs, which is presumed to be typical of potential subsurface soil exposures for current and future construction or maintenance workers. In addition, within each operational area, one or two borings were installed and a second subsurface sample was obtained at a depth just above the capillary fringe of the water table in order to evaluate the possible migration of Site COPCs from soil to groundwater. By contrast, some sampling locations were designated for surface sampling only, based on indications that the suspected impacts in such areas did not involve VOCs or likely resulted solely from airborne deposition and/or surface impacts (such as areas where flares, munitions, and/or rockets were fired or tested). The Target Area and the Trajectory Path (Figure 1-6, TA and TRA, respectively) where flares, munitions, and/or rockets were fired or tested are an example of areas where only surface sampling was performed. A record of soil borings is included in Appendix B, and a summary of detected Phase I soil sample results is included in Appendix F. Phase I soil sample locations are shown on Figure 1-6.

The Phase I soil evaluation, as detailed in the Phase I Technical Memorandum, can be summarized as follows:

- Soil sampling at 45 areas consistent with the specifications defined in Section 4 and Appendix A of Volume 2 of the Work Plan, except minor variations as noted in the Section 2.1 of the Phase I Technical Memorandum
- Collection of a total of 423 soil samples from 153 boring and 78 surface sample locations
- Laboratory analysis of the soil samples for the COPCs specified in Volume 2 of the Work Plan
- Qualitative assessment of the soil data to determine whether further data collection was necessary

- Quantitative screening-level risk assessment review of the soil data to determine whether further data collection was necessary
- Evaluation of the soil-to-groundwater pathway to determine whether additional groundwater investigation was necessary

3.1.2 **Groundwater**

3.1.2.1 Well Abandonment

During Phase I, 29 monitoring wells that were poorly constructed, damaged, or unnecessary were abandoned. These wells, which were identified in the Work Plan, were abandoned in accordance with the Work Plan and with NCAC—Title 15A, Subchapter 2C .0113. Phase I well abandonment and drilling services were provided by AE Drilling, and abandonment logs are included in Appendix G.

3.1.2.2 Well Installation

As described in the Work Plan, the following 29 monitoring wells were installed, developed, and surveyed during Phase I (15 Zone AB wells, 12 Zone CD wells, and 2 Zone EF wells) to evaluate the RAOs defined for the Site:

- MW179-H35AB
- MW180-H38AB
- MW181-I37AB
- MW182-K39AB
- MW184-N38AB
- MW185-L26AB
- MW186-M25AB
- MW187-M25AB
- MW188-M27AB
- MW190-N24AB
- MW191-K40AB
- MW203-J36AB
- MW205-M27AB
- MW207-M23AB
- MW208-L26AB
- MW183-O39CD
- MW192-P41CD
- MW193-Q40CD
- MW194-Q38CD
- MW195-M27CD
- MW196-N27CD
- MW197-O25CD
- MW198-Q30CD
- MW199-R29CD
- MW200-H38CD
- MW201-I35CD
- MW206-M27CD
- MW202-P45EF
- MW204-L45EF

Figure 1-4 shows the monitoring well locations, and Table 2-1 provides monitoring well construction details, dates of installation, and groundwater elevation data. Well installation and development procedures were performed in general accordance with Section 7.2 of Volume 2 of the Work Plan, except as noted in the Section 3.1 of the Phase I Technical Memorandum. Lithologic logs and well construction diagrams are included in Appendix C of the Phase I Technical Memorandum. Well construction details and geophysical logs for the bedrock wells are included in Appendix B of this RI report.

3.1.2.3 Groundwater Sampling

Each well installed during Phase I was sampled in accordance with Section 7.5 of Volume 2 of the Work Plan, for the full suite of analytes shown below:

- VOCs
- SVOCs
- Perchlorate
- Nitroaromatics (including picric acid)
- Pesticides
- Herbicides
- Metals (Target Analyte List [TAL], excluding calcium, iron, magnesium, potassium, and sodium)
- Organic acids
- Other inorganics: ammonia, chloride, cyanide, nitrate, sulfate, and sulfide

In addition, 19 property boundary wells that had been installed prior to the RI were sampled in accordance with Sections 3.2 and 7.5 of Volume 2 of the Work Plan and analyzed for VOCs, nitroaromatics, and perchlorate. Summaries of groundwater COPCs detected during Phase I are included in Table 3-2 for the Front Valley and Table 3-3 for the Back Valley.

3.1.2.4 Data Evaluation

An extensive suite of COPCs were detected in groundwater on-Site. A complete list of the COPCs analyzed and detected is presented in Appendix D of the Phase I Technical Memorandum and Appendix H of this report. The COPCs detected in groundwater were evaluated for spatial distribution, frequency of detection, and frequency of exceedances of applicable groundwater quality standards (for example, the 2L standard). In addition, a screening-level risk assessment was completed for each analyte detected in groundwater using the highest concentration detected in each monitoring well during the 2007, 2008, or Phase I RI sampling event.

During scoping of the approved RI/FS Work Plan, background levels in groundwater were taken into consideration. Prior to the 2008 site-wide groundwater monitoring event, a statistical comparison of groundwater data from nine background monitoring wells to the data from 117 Site (non-background) monitoring wells determined that the following chemicals in groundwater are not Site-related: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, vanadium, zinc, ammonia, chloride, cyanide, nitrite, sulfate, and sulfide (see Appendix E of Volume 1 of the approved RI/FS Work Plan). The background wells were selected to represent groundwater quality from locations upgradient of any known sources of contamination and to represent different hydrologic areas and hydrogeologic zones. As a result, groundwater sampling performed during the RI did not include these chemicals, and the RI baseline risk assessment does not include these chemicals as COPCs in groundwater.

To streamline the evaluation of the distribution of Site COPCs in groundwater, both a Front Valley and a Back Valley “primary plume” were defined and contoured. These primary plumes were selected based on the following criteria:

- Frequency of constituent detections

- Concentrations of constituents
- Frequency of applicable groundwater quality standards (for example, 2L standard) exceedances

The indicator compounds selected to define the primary plume for the Front Valley were trichloroethylene (TCE), tetrachloroethylene (PCE), chloroform, 1,2-dichloroethane (1,2-DCA), hexahydro-1,3,5-trinitro-1,3,5-triazine (also known as research department explosive [RDX]), and perchlorate. Indicator compounds selected to define the primary plume for the Back Valley were TCE, tert-butyl alcohol (TBA), chloroform, 1,2-DCA, RDX, and perchlorate.

Isoconcentration maps were prepared for the Surficial Aquifer System and the Transition Zone Aquifer System for both the Front Valley and the Back Valley primary plumes. Primary plumes were delineated as the extent of contiguous areas of groundwater within which the indicator compounds are above the established Site groundwater criteria (e.g., 2L standard, interim maximum allowable concentration [IMAC], or risk-based criteria [screening value]). Data gaps were identified and recommendations for Phase II groundwater investigation activities were developed. Detailed evaluation of the full list of the groundwater COPCs detected was completed in the BRA as described in Section 6.

3.1.3 **Surface Water**

Surface water sampling and analysis was completed as specified in the Work Plan. Phase I surface water activities included the following items:

- Surface water sampling at 53 locations in streams and ponds described in Section 5.2 of Volume 2 of the Work Plan
- Laboratory analysis of surface water samples for VOCs, nitroaromatics, picric acid, perchlorate, aluminum, iron, mercury, titanium, pesticides, pH, chloride, and hardness as specified in Section 5.3 of Volume 2 of the Work Plan
- Evaluation of the spatial distribution of detected COPCs
- Quantitative screening-level risk assessment for surface water using the highest concentration detected at each surface water sampling location during the 2007, 2008, 2009, or Phase I RI sampling event
- Screening-level ERA
- Evaluation of data gaps and development of recommended Phase II activities

3.1.4 **Sediment**

Sediment sampling and analysis was completed as specified in the Work Plan. Phase I sediment sampling activities included the following items:

- Sediment sampling at 54 locations in streams and ponds during low-flow conditions as described in Section 6.2 of Volume 2 of the Work Plan
- Laboratory analysis of surface water samples for VOCs, nitroaromatics, perchlorate, metals, pesticides, pH, moisture, and cyanide as specified in Section 6.3 of Volume 2 of the Work Plan
- Evaluation of the spatial distribution of detected COPCs
- Quantitative screening-level risk assessment for sediment using the Phase I RI data

- Screening-level ERA using the Phase I RI data
- Evaluation of data gaps and development of recommended Phase II activities

3.1.5 **Receptor Survey**

During Phase I, a survey of potential off-Site groundwater receptors was performed to supplement information that had been collected during a 2003 potential receptor survey. The potential receptor survey completed prior to the RI was described in detail in the *Data Summary Report* (Altamont 2006) and the Phase I Technical Memorandum. The groundwater potential receptor survey was completed in accordance with Sections 2.1.1 and 3.2 of Volume 2 of the Work Plan and included the following activities:

- Visiting the DENR Asheville Regional office and reviewing well records available from 2003 through March 2010
- Performing a windshield (i.e., drive by) survey to document all observed wells that had been installed since the 2003 survey and to identify changes in land use (for example, unimproved to residential dwelling) since 2003
- Contacting the owners of newly identified wells via letters to request additional information pertaining to their water supply wells, including seeking permission to sample their wells if the owners used water from them for potable purposes

The groundwater potential receptor survey identified four properties where residential water supply wells had been installed since 2003. To facilitate parcel identification, a unique tracking number consisting of the last four digits of the Buncombe County tax identification number was assigned to each property. The four digit number following the address is the last four digits of the tax identification number for the following properties:

- 31 Hunter Kilby Road (5403)
- 32 Hunter Kilby Road (6511)
- 11 Hunter Kilby Road (4845)
- 849 Bee Tree Road (8032)

The wells at the four properties listed above were sampled and analyzed for VOCs, nitroaromatics, and perchlorate. Two additional wells (17 Lauren Ridge Way [9368] and 80 McKinney Road [6783]) were also sampled for the same constituents in response to requests from the well owners. The analytical data were reviewed, validated, and provided to the residents. A map of surrounding properties and potential receptor wells is included as Figure 1-5, and a table of potential receptor wells is included as Table 1-2. The private wells were completed in fractured bedrock to depths equivalent to on-Site bedrock monitoring wells. The bedrock zones are monitored as part of the Site groundwater monitoring network.

3.1.6 **Phase I Data Gap Analysis**

The understanding of off-Site conditions was updated using the data obtained during Phase I, and an evaluation of soil, groundwater, surface water, and sediment data gaps was completed. The Phase I Technical Memorandum included the following conclusions and/or recommendations for Phase II:

- Phase I soil data were sufficient to support the BRA and/or define specific areas of impacted soils at 38 of the 45 areas sampled in Phase I.
- Additional soil sampling was recommended at seven areas (B109-137, B116-128, B122, APDA7-8-9, Bear Pit, DA23, and Debris Area 1) to support the BRA and/or define specific areas of impacted soil.
- Evaluation of naturally occurring metals concentrations was recommended for soil in areas unaffected by Site activities.
- Soil pH analysis was recommended at nine areas (B116-128, B117, B155, Debris Area, Process Sewer Outfall, Target Area, and Trajectory Paths 1 through 3) to evaluate the bioavailability of aluminum in soil.
- Additional groundwater investigation was required at nine locations (B107, B110-111-112 and B113, B114, B119-120, B142, B146, B147, B149, and DA9), and the installation of eight Zone AB wells and five Zone CD wells was recommended.
- Additional investigation of the Front Valley primary plume was required, and one Zone AB well, one Zone CD well, and one Zone EF well were recommended.
- Surface water, both on-Site and in Bee Tree Creek, was determined to be sufficiently characterized to support the BRA at the conclusion of Phase I. Consequently, no Phase II surface water sampling activities were recommended.
- Sediment, both on-Site and in Bee Tree Creek, was determined to be sufficiently characterized to support the BRA at the conclusion of Phase I. Consequently, no Phase II sediment sampling activities were recommended.
- Potential receptor information was considered complete and additional sampling of off-Site wells was not recommended for Phase II.

3.1.7 EPA and DENR Review and Comments

The Phase I Technical Memorandum was submitted to the EPA and DENR for review and approval. On September 20, 2010, the agencies provided comments on the Phase I Technical Memorandum. In their comments letter, the agencies requested clarification of specific technical details regarding the proposed Phase II field activities and the risk assessment process. In addition, the agencies requested that additional information, such as cross-sections, be included in the RI Report.

On November 3, 2010, the Companies provided a response to the agencies' comments. As part of that response, the Companies agreed to add the following elements to the Phase II scope of work:

- Installation of two monitoring wells (MW213-J33AB and MW214-I35AB) to evaluate the northern (upgradient) extent of VOC impacts in Zone AB in the Front Valley
- Installation of one monitoring well (MW216-G37AB) to evaluate the western (upgradient) edge of perchlorate impacts in Zone AB in the Front Valley
- Installation of paired Zone CD wells if the transition zone was more than 10 ft below Zone AB wells at the location of wells MW213-J33AB and MW216-G37AB

EPA and DENR approved the responses in an email dated November 17, 2010 and authorized the Phase II fieldwork. The Phase I Technical Memorandum was then revised to incorporate the approved response to comments, and the revised memorandum was submitted on April 27, 2011.

3.2 Phase II Fieldwork, Analysis, and Data Evaluation

The Phase II field activities began in December 2010 and were completed in April 2011. The Phase II fieldwork and data evaluation were completed consistent with the recommendations included in the revised Phase I Technical Memorandum and the methodology defined in the Work Plan. As described above, the Phase II activities were designed to close data gaps associated with soil and groundwater.

As detailed in the Phase I Technical Memorandum, characterization of surface water and sediment were adequate to support remedial option evaluation at the conclusion of Phase I. Consequently, surface water and sediment sampling was not performed during Phase II.

Although sampling of off-Site wells was not recommended in the Phase I Technical Memorandum, as the Phase II fieldwork was being completed the Companies became aware of a new potable residential well south of the Site at 70 Old Bee Tree Road (2241). The well owner was contacted, and the well (2241) was sampled during Phase II.

Phase II drilling services were provided by AE Drilling. All Phase II soil, groundwater, and IDW samples were shipped overnight to Lancaster, where they were analyzed consistent with the methods specified in Table A.4 of the QAPP. A technical review of the analytical data was performed by Lancaster as specified in Section D2.1 of the QAPP. Upon completion of the technical review, analytical data were transmitted as EDDs to CRA for further validation/verification using the criteria specified in Section D2.2 of the QAPP.

Phase II field activities, laboratory analyses, tabulated analytical data, data evaluation, and data gap analyses were presented in the Phase II Technical Memorandum dated October 21, 2011 and included as Appendix A (Altamont 2011b). Laboratory analytical reports for Phase II are included in Appendix C. Data verification and validation results for Phase II are included in Appendix D.

A summary of the Phase II scope and findings follows.

3.2.1 **Soil**

Section 2.6.1 of the Phase I Technical Memorandum identified the following seven areas where further soil sampling was required to support the BRA and/or to assist with defining the extent of impacted soil:

- Area B109-137
- Area B116-128
- Area B122
- APDA-7-8-9
- Bear Pit
- DA23
- Debris Area 1

Phase II sampling was completed at each of these seven areas consistent with the specifications in the Phase I Technical Memorandum and the Work Plan.

During Phase II, a total of 95 soil samples were collected from 23 borings, 2 excavations, and 18 surface sample locations. In addition, 12 soil samples were collected to establish background soil metals concentrations, and 36 locations were tested for soil pH to support the ERA. Phase II soil sample locations are shown on Figure 1-6. A summary of detected Phase II soil sample results is included in Appendix F. A summary of investigation activities performed in each area is included below.

3.2.1.1 Area B109-137

During Phase II, a 600-gallon, single-wall, steel underground storage tank (UST) was excavated and removed from the vicinity of Phase I boring B4 located on the north side of the B109 building slab. The tank, which appeared to have been used for heating oil, contained approximately 550 gallons of fluid. The fluid appeared to be primarily water. The contents of the tank were containerized and sampled for disposal purposes.

Two rounds of soil sampling were completed as described in the Phase II Technical Memorandum. Evaluation of the Phase II soil data indicated that the extent of soil with VOCs (trimethylbenzene, naphthalene, and xylenes) that pose a potentially unacceptable vapor intrusion risk had not been adequately defined around sample locations BS1A and SS1A. In addition, the residual concentrations of four constituents (1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, naphthalene, and xylenes) exceeded the maximum soil contaminant concentrations (MSCCs) for the soil-leaching-to-groundwater pathway specified in the DENR tank closure guidance.

3.2.1.2 Area B116-128

During Phase II, a concrete sump measuring approximately 4 ft by 5 ft by 9 ft deep was identified in the vicinity of boring B2. This sump was excavated and removed as detailed in the Phase II Technical Memorandum. Confirmation soil samples were collected from the base and sides of the excavation. These samples contained VOCs and nitroaromatics at concentrations greater than the Phase I sample results.

After considering the initial Phase II results, an additional 10 soil borings were drilled and sampled to define the horizontal and vertical extent of the VOC and nitroaromatic impacts in soil around the sump. The data from these Phase II borings (B5 through B14) were evaluated with respect to human health risk consistent with the exposure scenarios evaluated in the Phase I Technical Memorandum. These risk calculations showed that none of the concentrations in the delineation samples posed an unacceptable risk under any of the exposure scenarios evaluated in the Phase I Technical Memorandum.

Evaluation of the soil and groundwater data collected in the vicinity of the sump (i.e., Phase I and Phase II soil sampling at DA23 and current and historic groundwater data from nearby monitoring wells and extraction wells) suggests that the sump may be a contributing source to groundwater contamination found in BW-4, M85L-10, and the Front Valley extraction wells.

Approximately 55 cubic yards of soil and concrete rubble were excavated and disposed of off-Site as documented in the Phase II Technical Memorandum and discussed in Section 3.5.

3.2.1.3 Area B122

Phase II activities consisted of soil excavation and drilling soil borings to identify the source and extent of VOCs detected in soil during Phase I. Soil screening with an organic vapor analyzer (OVA) during excavation did not indicate the presence of organic vapors in soil in any additional areas. To corroborate the OVA screening results, four borings were advanced to assess the concentration of VOCs in soil. Soil samples were collected from each boring at any interval that exhibited elevated OVA screening values. Additionally, soil samples were collected at a depth slightly below the base of a nearby, closed subsurface chemical sewer and manhole. The samples were submitted for analysis of VOCs and analytical results were evaluated with respect to human health risk consistent with the exposure scenarios evaluated in the Phase I Technical Memorandum. These risk calculations showed that none of the concentrations in the delineation samples posed an unacceptable risk under any of the exposure scenarios evaluated.

3.2.1.4 APDA7-8-9

During Phase II, three soil borings (B9, B10, and B11) were advanced at the general locations specified in the Phase I Technical Memorandum, and two surface soil samples (S1 and S2) were also collected as specified. In each soil boring, samples were collected for laboratory analyses from the 2 ft-bgs to 3 ft-bgs interval, the 5 ft-bgs to 7 ft-bgs interval, and above the capillary zone. Surface soil samples were collected from the 6-inches-below-ground-surface (in-bgs) to 12 in-bgs interval. The surface samples were analyzed for aldrin, and the soil boring samples were analyzed for VOCs.

The COPC of primary concern in soil in this area, cyclohexane, was not detected in any of the soil boring samples. However, there were several J-flagged detections (i.e., estimated value since the analyte was detected at a concentration below the method detection limit) of other VOCs (acetone, isopropylbenzene, and methyl methacrylate), as well as a detection of p-isopropyltoluene in shallow soil sample B10S3 above the applicable soil-leaching-to-groundwater criterion. Consequently, these data were evaluated with respect to human health risk, consistent with the potential exposure scenarios identified in the Phase I Technical Memorandum. Preliminary risk calculations were performed using the methods described in the Phase I Technical Memorandum to determine whether additional soil data collection was warranted. These risk calculations showed that none of the concentrations in the additional soil borings pose an unacceptable risk under any of the exposure scenarios evaluated in the Phase I Technical Memorandum. In addition, although p-isopropyltoluene was detected in the shallow soil sample from boring B10, p-isopropyltoluene was not detected in the deeper sample from this boring, indicating that this constituent does not pose an actual risk of leaching from soil to groundwater in this area.

3.2.1.5 Bear Pit

During Phase II, two soil borings were advanced at the locations specified in the Phase I Technical Memorandum. In each boring, soil samples were collected at depths of 3 ft-bgs, 5 ft-bgs, and above the capillary fringe, which was encountered at 11 ft-bgs in boring B3 and 8 ft-bgs in boring B4. Samples were analyzed for phenol, RDX, and 2,4,6-trinitrotoluene (2,4,6-TNT).

Target analytes were not detected in any of the soil samples. As a result, the proposed monitoring well was deemed unnecessary and therefore was not installed.

The 2L standard for perchlorate was revised after the Phase II fieldwork was completed, and the revised 2L standard resulted in a lower soil-leaching-to-groundwater criterion for perchlorate. Comparison of the Phase I soil data to the revised soil-leaching-to-groundwater criteria indicated that the concentration of perchlorate detected in Phase I soil sample BPS1 exceeds the revised soil-leaching-to-groundwater criteria. This finding was addressed in Phase III as described in Section 3.3.

3.2.1.6 DA23

During Phase II, two soil borings (B4 and B5) were advanced downgradient of the Phase I boring B3 and soil samples were collected at 1 ft-bgs, 3 ft-bgs, and above the capillary zone (located at approximately 6 ft-bgs). Each sample was analyzed for VOCs. The target analyte, 1,2-DCA, was not detected in any of the samples. However, there were several J-flagged detections of other VOCs (including acetone, p-isopropyltoluene, and PCE). These data were evaluated with respect to potential human health risk, consistent with the exposure scenarios identified in the Phase I Technical Memorandum. In particular, industrial worker soil vapor intrusion exposure was evaluated based on 1,2-DCA concentrations observed in the Phase I field activity. Preliminary risk calculations were performed using the methods described in the Phase I Technical Memorandum for the purposes of determining whether additional soil data collection was warranted. The preliminary calculations included calculating risk estimates for the key receptors and exposure scenarios identified in the preliminary CSM for potential human exposure (Table 2 of the RI/FS Work Plan, Volume 1). For DA23, this included calculating preliminary risk estimates for industrial workers (including vapor intrusion), maintenance workers, and construction workers exposure to soil. The risk calculations were performed using the exposure factors outlined in Volume 1, Appendix F of the approved RI/FS Work Plan, and toxicity values that were compiled in accordance with EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9258.7-53 (which were presented in Appendix H of the Phase I Technical Memorandum). These preliminary, conservative risk calculations showed that no constituent concentrations in the samples collected from Phase II borings posed an unacceptable risk under any of the exposure scenarios evaluated. The evaluation also demonstrated that additional soil data collection was not warranted for DA23.

3.2.1.7 Debris Area 1

Phase II investigation activities in Debris Area 1 consisted of grid-based sampling in the vicinity of the Phase I sample S3 (Figure 1-6). A total of 32 samples were collected at 1 ft-bgs and 3 ft-bgs depths at each of 16 sample locations. Samples were submitted for analyses for octahydro-1,3,7,5-tetranitro-1,3,7,5-tetrazocine (also known as high melting explosive [HMX]) and RDX. HMX was not detected in any of the samples. RDX was detected in only one sample. However, the laboratory detection limits for RDX was above the respective soil-leaching-to-groundwater screening criteria. To evaluate if RDX in soil was leaching to groundwater, groundwater data from the closest downgradient monitoring well (M85L-12) was reviewed. The most recent samples collected from M85L-12 in 2007 and 2008 did not contain detectable concentrations of RDX, suggesting that RDX was not leaching to groundwater at Debris Area 1.

3.2.1.8 Background Soil Metals Evaluation

While site-specific soil background concentrations were developed during a previous RCRA investigation, as specified in the Phase I Technical Memorandum, additional soil sampling and analyses were completed during the Phase II field activity to further characterize the naturally occurring regional background concentration of metals in soil. Samples were collected from 12 on-Site areas that represent the range of soil and underlying rock types present at the Site. The locations selected represent areas remote from former Site operations and not known to have been impacted by Site activities or other anthropogenic sources of metals. At each of the 12 background sample areas, four discrete samples were obtained from 1 ft-bgs (following removal of the upper organic layer). The discrete samples were composited into one sample and analyzed for metals as specified in the Phase I Technical Memorandum.

These new background soil data were combined with previously available regional background soil data, and Site-specific background levels were calculated following EPA Region 4 guidance. Specifically, the background levels were calculated as two times the mean, which is consistent with the approved RI/FS Work Plan. The background levels were used to update the soil-leaching-to-groundwater analysis described in the Phase I Technical Memorandum. The updated tables with the new background levels were included as Appendix B of the Phase II Technical Memorandum. They are also presented on Table 6-1.

The background soil data were used in the RI HHRA to estimate background risks from exposures to naturally occurring metals concentrations in Site soils. These background calculations are further discussed in Section 6.5.2.1. To calculate background exposure concentrations, 95 percent upper confidence limits (UCLs) on the mean were used, consistent with EPA guidance.

3.2.1.9 Soil pH Sampling

The Phase I Technical Memorandum specified the collection of additional soil pH data to supplement existing soil pH measurements and provide additional basis for interpreting the ecological HQs for aluminum. Therefore, during Phase II, soil pH measurements were collected at the following areas:

- Area B116-128
- Area B117
- Area B155
- Debris Area 1
- Process Sewer Overflow Area
- Target Area
- Trajectory Paths 1 through 3

3.2.2 **Groundwater**

3.2.2.1 Well Installation, Sampling, and Analysis

The Phase I Technical Memorandum recommended additional groundwater investigation at nine locations (B107, B110-111-112 and B113, B114, B119-120, B142, B146, B147, B149, and DA9) and additional investigation of the Front Valley primary plume. A total of nine Zone AB wells, six Zone CD wells, and one Zone EF well were recommended for Phase II.

During Phase II, the following 16 monitoring wells were installed (7 Zone AB wells, 7 Zone CD wells and 2 Zone EF wells):

- MW209-I39AB
- MW212-K36AB
- MW213-J33AB
- MW214-I35AB
- MW215-G36AB
- MW216-G37AB
- MW223-L26AB
- MW217-J40CD
- MW218-J38CD
- MW219-O39CD
- MW220-L37CD
- MW221-O40CD
- MW224-N42CD
- MW226-G37CD
- MW222-K46EF
- MW225-T32F

During Phase II there were minor deviations from the Phase I Technical Memorandum recommendations regarding the types or locations of wells installed. These deviations were documented in Section 3.1 of the Phase II Technical Memorandum.

Phase II wells were drilled, developed, sampled, and surveyed as specified in the Work Plan and Phase I Technical Memorandum. Sections 3.3 through 3.14 of the Phase II Technical Memorandum provided a detailed discussion of well drilling and installation, groundwater sampling, and analytical results for each area retained for Phase II groundwater investigation. Lithologic logs and well construction diagrams for Phase II wells are included in Appendix B of this RI report. Geophysical logs for the bedrock wells are also included in Appendix B of this RI report.

3.2.2.2 Water Level Monitoring

Water level transducers and data loggers were used to monitor fluctuations in water levels in bedrock wells before, during, and after Phase II bedrock well installation. Evaluation of the water level data monitoring is provided in Sections 3.12 and 3.14 of the Phase II Technical Memorandum.

3.2.2.3 Groundwater Sampling

3.2.2.3.1 Sampling of Pre-Existing Wells

During Phase II, 22 of the pre-existing monitoring wells near the downgradient Site boundary were sampled for VOCs, nitroaromatics, and perchlorate to evaluate groundwater quality trends at and near the downgradient Site boundary. Results are discussed in detail in Section 3.15 of the Phase II Technical Memorandum.

3.2.2.3.2 Sampling of Two Off-Site Wells

Although not part of the specified Phase II activities, one off-Site residential well was sampled in February 2011 as part of Phase II and analyzed for VOCs, nitroaromatics, and perchlorate. In late 2010, the owner of a residential property located south of the Site at 70 Old Bee Tree Road installed a potable water supply well (2241) because the public water line located along Old Bee Tree Road did not have sufficient capacity to accommodate an additional residential connection. The EPA became aware of the well (2241) during the well permitting process and notified the Companies of the well. Altamont sampled this well in February 2011, consistent with previous potable well sampling activities. The well location is shown on Figure 1-5.

The analytical results were discussed in detail in Section 3.16 of the Phase II Technical Memorandum. The only compounds detected were toluene (at a concentration well below the 2L standard and the EPA Maximum Contaminant Level [MCL]) and tetrahydrofuran, which is commonly found in polyvinyl chloride (PVC) glue (which was used in the construction of the PVC cased well).

In September 2011 the well at 80 McKinney Road (6783) was also sampled in response to a request from the property owner. None of the compounds analyzed for were detected at concentrations equal to or above the method detection limit.

3.2.3 Phase II Data Gap Analysis and Recommended Phase III Activities

The understanding of Site conditions was updated using the data obtained during the Phase II investigation and an evaluation of soil and groundwater data gaps was completed. The Phase II Technical Memorandum included the following conclusions and/or recommendations for Phase III investigation activities:

3.2.3.1 Soil

- The Phase II data (in conjunction with the Phase I data) were sufficient to support the risk assessment, and the RI investigation fieldwork was deemed complete for five of the areas investigated during Phase II including Area B116-128, Area B122, APDA7-8-9, Bear Pit, and Debris Area 1.
- Collection of additional soil data during Phase III was warranted at two areas (Area B109-137 and DA23).
- Evaluation of background soil metal concentrations was complete.
- Evaluation of soil pH data was complete.

3.2.3.2 Groundwater

- Area B109-137: Installation of one Zone AB monitoring well was recommended to address the soil-leaching-to-groundwater pathway and to comply with DENR guidance regarding soil impacts in association with the UST that was removed during Phase II.
- Area B116-128: Installation of two Zone CD wells was recommended to define the vertical extent of COPCs (VOCs, nitroaromatics, and perchlorate) associated with the sump identified at B116 and to evaluate the presence/significance of a bedrock trough south of the sump.
- Area B119-120: Re-sampling of well MW220-L37CD was recommended to address the low sample volume collected from this well during Phase II.
- Area B147: Installation of two Zone AB wells in the vicinity of well MW180-H38AB was recommended to evaluate the distribution of TCE associated with the sumps and solvent distillation operation in the vicinity of Area B147.
- Area B149: Additional investigation was recommended in this area to further define the vertical and horizontal extent of COPCs (VOCs and perchlorate) in the Transition Zone Aquifer (Zone CD).

- Debris Area 1: Groundwater screening was recommended downslope of Debris Area 1 to evaluate nitroaromatics and perchlorate in groundwater.
- Bear Pit: Installation of one Zone AB well was recommended to evaluate perchlorate in groundwater.
- Front Valley Primary Plume: Installation of one Zone CD well was recommended north of Pond 2 to further evaluate COPCs in this area, and installation of one Zone EF well was recommended upgradient of Building 104 to both evaluate the interconnectivity of a 2,000 ft-msl fracture identified beneath the lower Front Valley and to further evaluate the extent of the COPCs (specifically VOCs) in the Bedrock Aquifer System.
- Back Valley Primary Plume: One Zone EF well was recommended in the central part of the Back Valley to evaluate the extent of the COPCs in the Bedrock Aquifer System.
- Site perimeter monitoring: Collection of water level and water quality data from the existing Site perimeter monitoring well network was recommended to further evaluate groundwater conditions at the Site boundary over time.

3.2.4 **EPA and DENR Review and Comments**

The Phase II Technical Memorandum was submitted to the EPA and DENR for review on October 20, 2011. The EPA and DENR provided comments to the Companies in a letter dated November 30, 2011. The November 30, 2011 letter also provided approval of the proposed Phase III fieldwork.

On January 20, 2012 the Companies provided a letter responding to the agencies comments.

3.3 Phase III Fieldwork, Analysis, and Data Evaluation

The Phase III field activities began in November 2011 and were completed in September 2012. The Phase III fieldwork and data evaluation were completed consistent with the recommendations included in the Phase II Technical Memorandum, the January 20, 2012 response to EPA and DENR comments, and the methodology defined in the Work Plan.

As Phase III progressed and the data were evaluated, additional field tasks were added. These additional field activities were reviewed and approved by EPA and DENR before they were implemented. Specifically:

- The PCE and TCE toxicity values were revised by the EPA after the Phase II Technical Memorandum was issued. Evaluation of soil data using the revised values indicated that some additional soil sampling for TCE was warranted at B113, B107, and B147 to support the risk assessment. The required samples were collected during Phase III.
- One Zone EF well was installed in Site reference grid L41 to refine the understanding of bedrock conditions downgradient from Area B104.
- A pumping test was completed on bedrock monitoring well MW227-J39EF to investigate the hydraulic characteristics of the Bedrock Aquifer System in Area B104 and to further evaluate the chloroform and the other COPCs detected in the well during Phase III activities.
- A soil gas survey was completed in Area B104 to investigate the source(s) of chloroform detected in groundwater in the area.

- Three potable water supply wells south of the Site (including 2241, 9368, and 9564) were sampled and analyzed for VOCs, nitroaromatics, and perchlorate.
- All Phase III soil, groundwater, surface water, and IDW samples were shipped overnight to Lancaster, where they were analyzed consistent with the methods specified in Table A.4 of the QAPP. A technical review of the analytical data was performed by the laboratory as specified in Section D2.1 of the QAPP. Upon completion of the technical review, analytical data were transmitted as EDDs to CRA for further validation/verification using the criteria specified in Section D2.2 of the QAPP.

3.3.1 **Soil**

During Phase III, a total of 23 soil samples were collected from six borings and four surface sample locations (Figure 1-6). A summary of all Phase III soil analytical results is included in Appendix H, and a summary of detected constituents for Phase III soil samples is included as Table 3-4.

A summary of investigation activities performed in each area is included below.

3.3.1.1 Area B109-137

Borings B5 through B8 were drilled to define the outer extent of VOCs in soil (to the north and northwest) around the location of the former UST and excavation area (the UST location is indicated by soil sample B8 on Figure 3-1). Boring B8 was drilled based on field evidence collected during the initial sampling (for example, elevated OVA readings collected from the soil from Boring B5). Soil samples were collected from each boring consistent with the specifications included in Section 2.1 of the Work Plan. The following samples were collected and submitted to Lancaster for VOC analysis:

- Boring B5: 0 to 1 ft-bgs, 22 to 23 ft-bgs, and 27 to 28 ft-bgs
- Boring B6: 0 to 1 ft-bgs, 14 to 15 ft-bgs, and 33 to 34 ft-bgs
- Boring B7: 1 to 2 ft-bgs, 5 to 6 ft-bgs, and 33 to 34 ft-bgs
- Boring B8: 0 to 1 ft-bgs, 5 to 6 ft-bgs, and 28 to 29 ft-bgs

Detections from the sampling are listed in Table 3-4.

3.3.1.2 Area DA23

Boring B6 (Figure 3-2) was drilled to the south of DA23 to further delineate VOCs in soil as recommended in the Phase II Technical Memorandum. Samples were collected at 0 to 1 ft-bgs, 5 to 6 ft-bgs, and 9 to 10 ft-bgs. Samples were submitted to Lancaster for VOC analysis. Detections are listed in Table 3-4.

3.3.1.3 Area B113

One soil boring (B12) was drilled to address the change in the TCE toxicity value. The boring was installed south of boring B5 (see Figure 3-1). Soil samples were collected at 0 to 1 ft-bgs, 5 to 6 ft-bgs, 10 to 11 ft-bgs (in response to elevated OVA readings), and 12 to 13 ft-bgs. Samples were submitted to Lancaster for VOC analysis. Detections are listed in Table 3-4.

3.3.1.4 Areas B107 and B147

Surface soil samples were collected in areas B107 and B147 (Figure 3-3) to address the change in the TCE toxicity value. Samples were submitted to Lancaster for VOC analysis. Detections are listed in Table 3-4.

3.3.2 **Groundwater**

3.3.2.1 Well Installation, Sampling, and Analysis

The Phase II Technical Memorandum recommended additional groundwater investigation at seven locations (B109-137, B116-128, B119-120, B147, B149, Debris Area 1, and Bear Pit) and additional investigation of the Front Valley and Back Valley primary plumes. During Phase III, a total of four Zone AB wells, four Zone CD wells, and two Zone EF wells were installed as recommended. In addition, one extra boring was drilled near Area B139 to confirm the depth to competent rock and one additional EF well was installed in grid M41 to evaluate bedrock conditions downgradient of Area B104. The following wells were installed during Phase III:

- MW230-H38AB
- MW231-H38AB
- MW232-I33AB
- MW233-O20AB
- MW234-I37CD
- MW235-P39CD
- MW236-N40CD
- MW237-I37CD
- MW227-J39EF
- MW228-O27EF
- MW229-L41EF

Figure 1-4 shows the monitoring well locations and Table 2-1 provides monitoring well construction details. During Phase III, AE Drilling installed and developed the 11 monitoring wells. The monitoring wells were constructed in accordance with the NCAC 2C, Well Construction Standards. All 11 monitoring wells were surveyed to the Site datum and coordinate system by WNC Professional Engineers and Surveyors, Inc., a North Carolina-licensed surveyor. The surveyed well locations are shown on Figure 1-4. Survey records are included in Appendix B.

Drilling was performed in accordance with the methods described in the Work Plan. No deviations occurred during the drilling, installation, or development of the Phase III monitoring wells. There was a minor deviation from the Phase II Technical Memorandum, as follows:

- Groundwater sampling was recommended downslope of Debris Area 1 to evaluate nitroaromatics in groundwater. During Phase III it was determined that surface water sampling at two locations downslope of the Debris Area would provide sufficient data, and groundwater sampling in this area was not necessary. This modification was approved by EPA via e-mail on November 21, 2011.

Lithologic logs and well construction diagrams for Phase III wells are included in Appendix B of this report. Geophysical logs for the bedrock wells are also included in Appendix B.

All monitoring wells installed during Phase III were developed and sampled for the full suite of Site groundwater analytes (VOCs, SVOCs nitroaromatics, perchlorate, CS, BZ, metals, pesticides, herbicides, methanol, ethanol, organic acids, ammonia, chloride, cyanide, nitrate, nitrite, sulfate, and sulfide). A complete summary of Phase III groundwater results is included in Appendix H, and summaries of Phase III groundwater detections are included on Table 3-2 and Table 3-3 for the Front Valley and Back Valley, respectively.

Monitoring well installation and sampling details, by area, are provided below:

Area B109-137: One Zone AB monitoring well (MW232-I33AB) was installed as recommended to address the soil-leaching-to-groundwater pathway and to comply with DENR guidance regarding soil impacts associated with the UST that was removed during Phase II.

Area B116-128: Two Zone CD wells (MW234-I37CD and MW237-I37CD) were installed as recommended to define the vertical extent of groundwater impacts associated with the sump identified at B116 and to evaluate the presence/significance of a bedrock trough south of the sump.

Area B119-120: Well MW220-L37CD was re-sampled as recommended to address the low sample volume collected from this well during Phase II. The well once again yielded a low sample volume and, as a result, only nitroaromatics and perchlorate were analyzed. Phase II VOC detections and Phase III nitroaromatic and perchlorate detections are summarized on Table 3-2.

Area B147: Two Zone AB wells (MW230-H38AB and MW231-H38AB) were installed in the vicinity of well MW180-H38AB to evaluate the distribution of TCE associated with the sumps and solvent distillation operation in the vicinity of Area B147.

Area B149: One Zone CD well (MW235-P39CD) was installed to further define the vertical and horizontal extent of COPCs (VOCs and perchlorate) in the Transition Zone Aquifer System.

Bear Pit: One Zone AB well (MW233-O20AB) was installed as recommended to evaluate perchlorate in groundwater.

3.3.2.1.1 Front Valley Primary Plume

Well MW239-P35CD, a Zone CD well, was installed north of Pond 2 to define the northern leading edge of the Front Valley primary plume. Only low-level constituent concentrations were detected as summarized on Table 3-2.

Well MW227-J39EF was installed as recommended in Area B104 to evaluate the interconnectivity of the 2,000 ft-msl fracture beneath the Front Valley and to further evaluate the extent of the COPCs (specifically VOCs) in the Bedrock Aquifer System. The 2,000 ft-msl fracture was not encountered in the well. However, higher-than-anticipated VOC concentrations were detected in both packer test results and the completed well as described below.

Drilling of MW227-J39EF was initiated on November 30, 2011 with a 12.75-inch hollow-stem auger (HSA) to 25 ft-bgs. The drilling tools were switched over to an 11.875-inch air bit and drilling continued 5 ft beyond the top of competent bedrock, which was encountered at 40 ft-bgs. An 8-inch-diameter steel surface casing was installed to 45 ft-bgs in the socket of competent rock and grouted in place. Air rotary drilling continued to a total depth of 303 ft-bgs, which was reached on December 7, 2011. Once drilling was completed, borehole geophysical logging was performed on the open borehole and indicated the presence of fractures at 48, 76, 96, 126, and 138 ft-bgs. Geophysical logs are included in Appendix B.

Inflatable straddle packers were used to seal off portions of the borehole and allow sampling of groundwater from isolated aquifer zones and, specifically, to straddle fractures that were encountered during drilling. The isolated zones sampled included 24 to 54 ft-bgs, 54 to 84 ft-bgs, 84 to 114 ft-bgs, and 114 to 144 ft-bgs. No samples were collected from isolated zones deeper than 144 ft (2,118 ft-msl) because the boring did not produce water below that depth. Specifically, packer zones 144 to 194 ft-bgs, 194 to 244 ft-bgs, and 244 to 300 ft-bgs did not yield sufficient water for sampling.

Groundwater samples collected from the isolated zones were analyzed for VOCs, nitroaromatics, and perchlorate. Chloroform, PCE, 1,2-DCA, and picric acid were detected at concentrations of 53,000, 86, 460, and 1,400 micrograms per liter (µg/L), respectively, in the sample collected in the 114 to 144 ft-bgs zone. The concentration of chloroform was higher than anticipated. Based on the results of geophysical logging and the location of water-bearing zones encountered during packer testing, MW227-J39EF was completed at a total depth of 142 ft-bgs with a 20-ft screen interval from 122 ft-bgs to 142 ft-bgs. The lower portion of the borehole below the screen section was grouted from 153 to 300 ft-bgs, plugged with bentonite to 145 ft-bgs, and backfilled with sand from 145 to 142 ft-bgs to anchor the bentonite plug before the well screen and casing were installed.

The completed monitoring well is constructed of four-inch nominal inside-diameter (ID) Schedule 40 PVC pipe. The screen section is 20 ft long and is machine-slotted with 0.010-inch slots. The filter pack material consists of #1 clean, washed, well-rounded silica sand. The bentonite seal is composed of commercially manufactured 3/8-inch-diameter sodium bentonite chips.

The well was developed and then sampled for the full suite of Site groundwater analytes. Detections are summarized on Table 3-2. As shown on Table 3-2, chloroform was detected at 24,000 µg/L in the sample from the developed well, and other VOCs were detected at concentrations similar to those detected in the packer test results from a depth consistent with the screened interval of the completed well. As a result of the elevated chloroform concentration, one additional EF well (MW229-L41EF) was installed downgradient of Area B104 as described below.

Well MW229-L41EF was installed downgradient of Area B104 to evaluate the extent of COPCs detected in well MW227-J39EF. Drilling began on January 12, 2012, with a 12.75-inch HSA advanced to 35 ft-bgs. The drilling tools were switched over to an 11.875-inch air rotary bit and drilling continued 5 ft beyond the top of competent bedrock, which was encountered at 48 ft-bgs. An 8-inch steel surface casing was installed to 53 ft-bgs in the socket of competent rock and grouted in place. Air rotary drilling continued to a total depth of 270 ft-bgs on January 17, 2012. Once drilling was completed, borehole geophysical logging was performed on the open borehole and indicated the presence of fractures at 65, 75, 98, 135, 190, and 228 ft-bgs. Geophysical logs are included in Appendix B.

Inflatable straddle packers were used to seal off portions of the borehole and allow sampling of groundwater from isolated aquifer zones and, specifically, to straddle fractures that were encountered during drilling. The isolated zones sampled included 45 to 95 ft-bgs, 95 to 145 ft-bgs, 145 to 200 ft-bgs, and 200 to 270 ft-bgs. Groundwater samples were collected from the isolated zones and analyzed for VOCs, nitroaromatics, and perchlorate. Chloroform, PCE, and TCE were detected at concentrations of 83, 19, and 22 µg/L, respectively, in the sample collected from the 200 to 270 ft-bgs zone.

Based on the results of geophysical logging and the location of water-bearing zones encountered during packer testing, MW229-L41EF was completed by installing the well to a depth of 240 ft-bgs with a 20-ft screen between 220 and 240 ft-bgs. The open borehole caved in from 270 to 256 ft-bgs during the packer testing. The lower portion of the borehole below the screen section was plugged with bentonite from 256 ft-bgs to 245 ft-bgs and backfilled with sand from 245 to 240 ft-bgs before the well screen and casing were installed.

The completed monitoring well is constructed of 4-inch nominal ID Schedule 40 PVC pipe. The screen section is 20 ft long and is machine-slotted with 0.010-inch slots. The filter pack material consists of #1 clean, washed, well-rounded silica sand. The bentonite seal is composed of commercially manufactured 3/8-inch-diameter sodium bentonite chips.

The well was developed and then sampled for the full suite of Site COPCs. Detections are summarized on Table 3-2 and the full analytical suite is reported in Appendix H.

3.3.2.1.2 Back Valley Primary Plume

Well MW228-O27EF was installed as recommended in the central part of the Back Valley to evaluate the extent of the COPCs in the Bedrock Aquifer System. The lithologic log and well construction diagram are included in Appendix B.

Drilling was initiated on December 1, 2012, with a 12.75-inch HSA to a depth of 25.5 ft-bgs. The drilling tools were switched over to an 11.875-inch air rotary bit, and drilling continued 5 ft beyond the top of competent bedrock, which was encountered at a depth of 88 ft-bgs. An 8-inch steel surface casing was installed to 95 ft-bgs in the socket of competent rock and grouted in place. Air rotary drilling continued to a total depth of 322 ft-bgs on December 14, 2012. Once drilling was completed, borehole geophysical logging was performed on the open borehole and indicated the presence of fractures at 158, 189, 240, and 259 ft-bgs. Geophysical logs are included in Appendix B.

Inflatable straddle packers were used to seal off portions of the borehole and allow sampling of groundwater from isolated aquifer zones and, specifically, to straddle fractures that were encountered during drilling. The isolated zones sampled included 86 to 136 ft-bgs, 132 to 182 ft-bgs, 178 to 228 ft-bgs, 224 to 274 ft-bgs, and 270 to 322 ft-bgs. No sample was collected from the 132 to 182 ft-bgs zone due to a lack of water production in that zone. Groundwater samples were collected from the isolated zones and analyzed for VOCs, nitroaromatics, and perchlorate. Based on the results of geophysical logging and the location of water-bearing zones encountered during packer testing, MW228-O27EF was completed by installing the well to a depth of 294 ft-bgs with a 20-ft screen between 274 and 294 ft-bgs. The lower portion of the borehole below the screen section was plugged with bentonite from 322 to 304 ft-bgs and backfilled with sand from 304 to 294 ft-bgs before the well screen and casing were installed.

The completed monitoring well consists of 4-inch nominal ID Schedule 40 PVC pipe. The screen section is 20 feet long and is machine-slotted with 0.010-inch slots. The filter pack material consists of #1 clean, washed, well-rounded silica sand. The bentonite seal is composed of commercially manufactured 3/8-inch-diameter sodium bentonite chips.

The well was developed and then sampled for the full suite of Site COPCs. Detections are summarized on Table 3-2.

3.3.2.2 Water Level Monitoring

Water level transducers and data loggers were used to monitor fluctuations in water levels in bedrock wells before, during, and after Phase III bedrock well installation. Evaluation of the water level data monitoring is discussed in Section 2.2.3.4.

3.3.2.3 Pumping Test in Well MW227-J39EF (B104)

Between April 25, 2012 and May 14, 2012, a step-drawdown and a long-term steady-state aquifer pumping test were performed on bedrock monitoring well MW227-J39EF. The aquifer test was performed to investigate the hydraulic characteristics of the Bedrock Aquifer System in Area B104 and to evaluate the detections of chloroform and other COPCs detected in the well during Phase III activities. A detailed discussion of the pumping test methods, analytical methods, and conclusions is included as Appendix I.

During these tests, a combination of electronic pressure transducers and manual gauging were used to monitor changes in water levels in the pumping well (MW227-J39EF) and surrounding wells. The water level data were used to evaluate the degree of interconnectedness between various aquifer systems at the Site and monitor the effect of pumping on wells screened in different zones.

As a first step, Altamont performed a step drawdown pumping test to estimate the specific capacity of the pumping well, establish a target pumping rate for a long-term constant-rate pumping test, and to determine the feasibility of performing a long-term pumping test. Evaluation of the step drawdown test data was used to establish a target pumping rate of 4.5 gallons per minute (gpm) for the long-term test.

During the long-term test, the pumping well was pumped at a rate of 4.6 gpm for 72 hours. Steady state drawdown in the pumping well was achieved at 6.5 hours. Recovery data were collected for approximately 60 hours after pumping stopped.

Several diagnostic and analytical solutions were applied to the step drawdown and long-term pumping data to evaluate aquifer characteristics. Analysis of the diagnostic flow plots indicated an aquifer dominated by a radial flow regime. However, an analysis of drawdown data from BW-4 (a bedrock well located approximately 680 feet northeast of the pumping well) suggested the presence of a highly conductive zone between the pumping well and BW-4.

Groundwater samples were collected from the pumping well during the step drawdown test and during the long-term test. These samples were analyzed for VOCs, nitroaromatics, and perchlorate. Analytical results for the groundwater samples for other VOCs, nitroaromatics, and perchlorate collected during the long-term pumping test were generally stable over the course of the pumping test.

Appendix I provides a more detailed discussion of the pumping test methods and findings.

3.3.3 **Surface Water**

Debris Area 1: Two surface water samples were collected downslope of this area to evaluate the potential presence of RDX. There were no RDX detections, but perchlorate was detected at low concentrations that are J-flagged. Results are included in Table 3-5 and Appendix H.

3.3.4 **Soil Gas**

After considering the results of the well sampling and aquifer testing at Area B104, a soil gas investigation was proposed to assess whether a source of chloroform was present in Area B104 and, if present, to delineate the source area. EPA and DENR were notified of the proposed work on May 18, 2012, and the notification included documentation that the data generated from the investigation would be considered level II qualitative data and data validation would not be performed. EPA and DENR reviewed the plans for the proposed soil gas investigation and requested an addendum to the QAPP to address soil gas sampling which was not included in the original QAPP. The requested addendum was submitted on June 14, 2012, and fieldwork began on July 5, 2012.

A detailed description of the soil gas investigation is included as Appendix J. In summary, 30 Gore® modules were installed to a depth of approximately 3 ft-bgs using hand-held equipment. The modules were removed on July 13, 2012 and shipped to the Gore® laboratory where they were analyzed for VOCs (by modified EPA Method 8260C) and nitroaromatics. No nitroaromatics were detected; however, there were several VOCs detected at relatively low concentrations.

Overall, the Gore® module results did not confirm a current significant shallow source of VOCs (including, and in particular, chloroform) in Area B104. Although the detections of chloroform in the area of the former building sump did verify that chloroform was historically present in the sump associated with Area B104, these results did not identify a definitive shallow continuing source for the chloroform detected in Phase III well MW227-J39EF.

3.3.5 **Off-Site Potable Well Sampling**

Three off-Site potable wells located south of the Site were sampled during Phase III to confirm the previous findings (i.e., no Site-related impacts) of off-Site groundwater quality assessments to the south of the Site, including the wells at the following properties:

- 17 Lauren Ridge Road (9368)
- 25 Lauren Ridge Road (9564)
- 70 Old Bee Tree Road (2241)

Each well was sampled in accordance with sampling procedures for domestic wells outlined in the Work Plan. The data is included in the laboratory report in Appendix C. The well locations are shown on Figure 1-5.

3.3.6 **Phase III Data Gap Analysis and Recommendations**

The understanding of Site conditions was updated using the data obtained during Phase III and an evaluation of soil and groundwater data gaps was completed. Based on these further evaluations, no significant data gaps were found, and the RI data set was deemed sufficient to fully support the BRA, as well as FS planning. As such, no additional RI data are required or recommended.

3.4 Groundwater and Surface Water Monitoring

3.4.1 **Site-Wide Assessment Monitoring**

In a letter dated September 12, 2011, the Companies submitted a proposed assessment monitoring plan to EPA and DENR. The plan described a groundwater and surface water monitoring program that would be followed, in parallel with but separate from the RI, until a final remedy is selected for the Site and a final compliance monitoring plan is developed and implemented. The proposed assessment monitoring would supplement the existing groundwater compliance-specific monitoring program defined in the 1997 *Operation and Maintenance Manual* (Rust 1997), which would be performed concurrently with the assessment monitoring.

The objectives of the monitoring program described in the plan were to:

- Monitor the concentrations of Site COPCs at the property boundary in both groundwater and surface water
- Develop additional temporal data on the stability of the leading edge and along the length of the primary groundwater plumes
- Develop additional temporal data on groundwater quality in source areas
- Develop additional temporal data on groundwater parameters, which may be used to evaluate attenuation mechanisms
- Develop additional temporal data for on-Site surface water quality

EPA and DENR approved the plan on October 6, 2011. The first sampling event under the approved plan occurred in fall 2011. The 2011 sampling event was documented in the *Annual Assessment Monitoring Report* dated August 20, 2012 (Altamont, 2012). Agency approval of the report was received on October 30, 2012. Additional sampling events have been performed in 2012, 2013, and 2014. It is anticipated that subsequent events will occur annually. The locations of monitoring points included in the plan are shown on Figures 1-7, 3-4, and 3-5.

Groundwater and surface water results from the annual assessment monitoring events are generally consistent with the results from previous groundwater sampling events.

3.5 Groundwater Potential Receptor Surveys

Most of the area to the south and east of the Site is served by the City of Asheville public water supply. However, the availability of public water supply is partially limited to the west and north of the Site.

During the spring and summer of 2003 (prior to the RI activities), an off-Site receptor survey was performed to identify and locate potable wells and springs located within 0.25 miles of the western, southern, and eastern portions of the Site property boundary. The area to the north of the Site was not evaluated because it is hydraulically upgradient of the Site in terms of groundwater flow. The 2003 survey identified a total of 34 domestic wells (28 wells west, five wells south, and one well east of the Site) and three springs west of the Site.

An off-Site sampling and analysis program was initiated to evaluate water quality. All 34 domestic wells and three springs identified during the 2003 survey were sampled between 2003 and 2004. Results of the receptor survey and sampling program are documented in the 2006 *Data Summary Report* (Altamont 2006).

During the RI, the off-Site receptor survey was updated as described in Section 3.1.5 and documented in the Phase I Technical Memorandum. The survey was completed in accordance with the specifications in Section 9.3 of Volume 1 of the Work Plan. Sampling of off-Site wells occurred during each phase of the RI. A chronology of historical off-Site well sampling is provided in Table 3-6.

3.6 Investigation Derived Waste

IDW generated during Phase I, Phase II, and Phase III consisted of soil cuttings, excavated soil, concrete rubble, purge water, decontamination fluids, spent sampling equipment (e.g., gloves, tubing, soil liners), and a decommissioned UST from Area B109 (including the water found in it). All of the IDW generated during the RI was handled, stored, sampled, and disposed of consistent with the procedures detailed in Volume 2 of the Work Plan. Soil cuttings and excavated material were containerized in either drums or roll-off containers. Representative samples from the containers were collected and submitted for analyses for RCRA waste characterization parameters. Results of the samples from each phase of investigation are provided in Appendix K.

All liquid IDW was processed in the Site groundwater remediation systems. All soil and excavated material as well as spent sampling equipment was transported and disposed of at the approved facility operated by Republic Services, Inc. in Union County, South Carolina (Republic Services Landfill). Additionally, as described in the Phase II Technical Memorandum, the UST removed from Area B109 was cleaned and also disposed of at the Republic Services Landfill.

IDW generated during Phase I, Phase II, and Phase III consisted of soil cuttings, excavated soil, concrete rubble, purge water, decontamination fluids, spent sampling equipment (e.g., gloves, tubing, soil liners), and a decommissioned UST from Area B109 (including the water found in it). All of the IDW generated during the RI was handled, stored, sampled, and disposed of consistent with the procedures detailed in Volume 2 of the Work Plan. Soil cuttings and excavated material were containerized in either drums or roll-off containers. Representative samples from the containers were collected and submitted for analyses for RCRA waste characterization parameters. Results of the samples from each phase of investigation are provided in Appendix K.

All liquid IDW was processed in the Site groundwater remediation systems. All soil and excavated material as well as spent sampling equipment was transported and disposed of at the approved facility operated by Republic Services, Inc. in Union County, South Carolina (Republic Services Landfill). Additionally, as described in the Phase II Technical Memorandum, the UST removed from Area B109 was cleaned and also disposed of at the Republic Services Landfill.

4.0 Nature and Extent of Site COPCs

This section provides a summary of the nature and extent of Site COPCs identified during the RI. This section includes a review of the quality of the data collected during the RI, summarizes the types of COPCs identified within each media, and discusses the distribution of COPCs above the criteria established for the Site within the various environmental media investigated.

4.1 Data Quality Review

A data quality evaluation was performed on all field data and laboratory analytical data generated during the RI. The purpose of the review was to determine whether the data collected during the field investigation are sufficient to support the BRA and support the identification of areas where further evaluation of remedial options will be carried forward in the FS. Steps for ensuring the collection of data appropriate for the decisions are outlined in the Section 8 of Volume 1 of the Work Plan and in the QAPP, included as Volume 3 of the Work Plan.

As discussed in Section 1, the soil sampling scope of work was designed using a biased-sampling approach, and RI soil samples were collected from locations where COPC concentrations were expected to be highest. Groundwater, surface water, and sediment locations were also biased toward areas of expected maximum concentrations based on Site-specific hydrogeologic and hydraulic characteristics. Therefore, tolerable limits were not set for evaluation of sampling data developed during the field investigation because a biased sampling design for groundwater, soil, surface water, and sediment was utilized. In addition, the highest concentrations from these high-biased data sets were used in the highly conservative screening-level risk assessment and SLERA after the initial phase of sampling (as discussed in Section 2 of this report and Section 9.5 of Volume 1 of the Work Plan) to provide further assurance that decision errors, if any, will favor too much sampling rather than too little sampling.

4.1.1 **Field Data**

Field data were reviewed to confirm that the following data quality objectives were met:

- Correct sample locations
- Correct sample collection methods
- Correct sample nomenclature and labeling
- Accurate measurements of field parameters
- Appropriate quality assurance/quality control (QA/QC) procedures
- Appropriate field audits

Evaluation of field data confirmed that the data are appropriate for their intended uses. Details are provided in the following paragraphs.

Sample locations were defined in the Work Plan, in subsequent Work Plan addenda, and in the Phase I and Phase II Technical Memoranda. The location of each sample was marked in the field and verified prior to sample collection. Field logs, including location sketches and measurements, were prepared as appropriate. Sample tracking sheets were prepared to confirm that all required samples were collected.

At the completion of each phase of sample collection, the sample tracking sheets were reviewed to confirm that all required samples had been collected.

As soil sampling was completed, each sample location was identified with a steel reinforcing bar (rebar) painted with fluorescent marking paint. Exceptions included soil samples collected from the Target Area and the Trajectory Areas (TRA1, TRA2, and TRA3). In these locations, wooden stakes were driven at each composite aliquot location. Nearly all of the soil samples were collected at the locations indicated in the Work Plan. However, as noted in the Phase I and Phase II Technical Memoranda, obstructions interfered with some of the proposed sample locations. In each of these situations, the sample location was modified as reported in the Phase I and Phase II Technical Memoranda. Field maps and figures presented initially in the Work Plan were updated at the conclusion of each phase to accurately depict the locations where soil samples were collected and the approximate spatial coordinates of each soil sampling location were derived from the mapped points using a Geographic Information System (GIS) software application. Monitoring well locations were surveyed to the Site datum and coordinate system and added to the Site GIS data set. Surface water and corresponding sediment sampling locations were identified in the field with rebar stakes fitted with metal sample identification tags and coordinates were approximated using GIS.

Sample collection methods and handling procedures for each media are described in Volume 2 of the Work Plan. Any deviations from the described sample collection methods are identified and explained in the Phase I and Phase II Technical Memoranda and in Section 3 of this report. As samples were collected, they were placed in new, laboratory-supplied containers appropriate for the parameters to be analyzed. Sample container, preservation, and holding times were specified in the QAPP. Sample labeling was consistent with the specification defined in the QAPP and used a sample nomenclature that tied the sample to the location. A sample label was affixed to each sample container, as the sample was collected. The label identified the sample name, location, time and date, and sampling personnel. Samples were packaged in coolers with ice and shipped to Lancaster using appropriate chain-of-custody procedures as specified in the QAPP.

During sample collection, field measurements such as vapor concentrations of VOCs, indicator parameters obtained during groundwater and surface water sampling, and any other relevant field observations were recorded on field sampling sheets or in field log books. Copies of the field sampling sheets for all phases of data collection are included in Appendix B. Field instruments were calibrated daily in accordance with the manufacturers’ specifications. Daily instrument calibration logs were maintained for each field instrument used. Copies of the instrument calibration logs are also included in Appendix B.

Additional QA/QC procedures for sampling activities were also defined in the QAPP. These procedures included the collection and analyses of QA/QC samples including field duplicates, Matrix Spike/Matrix Spike Duplicates (MS/MSD), field equipment decontamination (rinsate) blanks, and trip blanks. These samples were collected at the frequencies specified in the QAPP. Temperature blanks were included in the sample shipping containers and measured upon receipt at Lancaster.

To document that field activities were performed in accordance with the requirements of the Work Plan and QAPP, field audits occurred during each phase of investigation. A field audit checklist was completed for each audit. When a deviation from the requirements was noted, a corrective action report was prepared. Each corrective action report identified steps necessary to bring the noted deviation into compliance with the requirements. Copies of the field audit checklists and corrective action reports are included in Appendix E. The items noted in the field audits and corrective action reports were minor and not of a nature to invalidate any of the data collected.

4.1.2 **Laboratory Data**

Lancaster performed all laboratory analyses for samples collected during the RI except for the analysis of soil gas samples from the B104 Area, as described in Section 3.3.4. A laboratory Quality Management Plan was prepared by Lancaster and submitted to the EPA prior to conducting any analyses.

Specific QA/QC requirements for laboratory data are detailed in the QAPP. The initial data review was performed by Lancaster. Data qualifiers were subsequently assigned by Lancaster based on this review. Analytical data were transmitted as EDDs to CRA for further data verification and validation. Data verification was performed on all analytical data except the soil gas survey data as noted above in Section 3.3.4. Full validation was performed on a subset of the data representing approximately 10 percent of the total data set. Appendix D contains the data validation reports for the validated data for all applicable samples collected during the RI.

Based on the verification or validation procedures, data qualifiers assigned by the laboratory were confirmed, and additional qualifiers were assigned as appropriate by CRA. The verified/validated data were subsequently submitted to Altamont via EDDs for input into the Site data management system. The analytical results presented in the tables in this report contain qualifiers assigned by Lancaster and CRA. As summarized in the data validation reports, the data used for evaluation and interpretation were found to exhibit acceptable levels of accuracy and precision to meet the data quality objectives.

4.2 Data Evaluation Criteria

Criteria used to evaluate the completeness of the data for defining the nature and extent of Site COPCs are described in Section 9.5 of Volume 1 of the Work Plan. The evaluation includes both quantitative and qualitative metrics. These evaluations were performed following each phase of field investigation. The results of these evaluations were then utilized to identify data gaps that warranted additional data collection in subsequent phases of investigation. As stated in Section 3.3.6 and discussed further below, at the conclusion of Phase III the determination was made that the data from all areas sampled were sufficient to complete the BRA.

4.2.1 **Soil**

As described in Section 3, 541 soil samples were collected from 290 soil sample locations within 45 areas. Samples from each area were evaluated to determine whether the data collected were sufficient to adequately characterize the Site conditions and support the BRA within the respective area. The evaluation consisted of both a qualitative and a quantitative data assessment. The quantitative assessment included a screening-level risk assessment, which was performed consistent with the methodology described in Volume 1, Section 9.5.4.1 of the Work Plan, and a SLERA, which was performed consistent with the methodology described in Volume 4 of the Work Plan.

The screening-level risk assessment for soil used the highest contaminant concentrations detected in each soil sampling area to calculate upper-bound cumulative cancer and non-cancer risk estimates for the key receptors and exposure scenarios identified in the preliminary CSM for potential human exposure (Table 2 of the RI/FS Work Plan, Volume 1). The risk calculations were performed using the exposure factors in Volume 1, Appendix F of the RI/FS Work Plan and toxicity values that were compiled in accordance with EPA OSWER Directive 9258.7-53 (EPA 2003b).

Where the screening-level risk assessment evaluation showed that an area did not warrant remedial action (i.e., the upper-bound cumulative cancer risk and HI did not exceed 1 x 10^{-4} and 1, respectively), then no further sampling of the area was performed, and the area was not carried forward for the next phase of field investigation. Conversely, if the comparison to EPA's acceptable risk limits showed that remedial action for a particular sampling area was warranted (i.e., the upper-bound cumulative cancer risk or HI exceeds 1 x 10^{-4} or 1, respectively), then additional sampling was recommended for the area to further characterize the extent of the contaminant concentrations contributing most significantly to the upper-bound cumulative cancer risk and HI estimates. The data from subsequent soil sampling was then used to develop more representative exposure concentrations which were used in the BRA and/or used to delineate a sub-area for evaluation in the FS.

In addition to the quantitative data assessment, a qualitative assessment of the soil data was performed using the criteria described in Volume 1, Section 9.5.4.2 of the Work Plan. The qualitative evaluation was designed to identify circumstances in which even the conservative use of the data in the quantitative screening-level risk assessment could potentially underestimate the risks to an extent that would affect the reliability of the determination regarding the need for remedial action. The results of the quantitative and qualitative assessments were used to identify either areas where further characterization was warranted or areas where the data was sufficient to support the BRA.

The SLERA, which was concluded at the end of Phase I and included Steps 1 and 2 of the EPA's *Superfund Ecological Risk Assessment 8-Step Process*, was performed to determine if there was a high probability of no ecologically significant risk or if there was a need to conduct further evaluation in Step 3a. Step 1 (screening-level problem formulation) was provided in the ERA Work Plan. Step 2 comprised the screening-level ecological effects assessment and risk calculations. Maximum detected concentrations from each exposure area were used as the screening-level exposure estimates. These concentrations were divided by Ecotoxicity Screening Values (ESVs) to calculate HQs, as described in the ERA Work Plan. HQs less than 1 (to one significant digit) indicate that adverse impacts to wildlife are considered unlikely. Exposure units with HQs greater than 1 were carried to Step 3a, where the assumptions responsible for these HQs were further evaluated. Chemicals that, at this point in the process, lacked a reliable and appropriate ESV and detected bioaccumulative chemicals were also carried to Step 3a. The SLERA identified several areas where additional data on soil pH were necessary to interpret the HQs calculated for aluminum. These additional samples were collected during Phase II as described in the Phase II Technical Memorandum and Section 3.2.1.9 of this report.

At the conclusion of the Phase III soil sampling, the determination was made that the data from all areas sampled were sufficient to complete the BRA for soil.

4.2.2 **Groundwater**

Groundwater data were collected during: (1) pre-RI groundwater sampling activities (Altamont 2008 and 2009), (2) the three phases of RI field activities, and (3) the Annual Assessment Monitoring events. Additionally, 18 CERCLA compliance monitoring wells were sampled annually for select VOCs, nitroaromatic compounds, and metals.

At the end of each phase of the RI, the groundwater data were evaluated to determine the adequacy of the data for defining the extent of Site COPCs in groundwater. As part of this data evaluation, both the spatial distribution of groundwater COPCs and the maximum detected concentration of groundwater COPCs were evaluated.

To evaluate the spatial distribution of groundwater COPCs, plume maps were prepared depicting the lateral extent of groundwater indicator compound concentrations (as described in Section 3.1.2.4) above applicable 2L standard IMACs, or in the case of RDX, a screening value calculated by using the formulas specified under the 2L regulations in the Zones AB and CD (Figures 4-1 through 4-24). The plume maps were prepared using all groundwater data available since 2007. Where multiple data sets were available, the most recent results were utilized. Plume maps for Zone EF were not prepared because these wells were constructed in fractured bedrock and plume maps can not accurately depict a plume in fractured bedrock. However, concentrations of groundwater indicator compounds are provided for each Zone EF well on Figures 4-25 and 4-26. Plume maps are discussed in more detail in Section 4.3.3.

To evaluate concentration data, the maximum detected concentration for each COPC at each monitoring well from any sampling event between the 2007 Site-wide groundwater sampling and the assessment monitoring events was compared to the criteria defined in the Work Plan and Section 3.5 of the Phase I Technical Memorandum. This evaluation is discussed in detail in Section 6.

At the conclusion of Phase III data evaluation, the determination was made that the groundwater data were adequate to support the BRA. Collection of water level and water quality data will continue via the Annual Assessment Monitoring and will be used to evaluate groundwater conditions over time in both the Front Valley and the Back Valley.

4.2.3 **Surface Water and Sediment**

Surface water and sediment sampling were performed as part of the 2007 and 2008 Site-wide groundwater and surface water sampling events and during Phase I of this RI. Additional surface water sampling was performed as part of the Annual Assessment Monitoring. Surface water COPC concentrations were compared to the human health and ecological risk criteria presented in Section 4 of the Phase I Technical Memorandum. Sediment COPC concentrations were compared to the human health and ecological risk criteria presented in Section 5 of the Phase I Technical Memorandum.

These comparisons determined that both surface water and sediment data were adequate to complete the BRA.

4.3 Site COPCs Detected by Media

This section describes the frequency and extent of detections of Site COPCs in soil, groundwater, surface water, and sediment.

4.3.1 **Soil**

As described in Section 3, soil samples were collected from areas where there was a reasonable potential for Site-related COPC impacts to soil. Phase I soil samples were analyzed for specific parameters identified for each area in the Work Plan. Samples collected during subsequent phases were analyzed for parameters identified in the approved Phase I and Phase II Technical Memoranda or addenda. Soil analytical parameters included VOCs, nitroaromatics, perchlorate, SVOCs, pesticides, and TAL metals. The specific analytes for each area were selected based on a comprehensive review of the available information regarding former chemical handling and storage practices, former operations and processes, and known or suspected past releases. The soil sample locations for each phase of investigation are shown on Figure 1-6.

4.3.1.1 Volatile Organic Compounds

VOC analyses were performed on soil samples from 37 of the 45 areas where soil samples were collected. VOCs were detected in soil at 31 of the 37 areas. The most frequently detected VOCs in soil were acetone, cyclohexane, methylene chloride, TCE, toluene, and 1,2-DCA. Less frequent, yet common, detections of benzene, naphthalene, PCE, trimethylebenzenes, TBA, and vinyl chloride were reported. Several other VOCs were detected much less frequently in discrete areas. A complete listing of the VOCs detected for each area is included in Table 3-4 (Phase III data only) and Appendices A, F, and H.

4.3.1.2 Nitroaromatic Compounds and Perchlorate

Analyses for nitroaromatic compounds and perchlorate were performed on soil samples from all of the 45 areas where soil samples were collected. Nitroaromatic compounds were detected in soil at 21 of the 45 areas. The most frequently detected nitroaromatic compounds in soil were HMX, RDX, 2,6-dinitrotoluene, and 1-nitronaphthalene. Less frequent detections of nitrobenzenes, tetryl, 2,4,6-TNT, and other miscellaneous additional nitroaromatic compounds were reported for specific areas. Perchlorate was detected in soil at 22 of the 45 areas where soil samples were collected. A complete listing of the nitroaromatic compounds and perchlorate detected for each area is included in Table 3-4 (Phase III only) and Appendices A, F, and H.

4.3.1.3 Semivolatile Organic Compounds

SVOC analyses were performed on soil samples from 43 of the 45 areas where soil samples were collected. SVOCs were detected in soil at 34 of the 43 areas. A complete listing of the SVOCs detected for each area is included in Table 3-4 and Appendices A, F, and H.

4.3.1.4 Pesticides

Analyses for pesticides were performed on soil samples from 19 of the 45 areas where soil samples were collected. Pesticides were detected in soil in all of the 19 areas sampled. Pesticides reported include aldrin, chlordane, endosulfan, endosulfan sulfate, and heptachlor epoxide. A review of the Site history does not indicate that pesticides were manufactured or processed at the Site. The random distribution of pesticide compounds detected is likely related to routine vector control during facility operations. A complete listing of the pesticides detected for each area is included in Table 3-4 and Appendices A, F, and H.

4.3.1.5 Metals

Analyses for TAL metals were performed on soil samples from all of the 45 areas where soil samples were collected. Additionally, to evaluate the concentrations of metals detected, soil sampling and analyses for metals were performed during Phase II to establish the naturally occurring regional background concentration of metals in soil. Background soil samples were collected from 12 on-Site areas that represent the range of soil and underlying rock types present at the Site. The locations selected were not known to have been impacted by Site activities or other anthropogenic sources of metals. Site-specific background concentrations were established and metals results from the potential source areas were compared to the background levels as described in the Phase II Technical Memorandum. A complete listing of the metals detected for each area is included in Appendices A, F, and H.

4.3.2 **Groundwater**

As discussed in Section 3, each Site monitoring well (Figure 1-4) was sampled at least once for the following suite of COPCs:

- VOCs
- SVOCs
- Perchlorate
- Nitroaromatics (including picric acid)
- Pesticides
- Herbicides
- Metals (TAL, excluding calcium, iron, magnesium, potassium, and sodium)
- Organic acids

Other inorganics: ammonia, chloride, cyanide, nitrate, sulfate, and sulfide

Most of the Site monitoring wells were sampled one or more times during the pre-RI sampling events, during the RI, or during the 2011 Annual Assessment Monitoring event. As described in Section 3, sampling events completed after the initial event generally utilized an abbreviated analytical suite because COPCs that were not detected in the initial sampling event at any particular well were not analyzed in subsequent events for that well.

Groundwater indicator compounds were selected as described in Section 3.1.2.3. Front Valley VOC indicator compounds are TCE, PCE, chloroform, and 1,2-DCA, and Back Valley VOC indicator compounds are TCE, TBA, chloroform, and 1,2-DCA. The indicator compound for nitroaromatics is RDX for both the Front Valley and the Back Valley. Perchlorate was also selected as an indicator compound for both the Front Valley and the Back Valley. Concentrations of indicator compounds were posted on the cross-sections prepared for the Front Valley and the Back Valley (see Figures 4-27 through 4-44). Plume maps were prepared illustrating the distribution of these indicator compounds in groundwater in the Surficial Aquifer System (Zone AB) and the Transition Zone Aquifer System (Zone CD). These maps are included as Figures 4-1 through 4-24. Plume maps were not prepared for the Bedrock Aquifer System (Zone EF) because those wells are constructed in fractured bedrock and plume maps cannot accurately depict COPC distribution in fractured bedrock. However, indicator compound data for the Bedrock Aquifer System are posted on the maps (see Figures 4-25 and 4-26).

4.3.3 **Distribution of Groundwater COPCs**

Plume maps prepared for the Surficial Aquifer System and the Transition Zone Aquifer System, Figures 4-1 through 4-24, show the spatial extent of the indicator compounds based on the most recent data for each monitoring well. As indicated on the figures, the sampling events were completed between 2007 and 2012. The lowest contour value shown on any particular map is equal to the groundwater criteria established for the Site. This criterion is either the 2L standard or, if a 2L standard does not exist, other risk-based criteria derived for the Site as described in the Work Plan. Similar maps showing the areal extent of indicator compounds were prepared at the conclusion of each phase of investigation. These maps are included in the reports contained in Appendix A of this report.

Comparison of the spatial extent of Site COPCs in the Surficial Aquifer System and the Transition Zone Aquifer System can be made by reviewing the plume maps for like compounds in the two aquifer systems (e.g., comparing Figure 4-1 to Figure 4-2). Evaluation of the vertical distribution of Site COPCs within the various aquifer systems can be made by considering the data posted on the cross-sections (Figures 4-27 through 4-44).

4.3.3.1 Volatile Organic Compounds

Generally, VOC indicator compounds in the Transition Zone Aquifer System (Zone CD) in the Front Valley tend to have larger spatial extent than in the overlying Surficial Aquifer System (Zone AB). This observation, combined with the overall measured downward vertical hydraulic gradients discussed in Section 2.2.3.4 and shown on Figure 2-22, suggest that VOCs derived from the near-surface sources identified in Section 5.1 are migrating both laterally in response to hydraulic gradients (and the resulting increased groundwater flow velocity) within an aquifer system and vertically in response to the downward vertical gradients between the aquifer systems. Once VOCs migrate downward into the Transition Zone Aquifer System, the spatial spread becomes greater due to the increase in hydraulic conductivity in the Transition Zone Aquifer System. In some areas, (e.g., B147 and 105, and B116-128), VOC concentrations in the Transition Zone Aquifer System are higher than concentrations measured in the Surficial Aquifer System (see Figures 4-30 and 4-32).

The observed spatial extent for the VOC indicator compounds in the Back Valley does not show the same apparent increase in spatial extent between the Surficial Aquifer System and the underlying Transition Zone Aquifer System as in the Front Valley. This may be due to the effect of the groundwater extraction system currently operating downgradient of the source areas. However, similar to the Front Valley, VOC concentrations in the Transition Zone Aquifer System in the Back Valley are higher than concentrations measured in the Surficial Aquifer System at several locations (see Figures 4-40 and 4-42).

Posted data showing the distribution of VOCs in the Bedrock Aquifer System (Zone EF) are shown on Figures 4-25. As shown on Figure 4-25, a localized area of VOC impact (primarily chloroform) is identified around monitoring well MW227-J39EF in the central part of the Front Valley.

Evaluation of the plume maps indicate that some VOCs extend to the southern property boundary at very low concentrations. However, the data do not indicate off-Site migration at concentrations exceeding Site-specific criteria.

4.3.3.2 Nitroaromatic Compounds and Perchlorate

The spatial distribution of RDX and perchlorate in the Front Valley is shown on Figures 4-9 through 4-12. The spatial distribution of RDX and perchlorate in the Back Valley is shown on Figures 4-21 through 4-24. In the Front Valley, the areal extent and concentration of both RDX and perchlorate are generally greater in the Surficial Aquifer System than in the underlying Transition Zone Aquifer System.

The extent of RDX in the Back Valley, shown on Figures 4-23 and 4-24 indicates that RDX in the Surficial Aquifer System occurs in close proximity to the AP and DA9 while RDX in the Transition Zone Aquifer System was detected further downgradient. The magnitude of the concentrations in both the Surficial Aquifer System and the Transition Zone Aquifer System are similar. The spatial extent of perchlorate in the Back Valley is similar in both the Surficial Aquifer System and the Transition Zone Aquifer System (Figures 4-21 and 4-22). The vertical distribution of perchlorate in the Back Valley tends to show higher concentrations in the Transition Zone Aquifer System than in the Surficial Aquifer System.

Posted data showing the distribution of RDX and perchlorate in the Bedrock Aquifer System are shown on 4-26. As shown on Figure 4-26, localized areas of RDX and perchlorate impacts are identified in the vicinity of MW176-L41EF and MW229-L41E in the Front Valley and MW228-O27EF and BW-11 in the Back Valley.

Evaluation of the plume maps indicate that perchlorate extend to the southern property boundary at very low concentrations. However, the data do not indicate off-Site migration at concentrations exceeding Site-specific criteria.

4.3.3.3 Distribution of Groundwater COPCs Near the Site Boundary

As discussed in Section 4.2.2, property boundary monitoring wells in the Surficial Aquifer System, the Transition Zone Aquifer System, and the Bedrock Aquifer System have been sampled for Site COPCs during pre-RI sampling in 2007 and 2008, during the RI, and in the ongoing Annual Assessment Monitoring Program. The detections are summarized on Tables 3-2 and 3-3. Although there have been transient detections of TBA, TCE, 1,2-DCA, and RDX at or above the applicable groundwater criteria in one or more property boundary wells, with the exception of TBA (detected in MW192-P41CD) detections at or above the criteria are not repeated from one sampling event to the next and no increasing concentration trends are evident in the property boundary monitoring wells. With the exception of the TBA detection, the most recent sampling data collected in 2012 did not detect any concentrations in groundwater in the property boundary wells exceeding applicable criteria. Additionally, off-Site groundwater sampling (see Section 3.5 and Table 3-6) have not detected any Site-related compounds above applicable groundwater criteria.

The detections of TBA in monitoring well MW192-P41CD appear to be related to the repair of a Metropolitan Sewerage District (MSD) sewer line running parallel to the eastern Site boundary in the Front Valley. This MSD sewer line contains treated groundwater discharged from the Back Valley treatment system, which is known to contain TBA. MSD replaced a segment of old sewer line in 2011. As shown on Table 3-2, TBA was first detected during the Phase II RI sampling event in 2011 at an estimated (J) concentration of 4.5 µg/L, which is below the IMAC for TBA (10 µg/L). Subsequent sampling during the 2011 and 2012 annual assessment monitoring events reported TBA concentrations of 29 µg/L and 46 µg/L in 2011 and 2012 respectively. (Note: the 2012 data were presented in the 2012 Annual Assessment Monitoring Report, which was submitted to the EPA and DENR after the Draft RI Report was submitted.) These recent data indicate that a release of TBA may have occurred during the sewer line repair.

MW192-P41CD is a transition zone well. In this area of the Site, the transition zone is very shallow and discharges to Bee Tree Creek on Site. There is not a published standard for TBA in surface water. However, ENVIRON calculated both a human health and an ecological screening value for TBA in surface water. The concentration of TBA in groundwater in well MW192-P41CD is lower than the calculated screening value for surface water. Surface water sampling at multiple locations in Bee Tree Creek has not detected TBA. Therefore, there is no indication that TBA has migrated off-Site in groundwater discharging to surface water. Well MW192-P41CD and surface water in Bee Tree Creek will continue to be monitored as part of the assessment monitoring program.

4.3.4 **Distribution of Surface Water and Sediment COPCs**

As described in Sections 3.1 and 4.2.3, surface water sampling was performed as part of the 2007 and 2008 Site-wide groundwater and surface water sampling events and during Phase I and Phase II of the RI. Additional surface water sampling was performed during the 2011 Annual Assessment Monitoring event. Sediment sampling was performed during Phase I of the RI. Both surface water and sediment samples were collected at 53 locations. There are two additional locations where only surface water samples were collected, and two locations where only sediment samples were collected. The surface water and sediment sampling locations are shown on Figures 1-7 and 4-45. Surface water and sediment were sampled and analyzed for VOCs, SVOCs, nitroaromatics, perchlorate, pesticides, and metals.

In surface water, the primary Site COPCs detected were VOCs (chloroform, TBA, TCE, and 1,2-DCA), nitroaromatics (HMX and RDX), and perchlorate. Although metals were detected, metals have not been identified as Site-related COPCs. Table 3-5 summarizes surface water analytical results for VOCs, nitroaromatics, and perchlorate from each of the sampling events. Figure 4-45 shows concentrations from the most recent surface water sampling event for TCE and perchlorate at each sampling location. TCE and perchlorate are among the most frequently detected Site COPCs in surface water. The sampling period for results shown on Figure 4-45 extends from 2010 to 2012.

Generally, the highest concentrations of TCE and perchlorate in surface water occur in the upper reaches of both the Front Valley and the Back Valley. In the Front Valley, concentrations of TCE and perchlorate decrease downstream from an area located in the vicinity of groundwater source areas B116-128, B147, and DA23. In the Back Valley, concentrations of TCE and perchlorate in surface water decrease downstream from an area located in the vicinity of a groundwater source area at the AP and DA9. The distributions of VOCs, nitroaromatics, and perchlorate detected in surface water indicate they are a result of local discharge of groundwater into surface water.

Various SVOCs and pesticides were also reported in low concentrations in surface water. SVOCs were detected at multiple locations in both the Front Valley and Back Valley. Pesticides were detected in on-Site surface water bodies and at the upstream sampling location in Bee Tree Creek, which represents off-Site and upstream conditions. The random distribution of SVOCs and pesticides does not allow for identification of specific source areas.

Sediment results are discussed in detail in Section 5 of the Phase I Technical Memorandum. In sediment, various pesticides were the most frequently detected Site COPCs. There were also less frequent detections of VOCs and SVOCs. VOCs were detected in sediment in areas where surface water VOC detections indicate local discharge of groundwater into surface water. The random distribution of pesticides and SVOCs does not allow for identification of specific source areas.

As discussed in Section 6, there were no detections of Site COPCs in surface water or sediment that were above the human health risk criteria established for the Site.

5.0 Routes of COPC Migration and Transport

This section discusses the routes of migration and transport of Site COPCs. This discussion is based on data collected prior to and during this RI. This section summarizes information regarding sources of Site COPCs in various media, the extent of Site COPCs within the various media, transport mechanisms for Site COPCs within the various media, COPC concentration trends and stability, and potential current and future human and ecological receptors that may be exposed to Site COPCs. Further discussion regarding the human health and ecological receptor exposure assessment, including Site COPC release areas, media specific migration pathways, and receptor exposure scenarios, is included in Sections 6 and 7.

5.1 Source Areas

As discussed in Section 4, soil, groundwater, surface water, and sediment sampling was performed during the RI. One of the objectives of the sampling program was to identify the location of releases of Site COPCs into the various environmental media. Release of Site COPCs could occur at potential source areas such as former operational areas, waste management areas, debris disposal areas, and the DAs. Site COPCs released into the various environmental media can result in source areas for direct exposure to human or ecological receptors or as sources for inter-media transfer of Site COPCs (e.g., COPCs in soil leaching to groundwater or COPCs in groundwater discharging to surface water). The following sections discuss the various sources for either direct exposure or inter-media transfer.

5.1.1 Soil

As discussed in Section 3, a total of 541 soil samples were collected and analyzed from 290 soil sample locations from 45 areas during the multiple phases of the RI. The 45 potential source areas chosen for soil sampling were based on a comprehensive review of the available information on former chemical handling and storage practices, former operations and processes, and known or suspected past releases. The soil sampling scope of work was designed using a biased-sampling program in which soil samples were collected from locations where Site COPC concentrations were expected to be highest. If data from a previous investigation of the area were available, such data were also considered in biasing the sampling locations.

Figure 1-6 shows the soil sampling locations for each phase of the RI for each identified potential source area. Soil sampling was performed in intervals between the ground surface and the capillary fringe at the top of the saturated zone. Individual figures providing more detail on specific potential source area sampling locations, depths, and analytes were included in the Phase I and Phase II Technical Memoranda and as Figures 6-1 through 6-3 of this report. The sample results are summarized in Table 3-4 and in the Phase I and Phase II Technical Memoranda (see Appendix A). As discussed in Section 1 of this report and Section 4 of Volume 2 of the Work Plan, soil underlying the existing on-Site capped DAs was not further characterized during this RI because the caps are assumed to be performing as intended and preventing direct exposure to the underlying materials.

To evaluate direct exposure to human or ecological receptors, soil data at each potential source area were evaluated using qualitative and quantitative techniques to determine when sufficient data were obtained to support the BRA, as described in Section 4.2.1. Evaluation of soil data was further discussed in the HHRA and ERA, which are presented in Sections 6 and 7, respectively. Evaluation of the nature and extent of Site COPCs in soil identified the following soil source areas with the potential for unacceptable risks due to direct exposure:

- Area B116-128
- Area B109-137

Additionally, groundwater data were evaluated to identify locations where release of Site COPCs either to soil in the unsaturated zone above the capillary fringe, or areas where the release point may be at or below the first encountered groundwater, have resulted in Site COPCs entering the groundwater system. Groundwater data identified the following areas with residual soil or saturated zone COPC concentrations that appear to be resulting in impacts to groundwater:

Front Valley:

- Area B104
- Area B113
- Area B115
- Area B116-128
- Area B146
- Areas B147 and 105
- Area B114
- Area B149
- DA23 (capped)

Back Valley:

- AP (capped)
- DA9 (capped)

As discussed above, soil underlying the existing on-Site capped DAs was not sampled during the RI. However, groundwater data indicated that the AP, DA9, and potentially DA23 are ongoing sources for Site COPCs entering the groundwater system. The capped DAs 6, 7/8, and 10/11 do not appear to be current source areas for COPC impacts to groundwater. However, they will be retained as potential future source areas and monitoring wells in the vicinity of these DAs are included in the annual assessment monitoring program and will be included in any future modifications to the routine monitoring program.

For the other source areas for Site COPCs entering the groundwater system, with the exception of the B116-128 area, soil sampling did not identify areas of soil impacts above the saturated zone. Therefore, the source areas for groundwater COPCs appear to reside primarily in the saturated zone.

5.1.2 **Groundwater**

As discussed in Section 3, groundwater samples were collected from 175 on-Site monitoring wells and 8 off-Site potable water supply wells during the RI. Sampling locations are shown on Figures 1-4 and 1-5. The sample results are summarized in Tables 3-1 through 3-3, Appendix H, and in the Phase I and Phase II Technical Memoranda (see Appendix A). Groundwater data were evaluated to identify areas where Site COPCs in underlying groundwater result in source areas for direct exposure to human or ecological receptors or as a source for inter-media transfer of Site COPCs (groundwater discharging to surface water).

To evaluate direct exposure to humans (ecological receptors are not directly exposed to groundwater), groundwater data were evaluated using qualitative and quantitative techniques to determine when sufficient data were obtained to support the BRA, as described in Section 4.2.2. Evaluation of groundwater data was further discussed in the HHRA which is presented in Section 6. Evaluation of the nature and extent of Site COPCs in groundwater identified the following groundwater source areas with the potential for unacceptable risks due to direct exposure, either via dermal contact or vapor inhalation:

- P-7S
- MW180-H38AB
- MW223-L26AB
- MW231-H38AB

An additional 49 on-Site monitoring well locations were identified as having the potential for unacceptable exposure if the groundwater were to be used for potable or nonpotable purposes. The locations of these wells are shown on Figure 6-4. Off-Site groundwater sampling has not detected any Site-related compounds above applicable groundwater criteria.

5.1.3 **Surface Water**

Surface water sampling results are described in detail in Section 4. As discussed in Section 4, evaluation of surface water analytical data for on-Site streams indicate that the highest concentrations of Site COPCs are generally detected in the headwater portions of the Unnamed Branch and Gregg Branch and decrease downstream. Figure 4-45 illustrates the surface water sampling locations and the analytical results for TCE and perchlorate. TCE and perchlorate were the most frequently detected and widespread surface water COPCs, and the posted data show concentrations detected above the relevant 2B standards.

The RI did not identify any direct sources of surface water impacts. As discussed in Section 5.1.2, the surface water data and an evaluation of the geologic and hydrologic framework, presented in Section 2, suggest that the source of Site COPCs in surface water is the diffuse discharge of shallow groundwater containing Site COPCs.

Evaluation of surface water data is further discussed in the baseline HHRA and ERA presented in Sections 6 and 7, respectively. Site COPC concentrations in surface water samples collected from Bee Tree Creek, downstream of the confluence with on-Site streams, are either non-detectable or below the 2B standards and/or EPA National Criteria. Surface water analytical data for on-Site ponds indicate that Site COPC concentrations are either non-detectable or are detectable at concentrations below the 2B standards and/or EPA National Criteria. Evaluation of surface water data identified no locations where surface water Site COPC concentrations result in unacceptable human health or ecological risks.

5.1.4 **Sediment**

Sediment sampling was performed during Phase I of the RI. Sediment sampling locations correspond to the surface water sampling locations shown on Figure 4-45. The evaluation of sediment analytical results is discussed in the Phase I Technical Memorandum (Appendix A). Further evaluation of sediment results are discussed in the HHRA and ERA presented in Sections 6 and 7, respectively. The most frequently detected Site COPCs detected in sediment were pesticides. The random distribution of pesticides does not allow for identification of specific source areas. VOCs were detected in sediment in areas where surface water VOC detections indicate local discharge of groundwater into surface water. Evaluation of sediment data identified no locations where sediment Site COPC concentrations result in unacceptable human health or ecological risks.

5.2 Routes of Migration

Potential routes or pathways of COPC migration are listed on Table 6-2 (included in the HHRA [Section 6]), and include surface soils, subsurface soils, surface water (on-Site streams and ponds), sediment, and groundwater. Each potential pathway is evaluated below.

5.2.1 **Soil**

In general, soil source areas are either vegetated or covered with surfacing materials (e.g., asphalt, concrete, or synthetic caps on the DAs). The plant roots, leaf litter, and other surfacing materials reduce the risk of soil migration via erosion or aeolian transport. Migration of soil either on-Site or from on-Site to off-Site is not considered a significant pathway.

Potential exposure of future on-Site workers and terrestrial plants and animals are evaluated in Sections 6 and 7. Transport of contaminants to off-Site receptors via impacted soil is not considered a viable route of migration.

5.2.2 **Groundwater**

Historical groundwater analytical data indicate that groundwater on-Site is impacted by multiple COPCs (see Section 4). Groundwater indicator compounds including TCE, PCE, chloroform, 1,2-DCA, TBA, RDX, and perchlorate were used to create COPC plume maps for the Site (see Figures 4-1 to 4-26). These indicator compounds were selected because they are generally indicative of groundwater quality at the Site.

As is shown on the plume maps, concentrations of the groundwater indicator compounds are below the 2L standards or IMACs in all of the property boundary monitoring wells, except for a single detection of TCE in monitoring well MW154-O44C (at 3.4 µg/L, on 10/27/2011) which slightly exceeds the 2L standard of 3 µg/L. The significance of potential exposure of future on-Site workers, off-Site receptors, and ecological receptors to groundwater is evaluated in Sections 6 and 7.

5.2.3 Surface Water

Gregg Branch discharges to Bee Tree Creek within the Site property boundary. However, the Unnamed Branch flows off the southern Site boundary approximately 100 feet upstream of its confluence with Bee Tree Creek. Laboratory analysis of a 2011 surface water sample collected from location UBW1-044 (the surface water sample location at the property line) detected perchlorate at a concentration of 3.1 µg/L, which slightly exceeds the EPA National Surface Water Criteria of 2.8 µg/L. However, analytical data from Bee Tree Creek surface water sample location BTW1-P45, located off-Site and just downstream from the confluence of the Unnamed Branch and Bee Tree Creek did not detect perchlorate or any other COPC above the relevant criteria. No other surface water quality impacts were detected near the property boundaries.

These data indicate that transport of contaminants to off-Site receptors via surface water is not a significant route of migration. Potential exposure of future on-Site workers and aquatic plants and animals are evaluated in Sections 6 and 7.

5.2.4 Sediment

Historical analytical results for sediment samples indicate that constituents were either detected at concentrations below the laboratory method detection limit or detected at very low concentrations. Potential exposure of future on-Site workers and aquatic plants and animals is evaluated in Sections 6 and 7. Transport of contaminants to off-Site receptors via impacted sediment is not considered a viable route of migration.

5.3 COPC Concentration Trends and Stability

The persistence of a COPC in the environment is affected by the media in which it is detected, the physical and chemical characteristics of the COPC, and by a variety of environmental factors. Based on the results of the risk assessment described in Sections 6 and 7, specific COPC persistence in certain media will be evaluated in greater detail in the FS. However, because groundwater is the primary route of migration for COPCs to reach off-Site potential receptors, general COPC persistence in groundwater has been evaluated for the Site groundwater indicator compounds.

The primary factors that influence COPC persistence include the degradation rate/pathway of the COPC, geochemical and biological conditions in the aquifer, rate of dilution, and the presence of an ongoing source of the COPC. COPC persistence in groundwater can be evaluated by considering current and historical groundwater analytical data to identify trends in concentration or changes in plume geometry. Time-concentration plots for Site wells are included as Figures 5-1 to 5-23. As shown on the time-concentration plots, groundwater concentrations of Site indicator compounds are generally stable or decreasing. Evaluation of plume maps indicates that the plumes are relatively stable. There are a few wells in the Back Valley located in the interior of the plume (and near the potential source areas) that have groundwater concentrations that are increasing or remaining relatively constant. This may be related to changes in internal plume geometry in response to ongoing operation of the groundwater recovery system. However, as stated above, the outer (downgradient) extent of the plume remains generally unchanged over the past decade. Although the leading edge of the plumes for certain of the more mobile contaminants extends at points to the southern property boundary, there is no indication that Site COPCs have migrated in proximity to any potential receptor.

5.4 Potential Receptors

Section 4 of Volume 1 of the Work Plan discussed potential receptors, and Table 2 of the Work Plan provided a detailed description of potential receptors. Table 2 presented a comprehensive summary of the preliminary scope of the HHRA portion of the BRA. It showed the potential human exposure scenarios that were included in characterizing RME risks under current land use on-Site and off-Site and the potential human exposure scenarios that were included in characterizing RME risks under future land use on-Site and off-Site. Table 2 has been updated and is discussed in Section 6.

As discussed in Section 6.1, the HHRA is based on the assumption that land use and groundwater use on-Site are unrestricted, except within the fenced portion of each DA where access is strictly limited to personnel who monitor and maintain the effectiveness of the remedy specified by the 1988 ROD and 1989 ROD Amendment. Off-Site land use and groundwater use around the Site are currently unrestricted and are assumed to remain unrestricted in the HHRA.

6.0 Human Health Risk Assessment

6.1 Introduction

This section discusses the methodology and results of the HHRA portion of the BRA performed as part of the RI. The HHRA evaluates potential human health risks from releases of COPCs at or from the Site. The potential risks are evaluated under current and reasonably anticipated future land and groundwater uses at and surrounding the Site in the absence of remedial action.

The purpose of the HHRA is to determine whether RME, under current and reasonably anticipated future land and groundwater use at and around the Site, are sufficiently high to warrant remedial action. The HHRA described in this report is consistent with EPA risk assessment guidance and the EPA-approved Work Plan.

The remainder of Section 6 is organized as follows:

- Section 6.2: Data Selection and Preparation—This section discusses the data selected for use in evaluating potential human exposures.
- Section 6.3: Exposure Assessment—This section describes the scenarios for potential human exposure and discusses the estimation of exposure concentrations and chemical intakes for each exposure scenario.
- Section 6.4: Toxicity Assessment—This section discusses the selection and use of toxicity values for the COPCs evaluated in the risk assessment.
- Section 6.5: Risk Characterization—This section presents the risk estimates associated with each exposure scenario and discusses their significance. This section also identifies COCs which are defined as constituents that are significant contributors of potentially unacceptable risk. Uncertainties associated with the risk estimates are discussed in this section.
- Section 6.6: Summary and Conclusions—This section summarizes the findings and conclusions of the HHRA.

6.2 Data Selection and Preparation

The objectives of the RI data collection and strategies for determining when additional data collection is warranted were described in the approved RI/FS Work Plan, the Phase I Technical Memorandum, and the Phase II Technical Memorandum.

Soil, groundwater, sediment, and surface water data collected during the RI are evaluated in the HHRA, with the exception of soil data from areas that were subsequently excavated after soil sampling as part of interim measures during the RI (Altamont 2010b and 2011).

Validation of soil, groundwater, sediment, and surface water data used in the risk assessment was performed in accordance with the project QAPP described in Section 3.

In addition, the following procedures were used to prepare the data to support quantitative risk assessment. These procedures, which are based on EPA guidance on the HHRA (EPA 1989b), are as follows:

- Concentrations qualified as not detected (i.e., U or UJ qualified data) during data validation are evaluated as non-detections.
- Concentrations qualified as not usable (i.e., R qualified data) during data validation are not included in the risk assessment.
- Concentrations qualified as estimated (i.e., J qualified data) are included for quantitative assessment.
- Concentrations in duplicate field samples are averaged to obtain a representative concentration for the sample location. When a COPC was detected in only one sample of a duplicate pair, the average of the detected concentration and one half the quantitation limit is used in further calculations.
- The concentrations of 1,3-dichloropropene (total), endosulfan (total), chlordane (total), methylphenol (total), polychlorinated biphenyls (PCBs) (total), and xylenes (total) are the sums of the concentrations of the isomers or Aroclors that were detected and half the quantitation limits of the isomers or Aroclors that were not detected in the same sample but were detected in the same matrix at the Site. If no isomer or Aroclor was detected in a sample, the chemical is considered to be not detected in the sample.
- To distinguish background risks from Site-related risks, concentrations of metals in soil at or below the Site-specific background exposure concentrations[1] summarized on Table 6-1 (and discussed in Section 6.5.2.1) are considered to pose background risks and zero Site-related risks. Metal concentrations in soil in excess of the Site-specific background exposure concentrations are considered to pose potential Site-related risks.
- As a conservative assumption, concentrations of organic COPCs detected in on-Site matrices are assumed to pose potential Site-related risks.

6.3 Exposure Assessment

The potential exposures that are relevant under current and reasonably expected future land and groundwater uses at and around the Site are discussed in this section. These exposures are described in terms of potentially exposed populations and exposure pathways in Section 6.3.1. The scenarios for potential human exposure discussed in Section 6.3.1, in combination with the earlier discussions of potential source areas, COPCs, affected environmental media, and potential migration pathways, comprise the conceptual model of the Site.

The potential exposures via ingestion and dermal contact are quantified in terms of a dose as follows:

$$Dose = Concentration \cdot Intake$$

The dose for evaluating cancer risk is averaged over a lifetime and is called the lifetime average daily dose (LADD). For evaluating noncancer effects, the dose is averaged over the duration of exposure and is called the average daily dose (ADD). The concentration term in the dose equation refers to the average COPC concentration in an environmental medium to which a receptor population is exposed over the exposure duration. The intake term refers to the intake rate of the affected environmental

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[1] The background exposure concentrations are 95 percent UCLs on the mean; they are estimates of the average background soil concentration to which a receptor is exposed.

medium, which is a function of the magnitude, frequency, and duration of exposure. The methods for estimating the concentration term are discussed in Sections 6.3.2 and 6.3.3. The exposure factors that are used to quantify the magnitude, frequency, and duration of potential exposures are discussed in Section 6.3.4.

Inhalation exposures are quantified in terms of an exposure concentration, which is an air concentration that is time-weighted over the duration of exposure. The exposure concentration for evaluating cancer risk is an average over a lifetime. For evaluating chronic and subchronic noncancer effects, the exposure concentration is an average over the duration of exposure. The methods for estimating air concentrations are discussed in Sections 6.3.2 and 6.3.3.

The environmental setting at and around the Site, including climate, geology, hydrogeology, land cover, surface water bodies, water supply, and groundwater use, is discussed in Section 1, and therefore is not repeated in this section.

6.3.1 **Scenarios for Potential Human Exposure**

The scenarios for potential human exposures discussed below were initially presented in Section 4.3 of Volume 1 of the approved RI/FS Work Plan. Potential on-Site human exposures are discussed in Section 6.3.1.1 and potential off-Site exposures are discussed in Section 6.3.1.2. The discussion in these subsections is summarized in Table 6-2.

Corresponding to the subsections below, Table 6-2 is organized into two main sections—the first addresses potential on-Site exposures and the second addresses potential off-Site exposures. Within each section of the table, the information is organized by the potential receptor populations that are evaluated in the HHRA. For each potential receptor population, the table identifies the environmental media (e.g., soil) to which the potential receptor population may be exposed and the associated routes of exposure (e.g., ingestion). For each combination of potential receptor, media, and exposure route listed in the table, the table includes two columns that indicate whether the particular combination may exist under current land use, future land use, or both.

The scenarios for potential human exposure are based on the assumption that future on-Site land use and groundwater use will be unrestricted, except within the fenced portion of each DA where access is strictly limited to personnel who monitor and maintain the effectiveness of the remedy specified by the 1988 ROD and 1989 ROD Amendment. Off-Site land use and groundwater use around the Site are currently unrestricted and are assumed to remain unrestricted in the risk assessment. The last column in Table 6-2 includes brief explanatory notes for some of the combinations of potential receptor population, media, and exposure routes.

6.3.1.1 Potential On-Site Human Exposures

Potential on-Site exposures under current and future conditions are discussed in this section. Future on-Site exposures are based on the range of reasonable potential property uses that are currently under consideration.

6.3.1.1.1 Current Conditions

The Site is currently inactive. No commercial/industrial activities currently exist at the Site and all former buildings have been demolished (except for those used for on-Site security or remediation purposes). The Site is fenced along portions of its boundary, and on-Site roads are patrolled by security guards. Workers at the Site include those who are performing environmental investigation, remediation, and maintenance or construction activities (e.g., workers from local utilities), which are governed by a Site-specific and detailed HASP for the Site, or security guards who are authorized to work in limited parts of the Site. The on-Site workers are aware of the presence of potential chemical hazards at the property and the nature of these hazards, and they take appropriate precautions to ensure that they do not have unacceptable exposures.

Trespassers at the Site could be potentially exposed to environmental media under current conditions. Occasional trespassers have been reported by the security patrols at the Site. In general, these trespassers were apparently recreational users of the areas surrounding the Site and may have knowingly or unknowingly entered the property (e.g., along the northwestern boundary and near the ponds along the southeastern boundary). Potential exposure is reasonably likely along the Site boundaries, near the man-made ponds, and in the Back Valley during hunting season and is not reasonably likely during the summer at interior portions of the property because of distance from the boundaries, difficult terrain, and heavy vegetation. Potential exposure of trespassers may include:

- Incidental ingestion of surface soil, surface water, and sediment
- Dermal contact with surface water and sediment in the ponds, portions of the streams near the property boundary, and surface soil around these surface water bodies
- Inhalation of airborne particulates from surface soil or vapors from surface and subsurface soil or groundwater
- Recreational consumption of game animals from the Site and fish from the on-Site ponds and Bee Tree Creek

In summary, the only on-Site receptor under current conditions that warrants quantitative evaluation is the trespasser.

6.3.1.1.2 Future Conditions

Plans for future reuse of the Site have not been finalized, so the scenarios for potential human exposure are based on current expectations regarding the feasibility of reuse alternatives for different parts of the Site. The exposure scenarios focus comprehensively on the entire Site but assume that the existing remedies for the DAs will continue to prevent exposure within the fenced portion of the DAs themselves.

As shown on Table 6-2, this risk assessment assumes that the property may be redeveloped for commercial/industrial and/or residential reuse. For the purpose of this risk assessment, such redevelopment is assumed to include but not be limited to (1) above-ground or below-ground construction; (2) improvements (including, but not limited to, utilities, sewers, roads, and sidewalks); (3) potable use and nonpotable use (e.g., landscape irrigation, non-contact cooling water) of on-Site groundwater requiring the installation of groundwater wells or other devices for access to groundwater; and (4) alteration, disturbance, or relocation on-Site of the existing soil, landscape, and contours.

During future redevelopment of the Site, construction workers could be exposed to environmental media at the Site. During reuse of the redeveloped Site, receptors would include workers who may become exposed during performance of typical or routine industrial activities (industrial workers), workers who may become exposed during maintenance or minor subsurface construction (maintenance workers), residents, and visitors or trespassers. Except for the DAs, the scenarios for potential human exposure also allow the possibility that some or all of the property could be set aside for limited recreational use.

Potential exposure of industrial workers is assumed to include incidental ingestion and dermal contact with exposed surface soil and on-Site surface water and sediment (e.g., during lunch breaks at the streams and ponds). Industrial workers could also be exposed to the following:

- Vapors and particulates from surface soil
- Vapors from surface water
- Vapors from subsurface soil and groundwater that migrates into outdoor air
- Vapors from groundwater and subsurface soil that migrate through building foundations into indoor air

For the purposes of this BRA, these industrial workers are assumed to have potential future exposure via drinking water use of on-Site groundwater, although institutional controls to restrict use of groundwater may be considered in the FS for impacted on-Site groundwater areas.

Potential future exposure of construction workers and maintenance workers is assumed to include the following:

- Incidental ingestion and dermal contact with surface and subsurface soil, shallow groundwater (during excavations that extend into groundwater), surface water, and sediment in the on-Site streams and ponds
- Inhalation of airborne particulates and vapors from surface and subsurface soil
- Inhalation of vapors from groundwater and surface water.

Potential future exposure of residents is assumed to include incidental ingestion and dermal contact with exposed surface soil, and on-Site surface water and sediment (e.g., at the streams and ponds). Future hypothetical residents could also be exposed to the following:

- Vapors and particulates from surface soil
- Vapors from surface water
- Vapors from subsurface soil and groundwater that migrates into outdoor air
- Vapors from groundwater and subsurface soil that migrate through building foundations into indoor air

For the purpose of this BRA, the future hypothetical residents are also assumed to have potential exposure via drinking water use of on-Site groundwater, although institutional controls to restrict use of groundwater may be considered in the FS for impacted on-Site groundwater areas.

Potential future exposures of trespassers and recreational users are assumed to include the following:

- Incidental ingestion and dermal contact with surface soil, surface water, and sediment
- Inhalation of airborne particulates from surface soil, vapors from surface and subsurface soil, groundwater, and surface water
- Recreational consumption of game animals and fish from Pond 1 and Pond 2.

In summary, the risk assessment quantitatively evaluates the following potential on-Site receptor categories under future conditions: industrial worker; maintenance worker; construction worker; resident; recreational user, and trespasser.

6.3.1.2 Potential Off-Site Human Exposures

A 2003 survey of groundwater use within 0.25 miles of the Site identified some potable and nonpotable groundwater uses in residential areas to the southwest, south, and east of the Site. An updated groundwater well receptor survey was performed between March and July 2010 in accordance with Section 2.1.1 of the approved RI/FS Work Plan. As discussed in Section 6 of the Phase II Technical Memorandum, the survey confirmed four off-Site properties with residential water supply wells installed since the 2003 survey. Sampling of the off-Site wells concluded that no chemicals were present at concentrations above the 2L standard. Chloroform was detected at concentrations below the 2L standard of 70 µg/L in three of the wells. TBA was detected in one of the wells at 4.9 J µg/L. There is no 2L standard for TBA, but this concentration is below the IMAC concentration of 10 µg/L

These detections of chloroform and TBA may not be Site-related and thus do not necessarily indicate that there is any groundwater migration pathway from the Site to off-Site receptors. Nonetheless, the risk assessment conservatively assumes that future off-Site groundwater exposure is possible if COPCs in on-Site groundwater were to migrate off-Site. Potential off-Site receptors may include maintenance workers, recreational users, and nearby residents. In addition, surface water at the Site may affect off-Site groundwater and surface water (e.g., Bee Tree Creek) and, hence, lead to potential exposure of off-Site receptors, which would include maintenance workers, recreational users, and nearby residents.

Potential exposure of maintenance workers is assumed to include incidental ingestion and dermal contact with groundwater during excavations that extend into groundwater, with surface water and sediment in Bee Tree Creek, and inhalation of vapors from surface water or groundwater.

Potential exposure of recreational users is assumed to include incidental ingestion and dermal contact with surface water and sediments in off-Site streams, inhalation of vapors from Bee Tree Creek and groundwater, and recreational consumption of game animals and fish.

Potential exposure of off-Site residents is assumed to include incidental ingestion, dermal contact, and inhalation during residential uses of groundwater. Off-Site residents may be potentially exposed to airborne particulates from on-Site soil and/or vapors from on-Site soil and groundwater. Off-Site residents could also be exposed to vapors from groundwater that migrates through building foundations into indoor air.

As shown on Table 6-2, the exposure scenarios for off-Site receptors under future conditions are assumed to be the same as those that may occur under current conditions.

6.3.2 **Exposure Concentrations**

6.3.2.1 Soil Exposure Concentrations

Soil risk estimates were initially calculated for each of the 290 soil sample locations from the RI. This was done to facilitate the identification of areas with potentially unacceptable risks. The area characterized by each soil sample location was estimated using a Thiessen polygon tessellation (where polygon boundaries are halfway between neighboring sample locations), as shown in Figure 6-1. To streamline risk calculations for each location, the highest detected concentration of each COPC from any depth at each soil sample location was initially used. This initial set of soil concentrations represent upper-bound estimates of the actual exposure concentrations, and as such, the cumulative cancer and noncancer risk estimates calculated using these concentrations are considered upper-bound estimates.

If an upper-bound cumulative cancer or noncancer risk estimate for a soil sampling location exceeds the EPA risk management limits (i.e., cumulative cancer risk greater than 1 x 10^{-4} and/or HI greater than 1), then more representative exposure concentrations were estimated.

In evaluating soil direct contact exposures, the refined exposure concentrations were estimated by calculating a 95 percent UCL on the mean or an area-weighted mean using the soil data from the other sampling locations within the same area (as identified in Drawing 1 of Volume 2 of the Work Plan). Refinements were only made for the COPCs that contributed most to the upper-bound cumulative risk estimates. For the remaining COPCs, the maximum concentrations were still used as exposure concentrations. The UCLs and area-weighted means were conservatively calculated using the maximum detected concentrations from any depth at each sample location within an area. The UCL calculations were performed using ProUCL (Version 4.1.00), including the Kaplan-Meier method for datasets with non-detects. The recommended values from ProUCL were used for expediency, even though some of the recommended values are higher (more conservative) than those specified in EPA guidance[2]. The UCLs or area-weighted means were then used to estimate the cumulative cancer risk and HI for the exposure area. Where such refinements were made, the specific refinement for each case and rationale is discussed in Section 6.5.2. This approach (i.e., refining the exposure concentrations for only the COPCs contributing most to the cumulative risk) is efficient in that it avoids calculations (such as UCL calculations) that would not materially affect the cumulative cancer risk and/or HI estimates and is consistent with EPA guidance (EPA 1989b). This approach is also conservative, because it uses the maximum detected concentration, rather than 95 percent UCLs or area-weighted means, for many COPCs. The uncertainties associated with using such conservative estimates of exposure concentrations in evaluating the significance of potential exposures is discussed in Section 6.5.3.1.

In evaluating potential soil vapor intrusion exposures, if the upper-bound cumulative risk estimate for a sampling location exceeds the EPA risk management limits (i.e., cumulative cancer risk greater than 1 x 10^{-4} and/or HI greater than 1), then the exposure assessment was refined to use depth-weighted soil concentrations (rather than maximum concentrations) and to account for the available COPC mass in the soil under the hypothetical building. Specifically, the soil vapor intrusion calculations were refined to include a mass balance check, which ensured that the assumed mass of a COPC infiltrating into the hypothetical building over the exposure period does not exceed an upper-bound estimate of the COPC's mass in the vadose zone underlying the hypothetical building.

6.3.2.2 Groundwater Exposure Concentrations

Groundwater risk estimates are calculated for each of the 175 monitoring wells sampled during the RI. The risk estimates are conservatively calculated using the highest detected concentration for each COPC among the RI data (from June 2007 through February 2012). Groundwater data from wells that characterize the shallow groundwater are used to calculate vapor intrusion risk estimates. Groundwater data from wells that characterize groundwater within 10 feet of the ground surface, which is the maximum depth to which workers are reasonably expected to be exposed during subsurface activities

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[2] The recommended UCLs from ProUCL are not necessarily 95 percent UCLs but may represent up to 99 percent UCLs and may assume the data follow a distribution (e.g., normal or lognormal) that could provide more or less conservative estimates of the mean concentration than those specified for risk estimates in EPA guidance (EPA 1989b).

(e.g., via excavation), are used to calculate risk estimates for exposures during excavations that encounter groundwater.

As discussed further in Section 6.5.2.8.2, on-Site groundwater concentrations near the Site boundary (i.e., within 200 feet of the property line) are conservatively used to evaluate potential future off-Site receptor exposure to groundwater.

6.3.2.3 Sediment Exposure Concentrations

To assess potential exposures to sediment under current and future conditions, the highest detected concentration in sediment for each COPC is used in the risk assessment.

6.3.2.4 Surface Water Exposure Concentrations

To assess potential exposures to surface water under current and future conditions, the highest detected concentration in surface water for each COPC is used in the risk assessment.

6.3.3 **Fate and Transport Models**

The following models are used in the risk assessment to estimate exposure concentrations for the exposure scenarios discussed in Section 6.3.1. These models are used by EPA and state regulatory agencies for conservative screening level analysis. The following are brief descriptions of the models. Further details of these models are provided in Appendix L.

6.3.3.1 Vapor Emission from Exposed Soil

Vapor emissions from exposed soil are estimated using the Jury model (Jury et al. 1983) based on depletion over time, assuming conservatively that the soil is impacted from the ground surface to an infinite depth. A discussion of the model is provided in Appendix L (Section L3.1).

6.3.3.2 Vapor Intrusion into Buildings

Indoor air concentrations from migration of vapors from soil and groundwater into a building are estimated using the model described by Johnson and Ettinger (1991), which EPA recommends for screening level evaluations (EPA 2004a). Indoor air concentrations from migration of vapors from soil were initially calculated assuming that COPCs exist to an infinite depth. As described in Section 6.3.2, if this assumption resulted in risk estimates above the EPA risk management limits, then the indoor air concentrations were calculated using depth-weighted average vadose zone soil concentrations and a mass balance check. Further details are provided in Appendix L (Section L3.2).

The calculations in this risk assessment conservatively use hypothetical building characteristics and generic soil properties recommended by EPA (2004a) that are representative of the soil types at the Site (i.e., clay loam). To evaluate future exposure in commercial/industrial buildings, EPA's generic residential building parameters are conservatively used, with the exceptions of the building ventilation rate ($Q_{building}$) and the assumed pressure differential, because commercial/industrial buildings typically have higher ventilation rates than residential buildings and lower long-term pressure differentials. Specifically, to evaluate commercial/industrial buildings, the HHRA used an indoor air exchange rate of 1 hr^{-1} and a pressure differential of 1 Pa, based on professional judgment.

A discussion of the model and the input parameters used in the assessment is provided in Appendix L (Section L3.2).

6.3.3.3 Vapor Emission from Exposed Water

The model for estimating vapor emissions from exposed water surfaces in excavations is based on mass transfer coefficients recommended in EPA guidance (EPA 1995a). A discussion of the model and the input parameters used in the calculation is provided in Appendix L (Section L3.3).Air Dispersion

Annual average air concentrations are estimated using the empirical correlations presented in EPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (EPA 2002a), assuming a square source area, and using correlation coefficients for the Raleigh, North Carolina meteorological area. For soil exposures, the source area for industrial workers, maintenance workers, and construction workers is conservatively based on 12 acres, which is the size of the largest area sampled during the RI. For surface water exposures, the source area used to calculate the air dispersion factor is 2.7 acres, which is the size of the largest on-Site pond (Pond 2).

For groundwater exposures during excavations to the water table, the source area is based on a 15-by-15-ft excavation. The outdoor air concentrations due to vapor emission from the excavation area are estimated using EPA's SCREEN3 air dispersion model (EPA 1995b). For this scenario, the maximum 1-hour air concentrations are converted to maximum 24-hour average air concentrations using a conservative factor of 0.4 (EPA 1995).

6.3.3.4 Dust Emission

Emission of respirable soil particulates (PM_{10}) for industrial worker exposures to outdoor soil are calculated using the wind erosion model recommended by EPA (1996) with EPA default soil parameters and wind speed and anemometer height from the nearest weather station, which is located in Asheville, North Carolina (National Oceanic and Atmospheric Administration [NOAA] 2010).

The air concentration of respirable soil particulates during maintenance activities is conservatively set at 50 micrograms per cubic meter ($\mu g/m^3$). The PM_{10} level of 50 $\mu g/m^3$ is based on a time-weighted average assuming maintenance workers spend one-third of their exposure period excavating into the subsurface and two-thirds of their exposure period conducting maintenance activities that do not involve excavation into the subsurface. In calculating the time-weighted average, the 24-hour average National Ambient Air Quality Standards (NAAQS) value for PM_{10} of 150 $\mu g/m^3$ was used as the PM_{10} concentration during excavations, and a PM_{10} concentration of 1 $\mu g/m^3$ was used for the time during maintenance activities that do not involve excavation. The PM_{10} concentration during non-excavation maintenance activities is expected to be less than 1 $\mu g/m^3$, based on the wind erosion model recommended by EPA (1996) using wind speed from Asheville, North Carolina (NOAA 2010). These calculations are discussed in Appendix L (Section L3.1).

The PM_{10} level for construction activities is set at 50 $\mu g/m^3$, which is the former annual average NAAQS for PM_{10}, because construction workers are assumed to be performing excavations for a work year. It is conservatively assumed that the PM_{10} concentration would be at this limit every day for the entire period of construction worker exposure.

Uncertainties inherent in the models and the conservative assumptions that are used in this risk assessment to address such uncertainties (particularly the estimation of exposure concentrations) are discussed in Section 6.5.3.1.

6.3.4 **Exposure Factors**

The exposure factors for evaluating the exposures summarized in Table 6-2 (Scenarios for Potential Human Exposure) are from Volume 1, Appendix F of the approved RI/FS Work Plan. The exposure factors are also tabulated in Appendix L (Attachment L-1.07). In this risk assessment, standard default exposure factors recommended by EPA for estimating RME are used where available and appropriate. Where standard default exposure factors are not available or appropriate for an exposure scenario, the evaluation is performed using similarly conservative exposure factors that are based on Site-specific considerations and professional judgment.

6.3.4.1 Industrial Workers

In this risk assessment, potential exposure of industrial workers to soil and groundwater is conservatively evaluated using the standard default exposure factors that EPA (1991a) recommends for estimating RME. According to EPA, the standard default exposure factors are conservative assumptions about the magnitude, frequency, and duration of exposures, which, in combination, are intended to provide estimates of exposures that are higher than actual exposures to a large portion (90 to 99 percent) of a potentially exposed population. The EPA default values for industrial workers are summarized below:

- Soil Ingestion Rate

  The soil ingestion rate of 50 milligrams (mg)/day is EPA's standard default value for evaluating RME in commercial/industrial settings (EPA 1991a).

- Soil Dermal Contact Rate and Absorption

  The dermal contact rate is the product of the exposed skin surface area and the soil-to-skin adherence factor. The exposed skin surface area of 3,300 centimeter $(cm)^2$/day and the soil-to-skin adherence factor of 0.2 mg/cm^2 are EPA's recommended values for evaluating RME in commercial/industrial settings (EPA 2004b). The exposed skin surface area is based on the 50th percentile area of the head, hands, and forearms. The soil-to-skin adherence factor is based on the 50th percentile weighted soil-to-skin adherence factor for utility workers, which EPA has determined to be a high-end contact activity in commercial/industrial settings (EPA 2004b). The absorbed dose from dermal contact with soil is estimated by multiplying the dermal contact rate by EPA-recommended absorption factors for absorption from soil (EPA 2004b).

- Soil PM_{10}/Vapor and Groundwater Vapor Exposure Time

  Industrial workers are assumed to be at the Site and inhale vapors and particulates from Site-related sources for 8 hours per day, which is EPA's recommended value for full-time workers (EPA 2009a).

- Groundwater Ingestion

  Industrial workers are assumed to ingest 1 liter (L) of groundwater per day. This value is EPA's standard default value for evaluating drinking water exposures at commercial/industrial Sites (EPA 1991a).

- Exposure Frequency and Duration

The exposure frequency of 250 days per year is EPA's standard default value for evaluating RME in commercial/industrial settings (EPA 1991a). It is based on a 5-day work week and 50 weeks per year. The exposure duration of 25 years is EPA's standard default value for evaluating RME in commercial/industrial settings (EPA 1991a). It is the 95th percentile job tenure of workers in manufacturing. This combination of exposure frequency and exposure duration is expected to be conservative for the amount of time that workers are actually exposed to soil during outdoor activities, because industrial workers normally spend the majority of their time indoors. EPA has recommended the use of these values for evaluating high-end industrial worker exposures (EPA 1991a).

- Body Weight

  A body weight of 70 kilograms (kg) is EPA's standard value for assessing exposure of adults (EPA 1991a).

- Averaging Time

  The averaging time for evaluating cancer risk is equal to a lifetime of 70 years, and the averaging time for evaluating noncancer risk is equal to the exposure duration (EPA 1989b).

6.3.4.2 Maintenance Workers

The exposure factors used for evaluating potential exposure of maintenance workers to soil, groundwater, sediment, and surface water are as follows:

- Soil Ingestion Rate

  The ingestion rate of 100 mg/day is based on professional judgment regarding the mix of soil contact activities. The value assumes one-third of the activities will be similar to those of construction workers (with soil ingestion rate of 200 mg/day), and two-thirds of the activities will be similar to those of industrial workers (with soil ingestion rate of 50 mg/day).

- Soil and Sediment Dermal Contact Rate and Absorption

  The dermal contact rate is the product of the exposed skin surface area and soil-to-skin adherence factor. The exposed skin surface area of 3,300 cm^2/day and the soil-to-skin adherence factor of 0.2 mg/cm^2 are EPA's recommended values for evaluating RME in commercial/industrial settings (EPA 2004b). The exposed skin surface area is based on the 50th percentile area of the head, hands, and forearms. The soil-to-skin adherence factor is based on the 50th percentile weighted soil-to-skin adherence factor for utility workers, which EPA has determined to be a high-end contact activity, and is higher than or equal to the 50th percentile weighted soil-to-skin adherence factor for grounds keepers, landscapers, irrigation installers, gardeners, construction workers, and heavy equipment operators (EPA 2004b, Exhibit 3-3).

- Soil Exposure Frequency

  The exposure frequency of 65 days per year is based on professional judgment regarding the number of days per year of maintenance activities involving soil contact. It is the number of work days in 13 weeks (3 months) of such activities.

- Soil PM_{10}/Vapor Inhalation Exposure Time

Maintenance workers are assumed to be at the Site and inhale vapors and particulates from soil for 8 hours per day, which is EPA's recommended value for full-time workers (EPA 2009a).

- Groundwater and Surface Water Ingestion

  The incidental groundwater ingestion rate is the product of the hourly ingestion rate and exposure time. The ingestion rate of 0.005 L/hour is one-tenth of EPA's recommended value for incidental ingestion while swimming (EPA 1989b) and represents a very conservative estimate of incidental groundwater ingestion that could occur while workers are in an excavation pit. The exposure time of 2 hours per day for contact with groundwater or surface water during maintenance activities is based on professional judgment.

- Groundwater and Surface Water Dermal Contact

  The exposed skin surface area of 3,300 cm^2 is based on the EPA-recommended exposed skin surface area for evaluating high-end contact with soil by workers in industrial settings (EPA 2004b). Workers are conservatively assumed to be covered with groundwater over this exposed skin surface area for 2 hours per event. The chemical-specific permeability coefficient (K_p) for dermal absorption from groundwater is estimated following EPA guidance (EPA 1992a, EPA 2004b).

- Groundwater Exposure Frequency

  The exposure frequency of 16 days per year assumes that 25 percent of the maintenance work (65 days per year) involves excavations that encounter groundwater, based on professional judgment.

- Groundwater Vapor Inhalation Exposure Time

  Maintenance workers are assumed to be exposed to groundwater vapors 2 hours per day while performing maintenance activities in groundwater, based on professional judgment.

- Sediment Ingestion Rate

  The ingestion rate of 50 mg/day is 50 percent of the soil ingestion rate assumed for maintenance workers, based on professional judgment that simultaneous contact with surface water in this scenario would tend to wash sediment off hands and thereby reduce incidental sediment ingestion during hand-to-mouth contact.

- Sediment and Surface Water Exposure Frequency

  The exposure frequency of 50 days per year is based on 1 day per week of maintenance activities involving surface water contact for 50 weeks per year, based on professional judgment.

- Surface Water Vapor Inhalation Exposure Time

  The exposure time assumes 2 hours per day is spent performing maintenance activities at surface water bodies, based on professional judgment.

- Exposure Duration

  The exposure duration of 10 years is between the 90th percentile and 95th percentile job tenure of workers in construction (Burmaster 2000). Burmaster (2000) showed that the 90th and 95th percentiles are 7.7 years and 12.5 years, respectively. He used the same data to confirm that the

95th percentile job tenure for manufacturing workers matches EPA's industrial worker exposure duration of 25 years (EPA 1991a).

- Body Weight

  A body weight of 70 kg is EPA's standard value for assessing exposure of adults (EPA 1991a).

- Averaging Time

  The averaging time for evaluating cancer risk is equal to a lifetime of 70 years, and the averaging time for evaluating noncancer risk is equal to the exposure duration (EPA 1989b).

6.3.4.3 Construction Workers

The exposure factors used for evaluating potential exposure of construction workers to soil and groundwater during excavations associated with Site redevelopment construction activities are as follows:

- Soil Ingestion Rate

  The ingestion rate of 200 mg/day is the 90th percentile from the adult soil ingestion study published by Stanek et al. (1997). It is more appropriate than the 95th percentile (330 mg/day) from the same study, because in a study of only 10 adults, the 95th percentile is at or beyond the highest observed ingestion rate and, as such, has far more uncertainty than the 90th percentile. Using the 90th percentile is also consistent with EPA guidance on selecting exposure factors for estimating the RME.

- Soil Dermal Contact Rate and Absorption

  The dermal contact rate is the product of exposed skin surface area and soil-to-skin adherence factor. The exposed skin surface area of 3,300 cm^2/day and the soil-to-skin adherence factor of 0.2 mg/cm^2 are EPA's recommended values for evaluating RME in commercial/industrial settings (EPA 2004b). The exposed skin surface area is based on the 50th percentile area of the head, hands, and forearms. The soil-to-skin adherence factor is based on the 50th percentile weighted soil-to-skin adherence factor for utility workers, which EPA has determined to be a high-end contact activity, and is higher than or equal to the 50th percentile weighted soil-to-skin adherence factor for grounds keepers, landscapers, irrigation installers, gardeners, construction workers, and heavy equipment operators (EPA 2004b, Exhibit 3-3).

- Soil Exposure Frequency

  The exposure frequency of 130 days per year is based on professional judgment regarding the number of days of soil excavation or other high-intensity soil contact activities. It is the number of work days in 26 weeks (half of a year) of soil excavation or other high-intensity soil contact activities.

- Soil PM_{10}/Vapor Inhalation Exposure Time

  Construction workers are assumed to be at the Site and inhale vapors and particulates from soil for 8 hours per day, which is EPA's recommended value for full-time workers (EPA 2009a).

- Groundwater Ingestion

The incidental groundwater ingestion rate is the product of the hourly ingestion rate and exposure time. The ingestion rate of 0.005 L/hour is one-tenth of EPA's recommended value for incidental ingestion while swimming (EPA 1989b). The exposure time of 2 hours per day is the time in contact with groundwater during construction activities, based on professional judgment.

- Groundwater Dermal Contact

  The exposed skin surface area of 3,300 cm^2 is based on the 50th percentile area of the head, hands, and forearms (EPA 2004b). Workers are conservatively assumed to be covered with groundwater over this exposed skin surface area for 2 hours per event. K_P for dermal absorption from groundwater is estimated following EPA guidance (EPA 1992a, EPA 2004b).

- Groundwater Exposure Frequency

  The exposure frequency of 33 days per year assumes that 25 percent of the construction work (130 days per year) involves excavations that encounter groundwater, based on professional judgment.

- Groundwater Vapor Inhalation Exposure Time

  Construction workers are assumed to be exposed to groundwater vapors 2 hours per day while performing construction activities in groundwater, based on professional judgment.

- Exposure Duration

  The exposure duration of 1 year is based on professional judgment regarding the duration of Site redevelopment activities.

- Body Weight

  A body weight of 70 kg is EPA's standard value for assessing exposure of adults (EPA 1991a).

- Averaging Time

  The averaging time for evaluating cancer risk is equal to a lifetime of 70 years, and the averaging time for evaluating noncancer risk is equal to the exposure duration (EPA 1989b).

  Construction worker exposure to sediment and surface water is expected to be equal to or less than that of maintenance workers, because construction workers are assumed to be exposed to sediment and surface water for the same exposure frequency and shorter duration than maintenance workers.

6.3.4.4 Residents

In this risk assessment, potential exposure of residents to soil and groundwater is conservatively evaluated using the standard default exposure factors that EPA (1991a) recommends for estimating RME. According to EPA, the standard default exposure factors are conservative assumptions about the magnitude, frequency, and duration of exposures, which, in combination, are intended to provide estimates of exposures that are higher than actual exposures to a large portion (90 to 99 percent) of a potentially exposed population. The EPA default values for residents are summarized below:

- Soil Ingestion Rate

  The soil ingestion rates of 200 and 100 mg/day are EPA's standard default values for evaluating RME in residential settings by children and adults, respectively (EPA 1991a).

- Soil Dermal Contact Rate and Absorption

  The dermal contact rate is the product of the exposed skin surface area and the soil-to-skin adherence factor. The exposed skin surface area of 2,800 and 5,700 cm^2/day and the soil-to-skin adherence factor of 0.2 and 0.07 mg/cm^2 are EPA's recommended values for evaluating RME with soil by children and adults, respectively (EPA 2004b).

- Soil PM_{10}/Vapor and Groundwater Vapor Exposure Time

  Residents are assumed to be at home and inhale vapors and particulates from Site-related sources for 24 hours per day, which is an upper-bound estimate.

- Groundwater Ingestion

  Residents are assumed to ingest 2 L of groundwater per day. This is EPA's standard default value for evaluating drinking water exposures at residential sites (EPA 1991a).

- Exposure Frequency and Duration

  The exposure frequency of 350 days per year is EPA's standard default value for evaluating RME in residential settings (EPA 1991a). It is based on 7-days per week and 50 weeks per year. The exposure duration of 30 years is EPA's standard default value for evaluating RME in residential settings (EPA 1991a). It is the 90th percentile for time spent at one residence.

- Body Weight

  The body weight of 15 kg and 70 kg are EPA's standard values for assessing exposure of children and adults, respectively (EPA 1991a).

- Averaging Time

  The averaging time for evaluating cancer risk is equal to a lifetime of 70 years, and the averaging time for evaluating noncancer risk is equal to the exposure duration (EPA 1989b).

6.3.4.5 Recreational Users

Recreational users are evaluated as adolescents ages 7 through 16, which is the same age range that EPA recommends for evaluating trespasser or Site visitor scenarios (EPA 2000). The exposure factors used for evaluating potential exposure of recreational users to soil, surface water, sediment, and fish are as follows:

- Soil Ingestion Rate

  A soil ingestion rate of 100 mg/day is used for adolescent recreational users. EPA has recommended the use of this value for evaluating high-end exposures of adolescent and adult residents to soil (EPA 1991a).

- Soil and Sediment Dermal Contact Rate and Absorption

  The exposed skin area of 5,200 cm^2/day is based on the 50th percentile male and female areas of feet, lower legs, hands, forearms, and head for ages 7 through 16. The soil-to-skin adherence factor of 0.2 mg/cm^2 is the same as that for industrial workers and child residents (EPA 2004b). The absorbed dose from dermal contact with soil is estimated by multiplying the dermal contact rate by EPA-recommended absorption factors for absorption from soil (EPA 2004b).

- Soil PM_{10}/Vapor Inhalation Exposure Time

  Recreational users are assumed to be at the Site and inhale vapors and particulates from soil-related sources for 4 hours per day while recreating, based on professional judgment.

- Exposure Frequency and Duration

  The exposure frequency of 100 days per year for contact with soil is based on a conservative assumption that recreational users visit the Site 2 days per week for 50 weeks per year. The exposure duration of 10 years is based on the assumed age range of the recreational users (ages 7 through 16).

- Sediment Ingestion Rate

  The incidental sediment ingestion rate for recreational users is assumed to be 100 mg/day. This value is the same as EPA's default soil ingestion rate for adult residents (EPA 1991a).

- Surface Water Ingestion

  The incidental surface water ingestion rate is the product of the hourly ingestion rate and exposure time. The ingestion rate of 0.05 L/hr is EPA's recommended value for incidental ingestion while swimming (EPA 1989b). The exposure time of 2 hours/day assumes half the time at the Site involves swimming, based on professional judgment.

- Surface Water Dermal Contact

  The exposed skin area of 12,800 cm^2 is the 50th percentile male and female total body area for adolescents ages 7 through 16 (EPA 1997).

- Surface Water Vapor Inhalation Exposure Time

  Recreational users are assumed to inhale vapors from surface water sources 2 hours per day while recreating, based on professional judgment.

- Surface Water and Sediment Exposure Frequency

  Recreational users are assumed to be exposed to surface water 44 days per year based on 2 days per week of swimming during 153 days in May to September when the air temperature is at least 70 degrees F, based on professional judgment.

- Fish Ingestion Rate

  The fish ingestion rate of 0.0175 kg/day is the value EPA uses in developing the ambient water quality criteria (EPA 2000). This is an annualized rate for ingestion of fish from all sources, which must be used with an exposure frequency of 365 days per year. The annual fish ingestion rate is approximately 6.4 kg (14 lbs) per person. This ingestion rate is the same as the value used in 15A NCAC 02B.0208 and is essentially the same as the 95th percentile value of 0.018 kg/day for recreational freshwater anglers based on the median values from the three populations surveyed in the key studies discussed in EPA's *Exposure Factors Handbook* (1997).

- Fraction Ingestion from Site

  The fraction of fish ingested from the Site is assumed to be 0.5 (or 3.2 kg/year per person), based on professional judgment considering the size of the ponds at the Site and size of Bee Tree Creek adjacent to the Site relative to off-Site surface water bodies in the vicinity and the expectation that recreational users are likely to catch at least half of their fish off-Site.

- Body Weight

  The body weight of 45 kg is the average male and female body weight of adolescents ages 7 through 16 (EPA 1997).

- Averaging Time

  The averaging time for evaluating cancer risk is equal to a lifetime of 70 years, and the averaging time for evaluating noncancer risk is equal to the exposure duration of 10 years (EPA 1989b).

6.3.4.6 Trespassers

The exposure factors used for evaluating potential exposure of trespassers to soil, surface water, and sediment are the same as those for recreational users with the following exception:

- Sediment and Surface Water Exposure Frequency

  Trespassers are assumed to be exposed to surface water 22 days per year based on 1 day per week of swimming during 153 days in May to September when the air temperature is at least 70 degrees F, based on professional judgment.

Use of these exposure factors would result in risk estimates for surface water and sediment contact that are lower than those estimated for recreational users.

6.3.4.7 Off-Site Residents

The exposure factors used to evaluate off-Site residential exposure to airborne COPCs from on-Site soil and to off-Site groundwater are as follows:

- PM_{10}/Vapor Inhalation Exposure Time

  Off-Site residents are assumed to be at home 24 hours per day where they could potentially inhale vapors and particulates from on-Site soil-related sources or vapors from off-Site groundwater.

- Exposure Frequency

  An exposure frequency of 350 days per year is assumed and is based on EPA’s standard default value for evaluating RME in residential settings (EPA 1991a). It is based on 7 days per week for 50 weeks per year.

- Exposure Duration

  An exposure duration of 30 years is assumed and is based on EPA’s standard default value for evaluating RME in residential settings (EPA 1991a). It is the 90th percentile for time spent at one residence.

6.4 Toxicity Assessment

A toxicity assessment identifies potential adverse health effects that are associated with exposure to chemicals and determines the dose response relationship between exposure and the occurrence of adverse effects. The toxicity values used in this risk assessment were compiled from EPA's hierarchy of sources (EPA 2003a), as follows:

1. Integrated Risk Information System (IRIS)
2. Provisional Peer Reviewed Toxicity Values (PPRTV)
3. Other Toxicity Values

When a toxicity value was not available from the first two tiers of the hierarchy, other EPA and non-EPA sources (e.g., Agency for Toxic Substances and Disease Registry [ATSDR]) of toxicity values were consulted. The toxicity values used in the risk assessment and their sources are summarized in Appendix L (Section L.1) and are discussed below. The toxicity values used in this risk assessment are current as of September 29, 2012.

6.4.1 **Cancer Toxicity Values**

For chemicals that EPA assessed prior to the 2005 *Guidelines for Carcinogen Risk Assessment* (EPA 2005a), EPA considers chemicals belonging to the following cancer weight of evidence groups as human carcinogens:

- Group A—Known Human Carcinogen: Sufficient evidence of carcinogenicity in humans
- Group B1—Probable Human Carcinogen: Limited evidence of carcinogenicity in humans
- Group B2—Probable Human Carcinogen: Sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans
- Group C—Possible Human Carcinogen: Limited evidence of carcinogenicity in animals and inadequate or lack of evidence in humans

For chemicals that EPA assessed after the 2005 *Guidelines for Carcinogen Risk Assessment* (EPA 2005a), EPA uses the following cancer weight of evidence groups:

- Carcinogenic to Humans
- Likely to Be Carcinogenic to Humans
- Suggestive Evidence of Carcinogenic Potential
- Inadequate Information to Assess Carcinogenic Potential

As shown in Appendix L (Attachments L-1.01 and L-1.02), many of the COPCs in this risk assessment are not designated as Group A or as being “Carcinogenic to Humans,” which means EPA acknowledges that there is either inadequate evidence or a lack of evidence that these chemicals cause cancer in humans. Therefore, evaluating these COPCs as human carcinogens in the risk assessment is highly conservative.

Cancer slope factors (SFs) and unit risk factors (URFs) for these COPCs and their sources are shown in Appendix L (Attachments L-1.01 and L-1.02). The oral SFs and inhalation URFs represent 95 percent upper confidence bounds on the probability of getting cancer over a lifetime per unit dose. As recognized by EPA, there is significant scientific evidence that some of the SFs and URFs may be overly conservative and may ignore the potential existence of threshold doses. Nonetheless, they are used here as conservative assessment tools.

6.4.2 Noncancer Toxicity Values

Chemicals designated by EPA as belonging to the cancer weight-of-evidence Group D (Not Classifiable as to Human Carcinogenicity) are considered noncarcinogens. Chemicals not designated as belonging to any cancer group are also treated as noncarcinogens. Chronic and subchronic reference doses (RfDs) and inhalation reference concentrations (RfCs) and their sources are shown in Appendix L (Attachments L-1.01 and L-1.02).

The oral RfDs and inhalation RfCs represent conservative estimates of the daily exposure to the human population, including sensitive subpopulations (e.g., children), which are likely to be without an appreciable risk of deleterious effects during a lifetime. These RfDs and RfCs typically incorporate several safety factors to account for uncertainties in their derivation, which in combination often result in overall uncertainty factors of 1,000 or more. Furthermore, for many chemicals, there is significant scientific debate about the validity of these RfDs and RfCs and the association of these doses and concentrations to potential adverse health consequences. Nonetheless, the RfDs and RfCs are used here as conservative assessment tools.

6.4.3 Extrapolation of Toxicity Values

The EPA sources of toxicity values listed above do not provide dermal toxicity values for any of the COPCs. Therefore, oral toxicity values (i.e., oral SFs and RfDs) are used as dermal toxicity values in this risk assessment. Adjustments to the oral toxicity values, where appropriate, are made in this route-to-route extrapolation following EPA guidance (EPA 2004b).

The EPA sources of toxicity values listed above do not provide inhalation toxicity values (URFs and RfCs) for all of the COPCs. Route-to-route extrapolation from oral toxicity values was not performed to obtain inhalation toxicity values for these COPCs consistent with EPA guidance on performing inhalation risk assessments (EPA 2009a).

Uncertainties introduced by using extrapolated toxicity values are discussed in Section 6.5.3.3.

6.4.4 Lead

Exposure of residents to lead in soil during outdoor activities is evaluated using a residential screening level of 400 milligrams per kilogram (mg/kg) (40 CFR Part 745, Federal Register Volume 66, No. 4, January 5, 2001).

Exposure of industrial workers to lead in soil during outdoor activities is evaluated using an industrial screening level of 2,240 mg/kg. This screening level is calculated following EPA guidance (EPA 2003b), including updates (EPA 2009b). The industrial screening level is intended to protect female workers of child-bearing age who contact soil. The derivation of the industrial soil screening level is presented in Appendix L (Attachment L-2.06). As an additional point of reference, soil lead concentrations are also compared to EPA’s industrial Regional Screening Level of 800 mg/kg.

6.5 Risk Characterization

The health significance of the potential exposures described in Section 6.3 is discussed in the following subsections. Section 6.5.1 describes the methods for estimating cancer risks and noncancer HIs. Section 6.5.2 discusses the risk estimates and the significance of the potential exposures. Uncertainties in the risk evaluation are discussed in Section 6.5.3.

Supporting information detailing these risk calculations discussed in Section 6.5 is presented in Appendix L. Appendix L (Attachment L-11) also provides these risk calculations in EPA's Risk Assessment Guidance for Superfund (RAGS) Part D format (EPA 2001c).

6.5.1 Cancer and Noncancer Risks

The cancer risk associated with potential exposure to a carcinogenic chemical via ingestion and dermal contact is calculated by multiplying an estimate of the LADD for a particular exposure scenario by the cancer SF for the chemical, as follows:

$$Risk = LADD \cdot SF$$

For the inhalation route, the cancer risk is calculated using the chemical concentration in air (C_{air}) and the URF, as follows:

$$Risk = C_{air} \cdot URF \cdot \frac{ET \cdot EF \cdot ED}{AT_c}$$

where:

> ET is exposure time, EF is exposure frequency, ED is exposure duration, and AT_c is the averaging time for carcinogens.

The noncancer HQ associated with potential exposure via ingestion and dermal contact is calculated by dividing an estimate of the ADD for a particular exposure scenario by the RfD for the chemical, as follows:

$$HQ = \frac{ADD}{RfD}$$

For the inhalation route, the HQ is calculated using C_{air} and the RfC, as follows:

$$HQ = \frac{C_{air}}{RfC} \cdot \frac{ET \cdot EF \cdot ED}{AT_{nc}}$$

where:

> AT_{nc} is the averaging time for noncarcinogens.

The media-specific cumulative cancer risk and noncancer HI from exposure to the combination of COPCs at an area are estimated following EPA guidance (EPA 1989b), as follows:

$$Cumulative\ Risk = \sum_i Risk_i$$

$$Hazard\ \ Index = \sum_i HQ_i$$

where:

$Risk_i$ = estimated cancer risk for the ith COPC

HQ_i = hazard quotient for the ith COPC

This approach may result in estimates of media-specific cumulative cancer risk and HI that are more conservative than necessary. For example, different COPCs may cause different and unrelated noncancer health effects, so summing the HQs for their individual effects would overestimate the significance of their combined effects. Nonetheless, this approach is used here as a conservative assessment tool.

Media-specific cumulative cancer risks and HIs for each receptor population identified on Table 6-2 are compared with EPA's cancer risk limit of 1 x 10^{-4} and HI limit of 1, respectively, to help determine whether remedial action is warranted for a particular media at a particular area of the Site (EPA, April 22, 1991).

For exposures to soil, the cumulative cancer risk and HI estimates for each receptor population are calculated in two ways: (1) excluding cancer and noncancer risks associated with exposure to background levels of metals in soil (i.e., the background risks associated with the concentrations on Table 6-1); and (2) including risks from exposure to background metals in soil. In the discussion in Section 6.5.2, the first set of risk estimates are called “total” risks and the second set of risk estimates are called “Site-related” risks. The total risks provide a means for identifying high background levels of metals, and the Site-related risks provide the basis for determining whether remedial action is warranted. Specifically, the need for remedial action is determined by comparing the Site-related risks to the EPA’s limits for excess lifetime cumulative cancer risk and HI, which are 1 x 10^{-4} and 1, respectively.

As discussed in Section 6.5.2, the Site-related soil risk estimates were initially calculated using maximum detected concentrations for each soil sample location (see Figure 6-1) to streamline the identification of areas with potentially significant risks and the COPCs that drive the risk estimates, even though such concentrations are likely to overestimate the RME. For a location where these upper-bound risk estimates exceed EPA’s lifetime cumulative cancer risk of 1 x 10^{-4} or HI limit of 1, the exposure concentrations for the COPCs that contributed most to the upper-bound risk estimates were refined (e.g., using UCLs on the mean instead of the maximum concentrations, using the principle of mass conservation, etc.) to derive refined cumulative cancer risk and HI estimates for comparison to the EPA risk management limits. While the comparisons performed for each medium individually are suitable for comparison to the EPA RME risk limits because they were calculated with sufficiently conservative exposure factors and toxicity values to ensure that they represent RME risk estimates (or higher), the media-specific cumulative cancer risks and HIs are also summed for each receptor and compared with EPA’s cancer risk limit of 1 x 10^{-4} and HI limit of 1, respectively.

6.5.2 **Risk Characterization for Potentially Exposed Populations**

6.5.2.1 Background Soil Risks

For each potential receptor, estimates of cumulative cancer risk and noncancer HI associated with exposure to background concentrations of metals in soil are shown on Table 6-3. The background cancer and noncancer risk estimates on Table 6-3 were calculated using the exposure factors discussed in Section 6.3.4 and toxicity values discussed in Section 6.4. As indicated on Table 6-3, the background cumulative cancer risk for the six on-Site receptors in Table 6-2 (Scenarios for Potential Human

Exposure) range from 4 x 10^{-7} (for construction workers) to 4 x 10^{-5} (for on-Site residents). The background HIs among the receptors range from 0.08 (for industrial workers) to 0.6 (for on-Site residents). As noted above, the total soil risk estimates for each receptor population includes these background risks; the Site-related soil risk estimates discussed in the rest of Section 6.5.2 are in excess of these background risks.

6.5.2.2 On-Site Industrial Workers (Future Scenario)

6.5.2.2.1 Soil

Potential exposure of on-Site industrial workers to COPCs in soil at each location is evaluated in this risk assessment by conservatively assuming the following two alternate hypothetical cases: (1) the soil at each location is outdoors, and workers are assumed to be exposed to the outdoor soil for the entire work day; or (2) the soil at each location is under an occupied building, and workers are assumed to be exposed to COPCs in the soil via vapor intrusion for the entire work day. Using these alternate hypothetical cases is conservative and efficient, because it avoids the need to prorate the portion of the work day spent indoors and/or outdoors, and risk estimates for any combination of indoor and outdoor time periods would not exceed the higher of the risk estimates for the two alternative hypothetical cases.

Potential exposures for each hypothetical case were first evaluated using upper-bound estimates of RME cumulative cancer risk and HIs to streamline the risk assessment, as explained in Section 6.5.1. The initial estimates were calculated using the highest observed concentrations for all COPCs detected in soil at a location. These estimates are conservative upper-bound estimates, because the Site-related RME risks for a location would be lower if they were calculated using: (1) Site-related metal concentrations (i.e., those in excess of the Site-specific background levels); (2) concentrations representative of the average concentrations to which receptors would be exposed at the area; and (3) Site-specific exposure factors that account for the magnitude, frequency, and duration of exposures appropriate for the area.

The upper-bound estimates of total cumulative cancer risk and HI for potential exposure of industrial workers for each alternate hypothetical case (i.e., all day exposure to soil during outdoor activities or all day exposure to soil COPCs via vapor intrusion) are summarized in Appendix L (Attachment L-9.02). These risk estimates include contributions from background metal concentrations. Attachment L-9.02 shows that for outdoor soil exposures, two soil sampling locations have upper-bound total cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively[3]. It also shows that for soil vapor intrusion exposures, 15 soil sampling locations have upper-bound total cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively.

The Site-related risk estimates for these same soil exposure scenarios are summarized on Table 6-4. These risk estimates differ from the total risk estimates in Attachment L-9.02 in that they are calculated using metal concentrations in excess of the Site-specific background exposure concentrations presented on Table 6-1. Table 6-4 shows that the same locations identified on Attachment L-9.02 have upper-bound Site-related cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively. These locations are shown on Figure 6-2 and are listed below by soil sampling area (as identified in Drawing 1 of Volume 2 of the Work Plan).

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[3] Per Section 9.5.1 of the Work Plan, a comparison of soil concentrations to EPA's November 2012 Regional Screening Levels for Industrial Soil is included in Appendix L (Attachment L-10.01).

For exposure to soil during outdoor activities, the following soil sampling areas have upper-bound cumulative cancer risk and HI estimates that exceed 1 x 10^{-4} and 1, respectively:

- B116-128—location B116SUMPS3
- Debris Area 1—location Debris Area 1S3

For exposure to soil via vapor intrusion, the following soil sampling areas have upper-bound cumulative cancer risk and/or HI estimates that exceed 1 x 10^{-4} and 1, respectively:

- APDA-7-8-9—location APDA789B2
- B107—location B107B6
- B109-137—locations B109137BS1A and SS1A
- B113—locations B113B5 and B6
- B116-128—locations B116SUMPS1, SUMPS2, SUMPS3, and SUMPS4
- B146—location B146B1
- B147—location B147B2
- B149—location B149B5
- B155—location B155B4
- DA23—location DA23B3

Exposure to Soil During Outdoor Activities

The cumulative cancer risk estimate and noncancer HI estimate for industrial worker exposure to soil during outdoor activities at location B116SUMPS3 in area B116-128 are due almost entirely to a concentration of 1,2-DCA (i.e., 1,300 mg/kg). The cumulative cancer risk estimate and noncancer HI estimate for industrial worker exposure to soil during outdoor activities at location Debris Area 1S3 are due almost entirely to a concentration of RDX (i.e., 5,200 mg/kg). As such, these upper-bound Site-related risk estimates were refined by using conservative estimates of the average concentrations for 1,2-DCA and RDX for each area.

For area B116-128, a 95 percent UCL on the mean was calculated for 1,2-DCA by using the maximum concentration from each soil sample location for the B116-128 soil sampling area, as shown on Figure 6-2A. For Debris Area 1, an area-weighted mean was calculated for RDX by using the maximum concentration from each soil sampling location for the Debris Area 1 soil sampling area, as shown on Figure 6-2B. An area-weighted mean was calculated for Debris Area 1 (rather than a 95 percent UCL on the mean), because the frequency of detected concentrations of RDX was too low to support the calculation of a useable 95 percent UCL.

The refined risk estimates for each of these exposure areas are shown on Table 6-5.

This table shows that using a conservative estimate of the mean concentration for RDX in Debris Area 1 reduces the cumulative cancer risk and noncancer HI estimates to below EPA's limits of 1 x 10^{-4} and 1, respectively. Therefore, potential exposure of industrial workers to soil during outdoor activities in Debris Area 1 would not result in an unacceptable cancer or noncancer risk.

This table also shows that using a conservative estimate of the mean concentration for 1,2-DCA in area B116-128 reduces the cumulative cancer risk and noncancer HI estimates, but the noncancer HI estimate remains above EPA's limit of 1. Therefore, potential exposure of industrial workers to soil during outdoor activities in area B116-128 may result in an unacceptable noncancer risk.

The details of these calculations are discussed in Appendix L (Section L3.1).

Exposure to Soil via Vapor Intrusion

The upper-bound cumulative cancer risks and noncancer HIs presented on Table 6-4 are based upon the highly conservative assumption that the maximum COPC concentrations in soil are present immediately under the building foundation and that they remain at these concentrations over the entire exposure period (i.e., the COPC's mass is infinite). For the locations with soil concentrations resulting in upper-bound cumulative cancer risk or noncancer HI estimates that exceed EPA's acceptable risk limits, the soil vapor intrusion calculations for these estimates were refined by: (1) using depth-weighted vadose zone soil concentrations (rather than maximum concentrations); and (2) using a mass balance check (rather than assuming infinite mass). Using depth-weighted average soil concentrations rather than maximum soil concentrations provides a more representative estimate of a VOC's vapor concentration in the soil, which could potentially migrate into a building. This use of depth-weighted average concentrations is analogous to the EPA's (1996) recommendation to use depth-weighted average soil concentrations when modeling the volatilization of VOCs from soil. In both uses, the objective is to estimate a representative source vapor concentration for a boring when the boring has different concentrations from multiple depths. In both cases, the representative source vapor concentration is then used as the starting point in the modeling of vapor migration from the soil to either indoors or outdoors. The mass balance check ensures that the COPC mass assumed to enter the building via vapor intrusion does not exceed a conservative estimate of the COPC's mass in the soil under the building. The details of these calculations are discussed in Appendix L (Section L3.2.1).

The refined soil vapor intrusion risk estimates are summarized on Table 6-6, and are discussed below.

- For location APDA789B2 (see Figure 6-2C), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of cyclohexane (890 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B107B6 (see Figure 6-2D), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of TCE (0.66 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B109137BS1A (see Figure 6-2E), the upper-bound noncancer HI estimate for vapor intrusion exposure is predominantly due to concentrations of 1,2,4-trimethylbenzene (3.6 mg/kg), 1,3,5-trimethylbenzene (1.9 mg/kg), xylenes (total) (1.61 mg/kg), and naphthalene (1.9 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the noncancer HI estimate for industrial worker exposure to soil at this

location via vapor intrusion remains above EPA's limit of 1, due to primarily 1,2,4-trimethylbenzene. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in an unacceptable noncancer risk.

- For location B109137SS1A (see Figure 6-2E), the upper-bound noncancer HI estimate for vapor intrusion exposure is predominantly due to concentrations of 1,2,4-trimethylbenzene (14 mg/kg), 1,3,5-trimethylbenzene (10 mg/kg), xylenes (total) (7.6 mg/kg), and naphthalene (7.6 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion remains above EPA's limit of 1, due primarily to 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in an unacceptable noncancer risk.
- For location B113B5 (see Figure 6-2E), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of TCE (0.15 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B113B6 (see Figure 6-2E), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to concentrations of TCE (0.15 mg/kg) and cyclohexane (11 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B116SUMPS1 (see Figure 6-2A), the upper-bound cumulative cancer risk is due almost entirely to concentrations of 1,2-DCA (11 mg/kg) and vinyl chloride (0.16 mg/kg). The upper-bound noncancer HI is due almost entirely to concentrations of 1,2-DCA (11 mg/kg), cyclohexane (12 mg/kg), and vinyl chloride (0.16 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion remains above EPA's risk management limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in an unacceptable noncancer risk.
- For location B116SUMPS2 (see Figure 6-2A), the upper-bound cumulative cancer risk is due almost entirely to concentrations of 1,2-DCA (14 mg/kg), benzene (0.17 mg/kg), and 1,1,2-trichloroethane (0.4 mg/kg). The upper-bound noncancer HI is due almost entirely to concentrations of 1,2-DCA (14 mg/kg), cyclohexane (160 mg/kg), and benzene (0.17 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the cumulative cancer risk and noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion remain above EPA's risk management limits of 1×10^{-4} and 1, respectively. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in unacceptable cancer and noncancer risks.
- For location B116SUMPS3 (see Figure 6-2A), the upper-bound cumulative cancer risk is due almost entirely to concentrations of 1,2-DCA (1,300 mg/kg), vinyl chloride (4 mg/kg), benzene

(6.3 mg/kg), and 1,1,2-trichloroethane (2.9 mg/kg). The upper-bound noncancer HI is due to concentrations of 1,2-DCA (1,300 mg/kg), cyclohexane (1,600 mg/kg), benzene (6.3 mg/kg), vinyl chloride (4 mg/kg), and methylene chloride (4.8 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the cumulative cancer risk and noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion remain above EPA's risk management limits of 1 x 10^{-4} and 1, respectively. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in unacceptable cancer and noncancer risks.

- For location B116SUMPS4 (see Figure 6-2A), the upper-bound cumulative cancer risk and noncancer HI are due almost entirely to a concentration of 1,2-DCA (5.6 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion remains above EPA's risk management limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location may result in an unacceptable noncancer risk.
- For location B146B1 (see Figure 6-2F), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to concentrations of TCE (0.12 mg/kg) and 1,2-DCA (0.19 mg/kg). As shown on Table 6-6, when accounting for mass balance and using depth-weighted concentrations, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B147B2 (see Figure 6-2D), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of TCE (0.072 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B149B5 (see Figure 6-2G), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of TCE (0.21 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location B155B4 (see Figure 6-2D), the upper-bound noncancer HI estimate for vapor intrusion exposure is due almost entirely to a concentration of TCE (0.17 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth weighted concentration the noncancer HI estimate for industrial worker exposure to soil at this location via vapor intrusion is below EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.
- For location DA23B3 (see Figure 6-2A), the upper-bound cumulative cancer risk and noncancer HI estimates for vapor intrusion exposure are due almost entirely to a concentration of 1,2-DCA (2.9 mg/kg). As shown on Table 6-6, when accounting for mass balance and using a depth-weighted concentration, the noncancer HI estimate for industrial worker exposure to soil at this

location via vapor intrusion equals EPA's limit of 1. Therefore, potential exposure of industrial workers to soil via vapor intrusion at this location would not result in an unacceptable cancer or noncancer risk.

The locations in Table 6-5 and Table 6-6 that have unacceptable risks for industrial worker soil exposures are shown on Figure 6-3A.

The details of these calculations are discussed in Appendix L (Section L3.2.1).

Lead

The maximum detected lead concentration in soil at the Site is 79.6 mg/kg (at location B113B6). This concentration is well below the industrial Regional Screening Level of 800 mg/kg (and the residential screening level of 400 mg/kg).

As discussed in Section 6.4.4, exposure of industrial workers to lead in soil during outdoor activities is also evaluated using an industrial screening level of 2,240 mg/kg. This screening level is calculated following EPA guidance (EPA 2003b), including updates (EPA 2009b), and is intended to protect female workers of child-bearing age who contact soil. The derivation of this soil screening level is presented in Appendix L (Attachment L-2.06). Therefore, potential exposure of workers to lead concentrations in soil at the Site would not result in an unacceptable risk.

6.5.2.2.2 Groundwater

On-Site industrial workers could be exposed to COPCs in shallow groundwater to the extent that such COPCs volatilize and migrate into outdoor air or migrate through cracks in building foundations into indoor air, as discussed in Section 6.3.1.1. As discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) include the possibility of unrestricted future on-Site groundwater use. While institutional controls to restrict potable use of impacted on-Site groundwater may be considered during the FS as part of the evaluation of the existing remedy and potential remediation alternatives, this risk assessment evaluates the potential future exposure of on-Site industrial workers to groundwater via potable groundwater use.

The cumulative cancer risk and noncancer HI estimates for industrial worker exposure to groundwater via vapor intrusion and outdoor air inhalation are calculated using the highest detected concentration for each COPC from each on-Site shallow[4] monitoring well. The cumulative cancer risk and noncancer HI estimates for industrial worker exposure to groundwater via potable groundwater use are conservatively calculated using the highest detected concentration for each COPC from each on-Site well regardless of depth. The groundwater risk assessment results are summarized on Table 6-7.

Exposure to Shallow Groundwater via Inhalation of Outdoor Air

Table 6-7 shows that the cumulative cancer risk and noncancer HI estimates for industrial worker exposure to groundwater via inhalation of outdoor air are below EPA's risk management limits.

The details of these calculations are discussed in Appendix L (Section L3.3).

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[4] In evaluating groundwater vapor intrusion exposures "shallow" monitoring wells represent those wells that characterize the first encountered groundwater at a given location of the Site (e.g., water table).

Exposure to Shallow Groundwater via Vapor Intrusion

Table 6-7 shows that there are three shallow wells with noncancer HIs for industrial worker exposure to groundwater via vapor intrusion that exceed EPA's risk management limit of 1. These locations are shown on Figure 6-4A and are listed below:

Locations with Potentially Unacceptable Groundwater Vapor Intrusion Risk for Industrial Workers

Location	Well Zone	Primary Rationale
P-7S	A	TCE
MW180-H38AB	AB	TCE
MW223-L26AB	AB	TCE

The details of these risk calculations are discussed in Appendix L (Section L3.2.2).

- Well P-7S is located in the Back Valley immediately south of DA9 and has a noncancer HI of 3 for industrial worker vapor intrusion exposure to shallow groundwater. This noncancer HI is due almost entirely to a TCE groundwater concentration of 27 milligram per liter (mg/L) (HQ of 2.5) from September 2008. The concentration of TCE in this well is fairly stable with one older sample and one more recent sample having very similar concentrations, specifically 25 mg/L in June 2007 and 24 mg/L in October 2011. Therefore, industrial worker exposure to shallow groundwater via vapor intrusion at this location could potentially result in an unacceptable noncancer risk.
- Well MW180-H38AB is located in the Front Valley in the B105-139 area and has a noncancer HI of 3 for industrial worker vapor intrusion exposure to shallow groundwater. This noncancer HI is due almost entirely to a TCE groundwater concentration of 36 mg/L (HQ of 3.4) from March 2010. A subsequent sample (and duplicate sample) from October 2011 showed a lower concentration of 22 mg/L (duplicate averaged). While this more recent concentration is lower than the concentration used in the risk calculation, it would result in a noncancer HQ of 2. Therefore, industrial worker exposure to shallow groundwater via vapor intrusion at this location could potentially result in an unacceptable noncancer risk.
- Well MW223-L26AB is located in the Back Valley just south of DA9 and has a noncancer HI of 3 for industrial worker vapor intrusion exposure to shallow groundwater. This noncancer HI is due almost entirely to a TCE groundwater concentration of 30 mg/L (HQ of 2.8) from March 2011. This sample is the only one collected from this well. Therefore, industrial worker exposure to shallow groundwater via vapor intrusion at this location could potentially result in an unacceptable noncancer risk.

Exposure to Groundwater via Potable (and Nonpotable) Groundwater Use

As noted above and as discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) include the possibility of unrestricted future on-Site groundwater use. While institutional controls to restrict potable use of impacted on-Site groundwater may be considered during the FS, the risk assessment evaluates the potential future exposure of on-Site industrial workers to groundwater via potable groundwater use.

Table 6-7 shows that there are 49 monitoring wells with groundwater concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits. The details of these calculations are discussed in Appendix L (Section 3.4). Therefore, industrial worker exposure to groundwater via potable (and possibly via nonpotable) groundwater use could potentially result in an unacceptable cumulative cancer risk or noncancer HI. Figure 6-4A shows the location of these wells. As shown on Figure 6-4A, the wells with an unacceptable risk are at least 400 ft upgradient of the Site boundary, and there are wells downgradient of them that do not have an unacceptable risk.

In addition to the cumulative cancer risk and noncancer HI estimates summarized in Table 6-7, a comparison of the groundwater data to drinking water screening levels was performed. The details and results of this comparison are presented in Section 6.5.2.10.5.

6.5.2.2.3 Sum Across Media

Potential exposure of on-Site industrial workers to environmental media (i.e., soil, groundwater, surface water, sediment, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for each of the 45 areas at the Site where soil data were collected, by using: (1) the maximum boring-specific soil risks within an area; (2) the maximum well-specific groundwater risks from wells within an area; and (3) the maximum surface water and sediment risks among all surface water bodies at the Site. Sediment and surface water risk estimates for maintenance workers are used as a conservative surrogate for industrial workers. These summations are expected to represent risk estimates that exceed RME risks because they use media-specific risk estimates that individually represent at least an RME risk and the maximum of these within an area is used to represent the whole area.

The sums of the soil, groundwater, surface water, and sediment risks for on-Site industrial workers within each of the 45 areas are presented on Table 6-10. In addition to the 45 areas, Table 6-10 lists the monitoring wells that are not located within the 45 areas. For these locations, the summations include the groundwater, surface water, and sediment risks. To facilitate risk management decision-making, two sets of summed risk estimates are provided: one in which potable/nonpotable groundwater use risks are included and one in which potable/nonpotable groundwater use risks are not included (to represent where institutional controls are put in place to prohibit on-Site groundwater use).

With Potable/Nonpotable Groundwater Use

Upon summing the media-specific RME risk estimates, two additional areas (B156 and TRA3) exhibit a potentially unacceptable risk that was not identified by the media-specific cumulative cancer risk and/or HI estimates. Area B156 exhibits a noncancer HI of 2, which is primarily due to potable/nonpotable groundwater exposure to perchlorate in wells BW-11 (0.097 mg/L), MW149-O28C (0.097 mg/L), and MW168-O28B (0.086 mg/L). TRA3 exhibits a noncancer HI of 2, primarily due to potable/nonpotable use exposure to perchlorate (0.091 mg/L) and RDX (0.038 mg/L) in well MW152-Q27C. As presented in Table 6-10, if potable/nonpotable groundwater use is prevented by institutional controls, the noncancer HI estimate for industrial workers in these areas would not be above the EPA risk management limit of 1.

Without Potable/Nonpotable Groundwater Use

Upon summing the media-specific RME risk estimates, two additional areas (B115 and B147) exhibit potentially unacceptable risks that were not identified by the media-specific cumulative cancer risk and/or HI estimates after refinement.

Both of these areas have noncancer HIs of 2, due primarily to upper-bound soil vapor intrusion risk estimates for TCE. In area B147, this noncancer HI is due to a TCE concentration of 0.066 mg/kg in B147S2. In area B115, this noncancer HI is due to a TCE concentration of 0.057 in B115B1. After performing the refinements discussed above (i.e., using mass-balance check), the summed noncancer HI estimate for these areas are below EPA's risk management limit of 1. Therefore, potential exposure of industrial workers in these areas would not result in an unacceptable cancer or noncancer risk.

6.5.2.3 On-Site Maintenance Workers (Future Scenario)

6.5.2.3.1 Soil

On-Site maintenance workers could be exposed to on-Site soil during occasional subsurface maintenance activities. Potential exposures were first evaluated using upper-bound estimates of RME cumulative cancer risk and HIs to streamline the risk assessment, as explained in Section 6.5.1. The initial estimates were calculated using the highest observed concentrations for all COPCs detected in soil from any depth at a location. These estimates are conservative upper-bound estimates, because the Site-related RME risks for a location would be lower if they were calculated using: (1) Site-related metal concentrations (i.e., those in excess of the Site-specific background levels); (2) concentrations representative of the average concentrations to which the receptor would be exposed at the area; and (3) Site-specific exposure factors that account for the magnitude, frequency, and duration of exposures appropriate for the area.

The upper-bound estimates of total soil single-chemical cancer risk and HI for potential exposure of maintenance workers are summarized in Appendix L (Attachment L-9.02). These risk estimates include contributions from background metal concentrations. This table shows that, for maintenance worker exposure to soil, one soil sampling location (i.e., B116SUMPS3) has an upper-bound noncancer HI estimate that exceeds EPA's risk management limit of 1.

The Site-related risk estimates for the same soil exposure scenario are summarized on Table 6-4. These risk estimates differ from the total risk estimates on Attachment L-9.02 in that they are calculated using metal concentrations in excess of the Site-specific background exposure concentrations presented on Table 6-1. Table 6-4 shows that the same location (i.e., B116SUMPS3), identified on Attachment L-9.02, has an upper-bound Site-related noncancer HI estimate that exceeds the EPA risk management limit of 1. This location which is located in area B116-128 is shown on Figure 6-2.

The noncancer HI estimate for maintenance worker exposure to soil during subsurface maintenance activities at location B116SUMPS3 in area B116-128 is due almost entirely to a concentration of 1,2-DCA (i.e., 1,300 mg/kg). As such, this upper-bound Site-related noncancer HI risk estimate was refined by using a conservative estimate of the average concentrations for 1,2-DCA in the soil sampling area. A 95 percent UCL on the mean was calculated for 1,2-dichloroethene by using the maximum concentration from any depth at each soil sample location for the B116-128 soil sampling area, as shown on Figure 6-2A.

The refined risk estimates for this exposure area are shown on Table 6-5. This table also shows that using a conservative estimate of the mean concentration for 1,2-DCA in area B116-128 reduces the noncancer HI estimate to 0.9, below EPA's risk management limit of 1. Therefore, potential exposure of maintenance workers to soil in area B116-128 would not result in an unacceptable noncancer risk.

As shown on Table 6-5, the Site has no location with an unacceptable risk for maintenance worker exposure to soil.

The details of these calculations are discussed in Appendix L (Section L4.1).

6.5.2.3.2 Groundwater

On-Site maintenance workers could be exposed to on-Site shallow groundwater during occasional subsurface maintenance activities that encounter groundwater. The upper-bound cumulative cancer risk and noncancer HI estimates for these exposures are calculated using the highest detected concentration for each COPC from each on-Site shallow[5] monitoring well.

As summarized on Table 6-7, four shallow monitoring wells have concentrations that result in noncancer HI estimates exceeding EPA's risk management limit of 1. These locations are shown on Figure 6-4A and are listed below:

Locations with Potentially Unacceptable Groundwater Contact Risks for Maintenance Workers

Location	Well Zone	Primary Rationale
P-7S	A	TCE
MW180-H38AB	AB	TCE
MW223-L26AB	AB	TCE
MW231-H38AB	AB	TCE

The details of these risk calculations are discussed in Appendix L (Section L4.2).

- Well P-7S is located in the Back Valley immediately south of DA9 and has a noncancer HI of 10 for maintenance worker exposure to shallow groundwater. This noncancer HI is driven by dermal contact and vapor inhalation and is due almost entirely to a TCE groundwater exposure concentration of 27 mg/L (HQ of 10) from June 2007. The concentration of TCE in this well is fairly stable with two more recent samples having very similar concentrations, specifically 27 mg/L in August 2008 and 24 mg/L in October 2011. Therefore, maintenance worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.
- Well MW180-H38AB is located in the Front Valley in the B105-139 area and has a noncancer HI of 20 for maintenance worker exposure to shallow groundwater. This noncancer HI is driven by dermal contact and vapor inhalation and is due almost entirely to a TCE groundwater concentration of 36 mg/L (HQ of 20) from March 2010. A subsequent sample (and duplicate sample) from October 2011 has a lower concentration of 22 mg/L (duplicate averaged). While this more recent concentration is lower than the concentration used in the risk calculation, it would result in a noncancer HQ of 9. Therefore, maintenance worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.
- Well MW223-L26AB is located in the Back Valley just south of DA9 and has a noncancer HI of 10 for maintenance worker exposure to shallow groundwater. This noncancer HI is driven by dermal contact and vapor inhalation and is due almost entirely to a TCE groundwater

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[5] In evaluating groundwater contact exposures "shallow” monitoring wells represent those wells that monitor groundwater shallow enough for workers to encounter during excavation activities (i.e., less than or equal to 10 ft-bgs).

concentration of 30 mg/L (HQ of 10) from March 2011. This sample is the only one collected from this well. Therefore, maintenance worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.

- Well MW231-H38AB is located in the Front Valley in the B105-139 area and has a noncancer HI of 3 for maintenance worker exposure to shallow groundwater. This noncancer HI is driven by dermal contact and vapor inhalation and is due almost entirely to a TCE groundwater concentration of 6.6 mg/L (HQ of 3) from January 2012. This sample is the only one collected from this well. Therefore, maintenance worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.

6.5.2.3.3 Sediment

On-Site maintenance workers could be exposed to on-Site sediment during occasional maintenance activities that encounter sediment. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each on-Site sediment sample location. For metals, the Site-related risk estimates were calculated using metal concentrations in excess of the Site-specific soil background concentrations on Table 6-1. To streamline the risk assessment, the exposure frequency for potential exposures to sediment at the Site (see Section 6.3.4) was conservatively assigned to each surface water body. This conservative approach was used because it avoided the need to prorate the potential sediment exposure among the water bodies and it does not materially affect the risk assessment conclusions. Table 6-8 shows that none of the locations exhibit upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential maintenance worker exposure to sediment at the Site would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L4.3).

6.5.2.3.4 Surface Water

On-Site maintenance workers could be exposed to on-Site surface water during occasional maintenance activities that encounter surface water. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each on-Site surface water sample location. To streamline the risk assessment, the exposure frequency for potential exposures to surface water at the Site (see Section 6.3.4) was conservatively assigned to each surface water body. This conservative approach was used because it avoided the need to prorate the potential surface water exposure among the water bodies and it does not materially affect the risk assessment conclusions. Table 6-9 shows that none of the locations exhibit upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA’s risk management limits. Therefore, potential maintenance worker exposure to surface water at the Site would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L4.4).

6.5.2.3.5 Sum Across Media

Potential exposure of on-Site maintenance workers to environmental media (i.e., soil, groundwater, surface water, sediment, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for each of the 45 areas at the Site where soil data were collected by using: (1) the maximum boring-specific soil risks within an area; (2) the maximum well-specific groundwater risks from wells within an area; and (3) the maximum surface water and sediment risks among all surface water bodies at the Site. These summations are expected to represent risk estimates that exceed RME risks because they use media-specific risk estimates that individually represent at least an RME risk and the maximum of these within an area is used to represent the whole area.

The sums of the soil, groundwater, surface water, and sediment risks for on-Site maintenance workers within each of the 45 areas are presented on Table 6-11. In addition to the 45 areas, Table 6-11 lists the monitoring wells that are not located within the 45 areas. For these locations, the summations include the groundwater, surface water, and sediment risks.

Upon summing the media-specific RME risks, the only areas with potentially significant risks are areas APDA-7-8-9 and B105-139, which contain the wells with media-specific RME risk estimates above EPA limits for groundwater, as discussed in section 6.5.2.3.2.

6.5.2.4 On-Site Construction Workers (Future Scenario)

6.5.2.4.1 Soil

On-Site construction workers could be exposed to on-Site soil during future Site redevelopment construction activities. Potential exposures were first evaluated using upper-bound estimates of RME cumulative cancer risk and HIs to streamline the risk assessment, as explained in Section 6.5.1. The initial estimates were calculated using the highest observed concentrations for all COPCs detected in soil from any depth at a location. These estimates are conservative upper-bound estimates, because the Site-related RME risks for a location would be lower if they were calculated using: (1) Site-related metal concentrations (i.e., those in excess of the Site-specific background levels); (2) concentrations representative of the average concentrations to which the receptor would be exposed at the area; and (3) Site-specific exposure factors that account for the magnitude, frequency, and duration of exposures appropriate for the area.

The upper-bound estimates of total cumulative cancer risk and subchronic noncancer HI for potential exposure of construction workers are summarized in Appendix L (Attachment L-9.02). These risk estimates include contributions from background metal concentrations. This table shows that, for construction worker exposure to soil, one soil sampling location (i.e., B116SUMPS3) has an upper-bound subchronic noncancer HI estimate that exceeds EPA's risk management limit of 1.

The Site-related risk estimates for the same soil exposure scenario are summarized on Table 6-4. These risk estimates differ from the total risk estimates on Attachment L-9.02 in that they are calculated using metal concentrations in excess of the Site-specific background exposure concentrations presented on Table 6-1. Table 6-4 shows that the same location (i.e., B116SUMPS3), identified on Attachment L-9.02, has an upper-bound Site-related subchronic noncancer HI estimate that exceeds the EPA risk management limit of 1. This location, which is located in area B116-128, is shown on Figure 6-2.

The subchronic noncancer HI estimate for construction worker exposure to soil during subsurface construction activities at location B116SUMPS3 in area B116-128 is due almost entirely to a concentration of 1,2-DCA (i.e., 1,300 mg/kg). As such, this upper-bound Site-related HI estimate was refined by using a conservative estimate of the average concentrations for 1,2-DCA in the soil sampling area. A 95 percent UCL on the mean was calculated for 1,2-DCA by using the maximum concentration from each soil sample location for the B116-128 soil sampling area, as shown on Figure 6-2A.

The refined risk estimates for this exposure area is shown on Table 6-5. This table also shows that using a conservative estimate of the mean concentration for 1,2-DCA in area B116-128 reduces the subchronic noncancer HI estimate to 0.6, which is below EPA's risk management limit of 1. Therefore, potential exposure of construction workers to soil in area B116-128 would not result in an unacceptable noncancer risk.

As shown on Table 6-5, the Site has no location with an unacceptable risk for construction worker exposure to soil.

The details of these risk calculations are discussed in Appendix L (Section L5.1).

6.5.2.4.2 Groundwater

On-Site construction workers could be exposed to on-Site shallow groundwater during future Site redevelopment construction activities that encounter groundwater. The upper-bound cumulative cancer risk and subchronic noncancer HI estimates for these exposures are calculated using the highest detected concentration for each COPC from each on-Site shallow[6] monitoring well.

As summarized on Table 6-7, four shallow monitoring wells have concentrations that result in subchronic noncancer HI estimates exceeding EPA's risk management limit of 1. These locations are shown on Figure 6-4A and are listed below:

Locations with Potentially Unacceptable Groundwater Contact Risks for Construction Workers

Location	Well Zone	Primary Rationale
P-7S	A	TCE
MW180-H38AB	AB	TCE
MW223-L26AB	AB	TCE
MW231-H38AB	AB	TCE

The details of these risk calculations are discussed in Appendix L (Section L5.2).

- Well P-7S is located in the Back Valley immediately south of DA9 and has a subchronic noncancer HI of 10 for construction worker exposure to shallow groundwater. This subchronic noncancer HI is driven by dermal contact and is due almost entirely to a TCE groundwater exposure concentration of 27 mg/L (HQ of 10) from June 2007. The concentration of TCE in this well is fairly stable with two more recent samples having very similar concentrations, specifically 27 mg/L in August 2008 and 24 mg/L in October 2011. Therefore, construction worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.
- Well MW180-H38AB is located in the Front Valley in the B105-139 area and has a subchronic noncancer HI of 20 for construction worker exposure to shallow groundwater. This location-

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[6] In evaluating groundwater contact exposures "shallow" monitoring wells represent those wells that monitor groundwater shallow enough for workers to encounter during excavation activities (i.e., less than or equal to 10 ft-bgs).

specific upper-bound noncancer HI is due almost entirely to a TCE groundwater exposure concentration of 36 mg/L (HQ of 20) from March 2010. A subsequent sample (and duplicate sample) from October 2011 exhibited a lower concentration of 22 mg/L (duplicate averaged). While this more recent concentration is lower than the concentration used in the risk calculation, it would result in a subchronic noncancer HQ of 10. Therefore, construction worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.

- Well MW223-L26AB is located in the Back Valley just south of DA9 and has a subchronic noncancer HI of 20 for construction worker exposure to shallow groundwater. This subchronic noncancer HI is due almost entirely to a TCE groundwater concentration of 30 mg/L (HQ of 15) from March 2011. This sample is the only one collected from this well. Therefore, construction worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.
- Well MW231-H38AB is located in the Front Valley in the B105-139 area and has a subchronic noncancer HI of 3 for construction worker exposure to shallow groundwater. This subchronic noncancer HI is due almost entirely to a TCE groundwater exposure concentration of 6.6 mg/L (HQ of 3) from January 2012. This sample is the only one collected from this well. Therefore, construction worker exposure to shallow groundwater at this location could potentially result in an unacceptable noncancer risk.

6.5.2.4.3 Sediment and Surface Water

Potential exposure of on-Site construction workers to sediment and surface water is evaluated indirectly in this risk assessment by using exposure estimates for on-Site maintenance workers, as explained in Section 6.3.4.3. This streamlines the risk assessment and is conservative, because construction worker exposures to sediment and surface water are expected to be no higher than that of a maintenance worker. Therefore, the cumulative cancer risk and noncancer HI estimates for construction workers are expected to be no higher than the estimates discussed in Section 6.5.2.3. As discussed in Section 6.5.2.3, the upper-bound estimates of Site-related cancer and noncancer risks for on-Site maintenance worker exposure to sediment and surface water do not exceed EPA risk management limits. Therefore, potential construction worker exposure to sediment and surface water at the Site would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.4.4 Sum Across Media

Potential exposure of on-Site construction workers to environmental media (i.e., soil, groundwater, surface water, sediment, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for each of the 45 areas at the Site where soil data were collected, by using: (1) the maximum boring-specific soil risks within an area; (2) the maximum well-specific groundwater risks from wells within an area; and (3) the maximum surface water and sediment risks among all surface water bodies at the Site. Sediment and surface water risk estimates for maintenance workers are used as a conservative surrogate for construction workers. These summations are expected to represent risk estimates that exceed RME risks, because they use media-specific risk estimates that individually represent at least an RME risk and the maximum of these within an area is used to represent the whole area.

The sums of the soil, groundwater, surface water, and sediment risks for the on-Site construction worker within each of the 45 areas are presented on Table 6-11. In addition to the 45 areas, Table 6-11 lists the monitoring wells that are not located within the 45 areas. For these locations, the summations include the groundwater, surface water, and sediment risks.

Upon summing the media-specific RME risks, the only areas with potentially significant risks are areas APDA-7-8-9 and B105-139, which contain the wells with media-specific RME risk estimates above EPA limits for groundwater as discussed in section 6.5.2.4.2.

6.5.2.5 On-Site Resident (Future Scenario)

Under this scenario, on-Site residents could be exposed to soil COPCs during outdoor activities and via vapor intrusion and to groundwater COPCs via vapor intrusion, volatilization to outdoor air, and potable or nonpotable groundwater use. The results of risk calculations for these scenarios are discussed in Sections 6.5.2.5.1 and 6.5.2.5.2, respectively.

6.5.2.5.1 Soil

The exposure of on-Site residents to COPCs in soil at each location is evaluated in this risk assessment by conservatively assuming the following two alternate theoretical cases: (1) the soil at each location is outdoors, and residents are assumed to be exposed to the outdoor soil for the entire day; or (2) the soil at each location is under an occupied building, and residents are assumed to be exposed to COPCs in the soil via vapor intrusion for the entire day. Using these alternate theoretical cases is conservative and efficient, because it avoids the need to prorate the portion of the day spent indoors and/or outdoors, and risk estimates for any combination of indoor and outdoor time periods would not exceed the higher of the risk estimates for the two alternative theoretical cases.

Potential exposures for each theoretical case were first evaluated using upper-bound estimates of RME cumulative cancer risk and HIs to streamline the risk assessment, as explained in Section 6.5.1. The initial estimates were calculated using the highest observed concentrations for all COPCs detected in soil at a location. These estimates are conservative upper-bound estimates, because the Site-related RME risks for a location would be lower if they were calculated using: (1) Site-related metal concentrations (i.e., those in excess of the Site-specific background levels); (2) concentrations representative of the average concentrations to which receptors would be exposed at the area; and (3) Site-specific exposure factors that account for the magnitude, frequency, and duration of exposures appropriate for the area.

The upper-bound estimates of total cumulative cancer risk and HI for potential exposure of residents for each alternate theoretical case (i.e., all day exposure to soil during outdoor activities or all day exposure to soil COPCs via vapor intrusion) are summarized in Appendix L (Attachment L-9.02). These risk estimates include contributions from background metal concentrations. Attachment L-9.02 shows that for outdoor soil exposures, 17 soil sampling locations have upper-bound total cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively. It also shows that for soil vapor intrusion exposures, 29 soil sampling locations have upper-bound total cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively.

The Site-related risk estimates for these same soil exposure scenarios are summarized on Table 6-4. These risk estimates differ from the total risk estimates in Attachment L-9.02 in that they are calculated using metal concentrations adjusted to exclude the Site-specific background exposure concentrations presented on Table 6-1. Table 6-4 shows that for soil vapor intrusion exposures, the same locations identified on Attachment L-9.02 have upper-bound Site-related cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively. Table 6-4 also shows that for direct contact exposures, 15 soil sampling locations have upper-bound Site-related cumulative cancer risk or noncancer HI estimates that exceed the EPA risk management limits of 1 x 10^{-4} or 1, respectively. Two soil sampling locations (B110111112B6 and B156B2) had total upper-bound risks that exceeded EPA risk management limits but the upper-bound Site-related risks did not exceed EPA risk management limits for soil direct contact exposures. Because these locations did not contribute unacceptable Site-related risk, exposure at these locations is considered acceptable. The locations with upper-bound Site-related risks exceeding EPA risk management targets are listed below by soil sampling area (as identified in Figure 1-6).

For exposure to soil during outdoor activities, the following soil sampling areas have upper-bound cumulative Site-related cancer risk and HI estimates that exceed 1 x 10^{-4} and 1, respectively:

- APDA-7-8-9—location APDA789B2
- B105-139—locations B105139B4, B5, B7, and B8
- B107— location B107B3
- B109-137—location B109137B3
- B116-128—location B116SUMPS3
- B119-120—locations B119120B1, B3, and B4
- B125-136—location B125136B2
- B148—location B148B2
- DA23—location DA23B2
- Debris Area 1—location Debris Area 1S3

The details of these risk calculations are discussed in Appendix L (Section L6.1).

For exposure to soil via vapor intrusion, the following soil sampling areas have upper-bound cumulative Site-related cancer risk and/or HI estimates that exceed 1 x 10^{-4} and 1, respectively:

- APDA-7-8-9—locations APDA789B11, APDA789B2, and APDA789B3
- B107—location B107B6
- B109-137—locations B109137BS1A and SS1A
- B113—locations B113B4, B5, B6 and B8
- B115—locations B115B1 and B2
- B116-128—locations B116128B1, B5, B13, SUMPS1, SUMPS2, SUMPS3, and SUMPS4
- B146—location B146B1
- B147—locations B147B2, B5, B7, B9, and S2
- B149—location B149B5
- B155—location B155B4

- DA23—location DA23B3
- DUMP—location DUMPTP3

The details of these risk calculations are discussed in Appendix L (Section L6.2.1).

The upper-bound risk estimates for on-Site residential exposures that exceed EPA's limits were refined for the areas/locations where refinements of exposure concentrations were used for the industrial worker risk estimates (discussed in Section 6.5.2.2.1). Where these refinements were applied is discussed in the following sections. Refinement was not performed for the other areas/locations because it is likely that institutional controls will be used to preclude on-Site residential exposures.

Exposure to Soil During Outdoor Activities

Of the 15 locations with residential upper-bound risk estimates that exceed EPA's limits for RME risk, the exposure concentrations for two locations were refined (i.e., B116SUMPS3 [in B116-128] and Debris Area 1S3 [in Debris Area 1] and used for the refined industrial worker risk estimates. The refined exposure concentrations for Area B116-128 did not reduce the industrial worker risk estimates for this area to an acceptable level (see Section 6.5.2.2.1), which means it also cannot reduce the residential risks for this area to an acceptable level. For Debris Area 1, the refinement of the exposure concentration for RDX reduced the industrial worker risks to acceptable levels. Using the same RDX exposure concentration reduces the residential HI estimate to 1, but the remaining cumulative cancer risk estimate is still above 10^{-4}.

The risk estimates on Table 6-5 include the refined residential risk estimates for areas B116-128 and Debris Area 1.

The details of these risk calculations are discussed in Appendix L (Section L6.1).

Exposure to Soil via Vapor Intrusion

Of the 29 locations with residential upper-bound risk estimates that exceed EPA's limits for RME risk, the upper-bound risk estimates for 15 were refined and used for the refined industrial worker soil vapor intrusion risk estimates (i.e., using depth-weighted vadose zone soil concentration and using a mass balance check). As discussed in Section 6.5.2.2.1, the refined risk estimates for six of these locations (i.e., B109137BS1A, B109137SS1A, B116SUMPS1, B116SUMPS2, B116SUMPS3, and B116SUMPS4) did not reduce the industrial worker soil vapor intrusion exposure to within acceptable levels, which means those refinements also cannot reduce the residential risks for these locations to within acceptable levels. For the nine locations where the refined risk estimates for industrial worker soil vapor intrusion exposure were shown to be acceptable, only two of the locations (i.e., B113B5 and B147B2) would also result in acceptable residential risks. For the remaining seven locations (i.e., APDA789B2, B107B6, B113B6, B146B1, B149B5, B155B4, and DA23B3), the refined residential soil vapor intrusion risk estimates still exceed EPA's limits for RME risk.

The risk estimates on Table 6-6 include the refined residential risk estimates for these 15 locations.

The details of these risk calculations are discussed in Appendix L (Section L6.2.1).

6.5.2.5.2 Groundwater

On-Site residents could be exposed to COPCs in shallow groundwater to the extent that such COPCs volatilize and migrate into outdoor air or migrate through cracks in building foundations into indoor air, as discussed in Section 6.3.1.1. As discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) include the possibility of unrestricted future on-Site groundwater use. While institutional controls to restrict potable use of impacted on-Site groundwater may be considered during the FS as part of the evaluation of the existing remedy and potential remediation alternatives, this risk assessment evaluates the potential future exposure of on-Site residents to groundwater via potable groundwater use.

The cumulative cancer risk and noncancer HI estimates for residential exposure to groundwater via vapor intrusion and outdoor air inhalation are calculated using the highest detected concentration for each COPC from each on-Site shallow[7] monitoring well. The cumulative cancer risk and noncancer HI estimates for residential exposure to groundwater via potable groundwater use are conservatively calculated using the highest detected concentration for each COPC from each on-Site well regardless of depth. The groundwater risk assessment results are summarized on Table 6-7.

Exposure to Shallow Groundwater via Inhalation of Outdoor Air

Table 6-7 shows that the cumulative cancer risk and noncancer HI estimates for residential exposure to groundwater COPCs via inhalation of outdoor air are below EPA's risk management limits.

The details of these risk calculations are discussed in Appendix L (Section L6.3).

Exposure to Shallow Groundwater via Vapor Intrusion

Table 6-7 shows that there are five shallow wells with cancer risks or noncancer HIs for residential exposure to groundwater via vapor intrusion that exceed EPA's risk management limits of 1 x 10^{-4} or 1, respectively. These locations are shown on Figure 6-4B and are listed below:

Locations with Potentially Unacceptable Groundwater Vapor Intrusion Risk for On-Site Residents

Location	Well Zone	Primary Rationale
P-7S	A	TCE
MW180-H38AB	AB	TCE
MW187-M25AB	AB	1,2-DCA
MW223-L26AB	AB	TCE
MW231-H38AB	AB	TCE

The details of these risk calculations are discussed in Appendix L (Section L6.2.2).

- Well P-7S is located in the Back Valley immediately south of DA9 and has a cancer risk of 2 x 10^{-4} and a noncancer HI of 40 for residential vapor intrusion exposure to shallow groundwater. The cancer risk and noncancer HI are due almost entirely to a TCE groundwater concentration of 27 mg/L (single-chemical cancer risk of 2.1 x 10^{-4} and HQ of 43) from September 2008. The concentration of TCE in this well is fairly stable with one older sample and one more recent sample having very similar concentrations, specifically 25 mg/L in June 2007 and 24 mg/L in October 2011. Therefore, residential exposure to shallow groundwater via

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[7] In evaluating groundwater vapor intrusion exposures, "shallow" monitoring wells represent those wells that characterize the first encountered groundwater at a given location of the Site (e.g., water table).

vapor intrusion at this location could potentially result in unacceptable cancer and noncancer risks.

- Well MW180-H38AB is located in the Front Valley in the B147 area and has a cancer risk of 3 x 10^{-4} and a noncancer HI of 60 for residential vapor intrusion exposure to shallow groundwater. The cancer risk and noncancer HI are due almost entirely to a TCE groundwater concentration of 36 mg/L (single-chemical cancer risk of 2.7 x 10^{-4} and HQ of 57) from March 2010. A subsequent sample (and duplicate sample) from October 2011 showed a lower concentration of 22 mg/L (duplicate averaged). While this more recent concentration is lower than the concentration used in the risk calculation, it would result in a single-chemical cancer risk of 1.7 x 10^{-4} and a noncancer HQ of 35. Therefore, residential exposure to shallow groundwater via vapor intrusion at this location could potentially result in unacceptable cancer and noncancer risks.
- Well MW187-M25AB is located in the Back Valley in the APDA-7-8-9 area and has a cancer risk of 2 x 10^{-4} and a noncancer HI of 3 for residential vapor intrusion exposure to shallow groundwater. The cancer risk and noncancer HI are due almost entirely to a 1,2-DCA groundwater concentration of 10 mg/L (single-chemical cancer risk of 1.7 x 10^{-4} and HQ of 2.2) from March 2010. This sample is the only one collected from this well. Therefore, residential exposure to shallow groundwater via vapor intrusion at this location could potentially result in unacceptable cancer and noncancer risks.
- Well MW223-L26AB is located in the Back Valley just south of DA9 and has a cancer risk of 3 x 10^{-4} and a noncancer HI of 50 for residential vapor intrusion exposure to shallow groundwater. The cancer risk and noncancer HI are due almost entirely to a TCE groundwater concentration of 30 mg/L (single-chemical cancer risk of 2.3 x 10^{-4} and HQ of 47) from March 2011. This sample is the only one collected from this well. Therefore, residential exposure to shallow groundwater via vapor intrusion at this location could potentially result in unacceptable cancer and noncancer risks.
- Well MW231-H38AB is located in the Front Valley in the B105-139 area and has a noncancer HI of 10 for residential vapor intrusion exposure to shallow groundwater. This noncancer HI is due almost entirely to a TCE groundwater concentration of 6.6 mg/L (HQ of 10) from January 2012. This sample is the only one collected from this well. Therefore, residential exposure to shallow groundwater via vapor intrusion at this location could potentially result in an unacceptable noncancer risk.

Exposure to Groundwater via Potable (and Nonpotable) Groundwater Use

As noted above and as discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) include the possibility of unrestricted future on-Site groundwater use. While institutional controls to restrict potable use of impacted on-Site groundwater may be considered during the FS, the risk assessment evaluates the potential future exposure of on-Site residents to groundwater via potable groundwater use.

Table 6-7 shows that there are seventy one monitoring wells with groundwater concentrations which would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits. Therefore, residential exposure to groundwater via potable (and possibly via nonpotable groundwater use) could potentially result in an unacceptable cumulative cancer risk or noncancer HI. Figure 6-4B shows the location of these wells.

The details of these calculations are discussed in Appendix L (Section L6.4).

Further discussion of the potential for potable use of groundwater is provided in Section 6.5.2.10.5.

6.5.2.5.3 Sum Across Media

Potential exposure of on-Site residents to environmental media (i.e., soil, groundwater, surface water, sediment, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for each of the 45 areas at the Site where soil data were collected by using: (1) the maximum boring-specific soil risks within an area; (2) the maximum well-specific groundwater risks from wells within an area; and (3) the maximum surface water and sediment risks among all surface water bodies at the Site. Sediment and surface water risk estimates for recreational users were used as a surrogate for residents. These summations are expected to represent risk estimates that exceed RME risks because they use media-specific risk estimates that individually represent at least an RME risk and the maximum of these within an area is used to represent the whole area.

The sums of the soil, groundwater, surface water, and sediment risks for on-Site residents within each of the 45 areas are provided on Table 6-10. In addition to the 45 areas, Table 6-10 lists the monitoring wells that are not located within the 45 areas. For these locations, the summations include the groundwater, surface water, and sediment risks. Two sets of summed risk estimates are provided—one in which potable/nonpotable groundwater use risks are included and one in which potable/nonpotable groundwater use risks are not included (in case institutional controls are put in place to prohibit on-Site groundwater use).

With Potable/Nonpotable Groundwater Use

Upon summing the media-specific RME risk estimates, two additional areas (B122 and B124-135) and three individual wells not in soil areas (MW146-M43C, MW176-L41E, and MW229-L41EF) exhibit a potentially unacceptable risk that was not identified by the media-specific cumulative cancer risk and/or HI estimates. As can be seen on Table 6-13, if potable/nonpotable groundwater use exposure is prevented by institutional controls, the noncancer HI estimate for residents in the three wells would not be above the EPA risk management limit of 1. The noncancer HI estimate for areas B122 and B124-135, based primarily on soil exposure, would still be above the EPA risk management limit of 1.

Without Potable/Nonpotable Groundwater Use

As shown on Table 6-13, upon summing the media-specific RME risk estimates, three additional areas (B122, B124-135, and B156) exhibit potentially unacceptable risks that were not identified by the media-specific cumulative cancer risk and/or HI estimates after refinement. Area B122 exhibits a noncancer HI of 2, which is primarily due to residential soil vapor intrusion exposure to TCE at location B122B2 (0.002 mg/kg) and surface water direct contact with TCE in the Unnamed Branch at location UBW5-137 (0.096 mg/L). Area B124-135 exhibits a noncancer HI of 2, which is primarily due to residential soil direct contact exposure to copper at location B124135S3 (6,780 mg/kg), residential soil vapor intrusion exposure to mercury at location B124135B8 (0.34 mg/kg), and surface water direct contact exposure to TCE in the Unnamed Branch at location UBW5-137 (0.096 mg/L). Finally, area B156 exhibits a noncancer HI of 2, which is primarily due to residential soil direct contact exposure to cobalt at location B156B2 (111 mg/kg) and surface water direct contact exposure to TCE in the Unnamed Branch at location UBW5-137 (0.096 mg/L).

6.5.2.6 On-Site Recreational Users (Future Scenario)

6.5.2.6.1 Soil (via Contact)

On-Site recreational users could be exposed to on-Site soil during future recreational activities. Potential exposures were first evaluated using upper-bound estimates of RME cumulative cancer risk and HIs to streamline the risk assessment, as explained in Section 6.5.1. The initial estimates were calculated using the highest observed concentrations for all COPCs detected in soil at a location. These estimates are conservative upper-bound estimates, because the Site-related RME risks for a location would be lower if they were calculated using: (1) Site-related metal concentrations (i.e., those in excess of the Site-specific background levels); (2) concentrations representative of the average concentrations to which the receptor would be exposed at the area; and (3) Site-specific exposure factors that account for the magnitude, frequency, and duration of exposures appropriate for the area.

The upper-bound estimates of total cumulative cancer risk and HI for potential exposure of recreational users to soil are summarized in Appendix L (Attachment L-9.02). These risk estimates include contributions from background metal concentrations. This table shows that, for the recreational user's exposure to soil, two soil sampling locations have an upper-bound noncancer HI estimates that exceeds the EPA risk management limit of 1.

The Site-related risk estimates for this same soil exposure scenario is summarized on Table 6-4. These risk estimates differ from the total risk estimates on Attachment L-9.02 in that they are calculated using metal concentrations in excess of the Site-specific background exposure concentrations presented on Table 6-1. Table 6-4 shows that the same two locations identified on Attachment L-9.02 have upper-bound Site-related noncancer HI estimates that exceed the EPA risk management limit of 1. These two locations are shown on Figure 6-2 and are listed below by soil sampling area (as identified in Drawing 1 of Volume 2 of the Work Plan).

- B116-128—location B116SUMPS3
- Debris Area 1—location Debris Area 1S3

The noncancer HI estimate for recreational user exposure to soil at location B116SUMPS3 in area B116-128 is driven by vapor inhalation and is due almost entirely to a concentration of 1,2-DCA (i.e., 1,300 mg/kg). The noncancer HI estimate for recreational user exposure to soil at location Debris Area 1S3 is due to a concentration of RDX (i.e., 5,200 mg/kg). As such, these upper-bound Site-related noncancer HI estimates were refined by using conservative estimates of the average concentrations for 1,2-DCA and RDX for each area.

For area B116-128, a 95 percent UCL on the mean was calculated for 1,2-DCA by using the maximum concentration from each soil sample location for the B116-128 soil sampling area, as shown on Figure 6-2A. For Debris Area 1, an area-weighted mean was calculated for RDX by using the maximum concentration from each soil sampling location for the Debris Area 1 soil sampling area, as shown on Figure 6-2B. An area-weighted mean was calculated for Debris Area 1 (rather than a 95 percent UCL on the mean), because the frequency of detected concentrations of RDX was too low to support the calculation of a useable 95 percent UCL.

The refined risk estimates for each of these exposure areas are shown on Table 6-5.

This table shows that using a conservative estimate of the mean concentration for RDX in Debris Area 1 reduces the noncancer HI estimates to below EPA's risk management limit 1. Therefore, potential exposure of recreational users to soil in Debris Area 1 would not result in an unacceptable cancer or noncancer risk.

This table also shows that using a conservative estimate of the mean concentration for 1,2-DCA in area B116-128 reduces the noncancer HI estimate to below EPA's risk management limit 1. Therefore, potential exposure of recreational users to soil in area B116-128 would not result in an unacceptable cancer or noncancer risk.

As shown on Table 6-5, the Site has no location with an unacceptable risk for recreational user exposure to soil.

The details of these risk calculations are discussed in Appendix L (Section L7.1).

6.5.2.6.2 Soil (via Game Animal Consumption)

As noted in Section 6.3.1.1, recreational users could be exposed to COPCs in on-Site soil via not only direct contact but also uptake from soil into game animals that they consume. The potential significance of the game consumption exposure pathway was assessed by assuming that the main game animals that may be hunted at the Site are deer and wild turkey. Estimates of potential exposures from deer and wild turkey consumption were quantified following EPA guidance (2005) and are presented in Appendix L (Section L7.5). These estimates show that exposures from consumption of deer and wild turkey are much lower than exposures from direct contact (e.g., incidental soil ingestion)[8], which means the potential risks from game animal consumption are much lower than those discussed above. Because the estimates of Site-related cancer and noncancer risks for recreational user exposures to soil via direct contact do not exceed the EPA risk management limits, potential recreational user exposure from game animal consumption would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.6.3 Sediment

On-Site recreational users could be exposed to on-Site sediment during future on-Site recreational activities that encounter sediment. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each on-Site sediment sample location. For metals, the Site-related risk estimates were calculated using metal concentrations in excess of the Site-specific soil background concentrations on Table 6-1. To streamline the risk assessment, the exposure frequency for potential exposures to sediment at the Site (see Section 6.3.4) was conservatively assigned to each surface water body. This conservative approach was used because it avoided the need to prorate the potential sediment exposure among the water bodies and it does not materially affect the risk assessment conclusions. Table 6-8 shows that none of the locations have upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential recreational user exposure to sediment at the Site would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L7.2).

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[8] The comparison involves comparing the results in the following two sets of tables: (1) Attachments L-6.03 and 6.04—Unit Cancer Risk (and Hazard) Calculations for Exposure of Recreational Users to Soil; and (2) Attachment L-6.05—Potential Exposure to Soil Contaminants via Consumption of Game Animals.

6.5.2.6.4 Surface Water (via Contact)

On-Site recreational users could be exposed to on-Site surface water via direct contact (i.e., incidental ingestion, dermal contact, and inhalation of vapors) during future recreational activities that involve surface water. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each on-Site surface water sample location. To streamline the risk assessment, the exposure frequency for potential exposures to surface water at the Site (see Section 6.3.4) was conservatively assigned to each surface water body. This conservative approach was used because it avoided the need to prorate the potential surface water exposure among the water bodies and it does not materially affect the risk assessment conclusions. Table 6-9 shows that none of the locations have upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential recreational user exposure to surface water by direct contact at the Site would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L7.3).

6.5.2.6.5 Surface Water (via Fish Ingestion)

On-Site recreational users could be exposed to COPCs in on-Site surface water via consumption of fish caught in the three on-Site ponds. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each surface water sample location in the ponds. To streamline the risk assessment, the fish ingestion rate for potential consumption of fish from the Site (see Section 6.3.4) was conservatively assigned to each on-Site pond and Bee Tree Creek. This conservative approach was used because it avoided the need to prorate the fish ingestion rate among the ponds and Bee Tree Creek, and it does not materially affect the risk assessment conclusions. Table 6-9 shows that concentrations in Bee Tree Creek result in a noncancer HI of 2, which is above EPA's risk management limit of 1. This noncancer HI is almost entirely due to a chlordane concentration of 0.015 µg/L from the upstream location BTW3-U30 in 2007 (a location where chlordane has not been detected subsequently). Excluding this chlordane concentration from the data set, because it is not related to the Site, results in a noncancer HI for Bee Tree Creek that is 4 x 10^{-6}, which is below EPA's risk management limit. Therefore, potential recreational user exposure to surface water at the Site via fish ingestion would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L7.4).

6.5.2.6.6 Sum Across Media

Potential exposure of on-Site recreational users to environmental media (i.e., soil, surface water, sediment, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for each of the 45 areas at the Site where soil data were collected, by using: (1) the maximum boring-specific soil risks within an area; and (2) the maximum surface water and sediment risks among all surface water bodies at the Site. These summations are expected to represent risk estimates that exceed RME risks because they use media-specific risk estimates that individually represent at least an RME risk and the maximum of these within an area is used to represent the whole area.

The sums of the soil, surface water, and sediment risks for the on-Site recreational users within each of the 45 areas are summarized on Table 6-14.

Upon summing the media-specific RME risk estimates, two additional areas (APDA-7-8-9 and B105-139) exhibit potentially unacceptable risks that were not identified by the media-specific cumulative cancer risk and/or HI estimates after refinement. The noncancer HI estimate at APDA-7-8-9 is due primarily to (1) concentrations of aldrin and TCE in surface water and (2) to the concentration of aldrin (20 mg/kg) in soil at APDA789B2. The cumulative cancer risk estimate in B105-139 is due primarily to (1) concentrations of aldrin and TCE in surface water and (2) to the concentration of benzo(a)pyrene (22 mg/kg) in soil at B105139B8. These upper-bound Site-related risk estimates were refined by using conservative estimates of the average concentrations for aldrin and benzo(a)pyrene in soil at APDA-7-8-9 and B105-139 respectively.

For area APDA-7-8-9, a 95 percent UCL on the mean was calculated for aldrin by using the maximum concentration from each soil sample location for the APDA-7-8-9 soil sampling area, as shown on Figure 6-2C. For area B105-139, a 95 percent UCL on the mean was calculated for benzo(a)pyrene by using the maximum concentration from each soil sample location for the B105-139 soil sampling area

The refined single-chemical risk estimates for soil in these areas are shown in Attachment L-8.07. These soil risk estimates are included in the sum across media summarized on Table 6-14. This table shows that using conservative estimates of the mean concentration for aldrin in APDA-7-8-9 and benzo(a)pyrene in B105-139 reduces the cumulative cancer risk and noncancer HI estimates in each area to within the EPA limits of 1 x 10^{-4} and 1, respectively. Therefore, potential recreational user exposures at the Site, including summing across media, would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.7 On-Site Trespassers (Current Scenario)

6.5.2.7.1 Soil

Potential exposure of on-Site trespassers to soil is evaluated indirectly in this risk assessment by using exposure estimates for on-Site recreational users because the exposure factors for trespasser exposure to soil are the same as those for on-Site recreational users, as explained in Section 6.3.4.6. As discussed in Section 6.5.2.6, there are no areas of the Site with soil concentrations that would pose an unacceptable cumulative cancer or noncancer risk to recreational users; the same would be true for on-Site trespassers.

6.5.2.7.2 Sediment and Surface Water

Potential exposure of on-Site trespassers to sediment and surface water is evaluated indirectly in this risk assessment by using exposure estimates for on-Site recreational users, as explained in Section 6.3.4.6. This streamlines the risk assessment and is conservative, because trespasser exposures to sediment and surface water are expected to be no higher than that of a recreational user. Therefore, the cumulative cancer risk and noncancer HI estimates for trespassers are expected to be no higher than the estimates discussed in Section 6.5.2.6. As discussed in Section 6.5.2.6, there are no locations with sediment or surface water concentrations that would pose an unacceptable cumulative cancer or noncancer risk to recreational users; the same would be true for on-Site trespassers. Therefore, potential trespasser exposure to sediment and surface water at the Site would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.8 Off-Site Residents (Current Scenario)

6.5.2.8.1 On-Site Soil

Off-Site residents could be exposed to on-Site soil if airborne particulates and vapor from on-Site soil were to migrate off the Site. The upper-bound estimates of Site-related cumulative cancer risk and noncancer HI for potential exposure of off-Site residents to soil is conservatively based on the highest observed concentrations from any depth for all COPCs at each location, and these estimates are summarized on Table 6-4. These risk estimates are highly conservative because they do not account for air dispersion between the Site and off-Site residents. This conservative assumption streamlines the risk assessment calculations by avoiding the need to perform off-Site air dispersion modeling when it is not necessary. As discussed above, the Site-related risk estimates presented on Table 6-4 are calculated using metal concentrations in excess of the Site-specific background levels presented on Table 6-1. Table 6-4 shows that only one location (i.e., B116SUMPS3) has an upper-bound Site-related cumulative cancer risk and noncancer HI estimate that exceeds the EPA risk management limits of 1 x 10^{-4} and 1, respectively. This location, which is located in area B116-128, is shown on Figure 6-2.

The conservative upper-bound cumulative cancer risk and noncancer HI estimates for off-Site residential inhalation exposure to airborne particulates and vapor from soil at B116SUMPS3 are due almost entirely to a concentration of 1,2-DCA (i.e., 1,300 mg/kg). As such, the upper-bound Site-related cancer risk and noncancer HI estimates were refined by using a conservative estimate of the average concentrations for 1,2-DCA in the B116-128 area. A 95 percent UCL on the mean was calculated for 1,2-DCA by using the maximum concentration from any depth at each soil sample location for the B116-128 area, as shown on Figure 6-2A. This UCL represents a high-end estimate of the mean concentration in this area. The soil samples collected in this area characterize an area that is approximately 1 acre in size and approximately 2,000 feet from the Site boundary. The air dispersion factor for a 1 acre source at this distance upwind of a receptor is at least a factor 20 lower than the air dispersion factor used in the initial calculations, which were based on a 12 acre source and an on-source receptor.

The refined risk estimates for this exposure area using the 95 percent UCL and off-Site air dispersion factor are shown on Table 6-5. This table shows that the refined cumulative cancer risk and noncancer HI estimates are both below EPA's risk management limits of 10^{-4} and 1. Therefore, potential exposure of off-Site residents via inhalation of vapor and particulates from soil at area B116-128 would not result in an unacceptable cumulative cancer or noncancer risk.

As shown on Table 6-5, the Site has no location with an unacceptable risk for off-Site resident exposure to on-Site soil.

The details of these calculations are discussed in Appendix L (Section L9.1).

6.5.2.8.2 Groundwater

Site-related groundwater COPCs have not been observed in any off-Site potable water wells. Future exposure of off-Site residents to COPCs currently in on-Site groundwater that migrate off-Site in the future was evaluated by using groundwater concentrations observed in wells located within approximately 200 feet of the property line. The significance of these concentrations was evaluated in two ways: by comparing them to drinking water screening levels (see Section 6.5.2.10.5) and by calculating cumulative cancer and noncancer risks for potable groundwater use exposure.

In calculating cumulative cancer risks and noncancer HIs, only one well located within approximately 200 feet of the Site boundary had detected COPC concentrations that would result in unacceptable risks for drinking water exposure. Specifically, well MW156-P44A (Zone A) exhibited a noncancer HI of 3, which is almost entirely due to a manganese concentration of 14 mg/L observed on June 28, 2007. The details of these calculations are discussed in Appendix L (Section L9.2.2).

6.5.2.8.3 Sum Across Media

Potential exposure of off-Site residents to environmental media (i.e., on-Site soil, groundwater, sediment, surface water, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs. A sum is developed for this receptor by using: (1) the groundwater risk estimates presented for wells within 200 feet of the property boundary; (2) soil vapor and particulates inhalation risk estimates that represent the maximum from any location on-Site; and (3) sediment and surface water risk estimates that are based on the maximum detected concentrations from Bee Tree Creek, except for the chlordane result from the 2007 sample at location BTW3-U30, which was upstream of the Site and therefore not Site-related.

The sum of the soil, groundwater, sediment, and surface water risks for off-Site residents are summarized on Table 6-15.

No additional areas were identified as exhibiting potentially unacceptable risks upon summing the media-specific RME risk estimates. As discussed in Section 6.5.2.8.2, one well located within approximately 200 feet of the Site boundary had detected COPC concentrations that would result in unacceptable risks for drinking water exposure. Specifically, well MW156-P44A (Zone A) exhibited a noncancer HI of 3, which is almost entirely due to a manganese concentration of 14 mg/L observed on June 28, 2007.

6.5.2.9 Off-Site Maintenance Workers (Current Scenario)

6.5.2.9.1 On-Site Soil

Off-Site maintenance workers could be exposed to on-Site soil if airborne particulates and vapor from on-Site soil were to migrate off-Site. Potential exposure of off-Site maintenance workers to on-Site soil via the inhalation of airborne particulates and vapors is evaluated indirectly in this risk assessment by using exposure estimates for off-Site residents. This streamlines the risk assessment and is conservative, because off-Site maintenance worker exposures to on-Site soil are expected to be no higher than that of off-Site residents. Therefore, the cumulative cancer risk and noncancer HI estimates for off-Site maintenance workers are expected to be no higher than the estimates discussed in Section 6.5.2.8. As discussed in Section 6.5.2.8, the Site-related cancer and noncancer risks for an off-Site resident's exposure to on-Site soil do not exceed the EPA risk management limits. Therefore, potential off-Site maintenance worker exposure to on-Site soil via the inhalation of airborne particulates and vapors would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.9.2 Off-Site Groundwater

Off-Site maintenance workers could be exposed to off-Site shallow groundwater during occasional subsurface maintenance activities that encounter groundwater. Site-related groundwater COPCs do not currently extend off-Site. Future exposure of off-Site maintenance workers to on-Site groundwater COPCs that could migrate off-Site in the future was evaluated indirectly in this risk assessment using exposure estimates for on-Site maintenance workers based upon the groundwater concentrations observed in the wells located within approximately 200 feet of the Site boundary.

As summarized on Table 6-7 and presented on Figure 6-4A, there are no wells within 200 feet of the property line with concentrations that result in cumulative cancer risk or noncancer HI estimates for the on-Site maintenance worker that exceed EPA's risk management limits. Therefore, future off-Site maintenance worker exposure to shallow off-Site groundwater would not result in an unacceptable cumulative cancer risk or noncancer HI.

6.5.2.9.3 Sediment

Off-Site maintenance workers could be exposed to off-Site sediment in Bee Tree Creek during occasional maintenance activities that encounter sediment. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each off-Site sediment sample location in Bee Tree Creek. For metals, the Site-related risk estimates were calculated using metal concentrations in excess of the Site-specific soil background concentrations on Table 6-1. Table 6-8 shows that none of the locations have upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential maintenance worker exposure to off-Site sediment in Bee Tree Creek would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L4.3).

6.5.2.9.4 Surface Water

Off-Site maintenance workers could be exposed to off-Site surface water in Bee Tree Creek during occasional maintenance activities that encounter surface water. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each off-Site surface water sample location in Bee Tree Creek. Table 6-9 shows that none of the locations have upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential off-Site maintenance worker exposure to surface water in Bee Tree Creek would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L4.4).

6.5.2.9.5 Sum Across Media

Potential exposure of off-Site maintenance workers to environmental media (i.e., on-Site soil, groundwater, sediment, surface water, and air) is conservatively evaluated by summing the media-specific RME estimates of cumulative cancer risks and HIs.

As presented in Section 6.5.2.3.5 and on Table 6-11, upon summing the media-specific RME risks for on-Site maintenance workers the only areas with potentially significant risks are areas APDA-7-8-9 and B105-139, which contain the wells with media-specific RME risk estimates above EPA limits for groundwater, as discussed in section 6.5.2.3.2. These areas are more than one-third of a mile from the property boundary. As a result, off-site maintenance worker exposures would not result in unacceptable risks.

6.5.2.10 Off-Site Recreational Users (Future Scenario)

6.5.2.10.1 On-Site Soil

Off-Site recreational users could be exposed to on-Site soil if airborne particulates and vapor from on-Site soil were to migrate off the Site. Potential exposure of off-Site recreational users to on-Site soil via the inhalation of airborne particulates and vapors is evaluated indirectly in this risk assessment by using exposure estimates for off-Site residents. This streamlines the risk assessment and is conservative, because off-Site recreational user inhalation exposures to on-Site soil are expected to be no higher than that of an off-Site resident. Therefore, the cumulative cancer risk and noncancer HI estimates for off-Site recreational users are expected to be no higher than the estimates discussed in Section 6.5.2.8. As discussed in Section 6.5.2.8, the Site-related cancer and noncancer risks for an off-Site resident's exposure to on-Site soil do not exceed the EPA risk management limits. Therefore, potential off-Site recreational user exposure to on-Site soil via the inhalation of airborne particulates and vapors would not result in unacceptable cumulative cancer or noncancer risks.

6.5.2.10.2 Off-Site Surface Water (Contact)

Off-Site recreational users could be exposed to off-Site surface water via direct contact (i.e., incidental ingestion, dermal contact, and inhalation of vapors) during future recreational activities in Bee Tree Creek. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each off-Site surface water sample location in Bee Tree Creek. Table 6-9 shows that none of the locations have upper-bound Site-related cumulative cancer risks or noncancer HIs exceeding EPA's risk management limits. Therefore, potential off-Site recreational user exposure to off-Site surface water in Bee Tree Creek would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L7.3).

6.5.2.10.3 Off-Site Surface Water (Fish Ingestion)

Off-Site recreational users could be exposed to COPCs in off-Site surface water via consumption of fish caught from Bee Tree Creek. Site-related cumulative cancer risk and noncancer HI estimates were calculated using the highest detected concentration for each COPC from each off-Site surface water sample location in Bee Tree Creek. Table 6-9 shows that concentrations in Bee Tree Creek result in a noncancer HI of 2, which is above EPA's risk management limit of 1. This noncancer HI is almost entirely due to a chlordane concentration of 0.015 µg/L from the upstream location BTW3-U30 in 2007 (a location at which chlordane has not been detected subsequently). Excluding this chlordane concentration from the data set, because it is not related to the Site, results in a noncancer HI for Bee Tree Creek that is only 4×10^{-6}, which is below EPA's risk management limit. Therefore, potential off-Site recreational user exposure to surface water in Bee Tree Creek via fish ingestion would not result in unacceptable cumulative cancer or noncancer risks.

The details of these calculations are discussed in Appendix L (Section L7.4).

6.5.2.10.4 Sum Across Media

Potential exposure of off-Site recreational users to environmental media (i.e., soil, surface water, sediment, and air) is conservatively evaluated using the results for on-Site recreational users. As explained in Section 6.5.2.6.6, potential on-Site recreational user exposures, including summing across media, would not result in unacceptable cumulative cancer or noncancer risks. As a result, off-Site recreational user exposure would also not result in unacceptable risks.

6.5.2.10.5 Comparison to Drinking Water Screening Levels

Site-related[9] groundwater data were compared to drinking water screening levels equal to the 2L standard (including IMACs). For COPCs that do not have a 2L standard, a value was determined from the following hierarchy: (1) nonzero maximum contaminant level goals (MCLGs), (2) MCLs, or health-based limits (HBLs), calculated using the formulas specified under the 2L regulations at 15 NCAC 02L.0202(d)(I) and (2)[10]. Table 6-16 presents the groundwater screening levels for the groundwater COPCs.

The results of these comparisons are presented in Appendix L (Attachments L-7.06 and 7.07) and shown on Figure 6-5. Among the monitoring wells with concentrations that exceed the drinking water screening levels, 10 are located within approximately 200 feet of the Site boundary.

Locations within 200 Feet of Site Boundary with Groundwater Concentrations Exceeding Drinking Water Screening Levels

Valley	Location	Well Zone	Chemical	Concen-tration (mg/L)	Drinking Water Screening Level (mg/L)	Date	Number of More Recent Results
Front	MW156-P44A	A	Manganese	14	0.49	06/28/2007	0
Front	MW158-N44A	A	Manganese	2.72	0.49	06/27/2007	0
Front	MW158-N44A	A	RDX	0.00097	0.000318	06/27/2007	4
Front	MW167-O44A	A	Perchlorate	0.0046	0.002	06/28/2007	3
Front	MW154-O44C	C	Manganese	1.45	0.49	06/28/2007	0
Front	MW154-O44C	C	TCE	0.0034	0.003	10/27/2011	0
Back	MW163-T32C	C	Manganese	0.989	0.49	07/13/2007	0
Back	MW163-T32C	C	TBA	0.016	0.01	07/13/2007	2
Front	MW192-P41CD	CD	Manganese	2.27	0.49	03/01/2010	0
Front	MW192-P41CD	CD	RDX	0.00068	0.000318	03/01/2010	3

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[9] As discussed in Section 4.2.1 and Section 9.5.3 of the *RI/FS Work Plan, Volume 1 (Altamont 2009)*, a statistical comparison of groundwater data from nine background monitoring wells to the data from the rest of the monitoring wells determined that the following chemicals in groundwater are not Site-related: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, vanadium, zinc, ammonia, chloride, cyanide, nitrite, sulfate, and sulfide. These metals have been excluded from this evaluation.

[10] At the request of DENR, a comparison to EPA's May 2012 Regional Screening Levels for Tap Water is included in Appendix IIL.

Valley	Location	Well Zone	Chemical	Concen-tration (mg/L)	Drinking Water Screening Level (mg/L)	Date	Number of More Recent Results
Front	MW192-P41CD	CD	TBA	0.029	0.01	10/19/2011	1
Front	MW192-P41CD	CD	TBA	0.022	0.01	12/20/2011	0
Front	MW177-M44D	D	1,2-DCA	0.001	0.0004	09/19/2008	3
Front	MW204-L45EF	EF	1,2-DCA	0.0007	0.0004	03/11/2010	2
Front	MW204-L45EF	EF	1,2-DCA	0.0005	0.0004	10/18/2011	0
Front	MW175-Q40F	F	2-Nitrotoluene	0.0015	0.000159	07/02/2007	4
Front	MW177-M44F	F	1,2-DCA	0.0012	0.0004	06/27/2007	4
Front	MW177-M44F	F	1,2-DCA	0.0011	0.0004	09/19/2008	3

Only six of these 10 wells have detected concentrations in excess of the drinking water screening levels when considering only the most recent data from each well (see Figure 6-6 and Attachment L-6.07).

Locations within 200 Feet of Site Boundary with Most Recent Groundwater Concentrations Exceeding Drinking Water Screening Levels

Valley	Location	Well Zone	Chemical	Concen-tration (mg/L)	Drinking Water Screening Level (mg/L)	Date
Front	MW156-P44A	A	Manganese	14	0.49	06/28/2007
Front	MW158-N44A	A	Manganese	2.72	0.49	06/27/2007
Front	MW154-O44C	C	Manganese	1.45	0.49	06/28/2007
Front	MW154-O44C	C	TCE	0.0034	0.003	10/27/2011
Back	MW163-T32C	C	Manganese	0.989	0.49	07/13/2007
Front	MW192-P41CD	CD	Manganese	2.27	0.49	03/01/2010
Front	MW192-P41CD	CD	TBA	0.022	0.01	12/20/2011
Front	MW204-L45EF	EF	1,2-DCA	0.0005	0.0004	10/18/2011

6.5.3 Uncertainty Analysis

6.5.3.1 Exposure Concentrations

Most exposure concentrations for soil in this risk assessment are based on the highest concentrations detected in soil at each location, and refinements to the exposure concentrations (e.g., UCLs, area weighted averages) are calculated only when an upper-bound estimate of the RME media-specific cumulative cancer risk or noncancer HI exceeds EPA's risk management limits. As discussed in Section 6.3.2, this approach streamlines the risk assessment by avoiding the calculation of refinements (e.g., UCLs) that would not materially affect risk assessment conclusions regarding the need for interim measures and/or remedial action.

However, this approach inflates the cumulative cancer risk and noncancer HI estimates, because these estimates are entirely based on maximum detected concentrations. The use of maximum detected concentrations for all COPCs introduces more conservatism than necessary for RME estimates, because it assumes simultaneous worst case exposure. The inflation of these risk and HI estimates makes them closer to the EPA's cumulative cancer risk limit of 1×10^{-4} or noncancer HI limit of 1 than they would be if refinements such as UCLs were used for all COPCs.

The above discussion regarding soil exposure concentrations also applies to groundwater exposure concentrations for the excavation scenarios, because maintenance workers and construction workers would not be expected to be exposed to groundwater with the maximum detected concentrations of each COPC during every on-Site or off-Site excavation.

Most exposure concentrations that are based on mathematical modeling of chemical transfer from soil or groundwater to air are conservative for the same reasons discussed above, because the model estimates are based on the use of maximum detected concentrations in soil or groundwater. In addition, some model estimates are conservative, because they do not account for the reduction of COPC concentration or mass in the soil or groundwater as COPCs transfer from these media. Even for models that account for reduction of mass in the soil (e.g., the Jury model), risk calculations for ingestion and dermal contact with soil assume soil concentrations remain constant, which is consistent with EPA practice but contradicts the mass conservation principle. As a result, risk estimates that are based on the sum of risk estimates from soil and soil vapor/particulates are more conservative than necessary for RME estimates. These include the risk estimates discussed in Section 6.5.2.

6.5.3.2 Exposure Factors

As discussed in Section 6.3.4, most of the exposure factors used in the risk assessment are high-end (i.e., 90th to 95th percentile) estimates of the magnitude, frequency, and duration of potential exposures. When several such high-end factors are multiplied, the resulting estimates of dose will be higher than the 90th percentile of the distribution of exposures in the potentially exposed population and could be higher than the exposure to the maximally exposed individual, particularly when such exposure factors are combined with exposure concentrations that are based on maximum detected concentrations (as discussed above).

Also, the use of generic default exposure factors for evaluation of potential exposure of workers to soil is more conservative than necessary for RME estimates, which allow the use of site-specific considerations (EPA 1989b). For example, the "fraction contacted" terms used in this risk assessment assumes that industrial workers are exposed to soil for an entire work day at each area, but workers at commercial/industrial sites generally spend only a part of the work day at a particular part of a site.

6.5.3.3 Extrapolated Toxicity Values

As discussed in Section 6.4, the dermal toxicity values used in the risk assessment are oral toxicity values that were extrapolated to the dermal route without chemical-specific judgment regarding whether such extrapolation might be appropriate for a particular COPC. This is consistent with EPA guidance (2004b) and is a conservative approach to ensure that potential risk via the dermal route is not overlooked. However, some COPCs might exhibit different degrees of toxicity for the dermal route relative to the oral route. For such COPCs, the extrapolation approach used in the risk evaluation could introduce uncertainty.

6.5.3.4 Risk Characterization

The summation of cancer risks and HQs for multiple COPCs, as described in Section 6.5.1, is based on EPA guidance (1989b) to assume dose additivity, which means that COPCs in a mixture are assumed to have no synergistic or antagonistic interactions and each COPC has the same mode of action and elicits the same health effects. This approach is consistent with the EPA science policy discussed in its 1986 and 2000 guidelines for health risk assessment of chemical mixtures. Consistent with guidance, additive approaches are used for chemical mixtures when the toxicological data on the Site-specific mixtures is not available. In general, this approach can introduce significant uncertainty. However, the majority of the media-specific cumulative cancer risk and HI estimates in this risk assessment are dominated by contributions from no more than a few COPCs, so the media-specific cumulative risk estimates are nearly the same as those for the few key COPCs.

The media-specific risk estimates are suitable for comparison to the EPA RME risk limits because they are calculated with sufficiently conservative exposure factors and toxicity values to ensure that they represent RME risk estimates (or higher). The sum of these media-specific RME risk estimates across media for each receptor likely results in cumulative risk estimates that exceed RME risks.

6.6 Summary and Conclusions

The HHRA evaluated potential human health risks from hazardous substances present at the Site. The potential risks are evaluated under current and reasonably anticipated future land and groundwater uses at and surrounding the Site in the absence of remediation or groundwater institutional controls.

The purpose of the HHRA is to determine whether any RME risk, under current and reasonably anticipated future land use and groundwater use at and around the Site, is sufficiently high to warrant remedial action (including institutional controls).

The HHRA evaluated the following potentially exposed populations at and around the Site under current and reasonably expected future land use:

On-Site:

- Industrial workers
- Maintenance workers
- Construction workers
- Residents
- Recreational users
- Trespassers

Off-Site:

- Residents
- Maintenance workers
- Recreational users

The potential exposures evaluated for these receptors are summarized in Table 6-2 (Scenarios for Potential Human Exposure). These exposures were evaluated using Site characterization data representative of current and future Site conditions and accounted for the removal of impacted soil as interim measures during the RI (Altamont 2010b and 2011).

Results of the HHRA are summarized below by environmental media, including the identification of areas with estimates of unacceptable risk. For the purposes of the RI, the risk assessment evaluated exposures based on the assumption that future on-Site land use and groundwater use will be unrestricted, except within the fenced portions of each DA where access is strictly limited to personnel who maintain the effectiveness of the remedy specified by the 1988 ROD and 1989 ROD Amendment. However, institutional controls to restrict the Site to commercial/industrial reuse and to restrict groundwater use may be considered during the FS as part of the evaluation of the existing remedy and potential remediation alternatives. Off-Site land use and groundwater use around the Site are currently unrestricted and are assumed to remain unrestricted for purposes of the risk assessment.

Overall, there are no current unacceptable risks to human health from hazardous substances at the Site. Future uncontrolled exposures to on-Site workers and on-Site residents could pose unacceptable risks. With the exception of potential future off-Site potable/nonpotable groundwater use (see below), there are no potential future unacceptable risks to off-Site receptors from hazardous substances at the Site.

6.6.1 **Soil**

As presented on Figure 6-3A, there are no areas of the Site with soil concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering potential future maintenance worker, construction worker, trespasser, or recreational user exposure to soil.

As presented on Figure 6-3A, the following areas of the Site have soil concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering potential future industrial worker exposure to COPCs in soil:

- Area B116-128: soil sample locations B116SUMPS1, S2, S3, and S4, due predominately to the following COCs via vapor intrusion: 1,2-DCA, vinyl chloride, benzene, 1,1,2-trichloroethane, cyclohexane, and methylene chloride
- Area B109-137: soil sample locations B109137BS1A and B109137SS1A, due almost entirely to the following COCs via vapor intrusion: 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene

As presented on Figure 6-3B, the following areas of the Site have soil concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering potential future on-Site residential exposure to COPCs in soil:

- Area APDA-7-8-9: soil sample locations APDA789B11, APDA789B2, and APDA789B3
- Area B105-139: soil sampling locations B105139B4, B5, B7, and B8
- Area B107: soil sampling location B107B3 and B107B6
- Area B109-137: soil sampling location B109137B3, B109137BS1A, and SS1A
- Area B113: soil sampling locations B113B4, B5, B6 and B8
- Area B115: soil sampling locations B115B1 and B2
- Area B116-128: soil sample locations B116128B1, B5, B13, SUMPS1, SUMPS2, SUMPS3, and SUMPS4
- Area B119-120: soil sampling locations B119120B1, B3, and B4
- Area B125-136: soil sampling location B125136B2
- Area B146: soil sampling location B146B1
- Area B147: soil sampling locations B147B2, B5, B7, B9, and S2
- Area B148: soil sampling location B148B2
- Area B149: soil sampling location B149B5
- Area B155: soil sampling location B155B4
- Area DA23: soil sampling location DA23B2
- Area DUMP: soil sampling location: DUMPTP3

These estimates of unacceptable risk are due to soil direct contact and/or soil vapor intrusion exposures. Depending on the area, unacceptable risk estimates for soil direct contact were predominantly driven by the following COCs: aldrin, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene, arsenic, chromium, cobalt, benzene, 1,2-DCA, 1,1,2-trichloroethane, vinyl chloride, RDX, and cyclohexane. Unacceptable risk estimates for soil vapor intrusion are predominantly driven by the following COCs: benzene, bromoform, chloroform, cyclohexane, ethylbenzene, 1,2-DCA, naphthalene, 1,1,2-trichloroethane, methylene chloride, trichloroethylene, tetrachloroethylene, vinyl chloride, styrene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, isopropylbenzene, aniline, allyl chloride, xylenes (total), toluene, and mercury.

6.6.2 **On-Site Groundwater**

As presented on Figure 6-4A, there are no areas of the Site with groundwater concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA’s risk management limits of 1×10^{-4} and 1, respectively, when considering future industrial worker exposure to groundwater via inhalation of outdoor air. As presented on Figure 6-4A, the following areas of the Site have groundwater concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA’s risk management limits of 1×10^{-4} and 1, respectively, when considering future industrial worker exposure via vapor intrusion or potable/nonpotable groundwater use and maintenance worker/construction worker exposure via direct contact with groundwater:

- Monitoring well locations P-7S, MW180-H38AB, and MW223-L26AB, due almost entirely to TCE vapor intrusion as well as via dermal contact and vapor inhalation during excavations that extend to the water table
- Monitoring well location MW231-H38AB, due almost entirely to TCE via dermal contact and vapor inhalation during excavations that extend to the water table
- 49 monitoring well locations in addition to those listed above that have groundwater concentrations that could pose an unacceptable risk to on-Site industrial workers if groundwater were to be used in the future for potable (and possibly nonpotable) purposes. These well locations are shown on Figure 6-4A.

As presented on Table 6-7, there are no areas of the Site with groundwater concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering future residential exposure to groundwater via inhalation of outdoor air. As presented on Table 6-7 and Figure 6-4B, the following areas of the Site have groundwater concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering future residential exposure via vapor intrusion or potable/nonpotable groundwater use:

- Monitoring well locations P-7S, MW180-H38AB, MW223-L26AB, and MW231-H38AB, due almost entirely to TCE via vapor intrusion
- Monitoring well locations MW187-M25AB, due almost entirely to 1,2-DCA via vapor intrusion
- 71 monitoring well locations (including those listed above) have groundwater concentrations that could pose an unacceptable risk to on-Site residents if groundwater were to be used in the future for potable (and possibly nonpotable) purposes. These well locations are shown on Figure 6-4B.

6.6.3 **Sediment and Surface Water**

As presented on Tables 6-8 and 6-9, there are no locations at the Site with sediment or surface water concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1×10^{-4} and 1, respectively, when considering current or future trespasser exposure, future maintenance worker/construction worker exposure, or recreational user exposure.

6.6.4 **Off-Site Groundwater**

Lastly, as discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) recognize that off-Site groundwater use for potable purposes is a current and reasonably expected exposure scenario. To be conservative, the risk assessment evaluates the potential exposure of off-Site residents to groundwater via potable groundwater use by comparing the detected concentrations in on-Site monitoring wells located within approximately 200 feet of the Site boundary to drinking water screening levels. As shown on Figure 6-6, there are six on-Site monitoring wells within 200 feet of the Site boundary currently exhibiting detected concentrations in excess of the drinking water screening levels.

As shown on Table 6-7 and Figure 6-4B, there is only one on-Site monitoring well within 200 feet of the Site boundary (i.e., MW156-P44A) for which the cumulative cancer risk or noncancer HI for residential potable or nonpotable use, based on the maximum detected concentrations, are above EPA's risk management limits of 1×10^{-4} and 1, respectively. Hypothetical resident exposure to groundwater via potable use could be unacceptable if near boundary concentrations were present off-Site. However, as discussed in Section 3, the off-Site water well survey and water well sampling activities have observed no COPCs from the Site in off-Site groundwater at concentrations that exceed the 2L standards.

6.6.5 **Summing Across Media**

Potential exposure of receptors to environmental media (i.e., soil, groundwater, surface water, sediment, and air) is conservatively evaluated by summing by receptor the media-specific RME estimates of cumulative cancer risks and HIs.

Not considering the potential exposure of on-Site residents or the potential exposure of receptors to groundwater via potable/nonpotable use, the summing of media-specific RME risk estimates for industrial workers, maintenance workers, construction workers, trespassers, and recreational users did not identify any additional areas that would warrant remedial action.

If potable/nonpotable groundwater use exposure was considered for industrial workers, two additional areas (B156 and TRA3) would be identified as having a potentially unacceptable risk not identified by the media-specific cumulative cancer risk and/or HI estimates. In Area B156, this potentially unacceptable exposure is related to perchlorate in groundwater. In Area TRA3, this potentially unacceptable exposure is related to perchlorate and RDX in groundwater. If potable/nonpotable groundwater use exposure is prevented by institutional controls, the noncancer risks for industrial workers in these areas would be acceptable.

Finally, considering potential exposure of on-Site residents and accounting for potential potable/nonpotable groundwater use, two additional areas (B122 and B124-135) and three individual wells not in soil areas (MW146-M43C, MW176-L41E, and MW229-L41EF) would be identified as having a potentially unacceptable risk that was not identified by the media-specific cumulative cancer risk and/or HI estimates. If potable/nonpotable groundwater use exposure is prevented by institutional controls, the risks to residents in the areas of wells MW146-M43C, MW176-L41E, and MW229-L41EF would be acceptable.

6.6.6 **Chemicals of Concern**

A chemical is identified in this risk assessment as a Chemical of Concern (COC) if it is determined to significantly contribute to an unacceptable cumulative risk. More specifically, a chemical is defined as a COC if, at any location for which there is a potentially complete exposure pathway for a given receptor and matrix:

- The cumulative cancer risk estimate is greater than 10^{-4} and the single-chemical cancer risk is greater than 10^{-5}; and/or
- The noncancer HI estimate is greater than 1 and the chemical’s HQ is greater than 0.1

Table 6-17 provides the list of COCs identified by the risk assessment. The COCs are summarized by receptor and exposure media.

7.0 Ecological Risk Assessment

7.1 Introduction

The ERA discussed in this section is consistent with the EPA-approved Work Plan, Volume 4, which was based on the key elements of the following EPA and DENR guidance:

- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments Interim Final (1997)*
- *Guidelines for Ecological Risk Assessment (1998)*
- *ECO-Update: Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessment (2001a)*
- *Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment (2001b)*
- *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment (2003a)*
- *Guidelines for Performing Screening Level Ecological Risk Assessments within North Carolina (2003)*

In general, the ERA follows EPA's 8-Step process, as illustrated on Figures 7-1A and 7-1B. Steps 1 and 2 comprise the SLERA, while Steps 3 through 8 comprise the baseline ERA (BERA) (EPA 1997, EPA 1998, EPA 2001a). The SLERA evaluates potential risk to ecological receptors exposed to chemicals at the Site using highly conservative risk estimates and incorporating uncertainty in a precautionary (i.e., conservative) manner. The outcome of the SLERA is either a determination that there is a high probability of no ecologically significant risk or a determination that a BERA is necessary to evaluate certain SLERA results (EPA 1997).

When a BERA is necessary, the BERA begins with Step 3 of the ERA process. Step 3 (Problem Formulation) is commonly performed in two parts: Step 3a and Step 3b. Step 3a is an opportunity for refinement of potential risks using methods similar to those used in Steps 1 and 2 (EPA 2001a). Specifically, chemicals of potential ecological concern (COPECs) identified in the SLERA are re-evaluated and may be eliminated from further consideration based on the refinement of certain assumptions, such as use of realistic exposure estimates, consideration of more realistic measures of effect, and consideration of spatial distribution of contaminants. Chemicals and receptors identified as potentially significant in the refined screening analysis of Step 3a are carried to Steps 3b through 8. Step 3a concludes with a scientific management decision point (SMDP) at which stakeholders may consider the following:

- Whether the available information is adequate to conclude that the Site does not pose an unacceptable ecological risk, and therefore there is no need for further action on the basis of ecological risk
- Whether the available information is not adequate to make a decision and the ERA process should continue
- Whether the available information indicates a potential for an adverse ecological effect, and a more thorough assessment or remediation is warranted

During the RI, the following ERA work was completed and reviewed with EPA and DENR:

- Screening-level problem formulation, which is Step 1 of the SLERA and was presented in the ERA Work Plan
- Screening-level exposure assessment, screening-level effects assessment, and screening-level risk characterization, which are the elements of Step 2 of the SLERA and were presented in the Phase I Technical Memorandum

Based on the ERA-related findings in the Phase I Technical Memorandum, the following fieldwork was performed to support the ERA, as part of the next phase of the RI field investigation:

- Collection of background soil samples for the characterization of naturally occurring inorganics
- Collection of soil pH data from certain areas to further evaluate potential aluminum toxicity
- Delineation of a high aldrin soil concentration at the southern edge of the AP

Data from the above work as well as data collected for other purposes during later phases of the RI field investigation have been used to update the elements of the SLERA previously reported and used in Step 3a of the BERA. Discussion of the updated SLERA and the refined screening analysis performed in Step 3a of the BERA is organized as follows:

- Section 7.2 provides the SLERA (which incorporates all RI data and shows how the updated SLERA compares to the SLERA results presented in 2010)
- Section 7.3 provides Step 3a of the BERA (which is a new evaluation that also uses all the RI data)
- Section 7.4 provides the conclusions and SMDP

7.2 Screening-Level Ecological Risk Assessment

The SLERA includes the following steps and is organized as follows:

- Section 7.2.1 provides the Step 1: Screening-Level Problem Formulation
- Section 7.2.2 provides the Step 1: Screening-Level Ecological Effects Evaluation
- Section 7.2.3 provides the Step 2: Screening-level Exposure Estimate
- Section 7.2.4 provides the Step 2: Screening-Level Risk Calculation
- Section 7.2.5 provides the SLERA Uncertainties Evaluation
- Section 7.2.6 provides the conclusions of Step 3a of the BERA and the SMDP for the SLERA

7.2.1 **Step 1: Screening-Level Problem Formulation**

The ERA Work Plan initially presented many elements of the screening-level problem formulation. Some new elements are also discussed herein. As stated in the Work Plan, the objective of Step 1 of an ERA is to determine if viable ecological habitat exists for ecological receptors to have direct exposure or food chain exposure to Site-related chemicals. In this step, the environmental surroundings, receptor species/assemblages, habitat/cover types, and relevant environmental and biotic transfer mechanisms at the Site are evaluated and described. This section includes an ecological habitat characterization that is based on a compilation of existing information (e.g., Site history, maps, aerial photographs, and natural resource databases) and Site reconnaissance findings to identify wildlife and vegetative communities at the Site.

- The overall purpose of the screening-level problem formulation is to describe the environmental setting at and adjacent to the Site and to provide a preliminary evaluation of ecological exposure pathways and assessment endpoints. The screening-level problem formulation provides the framework for the SLERA and the methods for analyzing/characterizing risks (EPA 1998). The screening-level problem formulation identifies: 1) the assessment endpoints that reflect the management and ecosystem attributes that are to be protected; 2) the methods that are used to evaluate potential risks for each of the assessment endpoints; and 3) an ecological CSM that describes the relationships between stressors and the assessment endpoints. The remainder of this section presents the following components of the screening-level problem formulation:
- Environmental Setting
- Chemicals Detected
- Mechanisms of Ecotoxicity
- Potentially Exposed Receptors
- Identification of Potentially Complete Exposure Pathways and an Ecological CSM
- Identification of Generic Assessment and Measurement Endpoints

7.2.1.1 Environmental Setting

The following description of the Site's environmental setting is based on a preliminary ecological evaluation and a July 2008 Site reconnaissance performed by an ENVIRON Certified Ecologist and an ecological risk assessor (key photographs are provided in Appendix M1-1, and an EPA ecological checklist completed based on the 2008 Site reconnaissance is provided in Appendix M1-2).

As discussed in Section 3, the Site is comprised of 1,065 acres of mixed land use, with the majority of the Site consisting of relatively undisturbed, terrestrial habitat that is typical of the Appalachian Mountain region of North Carolina. The vast majority of the Site is not impacted by past Site operations and reflects biological communities and ecosystems typical of WNC. The northern portion of the Site consists of steeply to moderately sloped hills and valleys covered by mixed forest types, including areas dominated by hardwoods (e.g., oak, American beech, hickory) and mixed pines. The approximate northern one-third of the Site is not traversed by streams and does not contain surface water bodies, but rather the northern, forested portion of the Site provides the upland watershed for on-Site and nearby streams. The wildlife community within the northern, forested area is likely to include forest-dwelling birds, upland forest reptiles (e.g., snakes, turtles), small mammals (e.g., squirrels, opossums), deer, bears, bobcats, coyotes, turkeys, and possibly cougars. Former Site operations are not known to have occurred within the northern, forested area except that projectiles (e.g., rockets) may have been tested by discharging them over or into the northern portion of the Site. In addition, waste was disposed in pits in the northern portion of the Site (the DAs). Ground-based disturbance (e.g., roads) and development (e.g., buildings) within the northern, forested area are not apparent in historical aerial photographs or described in historical records reviewed during preparation of the Work Plan. Except for the small buildings used for remediation operations, structures at the Site have been demolished, though building foundations remain, and the Site is currently vacant.

Much of the habitat in the formerly active areas of the property reflects successional scrub-shrub and herbaceous vegetation characteristic of an environment where maintenance of building/operational grounds ceased and recolonization of indigenous and nuisance plant species has begun. The scrub-shrub and herbaceous areas of the Site provide habitat and food sources for passerine birds and raptors, small mammals (e.g., groundhogs, rabbits), reptiles (e.g., snakes, turtles), bears, turkeys, and deer. Habitat within the former operational areas may have potentially received discharges of chemicals and/or been subject to physical disturbance during former activities at the Site.

The most ecologically sensitive areas of the Site are its various aquatic habitats, including streams, wetlands, and ponds, as shown in Figure 1-3. The Site is principally comprised of two small watersheds, the Unnamed Branch and Gregg Branch, both of which drain to Bee Tree Creek. Bee Tree Creek is a cobble-bed, perennial stream approximately 30 to 40 feet wide that runs along part of the Site's eastern boundary. The main stems of the Unnamed Branch and Gregg Branch are variably 5 to 10 feet wide with primarily sand- or gravel/rock-dominated beds and incised banks. Some of the headwater tributaries to the Unnamed Branch and Gregg Branch are intermittent or ephemeral streams and were dry during ENVIRON's July 2008 Site reconnaissance. The stream network, where inundated, provides habitat for aquatic invertebrates, fish, and amphibians and a water source for birds and mammals. Disturbance of aquatic habitats due to former activities at the Site is variable throughout the Site. Road crossings have impacted riparian buffers and stream flow. In the Front Valley, aquatic habitats have been affected by direct discharges of chemicals and/or received runoff or eroded soil from disturbed upland areas.

A fish habitat assessment was performed by RMT North Carolina Inc. (RMT) in 2002. According to RMT (2002), its purpose was to assess the potential for off-Site migration of chemicals through fish that may inhabit the Unnamed Branch and Gregg Branch. RMT performed the assessment by making observations of stream conditions during a Site visit in August 2002. No fish specimens were collected during the Site visit. Based on the Site visit, RMT concluded that the Unnamed Branch is too small to support resident and/or transient fish populations. In Gregg Branch, RMT observed fish thought to be creek chub (*Semotilus atromaculatus*) in pools downstream from the two most downstream road-crossing culverts.

During ENVIRON's 2008 Site reconnaissance, several stream reaches were examined for the presence of benthic invertebrates, which can be an indicator of water quality. The observations of benthic invertebrates suggest generally high water quality, as mayflies, stoneflies, and caddisflies were identified on-Site, and these species comprise the EPA's *Ephemeroptera*, *Plecoptera*, *Tricoptera* (EPT) Index, a community metric based on the sensitivity of these families of organisms (EPA 1999). Water pennies, which were observed in the on-Site streams as well, are also a sensitive species whose presence is an indicator of good water quality (EPA 1999). While the July 2008 observations are qualitative rather than quantitative, they do provide a good context for the interpretation of results from later steps of the ERA.

In addition to the stream network, the following aquatic areas have been identified (photographs are provided in Appendix M1-1):

- Pond 1—a man-made surface water body, expected to be groundwater fed and fed by overflow from Pond 2; various algae and submerged vegetation observed during the July 2008 reconnaissance; fish, minnows, and aquatic invertebrates also observed during that reconnaissance (Photograph 1, Appendix M1-1)

- Pond 2—a man-made surface water body, expected to be groundwater fed; various algae and submerged aquatic vegetation observed during the July 2008 reconnaissance; bluegills and minnows also observed during that reconnaissance (Photograph 2, Appendix M1-1)
- Pond 2 Lacustrine Wetlands—wetlands influenced by the hydrology of Pond 2, consisting of emergent, herbaceous vegetation (Photograph 3, Appendix M1-1)
- Pond 3 (Natural Pond)—a small surface water body located near Gregg Branch confluence with Bee Tree Creek; approximately 50 percent of the surface area is vegetated with emergent, herbaceous vegetation, with minnows observed during the July 2008 reconnaissance (Photograph 4, Appendix M1-1); bermed sides were also observed but the origin of the berms is not known
- Vernal Pools—several such pools observed in vicinity of Pond 3, some dry and some holding water; shallow water depth with no vegetation observed during the July 2008 reconnaissance
- Building 143 Potential Wetland Area—very small (less than 25 ft in diameter) wet area located in vicinity of former Building 143 footprint; vegetation community dominated by rushes and sedges; vigor of plants during July 2008 drought indicative of groundwater-fed wetland (Photograph 5, Appendix M1-1)

7.2.1.2 Chemicals Detected

The SLERA considers all chemicals detected in the RI data to be preliminary COPECs. The preliminary COPECs at the Site are VOCs, SVOCs, metals, pesticides, nitroaromatics/amines, and perchlorate. The maximum concentration from the RI data for each detected chemical is listed on Tables 7-1A, 7-1B, 7-1C, and 7-1D for surface soil, surface water, groundwater, and sediment, respectively. The concentrations on these tables were compiled based on the following considerations:

- Surface soil is defined as the upper 1 foot of the soil column.
- Groundwater is evaluated for a subset of the monitoring wells that are sufficiently near a surface water feature to warrant consideration of ecological exposures at the groundwater/surface water interface.
- Surface sediment is defined as the upper 6 inches of the sediment column, which is the biologically active zone and the portion of the sediment column sampled.

7.2.1.3 Mechanisms of Ecotoxicity

Information about the mechanisms of toxicity is presented in this section without regard to chemical concentrations, because the intent is to convey a general understanding of possible effects rather than to describe the concentrations at which effects might occur. As such, the descriptions provided are not meant to imply that the effects have occurred, are occurring, or may occur in the future at the Site.

The mechanisms of ecotoxicity for chemicals vary depending on a wide range of factors, such as chemical concentration, the wildlife receptor species exposed, the exposure route (e.g., ingestion or direct contact), and environmental factors (e.g., pH, temperature, and oxygen levels).

7.2.1.3.1 Volatile Organic Compounds

VOCs tend to attenuate rapidly in surface soil due to their inherent volatility. Although reports on the effects of VOCs on wildlife under field conditions are limited, there have been extensive studies on the effects of VOCs under laboratory conditions. In laboratory test organisms, inhaled VOCs are typically metabolized in the liver, which may cause liver damage or the release of more toxic secondary metabolites. VOCs are not known to bioaccumulate because they are so rapidly metabolized and because of their tendency to volatilize in the environment. Excessive exposures to VOCs may cause neurological damage, and some VOCs are mutagenic, carcinogenic, fetotoxic, and/or teratogenic at high levels of exposure under laboratory conditions (EPA 1999b).

7.2.1.3.2 Semivolatile Organic Compounds

SVOCs include a wide variety of compound classes, such as phenols, organochlorine alkenes, phthalates, polycyclic aromatic hydrocarbons (PAHs), and pesticides. SVOCs vary greatly in regard to their toxicity (particularly the mechanisms), bioaccumulative potential, and tendency to metabolize. Excessive exposures to SVOCs or their metabolites may cause neurological damage, and some SVOCs are mutagenic, carcinogenic, fetotoxic, and/or teratogenic at high levels of exposure under laboratory conditions (EPA 1999b, Newman 1998, Sample et al. 1996).

PAHs such as benzo(a)pyrene, chrysene, fluoranthene, and pyrene are often released as a result of human activities, such as the incomplete combustion of fossil fuels or other organic materials. Some of these compounds are persistent and are known to be mammalian carcinogens, though the ecological effects of PAHs are not well characterized. Primary non-point sources of PAHs in the environment are aerial fallout (or rainout), road runoff (from the wear and leaching of asphalt, tire wear, vehicle exhaust, and dripping vehicle fluids), and combined storm sewer runoff (domestic sewage contains some PAHs). Most PAHs adsorb to solid particles in the environment, which significantly reduces the bioavailability and toxicity of the adsorbed PAHs.

PAHs have been shown to cause changes in liver enzymes and cell membranes but, in general, are not viewed as acutely toxic in vertebrates, because they are metabolized by the liver (EPA 2007a). PAHs are metabolized in the liver, where toxicity is associated with cytochrome P450-mediated conversion of the parent compound to toxic metabolic intermediates. Because PAHs are largely metabolized in fish, this diminishes risks to higher trophic levels, though does not entirely protect the fish from toxicity (Fuchsman et al. 2001). Sub-lethal effects attributed to PAHs in aquatic animals include reduced reproductive ability and fertility, developmental abnormalities, delayed or retarded maturation, histological changes, and carcinogenesis (Eisler 1987). In sediment-dwelling organisms, PAHs are known to have a narcotic effect that may also be compounded by organic chemicals other than PAHs in chemical mixtures (McGrath and DiToro 2009).

7.2.1.3.3 Metals

The potential adverse impacts on wildlife from trace metals (such as arsenic, barium, beryllium, chromium, copper, lead, and zinc) are well understood (Newman 1998). Chromium, copper, and zinc are essential for healthy enzyme function, and some organisms cannot survive without these metals. However, these naturally occurring metals may cause adverse effects when exposure occurs at concentrations that significantly exceed background levels. The toxicity and effects of trace metals may be greatly influenced by pH, hardness, and organic carbon content of the water in which they occur (EPA 2007b).

Imbalances in the essential trace metals may cause a decrease in photosynthetic ability, poor spawning/hatching success, teratogenesis, susceptibility to predation and disease, reduced growth, mortality, histopathological changes, organ dysfunction of the liver or kidneys, neurological defects, changes in respiration and osmoregulation, and anemia. Some metals may bioaccumulate, but this mechanism is thought to be of minor ecological concern. Because these metals are naturally occurring, many organisms have a capacity (albeit limited) to biotransform and/or eliminate naturally occurring concentrations (EPA 2007b).

7.2.1.3.4 Perchlorate, RDX, and HMX

Perchlorate is an inorganic compound often used as a component of propellants. Once present in water, it tends to stay dissolved rather than partition into sediment or volatilize into the air (EPA 2012b). Therefore, sediment exposures are expected to be dominated by exposure to pore water, which is assumed to be equal to surface water (EPA 2002). Perchlorate may bioaccumulate into plants and food crops and has been detected in milk, but bioaccumulation into animals is still not well known and is thought to be low (EPA 2002, ATSDR 2008, EPA 2012a). Perchlorate toxicity tests with invertebrates indicate acute and chronic systemic toxicity in sufficient concentration and inhibition of reproduction at lower concentrations (EPA 2002). Plant testing indicates effects in growth and survival (EPA 2002). In vertebrates, perchlorate is known to inhibit iodine transport from the bloodstream into the thyroid (Greer 2002). In fish, perchlorate may lead to slow development, improper scale and pigment formation, small size, and abnormal thyroid formation in larvae (Crane et al. 2005). In terrestrial vertebrates, perchlorate exposure may be associated with thyroid and pituitary hormones, thyroid histopathology, and changes in brain morphometry (EPA 2002).

RDX and HMX are relatively insoluble in water and are unlikely to bind to soil or sediment (ATSDR 1997, ATSDR 2012). Both RDX and HMX photodegrade once they enter surface waters, which explains their low frequency of detections in surface water (ATSDR 1997). Photodegradation half-lives of RDX and HMX may be on the order of days to a few weeks depending on the clarity of the water (ATSDR 1997, CHPPM 2001, CHPPM 2002). The bioaccumulation potential of both compounds is relatively low (ATSDR 1997, CHPPM 2002).

Avian studies indicated that HMX was retained as an indigestible bolus in the crop and no remarkable effects were noted (CHPPM 2001). HMX has generally low acute oral toxicity in rodents, presumably due to low gut uptake of ingested HMX (ATSDR 1997, CHPPM 2001). Subacute effects in mammals include low body weight, as well as changes in the liver, spleen, kidneys, and blood (ATSDR 1997).

RDX, unlike HMX, appeared to be readily absorbed through the mammalian gut where it is presumably metabolized in the liver and generally leaves the body through urine and exhaled CO_2 (CHPPM 2002). High doses led to tremors and death (CHPPM 2002). Mammalian studies show relatively low toxicity, though subacute doses led to some changes in organ morphology in the liver and spleen as well as in blood cells in mice, rats, dogs, and monkeys (CHPPM 2002). Avian studies indicate that RDX leads to decreased body weight, hematological effects, and a decrease in egg production (CHPPM 2002).

7.2.1.3.5 CS and BZ

CS and BZ are incapacitating agents. CS works as a type of tear gas comprised from 2-chlorobenzalmalononitrile and is a solid at room temperature. When immediately released as a tear gas, CS reacts with moisture on the skin and in the eyes, causing a burning sensation and a forceful and uncontrollable shutting of the eyes. Effects usually include tears streaming from the eyes, profuse coughing, exceptional nasal discharge that is full of mucus, burning in the eyes, and restricted breathing. The tear gas reaction is short-lived (approximately 10 minutes) (EPA 2005c). CS has a photochemical degradation reaction half-life of approximately 100 hours in the vapor phase. When released from soil, it has low mobility and does not volatilize. If released to water, it may adsorb to sediment or soil. Hydrolysis is a primary degradation pathway for soil (EPA 2005c). BZ blocks the action of acetylcholine both peripherally and centrally; BZ is a central nervous system depressant and disturbs integrative functions of memory. BZ is considered persistent in soil (US Army 2013).

7.2.1.4 Potentially Exposed Receptors

The identification of the categories of potential receptors most likely affected helps focus the SLERA. As documented in Section 7.2.1.1, there is a variety of wildlife present on the Site in the diverse habitats available. The base of the terrestrial food web consists of terrestrial invertebrates (from earthworms to insects) and primary production from plants. These are consumed by small vertebrates such as passerine birds and small herbivorous mammals. The top of the terrestrial food chain consists of predatory birds and mammals. The base of the aquatic food web consists of benthic invertebrates (worms, some crustaceans, and some insects). These are consumed by fish and amphibians, which are in turn consumed by birds and piscivorous mammals. The SLERA considers the variety of terrestrial and aquatic flora and fauna receptors present. In addition, species with threatened or endangered (T&E) listing statuses are specifically considered.

The United States Fish and Wildlife Service (USFWS) and the North Carolina Natural Heritage Program (NC NHP) are the federal and state agencies, respectively, responsible for monitoring and managing at-risk and protected species. The SLERA relied on information from both of these agencies to identify state and/or federally listed T&E species that may be present on or near the Site. The SLERA also included identification of the preferred habitats for the listed species, a determination of whether these preferred habitats are present on the Site, and consideration of whether the wildlife use of these habitats is likely to result in exposure to ecologically relevant environmental media with known or suspected chemical residues.

The results of the T&E evaluation for the Site, originally drafted in 2008 and updated in 2013, are presented in Appendix M1-3. Information on the preferred habits of the listed species was used during the July 2008 Site reconnaissance to evaluate potential presence of habitat on the Site, with particular consideration of the presence of habitat in the vicinity of known or suspected chemicals' residues in the environment. The results show that habitats are present for some species, but only a limited few species have the potential for exposure to chemicals in relevant environmental media (i.e., surface soil, surface water, and sediment). Specifically, among the three bird species on the T&E species table in Appendix M (Table M1-3), the Appalachian Bewick's wren, the peregrine falcon, and the Southern Appalachian Northern Sawwhet owl will have limited exposures, if any, on-Site, based on available habitat and the manner in which these species use the habitat. These three species will be represented in the ERA by the variety of avian species that are considered. The species evaluated in this ERA will also provide insight into potential exposures and risks for the three listed mammal species (Carolina northern flying squirrel and two bat species). The listed fish and bivalves could occur in Bee Tree Creek but would not occur in the Unnamed Branch due to the limited habitat of the Unnamed Branch. Among the listed plant species, the majority do not have preferred habitats on-Site.

7.2.1.5 Exposure Pathways and Ecological Conceptual Site Model

A potentially complete exposure pathway is one in which chemicals can be traced or expected to travel from the source to a receptor (EPA 1997). Therefore, before a potentially complete exposure pathway can be identified, it must demonstrate the necessary components: a chemical source, a release to the environment and migration in an environmental medium from the source to a receptor, and a receptor that can be affected by the chemical. The components of an exposure pathway have been discussed above. The potentially complete exposure pathways that are evaluated in the SLERA are illustrated in the ecological CSM in Figure 7-2.

7.2.1.6 Identification of Generic Assessment and Measurement Endpoints

Assessment endpoints are the ecological entities (e.g., populations of fish and aquatic invertebrates) and attributes (e.g., community diversity) that are to be protected (EPA 1997, 2003a). The selection of assessment endpoints depends on knowledge about the receiving environment, chemicals released (including ecotoxicological properties and concentrations that cause adverse impacts), and the values that will drive risk management decision-making (Suter et al. 1995).

According to EPA:

> *"An assessment endpoint is defined…as an explicit expression of the environmental value to be protected, operationally defined as an ecological entity and its attributes." (EPA 2003a, p. 1)*

The assessment endpoints considered for this Site are adverse effects to the structure and function of terrestrial and aquatic populations and communities. Because direct measurement of assessment endpoints is often difficult or impossible, measurement endpoints are used to provide the information necessary to evaluate whether the values associated with the assessment endpoint are being protected. A measurement endpoint is a measurable ecological characteristic and/or response to a stressor (Eco-EPA 1998, 2003a). Measurement endpoints, such as mortality, reproductive effects, and reduced growth are not directly measured in the SLERA. Rather, they are indirectly evaluated in the SLERA through the use of HQs. An HQ is the ratio of a chemical concentration to a conservative ESV relevant for the receptors being evaluated.

Surrogate receptors also must be identified for calculating SLERA exposure and risk estimates. The species used in these calculations are generally selected based on consideration of presence at the Site, as well as known or suspected sensitivity and exposure to the COPCs (EPA 1997).

The SLERA assessment endpoints and risk questions for the Site are identified as follows:

Ecological Receptor	Assessment Endpoint	Risk Questions
Terrestrial plant and invertebrate communities	Survival, Growth, and Reproduction of Terrestrial Plant and Invertebrate Communities	Are the maximum concentrations of constituents in soils greater than the soil screening benchmarks developed to screen for the survival, growth, or reproduction of terrestrial plants and soil invertebrate communities?
Aquatic community	Survival, Growth, and Reproduction of the Aquatic Community (including aquatic plants, aquatic invertebrates, amphibians/reptiles, and fish communities)	Are the maximum concentrations of constituents in surface water and sediments greater than the screening benchmarks developed for the protection of aquatic communities?
Mammal and bird populations	Survival, Growth, and Reproduction of Terrestrial and Aquatic-Dependent Bird and Mammal Populations	Are the maximum concentrations of constituents in environmental media at the Site greater than the benchmarks developed to screen for the survival, growth, or reproduction of terrestrial and aquatic-dependent birds and mammals? Which constituents are bioaccumulative compounds that could lead to exposures of terrestrial or aquatic-dependent wildlife through the food web that will require further evaluation in the BERA?

7.2.2 Step 1: Screening-Level Effects Evaluation

The screening-level ecological effects evaluation involves the identification of appropriate ESVs. ESVs are based on contaminant concentrations associated with a low probability of unacceptable risks to ecological receptors (EPA 2001a). Since these concentrations are based on conservative endpoints and sensitive ecological effects data, they represent a preliminary screening of Site contaminant concentrations to determine if there is a need to conduct further investigations at the Site. Preliminary COPECs with concentrations that exceed an ESV or COPECs lacking ESVs are further evaluated in Step 3a of the BERA. ESVs used in the SLERA are identified on Tables 7-1A, 7-1B, 7-1C, and 7-1D for surface soil, surface water, groundwater, and sediment, respectively. These are the same ESVs that were used in the SLERA presented in the Phase I Technical Memorandum. The bases for the ESVs are provided in Appendix M2, as follows:

- Appendix M2, Table M2-1a provides the basis of soil ESVs
- Appendix M2, Table M2-1b provides the basis of surface water (and groundwater) ESVs
- Appendix M2, Table M2-1c provides the basis of sediment ESVs.

The remainder of this section discusses the ESV hierarchy for each medium.

7.2.2.1 Soil Ecological Screening Values

Soil ESVs are intended to ensure protection of terrestrial organisms, including plants and soil invertebrates. Soil ESVs for the SLERA are based on the following hierarchy:

- EPA Ecological Soil Screening Levels (SSLs) (2007): The SSLs are the preferred soil screening values, because they are based on a variety of studies that consider effects at multiple levels of the food web.

- EPA Region 4 (2001b): This source of criteria is an EPA compilation of criteria from many sources, similar to EPA Region 5 (below). The Site is located in EPA Region 4; as such, Region 4 criteria will be considered before ESVs from Region 5
- EPA Region 5 (2003b): Like the Region 4 ESVs, this source of criteria is an EPA compilation of criteria from many sources. Region 5 often has criteria where other sources are lacking.

7.2.2.2 Surface Water Ecological Screening Values

Surface water ESVs used in the SLERA are freshwater chronic values (when available), because these values are intended to be protective of long-term exposures and are generally more conservative than acute values. National Recommended Water Quality Criteria (NRWQC) (EPA 2006) and similar criteria are intended to protect multiple species in a conservative fashion. The Redbook standards for aquatic life are intended to prevent chronic toxicity (DENR 2007). EPA Region 4 (2001b) and EPA Region 5 (2003b) use a combination of criteria from a variety of sources, including the NRWQC. The primary source for surface water ESVs is:

- EPA NRWQC (2006): These criteria reflect federal water quality guidelines that are enforceable under the Clean Water Act. The methodology for criteria development is typically robust with a minimum of eight genera and 15 species in each data set used to derive criteria.

The second tier ESVs are the lower of:

- DENR Surface Water Quality Standards (the Redbook) (2007): These criteria are enforceable under the NCAC and reflect the state's mandate for water quality.
- EPA Region 4 ESVs (2001b): This source of criteria is an EPA compilation of criteria from many sources, similar to EPA Region 5 (below). The Site is located in EPA Region 4; as such, Region 4 values are considered before considering ESVs from Region 5.

If a criterion is not available from any of the above three sources, Region 5 criteria is used:

- EPA Region 5 Ecological Screening Levels (EPA 2003b): Like the Region 4 ESVs, this source of criteria is an EPA compilation of criteria from many sources. Region 5 often has criteria where other sources are lacking.

7.2.2.3 Sediment Ecological Screening Values

Sediment ESVs are intended to ensure protection of the organisms that live and feed in direct contact with sediment (i.e., sediment benthos). Freshwater sediment ESVs for the SLERA are identified using the following hierarchy:

- EPA Region 4 (2001b): This source of criteria is an EPA compilation of criteria from many sources, similar to EPA Region 5 (below). The Site is located in EPA Region 4; as such, the Region 4 criteria will be considered before ESVs from Region 5.
- EPA Region 5 (2003b): Like the Region 4 ESVs, this source of criteria is an EPA compilation of criteria from many sources. Region 5 often has criteria where other sources are lacking.

7.2.2.4 Additional Considerations

On a case-by-case basis, secondary sources of criteria were considered when primary sources did not yield ESVs. Examples include:

- Screening values for explosives (e.g., Kuperman et al. 2006, Stevens et al. 2002, Sunhara et al. 2009, USACE 2013, Talmage et al. 1999)
- Tier 2 Secondary Chronic Values for surface water (Suter and Tsao 1996)
- British Columbia Ministry of Environment, Lands, and Parks criteria for freshwater water quality (Nagpal et al. 2006)
- EPA's ECOTOX database (EPA 2009)
- Oak Ridge National Laboratory's (ORNL's) Risk Assessment Information System database (ORNL 2012)
- ATSDR's toxicological profiles database (ATSDR 2009)
- MacDonald et al. 2000, Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems
- NOAA's Screening Quick Reference Tables (SQuiRT) (2008)

7.2.3 **Step 2: Screening-Level Exposure Estimates**

The SLERA presented in the Phase I Technical Memorandum provided estimates of exposure using the maximum concentration from each of the Site exposure units. In addition, the 2010 SLERA evaluated exposures on a location-by-location basis to facilitate the scoping of additional RI field investigation to support the ERA. For the purposes of the updated SLERA, which is to identify COPECs for evaluation in Step 3a, the SLERA exposure estimates for a particular environmental medium are now the Site-wide maximum detected concentrations for that medium. These SLERA exposure estimates are shown in Tables 7-1A, 7-1B, 7-1C, and 7-1D for surface soil, surface water, groundwater, and sediment, respectively.

Summary statistics for each medium considered in the SLERA is provided in Appendix M3, as follows: surface soil (Table M3-1A), surface water (Table M3-1B), groundwater (Table M3-1C), and sediment (Table M3-1D). GIS coordinates for all data associated with the SLERA are provided in Appendix M3 (Table M3-2). A subset of figures of exposure concentrations is provided in Appendix M4 in comparison to SLERA screening levels for each medium, as follows:

- Aldrin was detected in soil, surface water, groundwater, and sediment as indicated on Figure M4-1. The majority of concentrations were low, with the exception of high detections at a location adjacent to the AP (APDA789B1). The elevated concentration of aldrin at APDA789B1 was observed in the Phase I RI efforts, and so additional sampling in the vicinity of this location was done as part of Phase II RI efforts. Therefore, there is delineation data to show that this elevated location is very isolated, and aldrin has not been transported to the adjacent tributaries of Gregg Branch. Aldrin was detected at eight locations in the Unnamed Branch sediments and at two locations in surface water in the Unnamed Branch (UBW4-137 and UBW3A-J38). The potential for cumulative toxicity to aquatic organisms in the Unnamed Branch from multiple chemicals in the Unnamed Branch is evaluated further in the BERA. Aldrin was not detected in Bee Tree Creek.

- BZ was detected at two sediment locations, one in the Unnamed Branch and the other in a tributary to Gregg Branch. BZ detections (0.28 to 0.34 mg/kg) only slightly exceed the detection limits of 0.17 mg/kg. (Figure M4-2). In addition, there was no known use of BZ in the Back Valley, and the location in the tributary to Gregg Branch is upgradient from areas of previous Site-related activities. Based on the low detections relative to detection limits and the location on the Site, the Back Valley detection is considered suspect.
- CS was detected in the Back Valley in two soil samples and in the Front Valley in two soil and one sediment location (Figure M4-3). One of the Back Valley locations (BPS1) where CS was detected was sampled over a small spatial area grid and no other detections were seen. In general, each of these detections was low, relatively isolated, and did not show any patterns of transport.
- HMX results showing the most current data differ slightly from the HMX patterns using all data, so the most current data are shown on Figure M4-4A, and all results over time are shown on Figure M4-4B. The most current data show that HMX was detected at one soil location and two sediment locations in the Back Valley. The soil location in the vicinity of the detection (DA1S3) was extensively investigated, and HMX was not detected in any other soil sample from this area. HMX was detected at low concentrations at two sediment locations in Gregg Branch. HMX was detected at a number of soil and surface water locations in the Front Valley. It was also detected at one groundwater location (MW182-K39AB) in the AB zone of the surficial aquifer. When all results are considered over time, the only difference appears to be that HMX was detected once in groundwater in the Back Valley at a well screened in Zone B (MW166-028B). HMX was not detected in Bee Tree Creek at any point over time. Overall, detections in all media were at or below the screening-level criteria.
- Perchlorate detections for the most current data set and all results are provided on Figures M4-5A and M4-5B, respectively. The figures show a variety of detections in soil, surface water, groundwater, and sediment in the Front Valley and Back Valley. The only difference between the maps appears to be a detection in MW193-Q40CD in the Front Valley (i.e., it was not detected in the most current sampling effort but had previously been detected at this location at some point in the past). Overall, detections in all media were at or below the screening-level criteria.
- Picric acid was only detected at a single soil location when the most current sampling results were considered (B105/139-B5) (Figure M4-6A). The current data do not show any detections in surface water, groundwater, or sediment. Over time (as shown in Figure M4-6B), picric acid was detected in surface water at a single location in the Unnamed Branch (UBW5-I37).
- RDX results are shown for the current data and all results in Figures M4-7A and M4-7B, respectively. The only apparent difference over time is that RDX had been detected in groundwater in the past but the most current groundwater sampling did not show detected RDX (wells MW192-P41CD and MW155-P43C). RDX was detected at a number in soil, sediment, and groundwater in both the Front Valley and Back Valley. With limited exception, the detections were at or below the screening-level benchmarks for each medium. Only a single soil sample had a detected result that was within a range of 5 times the screening-level criterion, and

this sample was in an area of the Back Valley that was well characterized, showing only a single detection (DA1S3). This is the same location where HMX was detected.

- Tetryl was only infrequently detected in soil when current data were considered (Figure M4-8A). Previous sampling showed tetryl was detected in groundwater at two locations in the Front Valley (MW158-N44A and MW156-P44A). Tetryl was not detected in surface water or sediment. Detections in soil and groundwater were at or below screening-level criteria.
- TNB was only detected in four isolated locations in the Front Valley at concentrations below soil screening-level criteria (Figure M4-9). TNB was not detected in surface water, groundwater, or sediment.
- Trinitrotoluene (TNT) was detected in isolated locations in the Front Valley at four locations and Back Valley at two locations at concentrations below soil screening-level criteria (Figure M4-10). TNT was not detected in surface water, groundwater, or sediment.
- 2-Amino-4,6-DNT was detected at only three soil locations in the Front Valley at low concentrations (i.e., at or below the screening-level criterion). This compound was not detected in surface water, groundwater, or sediment (Figure M4-11).
- PAHs were detected at numerous locations around the Front and Back Valleys (Figure M4-12). The majority of locations had detected concentrations at or below the screening-level criteria for PAHs. There was a cluster of elevated PAH soil concentrations at location B105-139. Field personnel stated that locations B105-108 B7 and B8 were drilled through asphalt. This indicates two important things regarding exposure: (1) drilling through asphalt is the likely source of PAHs in the surface soil samples, and (2) wildlife are not exposed to PAHs under asphalt. The results at BTW1-P45 show elevated concentrations of PAHs in Bee Tree Creek sediments, but these concentrations do not appear to be related to the Site. First, there are no detections of PAHs in surface water, groundwater, or sediment anywhere in or near the Unnamed Branch. Therefore, the Unnamed Branch is not a vector for PAH transport from the Site. In addition, the PAH mixture in Bee Tree Creek is dominated by two PAHs, 1-methylnaphthalene (34 mg/kg) and 2-methylnaphthalene (65 mg/kg), comprising approximately 85 percent of the total PAHs observed at this location. The only location with 1-methylnaphthalene or 2-methylnaphthalene exceeding 1 mg/kg is area B109, where locations B109SS1A and B109BS1A had concentrations ranging from 31 mg/kg to 69 mg/kg. Area B109 is in the northwest portion of the Front Valley and is a location where a former UST removal occurred. There is no pattern of PAH detection between area B109 and location BTW 1-P45 that would suggest PAHs from B109 are the source of PAHs to Bee Tree Creek. In fact, area B109 is approximately 4,000 ft away from BTW1-P45 via the Unnamed Branch and neither 1-methylnaphthalene nor 2-methylnaphthalene were detected in the Unnamed Branch. Location B105139B8S1 had elevated total PAHs, at a maximum of 294 mg/kg, but 1-methylnapthalene and 2-methylnaphthalene were not detected at this location with detection limits less than a value of 0.5 mg/kg. Aside from area B109, the next highest value of 1-methylnaphthalene from any location on-Site was 0.31 mg/kg (soil location B119120B1). Therefore, the Site could not possibly be the source of these PAHs to Bee Tree Creek.
- Copper is the last figure illustrated (Figure M4-13). Copper is a naturally occurring inorganic but it was detected at a single soil location at an elevated concentration and therefore it is

illustrated for all locations. The elevated soil location where copper was detected is B124-135S3 in the Back Valley.

7.2.4 Step 2: Screening-Level Risk Characterization

The SLERA risk characterization integrates the exposure assessment and the effects assessment. Specifically, HQs are calculated as the ratio of the Site-wide maximum concentrations to the ESVs. HQs that do not exceed the threshold value of 1 are considered to show that chemical concentrations at the Site do not pose an unacceptable risk. Tables 7-1A, 7-1B, 7-1C, and 7-1D show the HQs calculated using the 2012 Site-wide maximum concentrations for surface soil, surface water, groundwater, and sediment, respectively. As a point of reference, the tables also show the HQs calculated using the Site-wide maximum concentrations that were available during preparation of the Phase I Technical Memorandum. These tables also identify the preliminary COPECs that are retained for further consideration in the BERA based on the following reasons:

- HQs are greater than or equal to the threshold value of 1
- Chemicals were detected but are lacking ESVs

Table 7-1E provides a summary of the preliminary COPECs identified in each medium. In addition, Table 7-1E identifies those preliminary COPECs that are potentially bioaccumulative according to EPA (2000, Eco-2007d, and 2012b). The bioaccumulative lists from each of these sources are provided in Tables M2-2A, M2-2B, and M2-2C, respectively.

7.2.5 SLERA Uncertainties Evaluation

A SLERA is designed to provide conservative estimates of the potential risks that may exist for receptors, and therefore, incorporates uncertainty in a precautionary manner. Uncertainty in an SLERA is "*the imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution*" (EPA 1997). Uncertainties that may lead to either an overestimation or an underestimation of risk are associated with each stage of risk assessment. The most significant uncertainties in this SLERA are the use of maximum detected concentrations and the use of generic screening benchmarks. Using the maximum detected concentrations is an extremely conservative method that overestimates potential exposures (and therefore also overestimates potential risk). With respect to the use of generic ESVs, the main sources of uncertainty arise from using ecological effects that may not be relevant to the Site and ignoring bioavailability of the chemicals:

- The generic nature of ESVs and use of ESVs that are often the lowest available: ESVs are typically selected from the low end of benchmarks from multiple valid sources that may range over an order of magnitude. Although the benchmarks were derived using valid, scientifically sound methods, many of them are for a wide range of organisms and conditions that are not relevant to the Site. Using such generic benchmarks as ESVs are likely to give HQs (i.e., estimates of risk) that are biased high.
- Ignoring bioavailability: Several Site-specific factors, including bioavailability, can affect the relationship between exposures and effects on wildlife receptors. Lack of consideration of bioavailability results in a bias toward higher risk, as the SLERA assumes all chemicals are fully bioavailable.

7.2.6 SLERA Scientific Management Decision Point

The SLERA SMDP represents a critical step in the ERA process where decision-making occurs. Based on the conservative comparison of Site-wide maximum concentrations to protective ESVs, there is adequate information to conclude that ecological risks to biologically significant populations of wildlife receptors are negligible for many of the chemicals detected in surface soil, surface water, groundwater, and sediment. However, the information is not adequate to make a decision, or the information indicates a potential for adverse ecological effects that must be analyzed further, because HQs exceeded the threshold value of 1. Furthermore, some preliminary COPECs lack ESVs. Table 7-1E shows the list of COPECs that are retained for further evaluation in Step 3a of the BERA.

7.3 Step 3a of the Baseline Ecological Risk Assessment

This section provides the initial step of the BERA (Step 3a), the BERA problem formulation. COPECs identified in the SLERA are evaluated further in the Step 3a BERA problem formulation using refined estimates of exposure and effects. The refinements provide a more realistic understanding of exposures and potential ecological risks to help inform further assessment or management decisions. The refinement of the COPECs identified in the SLERA is necessary to help focus further risk assessment. The outcome of this refined screening is that chemicals either are retained as COPECs or excluded from further evaluation in the BERA process. The remainder of this section is organized as follows:

- Section 7.3.1 summarizes the assessment endpoints considered in Step 3a
- Section 7.3.2 identifies the measurement endpoints used to refine COPECs
- Section 7.3.3 describes the refinement of COPECs for direct contact pathways
- Section 7.3.4 describes the evaluation of food web pathways
- Section 7.2.5 discusses uncertainties in the BERA (Step 3a) evaluation

7.3.1 Assessment Endpoints Considered in Step 3a of the BERA

The assessment endpoints and risk questions for Step 3a of the BERA are the same as those identified in the SLERA (Section 7.2.1.6). It is noted that survival, growth, and reproduction are individual organism attributes, and understanding potential risks to individual organisms can lead to the understanding of potential risks to populations and communities. Therefore, potential individual impacts are also considered.

7.3.2 Measurement Endpoints Used to Refine COPECs

The refinement of COPECs in Step 3a is based on the quantitative measurement endpoints described below, which are intended to answer the risk questions identified in Section 7.2.1.6.

For the terrestrial plant and invertebrate community:

- Measured concentrations of COPECs in surface soil are compared to benchmarks and concentrations reported in the literature to be protective of plants and invertebrates (“direct contact pathways”).

- A soil equilibrium partition (EqP) approach is used to evaluate organic COPECs and the potential effects of chemical mixtures on soil dwelling invertebrates.
- A consideration of the basis of the benchmark is discussed, along with some discussion of spatial scale of areas of interest and the density of vegetation where elevated HQs are seen.

For the aquatic community:

- Measured concentrations of COPECs in surface water, groundwater, and sediment in relation to benchmarks and concentrations are reported in the literature to be protective of invertebrates ("direct contact pathways").
- Surface water EqP approaches based on the target lipid model and the EPA narcosis model are used to evaluate organic COPECs and the potential effects of chemical mixtures on aquatic organisms.
- A sediment EqP approach is used to evaluate the potential narcotic effects from chemical mixtures.
- A consideration of habitat conditions and the presence of sensitive species is discussed where elevated HQs are seen.

For mammal and bird populations:

- Mammals and birds are evaluated via the comparison of modeled dietary intake of COPECs to doses reported in the literature as toxicity reference values (TRV) thresholds for adverse effects on survival or reproduction ("food web pathways").
- Mammal and bird populations are addressed through a range of surrogate receptor species that were identified in the ERA Work Plan and are discussed further in Section 7.3.4.
- A consideration of habitat conditions and the spatial scale of areas with elevated HQs is discussed.

7.3.3 **Refinement of COPECs for Direct Contact Pathways**

The refinement of COPECs for direct contact pathways is discussed in terms of the following assessment endpoints:

- Survival, Growth, and Reproduction of Terrestrial Plant and Invertebrate Communities
- Survival, Growth, and Reproduction of the Aquatic Community (including aquatic plants, aquatic invertebrates, amphibians/reptiles, and fish communities)

For these communities, refinement was considered concurrently in multiple ways. For metals in soil, background concentrations were considered in the calculation of refined HQs. For aluminum, the pH of soils was also considered. Refined ecological benchmarks relevant for these receptor groups were also used for inorganic constituents instead of the generic screening values used in the SLERA for inorganic constituents. Finally, EqP approaches were considered to evaluate the potential for cumulative toxicity due to chemical mixtures of organic constituents. Background levels for metals in soil were presented in Table 2-8B of the Phase II Technical Memorandum (Altamont 2011). The results of a background evaluation for groundwater were provided in Appendix E of the Work Plan, Volume 1. These results showed that the only metal in groundwater that is not considered attributable to background is manganese. Therefore, in the refinement of COPECs for groundwater, manganese was the only metal considered further.

Any chemical in soil or groundwater with a maximum detected concentration exceeding the soil background levels and having a refined benchmark was retained for evaluation on a location-by-location basis. This discussion below describes the exposure assessment and the refined risk characterizations for each assessment endpoint. Supporting information for the terrestrial plant and invertebrate community is provided in Appendix M5 and supporting information for the aquatic community is provided in Appendix M6.

Note that there are no definitive background values available for surface water or sediment; therefore, these media were not screened against background values. However, qualitative comparisons were made to the furthest upgradient location for Bee Tree Creek. Also, sediment concentrations were qualitatively compared to soil background as context for the understanding of potential risks related to sediment. These comparisons are provided in Section 7.3.3.2.

7.3.3.1 Refined Effects Assessment for Direct Contact Pathways

7.3.3.1.1 Terrestrial Plant and Invertebrate Community Diversity, Structure, and Function

Refined ecological benchmarks for the evaluation of the plant and invertebrate community are provided in Table M5-1. Efforts were made to identify ecological benchmarks specific to plants and invertebrates.

7.3.3.1.2 Aquatic Community Diversity, Structure, and Function

Refined ecological benchmarks for the evaluation of the aquatic community are provided in Appendix M6, as follows:

- Table M6-1: Refinement of COPECs: Effects-Based Surface Water Criteria for Aquatic Wildlife
- Table M6-2: Refinement of COPECs: BERA Sediment Criteria for Aquatic Wildlife

7.3.3.1.3 Refined BERA Surface Water and Sediment Criteria for Inorganics for Aquatic Wildlife

Effects-based benchmarks for inorganics were used in the BERA for a more realistic screening that focused on the aquatic community. The Risk Assessment Information System (ORNL 2012) collates benchmarks from a variety of sources. Benchmarks considered include values that reflect a measured adverse effect to the aquatic organisms, such as an EC20 (i.e., 20 percent of the organisms tested showed a response) or an EC25 (i.e., 25 percent showed a response). Lowest chronic values (LCVs) were also considered. The effects-based benchmarks for aquatic wildlife include the following:

- EC20 Daphnids
- EC20 Fish
- EC20 Sensitive Species
- EC25 Bass Population
- LCV Aquatic Plants
- LCV Daphnids

- LCV Fish
- LCV Non-Daphnid Inverts

Tables M6-1 and M6-2 provide the refined inorganic benchmarks, based on a compilation of effects based on benchmarks; compare the refined benchmarks to ESVs used in the SLERA; and identify the final selected benchmark used in the BERA. The selection of the refined benchmarks involved multiple considerations. The median benchmark for each COPEC was identified, as the median value reflects an unbiased central tendency estimate. The median values were then examined to evaluate: (1) the basis of the median benchmark; (2) the medium in which the chemical was detected (e.g., surface water or groundwater); and (3) the receptors most likely at risk (e.g., if a groundwater COPEC, more consideration was given to receptors likely to be present in the groundwater-surface water interface than to the fish in the water column). For example, aluminum was detected in both surface water and groundwater. The median value for aluminum is appropriate because it reflects a central tendency value reflective of daphnids, plants, and fish.

7.3.3.1.4 Refined BERA Surface Water and Sediment Criteria for Aquatic Wildlife

The bioavailability of chemicals in sediment may strongly influence the toxicity of some organic compounds. Several Site-specific factors particularly total organic carbon (TOC), can affect the relationship between exposures and effects on benthic invertebrates. EPA guidance indicates that expressing benchmarks in terms of the EqP for organic chemicals on a carbon-normalized basis (i.e., µg chemical per gram organic carbon) allows them to correlate measured effects on benthic invertebrates with the carbon-normalized concentrations (EPA 2003b, EPA 2003c, EPA 2008a).

EPA's 2008 guidance on *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms* details how to calculate Site-specific benchmarks for many chemicals and includes specific calculations for several pesticides present at the Site. According to the EPA (2008a), sediment benchmarks generated using the EqP approach are suitable for use in providing technical information to regulatory agencies because they are:

- Numeric values
- Chemical specific
- Applicable to most sediments
- Predictive of biological effects
- Protective of benthic organisms

EPA also states that "EqP theory holds that a nonionic chemical in sediment partitions between sediment organic carbon, interstitial (pore) water, and benthic organisms. At equilibrium, if the concentration in any one phase is known, then the concentrations in the others can be predicted. The ratio of the concentration in water to the concentration in organic carbon is termed the organic carbon-water partition coefficient (K_{oc}), which is a constant for each chemical" (EPA 2003b, EPA 2003c, EPA 2008a).

Surface water and sediment EqP criteria can be derived using both the target lipid model (TLM, McGrath and DiToro 2009) and the EPA narcosis approach (EPA 2003b, 2003c, 2008a). Table M6-4A provides the calculation of water quality benchmarks using the TLM approach and identifies those narcosis values directly from EPA guidance. The derivation of protective surface water quality benchmark (WQB) using the TLM EqP approach from McGrath and DiToro is:

$$\boldsymbol{log(C*w, 5\%\ chronic\ criterion) = m\ log(Kow) + log\left(C*\frac{L(5\%)}{ACR}\right) + \Delta c - Log(2)}$$

*C*w,5%,chronic* = *WQB protective of 95 percent of species in (in mmoles/L)*
m = *-0.936 (McGrath and Di Toro, 2009)*
Kow = *Octanol-water partition coefficient (L/kg)*
*C*L(5%)* = *28.94 (EPA 2013)*
ACR = *Acute to chronic ratio (unitless)*
ACR = *5.09 for PAHs and monoaromatic hydrocarbons and all except halogenated organic compounds*
ACR = *10.51 for halogenated organic compounds (arithmetic mean of ACRs in Table 3 in McGrath and Di Toro [2009])*
Δ c = *Log of compound class correction factor (McGrath and Di Toro, 2009)*
Δ c = *-0.352 for PAH*
Δ c = *-0.109 for monoaromatic hydrocarbons*
Δ c = *-0.339 for halogenated compounds*
log(2) = *Factor of 2 to account for the variability in predicted versus observed LC50 in Figure 2-2 of EPA (2008)*

Sediment EqP criteria are identified on Table M6-5. The sediment criteria using the EqP approach calculated are in units of micrograms of pesticide per gram of organic carbon in the sediment (μg/G_{oc}).

$$\text{Sediment Criterion } {}^{\mu g}/_{G_{oc}} = K_{oc} \text{ x WQC } {}^{\mu g}/_{L} \text{ x } 0.001$$

These values in μg/G_{oc} must be multiplied by the concentration of organic carbon in the sediment to arrive at a criterion in μg/kg sediment.

$$\text{Sediment Criterion } {}^{\mu g}/_{\text{KG sediment}} = \text{Criterion } {}^{\mu g}/_{G_{oc}} \times {}^{\text{G Organic Carbon}}/_{\text{KG Sediment}}$$

The surface water criteria used in the BERA are the same as for screening surface water, as described above for the TLM (Table M6-4A). The K_{oc} values are from standard sources. The average TOC in Site sediments is quite low (0.35 percent), and so the criteria are calculated using this value.

Some chemicals such as pesticides may also pose toxicity that is unrelated to narcosis. These compounds are other than nonpolar organics and have excess toxicity above the baseline toxicity predicted by the TLM (McGrath and Di Toro 2009). These compounds can be screened with conventional sediment screening values, which means sediment screening values estimated from equilibrium partitioning from NRWQC or DENR water quality criteria. This type of screening is conducted for pesticides in sediment.

At the direction of the EPA, the evaluation of potential risks for aquatic wildlife also includes consideration of potential toxicity to amphibians through the consideration of toxicity values from Tietge et al. 2005 and Goleman et al. 2002. To balance some of the uncertainties, data from Nieuwkoop and Faber 1994 are also considered. For example, Tietge et al. (2005) indicates metamorphous can be halted by perchlorate concentrations over 0.125 mg/L and Goleman et al. (2002) indicate forelimb emergence is delayed at 0.005 mg/L (as a lowest observable effect concentration [LOEC]) and tail reabsorption is delayed at 0.018 mg/L (also a LOEC). However, within the Goleman study, fewer than 60 percent of the organisms in the control treatment in the study reached the appropriate metamorphic stage at 70 days post-fertilization when compared to the normal table of frog development (Nieuwkoop and Faber 1994). This suggests that the conditions of the study were insufficient to promote normal growth. As such, it is difficult to determine the role of perchlorate in the delay of metamorphosis as development was hindered significantly by the control conditions. Therefore, the Site data are not compared to effects levels derived from the Goleman studies, given the noted uncertainties.

Ammonia was also considered in this assessment using a NRWQC value of 1.9 mg/L. Both surface water and groundwater were compared to this criterion.

Step 3a BERA Screening (Refinement of COPECs) and Location-Specific Risk Characterization for Direct Contact Pathways

The Step 3a BERA screening for direct contact pathways provides the evaluation for the terrestrial plant and invertebrate community and the evaluation of the aquatic wildlife community. The Step 3a BERA screening for each of these evaluations was performed in two parts for each of the preliminary COPECs identified for each medium in Table 7-1E, as follows for inorganics:

First, maximum concentrations are considered for inorganics in surface soil, surface water, and sediment:

(1)
$$\text{Hazard Quotient} = \frac{\text{Maximum Site Concentration}}{\text{Refined Ecological Benchmark}}$$

For those chemicals with HQs based on maximum concentrations exceeding the threshold value of 1, location-specific HQs are calculated.

(2)
$$\text{Hazard Quotient} = \frac{\text{Location - Specific Concentration}}{\text{Refined Ecological Benchmark}}$$

For inorganics, the HQs are calculated as the total HQ minus the contribution of HQ from background. Background values for each medium are shown in the BERA screening tables discussed later in this section.

(3)
$$\text{Hazard Quotients} = \text{HQ Total - HQ Background}$$

As mentioned previously, refined HQs less than or equal to the threshold value of 1 indicate that the chemicals do not pose an unacceptable risk. HQs that exceed the threshold value of 1 indicate a potentially unacceptable risk, although closer consideration may be warranted to understand whether this is the case (e.g., the magnitude of the HQ and the spatial distribution of elevated HQs), including the basis of the ecological benchmark and other considerations, such as qualitative observations in areas where samples were collected.

For organic chemicals, the HQ screening is not conducted. Rather, chemical mixtures are evaluated in terms of toxic units (TUs), where TUs less than or equal to the threshold value of 1 indicate that the chemicals do not pose an unacceptable risk. TUs are similar to HQs except that TUs reflect the sum of potential impact from chemical mixtures that can exert cumulative toxicity from a similar mode of action (McGrath and DiToro 2009, EPA 2003c, 2008a).

$$\text{Location-Specific Toxic Unit} = \sum \frac{\text{Location-Specific Concentration}}{\text{TLM Derived WQB}} \tag{4}$$

7.3.3.1.5 Risk Characterization for Terrestrial Plant and Invertebrate Communities

Table 7-2 provides the Step 3a BERA screening of Site-wide surface soil maximum concentrations (in excess of background levels) against the refined ecological benchmarks for plants and invertebrates (when available) and identifies the inorganic and nitroaromatic COPECs that required further evaluation based on HQs exceeding a value of 1. This table shows that 11 COPECs were retained for location-specific risk characterization of inorganics and identifies those organic chemicals.

The location-specific HQs for plants and invertebrates are provided in Appendix M5, on Table M5-2A for plants and on Table M5-2B for invertebrates. Table 7-3A provides a summary of plant hazard quotients greater than or equal to the threshold value of 1, sorted from highest to lowest.

Plants

Table 7-3A summarizes HQs greater than or equal to 1 and indicates that HQs range up to a value of 100, but the vast majority of HQs are less than 10[11]. Five locations have hazard quotients greater than or equal to a value of 10 for plants. These are related to isolated elevated concentrations of copper in area B124135, RDX in Debris Area 1, cobalt in B148, manganese in B135, and mercury at the Dump. Seven additional hazard quotients for plants were seen at a magnitude of 5 to 8. Two of these were at the Dump (strontium and manganese), two of these were at APDA789 (both were boron detections), others were at B113, TRA2, and B152 (zinc, manganese, selenium). Finally, another approximately 35 detected constituents had hazard quotients for plants ranging from 2 to 4. These were primarily for manganese and boron, with greater than 20 detections in this range of hazard quotients. Other chemicals included copper, cobalt, thallium, zinc, antimony, strontium, and thallium. The hazard quotients, in the range of 2 to the highest at 100 for copper at B124153, indicate that some very isolated areas of impact to plants cannot be definitively ruled out. However, observations at the Site indicate that the Site as a whole is densely vegetated, with exceptions in areas for roadways and the footprints of former buildings.

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[11] Note that these HQs exclude the contribution from background, and the background HQ values can be seen on Table 2 for plants and invertebrates. Note that both maximum HQs are shown, and the HQ minus background is shown. Where the HQs are the same (e.g., copper), this indicates that the contribution from background cannot be seen when using one significant figure for HQs.

The plant community as a whole is diverse and includes a variety of species that one would expect in this geographic region. The results of this evaluation indicate that if there are any impacts to individual plants, these do not affect the plant community and do not prevent the plant community from providing vital forage and habitat to wildlife species.

Soil Invertebrates

Table 7-3B provides a summary of invertebrate hazard quotients greater than or equal to the threshold value of 1, sorted from highest to lowest (excluding the organic chemicals evaluated using the soil EqP approach). In addition, the Soil EqP Evaluation is provided in Table 7-3C, and an additional six tables in Appendix M provide the technical basis of the summary table in Section 7 (Tables M5-3A, M5-3B, and M5-3C and Tables M5-4A, M5-4B, and M5-4C provide a summary of soil EqP results comparing a range of TOC using 1 percent, 3 percent, and 5 percent TOC estimates). The risk characterization results for soil invertebrates is summarized as follows:

The HQ results on Table 7-3B indicate that three locations have hazard quotients greater than a value of 10 for soil invertebrates (excluding organic constituents, which are discussed separately as part of the soil invertebrate EqP approach). These are related to the same isolated elevated concentrations of copper in area B124135 9 (hazard quotient of 80), RDX in Debris Area 1 (hazard quotient of 50), and mercury at the Dump (hazard quotient of 40), as was discussed for plants. There are four additional hazard quotients ranging from 6 to 8, one at the Dump (strontium), two at area B113 (zinc), and one at B134 (manganese). Approximately 20 additional hazard quotients range from 2 to 4, primarily for zinc, manganese, boron, and mercury. The possibility of potential isolated adverse impacts to soil invertebrates cannot be definitively ruled out by hazard quotients alone. It is possible that there are some isolated areas where some adverse impacts could occur for some individual soil dwelling invertebrates, particularly related to the single copper (Figure M4-13), RDX (Figure M4-7A and M4-7B), and mercury detections. However, the remainder of the hazard quotients shown in Table 7-3B are low, and none of these hazard quotients reflect a widespread area of adverse effects to the soil dwelling organisms.

The soil EqP approach for invertebrates is summarized on Table 7-3D for 1 percent, 3 percent, and 5 percent TOC. The actual TOC for the site is not known, but it is very likely between 1 percent and 5 percent. An inverse relationship exists for TUs such that with decreasing TOC increasing TUs are seen, both in the number of TUs exceeding the threshold value of 1 and in the magnitude of TUs. At 5 percent TOC, the majority of TUs for soil locations is less than the threshold value of 1 (Tables M5-3A, M5-3B, and M5-3C and Tables M5-4A, M5-4B, and M5-4C). However, as can be seen in Table 7-3D, 12 locations have TUs that exceed the threshold value of 1. The majority of these are related to PAHs detected in soil. The highest TUs are seen at locations B109137BS1A and B109137SS1A, where TUs are influenced by both PAHs and VOCs. The highest TU estimated with consideration of soil TOC at 5 percent was a TU value of 22 (B109137SS1A). The total PAHs at this location (B109137SS1A) was 140 mg/kg. This was not the location with the highest PAHs detected on the Site, because that was location B105139B8S1, where the total PAH concentration was 294 mg/kg. However, as seen in Table 7-3D, the maximum TU at location B105139B8S1 was approximately 10. The reason for these differences in TUs is due to the PAH composition, which differed between locations B109 and B105. The PAHs at B109 were dominated by methylnaphthalenes, while the PAHs at location B105 were more evenly divided among a variety of PAHs (Table M5-3A and M5-4A show the detailed organic chemical composition for each location). The following presents a summary of the differences between using the range of organic carbon estimates:

- Thirteen locations had TUs that exceeded the threshold value of 1 using the 5-percent soil organic carbon assumption. As noted using the two approaches, the target lipid model approach shows higher TUs than the EPA narcosis approach. This is partly due to the fact that the target lipid model approach can evaluate more compounds than the EPA narcosis approach.
- Sixteen locations had TUs that exceeded the threshold value of 1 using the 3-percent soil organic carbon assumption. Using a 3-percent organic carbon soil estimate identified three locations in addition to those locations identified using a 5-percent organic carbon estimate.
- Twenty-three locations had TUs that exceeded the threshold value of 1 using the 5-percent soil organic carbon assumption. Using a 1-percent organic carbon soil estimate identified 10 locations in addition to those locations identified using a 5-percent organic carbon estimate.

Among these 13 to 23 locations with TUs exceeding the threshold value of 1 (i.e., covering the range of TOC estimates), the following observations can be made:

- The locations are predominantly in four areas: B105139, B107, B109, B119120
- At least some of the samples collected from B105139, B107, and B119120 were collected from soils under asphalt or immediately adjacent to asphalt. Because asphalt is a source of PAHs, it is likely that some of these elevated TUs are influenced by the presence of recalcitrant PAHs from the asphalt that are not biologically available. Furthermore, samples collected from beneath asphalt reflect areas where exposure to soil invertebrates is likely to be low due to the presence of an impervious surface.
- The PAHs at area B109137 were not reported as being collected from beneath asphalt, and these reflect the highest TUs regardless of the estimated TOC considered. Therefore, potential risks to soil invertebrates cannot be ruled out. However, this area is very densely vegetated and does not visually appear to have an impaired soil dwelling community (i.e., when the soil dwelling community is significantly impaired, it can result in visual impacts to the above-ground vegetation). Although this qualitative line of evidence does not rule out the possibility of some potential adverse effects to the soil dwelling organisms in the area of B109, it does indicate that if such impairments are occurring, they are on a localized scale.

Aside from PAHs, the following chemicals and locations warrant some additional discussion because risks cannot be definitively ruled out based on the risk assessment. These are:

- Aldrin at APDA189B2, where a maximum detection of 12 mg/kg was detected: This location is well-delineated, and the distribution of aldrin is illustrated on Figure M4-1. Concentrations around this elevated location do not indicate adverse effects to soil invertebrates are likely.
- CS at locations BPS1, APDA789B8, B113B6, and B113B10: The distribution of CS is provided on Figure M4-3. As this figure shows, these are the only three locations where CS was detected in soil.
- Ortho-chlorobenzaldehyde at B113B6: However, the HQ of 1.4 is only slightly greater than the threshold value of 1 when 1-percent soil organic carbon is considered. The HQ is less than 1 for conditions when higher organic carbon is considered. Also, as indicated in the EqP tables (Appendix M5-3C), ortho-chlorobenzaldehyde was only detected at the single location of B113B6.

- RDX at locations B142B3 and B142B2: The detections of RDX in soil are illustrated on Figures M4-7A and M4-7B. RDX was detected in soil at 10 locations. The soil invertebrate ESV for RDX is 99 mg/kg (Table M5-1). The maximum RDX detection of 5,200 mg/kg was observed at Debris Area 1S3. The next highest detection anywhere on the Site was 5.4 mg/kg. As such, HQs for RDX are less than 1 for all but one location. However, potential risks to soil invertebrates cannot be ruled out for a single location (Debris Area 1S3).
- Ethylbenzene at location B107B6: An HQ of 11 was seen at location B107B6 using 1-percent soil organic carbon. However, at 3- to 5-percent soil organic carbon, the HQs ranged from 3.6 to 2.2, respectively. The HQs are based on a maximum detection of ethylbenzene of 13 mg/kg. Ethylbenzene was only detected at three soil locations, including B107B6. The other two locations at B109137 had detections of less than 1 mg/kg.
- Trimethylbenzenes at B109137SS1A: The EqP HQs range from 1.3 to 6.7 at this location using 1-percent organic carbon as shown in Appendix M5-3C. However, the HQs range from 0.4 to 3.2 when 3-percent organic carbon is considered. HQs are less than 1 when 5-percent organic carbon is considered.
- TNT at Disposal Area 23: The detections of TNT in soil are illustrated on Figure M4-10. The detection of TNT at DA23B6 was 60 mg/kg, and the next highest detection was 4.3 mg/kg. The ESV for TNT for soil invertebrates (Table M5-1) is 16 mg/kg, yielding an HQ of approximately 4 associated with the single location where the maximum concentration was observed.

Chemical distribution maps are also provided for 13 chemicals in Appendix M4 (e.g., PAHs, RDX, TNB, TNT, 2-amino-4,6-DNT, tetryl, perchlorate, and others). The results of this analysis for soil dwelling invertebrates using both HQs and TUs support the conclusions that there are no areas of widespread unacceptable risks to individual soil invertebrates and, therefore, adverse impacts are not expected for the soil invertebrate community as a whole. Potential risks to soil-dwelling organisms cannot be definitively ruled out for a variety of constituents when the EqP approach using 1-percent soil organic carbon is considered for organics. This applies to a number of constituents, each described below. When 3- or 5-percent soil organic carbon is considered, lower estimates of risk or no unacceptable risks are predicted. The location of each area with potential risks to soil-dwelling invertebrates is provided in Appendix M5-5. This evaluation is focused on the most exposed of soil dwelling invertebrates, and there are many invertebrates that are far less exposed that are also part of the soil invertebrate community. There may be some isolated areas where some potential impacts to the most exposed soil invertebrates may occur, but such isolated conditions cannot adversely impact the community of organisms. Because all risks associated with these chemicals and locations cannot be definitely ruled out, they are discussed further in Section 7.4.Aquatic Community Diversity, Structure, and Function

Tables 7-4A, 7-4B, and 7-4C provide the Step 3a BERA screening of Site-wide maximum concentrations for surface water, groundwater, and sediment against the refined ecological benchmarks for aquatic organisms and identify the inorganic COPECs that required further evaluation. These tables show that three COPECs were identified for surface water with HQs greater than or equal to 1 (aluminum, iron, and manganese), four COPECs were identified for groundwater with HQs greater than or equal to 1, and 14 COPECs were identified for sediment with HQs greater than or equal to 1. Tables 7-4A, 7-4B, and 7-4C also show that some COPECs lack benchmarks (surface water and groundwater both showed detections of ammonia, nitrate, and sulfide; groundwater also showed detected nitrate). These COPECs are also retained and are discussed as an uncertainty.

Table 7-4D provides a summary of the COPECs from Tables 7-4A, 7-4B, and 7-4C that are retained. It indicates which COPECs can be further evaluated by considering location-specific HQs and which must be addressed by discussion of uncertainties because they lack benchmarks.

The location-specific HQs that required further evaluation for surface water, groundwater, and sediment are provided in Appendix M6, Table M6-3A, M6-3B, and M6-3C, respectively. The surface water and sediment sample locations are shown on Figure 7-3. These tables show that the vast majority of COPECs were detected at concentrations that correspond to refined HQs that are well below the threshold value of 1.

Tables 7-5A, 7-5B, and 7-5C provide the location-specific risk characterization summaries for surface water, groundwater, and sediment, respectively. Overall, the detected chemicals do not pose an unacceptable risk to the aquatic community. The majority of HQs are less than 1 for inorganic constituents. Among those exceeding 1, the HQs are primarily less than or equal to 10 with one exception, with an HQ of 30 for iron in the Unnamed Branch. However, this HQ of 30 is based on total iron, while the dissolved iron HQ at that same location was less than 1 (Appendix M6-3A). As can be seen in Table 7-5A, all of the HQs greater than 1 for inorganics are based on total metals analyses, and none are based on dissolved metals, which are the bioavailable fraction. Therefore, these HQs are values that overestimate risk.

Similar to that described for surface water, Table 7-5B summarizes groundwater HQs for inorganics greater than or equal to a value of 1, and Appendix M6-3B provides the location-specific HQs for groundwater at all locations. The HQs on Table 7-5B range from 1 to 70, but only two locations exceed HQs of 10. These are HQs of 30 and 70, both for iron and both based on total iron measurements. There were no detections of dissolved iron in groundwater where both total and dissolved metals were analyzed (Table M3-1C). Similarly, the other HQs exceeding 1 are primarily inorganics based on total metals analysis. There are some lower HQs for VOCs, with an HQ of 5 for TCE at location MW223-L26AB and two HQs of 2 for t-butyl alcohol. There was also one HQ of 2 for chlordane in groundwater at MW205-M27AB. These HQs reflect detections at wells some distance away from actual water bodies where aquatic organisms reside. Therefore, these HQs reflect worst-case conditions. These constituents are evaluated further for surface water using the TLM approach that considers cumulative toxicity for all organic chemicals detected in surface water.

Table 7-5C presents the HQs for inorganics for sediment. As can be seen, the highest HQ is a value of 3 for manganese in sediment. There are some HQs in the range of 2 for tin, iron, selenium, and cadmium primarily in Gregg Branch. There were no dissolved metals in surface water at any of these locations, indicating that the partition from sediment to dissolved, bioavailable fractions of metals is very limited.

Organic chemicals for surface water and sediment were evaluated using EqP approaches, with results summarized on Tables 7-5D and 7-5E, respectively, based on narcosis toxicity endpoints. The surface water narcosis EqP evaluation is summarized in Table 7-5D. As can be seen on this table, the surface water TUs do not exceed the threshold value of 1 at any location. Supporting information is provided in Appendix M. Table M6-4A provides the approach for the calculation of water quality benchmarks using the TLM approach and the EPA narcosis model. Table M6-4B provides the location-specific results using the TLM and the EPA narcosis model approaches. Table M6-4B provides data for surface water collected at any time and therefore includes multiple data points for locations that were sampled on more than one occasion. Similarly, the surface water summary on Table 7-5D identifies locations that were sampled on multiple occasions. Because the sum of TUs does not exceed the threshold value of 1, this indicates that chemicals are not present at concentrations that will pose a cumulative narcotic effect to aquatic organisms.

The sediment EqP results are summarized in Table 7-5E for each location. As can be seen on this table, there is one location with a significantly elevated TU result of approximately 70. This is location BTW1-PW45. As was discussed previously, the only location with 1-methylnaphthalene or 2-methylnaphthalene exceeding 1 mg/kg is area B109, where locations B109SS1A and B109BS1A had concentrations ranging from 31 mg/kg to 69 mg/kg. Area B109 is in the northwest portion of the Front Valley and is a location where a former UST removal occurred. There is no pattern of PAH detection between area B109 and location BTW 1-P45 that would suggest PAHs from B109 are the source of PAHs to Bee Tree Creek. In fact, area B109 is approximately 4,000 ft away from BTW 1-P45 via the Unnamed Branch, and neither 1-methylnaphthalene nor 2-methylnaphthalene were detected in the Unnamed Branch. Location B105139B8S1 had elevated total PAHs, at a maximum of 294 mg/kg, but 1-methylnapthalene and 2-methylnaphthalene were not detected at this location with detection limits less than a value of 0.5 mg/kg. Aside from area B109, the next highest value of 1-methylnaphthalene from any location on-Site was 0.31 mg/kg (soil location B119120B1). Therefore, the Site could not possibly be the source of these PAHs to Bee Tree Creek. Two other locations in the Unnamed Branch show cumulative TUs slightly above the value of 1, but these are only marginal exceedances, and they are in areas of the Unnamed Branch with limited aquatic habitat. Overall, this sediment EqP approach supports the conclusion that Site-related chemical mixtures do not pose unacceptable risks to sediment-dwelling organisms. It is possible that sediment-dwelling organisms at location BTW 1-P45 experience some adverse effects, but a close evaluation of the chemical composition of the PAHs at the Bee Tree Creek location, combined with considerations of fate and transport on-Site, indicate that the PAHs at BTW 1-P45 are not Site-related.

Figure M4-12 indicates that PAHs were present in groundwater at monitoring well MW158-N44A and in nearby sediments at location BTW 1-P45 already discussed. PAHs in sediment at location BTW1-P45 are not present due to migration of Site-related PAHs from groundwater for the following reasons: (1) groundwater was analyzed for PAHs using method SW 8270C, and the results using SW 8270C showed all PAHs for MW158-N44A were non-detect; (2) groundwater was also analyzed for VOCs using method SW 8260B; method SW 8260B provides analytical results for naphthalene; Figure M4-12 shows that PAHs were detected for MW158-N44A, but this is based on only the low detection of naphthalene (0.002 mg/L) from method SW 8260B; and (3) total PAHs in sediment from BTW1-P45 were 117 mg/kg, driven by elevated concentrations of 1-methylnaphthalene (34 mg/kg) and 2-methylnapthalene (65 mg/kg); neither of these constituents were detected in groundwater, and it is not possible for such a low concentration of naphthalene (0.002 mg/L) in groundwater to yield such a high concentration of methylnaphthalenes in sediment. This evaluation of PAHs in groundwater further supports the conclusion that the Site is not the source of the PAHs observed in Bee Tree Creek.

Two additional locations in the Unnamed Branch (UBW 3A-J38 due to BZ and its breakdown product ortho-chlorobenzaldehyde and CS at UBW 5D-F37) also show cumulative TUs slightly above the value of 1, but the TUs are only marginally above the threshold value and they are in areas of the Unnamed Branch. While these are considered isolated locations (as illustrated on Figures M4-2 for CS and M4-3 for BZ), potential risks cannot be definitively ruled out.

The evaluation presented in Tables 7-5D and 7-5E is based on narcosis endpoints, as was discussed in detail in Section 7.3.3.1.4. As mentioned in Section 7.3.3.1.4, pesticides were also considered using conventional sediment benchmarks so that potential toxicity related to effects other than narcosis could be evaluated. The evaluation of potential sediment toxicity for pesticides using an EqP approach with conventional benchmarks based on NRWQC and DENR water quality criteria is presented in Table 7-5F and Table 7-5G, as follows:

- Table 7-5F summarizes the pesticides detected in surface water or sediment at any location, showing the frequency of detection and the maximum detected concentrations of each pesticide in surface water and sediment. Table 7-5F also shows the approach used for the derivation of sediment benchmarks based on either 1-percent organic carbon or 0.35-percent organic carbon in sediment. As indicated on Table 7-5F, sediment HQs were less than 1 for the majority of pesticides detected in sediment. Sediment HQs exceed a value of 1 for lindane (HQs range from 5 to 20), endosulfan (HQs range from 6 to 20), and heptachlor epoxide (HQs range from 2 to 4), with the range depending on the percent organic carbon, where higher organic carbon estimates result in lower HQ estimates.
- Table 7-5G provides a summary of location-specific sediment HQs for lindane, endosulfan, and heptachlor epoxide. Lindane HQs exceed a value of 1 at each of the five sediment locations detected (four locations in Gregg Branch and one location in the Unnamed Branch). Endosulfan HQs exceed the value of 1 at four locations if 1-percent organic carbon is considered and at eight locations if 0.35-percent organic carbon is considered. Heptachlor epoxide HQs exceed a value of 1 at only a single location, regardless of the organic carbon estimate.

The HQs for the three chemicals summarized in Table 7-5G (lindane, endosulfan, and heptachlor epoxide) are generally low and overall do not likely indicate an adverse effect to the sediment-dwelling community. However, based on these HQs, some isolated potential adverse impacts to some individual sediment-dwelling organisms cannot be definitely ruled out. Furthermore, as noted previously, there are some occasional historic detections of pesticides in surface water that exceed the DENR water quality standards, as was identified in Table 7-1C (aldrin, chlordane, and heptachlor). Therefore, additional discussion is provided for these pesticides considering each medium as provided below. This summary is based on a series of data tables provided in Appendix M6-6, the pesticide data summary tables:

- Lindane data for sediment detections were provided in Table 7-5G, as discussed above. Lindane was not detected in any surface water samples at concentrations exceeding DENR standards, as indicated in Table 7-1C. Lindane was only detected in four surface water samples (M6-6A) and 2 groundwater samples (M6-6B). None of the surface water samples exceed the DENR criterion of 0.00001 mg/L, and only one of the groundwater samples slightly exceeds the criterion. A groundwater sample showed a detection of lindane at 0.000015 mg/L, which only slightly exceeded the DENR value of 0.00001 mg/L. However, exceedance of the DENR criteria in surface water did not occur, as the surface water data demonstrated.
- Endosulfan data for sediment detections were provided in Table 7-5G, as discussed above. Endosulfan was not detected in any surface water samples at concentrations exceeding DENR standards, as indicated in Table 7-1C. Endosulfan was only detected in one surface water sample (see Table M6-7A) and two groundwater samples (see Table M6-7B). Neither of the groundwater sample detections exceed the DENR criterion for endosulfan of 0.00005 mg/L.
- Heptachlor data for sediment detections were provided in Table 7-5G, as discussed above. Heptachlor was detected at a maximum surface water concentration exceeding DENR standards, as indicated in Table M2-1B (the value shown for the NRWQC is also similar to the DENR water quality standard). Heptachlor data are available for 182 total and dissolved analyses (see

Table M6-8A). Total heptachlor was detected above DENR standards four times in 2007, three times in 2008, two times in 2009, and not at all in 2010 or 2011. Dissolved heptachlor was only detected above DENR standards twice, both times in 2009. The detections occurred in the Unnamed Branch. The presence of heptachlor in the surface water of the Unnamed Branch is not likely due to groundwater discharge, because heptachlor was only detected once in groundwater from MW149-1, which is screened in the D Zone and is located northwest of Pond 2, well away and downgradient from the Unnamed Branch (Appendix M6-8B). Heptachlor was not detected in soil or sediments. However, heptachlor epoxide was detected in sediments. The heptachlor epoxide in sediments is the likely source of heptachlor in surface water.

- Aldrin data for surface water, groundwater, and sediment are summarized on Figure M4-1A, and data are provided in Appendix M6-9A, M6-9B, and M6-9C, respectively. Aldrin data are available for 182 total and dissolved analyses in surface water. Aldrin was detected in total analyses nine times in surface water: five times in 2008 and four times in 2010. All aldrin detections in surface water occurred in samples collected from the Unnamed Brach. Aldrin was not detected at all in 2007 or 2009. Aldrin was not detected at any time in the dissolved phase. Where aldrin was detected in surface water it was generally co-located with aldrin in sediment. The aldrin detections in surface water samples are the most likely due to sediment suspension in the water column. Water in the Unnamed Branch is shallow and during high flow conditions has some suspended particulates. The presence of aldrin in surface water of the Unnamed Branch does not appear to be due to migration from soils. There are only four soil locations with low detected concentrations of aldrin that are close to the Unnamed Branch, and the surface water and sediment sample locations nearest these soil locations show aldrin was not detected (Figure M4-1). The maximum concentration of aldrin on Site (12 mg/kg) was detected in a soil sample collected from the AP. This location is near Gregg Branch, and there were no detections of aldrin in surface water or sediment in Gregg Branch in the vicinity of this location. The presence of aldrin in surface water of the Unnamed Branch does not appear to be due to migration from groundwater. There was only a single location where aldrin was detected in groundwater, and the nearest surface water location to the well did not show any detections of aldrin during any of the sampling from 2007 to 2010.
- Chlordane data for surface water and groundwater are provided on Tables M6-10A and M6-10B in Appendix M. Collectively 182 analyses for total and dissolved chlordane in surface water were performed. Chlordane was only detected twice, both times in total analyses and both detections exceed the DENR water quality standard of 0.000004 mg/L. One detection occurred in 2007 from Bee Tree Creek at the furthest upstream sample location (BTW3-U30) and upstream of the Site, and the second detection occurred in Gregg Branch in 2010. The concentration detected in Gregg Branch was lower than what was observed in Bee Tree Creek in 2007. There have been no other detections of chlordane in surface water at any point in time over 5 years of sampling. Chlordane was detected in groundwater at MW205-M27, MW223-L26AB, and MW182-K39AB. However, the groundwater concentrations of chlordane do not appear to be affecting the local surface water, as chlordane was not detected in the surface water of Ponds 1 and 2. Furthermore, the detections of chlordane in groundwater were only slightly above the analytical detection limit of approximately 0.003 µg/L.
- DDE was not detected in either sediments at concentrations that appear to pose either an elevated HQ using either EqP or conventional benchmarks, as was discussed in this section and presented in Table 7-5G. There are no DENR surface water standards for DDE, but DDE is discussed here

because the EPA identified that dichlorodiphenyldichloroethane (DDE), dichlorodiphenyltrichloroethane (DDT), and dichlorodiphenyldichloroethene (DDD) might be pesticides that also warrant further consideration. DDE data for surface water are available for 182 total and dissolved analyses (Appendix M6-11A). Total DDE was detected twice, and dissolved DDE was detected only once. The three detections of DDE occurred in 2009. DDE was not detected in 2007, 2008, 2010, or 2011. DDT and DDD were also analyzed 182 times each. DDT and DDD were not detected in any surface water sample. DDE was not detected in any groundwater samples (Appendix M6-11B). DDT (MW182-K39AB) and DDE (MW-149-1) were detected once each in groundwater but both detections were at very low concentrations, and they were not detected at the same well location.

There are two additional chemicals (TCE and manganese) that are unrelated to pesticides that warrant some additional discussion, as follows:

- TCE was detected in surface water at concentrations greater than a EPA Region 5 water screening value, which was a value used because there are no NRWQC or DENR standards for the protection of aquatic life for TCE. The EPA Region 5 value is a protective value, but it does not meet the more rigorous data requirements of the NRWQC or DENR criteria. TCE was detected in surface water from location UBW5-137 (at 0.068 to 0.096 mg/L) between 2009 and 2011 at concentrations only slightly greater than the conservative Region 5 screening value for aquatic organisms of 0.047 mg/L, yielding an HQ of approximately 2. Appendix M6-12A provides the TCE surface water data, sorted from highest concentrations to lowest concentrations. As can be seen in Appendix M6-12A, only three samples had concentrations greater than the screening value of 0.047 mg/L, and all three were from 2009 to 2011 in the same location already mentioned (UBW5-137). As such, potential impacts to some individual aquatic organisms cannot be definitively ruled out, but these HQs are very low, and it is reasonable to expect that this covers only a very limited space, as the locations upstream and downstream from UBW5-137 do not show elevated TCE. Location UBW5-137 is present near the headwaters of the Unnamed Branch, so in this location habitat conditions are likely limited to very shallow water depths, and these habitat conditions alone likely limit the presence of aquatic wildlife. Appendix M6-12B provides TCE groundwater data. Because TCE was detected in groundwater, with the highest concentration (30 mg/L) observed at MW223-L26AB (located in the Back Valley APDA-789), potential future risks due to TCE discharge to surface water cannot be definitively ruled out near this monitoring well location. However, it is notable that the groundwater location with the elevated detection from the Back Valley is not near the Front Valley Unnamed Branch location UBW5-137. Furthermore, Appendix M6-12B shows that the next highest TCE concentration from groundwater at any location adjacent to a surface water body is 0.37 mg/L, so this is an issue that is limited in spatial extent and focused on only the area in the vicinity of MW223-L26AB.
- Manganese was detected in sediments at a single location in the Unnamed Branch (UBW3A-J38) with an elevated concentration (2,200 mg/kg). This concentration is above background and sediment benchmarks, such as the NOAA SQuiRT values. However, a single detection is unlikely to impact the sediment dwelling organism community over any spatial scale beyond the immediate vicinity of the elevated detection.

In an evaluation separate from those already mentioned, consideration was given to the presence of perchlorate in surface water and sediment, particularly with regard to potential risks to amphibians.

Perchlorate concentrations are illustrated on Figures M4-5A and M4-5B. However, as noted on Table M4-1, the surface water and sediment thresholds are based on more general water and sediment quality criteria, not necessarily criteria specific to amphibians, as was identified in Section 7.3.3.1.4. Therefore, perchlorate surface water, sediment, and groundwater data are provided in Appendix M6-13A, M6-13B, and M6-13C, respectively, with both tables sorted from highest concentrations to lowest concentrations. The following observations can be made relative to the water criteria:

- Perchlorate concentrations in surface water ranged from 0.0002 mg/L to 0.069 mg/L with the maximum detected in 2007 at Station UBW5-137 in the Unnamed Branch. This detection is below the 0.125 mg/L threshold above which frog metamorphosis was interrupted in a study by Tietge et al (2005), with the maximum detection at the Site being half of the most harmful threshold. Only approximately 20 percent of the perchlorate detections exceeded even the lowest threshold of 0.005 mg/L. In fact, more than half of the perchlorate measurements show no detections at a detection limit of 0.0002 mg/L. In the most recent round of surface water samples collected in 2011 (12 samples total), only three samples were above detection limits (0.0052 mg/L to 0.029 mg/L) and all were contained within Unnamed Branch (UBW5-137, UBW4-137, UBW3A-J38). The results of the recent sampling confirm the conclusion that the location of perchlorate concentrations found in surface water in the most recent round of sampling is localized. Because the exceedances noted above appear to be limited to the general vicinity of the Unnamed Branch, they are not expected to result in unacceptable population-level risks to amphibians. As noted in Section 7.3.3.1.4, fewer than 60 percent of the organisms in the control treatment in the study reached the appropriate metamorphic stage at 70 days post-fertilization when compared to the normal table of frog development (Nieuwkoop and Faber 1994). This suggests that the conditions of the study were insufficient to promote normal growth. As such, it is difficult to determine the role of perchlorate in the delay of metamorphosis, because development was already hindered significantly by the control conditions. Perchlorate measurements in sediment are provided in Appendix M6-13B, and groundwater measurements are provided in Appendix M6-13C. As indicated, perchlorate was only detected twice at concentrations ranging from 0.0028 mg/kg to 0.038 mg/kg at locations in Gregg Branch (GBW1C-Q28) and the Unnamed Branch (UBW2-L41), respectively. Approximately 50 other sediment samples showed no detected perchlorate even with low detection limits (0.0021 mg/kg).
- Perchlorate was detected in groundwater at approximately 20 percent of the locations where sampled in monitoring wells relevant to the ERA (Appendix M6-13C). Detections ranged from 0.0002 mg/L to 0.14 mg/L. As indicated in the EPA comment, perchlorate was detected at a maximum concentration of 0.14 mg/L in groundwater well MW205-M27. MW205-M27 is located in the Back Valley, and there are sample locations both upstream and downstream in Gregg Branch from this groundwater sample location (Figure M4-5A and M4-5B). Groundwater in the vicinity of the maximum detection in groundwater may be flowing into Bee Tree Creek downstream of where the sampling of surface water occurred. Figure M4-5A shows that MW149-1, MW183-039CD, and MW235-P39CD are nearest Pond 2. The perchlorate concentrations from these wells range from 0.002 mg/L to 0.074 mg/L, well below the 0.125 mg/L severe-effect threshold of no metamorphosis. There are also wells on the eastern side of Pond 2 showing no detections of perchlorate. Finally, the surface water of Pond 2 shows low detections of perchlorate over time (0.00031 to 0.0011 mg/L), and the sediment of Pond 2 shows perchlorate was not detected. Based on this information and ongoing pilot studies and

monitoring for perchlorate, the surface water monitoring and sediment monitoring were adequate to address perchlorate.

An evaluation for ammonia in surface water and groundwater was conducted. Ammonia in surface water was not detected in approximately 40 percent of the locations sampled (Appendix M6-14A). Where detected in surface water, detections ranged from 0.03 mg/L to 0.058 mg/L. The maximum detection was in Pond 2. This is the maximum detected concentration of ammonia in surface water at the Site, and it does not exceed the EPA NRWQC of 1.9 mg/L. In groundwater the maximum detected concentrations of ammonia were: 3.2 mg/L at monitoring well MW156 P44-A (adjacent to Pond 1), and 2.6 mg/L at MW182-K39AB (along the Unnamed Branch). All other groundwater detections were less than the NRWQC of 1.9 mg/L. MW156 P44-A is south of Pond 1 and is not near Pond 2 (Figure 1-4). The monitoring well nearest Pond 2 (MW193 Q40CD) showed ammonia was not detected with a detection limit of 0.05 mg/L (Figure 1-4 and Appendix M6-14B). Further, ammonia was not detected in Pond 1, and the detection of ammonia in Pond 2 yields an HQ of only 0.03. Based on this information, it is not considered that the ammonia in groundwater poses an unacceptable risk to either Ponds 1 or 2.

Qualitative observations of the biological community were made during the Phase I surface water collection efforts, and these observations confirm the overall conclusions drawn on Tables 7-5A, 7-5B, and 7-5C. The qualitative observations are provided in Appendix M8. These results show that a broad range of aquatic organisms are present in the aquatic features, including mayflies, stoneflies, and caddisflies. Additional observations include:

- Bee Tree Creek locations show considerable diversity among sensitive species, as would be expected given the high-quality rock and cobble habitat of this creek (e.g., see Appendix M1-1, Photo 6). Each location shows a range of sediment-dwelling organisms characterized as sensitive, such as caddisfly larvae, mayfly larvae, gilled snails, riffle beetles, stonefly larvae, and water pennies.
- Sensitive species were also seen in Gregg Branch, such as caddisfly larvae, mayfly larvae, gilled snails, and water pennies. The more limited presence of sensitive species in Gregg Branch compared to Bee Tree Creek is typical of the more limited flow and size of Gregg Branch relative to Bee Tree Creek (e.g., see Appendix M1-1, Photo 7, where Gregg Branch was just inches deep, and Photo 8 showing a dry portion of Gregg Branch). Therefore, the presence of sensitive organisms, even to a lesser extent than Bee Tree Creek, is a good sign of water quality and the condition of the sediment-dwelling community.
- The Unnamed Branch has the lowest habitat quality of the aquatic features at the Site, as illustrated in Appendix M1-1, Photo 11. As indicated in Appendix M8, the presence of sediment-dwelling organisms was variable within the Unnamed Branch. For example, location UBW-1A-M42 and UBW-1B-M42 showed a range of species similar to that seen in Bee Tree Creek. This location is downstream on the Unnamed Branch near Pond 1. Locations further upstream with less water depth and flow showed fewer species present, as would be expected in the more limited habitat (e.g., UBW-6-I37, where field notes in M8 show caddisfly and mayfly larvae present in areas of “incredibly low flow” and “very muddy and silty” conditions, and UBW-5-I37, where only caddisfly larvae were seen among the sensitive species again in an area with low flow conditions).

7.3.4 **Evaluation of Food Web Pathways**

Food web pathways were considered for all preliminary COPECs identified in the SLERA as being potentially bioaccumulative. Table 7-1E provided a list of preliminary COPECs for consideration in Step 3a of the BERA. This section discusses the following elements of the evaluation of food web pathways:

- Wildlife Receptors and Exposure Pathways for Food Web Pathways (Section 7.3.4.1)
- Exposure Assessment for Food Web Pathways (Section 7.3.4.2)
- Effects Assessment for Food Web Pathways (Section 7.3.4.3)
- Risk Characterization for Food Web Pathways (Section 7.3.4.4)

7.3.4.1 Wildlife Receptors and Exposure Pathways for Food Web Pathways

Most healthy ecosystems support a large number of individual species representing a variety of feeding guilds. However, it is not feasible to complete risk calculations for all potentially exposed species. Moreover, such an effort would be duplicative because of the similarity of exposure patterns among closely related species and among those with similar feeding guilds. For these reasons, surrogate receptors of interest are selected to represent the different feeding guilds. The following mammal and bird receptors were identified in the ERA Work Plan and are included in this evaluation:

Terrestrial	Aquatic
Deer Mouse—omnivore Short-Tailed Shrew—carnivore Mink—piscivore[12]/carnivore American Robin—omnivore Screech Owl—carnivore	Mallard Ducks—omnivore and herbivore Green Heron—piscivore Little Brown Bat—insectivore Mink—carnivore

These species are both known to be susceptible to food web exposures or are representative prey of organisms that are susceptible to food web exposures (EPA 1993). They reflect a range of trophic levels (e.g., small carnivorous mammal as compared to a small omnivorous mammal) and thus dietary exposure. Furthermore, dietary and toxicological information is available for these species, making them good candidate species for food web modeling (e.g., EPA 1993, Sample et al. 1996). As such, the selected species can be used as surrogate species to represent the types of exposures and potential impacts that could occur to other wildlife species at the Site. These animals are commonly found in North Carolina. The mink integrates terrestrial and aquatic carnivorous mammal components (including piscivorous), and both terrestrial and aquatic exposures are considered for mink.

7.3.4.2 Exposure Assessment for Food Web Pathways

The food web evaluation considered two types of exposure point concentrations (EPCs), the maximum (worst case) and a central tendency estimate, characterized by the UCL when available (or the average when the UCL exceeded the maximum).

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[12] Fish-eating

- Worst Case: This scenario uses maximum media concentrations to give upper-bound estimates of exposures for the Site because wildlife do not remain fixed around a single point in space.
- A Central Tendency Case (UCL or Average): This scenario uses average media concentrations that more realistically estimate the types of exposures that are likely to occur as animals move around the Site.

The exposure assessment yields estimates of total daily intake (TDI) of COPECs for the wildlife receptors of interest (ROIs) via diet and incidental ingestion of soil, surface water, and sediment while foraging or preening/grooming. TDIs were calculated based on the methodology described by EPA (1993) and in accordance with the ERA Work Plan. TDIs are estimated as functions of an EPC, food ingestion rate, and composition of diet, body weight, and area use factor (AUF).

Dietary intakes are calculated for each upper trophic level receptor species using the following equation (EPA 1993, ORNL 1994):

$$\mathrm{Exposure} = \mathrm{AUF} \times \left[\frac{\mathrm{IR}_{sw} \times \mathrm{C}_{sw} + \mathrm{IR}_{ss} \times \mathrm{C}_{ss} + \mathrm{IR}_{sd} \times \mathrm{C}_{sd} + \mathrm{IR}_{f} \times \mathrm{C}_{f}}{\mathrm{BW}} \right]$$

Where:

$$\mathrm{C}_{f} = \sum \left(\mathrm{F}_{AP} \times \mathrm{C}_{AP} + \mathrm{F}_{AI} \times \mathrm{C}_{AI} + \mathrm{F}_{F} \times \mathrm{C}_{F} + \mathrm{F}_{TP} \times \mathrm{C}_{TP} + \mathrm{F}_{TI} \times \mathrm{C}_{TI} + \mathrm{F}_{PM} \times \mathrm{C}_{PM} \right)$$

And where:

Exposure = Oral intake of chemical in diet (mg/kg-day)
AUF = Area Use Factor (unitless percentage) (literature)
IR_{sw} = Ingestion rate of surface water (L of surface water/individual/day) (literature)
C^{sw} = Chemical concentration in surface water (mg/L surface water) (measured)
IR_{ss} = Ingestion rate (kg fresh weight of surface soil/individual/day) (literature)
C_{ss} = Chemical concentration in surface soil (mg/kg surface soil) (measured)
IR_{sd} = Ingestion rate of sediment (kg fresh weight of sediment/individual/day) (literature)
C_{sd} = Chemical concentration in sediment (mg/kg sediment) (measured)
IR_{f} = Ingestion rate of food (kg fresh weight of food/individual/day) (literature)
C_{f} = Chemical concentration in food (mg/kg fresh weight food) (calculated)
BW = Body weight (kg) (literature)
F_{ap} = Fraction of the diet composed of aquatic plants (unitless) (literature)
C_{ap} = Chemical concentration in aquatic plants (mg/kg fresh weight, calculated from models)
F_{ai} = Fraction of the diet composed of aquatic invertebrates (unitless) (literature)
C_{ai} = Chemical concentration in aquatic invertebrates (mg/kg fresh weight, calculated from models)
F_{f} = Fraction of the diet composed of fish (unitless) (literature)
C_{f} = Chemical concentration in fish (mg COPEC/kg fresh weight, calculated from models)
F_{tp} = Fraction of the diet composed of terrestrial plants (unitless) (literature)
C_{tp} = Chemical concentration in terrestrial plants (mg/kg fresh weight, calculated from models)

F_{ti} = Fraction of the diet composed of terrestrial invertebrates (unitless) (literature)

C_{ti} = Chemical concentration in terrestrial invertebrates (mg/kg fresh weight, calculated from models)

F_{pm} = Fraction of the diet composed of prey mammals (unitless) (literature)

C_{pm} = Chemical concentration in prey mammals (mg/kg fresh weight, calculated from models)

This equation includes ingestion of soil, sediment, and surface water. The dietary dose for these media is estimated by multiplying the amount of each medium that is ingested by the chemical concentration in these media. The dietary dose for food is obtained by summing the proportion of each dietary component multiplied by the concentration in each dietary component and multiplying that by the food ingestion rate. The concentration of chemicals in food and prey items (plants, invertebrates, small mammals, and fish) are estimated using COPEC concentrations in Site media and literature-derived bioaccumulation factors (BAFs) and biota-sediment accumulation factors (BSAFs). If a receptor does not consume a given prey item, the fraction of the diet for that item is 0. Likewise, if a receptor does not consume a given medium, the amount of that medium consumed is 0. The receptor parameters (such as dietary composition, body weight, food, water, sediment, and soil intake rate) are consistent with EPA guidance and scientific literature, as was reported in the ERA Work Plan (ORNL 1994, which is based on EPA 1993).

Absorption factors and AUFs are also a component of the TDI. A conservative default value of 1 is used as the absorption factor (i.e., the fraction of chemical ingested that is absorbed into the system). This assumption likely overestimates the TDIs, as laboratory toxicity tests often use highly available forms of the test chemical, whereas actual bioavailability under natural conditions is considerably lower. AUFs are the estimation of dose to account for the possibility that some wildlife ROIs may obtain some food from outside of the study area. An AUF is the ratio of the animals' home range and the area of the Site (or wetlands, as appropriate given the scenarios considered). AUF values of 1 were used in the food web calculations, and values other than 1 were discussed on a case-by-case basis.

Species-specific exposure parameters for mammal and bird species were provided in the ERA Work Plan and are provided in Appendix M7, as follows:

- Table M7-1A: American Robin Exposure Parameters
- Table M7-1B: Green Heron Exposure Parameters
- Table M7-1C: Mallard Duck Exposure Parameters
- Table M7-1D: Screech Owl Exposure Parameters
- Table M7-1E: Deer Mouse Exposure Parameters
- Table M7-1F: Mink Exposure Parameters
- Table M7-1G: Short-tailed Shrew Exposure Parameters
- Table M7-1H: Little Brown Bat Exposure Parameters

The bioaccumulation and bioconcentration factors used for the food web modeling were obtained from literature sources such as Sample et al.1998, Baes et al. 1984, Travis and Arms 1988, Belfroid et al. 1994, Belfroid et al. 1995, Beyer 1990, Beyer et al. 1996, and other related literature. Bioaccumulation and bioconcentration factors are provided along with the food web uptake approaches in Appendix M7, as follows:

- Table M7-2A: Food Web Uptake Approach for Soil to Terrestrial Plants
- Table M7-2B: Food Web Uptake Approach for Soil to Terrestrial Invertebrates
- Table M7-2C: Food Web Uptake Approach for Soil to Prey Mammals
- Table M7-2D: Food Web Uptake Approach for Water to Aquatic Plants
- Table M7-2E: Food Web Uptake Approach for Water to Aquatic Invertebrates
- Table M7-2F: Food Web Uptake Approach for Water to Fish
- Table M7-2G: Food Web BSAF Uptake Approach for Sediment to Aquatic Invertebrates and Fish

Species-specific TDIs are discussed further in Section 7.3.4.4.

7.3.4.3 Effects Assessment for Food Web Pathways

The effects assessment for wildlife is based on TRVs that relate ingested daily dose to ecotoxicological endpoints. TRVs are literature-derived concentrations or doses that give an understanding of potential toxicity via dietary intake (e.g., Sample et al. 1996). No observed adverse effect level (NOAEL) TRVs are indicative of doses of chemicals that have had no deleterious effects on a wildlife receptor. Lowest observed adverse effect levels (LOAEL) TRVs are the minimum doses of constituents where deleterious effects are apparent. They are used as follows:

- Worst Case: The NOAEL TRVs are used with maximum detected concentrations.
- Central Tendency Case: The NOAEL TRVs are used with UCL or average concentrations.
- Central Tendency Case: The LOAEL TRVs are used with UCL or average concentrations.

The TRVs are taken from a variety of standard sources (EPA 2007c and Sample et al. 1996). All TRVs considered in this ERA are provided in Appendix M7, Table M7-3.

7.3.4.4 Risk Characterization for Food Web Pathways

Like the direct-contact pathway, risk characterization for the food web pathways involves the integration of the exposure assessment and effects assessment to evaluate the likelihood, severity, and spatial distribution of predicted or observed effects. For the food web pathways, this is an HQ that compares the TDI and TRV.

$$\text{Hazard Quotient} = \frac{\text{TDI}}{\text{TRV}}$$

For metals, the HQs presented reflect the total HQ minus the contribution of HQ from background. Risk characterization for measurement endpoints involves mathematical comparison of exposure and effects estimates for each measurement endpoint (an HQ). Exposure estimates that are below the relevant effects metric (the TRV) indicate that adverse effects to a given receptor are unlikely. Therefore, HQs less than or equal to the threshold value of 1 (to one significant figure, EPA 1997) indicate that the constituents do not pose an unacceptable risk. Exposure estimates that exceed the relevant effects metric indicate that further investigation is warranted to define the potential for adverse effects at the population level, as well as the spatial extent and severity of any such adverse effects (Barnthouse et al. 2008a).

The risk characterization for food web pathways relies on comparisons of COPEC concentrations to toxicity benchmarks in two scenarios, as described previously.

	Scenario		
	Worst Case	**Central Tendency Case**	
Exposure Point Concentration	Maximum chemical concentrations	UCL or average chemical concentrations	UCL or average chemical concentrations
Effects Measure **(Toxicity benchmarks)**	NOAEL (no effects benchmark)	NOAEL (no effects benchmark)	LOAEL (low effects benchmark)

Appendix M7 (Tables M7-4A and M7-4B) provides the detailed information about the food web modeling for all terrestrial and aquatic oriented mammals and birds. The results show that for the vast majority of chemicals and areas of exposure, HQs are well below the threshold value of 1. These results indicate that the vast majority of chemicals present in soil, surface water, and sediment are not likely to pose unacceptable risks to mammal and populations of other organisms at the Site. However, as noted in Tables M7-4A and M7-4B, some HQs exceed the threshold value of 1. Therefore, additional evaluation is provided for these HQs, as discussed below.

7.3.4.4.1 Risk Summary for Terrestrial Mammals and Birds

Tables 7-6A provides a summary of the COPECs with an HQ greater than or equal to 1 using the refined cases showing both the NOAEL and the LOAEL HQs compared to UCL or average concentrations. The worst case HQs are shown in Appendix M, Tables M7-4A. Table 7-6A summarizes NOAEL and LOAEL HQs at any location for any of the terrestrial mammals and birds where any COPEC has a central tendency HQ greater than or equal to 1 for any receptor (e.g., if the HQ for a COPEC exceeds a value of 1 for the American robin, the HQs for that COPEC are shown for all terrestrial wildlife receptors. For naturally occurring inorganics, the HQ shown reflects the HQ excluding contributions from background. Background HQs for naturally occurring inorganics using the food web model range from less than 1 (most COPECs) to 30 (vanadium for the robin), and calculated results are provided in Table M9-1A.

The NOAELs and LOAELs central tendency (UCL or average) HQs are summarized on Table 7-6A for each receptor. The central tendency HQs are shown because these reflect the more realistic exposures that may occur for wildlife. Maximum HQs are provided in the supporting documentation for completeness of this ERA, but there are no reasonable expectations that any mammal or bird would be exclusively exposed to only the maximum conditions at any given area (Appendix M, Table M7-4A). Table 7-6A shows that very few UCL or average HQs exceed the threshold value of 1 using either the NOAEL or LOAEL HQs. The locations where the UCL or average HQs exceed a value of 1 for both NOAELs and LOAELs are illustrated on Figure 7-4 (i.e., areas of potential interest based on UCL or average HQs). The following discussion is provided for each of the areas and COPECs contributing to the elevated UCL or average HQs compared to either NOAELs or LOAELs, generally starting from APDA789 and ending with the TA:

APDA-7-8-9: Central tendency NOAEL and LOAEL HQs for aldrin exceed a value of 1 for the American robin and the screech owl (ranging from 7 to 60). Aldrin detections for the Site are illustrated in Appendix M (Figure M4-1). These HQs are driven by a single detection of aldrin (12 mg/kg) in soil at the edge of the AP. Only two detections of aldrin were seen at APDA789, where the next highest was 0.00026 mg/kg. This area has been well-delineated. Figure 7-4 shows the area where the elevated aldrin was detected in soil. This area is approximately 0.2 acres. The HQs are significantly influenced by this single detection. In fact, Phase II soil sampling around this area showed that the elevated detection is very isolated. Table 7-6A shows that if the size of this area is compared to the American robin and screech owl home ranges, the HQs would be much lower, with LOAEL HQs less than 1 for both receptors. Based on this information, aldrin does not appear to pose an unacceptable risk to mammal and bird populations via the food web, but risks to individual mammals or birds cannot be definitively ruled out by hazard quotients alone. However, because mammals and birds feed over large areas relative to the isolated elevated detection of aldrin, even adverse impacts to individual mammals and birds is unlikely. Note that small home range species like the mouse and shrew show NOAEL and LOAEL HQs less than the threshold value of 1.

The APDA area also shows elevated NOAEL HQs for the mink and the short-tailed shrew exposed to endosulfan. Endosulfan was detected only once in eight samples, with a detection of 0.00046 mg/kg. However, a single non-detection, with a detection limit of 31 mg/kg skewed the average results to 1.9 mg/kg, resulting in elevated HQs. Maximum HQs are well below the threshold value of 1 (Appendix M, Table M7-4A).

The APDA area also shows elevated NOAEL HQs for the American robin and the screech owl exposed to heptachlor epoxide. Heptachlor epoxide was detected at very low concentrations, with the maximum detection of 0.0051 mg/kg at B104-145 and the next highest of 0.0031 mg/kg at APDA789. The UCL or average concentration at APDA789 was significantly influenced by a single sample with an elevated detection limit of 0.22 mg/kg (so 0.11 mg/kg when one-half of the detection limit was used). There were two other detections at APDA789 at 0.00091 mg/kg and 0.00043 mg/kg. Therefore, the non-detected value was orders of magnitude greater than any actual detections. The maximum HQ is well below the threshold value of 1 (Appendix M, Table M7-4A).

B104-145: Copper was detected at B104-145 at a maximum concentration of 159 mg/kg. The next highest detection for copper in this area was 37.1 mg/kg. The central tendency estimate results in a NOAEL HQ of 2 for the American robin. This is considered an overestimate of the central tendency due to the single elevated detection. Copper detections for the Site are illustrated in Appendix M (Figure M4-13). This location also has a NOAEL HQ of 2 for the screech owl exposed to heptachlor epoxide when it is assumed that the owl spends 100 percent of its time at this area. Heptachlor epoxide was detected in one of two samples analyzed at a concentration of 0.0051 mg/kg. When the owls' actual home range is considered, the HQ is much less than the threshold value of 1.

B105-139 and B119-120: The central tendency NOAEL and LOAEL HQs for high molecular weight (HMW) PAHs range from 4 to 20 for deer mice and short-tailed shrews at B105-139 and B119-120. The HMW concentrations at B105-139 were seen at two locations (B7 and B8) ranging in concentration from approximately 140 mg/kg to 240 mg/kg, respectively. The RI/FS Work Plan states that B7 was to "be located in area of accumulation outside of B105 slab in the vicinity of floor drains and 4 foot deep interior sump" and B8 was to "be located outside of B105 slab south of interior sump rooms and 10 feet deep interior sump." Field personnel stated that B7 and B8 were drilled through asphalt. Area B119-120 had three elevated PAH concentrations ranging from 71 to 101 mg/kg, also obtained from locations drilled through asphalt. This indicates two important things regarding exposure: (1) drilling through asphalt is the likely source of PAHs in the surface soil samples, and (2) wildlife is not exposed to PAHs under asphalt. Based on this information, HMW PAHs do not pose an unacceptable risk to mammal and bird populations via the food web. PAH concentrations for the Site are illustrated in Appendix M (Figure M4-12).

B107: This area had NOAEL PAHs HQ equal to 1 for the deer mouse and the short-tailed shrew. Area B107 had a former UST removal action (concentration 30.9 mg/kg) and the sample (B107B3) was located near two wash-water sumps near the northeastern corner of Building 107 adjacent to an asphalt driveway. These low HQs do not indicate an unacceptable risk.

B109-137: Location B109 had elevated total PAHs (a maximum of approximately 140 mg/kg). HMW PAHs ranged from non-detections to 44 mg/kg. HMW PAH HQs at area B109-137 range from less than 1 to 7 for the American robin, deer mouse, and the shrew. Area B109 is in the northwest portion of the Front Valley and is a location where a former UST removal occurred. LOAEL HQs are at the threshold level of 1 for deer mice and shrews at this location. As illustrated on Figure M4-12, the area around B109 does not have elevated PAHs.

B110-111, B113, B115, and B117: Each of these areas has one or more COPECs with NOAEL HQs greater than or equal to the threshold value of 1 for the robin or the owl, but the LOAEL HQs do not exceed the threshold value of 1. This includes chromium and copper (B110-111); lead, zinc, and aldrin (B113); heptachlor epoxide (B115); and lead (B117).

B124-135: The central tendency NOAEL HQs for the American robin, the deer mouse, the mink, and the short-tailed shrew range from 3 to 20 for copper and LOAEL HQs range from less than 1 (mink and robin) to 3 (mouse and shrew). These HQs are influenced by a single elevated concentration of copper (6,780 mg/kg) from location B124-135S3, which is a polygon that is approximately 0.1 acre, which is very small even for small home range species. Copper does not bioaccumulate, and thus a single elevated copper concentration is not expected to bioaccumulate through the food web. The next highest copper concentration at this area from any location sampled is less than 35 mg/kg (location B124-135B8S1). Furthermore, the nearest surface water and sediment location is Gregg Branch location GBW1A-R33. Copper was not detected in surface water or sediment in Gregg Branch, so this is not a source to adjacent creek. LOAEL HQs in the range of 3 for the small home range receptors are low in magnitude, but the fact that they are influenced by a single elevated detection indicates copper is not likely to pose an unacceptable risk to mammal and bird populations via the food web. Copper concentrations for the Site are illustrated in Appendix M (Figure M4-13). There are also NOAEL HMW PAH HQs of 2 for the deer mouse and the shrew. The LOAEL HQs are less than 1.

B153, BP, Dump, and TA: These areas have NOAEL HQs of 2 to 3 for heptachlor epoxide (owl at BP153; lead (robin at BP and Dump); and chromium (robin at TA). All have LOAEL HQs less than 1. The owl HQ is based on the owl spending 100 percent of its time foraging at location BP153, which is an overestimate of exposure.

Disposal Area 23: The central tendency HQ for the deer mouse was 20 for 2,4,6-TNT. This is based on a single detection of 2,4,6-TNT of 60 mg/kg at location DA23B1 which represents an area of approximately 0.1 acre. No other detections of 2,4,6-TNT were seen at DA23 and the next highest detection of 2,4,6-TNT anywhere on-Site is at APDA789B2S1, where a detection of 4.3 mg/kg was seen. The distribution of 2,4,6-TNT concentrations around the Site is illustrated in Appendix M (Figure M4-10). 2,4,6-TNT was only detected at eight locations total among all areas, and aside from the two detections just mentioned, the six remaining detections were less than 1 mg/kg (one detection [plus a duplicate] at the Bear Pit, one detection at B105139, one detection at B110111, two detections at B147). The HQ of 20, in addition to being influenced by a single concentration, assumes that the deer mouse gets all of its food from plants that uptake the 2,4,6-TNT, which is unlikely. Based on this information, 2,4,6-TNT does not pose an unacceptable risk to mammal and bird populations via the food web. There are also NOAEL HQs that range from 2 to 3 at DA23 for the robin, deer mouse, and the shrew. LOAEL HQs are less than 1. DA23B2 was drilled in a drainage ditch, and this ditch was asphalt-lined, so these HQs are considered to be influenced by the asphalt that is not likely bioavailable.

Debris Area 1: The central tendency NOAEL HQs for RDX range from 4 to 9 for the American robin, the deer mouse, mink, and the short-tailed shrew at Debris Area 1. Elevated HQs are based on a single detection of RDX at 5,200 mg/kg (RDX concentrations are illustrated on Figure M4-7A and M4-7B). The spatial extent of this area is 0.01 acres, so the robin and mink HQs calculated using home range estimates are well below the value of 1. No other detections of RDX were seen at Debris Area 1. The next highest detection of RDX anywhere on the Site is 5.4 mg/kg at B142B3, and there are no other elevated HQs for RDX anywhere on the Site. Based on this information, RDX does not pose an unacceptable risk to mammal and bird populations via the food web.

In summary, Appendix M7, Table M7-4A shows that the vast majority of COPECs considered in the Step 3a refinement of COPECs via food web modeling have HQs that are less than the threshold value of 1, indicating that they do not pose an unacceptable risk. Table 7-6A shows the full summary of all COPECs with any central tendency HQs greater than or equal to 1 for both NOAELs and LOAELs. As discussed in detail above, the few elevated HQs seen in more realistic exposure estimates are sufficiently low or isolated in spatial extent (or both) such that they do not indicate a reasonable potential for an unacceptable risk for terrestrial mammals and birds at the Site. However, some potential risks cannot be definitively ruled out for all individual mammals and birds. Therefore, these chemicals and locations are discussed further in Section 7.4.

7.3.4.4.2 Risk Summary for Aquatic-Oriented Mammals and Birds

A full evaluation of COPECs for aquatic-oriented mammals and birds is provided in Appendix M7-4B, and the vast majority of HQs for all receptors are below the threshold value of 1. Contributions from background for naturally occurring inorganics are not considered for the aquatic-oriented mammals and birds. Table 7-6B provides a summary of any COPEC with an HQ greater than or equal to 1 at any location for aquatic-oriented mammals and birds. As shown, only heptachlor has an HQ exceeding 1 for the green heron using the NOAEL. The HQ for the green heron is 0.3 when the LOAEL is considered. This analysis included all surface water data from 2007 to 2011. Heptachlor was detected at a maximum concentration of 0.000012 mg/L during 2007 and 2008 at sampling from locations UBW2-L41 and UBW6-137., respectively. The next highest concentration anywhere on-Site was an order of magnitude lower at 0.0000087 mg/L. Heptachlor was detected in 2008 and 2009 in UBW2-L41, but concentrations were lower, ranging from 0.000004 mg/L to 0.000006 mg/L. Heptachlor was not detected in UBW6-137 during 2009 or 2010. Heptachlor was not detected in either of these locations or any of the 52 locations sampled in 2010. Finally, these HQs for the green heron are considered biased high because although the green heron has a small home range, it is highly unlikely to find the unnamed drainage as suitable habitat to reflect 100 percent exposure over time when more suitable pond and creek habitat is available nearby.

In conclusion, when using a central tendency exposure concentration, the vast majority of all HQs for all receptors did not exceed the threshold value of 1 when the NOAEL was used and none exceeded the threshold value of 1 when the LOAEL was used. These HQs are very low and support the conclusion that the chemicals present in surface water and sediment at the Site do not pose an unacceptable risk to aquatic-oriented wildlife at the Site.

7.3.5 **BERA (Step 3a) Uncertainties Evaluation**

Evaluation of key uncertainties is an important element of the risk characterization (EPA 1997). In many cases, unavoidable uncertainty in a Step 3a BERA problem formulation is balanced by purposefully conservative assumptions. The uncertainties associated with this ERA are summarized in Table 7-7. Appendix M9 presents information related to uncertainties:

- Table M9-1A: Calculation of Background HQs for Plants and Invertebrates
- Table M9-1B: Calculation of Background HQs for Terrestrial Mammals and Birds
- Table M9-2A: Evaluation of Detection Limits for Surface Soil
- Table M9-2B: Evaluation of Detection Limits for Surface Water
- Table M9-2C: Evaluation of Detection Limits for Sediment
- Table M9-2D: Evaluation of Detection Limits for Groundwater

The uncertainties in the Step 3a BERA evaluation for the Site are similar to those observed in a typical ERA, and the data are sufficient to support the conclusions identified in Section 7.4. The following notes are provided:

- Table 7-7 shows that many of the uncertainties lead to an overestimate of risk estimates. Tables M9-2A, M9-2B, and M9-2C provide a summary of detection limits compared to ESVs used in the SLERA, only showing those chemicals and locations where detection limits exceeded SLERA ESVs. Note that there were thousands of locations and chemicals where detection limits were well below the ESVs. Overall, the detection limits used in the Phase I and Phase II efforts were sufficiently low to support Step 3a of the BERA.
- Table 7-1E identifies each of the preliminary COPECs that were detected but lack ESVs in the SLERA, but TRVs were found and used in the BERA. For example, the soil COPECs lacking TRVs in the SLERA were captured in the BERA using the EqP approach. Similarly, the organic COPECs in surface water and sediment were addressed in the BERA using the TLM and EPA EqP approaches. For COPECs for which chemical-specific ESVs could not be found, like CS (sediment) and BZ (surface water and sediment), reasoned and conservative surrogate values were identified (Table M4-1 identifies some surrogate values). There were a number of naturally occurring COPECs, such as sodium, magnesium, potassium, sulfide, nitrate, and nitrite, that were not addressed in the ERA, because they have no ESVs, and they are ubiquitous in the environment. Ammonia was detected in surface water and groundwater, but detections were very low and infrequent (highest surface water detection was 0.058 mg/L, and the majority of the groundwater detections were less than 1 mg/L with only two exceptions that range from 2.6 to 3.2 mg/L). There are a few remaining COPECs that could not be addressed through the use of ESVs: aluminum in soil and beryllium, boron, and titanium, in sediment. Aluminum was addressed through consideration of pH in soil. The results of this analysis are provided in

Appendix M9, Tables M9-3A and M9-3B. Based on soil pH, aluminum is not an issue at the Site. Beryllium was detected in only 10 sediment samples at a range of concentrations of 0.133 to 1.15 mg/kg. Three beryllium detections were in the Ponds (one detection in each of Ponds 1, 2, and 3); five detections were in locations in the Gregg Branch; and two of the lowest detections were in the Unnamed Branch. The background soil beryllium concentration was approximately 2 mg/kg, which is higher than the detections seen in Site sediment. Boron was detected in nine sediment locations (eight in Gregg Branch, one in the Unnamed Branch) at a range of concentrations of 4.43 to 9.78 mg/kg. Boron was detected at approximately 8 mg/kg in background soil samples. Collectively, this information supports the conclusion that while the lack of ESVs is an uncertainty for some of these chemicals, this uncertainty does not alter the conclusions of this ERA or prevent conclusions from being drawn.

The data and analysis of this uncertainty support the conclusion that this uncertainty does limit the overall SMDP conclusions identified in Section 7.4.

7.4 Summary and Step 3a BERA Scientific Management Decision Point

The SMDP is a critical step in the ERA process where risk management decision-making occurs. Generally, the following types of decisions are considered at the SMDP:

- The chemicals do not pose an unacceptable risk and no further action is warranted;
- Further investigation or ERA is needed; or,
- The risk assessment is sufficient to support risk management decisions.

The SLERA and Step 3a of the BERA were performed in a manner consistent with standard EPA guidance. As such, the SLERA compared maximum detected concentrations in each environmental medium to highly conservative screening criteria in order to focus subsequent risk analyses on only the chemicals and media that required further evaluation. The information developed in the SLERA was not adequate to make a decision for some chemicals in surface soil, surface water, groundwater, and sediment. Therefore the ERA continued into the initial step of a BERA (Step 3a). The initial step of the BERA refined the COPEC identified in the SLERA by using more realistic estimates of exposure and measures of effect that reflect Site-specific conditions. Step 3a of the BERA evaluated risks for the following assessment endpoints:

Terrestrial plant and invertebrate community diversity, structure, and function

Aquatic community diversity, structure, and function

Mammal and bird population survival and reproductive ability

The Step 3a BERA evaluation compared exposure to effects in the form of HQs. The risk characterizations for the plant and invertebrate community as well as the aquatic community showed that the vast majority of the refined HQs are less than the threshold value of 1. Although some refined HQs exceed a value of 1, the occasions were generally limited, risk estimates were conservative, and, therefore, the chemicals present do not pose an unacceptable risk to the soil invertebrate and plant communities, but it is acknowledged that on very isolated scales some risks to individual soil invertebrates and some individual plants cannot be definitively ruled out by the risk assessment alone. Those ecological receptor groups, chemicals of primary interest, and overall conclusions of the risk assessment that can inform risk management decisions are summarized on the ERA Summary Table (Table 7-8).

Similarly, for mammal and bird populations, the HQs using more realistic exposure considerations showed the majority of HQs were below the threshold value of 1. Very few of the realistic exposure estimates for mammals and birds yield any HQs greater than 1, and those that exceed 1 are very low and reasonably explained when examined closely. Based on the information developed in the ERA (including the SLERA and Step 3a of the BERA), it is concluded that conditions at the Site do not pose unacceptable risks to mammals and bird populations. However, some risks to individual mammals or birds cannot be definitively ruled out by the risk assessment alone. Those mammals and birds with potential risks, chemicals of primary interest, and the areas where such potential risks may exist are provided on the ERA Summary Table (Table 7-8) along with the assessment information that can inform risk management decisions.

8.0 Site Redefinition

This section provides a brief discussion of the proposed redefinition of the CERCLA site boundary for the Site. The proposed redefinition of the Site boundary will be considered by the EPA with the decision documented in the Record of Decision for the Site.

The Site as it is currently defined on the EPA NPL consists of a tract of land of approximately 1,065 acres (which differs from the original acreage specified in the ROD [EPA, 1988 and 1989a] and was discussed previously in Section 1.2.1 of this document). TRC Environmental Corporation (TRC), on behalf of Chemtronics Inc., performed a comprehensive evaluation of the historical Site files, records, previous Site investigation reports, and historical aerial photographs; performed reconnaissance of the Site on multiple events to make field observations and verify historical records; and prepared a technical memorandum titled *Redefinition of the Chemtronics Site Boundary* dated May 2013. The Site redefinition document is attached to this RI report as Appendix N.

TRC completed the redefinition evaluation in accordance with EPA's Fact Sheet dated May 1996 titled *Clarifying the Definition of 'Site' under the National Priorities List* (EPA's Site Redefinition Guidance). EPA's Site Redefinition Guidance acknowledges that at the time of initial NPL listing there may only have been a limited amount of information about the nature and extent of contamination, because the listing focuses on identifying potential threats posed by the Site and not on delineating the Site boundary. Such was the case when the Site boundary was first defined. Since that time, the Site has been the subject of a number of extensive environmental investigations, including the RI presented herein, with the main purpose of defining the chemical constituents present on the Site and determining the horizontal and vertical delineation of those compounds. In accordance with EPA guidance, this Site represents an ideal candidate for redefinition at this time, because there is a sound technical basis available for redefining the Site to include only those portions known to be potentially impacted plus a proposed buffer area around those impacted areas.

The purpose of the redefinition evaluation performed was to:

- Identify those portions of the Site that should be retained as part of the redefined CERCLA site (and be the subject of the ongoing remedial action)
- Identify those portions of the Site that may be excluded or removed from the redefined Site based on the absence of evidence suggesting adverse impact by chemicals or manufacturing operations.

Based on TRC's evaluation, a proposed Redefined Site Boundary was developed that:

- Includes those portions of the Site that were historically utilized as an active part of the former industrial operations, contain waste residues, or were utilized for waste disposal
- Includes those portions of the Site that exhibit documented impacts and releases from the former industrial Site operations (i.e., contain affected soil, sediment, surface water, and/or groundwater)
- Includes a 260 acre buffer that ranges from 200 to 500 ft (between the areas affected by historical Site operations and the Redefined Site Boundary).

The proposed Redefined Site Boundary—the portion of the Site to be retained as part of the newly defined CERCLA Site—consists of approximately 535 acres of the entire 1,065 acre Site and includes those portions of the Site affected by Site-related activities. Approximately 260 acres of the 535 acre Redefined Site consist of the additional buffer around those affected areas of the Site. The proposed Redefined Site Boundary is illustrated on Figure 8-1.

9.0 Summary and Conclusions

This section summarizes the results of the Site-wide RI performed at the Site and includes a summary of the Site geologic and hydrologic framework, the selection of Site COPCs by media, sampling activities by media, COPCs detected in each media, source areas, potential receptors, and the results of the BRA. This section also identifies those source areas retained for further evaluation in the FS.

9.1 Site Hydrologic and Geologic Framework

The majority of the approximate 1,065 acre Site is situated within one of two local watersheds (the Unnamed Branch in the Front Valley and Gregg Branch in the Back Valley), both of which are part of a larger watershed (Bee Tree Creek) and a regional watershed (Swannanoa River).

The Site is underlain by regolith overlying metamorphic rocks including metagraywacke, schistose metagraywacke, and amphibolite. Foliation within these rocks trends in a northeast-southwest direction. Fractures are oriented in both northeast-southwest and northwest-southeast directions. The orientation of the foliation and the fractures control Site topography and drainage features as well as groundwater flow in the underlying bedrock. Differential weathering rates of the bedrock result in an uneven top of bedrock topography.

Groundwater at the Site exists in a three-part aquifer consisting of a Surficial Aquifer System, a Transition Zone Aquifer System and a Bedrock Aquifer System. These three aquifer systems are interconnected but have different characteristics that influence groundwater flow and potential Site COPC transport mechanisms within them. The three aquifer systems are interconnected with a predominantly downward vertical gradient between the various systems. Groundwater flow is predominantly toward the southeast in all of the aquifer systems. Locally, groundwater in the Surficial Aquifer System and the Transition Zone Aquifer System may discharge to the Unnamed Branch, Gregg Branch, or Bee Tree Creek.

9.2 Site COPCs

COPCs were selected for each media (soil, groundwater, surface water, and sediment) based on a review of known Site chemical usage, results of previous sampling activities, and readily available analytical methods. The following COPCs were selected for analyses:

- Soil COPCs varied by area but consisted of VOCs, SVOCs, nitroaromatics, perchlorate, pesticides/herbicides, metals, CS, BZ, and cyanide.
- Groundwater COPCs included VOCs, SVOCs, nitroaromatics, and perchlorate, as well as CS, BZ, metals, pesticides/herbicides, methanol, ethanol, organic acids, ammonia, chloride, cyanide, nitrate, nitrite, sulfate, and sulfide.
- Surface water COPCs included VOCs, nitroaromatics, perchlorate, metals, pesticides, chloride, and hardness.
- Sediment COPCs included VOCs, SVOCs, nitroaromatics, perchlorate, pesticides, CS, BZ, and metals.

9.3 Sampling Activities

The RI fieldwork was completed in three phases, which were performed between December 2009 and September 2012. Field sampling activities included:

- Collection of a total of 541 soil samples from 290 soil sampling locations within 45 areas
- Collection of groundwater samples from 175 new or existing Site monitoring wells
- Collection of surface water and sediment samples from 53 locations

Samples were analyzed for the selected COPCs and the analytical results were subsequently verified/ validated. Once the results were accepted, evaluation of results for each media was performed to identify potential source areas of Site COPCs and to delineate the extent of Site COPCs sufficient to support the BRA.

9.4 Site COPCs Detected

This section describes the COPCs that were detected in samples collected from various media during the RI:

9.4.1 **Soil**

Site COPCs detected in soil consist primarily of VOCs, nitroaromatic compounds, and perchlorate. SVOCs and pesticides were also detected at a lesser frequency or concentration. VOC analyses were performed on soil samples from 37 of the 45 areas where soil samples were collected. VOCs were detected in soil in 31 of the 37 areas. The most frequently detected VOCs in soil were acetone, cyclohexane, methylene chloride, TCE, toluene, and 1,2-DCA. Analyses for nitroaromatic compounds and perchlorate were performed on soil samples from all of the 45 areas in which soil samples were collected. Nitroaromatic compounds were detected in soil in 21 of the 45 areas. The most frequently detected nitroaromatic compounds in soil were RDX, HMX, 2,6-dinitrotoluene, and 1-nitronaphthalene.

9.4.2 **Groundwater**

Site COPCs detected in groundwater consisted primarily of VOCs, nitroaromatic compounds, and perchlorate. Metals were evaluated, and with the exception of manganese, were detected within the Site-specific background concentrations. Areas in both the Front Valley and the Back Valley in which groundwater COPC concentrations exceeded applicable groundwater criteria were delineated and source areas identified. The groundwater data do not indicate off-Site migration of VOCs, nitroaromatics, or perchlorate at concentrations exceeding applicable groundwater criteria.

9.4.3 **Surface Water and Sediment**

The most frequently detected Site COPCs in surface water were VOCs and perchlorate. The distribution of COPCs in surface water indicates that the indirect source of COPCs in surface water is discharge of shallow groundwater containing Site COPCs. Site COPC concentrations in surface water samples collected from Bee Tree Creek, downstream of confluence with on-Site streams, are either non-detectable or below the 2B standard and/or EPA National Criteria.

The most frequently detected Site COPCs in sediment were pesticides. The random distribution of pesticides in sediment does not allow for identification of any specific source areas. VOCs were detected in sediment in areas where surface water VOC detections indicate local discharge of groundwater into surface water.

9.5 Potential Receptors

To quantify the potential risks to human health and ecological receptors, a BRA was performed. The BRA included both an HHRA and an ERA. Soil, groundwater, sediment, and surface water data collected during the RI were evaluated in the BRA. The BRA was performed in an iterative manner using data collected during each phase of the RI to refine subsequent data collection activities.

The HHRA evaluated the following potentially exposed populations at and around the Site under current and reasonably expected future land use:

On-Site:

- Industrial workers
- Maintenance workers
- Construction workers
- Residents
- Recreational users
- Trespassers

Off-Site:

- Residents
- Maintenance workers
- Recreational users

The ERA evaluated various aquatic and terrestrial receptors. Terrestrial receptors include invertebrates (from earthworms to insects), small vertebrates such as passerine birds and small herbivorous mammals, predatory birds, and mammals. Aquatic receptors include benthic invertebrates (worms, some crustaceans, some insects), fish and amphibians, birds, and piscivorous mammals.

9.6 Results of the BRA

The following section discusses the results of the HHRA and ERA components of the BRA.

9.6.1 **HHRA**

Results of the HHRA indicate that overall there are no unacceptable risks to human health at the Site when considering current receptors and exposure pathways. Future uncontrolled exposures to on-Site workers could pose potential unacceptable risks. With the exception of potential future off-Site potable/nonpotable groundwater use, there are no potential future unacceptable risks to off-Site receptors from hazardous substances at the Site.

9.6.1.1 Soil

There are no areas of the Site with soil concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering potential future maintenance worker, construction worker, trespasser, or recreational user exposure to soil.

The following areas of the Site have soil concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering potential future industrial worker exposure to COPCs in soil:

- Area B116-128: soil sample locations B116SUMPS1, S2, S3, and S4, due predominately to the following COCs via vapor intrusion: 1,2-DCA, vinyl chloride, benzene, 1,1,2-trichloroethane, cyclohexane, and methylene chloride
- Area B109-137: soil sample locations B109137BS1A and B109137SS1A, due almost entirely to the following COCs via vapor intrusion: 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene

The following areas of the Site have soil concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering potential future on-Site residential exposure to COPCs in soil:

- Area APDA-7-8-9: soil sample locations APDA789B11, APDA789B2, and APDA789B3
- Area B105-139: soil sampling locations B105139B4, B5, B7, and B8
- Area B107: soil sampling locations B107B3 and B107B6
- Area B109-137: soil sampling locations B109137B3, B109137BS1A and SS1A
- Area B113: soil sampling locations B113B4, B5, B6 and B8
- Area B115: soil sampling locations B115B1 and B2
- Area B116-128: soil sampling locations B116128B1, B5, B13, SUMPS1, SUMPS2, SUMPS3, and SUMPS4
- Area B119-120: soil sampling locations B119120B1, B3, and B4
- Area B125-136: soil sampling location B125136B2
- Area B146: soil sampling location B146B1
- Area B147: soil sampling locations B147B2, B5, B7, B9, and S2
- Area B148: soil sampling location B148B2
- Area B149: soil sampling location B149B5
- Area B155: soil sampling location B155B4
- Area DA23: soil sampling location DA23B2
- Area DUMP: soil sampling location: DUMPTP3

These estimates of unacceptable risk are due to soil direct contact and/or soil vapor intrusion exposure. Depending on the area, unacceptable risk estimates for soil direct contact are predominantly driven by the following COCs: aldrin, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene, arsenic, chromium, cobalt, benzene, 1,2-DCA, 1,1,2-trichloroethane, vinyl chloride, RDX, and cyclohexane. Unacceptable risk estimates for soil vapor intrusion are predominantly driven by the following COCs: benzene, bromoform, chloroform, cyclohexane, ethylbenzene, 1,2-DCA, naphthalene, 1,1,2-trichloroethane, methylene chloride, TCE, PCE, vinyl chloride, styrene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, isopropylbenzene, aniline, allyl chloride, xylenes (total), toluene, and mercury.

9.6.1.2 On-Site Groundwater

There are no areas of the Site with groundwater concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering future industrial worker exposure to groundwater via inhalation of outdoor air.

As presented on Figure 6-4A, the following areas of the Site have groundwater concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering future industrial worker exposure via vapor intrusion or potable/nonpotable groundwater use and maintenance worker/construction worker exposure via direct contact with groundwater:

- Monitoring well locations P-7S, MW180-H38AB, and MW223-L26AB, due almost entirely to TCE vapor intrusion as well as via dermal contact and vapor inhalation during excavations that extend to the water table
- Monitoring well location MW231-H38AB, due almost entirely to TCE via dermal contact and vapor inhalation during excavations that extend to the water table
- 49 monitoring well locations in addition to those listed above have groundwater concentrations that could pose an unacceptable risk to on-Site industrial workers if groundwater were to be used in the future for potable purposes. These well locations are shown on Figure 6-4A.

As presented on Figure 6-4B, there are no areas of the Site with groundwater concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering future residential exposure to groundwater via inhalation of outdoor air.

As presented on Figure 6-4B, the following areas of the Site have groundwater concentrations that could result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering future residential exposure via vapor intrusion or potable/nonpotable groundwater use:

- Monitoring well locations P-7S, MW180-H38AB, MW223-L26AB, and MW231-H38AB, due almost entirely to TCE via vapor intrusion
- Monitoring well locations MW187-M25AB, due almost entirely to 1,2-DCA via vapor intrusion
- 71 monitoring well locations (including those listed above) have groundwater concentrations that could pose an unacceptable risk to on-Site residents if groundwater were to be used in the future for potable (and possibly nonpotable) purposes. These well locations are shown on Figure 6-4B.

9.6.1.3 Sediment and Surface Water

As presented on Tables 6-8 and 6-9, there are no locations at the Site with sediment or surface water concentrations that would result in cumulative cancer risk or noncancer HI estimates above EPA's risk management limits of 1 x 10^{-4} and 1, respectively, when considering current or future trespasser exposure, future maintenance worker/construction worker exposure, or recreational user exposure.

9.6.1.4 Off-Site Groundwater

Lastly, as discussed in Section 6.3.1, the scenarios for potential human exposure (see Table 6-2) recognize that off-Site groundwater use for potable purposes is a current and reasonably expected exposure scenario. To be conservative, the risk assessment evaluates the potential exposure of off-Site residents to groundwater via potable groundwater use by: (1) comparing the detected concentrations in on-Site monitoring wells located within approximately 200 feet of the Site boundary to drinking water screening levels, and (2) calculating cumulative cancer and noncancer risks for potable groundwater use exposures considering the same monitoring wells located within 200 feet of the Site boundary.

As shown on Figure 6-6, there are six on-Site monitoring wells within 200 feet of the Site boundary currently exhibiting detected concentrations in excess of the drinking water screening levels. As shown on Figure 6-4B, there is only one well located within approximately 200 feet of the Site boundary that has detected COPC concentrations that would result in unacceptable risks for drinking water exposure. Hypothetical resident exposure to groundwater via potable use could be unacceptable if near boundary concentrations were present off-Site. However, as discussed in Section 3, the off-Site water well survey and water well sampling activities found no COPCs from the Site in off-Site groundwater at concentrations that exceed the 2L standard.

9.6.1.5 Chemicals of Concern

As discussed in Section 6.6.6, a chemical is identified in this risk assessment as a COC if it is determined to significantly contribute to an unacceptable cumulative risk. More specifically, a chemical is defined as a COC if, at any location for which there is a potentially complete exposure pathway for a given receptor and matrix:

- The cumulative cancer risk estimate is greater than 10^{-4} and the single-chemical cancer risk is greater than 10^{-5}; and/or
- The noncancer HI estimate is greater than 1 and the chemical's HQ is greater than 0.1.

Table 6-17 provides the list of COCs identified by the risk assessment. The COCs are summarized by receptor and exposure media.

9.6.2 **Results of the ERA**

Based on the information developed in the ERA, it is concluded that conditions at the Site do not pose unacceptable risks to ecological populations and communities. The ERA provides a summary of key issues as they may relate to risk management decisions for the Site.

9.7 Areas Retained for the FS

Based on the results of the BRA performed for the Site, the specific areas listed below have been identified as warranting further evaluation for remedial action in the FS.

9.7.1 **Soil**

The following soil areas have been retained for further evaluation in the FS:

- B116-128—location B116SUMPS1, S2, S3, and S4

  Retained due to potentially unacceptable vapor intrusion risks due to 1,2-DCA, vinyl chloride, benzene, 1,1,2-trichloroethane, cyclohexane, and methylene chloride detections in soil.

- Debris Area 1—location Debris Area 1S3

  Retained for the FS not because of unacceptable human health or ecological risks but because alternatives will be evaluated for removal of debris in the area (e.g., drums and rocket parts, as noted in the Phase I Technical Memorandum).

- B109—Former UST location

  Retained due to potentially unacceptable vapor intrusion risks due to 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene detections in soil.

The following soil areas have also been retained for further evaluation in the FS, including utilizing institutional controls to reduce the possibility of residential exposure.

- APDA-7-8-9—locations APDA789B11, APDA789B2, and APDA789B3
- B105-139—locations B105139B4, B5, B7, and B8
- B107—locations B107B3 and B107B6
- B109-137—locations B109137B3, B109137BS1A and SS1A
- B113—locations B113B4, B5, B6 and B8
- B115—locations B115B1 and B2
- B116-128—locations B116128B1, B5, B13, SUMPS1, SUMPS2, SUMPS3, and SUMPS4
- B119-120—locations B119120B1, B3, and B4
- B125-136—locations B125136B2
- B146—location B146B1
- B147—locations B147B2, B5, B7, B9, and S2
- B148—location B148B2
- B149—location B149B5
- B155—location B155B4
- DA23—location DA23B2
- DUMP—location DUMPTP3

9.7.2 **Groundwater**

Areas in both the Front Valley and the Back Valley have been identified and retained for further evaluation in the FS for COPCs in groundwater. Reduction of the concentration of COPCs in these areas will address the direct exposure scenarios detailed in Section 8.6 and minimize the potential for future unacceptable risks from on-Site and off-Site groundwater exposure. The areas, the primary COPCs, and the affected aquifer systems are identified below:

Areas Retained for Further Evaluation for Groundwater

Area Name	COPCs	Aquifer System(s)	Figure(s)
B104	Chloroform	Bedrock	4-25
B113	TCE, PCE, 1,2-DCA, RDX	Surficial and Transition Zone	4-1 through 4-4, 4-7 through 4-10
B114	Perchlorate	Surficial	4-11
B115	TCE, RDX, Perchlorate	Surficial and Transition Zone	4-1, 4-2, 4-9, 4-10, 4-11, 4-12
B116-128	1,2-DCA	Surficial, Transition Zone, and Bedrock	4-7, 4-8, 4-25
B146	TCE	Surficial	4-1
B147 and B105	TCE, RDX, Perchlorate	Surficial and Transition Zone	4-1, 4-2, 4-9 through 4-12
B149	TCE	Transition Zone	4-2
DA23	TCE, PCE, 1,2-DCA, RDX, Perchlorate	Surficial, Transition Zone, and Bedrock	4-1 through 4-4, 4-7 through 4-12, 4-25, 4-26
AP	TCE, PCE, 1,2-DCA, TBA, RDX, Perchlorate	Surficial, Transition Zone, and Bedrock	4-13 through 4-16, 4-19, through 4-26
DA9	TCE, 1,2-DCA, RDX, Perchlorate	Surficial, Transition Zone and Bedrock	4-13, 4-14, 4-19 through 4-26

The FS will also consider the prevention of potable/nonpotable groundwater use exposures by institutional controls.

9.7.3 **On-Site Capped Disposal Areas**

The on-Site capped DAs were addressed consistent with the 1998 ROD and the 1989 ROD Amendment (EPA 1988 and 1989) and contain materials closed in-place. The following on-Site capped DAs will be retained for consideration in the FS:

- DA6
- DA7/8
- DA9
- DA10/11
- DA23
- AP

9.8 Ongoing Site Activities

The Site has been inactive since 1994. The only ongoing authorized Site activities are CERCLA-related remedial activities, occasional utility maintenance/repair work, and security guard patrols.

Daily activities that occur at the Site include maintaining the operating groundwater extraction/treatment systems in the Front Valley and the Back Valley. Maintenance and operation of the extraction/treatment systems includes recording daily flow records and pH measurements of the treatment systems. Routine maintenance of the extraction well network, treatment system, the six capped DAs, and the roads occurs on a 5-day-a-week basis. There are 24-hour manned security operations.

Monthly activities include distribution of monthly billing and compliance reports to MSD per requirements stated in the Permit to Discharge Remediated Water from Groundwater Recovery and distribution of monthly status reports and project schedule to EPA and DEQ. A well inspection is performed each month. Depth-to-water measurements are collected, and the status of well housing and access to 62 wells (including 13 extraction wells) is noted.

Once per quarter, a Site perimeter and sign inspection event occurs that includes walking the Site perimeter and maintaining the Site-specific security signs.

Semiannual compliance samples are collected from the two treatment systems and the metered discharge point and a report is distributed to MSD.

Annually, 18 wells and the two treatment systems are sampled for constituents listed in the ROD and Operations and Maintenance manual. An additional 55 wells are sampled for constituents listed in the 2011 Annual Assessment Monitoring Plan. An inspection of each on-Site well, including groundwater level measurements, is performed each year during the month of April.

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FIGURES

TABLES

APPENDICES