FINAL

REMEDIAL INVESTIGATION REPORT

FOR THE

CENTRAL BURN PITS (RVAAP-49)
AT THE
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

VOLUME 1

PREPARED FOR

US Army Corps of Engineers®

LOUISVILLE DISTRICT

CONTRACT No. GS-10F-0076J
DELIVERY ORDER W912QR-05-F-0033

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LIST OF ACRONYMS

ABS_{GI}	Gastrointestinal adsorption factor
AOC	Area of Concern
amsl	Above Mean Sea Level
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BAFs	Bioaccumulation factors
BCF	Bioconcentration factor
BDL	Below Detection Limits
BGS	Below-Ground Surface
BHHRA	Baseline Human Health Risk Assessment
BRA	Baseline Risk Assessment
CBP	Central Burn Pits
CDI	Chronic daily intake
CELRL	Corps of Engineers, Louisville District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHPPM	Center for Health Promotion and Preventive Medicine
CMS	Corrective Measures Study
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cPAH	Carcinogenic PAHs
CRREL	Cold Regions Research and Engineering Laboratory
C_{sat}	Saturation concentration
CSF	Cancer slope factor
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
DA_{event}	Absorbed Dose per Event
DAF	Dilution and Attenuation Factor

LIST OF ACRONYMS (continued)

DoD	Department of Defense
DNT	Dinitrotoluene
DQO	Data Quality Objective
DUL	Dust Loading Factor
EPC	Exposure Point Concentration
ESV	Ecological Screening Value
EU	Exposure Unit
FCM	Food Chain Modeling
FS	Feasibility Study
ft	feet
FWHHRAM	Facility Wide Human Health Risk Assessment Manual
G	Gram
GAF	Gastrointestinal absorption factor
GOCO	Government Owned Contractor Operator
GSA	U.S. General Services Administration
ha	Hectare
HASP	Health and Safety Plan
HI	Hazard Index
HMX	Octahydro-1,3,5,7-Tetranitro-1,3,5,7-Tetrazocine
HQ	Hazard Quotient
HSA	Hollow Stem Auger
ID	Inside Diameter
IDW	Investigation-Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead
ILCR	Incremental Lifetime Cancer Risk
in	inch
IOC	Industrial Operations Command
IRA	Interim Removal Action

LIST OF ACRONYMS (continued)

IRP	Installation Restoration Program
JMC	Joint Munitions Command
kg	kilogram
L	liter
LOAELS	Lowest-Observed-Adverse-Effects Level
m	meter
MCL	Maximum Contaminant Level
MEC	Munitions and Explosives of Concern
mg	milligram
mg/kg	milligrams per kilogram
mg/L	mailgrams per liter
mi	mile
MI	Mobility index
MKM	MKM Engineers, Inc
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAAQS	National Ambient Air Quality Standards
NAD	No Asbestos Detected
NAPL	Non-aqueous phase liquid
NCEA	National Center for Environmental Assessment
NOAELs	No-Observed-Adverse Effects Level
NPL	National Priority List
NTU	Nephelometric turbidity
OD	Outside Diameter
OEPA	Ohio Environmental Protection Agency
OHARNG	Ohio Army National Guard
ONG	Ohio National Guard
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
OSWER	Office of Solid Waste and Emergency Response

LIST OF ACRONYMS (continued)

OSC	Operations Support Command
PAH	Poly Aromatic Hydrocarbon
PBC	Performance Based Contract
PCB	Poly Chlorinated Biphenyl
PEF	Particulate Emission Factor
PID	Photo Ionization Detector
PPRTV	Provisional Peer Reviewed Toxicity Values
PRG	Preliminary Remediation Goal
PVC	Poly Vinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
QCSR	Quality Control Summary Report
RAIS	Risk Assessment Information System
RBS	Risk-Based Concentration
RBSC	Risk-Based Screening Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
RDI	Recommended Daily Intake
RDX	Hexahydro-1,2,5-Trinitro-1,3,5-Triazine
RGO	Remedial Goal Option
RfC	Reference Concentration
RFD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RRSE	Relative Risk Site Evaluation
RVAAP	Ravenna Army Ammunition Plant

LIST OF ACRONYMS (continued)

SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SERA	Screening Ecological Risk Assessment
SHASP	Site Health and Safety Plan
SOW	Scope of Work
SQL	sample Quantitaion Level
SRC	Site Related Compounds
SSLs	Soil Screening Levels
STSC	Superfund Technical Support Center
SUF	Site Use Factor
SVOC	Semi-volatile Organic Compound
TAL	Target Analyte List
TCL	Target Compound List
TEF	Toxicity Equivalence Factor
TNT	Trinitrotoluene
TOC	Total Organic Carbon
TRW	Technical Review Workgroup
TSCA	Toxic Substances Control Act
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper Confidence Level
UCL-N	Upper Confidence Limit - Normal
UCL-L	Upper Confidence Limit - Lognormal
USACE	U.S. Army Corps of Engineers
USDASCS	U.S Department of Agriculture Soil Conservation Service
USEPA	U.S. Environmental Protection Agency
USCS	Unified Soil Classification System
UTL	Upper Tolerance Level

LIST OF ACRONYMS (continued)

µg/kg	Microgram per kilogram
µg/L	Microgram per Liter
UXO	Unexploded Ordnance
VF	Volatilization Factor
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

This Remedial Investigation (RI) Report characterizes the nature and extent of contamination, evaluates the fate and transport of contaminants, and assesses the risk to human health and the environment, resulting from operations at Central Burn Pits (CBP) at the Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio. CBP was utilized primarily for open burning of non-explosive waste materials and some open disposal of non-hazardous waste material. Actual operation dates for the burn pits is unknown, but the area was believed to have been first utilized shortly after the installation opened and continued through the mid-1970s.

The overall purpose of this RI Report is to describe the investigations completed at CBP at RVAAP, and to define the vertical and horizontal extent of contamination. The specific objectives of the RI are:

- Characterize the sources of contamination at CBP to evaluate remedial actions. Information on source locations, types and amounts, potential releases, physical and chemical properties of wastes present, and engineering characteristics will be evaluated.
- Characterize the nature and extent of contamination at CBP so a baseline risk assessment can be conducted to evaluate the potential threats to human health and the environment and to develop Preliminary Remediation Goals (PRGs), if needed.
- Characterize the physical environment of CBP and its surroundings to the extent necessary to define potential transport pathways and receptor populations and provide sufficient data for preliminary screening of remedial action alternatives.

This RI report was produced to fulfill the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at RVAAP. This information will be used in conjunction with other reports, to prioritize environmental restoration at installation areas of concern (AOC) on the basis of their relative potential threat to human health. Results of the risk assessments will be used to determine whether a "response complete with no further action" is justified or whether further remedial actions will be required.

PAST AND CURRENT INVESTIGATIONS

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) conducted a Relative Risk Site Evaluation for Newly Added Sites at the RVAAP in 1998 (*Hazardous and Medical Waste Study No. 37-EF-5360-99*, 19-23 October 1998). This study indicated CBP a high-priority area of concern (AOC).

The results from the USACHPPM investigation as well as past activities at the site guided the objectives and sampling design of the RI at CBP. As detailed in the *Sampling and Analysis Plan Addendum for the RI at Central Burn Pits (AOC 49)* (MKM, 2001a), the RI objectives were to determine the nature and extent of potential contamination at the site in the following media:

- surface soil;
- subsurface soil;

- surface water;
- groundwater; and
- sediments.

The objectives of the RI were met through the field investigations conducted between June and October 2001. Field investigation included sampling of surface soil, subsurface soil, surface water, groundwater and sediments. Eight soil borings were selected to complete as groundwater monitoring wells. In addition to collecting samples to meet the RI objectives, aquifer testing was conducted at each well to characterize subsurface lithologic conditions.

CONCEPTUAL SITE MODEL

Information gathered during the RI has been used to develop a conceptual model for CBP. The elements for the conceptual model are as follows:

- The topography of CBP consists of gently undulating slopes that increase in elevation from north to south at the site. Elevations range from 292 to 298 m (960 to 980 ft) amsl.
- Low-permeability soil, backfill material and glacial sediments cover much of the ground surface at CBP.
- Groundwater is present in the sandier interbeds found in glacial materials that occur within 4.6 m (15 ft) of the ground surface at CBP. The glacial drift thickness is presumed to range from 9.1 m (30 ft) to over 30.5 m (100 ft) thick. The more permeable sand units may be laterally discontinuous. It is not known whether the monitoring wells installed during the RI are in hydraulic communication with one another. Groundwater is presumed to flow toward the northwest based on the topography of the site and potentiometric surface data.
- Surface water follows the lie of the land across CBP. A topographic high is located in the south of the area with a general south-north trend. Sand Creek is located adjacent to the northwestern boundary of CBP. Runoff flows to and follows a drainage ditch system that empties into Sand Creek.
- Contaminant sources at CBP originate from the residues of open burning and disposal of waste materials from manufacturing operations. Compounds such as explosives, propellants, metals, semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs) may be present.

NATURE AND EXTENT OF CONTAMINATION

The RI evaluated the nature and extent of potential contamination in:

- surface soil (0 to 1 ft);
- subsurface soil (greater than 1 ft bgs);
- groundwater;
- surface water; and
- sediment.

A summation of the analytical results are presented and briefly discussed below.

Soil (0 to 3 ft)

- One explosive compound (2,4,6-trinitrotoluene) was detected in one surface soil sample (SS-010) in each sample interval (0 to 1 ft and 1 to 3 ft). The concentration in the deeper sample was less than that of the surface sample.
- One propellant (nitrocellulose) was detected at five sample locations in the 0 to 1 ft interval. At one sample location (SS-080), nitrocellulose was also detected in the 1 to 3 ft interval. The concentration in the deeper sample was less than that of the surface sample.
- All samples from both intervals had at least one inorganic compound detected that exceeded background and/or PRGs values. Arsenic was the most common analyte present above established criteria. Cyanide exceeded the PRGs in 13 sample locations in the 0 to 1 ft interval and five sample locations from the 1 to 3 ft interval.
- At least one pesticide was detected in three surface sample locations (0 to 1 ft), although none exceeded PRGs. The concentrations in two of the samples were below detection limits.
- Polychlorinated biphenyl (PCB) Aroclor 1254 was detected in 3 surface soil samples (0 to 1 ft). All concentrations were below PRGs.
- No VOCs or SVOCs were detected in any surface soil sample.
- All surface soil samples submitted for asbestos analysis resulted in no asbestos detected (NAD).
- No explosives, VOCs, pesticides or PCBs were detected in any of the surface samples from the nine soil borings completed.
- One surface soil boring sample contained nitrocellulose and nitroguanidine and one sample contained nitrocellulose.
- All surface samples from the soil borings had at least one inorganic that exceeded background or PRGs values.
- One surface soil boring sample contained eight SVOCs, seven of which exceeded background and/or PRG values.

Soil Boring (>3 ft bgs)

- No explosives, propellants, pesticides, PCBs, VOCs, or SVOCs were detected in any of the soil boring samples (>3 ft).
- All eight soil boring samples (>3 ft) contained at least one inorganic above background and/or PRG values.

Sediment

- No explosives, pesticides, or PCBs were detected in any of sediment samples.
- A propellant (nitrocellulose) was detected in two sediment locations.
- All nine sediment samples contained at least one inorganic above background and/or PRG values.
- Acetone was detected in one sediment sample and methylene chloride was detected in another. Neither VOC concentration exceeded background or PRG values.
- Total organic carbon (TOC) was measured in eight sediment samples with a maximum concentration of 57,000 mg/kg (SD-007) and a minimum of 1,100 mg/kg (SD-005).

- Eight SVOCs were detected in one sample (SD-002). All concentrations were below detection limits. One compound, benzo(a)pyrene, was detected above the PRG value.

Surface Water

- All three surface water samples were taken from Sand Creek.
- No explosives, propellants, pesticides, PCBs, VOCs, or SVOCs were detected in any of the surface water samples.
- Calcium and magnesium exceeded their background values in all three surface water samples, and arsenic exceeded the PRG value at two locations.

Groundwater

- No explosives, propellants, pesticides, PCBs, or SVOCs were detected in any of the groundwater samples.
- All eight groundwater samples contained at least one inorganic compound that exceeded background and/or PRG values.
- Acetone was detected in one sample at a concentration that did not exceed its background and/or PRG value.

FATE AND TRANSPORT

The primary contaminant migration pathways of concern for contaminants at CBP are overland runoff and transport in surface drainage channels, including Sand Creek.

BASELINE HUMAN HEALTH RISK ASSESSMENT (BHHRA)

A BHHRA was performed to assess the potential current and future risks associated with human exposure to site-related contaminants found at CBP. Future land uses assumed ownership by the National Guard Bureau for training purposes; use by recreational hunters and fishermen; and use as a residential farm. Risks were evaluated for a National Guard trainee and a National Guards resident/trainer; a hunter/trapper; security maintenance worker; and a resident farmer (adult and child).

Chemicals of Potential Concern (COPCs) were selected and toxicological and exposure factors were applied to evaluate risk. As shown below, the risk assessment demonstrated that some potential risks exist for some of the receptors under specific conditions.

Summary of BHRRA Potential Risk

Receptor	**Non-Carcinogenic**	**Incremental Lifetime Cancer Risk**
Security guard/maintenance worker	HI <1 (no adverse non-carcinogenic health effects)	Within USEPA target risk range of 1E-04 to 1E-06, does not exceed OEPA's target of 1E-05.
Hunter/Trapper	HI <1 (no adverse non-carcinogenic health effects)	<1E-06; does not exceed USEPA or OEPA target risk ranges.
National Guard resident	HI >1 ***only*** if it is assumed that groundwater is used for domestic purposes. Arsenic the primary driver.	Exceeds USEPA target risk only if shallow groundwater is used for domestic purposes; exceeds OEPA target risk value. Arsenic is primary risk driver.
National Guard trainee	HI >1 for surface soil. Risk is driven by inhalation of manganese. HI for no other contaminant exceeded 1. See the Uncertainty section.	Within USEPA target risk range of 1E-04 to 1E-06. Arsenic is primary risk driver.
Adult resident farmer	HI>1 for all media combined ***only*** if it is assumed that receptor is using shallow groundwater for domestic purposes. See the Uncertainty section.	Not applicable
Child resident farmer	HI >1 for groundwater, surface soil, and subsurface soil. However, target-organ specific HI > 1 ***only*** if it is assumed that groundwater is used for domestic purposes and the ingestion of foodstuffs pathways are evaluated. Arsenic is the primary risk driver. See the Uncertainty discussion.	Not applicable
Lifelong resident farmer	Not applicable.	Exceeds USEPA target risk range only if it is assumed that shallow groundwater is used for domestic purposes. Exceeds OEPA target risk value. Arsenic is primary driver.

Several significant uncertainties associated with the risk assessment were identified as outlined in Section 6.7 and must be considered carefully when making risk management decisions for the CBP.

SCREENING ECOLOGICAL RISK ASSESSMENT (SERA)

A Screening Ecological Risk Assessment (SERA) was performed to assess whether adverse ecological impacts are present at CBP as a result of site-related contaminants detected.

To complete the SERA, initially, potential receptor groups were identified and complete exposure pathways defined. Next the contaminant concentrations detected were compared to ecological screening values (ESVs) to select COPCs. Finally the COPCs were refined through food chain modeling for mammals and birds, while also considering other factors such as suitable habitat and spatial distribution of contaminants.

Ecological impact was evaluated for plants; soil and sediment invertebrates; aquatic organisms; and terrestrial wildlife. Three types of mammals and birds were evaluated: insectivores/herbivores, carnivores, and piscivores. The ecological risk calculations showed:

Summary of SERA Potential Risk

Type of Species	Screening Results	Notes
Terrestrial plants and soil invertebrates	Copper, lead and zinc retained as COPC's.	Several COPCs, though not retained, are potentially bioaccumulative, so they were evaluated further in wildlife.
Sediment Invertebrates	No COPC's retained.	None of the COPCs were bioaccumulative, so no further evaluation was conducted.
Aquatic Organisms	No COPC's retained.	None of the COPCs were bioaccumulative, so no further evaluation was conducted.
Terrestrial Wildlife – Carnivores	Conservative scenario and NOAEL resulted in no chemicals having an HQ >1. No COPCs retained.	Because conservative scenario and NOAEL did not result in HQ >1, the risk was determined to be acceptable.
Terrestrial Wildlife – Insectivores/ Herbivores	Average scenario and NOAEL resulted in HQ>1 for: arsenic (vole and shrew); lead (robin and shrew), cadmium, chromium, and zinc (robin only)	Because conservative bioavailability assumptions were made, few LOAEL exceedances, lack of habitat in areas with greatest chemical concentrations, and similarity of site average concentrations to background concentrations, risks were determined to be acceptable.

RECOMMENDATIONS

Conservative toxicity and exposure values were used to calculate the potential risk. The BHHRA indicated a potential risk to a National Guard trainee due to exposure to manganese via the inhalation exposure pathway. The risk estimates presented likely overestimate the actual potential for non-carcinogenic risk. Additionally, the manganese concentrations detected may represent background conditions. It is recommended that the risk management team carefully consider the need for further investigation or remedial action based on the risk assessment results for this receptor taken at face value.

RVAAP's risk management team should evaluate the need for institutional controls such as deed restrictions to limit the future use of the CBP area. Deed restrictions can be used to prevent residential and/or farmland use in the future. The same mechanism can be used to prevent the use of shallow groundwater for domestic purposes. Additionally, the uncertainties presented in Section 6.7 of this RI should be carefully considered in the overall risk management decisions that are made for CBP.

For example, the primary risk driver for groundwater at CBP is arsenic. However, arsenic is a naturally occurring metal and was detected in soils and groundwater at concentrations similar to or slightly above RVAAP background criteria but within the range of naturally occurring background. The RVAAP background benchmarks reported arsenic concentrations ranging from 11 ug/L (filtered overburden) to 215 ug/L (unfiltered overburden). The maximum arsenic concentration detected in CBP monitoring wells was 35.1 ug/L (filtered overburden).

During the RI, debris piles/berms of soil like materials were observed in the west and north portions of the CBP AOC. These were not evaluated during this RI, recommend characterization of these debris piles/berms be conducted.

1.0 INTRODUCTION

This report documents the results of the Remedial Investigation (RI) at Central Burn Pits (CBP) which is located at the U. S. Army's Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio (Figure 1-1). The RI field activities and the preliminary draft of the RI Report were conducted on behalf of the U.S. Department of Defense (DoD) by MKM Engineers, Inc. (MKM) and their subcontractors, under contract number DAAA09-98-G-0001 with the Joint Munitions Command (JMC). The RI Report is being completed on behalf of the United States Army Corps of Engineers (USACE) in accordance with United States General Services Administration (GSA) Environmental Advisory Services Contract GS-10-F-0076J (Delivery Order W912QR-05-F-0033) under a Performance Based Contract (PBC). The RI was performed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 following work plans reviewed and approved by the Ohio Environmental Protection Agency (Ohio EPA).

This document summarizes the findings of the field activities conducted between June and August 2001 at CBP. The environmental setting, field program, and nature and extent of contamination are discussed in this document. Human health and ecological risk assessments were performed as part of the RI and are presented in this report. Results of the data analysis and risk assessments were used to develop a revised conceptual model for CBP to support the investigation summary and conclusions that are the framework for decisions regarding future IRP and CERCLA actions at CBP.

1.1 PURPOSE AND SCOPE

The purposes of the RI Report are to describe the investigations conducted at CBP at RVAAP; evaluate and identify the environmental impact posed by past operations; and confirm or refute the existence of contamination at concentrations exceeding remedial goals or that pose an unacceptable risk to human health or the environment. The specific objectives of the RI are as follows:

- Characterize the physical environment of CBP and its surroundings to the extent necessary to define potential transport pathways and receptor populations.
- Characterize the nature and extent of contamination at CBP so a baseline risk assessment can be conducted to evaluate the potential threats to human health and the environment and to develop Preliminary Remediation Goals (PRGs), if needed.
- Provide sufficient data and information from the RI and risk assessments to facilitate the evaluation of remedial action alternatives. Information such as source locations, types and amounts of contaminants, potential releases, physical and chemical properties of wastes present, and engineering characteristics shall be evaluated.

Investigation-specific objectives were developed using the Data Quality Objective (DQO) approach presented in the Facility Wide Sampling and Analysis Plan (SAP) for Ravenna Army Ammunition Plant (USACE, 1996).

The investigative approach to the RI at CBP involved a combination of field and laboratory activities to characterize the area of concern (AOC). Field investigation techniques included surface soil sampling; soil boring and sampling; monitoring well installation and groundwater sampling; aquifer testing; and surface water and sediment sampling. The field program was conducted in accordance with the Facility Wide SAP (USACE, 1996), the SAP Addendum for the Remedial Investigation at Central Burn Pits (AOC 49) (MKM, 2001a), and the Final Work Plan for Remedial Investigation Central Burn Pits (MKM, 2001b).

1.2 BACKGROUND INFORMATION

This section briefly describes the RVAAP installation and the CBP, previous investigations, and regulatory guidance followed when conducting this RI.

1.2.1 General Site Description

RVAAP is a 1,481-acre portion of the 21,419-acre Ravenna Training and Logistics Site (RTLS) of the Ohio Army National Guard (OHARNG). A total of 19,938 acres of the former 21,419-acre RVAAP was transferred to the United State Property and Fiscal Officer (USP&FO) for Ohio in 1996 and 1999 for use by the OHARNG as a military training site. The current RVAAP consists of 1,481 acres in several distinct parcels scattered throughout the confines of the Ohio Army National Guard (OHARNG) Ravenna Training and Logistics Site (RTLS). The RVAAP and RTLS are co-located on contiguous parcels of property and the RTLS perimeter fence encloses both installations. Since the Installation Restoration Program (IRP) encompasses past activities over the entire 21,419 acres of the former RVAAP, the site description of the RVAAP includes the combined RTLS and RVAAP properties. The RVAAP was previously operated as a government-owned, contractor-operated (GOCO) U.S. Army facility. Currently, the installation is jointly operated by the U.S. Army Rock Island BRAC Field Office and the OHARNG.

The RVAAP is located within the confines of the RTLS which is in northeastern Ohio within Portage and Trumbull counties, approximately 4.8 kilometers (3 miles) east northeast of the town of Ravenna and approximately 1.6 kilometers (1 mile) northwest of the town of Newton Falls. The RVAAP portions of the installation are solely located within Portage County. The installation consists of a 17.7-kilometer (11-mile) long, 5.6-kilometer (3.5-mile)-wide tract bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad on the south; Garrett, McCormick and Berry roads on the west; State Route 534 to the east, and the Norfolk Southern Railroad on the north (see Figures 1-1 and 1-2). The installation is surrounded by several communities: Windham on the north, Garrettsville 9.6 kilometers (6 miles) to the northwest, Newton Falls 1.6 kilometers (1 mile) to the east, Charlestown to the southwest, and Wayland 4.8 kilometers (3 miles) southeast.

Industrial operations at RVAAP consisted of 12 munitions-assembly facilities referred to as “load lines.” Load Lines 1 through 4 were used to melt and load 2,4,6-trinitrotoluene (2,4,6-TNT) and Composition B into large-caliber shells and bombs. The operations on the load lines produced explosive dust, spills, and vapors that collected on the floors and walls of each building. Periodically, the floors and walls were cleaned with water and steam. The liquid, containing 2,4,6-TNT and Composition B, was known as “pink water” for its characteristic color. Pink water was collected in concrete holding tanks, filtered, and pumped into unlined ditches for transport to earthen settling ponds. Load Lines 5 through were used to manufacture fuzes, primers, and boosters. Potential contaminants in these load lines include lead compounds, mercury compounds, and explosives. From 1946 to 1949, Load Line 12 was used to produce ammonium nitrate for explosives and fertilizers prior to its use as a weapons demilitarization facility.

In 1950, the facility was placed in standby status and operations were limited to renovation, demilitarization, and normal maintenance of equipment, along with storage of munitions. Production activities were resumed during the Korean Conflict (July 1954 to October 1957) and again during the Vietnam Conflict (May 1968 to August 1972). In addition to production missions, various demilitarization activities were conducted at facilities constructed at Load Lines 1, 2, 3, and 12. Demilitarization activities included disassembly of munitions and explosives melt-out and recovery operations using hot water and steam processes. Periodic demilitarization of various munitions continued through 1992.

In addition to production and demilitarization activities at the load lines, other facilities at RVAAP include sites that were used for the burning, demolition, and testing of munitions. These burning and demolition grounds consist of large parcels of open space or abandoned quarries. Potential contaminants at these AOCs include explosives, propellants, metals, waste oils, and sanitary waste. Other types of AOCs present at RVAAP include landfills, an aircraft fuel tank testing facility, and various general industrial support and maintenance facilities.

1.2.2 Site Description and History

CBP is located in the east-central area of the facility on Paris-Windham Road at the intersection of Lumber Yard Road (Figure 1-3). The site is approximately 47 acres in size and was originally used as a lumber and building materials storage area. CBP was later utilized for open burning of non-explosive waste material, electrical components, wooden boxes, and scrap and the disposal of other non-hazardous waste material. The actual period of operation of the burn pits is unknown but it is believed to have begun shortly after the installation opened and continued into the mid-1970s. CBP is bounded by Paris-Windham Road to the east, old railroad beds to the north (Track 39) and south (Track 33), and Sand Creek to the west-northwest.

Based on preliminary site assessments, three main, negatively impacted areas were identified within the confines of the site. Two burn areas (100 ft x 70 ft and 250 ft x 90 ft) were noted on the eastern portion of the site just north of Lumber Yard Road; each characterized by distressed vegetation, scattered debris and scrap articles. The third area (150 ft x 200 ft), which exhibits discolored soil and some distressed vegetation and debris is also on the eastern portion of the site but is positioned just north of Lumber Yard Road. The types of debris and scrap materials identified within the burn areas include:

- Small pieces of transite siding (<2 ft^2 in size);
- Rubble (i.e., small stones and cinders);
- Scrap metal items including small scrap steel pieces, molten lead and rusted drums (empty);
- Miscellaneous debris composed of rubber, glass, ceramic and plastic; and
- Railroad ties, wooden debris and naturally occurring tree components.

The main burn areas were the focus of this RI.

A 12-inch vitrified tile sanitary sewer main traverses CBP from south to north. This line was the main to the Sand Creek treatment plant and was fed by a 6-inch cast iron force main from Load Lines 1, 2, 3, and 12 to the east and a 12-inch vitrified tile main from Load Line 4 and Atlas Yard to the south/southwest. There are no indications that the CBP contributes to the sanitary sewer main; therefore, no investigation of the sanitary sewer was included in this RI.

During the investigation numerous debris piles/berms of soil like materials were observed in the west and north portions of the AOC. The origin of the materials is unknown. The investigation and characterization of these debris piles/berms was not included in the original scope of work and therefore, not addressed in this report. These materials will be evaluated during the Fall of 2005 and results will be presented in the Feasibility Study (FS) report.

1.2.3 Previous Investigations

One previous investigation that included collecting/analyzing environmental samples for metals, explosives, and organic constituents was completed at the CBP. Surface soil samples and one subsurface sample were collected within the main burn areas. The samples contained elevated levels of several metals including copper and lead. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) conducted a Relative Risk Site Evaluation for newly added sites at the RVAAP in 1998 (Hazardous and Medical Waste Study No. 37-EF-5360-99, 19-23 October 1998 [USACHPPM, 1998]). From the 13 sites evaluated, five were classified as high-priority AOCs including the CBP. The report indicates that hunters and trespassers are potential receptors for exposure to soil contamination.

1.2.4 Regulatory Authorities

The approach to addressing environmental conditions at RVAAP is regulatory-based following the frameworks established by primary regulatory drivers including CERCLA, Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA), and applicable State environmental regulations.

1.3 REPORT ORGANIZATION

This RI Report is organized to meet Ohio EPA requirements in accordance with U.S. Environmental Protection Agency's (USEPA's) CERCLA Superfund process and USACE guidance. The remainder of this report contains:

- Section 2.0 – physical setting of the study area;
- Section 3.0 – data collection methodologies and data management programs;
- Section 4.0 – results of the RI including the nature and extent of contamination;
- Section 5.0 – fate and transport of the contaminants of concern;
- Section 6.0 – baseline human health risk assessment (BHHRA);

- Section 7.0 – screening ecological risk assessment (SERA);
- Section 8.0 – results and conclusions;
- Section 9.0 – recommendations; and
- Section 10.0 – references.

The appendices contain RI support data and information including boring logs, well construction diagrams, analytical data tables, data quality assessments, a quality assurance summary, risk assessment data tables and other detailed information used to make interpretations presented herein.

2.0 ENVIRONMENTAL SETTING AT RVAAP

This section describes the physical characteristics of CBP and its adjacent environment that are factors in interpreting the potential contaminant transport pathways, receptor populations, and exposure scenarios with respect to the evaluation of human health and ecological risks.

2.1 SURFACE FEATURES

The topography at CBP is characterized by gently undulating contours that decrease in elevation from a local topographic high in the southeast portion of the AOC. Elevations vary from 292 to 298 m (960 to 980 ft) amsl across the AOC (Figure 1-3). The relatively flat topography across the majority of the CBP is the result of historical grading and fill activities that were used during the development of the AOC.

USACE mapped the installation topography in February 1998 using a 5.1-cm (2-ft) contour interval with an accuracy of 0.51 mm (0.02 foot). USACE based the topographic information on aerial photographs taken during spring 1997. This survey is the basis for the topography illustrated in figures within this RI report.

2.2 METEOROLOGY AND CLIMATE

RVAAP is located in a humid continental climate characterized by warm, humid summers and cold winters. Precipitation varies widely throughout the year. The driest month is February (on average) and the wettest month is July. Data from the National Weather Service compiled from 1951 to 1998 indicate that the average rainfall for the area is 98.3 cm (38.72 in) annually. The average snowfall is 107.7 cm (42.4 in) annually.

2.3 SURFACE WATER HYDROLOGY

A topographic high is located near the southwestern portion of the site, which decreases towards the north. Sand Creek is located adjacent to the northwestern boundary of CBP. Surface water intermittently flows in several drainage ditches located on site (see Figure 1-3). The drainage ditches generate flow mainly from surface water runoff and precipitation events following the topography of the AOC. Eventually, the majority of surface water drains to Sand Creek. The ditches tend to hold water for extended periods due to the low permeability of most soil at CBP.

The RVAAP-wide drainage feeds the West Branch of the Mahoning River, located just west of the installation. The West Branch of the Mahoning River in turn flows to the Michael J. Kirwan Reservoir, immediately south of RVAAP across State Highway 5.

2.4 GEOLOGY

Lithologic logs from eight borings, advanced during the RI and completed as monitoring wells, were used to characterize the surface and subsurface geology at CBP. The boring logs, which detail the vertical lithologic sequences, are found in Appendix A.

2.4.1 Glacial Deposits

RVAAP is located within the Glaciated Allegheny Plateau physiographic region of Ohio. Pennsylvanian bedrock is overlain by Wisconsinian-Age glacial deposits. The Lavery Till is found in the western part of the installation and the younger Hiram Till is found in the remaining eastern portion, where CBP is located (Figure 2-1).

The Hiram Till has the highest clay content of tills in northeastern Ohio (White, 1982). Unweathered Hiram Till is dark gray and turns a dark brown when exposed to the atmosphere. Soil associated with the Hiram Till at RVAAP includes the Mahoning silt loam complex.

The thickness of the glacial deposits varies across the installation. Other RVAAP documents have stated that a buried valley may cut across part of the installation. However, no presence of the valley has been discovered during investigation activities to date.

Subsurface lithology at CBP consists mostly of clay to sand-rich silt tills with interbedded sands scattered throughout. These deposits are generally firm, moderately plastic, and tend to hold water where encountered. Deposits with higher concentrations of sand and gravel generally control the elevation of the shallow water table zone, and bio-turbation has been observed to act as a conduit for the local shallow water table at various locations at CBP. Cross-sections of the subsurface at CBP illustrate the lateral distribution and variation of these discontinuous glaciated sediments (Figures 2-2 to 2-6).

2.4.2 Sedimentary Rocks

Bedrock outcrops at several areas across RVAAP. According to general geological documents published by the State of Ohio, the Sharon Member of the Pennsylvanian Pottsville Formation is believed to be the underlying bedrock beneath CBP (USACE, 2001).

2.5 SOIL

According to the Soil Survey of Portage County, Ohio (USDASCS, 1978) RVAAP soils are described as being nearly level to gently sloping, and are poor to moderately well drained.

Four soil types are found at CBP and adjacent areas: the Mahoning silt loam (0-2% and 2-6% slopes), Trumbull silt loam (0-2% slopes) and Ellsworth silt loam (6-12% slopes). The Ellsworth silt loam is found near the southwestern boundary of the AOC. Sloped soil along drainage pathways, rapid runoff, and severe erosion are characteristics of the Ellsworth silt loam. The Trumbull silt loam is found in the eastern portion of the AOC. Nearly level along drainage pathways and deep, poorly drained soil characterize the Trumbull silt loam. The Mahoning silt loam covers the remainder of CBP (western and extreme eastern boundary). The Mahoning silt loam is characterized by more gently sloped land with medium to rapid runoff with severe seasonal wetness and slow permeability.

2.6 HYDROGEOLOGY

This section describes the unconsolidated sediments and bedrock characteristics found at RVAAP and the CBP.

2.6.1 Unconsolidated Sediments

Saturated sands and gravels are found within the glacial outwash and buried valley sediments in Portage County. Wells drilled into these saturated zones may provide sufficient potable water for residential use. These shallow zone aquifers are recharged from infiltration of surface water (streams, ponds, etc.) and precipitation.

2.6.2 Bedrock

The Sharon Conglomerate bedrock was the primary source of potable groundwater at RVAAP during its active phase. Most facility production wells were completed in this unit, although some wells were completed in the overlying Sharon Shale. The highest yields were determined to come from the quartz-pebble conglomerate facies and from jointed and fractured zones. Bedrock was not encountered when installing the CBP monitoring wells.

2.7 DEMOGRAPHY AND LAND USE

The population centers closest to RVAAP include the city of Ravenna (population 11,771), located approximately 4.8 kilometers (3 miles) from the installation, and the city of Newton Falls (population 5,002), located approximately 1.6 km (1 mi) from the southeastern installation boundary in Trumbull County. Other nearby population centers include Windham to the north, Garrettsville 9.6 kilometers (6 miles) to the northwest, Charlestown to the southwest, and Wayland 4.8 kilometers (3 miles) to the southeast. According to the 2000 Census, the total populations of Portage and Trumbull counties were 152,061 and 225,116, respectively. Larger towns near RVAAP include Akron (west-southwest) and Youngstown (east-southeast).

The RVAAP installation is located in a rural area, and is not close to any major industrial or other developed areas. Based on data from the United States Census Bureau (1992) and the Portage County Soil and Water Conservation District Resources Inventory (1985), approximately 55 percent of Portage County, in which a majority of RVAAP acreage is located, consists of either woodland or farmland acreage. Grass, shrubs, and small trees are found at CBP. The Michael J. Kirwan Reservoir (also known as the West Branch Reservoir) is the closest major recreational area and is located nearest to the western half of RVAAP south of State Route 5.

2.8 ECOLOGY

Before the government acquired the property in the 1940s, much of the land at RVAAP, including CBP, was cleared for agricultural use. Over 80 percent of RVAAP is now forest. The limited field cover growth is the result of earlier agricultural practices that left these sites with poor top soil that still limits forest regeneration. Several thousand acres of agricultural fields were planted with trees during the 1950s and 1960s, but these plantings did not take well in areas with poor topsoil. Some fields, leased for cattle grazing during the same period, were subsequently delayed in their reversion to forest. A few fields have been brush hogged, maintaining them as old field.

Portions of the installation satisfy the regulatory definition of jurisdictional wetland. Wetland areas at RVAAP include seasonally saturated wetlands, wet fields, and forested wetlands. Most of these wetland areas exist because of poorly drained and hydric soil. Beaver impoundments contribute to wetland diversification on the site.

The flora and fauna presented at RVAAP are varied and widespread. A total of 18 plant communities have been identified on facility property including marsh, swamp, and forest communities. Sixteen plant species listed as Ohio State Potentially Threatened have been identified at RVAAP:

- Gray Birch;
- Round-leafed Sundew;
- Closed Bentian;
- Butternut;
- Blunt Mountain-Mint;
- Northern Rose Azalea;
- Large Cranberry;
- Hobblebush;
- Long Beech Fern;
- Woodland Horsetail;
- Weak Sedge;
- Straw Sedge;
- Water Avens;
- Tall St. John's Wort;
- Swamp Oats; and
- Shining Ladies'-tresses.

A complete list of all rare species (plant and animal) found on RVAAP is provided in Appendix B.

A large variety of animals have been identified on installation property including 26 species of mammals, 143 species of birds, and 41 species of fish. Animal species listed as Ohio State Endangered (1999 inventory) include the Northern Harrier, Common Barn-Owl, Yellow-Bellied Sapsucker, Mountain Brook Lamprey, Graceful Underwing, Little Blue Heron, American Bittern, Canada Warbler, Osprey, and the Trumpeter Swan. Several animal species present at RVAAP are also listed as Ohio State Special Concern. These include:

- Sora;
- Virginia Rail;
- Four-toed Salamander;
- Smooth Green Snake;
- Woodland Jumping Mouse;
- Sharp-shinned Hawk;
- Solitary Vireo;
- Pygmy Shrew;
- Star-nosed Mole;
- Red-shouldered Hawk;
- Henslow's Sparrow;
- Cerulean Warbler;
- Common Moorhen; and
- Eastern Box Turtle.

Restricted land use and sound forest management practices have preserved and enabled large forest tracts to mature. Habitat conversion at RVAAP has focused on restoration of the forests that covered the area prior to its being cleared for agriculture. The reversion of these agricultural fields to mature forest provides a diversity of habitats from old field through several successional stages. Overall, the trend towards forest cover enhances the area for use by forest species, both plant and animal. Future IRP activities will require consideration of these species to ensure detrimental effects on threatened or endangered RVAAP flora and fauna do not occur. This will be discussed in the Ecological Risk Assessment presented in Section 7.0. There are no federal, state, or local parks or protected areas on RVAAP facility property.

3.0 CENTRAL BURN PITS INVESTIGATION

This section describes the field and analytical methods implemented during the RI. The field and analytical programs were conducted in accordance with the RVAAP Facility Wide SAP (USACE, 1996), the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (2001b). Investigation objectives, rationale for sampling locations, sampling methods, and sampling locations are briefly discussed in this section.

3.1 RI FIELD ACTIVITIES

Field activities conducted between June through October 2001 included:

- Conducting a munitions and explosives of concern (MEC) avoidance screen before field activities were initiated;
- Collecting surface soil samples;
- Collecting subsurface soil samples;
- Installing eight monitoring wells;
- Conducting well slug tests;
- Collecting groundwater samples from monitoring wells;
- Collecting surface water samples from drainage pathways; and
- Collecting sediment samples from drainage pathways.

Table 3-1 summarizes the types and numbers of samples that were collected, collection method, rationale for collecting the samples, and the analyses conducted on the samples.

Sampling points for the RI were located to assess the impact that CBP operations may have had on soil, sediment, surface water, and groundwater; and to evaluate where contaminants related to the former processes may have impacted the AOC. The following sections describe the rationales for and methods of sample collection during the RI. Photographs of the RI activities are provided in Appendix C. Investigation objectives, sampling methods, and sampling locations and rationale are briefly described.

Before initiating any field activities, a MEC survey was conducted to ensure worker safety during the RI investigation. Unexploded ordnance (UXO) personnel surveyed all areas where personnel and/or equipment might traverse. All anomalies were noted and safe pathways were established. Appendix D contains the MEC Avoidance Summary Report.

Table 3-1. Summary of Sampling and Analysis

Sample Type	Quantity	Collection Method	Sample Numbers	Sample Depths	Rationale	Laboratory Parameters
Soil						
Soil (0 to 3 ft)	63 total (2 samples from 29 locations, 1 sample from 5 locations)	Hand Auger	SS001-SS034	0-1' bgs, 1-3' bgs	Assess potential impact to surface soil	Explosives, TAL Metals, Cyanide, Asbestos, PCBs & Pesticides[1]
Soil Borings						
Soil Borings	17 total (2 samples from each of the 8 completed borings, 1 sample from the boring that had refusal)	Hand auger (first interval), Drill Rig/Split Spoon (second interval)	SB001-SB008, and SB003a	0-1' bgs, >3' bgs	Characterize potential sources of subsurface contamination	Explosives, TAL Metals, Cyanide & PCBs[1]
Groundwater						
Groundwater	8 total (1 sample from each monitoring well)	Micro-purging	MW001-MW008	Not applicable	Establish background groundwater quality and assess potential impact to groundwater from the Central Burn Pits	VOC, SVOC, Explosives, Propellants, TAL Metals, Cyanide, & PCBs/Pesticides
Surface Water						
Surface Water	3 total	Submersion	SW005, SW006, SW008	Not applicable	Assess surface water quality	Explosives, TAL Metals & Cyanide[1]
Sediment						
Ditch Sediment	9 total	Hand Auger, Scoop or Trowel	SD001-SD009	0-0.5' bgs	Characterize potential impact to surface soil	Explosives, TAL Metals, Cyanide, TOC & Grain Size[1]

[1] 10% of these samples were analyzed for propellants, VOCs, SVOCs, pesticides, and PCBs as indicated in the Revised 2001 Facility-Wide Sampling and Analysis Plan for RVAAP.

3.1.1 Soil Sampling

Soil samples were collected from the surface (0 to 1 ft interval) and subsurface (> 1 ft). The types of soil samples collected, the sampling interval (if applicable), and the rationale for sampling are listed below in Table 3-2.

Table 3-2. Soil Sampling Intervals

Sample Type	Sampling Interval	Rationale for Actual Depth
Surface Soil	0 to 1 ft	Predetermined depths specified in the work plan
Subsurface Soil	> 1 ft	Predetermined depths specified in the work plan
Monitoring Well Boreholes	1st Interval: 0 to 1 ft 2nd Interval: Varied	Predetermined depth specified in the work plan Immediately above saturated zone or headspace reading

3.1.1.1 Soil Samples (0 to 3 ft)

Soil sampling from 0 to 1 m (0 to 3 ft) was performed to:

- assess the potential impact to the surrounding soil from CBP activities;
- evaluate soil conditions outside the main open burn/open detonation areas; and
- determine the extent of identified contamination (if present).

The soil locations were selected with consideration to site history and topography. Soil samples were not collected to evaluate the numerous stockpiles of soil like materials staged on the west and north portions of the AOC. Thirty-four soil sample locations were identified at CBP (Figures 3-1 and 3-2). Twenty-eight of the samples were biased towards evidence (historical and visual) of past activities at this AOC. Visual evidence included remnants of past operations, stressed vegetation, and/or surface water flow pathways. Six of the sample locations were randomly selected from grids outside the former open burning areas, but within the confines of the perimeter of the site, to define the lateral extent of potential contamination.

The soil samples were collected using the bucket hand auger method as described in section 4.5.2.1.1 of the Facility Wide SAP for RVAAP (USACE, 2001). Two samples were collected at each sample point when possible. The first sample was collected as a surface soil sample from a depth interval of 0 to 0.3 m (0 to 1 ft) and the second was collected as a subsurface soil sample from a depth interval of 0.3 to 0.9 m (1 to 3 ft). Thirty-four surface soil samples were collected from the 0 to 0.3 m (0 to 1 ft) bgs interval (Figure 3-1) and 29 subsurface soil samples were collected from the 0.3 to 0.9 m (1 to 3 ft) bgs interval (Figure 3-2). The reduction in the number of samples collected in the 0.3 to 0.9 m (1 to 3 ft) bgs interval was due to auger refusal.

Table 3-1 listed the analyses to be completed for the soil samples. In addition, seven split samples were collected by the Ohio EPA. Table 3-3 summarizes the surface (0 to 0.3 m) and subsurface (0.3 to 0.9 m) soil samples collected.

Soil samples were immediately placed into a cooler containing ice. Each cooler submitted to the laboratory was accompanied by a completed chain-of-custody form. Field sampling forms documenting the sampling activities are presented in Appendix E. Soil analytical results from 0 to 3 ft are presented in Appendix F.

Table 3-3. Summary of Surface (0 to 1 ft) and Subsurface (1 to 3 ft) Soil Samples for the Central Burn Pits Remedial Investigation

Facility/Building No.	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Surface Soil Samples						
Central Burn Pits	0-1	CBP	CBPSS-001-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-002-001-SO	Yes	8/13/2001	----
Central Burn Pits	0-1	CBP	CBPSS-003-001-SO	Yes	9/5/2001	----
Central Burn Pits	0-1	CBP	CBPSS-004-001-SO	Yes	9/4/2001	----
Central Burn Pits	0-1	CBP	CBPSS-005-001-SO	Yes	9/4/2001	----
Central Burn Pits	0-1	CBP	CBPSS-006-001-SO	Yes	9/6/2001	----
Central Burn Pits	0-1	CBP	CBPSS-007-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-008-001-SO	Yes	8/13/2001	----
Central Burn Pits	0-1	CBP	CBPSS-009-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-010-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-011-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-012-001-SO	Yes	9/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-013-001-SO	Yes	9/5/2001	----
Central Burn Pits	0-1	CBP	CBPSS-014-001-SO	Yes	9/6/2001	----
Central Burn Pits	0-1	CBP	CBPSS-015-001-SO	Yes	9/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-016-001-SO	Yes	9/4/2001	----
Central Burn Pits	0-1	CBP	CBPSS-017-001-SO	Yes	9/4/2001	----
Central Burn Pits	0-1	CBP	CBPSS-018-001-SO	Yes	9/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-019-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-020-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-021-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-022-001-SO	Yes	8/31/2001	----
Central Burn Pits	0-1	CBP	CBPSS-023-001-SO	Yes	9/6/2001	----
Central Burn Pits	0-1	CBP	CBPSS-024-001-SO	Yes	9/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-025-001-SO	Yes	8/30/2001	----
Central Burn Pits	0-1	CBP	CBPSS-026-001-SO	Yes	8/8/2001	----
Central Burn Pits	0-1	CBP	CBPSS-027-001-SO	Yes	8/8/2001	----
Central Burn Pits	0-1	CBP	CBPSS-028-001-SO	Yes	8/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-029-001-SO	Yes	9/5/2001	----
Central Burn Pits	0-1	CBP	CBPSS-030-001-SO	Yes	8/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-031-001-SO	Yes	8/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-032-001-SO	Yes	9/5/2001	----
Central Burn Pits	0-1	CBP	CBPSS-033-001-SO	Yes	8/7/2001	----
Central Burn Pits	0-1	CBP	CBPSS-034-001-SO	Yes	8/7/2001	----
Subsurface Soil Samples						
Central Burn Pits	1-3	CBP	CBPSS-001-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-002-002-SO	No	----	Not collected due to auger refusal
Central Burn Pits	1-3	CBP	CBPSS-003-002-SO	Yes	9/5/2001	----
Central Burn Pits	1-3	CBP	CBPSS-004-002-SO	Yes	9/4/2001	----

Table 3-3. Summary of Surface (0 to 1 ft) and Subsurface (1 to 3 ft) Soil Samples for the Central Burn Pits Remedial Investigation (continued)

Facility/Building No.	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Central Burn Pits	1-3	CBP	CBPSS-005-002-SO	Yes	9/4/2001	----
Central Burn Pits	1-3	CBP	CBPSS-006-002-SO	No	----	Not collected due to auger refusal
Central Burn Pits	1-3	CBP	CBPSS-007-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-008-002-SO	Yes	8/13/2001	----
Central Burn Pits	1-3	CBP	CBPSS-009-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-010-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-011-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-012-002-SO	Yes	9/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-013-002-SO	No	----	Not collected due to auger refusal
Central Burn Pits	1-3	CBP	CBPSS-014-002-SO	Yes	9/6/2001	----
Central Burn Pits	1-3	CBP	CBPSS-015-002-SO	Yes	9/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-016-002-SO	No	----	Not collected due to auger refusal
Central Burn Pits	1-3	CBP	CBPSS-017-002-SO	Yes	9/4/2001	----
Central Burn Pits	1-3	CBP	CBPSS-018-002-SO	Yes	9/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-019-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-020-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-021-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-022-002-SO	No	----	Not collected due to auger refusal
Central Burn Pits	1-3	CBP	CBPSS-023-002-SO	Yes	9/6/2001	----
Central Burn Pits	1-3	CBP	CBPSS-024-002-SO	Yes	9/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-025-002-SO	Yes	8/30/2001	----
Central Burn Pits	1-3	CBP	CBPSS-026-002-SO	Yes	8/8/2001	----
Central Burn Pits	1-3	CBP	CBPSS-027-002-SO	Yes	8/8/2001	----
Central Burn Pits	1-3	CBP	CBPSS-028-002-SO	Yes	8/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-029-002-SO	Yes	9/5/2001	----
Central Burn Pits	1-3	CBP	CBPSS-030-002-SO	Yes	8/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-031-002-SO	Yes	8/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-032-002-SO	Yes	9/5/2001	----
Central Burn Pits	1-3	CBP	CBPSS-033-002-SO	Yes	8/7/2001	----
Central Burn Pits	1-3	CBP	CBPSS-034-002-SO	Yes	8/7/2001	----

3.1.1.2 Soil Boring Samples

Soil boring samples were collected to:

- assess the potential impact of CBP activities on the surrounding soil;
- characterize the soil outside the main open burn/open detonation areas; and
- determine the horizontal and vertical extent of identified contamination (if present).

Soil samples were collected from nine soil borings used to subsequently install monitoring wells. Sample locations are illustrated in Figure 3-3 and 3-4. Two samples from each soil boring were collected. The first sample was a surface soil sample taken at the 0 to 0.3 m (0 to 1 ft) bgs interval (Figure 3-3). Based upon visual observation (just above saturation point) and/or field measurement (headspace testing with a photo ionization detector [PID]), a deeper sample was also collected (Figure 3-4). Depths for the second sample were as follows:

- SB-001- 28-30 ft bgs;
- SB-002 - 22-24 ft bgs;
- SB-003a - 21-23 ft bgs;
- SB-004 - 18-20 ft bgs;
- SB-005 - 17-18 ft bgs;
- SB-006 - 20-22 ft bgs;
- SB-007 - 22-24 ft bgs; and
- SB-008 - 18-20 ft bgs.

Two discrete soil samples were collected from each completed boring (SB-001, SB-002, SB-003a, SB-004, SB-005, SB-006, SB-007, and SB-008). All subsurface soil sampling was conducted in accordance with the Facility Wide SAP for RVAAP (USACE, 1996), the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (MKM, 2001b). The first interval was collected using the bucket hand auger method. The second interval was collected with a standard 5.1-cm (2-inch) out-side diameter (OD), 61-cm (24-inch) long stainless steel split-spoon sampler utilizing the hollow stem auger drilling method as described in section 4.4.2.5.1 of the Facility Wide SAP for RVAAP (USACE, 1996).

Subsurface samples were divided into pre-cleaned jars with Teflon®-lined lids, provided by Severn Trent Laboratories, and into a new disposable re-sealable bag. Each bag was allowed to volatilize at least 20 minutes before the tip of a PID was inserted to screen the headspace for the presence of organic vapors. The split-spoon was equipped with a sand catcher to minimize loss of sample.

The original location boring at SB-003 encountered refusal at 1 ft. A surface soil sample was collected at SB-003. A new location, SB-003a, was selected northwest from SB-003. Two samples were collected at SB-003a.

Table 3-4 lists the soil boring sample locations. One split sample was collected by the Ohio EPA for analysis by an independent USACE approved laboratory.

Samples were immediately placed into a cooler containing ice. Each cooler submitted to the laboratory was accompanied by a completed chain-of-custody form. Field sampling forms documenting the subsurface sampling activities are presented in Appendix A. Subsurface soil analytical results are presented in Appendix G.

Table 3-4. Summary of Soil Boring Samples for Central Burn Pits Remedial Investigation

Facility/Building No.	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Surface Soil Boring Samples						
Central Burn Pits	0-1	CBP	CBPSB-001-0001-SO	Yes	8/1/2001	----
Central Burn Pits	0-1	CBP	CBPSB-002-0001-SO	Yes	8/1/2001	----
Central Burn Pits	0-1	CBP	CBPSB-003-0001-SO	Yes	8/2/2001	----
Central Burn Pits	0-1	CBP	CBPSB-003a-0001-SO	Yes	8/9/2001	----
Central Burn Pits	0-1	CBP	CBPSB-004-0001-SO	Yes	8/9/2001	----
Central Burn Pits	0-1	CBP	CBPSB-005-0001-SO	Yes	8/2/2001	----
Central Burn Pits	0-1	CBP	CBPSB-006-0001-SO	Yes	8/1/2001	----
Central Burn Pits	0-1	CBP	CBPSB-007-0001-SO	Yes	8/1/2001	----
Central Burn Pits	0-1	CBP	CBPSB-008-0001-SO	Yes	8/1/2001	----
Subsurface Soil Boring Samples						
Central Burn Pits	28-30 ft	CBP	CPBSB-001-0002-SO	Yes	8/7/2001	----
Central Burn Pits	22-24 ft	CBP	CBPSB-002-0002-SO	Yes	8/8/2001	----
Central Burn Pits	21-23 ft	CBP	CBPSB-003a-0002-SO	Yes	8/9/2001	----
Central Burn Pits	18-20 ft	CBP	CBPSB-004-0002-SO	Yes	8/8/2001	----
Central Burn Pits	17-18 ft	CBP	CBPSB-005-0002-SO	Yes	8/9/2001	----
Central Burn Pits	20-22 ft	CBP	CBPSB-006-0002-SO	Yes	8/7/2001	----
Central Burn Pits	22-24 ft	CBP	CBPSB-007-0002-SO	Yes	8/7/2001	----
Central Burn Pits	18-20 ft	CBP	CBPSB-008-0002-SO	Yes	8/6/2001	----

3.1.2 Groundwater Investigation Activities

Eight monitoring wells were installed in the shallow water table zone at CBP during the RI (Figure 3-5). The groundwater activities were conducted to:

- determine whether open burning activities had adversely impacted groundwater quality underlying the AOC;
- evaluate the quality of groundwater upgradient of CBP; and
- collect data pertaining to the groundwater flow regime at CBP.

Monitoring wells were located in the suspected down-gradient direction from the areas believed most likely impacted by activities at this AOC to evaluate potential subsurface contamination. One well (MW-001) was located in the up-gradient direction from the CBP.

Slug tests were conducted on the wells, one round of groundwater samples were collected, and three rounds of water level data were collected.

3.1.2.1 Monitoring Well Installation and Development

The installation, development, and sampling of monitoring wells were conducted in accordance with the Facility Wide SAP for RVAAP (USACE, 1996) and the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (MKM, 2001b). Monitoring wells were installed using hollow-stem auger drilling methods under the direct supervision of a qualified geologist. A 21 cm (8.25 in) inside diameter, hollow-stem auger was used to advance the borehole through unconsolidated material to an average depth of 8.4 m (27.5 ft) bgs.

Monitoring wells were constructed in each borehole, following termination of drilling at the appropriate depth. A 3.05 m (10 ft) section of new, pre-cleaned 5.0 cm (2.0 inch) schedule 40 polyvinyl chloride (PVC) 0.010 slot screen was set to straddle the static water level determined during drilling activities. The well was completed to the surface using new, schedule 40 PVC riser. The screen and riser were placed into the borehole through the drill stem augers during well construction. Placement of clean Global No. 7 sand filter pack was tremied in place from the bottom of the boring to approximately 0.6 m (2 ft) above the top of the well screen. The filter pack was sealed with 0.6 m (2 ft) of bentonite pellets. A Type 1 Portland cement with 7% bentonite grout was tremied to complete the remainder of annular space to the surface. Each well was finished at the surface with protective steel surface casing. Three steel posts were installed around each well. Monitoring well installation procedures are provided in Section 4.3.2 of the Facility Wide SAP for RVAAP (USACE, 1996). Well construction diagrams are provided as part of Appendix A.

At least 48 hours after completion (and no longer than seven days), static water level and total well depth were recorded and each monitoring well was developed so that a representative groundwater sample could be collected. At least five borehole volumes were removed from each well using a submersible pump. Wells were developed in accordance with work plan specifications. Well development records are provided in Appendix H.

3.1.2.2 In-Situ Permeability Testing

Slug tests were performed at the eight CBP wells to estimate the hydraulic conductivity of the unconsolidated material surrounding each well screen. A transducer was used to collect the falling and rising head data. First, the rising head was conducted by inserting a stainless steel slug into the well and recording water levels until the groundwater returned to static levels. After it was determined that the groundwater elevations had stabilized, the falling head test was conducted by removing the slug and collecting data until static conditions were achieved. The slug testing of monitoring wells was conducted in accordance with the Facility Wide SAP for RVAAP (USACE, 1996) and the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (MKM, 2001b). Slug test data records are provided in Appendix I.

3.1.2.3 Groundwater Sampling

Before collecting groundwater samples, each well's condition was evaluated and noted. Casing headspace was field screened at each well using a handheld PID. The depth to water and depth to the bottom of the well casing were measured and recorded. Each well was purged using micropurge techniques. Purging continued until water quality indicators such as pH, temperature, dissolved oxygen, and conductivity were stabilized (three consecutive readings within 10% of each other). Samples were collected within 24 hours of purging each monitoring well and placed into pre-cleaned bottles provided by Severn Trent Laboratories, Inc.

All groundwater sampling was conducted in accordance with the procedures provided in Section 4.3.4 of the Facility Wide SAP for RVAAP (USACE, 1996). Samples that were to be analyzed for TAL dissolved metals were field-filtered immediately after collection. Samples were immediately placed into a cooler containing ice and submitted to the laboratory under a completed chain of custody.

Wells were developed in accordance with work plan specifications to obtain the lowest turbidity readings possible. Characteristics of the glacial materials in which the wells are set include abundant mobile fines. Historically it has been very prominent that turbidity readings are greater than 5 nephelometric turbidity (NTU). Only bedrock wells have shown turbidity less than 5 NTU. Micropurge sampling methods were employed for wells whenever possible. Despite these measures, turbidity levels remained above 5 NTU in MW-001, MW-002, MW-003, MW-004, MW-006, and MW-007. Turbidity readings greater than 5 NTU may affect sample quality. Accordingly, only filtered metals samples were obtained.

Table 3-5 summarizes groundwater samples collected. One split sample was collected by the Ohio EPA. Well purging and sampling records are provided in Appendix H and analytical results from the samples are presented in Appendix J.

Table 3-5. Groundwater Samples for the Central Burn Pits Remedial Investigation

Facility/Building No.	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Central Burn Pits	CBP	CBPGW-001-0001-GW	Yes	8/23/2001	----
Central Burn Pits	CBP	CBPGW-002-0001-GW	Yes	8/24/2001	----
Central Burn Pits	CBP	CBPGW-003-0001-GW	Yes	8/29/2001	----
Central Burn Pits	CBP	CBPGW-004-0001-GW	Yes	8/24/2001	----
Central Burn Pits	CBP	CBPGW-005-0001-GW	Yes	8/27/2001	----
Central Burn Pits	CBP	CBPGW-006-0001-GW	Yes	8/22/2001	----
Central Burn Pits	CBP	CBPGW-007-0001-GW	Yes	8/23/2001	----
Central Burn Pits	CBP	CBPGW-008-0001-GW	Yes	8/22/2001	----

3.1.2.4 Water Level Measurements

Static water level and total depth measurements were taken and recorded at each monitoring well on three separate occasions to provide data on the groundwater flow regime underlying the CBP. These data were collected during August 2001, January 2002, and September 2003. Groundwater elevation data are included in Appendix K. Well survey information is included in Appendix L.

3.1.3 Surface Water

Surface water samples were collected from the main flow ways at the CBP to:

- evaluate whether surface water is being impacted by runoff from the CBP; and
- identify the migration pathways for contaminated runoff (if any) from the CBP.

Eight locations were selected to evaluate whether contaminants could be impacting surface water within the AOC (Figure 3-6). In addition, the downstream stream sample from CBP (S-7) collected as part of the *Facility-wide Biological and Water Quality Study 2003 (USACE, 2005*) is shown on Figure 3-6.

Surface water samples could be collected at only three (SW-005, SW-006, and SW-008) of the eight proposed locations due to lack of water. Samples were collected beginning with the furthest downstream point and moving upstream, to minimize the turbidity effects on water quality. The surface water was collected as described in Section 4.6.2.1.1 of the Facility Wide SAP for RVAAP (USACE, 1996). Direct fill of hand held bottles were used to sample water in the drainage ditches. Each container was submerged into the water, with the cap in place. The cap was removed and the container was allowed to slowly and continuously fill. Water quality measurements (pH, conductivity, dissolved oxygen content, and temperature) were recorded just prior to sample collection. Table 3-6 summarizes the surface water samples collected.

Samples were immediately placed into a cooler containing ice and submitted to the laboratory under a completed chain-of-custody. One split sample was collected by the Ohio EPA for analysis by an independent USACE approved laboratory.

Field sampling forms for the surface water are presented in Appendix M and analytical results are presented in Appendix N.

Table 3-6. Summary of Surface Water Samples for the Central Burn Pits Remedial Investigation

Facility/Building No.	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Central Burn Pits	CBP	CBPSW-001-0001-SW	No	----	Surface water not present at time of sampling
Central Burn Pits	CBP	CBPSW-002-0001-SW	No	----	Surface water not present at time of sampling
Central Burn Pits	CBP	CBPSW-003-0001-SW	No	----	Surface water not present at time of sampling
Central Burn Pits	CBP	CBPSW-004-0001-SW	No	----	Surface water not present at time of sampling
Central Burn Pits	CBP	CBPSW-005-0001-SW	Yes	9/10/2001	----
Central Burn Pits	CBP	CBPSW-006-0001-SW	Yes	9/10/2001	----
Central Burn Pits	CBP	CBPSW-007-0001-SW	No	----	Surface water not present at time of sampling
Central Burn Pits	CBP	CBPSW-008-0001-SW	Yes	9/18/2001	----

3.1.4 Sediment

Sediment samples were collected from the main flow ways at the CBP to:

- evaluate whether sediments are being impacted via surface water runoff at the CBP;
- evaluate the migration pathway for contaminants that may have been suspended in surface water runoff; and
- evaluate whether contaminants may have migrated beyond the AOC.

Nine locations were selected to evaluate whether the drainage system at CBP allowed contaminants to migrate beyond the AOC (Figure 3-7). In addition, the downstream stream sample from CBP (S-7) collected as part of the *Facility-wide Biological and Water Quality Study 2003 (USACE, 2005*) is shown on Figure 3-7. Eight of the sediment samples were to be co-located with the surface water sample locations. Table 3-7 summarizes the sediment samples collected.

All sediment samples were collected from 0 to 0.15 m (0 to 0.5 ft) below the sediment-water interface along the drainage ditches and Sand Creek. Sediment samples were collected using a scoop or trowel. Five of the nine sediment samples (SD-001, SD-002, SD-003, SD-004, and SD-007) were collected as soil samples from 0 to 0.3 m (0 to 1 ft) because sediment was not present during sampling. A stainless steel hand auger was used for sediment samples collected as soil samples. Sampling procedures are described in the Facility Wide SAP for RVAAP (USACE, 1996) Section 4.5.2.1 and the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (MKM, 2001b).

Sediment samples from CBP were homogenized and placed into sample containers. Samples were immediately placed into a cooler containing ice and submitted to the laboratory under a completed chain-of-custody.

Table 3-1 listed the analyses completed on the sediment/soil samples. One split sample was collected by the Ohio EPA. Field sampling forms are presented in Appendix O and analytical results from the samples are presented in Appendix P.

Table 3-7. Sediment Sample List for Central Burn Pits Remedial Investigation

Facility/Building No.	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
Central Burn Pits	CBP	CBPSD-001-0001-SD	Yes	8/9/2001	“Converted” to soil sample due to field conditions.
Central Burn Pits	CBP	CBPSD-002-0001-SD	Yes	9/18/2001	“Converted” to soil sample due to field conditions.
Central Burn Pits	CBP	CBPSD-003-0001-SD	Yes	8/10/2001	“Converted” to soil sample due to field conditions.
Central Burn Pits	CBP	CBPSD-004-0001-SD	Yes	8/9/2001	“Converted” to soil sample due to field conditions.
Central Burn Pits	CBP	CBPSD-005-0001-SD	Yes	9/10/2001	----
Central Burn Pits	CBP	CBPSD-006-0001-SD	Yes	9/10/2001	----
Central Burn Pits	CBP	CBPSD-007-0001-SD	Yes	8/10/2001	“Converted” to soil sample due to field conditions.
Central Burn Pits	CBP	CBPSD-008-0001-SD	Yes	9/18/2001	----
Central Burn Pits	CBP	CBPSD-009-0001-SD	Yes	8/9/2001	----

3.1.5 Investigation-Derived Waste

During field activities, investigation-derived waste (IDW) was generated. The accumulated soil and water was characterized and disposed. Representative composite samples of the waste materials were collected and analyzed per the requirements of the disposal facility. The following summarizes the CBP waste management disposition operations.

- Excess soil cuttings generated from soil sampling, drilling operations and sediment sampling were containerized in 55-gallon steel drums and stored until disposition. Based on the composite sampling and analyses, the soil was determined to be non-hazardous. These materials were disposed at the County Wide RDF landfill in East Sparta, Ohio.
- Monitoring well development/purging and equipment decontamination generated IDW wastewater. Based on laboratory analytical results, the wastewater was determined to be non-hazardous. The wastewater was transported to Chemical Solvents in Cleveland, Ohio for disposal.

All IDW was collected, stored, sampled/analyzed, and disposed in accordance with all applicable federal, state, and/or local rules, laws, and regulations. Appendix Q contains copies of the composite sample field sampling forms, chain-of-custody forms for composite samples, the analytical reports, and manifests used to track the IDW.

3.2 DATA ANALYSES AND QUALITY

This section briefly describes the data quality procedures that were followed during the RI, and discusses the quality of the data collected.

3.2.1 Laboratory Analysis

Analytical laboratory procedures were completed in accordance with applicable professional standards, EPA requirements, government regulations and guidelines, and specific project goals and requirements. All samples collected during the investigation were analyzed by Severn Trent Laboratory in Chicago, Illinois, a USACE Center of Excellence-validated laboratory under contract for the investigation. Quality assurance (QA) split samples were collected for each media by an Ohio EPA representative. These split samples were prepared, packaged, and submitted to GPL Laboratories for analysis. Laboratories supporting this work have statements of qualifications including organizational structures, QA manuals and standard operating procedures, which are available upon request.

Samples were analyzed in accordance with the Facility Wide SAP for RVAAP (USACE, 1996), the SAP Addendum for CBP (MKM, 2001a), and the Work Plan for CBP (MKM, 2001b). The DQOs established for the CBP RI comply with EPA Region V guidance. The requirements for sample collection, handling, analysis criteria, target analytes, laboratory criteria, and data validation criteria at CBP are consistent with EPA requirements for National Priority List (NPL) sites. DQOs for this project included analytical precision, accuracy, representativeness, completeness, comparability and sensitivity for the measurement data.

The analytical laboratories were required to strictly adhere to the SAP to ensure good quality data would be provided. The laboratory was required to perform all analyses in compliance with EPA SW-846 (EPA, 1990), Test Methods for Evaluating Solid Waste, Physical/Chemical Methods analytical protocols. EPA SW-846 chemical analytical procedures were followed for the analyses of metals, VOCs, SVOCs, pesticides, PCBs, explosives, and cyanide. Laboratories were required to comply with all methods as written; recommended procedures suggested in the methods were considered to be requirements.

The requisite number of QA/quality control (QC) samples was obtained during the CBP RI. QC samples for this project included equipment rinses, trip blanks, field blanks, field duplicates, laboratory method blanks, laboratory control samples, laboratory duplicates and matrix spike/matrix spike duplicate (MS/MSD) samples. These samples were collected to meet the following requirements:

- Laboratory method blanks and laboratory control samples were employed to determine the accuracy and precision of the analytical method as implemented by the laboratory.
- Matrix spike samples provided information about the effect of the sample matrix on the measurement methodology.
- Laboratory sample duplicates and MS/MSDs assisted in determining the analytical reproducibility and precision of the analysis for the samples of interest.
- Field blanks, consisting of potable water used in the decontamination process, equipment rinseate blanks, and trip blanks, were submitted for analysis along with field duplicate (co-located) samples to provide a means to assess the quality of the data resulting from the field sampling program.
    - Field blank samples were analyzed to determine procedural contamination at the site that may contribute to sample contamination.
    - Equipment rinseate blanks were used to assess the adequacy of equipment decontamination processes for groundwater sample collection.
    - Trip blanks were used to assess the potential for VOC contamination of samples due to contaminant migration during sample shipment and storage.
    - Field duplicate samples were analyzed to determine sample heterogeneity and sampling methodology reproducibility.

Analytical data reports from Severn Trent Laboratories were forwarded to Purves Environmental for QA review, comparison, and validation. The QC results were evaluated and summarized in the CBP Quality Control Summary Report (QCSR) provided in Appendix R.

MKM will maintain the CBP RI project files; including all relevant records, reports, logs, field notebooks, pictures, subcontractor reports, correspondence and chain-of-custody forms. These files will remain in the custody of the MKM Project Manager, until they are transferred to OSC and RVAAP.

3.2.2 Data Review, Validation, and Quality Assessment

Samples were properly packaged for shipment and dispatched to Severn Trent Laboratory for analysis under completed chain-of-custody forms. When transferring the possession of samples, the individuals relinquishing custody and the individual receiving the samples signed their names and noted the date and time of transfer on the record. All shipments complied with applicable Department of Transportation regulations for environmental samples.

Analytical data was produced, reviewed, and reported by the laboratory in accordance with specifications outlined in the CBP SAP and the laboratory's QA manual. Laboratory reports included documentation verifying compliance with sample log-in procedures, analytical holding times, and QC procedures for analyses. The laboratory reports also provide information pertaining to percent recovery attained in laboratory spike samples, calibration curves (initial and continuing), dilutions, and detection limits. The laboratory flagged suspect data if results warranted.

Severn Trent Laboratories performed in-house analytical data reduction under the direction of the Laboratory Project Manager and QA Officer. These individuals were responsible for assessing data quality and informing MKM of any data that were considered “unacceptable” or required caution on the part of the data user in terms of its reliability. This notification allowed MKM to determine the need for re-collection or re-analysis of any samples to achieve DQOs. Data reduction, review and reporting by the laboratory were conducted as follows:

- Raw data produced by the analyst were turned over to the analyst’s supervisor.
- The supervisor reviewed the data for attainment of QC criteria as outlined in the established methods and for overall reasonableness.
- Upon acceptance of the raw data by the supervisor, a report was generated and sent to the Laboratory Project Manager.
- The Laboratory Project Manager reviewed all reports and, based on that review, generated final reports.
- The final data were delivered to MKM, who forwarded the packages to Purves Environmental for data validation.

Severn Trent Laboratory prepared and retained full analytical and QC documentation for the project in both hard (paper) copy and electronic storage media (e.g. magnetic tape) as directed by the analytical methodologies employed. Severn Trent Laboratory provided the following information to MKM in each analytical data package submitted:

- Cover sheets listing the samples included in the report and narrative comments describing problems encountered in analysis;
- Tabulated results of inorganic and organic compounds identified and quantified; and
- Analytical results for QC sample spikes, sample duplicates, initial and continuing calibration verifications of standards and blanks, method blanks and laboratory control sample information.

Upon receipt, MKM compared the data packages to the chain-of-custody forms to ensure all analyses had been conducted and results were provided. Purves Environmental systematically verified and validated the data to ensure that the precision and accuracy of the analytical data were adequate for their intended use. The validation process minimized the potential of using false or negative results in the decision-making process and ensured that detected and non-detected compounds were accurately identified. This approach was consistent with the DQOs for the project and with the analytical methods, and appropriate for determining contaminants of concern and calculating risk.

The data validation determined that the data is 100 percent complete and usable, and that it satisfies the DQOs for this project. The data validation reports are presented in Appendix R.

3.3 DEVIATIONS FROM THE WORK PLAN

Every effort was made to complete the field activities in accordance with the approved work plan. However, in some instances, circumstances or field conditions necessitated a modification. Table 3-8 provides specific deviations from the work plan. A summary of the changes made during the CBP investigation are noted below.

- Soil Boring SB-003 was relocated to SB-003a due to auger refusal at 1 ft.
- The 1 to 3 ft interval for samples SS-002, SS-006, SS-013, SS-016 and SS-022 was not collected due to auger refusal.
- Surface Water samples SW-001, SW-002, SW-003, SW-004 and SW-007 were not collected because surface water was not present at the time of sampling.
- At some ditch locations, no sediment was present. The ditch had established vegetation supported by soil. In those cases, a soil sample was collected from the 0 to 1 ft range. The following samples that had been planned as sediment samples were 'converted' to soil samples due to field conditions: SD-001, SD-002, SD-003, SD-004, and SD-007.

Although deviations were implemented, the objectives of the CBP RI were still achieved.

Table 3-8. Deviations from Central Burn Pits Work Plan

Sample Type		Quantity	Purpose/Rationale	Laboratory Parameters
Soil	Proposed	68 total 2 per hole (CBPSS-001-0001-SO through CBPSS-034-002-SO)	Assess potential impact to surface soils from previous site operations.	Explosives TAL Metals Asbestos PCBs Cyanide
	Actual	63 total 5 samples not collected from 1-3 ft interval due to auger refusal		Explosives TAL Metals Asbestos PCBs Cyanide Pesticides
Sediment	Proposed	9 total (CBPSD-001-0001-SD through CBPSD-009-0001-SD)	Characterize potential impact within the main flow ways and Sand Creek.	Explosives TAL Metals Cyanide TOC Grain Size
	Actual	9 total 5 samples collected as soil because sediment was not present at time of sampling		
Soil Borings	Proposed	16 total, 2 per boring (CBPSB-001-0001-SO through CBPSB-008-0002-SO)	Assess potential impact to subsurface soils from previous site operations.	Explosives TAL Metals PCBs Cyanide
	Actual	17 total (2 samples from each of the 8 completed borings, 1 sample from the boring that had refusal)		

Table 3-8. Deviations from Central Burn Pits Work Plan (continued)

Sample Type		Quantity	Purpose/Rationale	Laboratory Parameters
Surface Water	Proposed	8 total (CBPSW-001-0001-SW through CBPSW-008-0001-SW)	Evaluate surface water quality in the main flow ways of the site and Sand Creek.	Explosives TAL Metals(unfiltered) Cyanide
	Actual	3 total 5 proposed sites were dry at time of sampling		
Groundwater	Proposed	8 total (CBPGW-001-0001-GW through CBPGW-008-0001-GW)	Assess groundwater quality associated with potential sources of contamination.	Explosives TAL Dissolved Metals (filtered) Propellants VOCs SVOCs Pesticides PCBs Cyanide
	Actual	8 total		

4.0 NATURE AND EXTENT OF CONTAMINATION

This section summarizes the soil (surface and subsurface), groundwater, surface water, and sediment analytical results obtained from the environmental sampling conducted at CBP. The results are organized by media: soil, groundwater, surface water, and sediment. Tables summarizing exceedances of background and/or PRGs are presented. The evaluation completed in this section is a preliminary comparison and is not intended to be used alone for making risk management decisions. The human health and ecological risk assessments, presented later in this report, further discuss and evaluate the contaminants detected during this RI. The comparison data along with the risk assessment results will form the basis for risk management decisions.

Background criteria were established during the completion of the Winklepeck Phase II RI (USACE, 1999). Naturally occurring concentrations for inorganics in soil, sediment, surface water, and groundwater were established. If a TAL metal was not analyzed and/or reported as non-detected, the background value was established as zero (USACE, 2001). Therefore, some metals (in particular cyanide) are reported as exceeding background when in fact actual concentrations are low and likely within the accepted range of naturally occurring values in Ohio. Table 4-1 provides the facility-wide inorganic background for surface soil, subsurface soil, sediment, and surface water.

QC results from trip blanks, field duplicates, and equipment rinseate samples are discussed separately in Appendix R.

USEPA Region IX PRGs represent a 1 x 10^{-6} risk level for carcinogenic effects and a hazard level of 1.0 for non-carcinogenic effects. These PRGs represent individual constituent concentrations but do not account for potential impacts from multiple contaminants. Although these values may or may not indicate an unacceptable risk or a situation requiring remediation, it does form a basis and initial screening to be followed by a human health risk assessment.

All positive detections in soil (surface or subsurface) were screened against residential soil PRGs. These PRG values were calculated for a human receptor hypothetically exposed to chemicals in soil assuming a residential use scenario. All positive detections in groundwater or surface water were screened against tap water PRGs. These tap water PRGs were calculated for a human receptor hypothetically using groundwater or surface water as a domestic water supply.

Table 4-1. RVAAP Facility Wide Background Criteria

Analyte	Surface Soil (mg/kg)	Subsurface Soil (mg/kg)	Sediment (mg/kg)	Surface Water (ug/L)	Groundwater Bedrock Zone Filtered (ug/L)	Groundwater Bedrock Zone Unfiltered (ug/L)	Groundwater Unconsolidated Zone Filtered (ug/L)	Groundwater Unconsolidated Zone Unfiltered (ug/L)
Cyanide	0	0	0	0	0	0	0	0
Aluminum	17,700	19,500	13,900	3,370	0	9,410	0	0
Antimony	0.96	0.96	0	0	0	0	0	0
Arsenic	15.4	19.8	19.5	3.2	0	19.1	11.7	11.7
Barium	88.4	124	123	47.5	256	241	82.1	82.1
Beryllium	0.88	0.88	0.38	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0
Calcium	15,800	35,500	5,510	41,400	53,100	48,200	115,000	115,000
Chromium	17.4	27.2	18.1	0	0	19.5	7.3	7.3
Cobalt	10.4	23.2	9.1	0	0	0	0	0
Copper	17.7	32.3	27.6	7.9	0	17	0	0
Iron	23,100	35,200	28,200	2,560	1,430	21,500	279	279
Lead	26.1	19.1	27.4	0	0	23	0	0
Magnesium	3,030	8,790	2,760	10,800	15,000	13,700	43,300	43,300
Manganese	1,450	3,030	1,950	391	1,340	1,260	1,020	1,020
Mercury	0.036	0.044	0.059	0	0	0	0	0
Nickel	21.1	60.7	17.7	0	83.4	85.3	0	0
Potassium	927	3,350	1,950	3,170	5,770	6,060	2,890	2,890
Selenium	104	105	107	0	0	0	0	0
Silver	0	0	0	0	0	0	0	0
Sodium	123	145	112	21,300	51,400	49,700	45,700	45,700
Thallium	0	0.91	0.89	0	0	0	0	0
Vanadium	31.1	37.6	26.1	0	0	15.5	0	0
Zinc	61.8	93.3	532	42	52.3	193	60.9	60.9

4.1 SOIL SAMPLING ANALYTICAL RESULTS

The following sections present a summation and initial screening of the analytical data for soil samples collected during the RI.

4.1.1 Soil Sampling (0 to 3 ft)

Seventy-two soil samples were collected from 43 various locations during the RI at CBP. Thirty-four surface soil samples were collected from the 0 to 1 ft interval (see Figure 4-1) and 29 subsurface soil samples were collected from the 1 to 3 ft interval (Figure 4-2). Five of the original 34 proposed subsurface soil sample locations were unable to be sampled due to auger refusal. In addition, surface soil samples were collected from the 0 to 1 ft interval from the nine attempted monitoring well soil boring locations shown in Figure 4-3 and are discussed in this section. One of the originally proposed eight boring locations (SB-003) encountered auger refusal at 1 ft, so an additional location (SB-003a) was augered and sampled for both 0 to 1 ft (and greater than 1 ft), resulting in 9 surface soil samples. A monitoring well was installed at SB-003a but not SB-003. All positive detections were compared to RVAAP background and PRG values as previously discussed. No asbestos was detected in the shallow soil samples collected for asbestos analysis.

Complete analytical results for the soil sampling are tabulated in Appendix F and Appendix G; as well as the complete laboratory reports. The data screening results are summarized in Tables 4-2, 4-3, and 4-4. Analytes detected above background and/or PRGs are illustrated on Figures 4-1, 4-2, and 4-3.

Other details pertinent to the shallow soil analytical results:

- No asbestos was detected above detection limits in the 0 – 1 ft sampling interval.
- Pesticides (4,4’-DDE and 4,4’-DDT) were detected in the 0 – 1 ft sampling interval but do not exceed PRGs. Endrin and Endosulfan II were detected. These two compounds do not have background or PRG values.
- An explosive (2,4,6-TNT) was detected in the 0 – 1 ft and 1 – 3 ft sampling intervals at SS-010. Both detections are below the PRG value.
- No VOCs, SVOCs, asbestos, pesticides, or PCBs were detected above detection limits in the 1 – 3 ft sampling interval.
- The propellants detected are shown as exceeding background since background for propellants is zero. However, none of the concentrations exceeded PRGs.
- SVOCs were detected in one shallow soil boring sample (SB-003A) at a concentration below background and its PRG with the exception of benzo(a)pyrene.
- The PCB Aroclor 1254 was detected in three 0 – 1 ft interval shallow soil samples (SS-013, SS-014, and SS-015) at concentrations that did not exceed its PRG.
- Pesticides 4,4’-DDE and 4,4’-DDT were detected in shallow soil sample SS-002 (0 – 1 ft) at concentrations below PRGs.
- Pesticides endosulfan II, endrin, and gamma-chlordane were detected in shallow soil sample SS-014 (0 – 1 ft) at concentrations below PRGs.

- No background concentrations were established for cadmium and cyanide; therefore, each was assigned a background value of zero. Although concentrations of these constituents are shown to exceed background, they do not exceed PRGs.
- Four of the cadmium, five of the mercury, and two of the cyanide detections above background in the 0 – 1 ft samples were blank qualified. Six of the 18 beryllium detections above background in the 1 – 3 ft samples were blank qualified.
- Other inorganic constituents were detected. Only arsenic, chromium, manganese, lead, and iron exceeded background or PRGs. Lead exceeded the PRG in one location (SS-018 0 – 1 ft).

4.1.2 Subsurface Soil Boring Samples (> 3 ft)

Eight soil samples were collected from depths greater than 3 ft from soil borings that were completed as groundwater monitoring wells. As mentioned, the proposed boring at location SB-003 encountered auger refusal at 1 ft and the monitoring well borehole was moved to SB-003a. Analytical results are provided for subsurface soil samples in Table 4-5. All analytes detected above background and PRGs are illustrated in Figure 4-4. Tabulated analytical results and laboratory analytical reports are provided in their entirety in Appendix G.

Other details pertinent to the at-depth soil sample analytical results:

- No explosives, propellants, VOCs, SVOCs, pesticides, or PCBs were detected above detection limits.
- No background concentrations were established for antimony, cadmium, cyanide, or silver; therefore, each was assigned a background value of zero. Although concentrations of these constituents are shown to exceed background, they do not exceed PRGs.
- Other inorganic constituents were detected, only concentrations of iron and arsenic exceeded background or PRGs.

1 **Table 4-2. Summary of Surface Soil (0 to 1 ft) Data Screening Results**

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (0-1 ft)	Region 9 PRG (Residential Soil)	Units	CBPSS-001-0001-SO 8/30/2001	CBPSS-002-0001-SO 8/13/2001	CBPSS-003-0001-SO 9/5/2001	CBPSS-004-0001-SO 9/4/2001	CBPSS-005-0001-SO 9/4/2001	CBPSS-006-0001-SO 9/6/2001	CBPSS-007-0001-SO 8/30/2001	CBPSS-008-0001-SO 8/13/2001	CBPSS-009-0001-SO 8/30/2001	CBPSS-010-0001-SO 8/30/2001	CBPSS-011-0001-SO 8/30/2001
Cyanide 9012A	Cyanide, Total,Solid		SS	0	1200	mg/kg	*2.2*			*1.2*		*85.7*	*1.5*			*2.3*	
		B	SS	0	1200	mg/kg		*0.4*									
Explosives 8330	2,4,6-TNT,Solid		SS	--	16000	ug/kg										*180*	
PCB TCL 8082	Aroclor 1254,Solid		SS	--	220	ug/kg											
Pesticides 8081A	4,4'-DDE,Solid	J	SS	--	1700	ug/kg		*1.8*									
	4,4'-DDT,Solid	J	SS	--	1700	ug/kg		*2.7*									
	Endosulfan II,Solid		SS	--	--	ug/kg											
	Endrin,Solid	J	SS	--	--	ug/kg											
	gamma-Chlordane,Solid		SS	--	--	ug/kg											
	Heptachlor epoxide,Solid	J	SS	--	53	ug/kg						*0.58*					
Propellants 8330	Nitrocellulose	B	SS	--	--	mg/kg		*0.76*				*0.94*		*0.81*			
TAL Metals 6010B	Aluminum,Solid		SS	17700	76000	mg/kg	11000	10100	10100	*29700*	8070	*26700*	*23600*	17600	11400	10200	15100
	Antimony,Solid		SS	0.96	31	mg/kg		0.4							0.32		
		B	SS	0.96	31	mg/kg			0.2								
	Arsenic,Solid		SS	15.4	0.39	mg/kg	***19.7***	***25.2***	**11.3**	***32.8***	**11**			***25.5***	***19.5***	**2.9**	**11.4**
		B	SS	15.4	0.39	mg/kg						**1.7**					
	Barium,Solid		SS	88.4	5400	mg/kg	51.1	*102*	60.6	*242*	58.1	*354*	*208*	65	68.3	*120*	64
	Beryllium,Solid		SS	0.88	150	mg/kg	0.52	0.49		*3.9*	0.48	*3*	*3.1*	0.71	0.79	*1.5*	0.53
		B	SS	0.88	150	mg/kg			0.39								
	Cadmium,Solid		SS	0	37	mg/kg	*0.43*	*0.52*			*1.1*					*0.57*	*0.51*
		B	SS	0	37	mg/kg				*0.34*		*0.18*					
	Calcium,Solid		SS	15800	--	mg/kg	576	14500	1600	*172000*	3090	*182000*	*149000*	674	563	*50600*	3100
	Chromium,Solid		SS	17.4	30	mg/kg	15.8	*18.2*	12.9	***48.8***	13.6	*26.5*	4.4	*20.1*	14.9	9.9	17.1
	Cobalt,Solid		SS	10.4	900	mg/kg	*11.2*	8.1	6.2		6.9			*10.9*	*22.3*	1.8	5.6
		B	SS	10.4	900	mg/kg				0.75		0.47					
	Copper,Solid		SS	17.7	3100	mg/kg	17.2	*20.5*	7.8	*43.8*	13.7	12.3	1.5	9.7	7.1	12.5	11.1
	Iron,Solid		SS	23100	23000	mg/kg	***26700***	22800	18200	8330	22200	5450	1420	***29800***	***30000***	9460	***24800***
	Lead,Solid		SS	26.1	400	mg/kg	16.9	*99.6*	12.9	*29.1*	*35.6*	14.7	10.9	*35.2*	23	*59.7*	22.3
	Magnesium,Solid		SS	3030	--	mg/kg	2920	1840	1580	*22300*	1590	*21200*	*16300*	2230	1810	*5620*	2080
	Manganese,Solid		SS	1450	1800	mg/kg	301	544	671	***2590***	584	***5410***	***2860***	513	1440	1310	284
	Mercury,Solid		SS	0.04	23	mg/kg										*0.05*	*0.045*
		B	SS	0.04	23	mg/kg	0.021	0.027	0.032	0.03	0.035	0.013	0.019	0.038	0.033		
	Nickel,Solid		SS	21.1	1600	mg/kg	*22.1*	16.4	9.4	4.6	14.8	4.5		13.4	12.2	4.9	11.1
		B	SS	21.1	1600	mg/kg							0.95				
	Potassium,Solid		SS	927	--	mg/kg	*1190*	*1070*	777	*2320*	*1140*	*1260*	*1700*	*1710*	919	820	*1090*
	Selenium,Solid		SS	1.4	390	mg/kg			0.85	*1.5*	0.76		*1.8*		0.98	*1.6*	0.44
	Silver,Solid	B	SS	0	390	mg/kg		*0.27*									
	Sodium,Solid		SS	123	--	mg/kg		*137*		*999*		*1000*	*947*	*137*		*276*	
		B	SS	123	--	mg/kg			35.6						67.7		
	Thallium,Solid		SS	0	5.2	mg/kg		*0.21*									
	Vanadium,Solid		SS	31.1	78	mg/kg	17.4	19.1	21.6	2.5	14.5	8.3	3.7	*37*	27.8	6.3	29
	Zinc,Solid		SS	61.8	23000	mg/kg	57.5	*246*	35	30.4	*110*	14.7	8.2	*66.5*	60.7	60	*62.6*

Table 4-2. Summary of Surface Soil (0 to 1 ft) Data Screening Results (continued)

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (0-1 ft)	Region 9 PRG (Residential Soil)	Units	CBPSS-012-0001-SO	CBPSS-013-0001-SO	CBPSS-014-0001-SO	CBPSS-015-0001-SO	CBPSS-016-0001-SO	CBPSS-017-0001-SO	CBPSS-018-0001-SO	CBPSS-019-0001-SO	CBPSS-020-0001-SO	CBPSS-021-0001-SO	CBPSS-022-0001-SO
							9/7/2001	9/5/2001	9/6/2001	9/7/2001	9/4/2001	9/4/2001	9/7/2001	8/30/2001	8/30/2001	8/30/2001	8/31/2001
Cyanide 9012A	Cyanide, Total,Solid		SS	0	1200	mg/kg					*0.77*	*4.7*	*0.57*				*6.1*
		B	SS	0	1200	mg/kg				*0.36*							
Explosives 8330	2,4,6-TNT,Solid		SS	--	16000	ug/kg											
PCB TCL 8082	Aroclor 1254,Solid		SS	--	220	ug/kg		*32*	*44*	*45*							
Pesticides 8081A	4,4'-DDE,Solid	J	SS	--	1700	ug/kg											
	4,4'-DDT,Solid	J	SS	--	1700	ug/kg											
	Endosulfan II,Solid		SS	--	--	ug/kg			*3.4*								
	Endrin,Solid	J	SS	--	--	ug/kg			*1.9*								
	gamma-Chlordane,Solid		SS	--	--	ug/kg			*4.7*								
	Heptachlor epoxide,Solid	J	SS	--	53	ug/kg											
Propellants 8330	Nitrocellulose	B	SS	--	--	mg/kg											
TAL Metals 6010B	Aluminum,Solid		SS	17700	76000	mg/kg	13900	9820	*19500*	11600	17200	9950	13300	11000	10400	9290	*18800*
	Antimony,Solid		SS	0.96	31	mg/kg		0.65					0.5				
		B	SS	0.96	31	mg/kg									0.23		
	Arsenic,Solid		SS	15.4	0.39	mg/kg	**9.4**	**11.9**	***17.2***	**11**	**5.8**	**11**	***19.3***	**12.8**	**11.3**	**9.8**	**4.1**
		B	SS	15.4	0.39	mg/kg											
	Barium,Solid		SS	88.4	5400	mg/kg	*125*	*417*	*274*	*141*	*174*	68.4	*288*	*97.7*	*246*	36.8	*225*
	Beryllium,Solid		SS	0.88	150	mg/kg	0.61	0.61	*0.98*	0.74	*2.6*	0.66	*0.99*	0.57	0.46	0.44	*2.3*
		B	SS	0.88	150	mg/kg											
	Cadmium,Solid		SS	0	37	mg/kg	*0.28*	*1.2*	*0.47*	*0.5*	*0.25*	*0.45*	*1.5*	*0.63*	*2.2*	*0.49*	
		B	SS	0	37	mg/kg											*0.12*
	Calcium,Solid		SS	15800	--	mg/kg	*33100*	*95700*	*160000*	*28900*	*90200*	7920	*41000*	721	5430	431	*132000*
	Chromium,Solid		SS	17.4	30	mg/kg	16.1	10.6	*20.2*	15.5	6.1	16.7	*24.4*	14.7	*22.6*	11.4	16.7
	Cobalt,Solid		SS	10.4	900	mg/kg	6.7	2.9	6	*11.6*	2.4	6.5	7	*13.9*	9.8	5	1
		B	SS	10.4	900	mg/kg											
	Copper,Solid		SS	17.7	3100	mg/kg	13.4	*1260*	*241*	*30.3*	8.2	13.6	*77.2*	14.1	*98.1*	11	5.7
	Iron,Solid		SS	23100	23000	mg/kg	18800	10800	20400	***29500***	8050	19600	***50200***	***26000***	***107000***	***25800***	6270
	Lead,Solid		SS	26.1	400	mg/kg	*27.2*	*392*	*142*	*28.9*	*40.9*	19.6	***493***	20.9	*371*	18.6	3.8
	Magnesium,Solid		SS	3030	--	mg/kg	*3150*	*3980*	*5380*	1870	*11000*	2440	*3820*	1900	1890	1370	*9660*
	Manganese,Solid		SS	1450	1800	mg/kg	546	480	1050	*1500*	1320	665	1240	***2720***	1110	267	***2550***
	Mercury,Solid		SS	0.04	23	mg/kg				*0.054*	*0.071*		*0.054*	*0.045*	*0.045*	*0.046*	
		B	SS	0.04	23	mg/kg	0.032		0.033			0.03					0.0057
	Nickel,Solid		SS	21.1	1600	mg/kg	13.6	12.6	*24.5*	11.6	5.4	13.2	*23.9*	11.5	19	9.4	9.1
		B	SS	21.1	1600	mg/kg											
	Potassium,Solid		SS	927	--	mg/kg	*1220*	566	*1480*	*1060*	*1000*	*966*	*1570*	785	*1560*	655	*1690*
	Selenium,Solid		SS	1.4	390	mg/kg		*1.8*		1.3		0.63	0.44	0.46	0.93		*2*
	Silver,Solid	B	SS	0	390	mg/kg		*0.21*		*0.22*			*0.25*	*0.16*	*0.22*		
	Sodium,Solid		SS	123	--	mg/kg		114			*363*		*197*				*581*
		B	SS	123	--	mg/kg	91.8		117	76.6		46.8					
	Thallium,Solid		SS	0	5.2	mg/kg											
	Vanadium,Solid		SS	31.1	78	mg/kg	23.5	16	*32*	27.4	8.2	16.9	27.7	22.2	20.2	21	7.5
	Zinc,Solid		SS	61.8	23000	mg/kg	*65.1*	*1500*	*368*	*108*	44.5	41.8	*762*	55.7	*517*	49.7	19.7

Table 4-2. Summary of Surface Soil (0 to 1 ft) Data Screening Results (continued)

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (0-1 ft)	Region 9 PRG (Residential Soil)	Units	CBPSS-023-0001-SO	CBPSS-024-0001-SO	CBPSS-025-0001-SO	CBPSS-026-0001-SO	CBPSS-027-0001-SO	CBPSS-028-0001-SO	CBPSS-029-0001-SO	CBPSS-030-0001-SO	CBPSS-031-0001-SO	CBPSS-032-0001-SO	CBPSS-033-0001-SO	CBPSS-034-0001-SO
							9/6/2001	9/7/2001	8/30/2001	8/8/2001	8/8/2001	8/7/2001	9/5/2001	8/7/2001	8/7/2001	9/5/2001	8/7/2001	8/7/2001
Cyanide 9012A	Cyanide, Total,Solid		SS	0	1200	mg/kg		*1.2*	*0.51*	*0.64*	*3.7*							
		B	SS	0	1200	mg/kg												
Explosives 8330	2,4,6-TNT,Solid		SS	--	16000	ug/kg												
PCB TCL 8082	Aroclor 1254,Solid		SS	--	220	ug/kg												
Pesticides 8081A	4,4'-DDE,Solid	J	SS	--	1700	ug/kg												
	4,4'-DDT,Solid	J	SS	--	1700	ug/kg												
	Endosulfan II,Solid		SS	--	--	ug/kg												
	Endrin,Solid	J	SS	--	--	ug/kg												
	gamma-Chlordane,Solid		SS	--	--	ug/kg												
	Heptachlor epoxide,Solid	J	SS	--	53	ug/kg												
Propellants 8330	Nitrocellulose	B	SS	--	--	mg/kg							*0.87*			*1.2*		
TAL Metals 6010B	Aluminum,Solid		SS	17700	76000	mg/kg	13700	14400	8950	17500	16100	13300	11300	14500	15000	7380	12000	3740
	Antimony,Solid		SS	0.96	31	mg/kg							0.49			0.3		0.25
		B	SS	0.96	31	mg/kg			0.24									
	Arsenic,Solid		SS	15.4	0.39	mg/kg	**13.4**	**8.6**	**7.9**	**4.3**	**7**	**13.7**	**8.9**	**11.7**	***19.6***	**10**	**10**	**4.6**
		B	SS	15.4	0.39	mg/kg												
	Barium,Solid		SS	88.4	5400	mg/kg	82.7	*115*	*96.6*	*225*	*108*	60.5	48.9	80	54.8	55.2	60.1	66
	Beryllium,Solid		SS	0.88	150	mg/kg	0.59	*1.2*	*1.2*	*2.4*	*1.2*	0.57	0.42	0.8	0.72	0.44	0.56	0.45
		B	SS	0.88	150	mg/kg												
	Cadmium,Solid		SS	0	37	mg/kg		*0.22*	*0.22*	*0.33*						*0.21*		*0.44*
		B	SS	0	37	mg/kg	*0.11*											
	Calcium,Solid		SS	15800	--	mg/kg	4340	*23100*	*44100*	*170000*	*15900*	356	808	1480	3920	1620	1910	*62500*
	Chromium,Solid		SS	17.4	30	mg/kg	*21.1*	12.4	6.4	9.7	17.1	15.4	13.5	*17.6*	*19.6*	10.5	15.5	5.6
	Cobalt,Solid		SS	10.4	900	mg/kg	5.9	9	2.2	4.1	*10.5*	*11.2*	5.6	*14.7*	*12.6*	6.5	8.7	2.7
		B	SS	10.4	900	mg/kg												
	Copper,Solid		SS	17.7	3100	mg/kg	*23.6*	8	10.6	10.4	12.1	7.5	8.2	9.8	16.6	11.4	14.4	6.1
	Iron,Solid		SS	23100	23000	mg/kg	***29600***	17900	9110	8650	***25700***	***23100***	19600	***30600***	***28800***	16500	20300	5530
	Lead,Solid		SS	26.1	400	mg/kg	*29.9*	14.7	*42.1*	25	5.3	*27.9*	15.5	17	20	18.2	23.4	13.1
	Magnesium,Solid		SS	3030	--	mg/kg	2680	*4360*	*4670*	*12000*	*4190*	1790	1700	2270	*4680*	2160	2610	1920
	Manganese,Solid		SS	1450	1800	mg/kg	228	1390	785	***2420***	1000	1120	323	1240	395	311	312	460
	Mercury,Solid		SS	0.04	23	mg/kg		*0.042*				*0.079*					*0.05*	
		B	SS	0.04	23	mg/kg	0.025		0.027	0.023	0.032		0.035	0.039	0.027	0.034		0.019
	Nickel,Solid		SS	21.1	1600	mg/kg	16.6	9.3	6.2	11.7	13.3	10.1	9.1	14.4	*26.6*	15.8	18.2	9.3
		B	SS	21.1	1600	mg/kg												
	Potassium,Solid		SS	927	--	mg/kg	*1350*	*1090*	650	*1680*	*1560*	*936*	600	*1540*	*2630*	726	*1660*	491
	Selenium,Solid		SS	1.4	390	mg/kg			*1.4*	*1.8*	0.49	0.52	0.96			0.54	0.45	
	Silver,Solid	B	SS	0	390	mg/kg		*0.32*										
	Sodium,Solid		SS	123	--	mg/kg		*144*	*192*	*589*	116			115	88.7			
		B	SS	123	--	mg/kg	59.8						36.4			32.8		
	Thallium,Solid		SS	0	5.2	mg/kg												
	Vanadium,Solid		SS	31.1	78	mg/kg	23.9	19.8	7.4	12.1	24.6	25.9	23.2	*32.6*	23	12.6	21.4	4.8
	Zinc,Solid		SS	61.8	23000	mg/kg	*70.6*	48.4	47.8	*63.8*	59.2	*63.4*	38.4	*76.3*	*62.9*	53.5	*69*	*496*

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect *italics* – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

Table 4-3. Summary of Subsurface Soil (1 to 3 ft) Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (1-3 ft)	Region 9 PRG (Residential Soil)	Units	CBPSS-001-0002-SO	CBPSS-003-0002-SO	CBPSS-004-0002-SO	CBPSS-005-0002-SO	CBPSS-007-0002-SO	CBPSS-008-0002-SO	CBPSS-009-0002-SO	CBPSS-010-0002-SO	CBPSS-011-0002-SO	CBPSS-012-0002-SO	CBPSS-014-0002-SO	CBPSS-015-0002-SO	CBPSS-017-0002-SO	CBPSS-018-0002-SO
							8/30/2001	9/5/2001	9/4/2001	9/4/2001	8/30/2001	8/13/2001	8/30/2001	8/30/2001	8/30/2001	9/7/2001	9/6/2001	9/7/2001	9/4/2001	9/7/2001
Cyanide 9012A	Cyanide, Total,Solid		SS	0	1200	mg/kg			*2.4*		*1.1*			*1.7*						
Explosives 8330	2,4,6-TNT,Solid	J	SS	--	16000	ug/kg								*66*						
Propellants 8330	Nitrocellulose	B	SS	--	--	mg/kg						*0.68*								
TAL Metals 6010B	Aluminum,Solid		SS	19500	76000	mg/kg	13900	10400	*31100*	9020	*22500*	17300	12100	*27000*	14800	14000	14800	11300	6800	12500
	Antimony,Solid		SS	0.96	31	mg/kg						0.36	0.44				0.29			
		B	SS	0.96	31	mg/kg														
	Arsenic,Solid		SS	19.8	0.39	mg/kg	**11.2**	**10.7**	***31***	**10.1**	0.28	***27.5***	**10.7**	**2.7**	**14.6**	**15.6**	**6.9**	**6.1**	**8.6**	**8.1**
	Barium,Solid		SS	124	5400	mg/kg	47.3	72.3	*294*	53.2	*179*	61.8	67.6	*255*	58.2	87.1	59.3	74.8	53.5	89.2
	Beryllium,Solid		SS	0.88	150	mg/kg	0.54		*4.1*	0.46	*2.8*	0.82	0.62	*4.2*	0.55	0.87	0.58	0.56	0.44	0.52
		B	SS	0.88	150	mg/kg		0.36												
	Cadmium,Solid		SS	0	37	mg/kg	*0.38*			*0.64*			*0.26*	*0.41*	*0.38*				*0.28*	*0.29*
		B	SS	0	37	mg/kg										*0.099*	*0.15*	*0.098*		
	Calcium,Solid		SS	35500	--	mg/kg	619	1020	*166000*	5300	*129000*	532	714	*156000*	1270	1750	3800	3020	19400	7010
	Chromium,Solid		SS	27.2	30	mg/kg	18	13.2	*57.3*	14.7	5.8	20.7	14.9	6.4	18.5	19.6	18.4	14.6	8.7	15.8
	Cobalt,Solid		SS	23.2	900	mg/kg	8.7	8.4		6.4	0.65	8	10.8	0.66	6.1	12.4	8.4	6.4	4.3	6.8
	Copper,Solid		SS	32.3	3100	mg/kg	15.4	6.7	*46.9*	12.1	2.7	16	8.9	6.6	16.4	22.2	24.9	10	12.1	16.1
	Iron,Solid		SS	35200	23000	mg/kg	**24300**	17700	7450	19700	3040	**34600**	**23600**	4310	**25500**	**29700**	**25800**	20200	13100	20600
	Lead,Solid		SS	19.1	400	mg/kg	13.4	14.5	*34*	*19.2*	9.9	*21.8*	*22.7*	*33*	13	12.2	14.1	9.8	13.3	*65.9*
	Magnesium,Solid		SS	8790	--	mg/kg	2680	1530	*21800*	2070	*14300*	2570	1870	*16400*	2510	4150	2710	1860	2500	2170
	Manganese,Solid		SS	3030	1800	mg/kg	296	1360	**2670**	416	**2390**	202	798	***3340***	100	304	201	424	492	402
	Mercury,Solid		SS	0.04	23	mg/kg		0.038					*0.046*	0.039						
		B	SS	0.04	23	mg/kg	0.03		0.034	0.023	0.018	0.025			0.028	0.017	0.027	0.037	0.017	0.038
	Nickel,Solid		SS	60.7	1600	mg/kg	17	9.1	4.5	13.5	1.9	15	12.6	2.7	15.2	33.7	18.1	12.5	8.4	12.5
	Potassium,Solid		SS	3350	--	mg/kg	1520	655	2270	1030	1520	1910	945	1470	1260	1710	1410	1000	724	951
	Selenium,Solid		SS	1.5	390	mg/kg	0.52	0.83			*1.8*		0.62	*2.7*					0.53	
		B	SS	1.5	390	mg/kg						0.16								
	Sodium,Solid		SS	145	--	mg/kg			*946*		*901*	*146*		*733*		117				
		B	SS	145	--	mg/kg		29.5					39.1				72.4	52.1	59.1	60.3
	Thallium,Solid		SS	0.91	5.2	mg/kg		*4.1*												
	Vanadium,Solid		SS	37.6	78	mg/kg	24.1	22.6	2.7	16	6.3	33.7	25	4.9	25.1	21.7	25.5	19.3	11.5	22.8
	Zinc,Solid		SS	93.3	23000	mg/kg	52.1	38.2	39.2	67.8	12.9	63.5	64.6	56.2	52.7	68.3	75.3	44.4	39.6	*122*

Table 4-3. Summary of Subsurface Soil (1 to 3 ft) Data Screening Results (continued)

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (1-3 ft)	Region 9 PRG (Residential Soil)	Units	CBPSS-019-0002-SO	CBPSS-020-0002-SO	CBPSS-021-0002-SO	CBPSS-023-0002-SO	CBPSS-024-0002-SO	CBPSS-025-0002-SO	CBPSS-026-0002-SO	CBPSS-027-0002-SO	CBPSS-028-0002-SO	CBPSS-029-0002-SO	CBPSS-030-0002-SO	CBPSS-031-0002-SO	CBPSS-032-0002-SO	CBPSS-033-0002-SO	CBPSS-034-0002-SO
							8/30/2001	8/30/2001	8/30/2001	9/6/2001	9/7/2001	8/30/2001	8/8/2001	8/8/2001	8/7/2001	9/5/2001	8/7/2001	8/7/2001	9/5/2001	8/7/2001	8/7/2001
Cyanide 9012A	Cyanide, Total,Solid		SS	0	1200	mg/kg							*3.1*	*0.62*							
Explosives 8330	2,4,6-TNT,Solid	J	SS	--	16000	ug/kg															
Propellants 8330	Nitrocellulose	B	SS	--	--	mg/kg															
TAL Metals 6010B	Aluminum,Solid		SS	19500	76000	mg/kg	17800	10900	12700	12000	16200	12000	16000	13900	17500	16400	12700	13400	11700	15400	3730
	Antimony,Solid		SS	0.96	31	mg/kg													0.41		
		B	SS	0.96	31	mg/kg				0.17											
	Arsenic,Solid		SS	19.8	0.39	mg/kg	**10.7**	**9.5**	**11.9**	**13.7**	**11.1**	**4.8**	**5.7**	**13.6**	**11**	**14.3**	**12.1**	**14.4**	**13.6**	**11.6**	**5.3**
	Barium,Solid		SS	124	5400	mg/kg	66.7	73	58.5	87.7	66.2	*125*	*241*	97.9	62.9	81.4	81.1	45.8	78.3	65.2	41.6
	Beryllium,Solid		SS	0.88	150	mg/kg	0.66	0.6	0.57	0.8	0.78	*1.7*	*2.2*	0.82	0.64	0.78	0.71	0.69	0.68	0.7	
		B	SS	0.88	150	mg/kg															0.3
	Cadmium,Solid		SS	0	37	mg/kg	*0.48*	*0.37*	*0.41*				*0.25*								*0.3*
		B	SS	0	37	mg/kg				*0.085*	*0.11*	*0.12*									
	Calcium,Solid		SS	35500	--	mg/kg	1050	1640	1140	1830	3300	*58500*	*126000*	6600	531	1260	1290	5190	1770	2190	*53700*
	Chromium,Solid		SS	27.2	30	mg/kg	22.3	15.9	17.2	17.6	20.8	5.8	10.8	16.8	20.5	19.7	16.1	18.4	16.7	19.1	8.9
	Cobalt,Solid		SS	23.2	900	mg/kg	7.3	8.4	10.1	12.3	10.1	1.8	3.8	19.3	12.1	9	11.7	11.9	11.6	11.1	4.3
	Copper,Solid		SS	32.3	3100	mg/kg	16.7	10.6	15.3	21.2	18.5	7.6	10.2	11.5	12.1	17.3	9.5	17.4	16	15.4	6.5
	Iron,Solid		SS	35200	23000	mg/kg	**30000**	**24500**	**23000**	**26400**	**31400**	8000	8210	**30000**	**27800**	**26200**	**25000**	**29400**	**26300**	**26000**	9250
	Lead,Solid		SS	19.1	400	mg/kg	16.5	*35*	15	11.8	12.8	*23.7*	*60*	8	13.3	15.9	12.1	15.3	15.7	12.4	13.2
	Magnesium,Solid		SS	8790	--	mg/kg	2990	1930	2930	3850	3050	6940	*10300*	2700	2830	3320	2270	5200	3620	3760	1200
	Manganese,Solid		SS	3030	1800	mg/kg	145	516	249	374	340	1180	**2180**	**2090**	603	261	1050	301	515	286	412
	Mercury,Solid		SS	0.04	23	mg/kg									*0.044*						
		B	SS	0.04	23	mg/kg	0.03	0.031	0.028	0.015	0.036	0.022	0.031	0.023		0.021	0.037	0.013	0.023	0.03	0.021
	Nickel,Solid		SS	60.7	1600	mg/kg	14.5	11.9	20.6	30.6	19	4.5	13.9	13.3	15.1	20.8	15.3	27.2	25.6	23.4	10.7
	Potassium,Solid		SS	3350	--	mg/kg	1580	1180	1500	1350	1320	722	1520	1260	1720	1530	1300	2520	1150	2370	613
	Selenium,Solid		SS	1.5	390	mg/kg	0.51					*1.6*	*1.6*	0.61							
		B	SS	1.5	390	mg/kg															
	Sodium,Solid		SS	145	--	mg/kg				86.1		*251*	*514*	137	96.5		117	125		89.2	
		B	SS	145	--	mg/kg					53.5					54.9			42.4		
	Thallium,Solid		SS	0.91	5.2	mg/kg															
	Vanadium,Solid		SS	37.6	78	mg/kg	35.5	22.5	21.6	18.7	29.7	6.8	11.8	26.8	32.7	28.2	26.4	19.6	18.8	23.3	6.8
	Zinc,Solid		SS	93.3	23000	mg/kg	52.3	71	56	64.3	57.9	31.2	61.7	52.8	56.2	53	69	62.5	63.4	64.6	*422*

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect

italics – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

Table 4-4. Summary of Soil Boring Surface Soil (0 to 1 ft) Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (0-1 ft)	Region 9 PRG (Residential Soil)	Units	CBPSB-001-0001-SO	CBPSB-002-0001-SO	CBPSB-003-0001-SO	CBPSB-003A-0001-SO	CBPSB-004-0001-SO	CBPSB-005-0001-SO	CBPSB-006-0001-SO	CBPSB-007-0001-SO	CBPSB-008-0001-SO
							8/1/2001	8/1/2001	8/2/2001	8/9/2001	8/2/2001	8/2/2001	8/1/2001	8/1/2001	8/1/2001
Cyanide 9012A	Cyanide, Total,Solid		SB	0	1200	mg/kg	*0.72*		*0.76*	*0.75*					
		B	SB	0	1200	mg/kg								*0.24*	
Propellants 8330	Nitrocellulose	B	SB	--	--	mg/kg				*1.2*	*1.1*				
	Nitroguanidine	J	SB	--	6100	mg/kg				*0.061*					
SVOCs TCL 8270 C	Benzo(a)anthracene,Solid	J	SB	110	620	ug/kg				*180*					
	Benzo(a)pyrene,Solid	J	SB	100	62	ug/kg				***200***					
	Benzo(b)fluoranthene,Solid	J	SB	140	620	ug/kg				*240*					
	Benzo(k)fluoranthene,Solid	J	SB	54	6200	ug/kg				*240*					
	Chrysene,Solid	J	SB	120	62000	ug/kg				*200*					
	Fluoranthene,Solid	J	SB	290	2300000	ug/kg				270					
	Indeno(1,2,3-cd)pyrene,Solid	J	SB	54	620	ug/kg				*130*					
	Pyrene,Solid	J	SB	230	2300000	ug/kg				*230*					
TAL Metals 6010B	Aluminum,Solid		SB	17700	76000	mg/kg	10700	13600	4420	7890	12200	11200	11400	15400	15400
	Antimony,Solid		SB	0.96	31	mg/kg	0.32		*1.8*			0.37			
		B	SB	0.96	31	mg/kg		0.26							
	Arsenic,Solid		SB	15.4	0.39	mg/kg	**8.6**	**11.6**	**8.3**	***20.6***	**8.9**	**14**	**9.5**	**11.4**	**11.6**
	Barium,Solid		SB	88.4	5400	mg/kg	78.9	54.8	*98.2*	86.1	312	61.6	55.7	60.6	61.7
	Beryllium,Solid		SB	0.88	150	mg/kg	0.56	0.54	0.48	0.84	0.49	0.64	0.45	0.53	0.52
	Cadmium,Solid		SB	0	37	mg/kg			*0.29*	*0.33*	*0.24*				
	Calcium,Solid		SB	15800	--	mg/kg	2450	1400	15500	*56900*	9000	1000	477	1450	1500
	Chromium,Solid		SB	17.4	30	mg/kg	13.5	16.4	14.2	7.1	*18.6*	15	13.5	*20.5*	*18.8*
	Cobalt,Solid		SB	10.4	900	mg/kg	6.9	*11.1*	3	2.8	6.4	*16*	6.7	6.3	5.6
	Copper,Solid		SB	17.7	3100	mg/kg	8.9	7	17	11.5	*31.3*	14.9	7.7	13	12.2
	Iron,Solid		SB	23100	23000	mg/kg	19600	23000	18200	10400	20100	***26000***	19700	***28000***	***24100***
	Lead,Solid		SB	26.1	400	mg/kg	15.3	22.1	*107*	24.2	*129*	18.8	20.3	24.1	17.2
	Magnesium,Solid		SB	3030	--	mg/kg	1770	1840	2940	*3930*	2270	2030	1760	2380	2310
	Manganese,Solid		SB	1450	1800	mg/kg	643	1220	469	707	462	*1610*	425	167	373
	Mercury,Solid		SB	0.04	23	mg/kg		*0.058*	*0.041*		*0.042*			*0.043*	
		B	SB	0.04	23	mg/kg	0.037			0.0074		0.03	0.038		0.036
	Nickel,Solid		SB	21.1	1600	mg/kg	11.9	10.7	10.4	7.4	14.1	15.3	10.4	14.2	13.5
	Potassium,Solid		SB	927	--	mg/kg	889	*961*	534	865	*1010*	906	798	*985*	*1370*
	Selenium,Solid		SB	1.4	390	mg/kg	0.94	*1.4*	*1.5*		0.8	*1.4*	0.72	0.98	1.3
	Sodium,Solid		SB	123	--	mg/kg			92.1	*175*	106				
		B	SB	123	--	mg/kg	71.3	60.5				57.5	54	59.7	76.1
	Thallium,Solid		SB	0	5.2	mg/kg					*0.18*				
	Vanadium,Solid		SB	31.1	78	mg/kg	21.6	29.9	7.5	8.9	24.8	22.8	23.7	*33.3*	29.5
	Zinc,Solid		SB	61.8	23000	mg/kg	36.7	43.3	*140*	*117*	*237*	48.7	47.1	59.2	41.2

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect

italics – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

Table 4-5. Summary of Soil Boring Subsurface (>3 ft) Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Soil Background Criteria (1-3 ft)	Region 9 PRG (Residential Soil)	Units	CBPSB-001-0002-SO	CBPSB-002-0002-SO	CBPSB-003A-0002-SO	CBPSB-004-0002-SO	CBPSB-005-0002-SO	CBPSB-006-0002-SO	CBPSB-007-0002-SO	CBPSB-008-0002-SO
							8/7/2001	8/8/2001	8/9/2001	8/8/2001	8/9/2001	8/7/2001	8/7/2001	8/6/2001
Cyanide 9012A	Cyanide, Total,Solid		SB	0	1200	mg/kg				*0.68*				
TAL Metals 6010B	Aluminum,Solid		SB	19500	76000	mg/kg	13300	9460	14900	8640	13800	7790	7270	14700
	Antimony,Solid	B	SB	0.96	31	mg/kg				0.25				0.2
	Arsenic,Solid		SB	19.8	0.39	mg/kg	**13.3**	**18.3**	***25***	**17.5**	***22.3***	**16.7**	***26.2***	**16.9**
	Barium,Solid		SB	124	5400	mg/kg	47	32.2	50.8	34.2	49.1	23.7	31.5	49.1
	Beryllium,Solid		SB	0.88	150	mg/kg	0.67	0.46	0.72	0.41	0.74		0.35	0.72
		B	SB	0.88	150	mg/kg						0.35		
	Calcium,Solid		SB	35500	--	mg/kg	8370	9660	6830	9780	6510	16300	11500	7490
	Chromium,Solid		SB	27.2	30	mg/kg	18.7	14	20.4	13	19.2	10.9	11	20
	Cobalt,Solid		SB	23.2	900	mg/kg	12.6	9.8	13.6	8.9	13.7	7.5	7.7	13.2
	Copper,Solid		SB	32.3	3100	mg/kg	18.2	21.1	18.2	21.3	18.1	20	18.5	18
	Iron,Solid		SB	35200	23000	mg/kg	**29900**	**25600**	**33900**	**24600**	**32100**	21300	20900	**31300**
	Lead,Solid		SB	19.1	400	mg/kg	7.7	7.1	11.8	7.9	12.4	*27.9*	14.9	10.5
	Magnesium,Solid		SB	8790	--	mg/kg	6850	7160	7200	7000	7010	5820	6840	7240
	Manganese,Solid		SB	3030	1800	mg/kg	321	357	349	363	320	369	342	322
	Mercury,Solid	B	SB	0.04	23	mg/kg	0.011	0.0081		0.012		0.0099	0.012	
	Nickel,Solid		SB	60.7	1600	mg/kg	28.2	22.3	30.4	20.4	30.1	17.2	17.7	29.8
	Potassium,Solid		SB	3350	--	mg/kg	2960	2040	3230	1820	2940	1620	1460	*3410*
	Sodium,Solid		SB	145	--	mg/kg	*191*	*149*	*232*	119	*240*	109	129	*168*
	Vanadium,Solid		SB	37.6	78	mg/kg	18.8	15.9	21.1	15	19.4	13.9	13.1	21.1
	Zinc,Solid		SB	93.3	23000	mg/kg	63	61.7	62.5	59.8	62.4	47.9	53.1	68

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect
italics – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

4.1.3 Sediments

Nine sediment samples were collected during the RI at CBP. Five of the nine sediment samples were collected as soil because sediment was not present at time of sampling. Results from the sediment samples were compared to Facility Wide background concentrations for sediments and/or PRGs for residential soil. A summary of sediment exceedances are provided in Table 4-6. All analytes detected above background and/or PRGs are illustrated on Figure 4-5. Tabulated analytical results and laboratory reports are presented in their entirety in Appendix P.

Other details pertinent to the sediment analytical results:

- No explosives, pesticides, or PCBs were detected above detection limits.
- The propellants detected do not exceed PRGs.
- Several SVOCs [benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene] were detected in one sample (SD-002) at concentrations below PRGs.
- No background concentrations were established for antimony, cadmium, cyanide, or silver; therefore, each was assigned a background value of zero. Concentrations of these constituents were detected but they do not exceed PRGs.
- Acetone was detected in one sample (SD-008) and methylene chloride was detected in one sample (SD-002). Both of these VOCs are common laboratory contaminants, however these results are evaluated as site related. The detected concentrations of these VOCs did not exceed PRGs.
- TOC was measured with a concentration range of 1,000 to 57,000 mg/kg.
- Other inorganics were detected but did not exceed background or PRGs.

Table 4-6. Summary of Sediment Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Sediment Background Criteria	Region 9 PRG (Residential Soil)	Units	CBPSD-001-0001-SD 8/9/2001	CBPSD-002-0001-SD 9/18/2001	CBPSD-003-0001-SD 8/10/2001	CBPSD-004-0001-SD 8/9/2001	CBPSD-005-0001-SD 9/10/2001	CBPSD-006-0001-SD 9/10/2001	CBPSD-007-0001-SD 8/10/2001	CBPSD-008-0001-SD 9/18/2001	CBPSD-009-0001-SD 8/9/2001
Cyanide 9012A	Cyanide, Total,Solid		SD	0	1200	mg/kg	*0.51*	*1.2*			*1*		*0.9*		
Others	TOC Average Duplicates, Solid		SD	--	--	mg/kg	*22000*	*20000*	*23000*	*14000*	*1000*	*1100*	*57000*	*5600*	*43000*
Propellants 8330	Nitrocellulose	B	SD	--	--	mg/kg		*0.6*						*0.65*	
SVOCs TCL 8270 C	Benzo(a)anthracene,Solid	J	SD	--	620	ug/kg		*180*							
	Benzo(a)pyrene,Solid	J	SD	--	62	ug/kg		***210***							
	Benzo(b)fluoranthene,Solid	J	SD	--	620	ug/kg		*250*							
	Benzo(k)fluoranthene,Solid	J	SD	--	6200	ug/kg		*210*							
	Chrysene,Solid	J	SD	--	62000	ug/kg		*240*							
	Indeno(1,2,3-cd)pyrene,Solid	J	SD	--	620	ug/kg		*140*							
	Phenanthrene,Solid	J	SD	--	2300000	ug/kg		*170*							
	Pyrene,Solid	J	SD	--	2300000	ug/kg		*350*							
TAL Metals 6010B	Aluminum,Solid		SD	13900	76000	mg/kg	12400	11000	*19100*	11800	834	1140	13400	2320	*15500*
	Antimony,Solid		SD	0	31	mg/kg	*0.32*								
	Arsenic,Solid		SD	19.5	0.39	mg/kg	13.2	10.5	16.8	12.9	3.7	5.2	4.6	9.6	***20.1***
	Barium,Solid		SD	123	5400	mg/kg	*129*	*169*	*214*	87	6.4	7.1	77.9	22.9	74.9
	Beryllium,Solid		SD	0.38	150	mg/kg	*1.3*	*0.92*	*1.1*	*0.76*			*0.77*		
		B	SD	0.38	150	mg/kg						0.064		0.16	*0.79*
	Cadmium,Solid		SD	0	37	mg/kg	*0.64*	*1.4*	*0.86*	*0.26*			*0.63*		
	Calcium,Solid		SD	5510	--	mg/kg	*23500*	*32600*	*23100*	2000	409	515	*9720*	1580	3610
	Chromium,Solid		SD	18.1	30	mg/kg	16	15	*20.8*	15.3	1.6	2	*19*	4.2	*21.6*
	Cobalt,Solid		SD	9.1	900	mg/kg	*14.2*	*9.2*	*10*	*9.2*	1.1	1.3	*11.9*	3.5	*11.4*
	Copper,Solid		SD	27.6	3100	mg/kg	*141*	*30.5*	*27.7*	13.6	1.8	2.2	22.6	6.6	16.6
	Iron,Solid		SD	28200	23000	mg/kg	***65700***	17900	21600	22700	3330	4610	22400	10200	***29600***
	Lead,Solid		SD	27.4	400	mg/kg	20.4	*79.5*	*71.8*	15.4	2.1		*38.5*	3.6	*29.8*
		B	SD	27.4	400	mg/kg						1.6			
	Magnesium,Solid		SD	2760	--	mg/kg	*4820*	*3220*	*3610*	2360	362	498	*3330*	1060	*4180*
	Manganese,Solid		SD	1950	1800	mg/kg	***2590***	976	1060	743	65.8	107	484	450	176
	Mercury,Solid		SD	0.06	23	mg/kg		*0.11*	*0.067*						
		B	SD	0.06	23	mg/kg	0.031			0.023			0.055		0.026
	Nickel,Solid		SD	17.7	1600	mg/kg	*20.9*	*20.4*	*22.3*	17.4	2.6	3	*22.5*	6.3	*25.8*
	Potassium,Solid		SD	1950	--	mg/kg	1160	958	1550	1660		188	*2360*	320	*3300*
		B	SD	1950	--	mg/kg					169				
	Selenium,Solid		SD	1.7	390	mg/kg		1.1							0.6
	Silver,Solid	B	SD	0	390	mg/kg	*0.18*	*0.39*						*0.31*	
	Sodium,Solid		SD	112	--	mg/kg	*260*	*155*	*159*	*125*					
		B	SD	112	--	mg/kg					26.2	26.1	106	69.2	*226*
	Vanadium,Solid		SD	26.1	78	mg/kg	14.7	17.4	*30.4*	23.3	1.6	2.5	23.1	5.3	*27.1*
	Zinc,Solid		SD	532	23000	mg/kg	490	484	245	106	11.4	13.6	264	36.4	78
VOCs TCL 8260B	Acetone,Solid		SD	--	14000000	ug/kg								*10*	
	Methylene chloride,Solid		SD	--	9100	ug/kg		*9*							

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect *italics* – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

4.1.4 Surface Water

Other details pertinent to the surface water analytical results:

- No explosives, propellants, cyanide, pesticides, PCBs, VOCs, or SVOCs were detected above detection limits;
- Metals and cyanide samples were not filtered, therefore results represent total concentrations; and
- Other inorganic constituents were detected, although no concentrations exceeded background and/or PRGs.

Table 4-7. Summary of Surface Water Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Surface Water Background Criteria	Region 9 PRG (Tap Water)	Units	CBPSW-005-0001-SW	CBPSW-006-0001-SW	CBPSW-008-0001-SW
							9/10/2001	9/10/2001	9/18/2001
TAL Metals 6010B	Aluminum	B	SW	3370	36000	ug/L	98.6		34.2
	Arsenic		SW	3.2	0.045	ug/L	***3.2***	**2**	
	Barium		SW	47.5	2600	ug/L	44.5	42.2	39.9
	Calcium		SW	41400	--	ug/L	*68000*	*69500*	*75500*
	Iron		SW	2560	11000	ug/L	706	374	296
	Magnesium		SW	10800	--	ug/L	*20400*	*19900*	*20800*
	Manganese		SW	391	880	ug/L	180	147	116
	Potassium		SW	3170	--	ug/L	1830	1890	2200
	Sodium		SW	21300	--	ug/L	6910	6910	7430
	Zinc		SW	42	11000	ug/L	12.6		
		B	SW	42	11000	ug/L		7.9	8.5

J = organics, estimated due to concentration < RL, but >MDL
B = inorganics, estimated due to concentration < RL, but >MDL
U = nondetect
italics – value ≥ background criteria
bold – value ≥ PRG
bold italics – value ≥ background criteria and PRG

4.1.5 Groundwater

Eight groundwater samples were collected from newly installed monitoring wells (MW-001 through MW-008). Groundwater samples were collected in order to identify any subsurface contamination of the shallow water table. The groundwater analytical results were compared to background values and USEPA Region IX tap water PRGs. PRGs were used because a more complete list values exists than for MCLs, and the PRGs are more conservative than MCLs. A summary of exceedances is presented in Table 4-8. All analytes detected above background and PRGs are illustrated on Figure 4-7. Tabulated analytical results and laboratory reports are provided as Appendix J.

Other details pertinent to the groundwater analytical results:

- No explosives, propellants, cyanide, pesticides, PCBs, or SVOCs were detected above detection limits; and
- Acetone was detected in one sample (MW-005), however the concentration does not exceed PRGs.

4.2 IN SITU PERMEABILITY TESTING RESULTS

Following installation of the monitoring wells a slug test was completed to determine the in-situ permeability of the aquifer underlying the CBP. Table 4-9 shows the results of the slug tests performed in October 2001.

Based on the results of the slug tests, hydraulic conductivities average 1.20 x 10^{-6} cm/s in the soil underlying CBP. The field measurements and test data are provided in Appendix I along with the calculation worksheets for the tests. Previous slug tests performed at wells located at other sites within RVAAP indicate average hydraulic conductivities between 3.87 x 10^{-2} cm/s to 4.46 x 10^{-6} cm/s (USACE, 1999).

Data from the three rounds of well gauging were used to produce potentiometric surface maps for CBP (Figures 4-8 through 4-10). The water level data suggests that groundwater flows in a northwesterly direction at CBP. Groundwater flows to the northwest at a gradient of approximately 0.012 ft/ft.

Table 4-8. Summary of Groundwater Data Screening Results

Group	Analyte	Qualifier	Media	RVAAP Ground Water Background Criteria	Region 9 PRG (Tap Water)	Units	CBPGW-001-0001-GW	CBPGW-002-0001-GW	CBPGW-003-0001-GW	CBPGW-004-0001-GW	CBPGW-005-0001-GW	CBPGW-006-0001-GW	CBPGW-007-0001-GW	CBPGW-008-0001-GW
							8/23/2001	8/24/2001	8/29/2001	8/24/2001	8/27/2001	8/22/2001	8/23/2001	8/22/2001
TAL Metals 6010B	Aluminum		GW	--	36000	ug/L	*1360*	*612*				*340*		
		B	GW	--	36000	ug/L				*101*	*21.3*			
	Arsenic		GW	11.7	0.045	ug/L	*35.1*	7.7	*19.9*		7.6	4		3.8
		B	GW	11.7	0.045	ug/L							2	
	Barium		GW	82.1	2600	ug/L	20.3	18.8	27.9	68.2	55.1	*110*	26	31.4
	Calcium		GW	115000	--	ug/L	*308000*	*165000*	*196000*	72000	72900	71600	*280000*	*236000*
	Cobalt	B	GW	0	730	ug/L	*4.4*	*3.8*					*3.2*	*2.3*
	Copper		GW	0	1500	ug/L					*15.8*			
		B	GW	0	1500	ug/L	*5.7*	*5*		*3.6*		*3.9*	*4.2*	*3.2*
	Iron		GW	279	11000	ug/L	*6530*	*2140*	*632*	*1420*	*548*	*1310*	181	
	Magnesium		GW	43300	--	ug/L	*151000*	*101000*	*111000*	26300	28500	26800	*146000*	*122000*
	Manganese		GW	1020	880	ug/L	198	110	103	121	57.4	83.6	144	159
	Nickel	B	GW	0	730	ug/L	*6.6*	*7.1*	*7.4*				*3.8*	*3.9*
	Potassium		GW	2890	--	ug/L	*7590*	*4970*	*8280*	2850	2440	2640	*8860*	*7600*
	Selenium	B	GW	0	180	ug/L		*1.9*						
	Silver	B	GW	0	180	ug/L			*1.4*					
	Sodium		GW	45700	--	ug/L	*51500*	*46200*	*76900*	14000	17900	13400	*64100*	43400
	Vanadium	B	GW	0	36	ug/L	*3.2*							
	Zinc		GW	60.9	11000	ug/L	25.7	14.3	23.8	17.8	15.2	38.6	17.9	27.6
VOCs TCL 8260B	Acetone		GW	--	5500	ug/L					*4*			

J = organics, estimated due to concentration < RL, but >MDL B = inorganics, estimated due to concentration < RL, but >MDL U = nondetect

italics – value ≥ background criteria **bold** – value ≥ PRG ***bold italics*** – value ≥ background criteria and PRG

Table 4-9. Hydraulic Conductivities in Central Burn Pits RI Monitoring Wells

Monitoring Well ID	Screened Interval Depth (ft)	Total Depth (ft)	Geologic Material Adjacent to Screen	Hydraulic Conductivity (cm/s) Based on Slug Testing
MW-001	21.75-31.75	32.25	clayey silt w/silty sand interbeds	4.98 E-7
MW-002	19.5-29.5	30	clayey silt	5.20 E-7
MW-003	14.5-24.5	25	clay; clayey silt	1.70 E-8
MW-004	17-27	27.5	clayey silt	3.70 E-6
MW-005	14.5-24.5	25	clay; clayey silt w/ sand interbeds	3.13 E-6
MW-006	12.5-22.5	23	clay; clayey silt; clayey sand	1.00 E-6
MW-007	19.5-29.5	30	clayey silt w/silty sand interbeds	5.68 E-7
MW-008	15-25	25.5	clay; clayey silt; clayey sand	1.31 E-7

5.0 CONTAMINANT FATE AND TRANSPORT

This section contains information on chemical properties and degradation potential of the chemicals detected at concentrations in excess of established background, and the environmental conditions of the site and hydrological considerations that are likely to affect contaminant fate and transport near the CBP and the surrounding area. Section 5.1 contains a general discussion of the various chemical and physical properties of these chemicals. Section 5.2 discusses the potential for chemical compounds to biodegrade or undergo other transformations. Section 5.3 presents a discussion of transport pathways where migration and attenuation might be occurring and how spatial and temporal variations in hydrologic conditions might be affecting transport. Section 5.4 presents an overall summary of contaminant migration in and around the CBP.

Section 4.0 detailed the chemicals identified as being present in the CBP environmental media at concentrations greater than background. The media affected are surface soil, subsurface soil, groundwater, surface water, and sediment. Several of these chemicals, which are discussed in following sections, were detected only in a few samples, in one medium or another, at concentrations exceeding the applicable chemical of potential concern (COPC) screening level (Tables 2.1 through 2.6 in Appendix S). For example, Aroclor-1254 was detected in one shallow surface soil sample (CBPSS-014-0001-FD) at a concentration of 0.24 mg/kg, which is slightly greater than the screening level (0.222 mg/kg), but Aroclor-1254 was not detected at concentrations greater than screening levels in any other environmental medium. In general, the detections of SVOCs (including PAHs), herbicides, pesticides, PCBs and explosive compounds at concentrations exceeding COPC screening levels were very limited.

The emphasis of this section is to describe the fate and transport of the chemicals that were detected in excess of background with an emphasis on COPCs selected in Section 2.0. It is expected that the fate and transport of minor site contaminants would be similar to the major contaminants (i.e., COPCs) that have similar physical and chemical properties.

5.1 CHEMICAL AND PHYSICAL PROPERTIES AFFECTING CHEMICAL MOBILITY

Table 5-1 presents physical and chemical properties of the organic chemicals detected at the CBP at concentrations exceeding background. Table 5-2 is a simple representation of the gross mobility of metal ions that is expected under various combinations of oxidation-reduction (redox) potential and pH. These properties can be used to qualitatively estimate the environmental mobility and fate of site contaminants. The properties that are discussed include the following:

- Specific gravity;
- Vapor pressure;
- Water solubility -Henry's Law Constant;
- Octanol/water partition coefficient (K_{ow});
- Organic carbon partition coefficient (K_{oc});
- Soil-water distribution coefficient (K_d);

- Bioconcentration factor (BCF); and
- Mobility index (MI).

Literature values of the water solubility, K_{ow}, K_{oc}, vapor pressure, Henry's Law constant, BCF, MI, and specific gravity are presented for each organic chemical, when available, in Table 5-1. A discussion of the environmental significance of each of these parameters follows.

5.1.1 Specific Gravity

Specific gravity is the ratio of the density of a given volume of pure chemical at a specified temperature (usually 20°C) to the density of the same volume of water at a given temperature (usually 4°C). Its primary use is to determine whether a liquid chemical will have a tendency to float or sink in water if it is present as a pure chemical (i.e., at very high concentrations). Non-aqueous phase liquids (NAPLs) such as chlorinated aliphatic compounds with a specific gravity greater than 1 will tend to sink if present as a pure liquid or mixture of pure liquids. This is true whether the NAPL is present in a water body or in a matrix such as soil. Chemicals with a specific gravity less than 1 (e.g., ketones) will tend to float. This physical characteristic becomes important only when the chemicals are at very high concentrations and are liquid when they are in pure phase. For the CBP, no NAPLs were detected, although a low concentration of acetone was observed in one groundwater sample. Therefore, the characteristic of specific gravity is not expected to be important for the CBP.

5.1.2 Vapor Pressure

Vapor pressure provides an indication of the rate at which a chemical volatilizes from both solid and aqueous matrices. It is of primary importance at environmental interfaces such as surface soil/air and surface water/air. In unsaturated soils, volatility also governs the rate at which interstitial air pockets become saturated with chemical vapor. Volatilization from stream sediments could also be significant under low flow conditions (i.e., during summer months and drought conditions) when the sediments are exposed to the atmosphere in a dry creek bed. Volatilization is not as important when evaluating contaminated groundwater and subsurface soils that are not exposed to the atmosphere. Vapor pressures for ketones and halogenated aliphatics are generally many times greater than vapor pressures for PAHs, herbicides, pesticides, energetic compounds, and phthalate esters. Generally, the more volatile chemicals are liquid at normal temperatures and pressures whereas the less volatile chemicals are solids under the same conditions. Chemicals with greater vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Volatilization from surface water, surface soil, and sediment is a significant loss process for VOCs. Volatilization is not significant for most inorganics unless the inorganic materials have been converted to orgnometallic compounds through biochemical action.

Table 5-1. Environmental Fate and Transport Properties for Organic Chemicals

Chemical	Specific Gravity (@ 20/4°C)(1)	Vapor Pressure (mm Hg @ 20°C)(1)	Solubility (mg/L @ 20°C)(1)	Octanol/Water Partition Coefficient(2)	Organic Carbon Partition Coefficient(3)	Henry's Law Constant (atm-m3/mole)(1,2)	Bioconcentration Factor (mg/L/mg/kg)	Mobility Index log((solubility*VP)/K_{oc})(4)
EXPLOSIVES								
2,4,6-Trinitrotoluene	1.65 (6)	2.02E-06	124	10E1.60	308	4.87E-09	10E1.61	-6.09E+00
Nirocellulose	1.67 (6)	NA	NA	NA	NA	NA	NA	NA
Nitroguanidine	1.71 (6)	NA	NA	NA	NA	NA	NA	NA
KETONES								
Acetone	0.7899	2.66E+2 (25°C)	Miscible	5.75E-01	7.08E+03 (2)	4.276E-5 (25°C)	3.81E-1(5)	NA
HALOGENATED ALIPHATICS								
Methylene Chloride	1.3266	4.29E+2 (25°C)	1.67E+04 (25°C)	1.78E+01	1.17E+01(4)	3.19E-3 (25°C)	6.00E+00	5.79E+00
PESTICIDES								
4,4'-DDE	NA	6E-06 (25 C) (5)	1.2E-01 (25 C) (5)	4.9E+05 (5)	5.01E+04 (5)	2.1E-05 (5)	8.13E+04 (5)	-1.08E+01
4,4'-DDT	1.55 (7)	1.6E-07 (5)	2.5E-02 (5)	2.29E+06 (5)	1.52E+05 (5)	8.1E-06 (5)	9.33E+04 (5)	-3.58E+00
Endosulfan I	1.745 (8)	1E-05 (25 C) (5)	5.1E-01 (5)	6.76E+03 (5)	6.32E+03 (5)	1.05E-05 (5)	1.05E+03 (5)	-9.09E+00
Endosulfan II	1.745 (8)	1E-05 (25 C) (5)	4.5E-01 (5)	6.76E+03 (5)	6.77E+03 (5)	1.31E-05 (5)	1.05E+03 (5)	-9.18E+00
Endrin	1.7	3E-06 (5)	2.5E-01 (5)	3.63E+04 (5)	1.14E+04 (5)	7.52E-06 (20 C) (5)	1.48E+03 (5)	-1.02E+01
Gamma Chlordane	1.59-1.63 (25 °C) (9)	9.8E-06 (25 C) (5)	5.6E-02 (25) (5)	2.09E+03 (5)	1.22E+03 (5)	4.86E-05 (5)	3.16E+03 (5)	-9.35E+00
Heptachlor Epoxide	1.57 (9 °C) (9)	1.95 E-05 (30 C) (5)	2E-01 (25 C) (5)	2.51E+05 (5)	1.06E+01 (5)	9.5E-06 (5)	1.45E+04 (5)	-6.43E+00
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)								
Benzo(a)anthracene	1.274	5.00E-09	1E-2 (24°C)	4.07E+05	3.98E+05	6.60E-07	5.30E+04	-1.59E+01
Benzo(a)pyrene	1.351	5.00E-09	3.8E-3 (25°C)	9.55E+05	1.02E+06	4.9E-7 (25°C)	1.40E+05	-1.67E+01
Benzo(b)fluoranthene	NA	5.00E-07	1.2E-3 (25°C)	3.72E+06	1.23E+06	1.20E-05	1.40E+05	-1.53E+01
Benzo(k)fluoranthene	NA	9.59E-11	5.5E-4 (25°C)	6.92E+06	1.23E+06	1.04E-03	1.40E+05	-1.94E+01
Chrysene	1.274 (20°C)	6.3E-9 (25°C)	6E-3 (25°C)	4.07E+05	3.98E+05	1.05E-6 (25°C)	5.30E+04	-1.60E+01
Fluoranthene	1.252	5.0E-6 (25°C)	2.65E-1 (25°C)	2.14E+05	1.07E+05	6.5E-6 (25°C)	1.20E+04	-1.09E+01
Indeno(1,2,3-cd)pyrene	NA	1E-10 (25°C)	6.20E-02	4.57E+07	3.47E+06	6.95E-8 (25°C)	3.50E+05	-1.77E+01
Phenanthrene	0.980 (4°C)	1E+0 (118.2°C)	8.16E-1 (21°C)	2.88E+04	1.40E+04	3.93E-5 (25°C)	4.70E+03	-4.23E+00
Pyrene	1.271 (23/4°C)	2.5E+0 (200°C)	1.6E-1 (26°C)	1.51E+05	1.05E+05	5.1E-6 (25°C)	1.20E+04	-5.42E+00

Table 5-1. Environmental Fate and Transport Properties for Organic Chemicals (continued)

Chemical	Specific Gravity (@ 20/4°C)(1)	Vapor Pressure (mm Hg @ 20°C)(1)	Solubility (mg/L @ 20°C)(1)	Octanol/Water Partition Coefficient(2)	Organic Carbon Partition Coefficient(3)	Henry's Law Constant (atm-m3/mole)(1,2)	Bioconcentration Factor (mg/L/mg/kg)	Mobility Index log((solubility*VP)/K_{oc})(4)
PCBs								
Aroclor-1254	1.50 (25°C)(3)	7.71E-5(3)	3.1E-2(3)	1.1E+6(3)	5.30E+05	2.6E-3(3)	1.30E+05	-1.13E+01

NA = Not available

1 Numbers in parentheses indicate temperatures for applicable value. For example, (20/4oC) indicates that density of the chemical was measured at 20oC; whereas, density of water was measured at 4oC.

2 Mabey, W.R., J.H. Smith, R.T. Podoll, H.L. Johnson, T. Mill, T.-W. Chou, J. Gates, I.W. Partridge, H. Jaber, and D. Vandenberg, 1982. Aquatic Fate Process Data for Organic Priority Pollutants. U.S. EPA Report No. 440/4-81-014, December, 1982, unless otherwise noted.

3 U.S. EPA, 1996. Soil Screening Guidance, unless otherwise noted.

4 Calculated value (using values in this table).

5 Syracuse Research Corporation. Online Database: Interactive Physical Properties Database Demo. http://www.syrres.com/esc/chemfate.htm Web site last updated December 3, 2004.

6 Meyer et al., 2002 - See text for full reference.

7 IPCS INTOX Databank, http://www.intox.org/databank/index.htm, downloaded on January 11, 2005.

8 Value is for Endosulfan taken from: http://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+@rel+72-20-8, downloaded on January 11, 2005.

9 Taken from: http://www.epa.gov/OGWDW/dwh/t-soc/, downloaded on January 11, 205.

Table 5-2. Relative Mobilities of Select Metals Under Various Environmental Conditions

Relative Mobility	Environmental Conditions			
	Oxidizing	Acidic	Neutral/Alkaline	Reducing
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg,Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:
As = Arsenic
Ag = Silver
Ba = Barium
Be = Beryllium
Cd = Cadmium
Cr = Chromium
Cu = Copper
Fe = Iron
Hg = Mercury
Ni = Nickel
Pb = Lead
Se = Selenium
Zn = Zinc
Eh = Standard Redox Potential

Source: Swartzbaugh, et al. Remediating Sites Contaminated with Heavy Metals
Hazardous Materials Control, November/December 1992.

5.1.3 Water Solubility

Solubilities are easily determined under laboratory conditions. Many chemicals of environmental interest are often considered to be insoluble in reference books (e.g., The “Handbook of Chemistry and Physics”) because they are insoluble for most practical situations. However, all chemicals are soluble to some extent in water and even those that are classified as insoluble may be soluble in the parts per billion (ug/L) or parts per million (mg/L) concentration ranges. These ranges may yield toxic effects and are routinely measured during environmental work.

The rate at which a chemical is leached from soil by infiltrating precipitation is proportional to its water solubility. More soluble chemicals are more readily leached than less soluble chemicals. The water solubilities presented in Table 5-1 indicated that ketones and halogenated aliphatics are usually several orders of magnitude more water soluble than explosives, pesticides, herbicides, PCBs, and some of the PAHs. PCBs, in particular, are not frequently detected as dissolved compounds in aqueous samples because of their low solubility.

5.1.4 Henry’s Law Constant

Both vapor pressure and water solubility are useful for determining volatilization rates from surface water bodies and groundwater. The measured ratio of these two parameters (the Henry's Law constant) under equilibrium conditions is used to calculate the equilibrium chemical concentrations in the vapor (air) phase versus the liquid (water) phase for the dilute solutions commonly encountered in environmental settings. In general, chemicals having a Henry's Law constant less than 1 x 10^{-5} atm-m^3/mole, such as pesticides, PCBs, and PAHs, should volatilize very little and should be present only in minute amounts in the atmosphere or soil vapor. For chemicals with a Henry's Law constant greater than 5 x 10^{-3} atm-m^3/mole, such as many of the halogenated aliphatics, volatilization and diffusion in soil vapor could be significant.

5.1.5 Octanol/Water Partition Coefficient (Kow)

K_{ow} is a measure of the equilibrium partitioning of chemicals between octanol and water as determined under laboratory conditions. A linear relationship between the K_{ow} and the uptake of chemicals by fatty tissues of animal and human receptors, or the BCF, has been established (Lyman et al., 1990). The K_{ow} is also useful in characterizing the sorption of compounds by organic soils where experimental values for soil are not available. Pesticides and aromatic compounds, lacking functional groups that enhance water solubility, are several orders of magnitude more likely to partition to fatty tissues than the more soluble VOCs. K_{ow} values are also used to estimate BCFs in aquatic organisms.

5.1.6 Organic Carbon-Water Partition Coefficient (Koc)

K_{oc} indicates the tendency of a chemical to adhere to organic matter contained in soils under laboratory conditions. Many VOCs, for example, have relatively low K_{oc} values and tend to be fairly mobile in the environment as a result of groundwater or surface water movement. Chemicals with high K_{oc} values generally have low water solubility and vice versa. This parameter may be used to infer the relative rates at which the more mobile chemicals (e.g., ketones and halogenated aliphatics) are transported in groundwater. Chemicals such as most pesticides, PCBs, and PAHs are relatively immobile in the soil and are preferentially bound to the soil. These compounds are not subject to groundwater transport to the same extent as compounds with higher water solubilities. However, these immobile chemicals can be transported by erosional processes when they occur in surface soils and sediments.

Several factors affect the measured value of K_{oc}. Values of K_{oc} usually decrease with increasing temperature. In addition, the fine silt and clay fraction of soil and sediments may have a greater tendency to absorb chemicals because they often have a higher concentration of organic matter and more adsorption sites per unit volume.

5.1.7 Soil-Water Distribution Coefficient (Kd)

K_d is a measure of the equilibrium distribution of a chemical in soil/water systems. The K_d of organic chemicals is a function of both the K_{oc} and the fraction of organic carbon in the soil (f_{oc}):

$K_d = K_{oc} * f_{oc}$

The degree to which organic chemicals sorb to soils is very important when assessing migration potential. If a chemical tends to sorb strongly to soil, there is much less probability that the chemical will reach groundwater and affect the groundwater quality. In sediments, a high degree of sorption similarly indicates that the chemical is more likely to be transported in entrained sediments than as a dissolved species in surface water.

Chemicals, such as PAHs, that migrate slowly through soil and the upper unsaturated rock units have a relatively long time period where they are subjected to biodegradation processes before they reach the first water-bearing rock unit. As a consequence of low migration potential, there is a very low probability that chemicals with very high K_d values (i.e., PAHs) will reach surface water bodies via groundwater flow. However, if PAHs or pesticides are present at the ground surface, eroded, and transported in surface runoff with soil particles (as a sorbed phase), then there is potential for these compounds to reach adjacent stream channels.

For metals, the sorption coefficients are, in large part, a representation of the ion exchange tendencies of the metals with the soil. Table 5-3 presents sorption coefficients for cyanide and the metals (except calcium, magnesium, potassium, and sodium) that were detected at the CBP. Other factors aside, the more positively charge an ion is, the more tightly it is bound to soils. Ions that bind tightly tend to displace ions that are less tightly bound because the ions compete for the same ion exchange sites. In addition, soils with high organic material content tend to bind metals in large chemical complexes. This process is described in the section below. Cyanide, being a negatively charged ion is relatively mobile by itself, however, if forms very strong complexes with iron and other metals in the environment that effectively immobilize it. These complexes dramatically reduce the availability of cyanide to organisms because the complexes are difficult to decompose.

Table 5-3. Soil-Water Partition Coefficients for Metals

Inorganic Element	K_d at pH = 5.5[(1)] (L/kg)	K_d at pH = 6.2[(2)] (L/kg)	K_d[(3)] (L/kg)
Aluminum	NA	NA	1,500
Antimony	NA	NA	45
Arsenic	26	28	200
Barium	21	33	41
Beryllium	NA	NA	790
Cadmium	27	42	75
Chromium (as Cr^{+3})	2,100	420,000	1,800,000
Chromium (as Cr^{+6})	NA	NA	850
Cobalt	NA	NA	45
Copper	NA	NA	428
Cyanide (CN^-)	NA	NA	10
Iron	NA	NA	25
Lead	NA	NA	900
Manganese	NA	NA	65
Mercury	NA	NA	52
Nickel	28	42	65
Selenium	12	75	5
Silver	NA	NA	8
Thallium	NA	NA	71
Vanadium	NA	NA	1,000
Zinc	26	42	62

[1] Values from Illinois EPA Tiered Approach to Corrective Action Objectives (TACO) Program; pH of 5.5 is the average soil pH at MGBG.
[2] Values from Illinois EPA TACO Program; pH of 6.2 is the average ground water pH at MGBG.
[3] Values from the U.S EPA-sponsored Risk Assessment Information System (RAIS) Internet site: "http://risk.lsd.ornl.gov/rap_hp.html"
NA = Not available
Kd = Soil-water distribution coefficient.

5.1.8 Chemical Complex Formation

Metals may form chemical complexes or combinations that alter the mobility of the metals. This may also occur for non-metals. Some of the most important environmental chemicals that form metal complexes are the humic substances. These complex mixtures of organic acids and other organic matter are formed naturally in shallow surface soils, in pond bottoms, lake bottoms, etc. through the decay of vegetable matter. These substances, after binding with a metal, can increase its mobility by dissolving into an aqueous phase. If the humic substances are adsorbed to a solid substrate such as soil, sediment, or vegetation, they will tend to remove metal ions from solution by binding to the metals and fixing them to the solid substrate. The binding equilibria are affected by pH. At low pH, the bound metals are released and at high pH the metals are preferentially bound. Iron is an exception to this rule (Dragun, 1988). Fulvic acid is a component of humic substances. The pH at which fulvic acid complexes begin to release relatively large proportions of bound metals has been shown to be less than 5 (Dragun, 1988). Thus, most metals are expected to be preferentially bound to the humic substances at pH values greater than 5.

As indicated in the previous section, the non-metal cyanide forms extremely tight bonds with iron. Each cyanide ion can bind with 6 iron ions to yield the ferricyanide or ferrocyanide complexes, depending on whether the cyanide is binding with iron(III) or iron(II). In each case the negative logarithm of the complex formation constant (pK_f) is greater than 35 (Lang, 1985). Very few inorganic complexes have pK_fs this large, which is an indication of the tenacity with which the complexes retain the cyanide and prevent it from becoming available to human and other receptors.

5.1.9 Bioconcentration Factor

BCF represents the ratio of aquatic-animal-tissue concentration to water concentration. The ratio is both contaminant- and species-specific. When site-specific values are not measured, literature values are used or the BCF is derived from the K_{ow}. Many of the pesticides and PAHs will bioconcentrate at levels three to five orders of magnitude greater than those concentrations found in the water, but VOCs and explosive compounds are not as readily bioconcentrated. Any bioconcentration that occurs generally requires that the chemical of interest be in the dissolved state, otherwise the chemical is inaccessible to the organism. For plants, this means that the chemical must be dissolved in the surrounding soil. For other organism that can inhale, aspirate, or ingest solid particles, the chemical may be bound to the particles and released after ingestion.

5.1.10 Mobility Index

The MI is a quantitative estimator of mobility that uses water solubility (S), vapor pressure (VP), and the K_{oc} (Laskowski et al., 1983). It is defined as

$$MI = \log((S*VP)/K_{oc})$$

A scale to evaluate MI, as presented by Ford and Gurba (1984), is:

Relative MI	Mobility Description
>5	Extremely mobile
0 to 5	Very mobile
-5 to 0	Slightly mobile
-0 to -5	Immobile
< -10	Very immobile

Of the organic chemicals detected at the CBP, chlorinated solvents (e.g., methylene chloride) and ketones (e.g., acetone) generally have MIs greater than 5 and are considered to be extremely mobile. Lighter molecular weight PAHs, such as naphthalene, have MIs ranging from -5 to 0 and are considered slightly mobile. Heavier molecular weight PAHs [e.g., benzo(a)pyrene] are classified as very immobile, having MIs less than -10.

5.1.11 Miscellaneous Characteristics

The solubility and mobility of an inorganic chemical is strongly influenced by its valence state(s) and mineral forms present in soils (e.g., silicates, hydroxides, oxides, and carbonates). The solubility of a metal also depends largely on the pH and redox potential (Eh) of its environment, the ambient temperature, and other ionic species in solution (the Debye-Huckel theory). Nearly all metals have increased solubility and mobility at lower water pH values (e.g., < 5.0). Some metals such as aluminum, however, have increased solubilities at both low (less than 5) and high pH values (greater than 8). Iron and manganese are examples of metals that have more than one valence state and are more soluble in the reduced valence states. For example, Iron(+3) and Manganese(+4) are generally less soluble than Iron(+2) and Manganese(+2) in the environment. As a result, these metals are more mobile under reducing conditions. Chromium(+6), however, is more mobile than Chromium(+3) under typical environmental conditions. The mobility is highly dependent on the anions that are associated with the metal. For example, silver nitrate is very soluble in water but nearly all other silver compounds are highly insoluble. The solubility product constants reported in the chemistry literature vary with the type of chemical complex formed. Metals can be rapidly transformed from one oxidation state to another as they encounter different local environments. For example, manganese that may have been dissolved from local geologic materials at one location may precipitate out of solution as the groundwater containing the dissolve manganese migrates to another area.

5.2 CHEMICAL PERSISTENCE AND DEGRADATION PROCESSES

Degradation and other transformation processes that affect site contaminants are discussed in this section. Degradation leads to the following possibilities, depending on the contaminant of interest and the contaminant's environment:

- transfer of the chemically unaltered contaminant from one environmental medium to another (physical changes may occur, e.g., transfer of dissolved contaminant to vapor);
- transformation of the original contaminant into a less toxic chemical;

- transformation of the original contaminant into a more toxic or otherwise problematic chemical; and
- transfer of a chemically or biochemically transformed contaminant from one environmental medium to another.

All of these may occur individually or together and more than one of these processes may occur for any single chemical. Consequently, the number and complexity of possibilities depends partly on the number of contaminants and partly on which contaminants are present, as well as the geochemical conditions present at various locations within the site.

For organic chemicals, degradation typically involves a gradual reduction in the molecular weight of the chemical as molecular bonds are cleaved. Cleavage may occur in sequential steps with the most susceptible bonds being cleaved first. Because of this, larger, more complex molecules that have more chemical bonds commonly have more molecular degradation pathways than smaller molecules. With the changes in molecular structure come changes in chemical and physical properties. For example, daughter compounds are commonly more volatile than their parent compounds. They may also be more or less toxic than the parent compound. For inorganic chemicals, degradation may be a purely inorganic chemical reaction that results in a change of valence state. Depending on the chemical, it may also involve biochemical reactions that transform the inorganic chemical into an organometallic compound or another inorganic species.

Hydrolysis, biodegradation, photolysis, and chemical oxidation/reduction reactions are four processes that are important for many environmental investigations because the potential for their occurrence is high, depending on the contaminants that are present and where those contaminants are located. These four processes are discussed in more detail below.

Hydrolysis is a reaction between the chemical of interest and water that results in a cleavage of the water molecules. Many of these reactions can be catalyzed by the presence of acids or bases.

Biodegradation is a generic term that includes oxidation or reduction transformations resulting from enzymatic or other biochemical processes that occur in or near living organisms. Many of these reactions take place in naturally occurring microorganisms such as bacteria that are present in the Earth’s crust, especially at the Earth’s surface. A chemical or family of chemicals (e.g., chlorinated solvents or ketones) may be highly susceptible to transformation by one type of microorganism but much less so by other organisms. Consequently, the rates of biodegradation can vary widely from no degradation to very rapid degradation, depending on the presence of organisms that can degrade the chemicals. The presence of other chemicals and the ambient conditions can also greatly influence the potential for, and the rate of, degradation.

Photolysis is a cleavage of a chemical bond induced by light, especially ultraviolet wavelengths. Hence environmental photolysis characteristically occurs at the Earth’s surface in surface water, shallow surface soils, shallow sediments exposed to air, and in the atmosphere. Atmospheric contaminants may be washed out of the atmosphere in precipitation or they may deposit onto the surfaces of soil, sediment, surface water, or man-made structures such as Lumber Yard Road.

When data are not available for a particular medium (e.g., groundwater), mathematical modeling may be useful for estimating or predicting the concentrations of contaminants in that medium. The model is used to translate contaminant concentrations in one medium to concentrations in the medium of interest based on knowledge of site conditions and the chemical and physical properties of the contaminants. A very simple air dispersion model was used to estimate travel distance of historic CBP combustion plumes.

If the concentration of a degrading chemical is plotted over time the rate of concentration decrease is generally the greatest early in the degradation process. The rate of concentration decrease becomes less as time goes on because the rate of degradation at any time is typically proportional to the remaining concentration of the chemical. First order decay models are commonly used to represent concentrations over time because the models are simple to use. The true degradation process, however, may not follow a first order decay process. Many different decay processes may occur in concert, therefore the first order decay rate will be a composite of all of the pertinent processes. This often leads to significant uncertainties in estimating degradation rates. Any uncertainties associated with estimating the degradation rates translate into uncertainties in estimates of future concentrations.

A characteristic of simple, first order decays is the useful relationship between half-life and degradation rate. A half-life is the time required to reduce a concentration to one-half of its value. Chemicals with long half-lives have a long persistence in the environment whereas chemicals with short half-lives degrade or disperse quickly. For first order decays the half-life, ($t_{1/2}$) is equal to the natural logarithm (Ln) of 2 divided by the degradation rate constant, k, (i.e., $t_{1/2} = \mathrm{Ln}(2)/k$). Table 5-4 presents half-lives of select organic COPCs detected at the CBP. The half-lives presented in Table 5-4 and discussed below are taken from literature studies and may not accurately represent degradation rates at the CBP but they provide indications of relative degradation rates to be expected for these compounds.

Table 5-4. Ranges of Biodegradation Rates for Organic Chemicals

Chemical	SOIL		GROUND WATER	
	Short Half-Life	Long Half-Life	Short Half-Life	Long Half-Life
	(days)	(days)	(days)	(days)
Explosives				
2,4,6-Trinitrotoluene	>360 (2)	>360 (2)	0.02 (3)	0.9 (3)
Nitrocellulose	NA (4)	NA (4)	NA (4)	NA (4)
Nitroguianidine	NA (4)	NA (4)	NA (4)	NA (4)
Volatile Organic Chemicals				
Acetone	1	7	2	14
Methylene Chloride	7	28	14	56

Table 5-4. Ranges of Biodegradation Rates for Organic Chemicals (continued)

Chemical	SOIL		GROUND WATER	
	Short Half-Life	Long Half-Life	Short Half-Life	Long Half-Life
	(days)	(days)	(days)	(days)
Pesticides				
4,4'-DDE	730	5700	16	11000
4,4'-DDT	730	5700	16	11000
Endosulfan I	NA	9.1	NA	9.1
Endosufan II	NA	9.1	NA	9.1
Endrin				
Gamma Chlordane	283	1400	566	2770
Heptachlor Epoxide	33	552	1	1104
Polychlorinated Biphenyls				
Aroclor-1254	> 3700 (5)	> 3700 (5)	> 3700 (5)	> 3700 (5)
Polycyclic Aromatic Hydrocarbons				
Benzo(a)anthracene	102	680	204	1360
Benzo(a)pyrene	57	530	114	1060
Benzo(b)fluoranthene	360	610	720	1220
Benzo(k)fluoranthene	5	23	10	389
Chrysene				
Fluoranthene	140	440	280	880
Indeno(1,2,3-cd)pyrene	560	730	1200	1460
Phenanthrene	16	200	32	400
Pyrene	210	1900	420	3800

[1] Except where noted, ranges of biodegradation half-life values are from Howard et al., 1991.
[2] Based on control sample data from: Widrig et al., Envrionmental Toxicology and Chemistry, Vol. 16, No. 6, 1997, SETAC.
[3] Data from Reviews in Environmental Contaminant Toxicology, Vol 161:1-156, Springer-Verlag, 1999
[4] Assume to be greater than 365 days, based on properties of cellulose.
[5] Rough estimate based on: Erickson, 2001 - See text references for full citation. Acual half-lives vary widely.
NA = Not available.

The fate and transport of each contaminant detected at the CBP is described below. The chemicals are discussed in groups that are indicated by their analytical fractions (e.g., VOCs, explosives) because these fractions generally represent chemicals with similar properties.

5.2.1 Volatile Organic Chemicals

Two chemicals in this category, acetone and methylene chloride, were detected at the CBP in sediment and groundwater. The maximum sediment acetone concentration was 16 ug/kg; the maximum groundwater concentration was 4 ug/L; the maximum sediment methylene chloride concentration was 10 ug/kg; the maximum groundwater concentration was 0.6 ug/L.

Acetone is an aliphatic ketone, and methylene chloride is a chlorinated aliphatic compound with a single carbon atom. Acetone is completely miscible with water whereas methylene chloride is less soluble and separates as a distinct phase when mixed with water. Being low molecular weight VOCs with low adsorption potential, these compounds are considered to be highly mobile in the environment.

Hydrolysis is generally not a significant fate process for acetone and methylene chloride. Acetone has a high vapor pressure and, once released to the atmosphere, photolysis and reaction with hydroxyl radicals result in an average half-life of 22 days (Howard, 1990). Biodegradation mechanisms can be important for acetone. Acetone has a relatively low toxicity and is not problematic at the detected concentrations from a risk perspective. Methylene chloride also has a high vapor pressure and will volatilize easily from surface soils, drainage channels, and streams. Neither hydrolysis nor photolysis are expected to be significant degradation mechanisms for methylene chloride (Mabey et al., 1982), but biodegradation may be a significant degradation mechanism (U.S. Navy, 1998). At the low detected concentrations it would be impractical if not impossible to measure biodegradation rates. Neither of these two compounds was selected as a COPC and they are not discussed further.

5.2.2 Semi-Volatile Organic Chemicals

In this chemical category, only PAHs were detected at the CBP. PAHs were detected as deep as 3 ft bgs in soil. One sediment sample, CBPSD-002-0001-SD, also contained detectable PAHs.

Tables 2.1 through 2.6 (Appendix S) indicate which PAHs were detected at the CBP and, of those, which were selected as COPCs in various media. Four PAHs were selected as ecological COPCs in sediments (See Section 7.0). All detected soil and sediment PAH concentrations were within the range of 93 to 360 ug/kg, regardless of depth or location. The sparse distribution of low PAH concentrations indicates that the reservoir of PAHs is low at the CBP.

PAHs, as a group, are much more likely to bind to soil and to be transported via erosion and surface water runoff than to be solubilized (UN, 1998). Migration of PAHs to groundwater is a concern most often associated with subsurface soil that may be in contact with groundwater. CBP PAHs are limited to the upper 3 ft of soil. Furthermore, the concentrations of PAHs that migrate to groundwater may not be detectable, especially when the soil PAH concentrations are low. This condition was observed at CBP.

PAHs are subject to slow degradation via aerobic bacterial metabolism, but may be relatively persistent in the absence of microbial populations or macronutrients such as phosphorus and nitrogen.

Landspreading applications have indicated that PAHs are highly amenable to microbial degradation in soil. The rate of degradation is influenced by temperature, pH, oxygen concentrations, initial chemical concentrations, and moisture. Photolysis, hydrolysis, and oxidation are not important fate processes for the degradation of PAHs in soil (ATSDR, 1997).

The most important fates of PAHs in water are photo-oxidation, chemical oxidation, and biodegradation. Metabolism in higher animals is another degradation pathway and becomes important when the PAHs are metabolized to carcinogenic chemical species (UN, 1998). PAHs do not contain functional groups that are susceptible to hydrolytic action, and hydrolysis is considered to be an insignificant degradation mechanism. The rate of photodegradation is influenced by water depth, turbidity, and temperature. Turbidity and depth screen chemicals from sunlight exposure more effectively as depth increases. Degradation rates increase with temperature. Benzo(a)pyrene, a CBP

COPC for human and ecological risks, is reported to be resistant to photodegradation. PAHs may also be metabolized by microbes under oxygenated conditions (ATSDR, 1997).

The longest PAH half-life (of those shown in Table 5-4) is about four years in groundwater and one year in soil. Thus, PAH concentrations should decrease significantly within a decade and should be completely degraded in less than 30 years in groundwater and less than 10 years in soil.

5.2.3 Pesticides and Polychlorinated Biphenyls

Gamma-chlordane, Endrin, Endosulfan I and Endosulfan II, heptachlor epoxide, 4,4'-DDE, and 4,4'DDT were the only pesticides detected at the CBP in any of the investigated media. All of these detections were within 1 ft of ground surface and none of the detections exceeded 5 ug/kg.

Volatilization is not expected to be a significant degradation pathway for pesticides. Photolysis is possible in upper depths of water bodies such as Sand Creek, although this mechanism is temperature dependent. An example half-life is one day for 4,4'-DDT during summer months. For photolysis to occur, the pesticides must migrate to a nearby water body. The likelihood of detecting pesticides in a water body is low because the detected pesticides would have to migrate via overland runoff to the water body. Dilution and dispersion effects are likely to predominate to reduce the pesticides to undetectable concentrations in surface water and sediments. This is consistent with not having detected any pesticides in surface water or sediment. Dissolution of pesticides into groundwater is also not expected to occur at a rate that would support detection of pesticides in groundwater. Overall, pesticide migration is expected to be minimal and natural degradation of pesticides is likely to reduce the concentrations over time. No pesticides were selected as human health or ecological COPCs.

A PCB mixture, Aroclor 1254, was also detected in four soil samples collected from SS-013, SS-014, and SS-015. One of the detections (240 ug/kg) was from a field duplicate collected at SS-014; all other detections were less than 50 ug/kg. These locations form a triangle east of Lumber Yard Road that covers approximately 100 square ft. The area of PCB contamination is a relatively small source of PCB contamination. The relatively low PCB concentrations indicate that the total mass of PCBs is also low in the vicinity of these three locations. No PCB detections were observed in any other media. Aroclor 1254 was selected as a human health COPC in surface and shallow soils. It was not selected as an ecological COPC in any media.

PCBs are chlorinated aromatic chemicals that are recalcitrant to environmental degradation. Their low solubility and high adsorption coefficients render them almost immobile in soils, except in surface water runoff. In runoff they are transported as adsorbed PCBs. They have low vapor pressures but can slowly evaporate from surface soils and sediments exposed to the atmosphere (Erickson, 2001). At the CBP, soil contaminated with Aroclor 1254 in the vicinity of SS-013, SS-014, and SS-015 would be expected to move eastward via overland runoff toward lower elevations by way of drainage channels that drain the area east of Lumber Yard Road (Figure 3-1). No PCBs were detected in nearby drainage channel sediments, therefore dilution and dispersion effects are presumed to be operating to reduce PCB contaminant concentrations to less than detectable levels downgradient of the impacted area.

Being lypophillic, these chemicals tend to accumulate in fatty tissues of animals, including aquatic organisms. After first distributing preferentially to the liver and muscle tissue, PCBs are subsequently redistributed to other tissues and organs that contain fat. PCB excretion is very slow so bioaccumulation occurs even at low exposure levels. As long as exposure continues, a true steady state is never achieved. (ATSDR, 2004a). The low levels of contamination observed at the CBP, however, are not expected to yield threatening PCB levels in aquatic species. This is discussed further in Section 7.0.

Under certain aerobic (oxidizing) or anaerobic (reducing) conditions, PCBs can be degraded through biological processes. Partial dechlorination of the more highly chlorinated congeners occurs under anaerobic (reducing) conditions. Under aerobic (oxidizing) conditions, microorganisms preferentially attack the lower chlorinated congeners (Erickson, 2001). It is not known whether either of these two mechanisms is operating at the CBP. This may not be determined based on the low levels of Aroclor 1254 detected, and it is not viewed to be necessary given the low levels detected.

5.2.4 Explosive Compounds and Propellants

Three nitrogen-containing energetic compounds, one explosive (TNT) and two propellants (nitrocellulose and nitroguanidine), were detected in soil samples. Nitrocellulose was the most widely detected explosive compound (See Section 4.0) with a maximum concentration of 1.45 mg/kg in soil, and 1.1 mg/kg in sediment; it was not detected in aqueous media; Nitroguanidine was detected in one sample (CBPSB-003A-0001-SO) and its duplicate at 0.061 and 0.071 mg/kg, respectively. TNT was detected in two samples at the same location. It was detected in two different sediment sampling locations (SD-001 and SD-008) at 1.1 mg/kg or less. No other explosives compounds were detected in any other environmental media.

Although nitrocellulose (cellulose nitrate) may be incorporated into propellant mixtures, it has a very low solubility in water and, consequently, exhibits very limited mobility. It is a fibrous material comprised essentially of cellulose fibers that have been modified to contain NO_3 functional groups (Meyer et al., 2002). The chemical composition, however, suggests that any environmental degradation of this chemical could release nitrates or nitrites to the environment. Because of its low solubility, relatively slow degradation rates in the environment are expected. Most nitrocellulose would be expected to migrate via overland transport, including migration via drainage channels in sediments and as suspended nitrocellulose particles. This is borne out by most nitrocellulose detections occurring in surface soil and two sediment sampling locations. Drainage channels flow from the center of the CBP toward the north and northeast. The soil and sediment reservoir of nitrocellulose appears to be very limited because of the low concentrations. Transport of nitrocellulose via overland runoff is expected to continue into the future until the soil reservoir is depleted. Because of its low solubility it is expected move in particulate form at detectable concentrations but any dissolved nitrocellulose (e.g., in groundwater or surface water) will probably be undetectable.

TNT was detected in two soil samples at CBPSS-010, indicating that the TNT was probably released to surface soils and migrated deeper into the soil column under the influence of precipitation and gravity. The surface soil concentration (180 ug/kg) is about three times the deeper soil concentration

(66 ug/kg). The deeper soil sample was collected over the 1 to 3-ft interval. These data indicate that the TNT has not migrated very far since the presumed surface soil release. TNT was not selected as either type of COPC in any media. Numerous laboratory studies and past site investigations at DoD facilities have yielded information on the biodegradation of energetic compounds. TNT in soils, groundwater, and surface water can degrade biotically or abiotically, and can degrade under a fairly wide range of pH and Eh conditions (Brannon et al., 1998). The two most common degradation products found in soils and groundwater have been 2-amino-4,6-dinitrotoluene (2ADNT) and 4ADNT (Pennington et al., 1999a,b,c). No evidence of biodegradation (e.g., detections of the aminodinitrotoluenes) was detected.

5.2.5 Metals

Metals are highly persistent environmental contaminants because they do not biodegrade. However, their valence states can readily change based on pH and Eh conditions, biotic uptake and assimilation into living organisms, and decay and decomposition of dead plant matter. The major fate mechanisms for metals are adsorption to the soil matrix or precipitation as a mineral coating, uptake and bioaccumulation in plants, or transport through the hydrologic system. Table 5-2 presents a qualitative characterization of select metal mobilities in the environment as a function of ambient conditions. Because the chemical properties of the metals can vary significantly from metal to metal, only those metals detected at the CBP that have concentrations in excess of background are described here. Metals that have similar properties (as presented in Table 5-2 or discussed in the text) will behave similarly with regard to fate and transport.

Metals commonly form carbonates, silicates, oxides, and hydroxides after they have been released to the environment and interact with carbon dioxide, oxygen, and water in their surroundings. The carbonate, oxide, and hydroxide equilibria that dictate whether one chemical species predominates over another, are sensitive to the surrounding pH and redox potentials. At high pH values oxides and hydroxides form readily. At pH values less than about 4 these species are essentially non-existent, except under highly oxidizing conditions.

The Earth serves as an almost limitless reservoir of metals. Soils, surface water, groundwater, and sediments are typically well-buffered with respect to pH (i.e., pH is not easily changed). Based on geotechnical data from RVAAP load line soil samples, the pH of soils measured at RVAAP Load Lines is typically in the range of 5.5 to 7.4 (USACE, 2003a, 20003b, 2003c). Load Line soil samples occasionally exhibit pH values less than 5.0, but they are rare (USACE, 2003a, 20003b, 2003c). Therefore, low pH values are evidently limited to small soil volumes, indicating that any increased mobility due to depressed pH values will be confined to small areas. The pH range cited above is a commonly observed soil pH range and the same pH range is expected for the CBP. The pH buffering capacity near neutral to slightly acidic pH values tends to limit the ability of most metals to migrate rapidly because they tend to precipitate as solids or to bind tightly to soil particles through cation exchange. The positively charged metals or oxocation metal ions adsorb to negatively charged silanol groups at the surface of the soil or sediment particles, which are often silicate minerals. In general, the more highly positive a cation is, the more tightly bound it will be to the soil. Hence, monovalent ions (e.g., potassium, sodium) are not tightly bound whereas the trivalent aluminum is.

Each of the metals detected at the CBP (except for the macronutrients, calcium, magnesium, potassium, and sodium) is described briefly below regarding its most important environmental chemistry characteristics and information concerning plant uptake. These factors affect the mobility and the fate of metals in the environment.

Aluminum, atomic symbol Al, (not listed in Table 5-2) is a naturally occurring component of silicate minerals and other minerals. It does not migrate readily because its aqueous ion has a positive charge of "+3". This high charge causes aluminum ions in solution to preferentially bind to negatively charged soil adsorption sites such as silanol groups located at the surfaces of silicate minerals. Aluminum also readily precipitates from solutions as aluminum hydroxides. Aluminum dissolves in infiltrating precipitation, however, and may be taken up by plants from the resulting subsurface and surface soil solutions of aluminum. Any industrial releases of this metal to soils are not expected to migrate significantly. Releases to surface water will have the greatest mobility because aluminum adsorbed to sediments is transported this way and aluminum in the dissolved phase can move for long distances before being completely removed from solution by binding to sediments and soils. Aluminum that is taken up by plants will be redeposited to soils when the vegetation dies or releases leaves, branches, etc. Aluminum is not known to be transformed biologically. This metal was selected as a human health and ecological risk COPC in CBP soils and sediments.

Antimony, atomic symbol Sb, (not listed in Table 5-2) is similar to arsenic (described below) in chemistry. This metal, commonly classified as a metalloid because its chemical properties lie between those of true metals and non-metals, has a mean concentration in soils around the world of approximately 1 mg/kg (Emsley, 2001). Stibnite (Sb2S3), a sulfide, is the predominant mineral of antimony found in native ores (Van Nostrand, 1976). The two prevalent valence states of antimony are Sb(III) and Sb(V). These relatively high oxidation charges tend to limit the mobility of antimony in the environment. This metal was selected as an ecological COPC in CBP sediments but was not selected as a COC for any other media for ecological or human health risk. Overland runoff and migration in drainage channels are the expected primary migration pathways for this metal. Volatilization after conversion to organometallic chemical species is not expected to be a significant fate, especially because of the low concentrations of antimony at the CBP.

Arsenic, atomic symbol As, is a human health COPC in the CBP surface and subsurface soils, sediments, and groundwater because its concentrations exceed human health screening levels in those media. It was selected as an ecological COPC in surface soil and sediments because its maximum concentration exceeded the ecological screening criteria for those media. This metal is a naturally occurring metal, commonly classified as a metalloid because it has properties that are transitional between metallic and non-metallic chemical elements. In minerals, this element commonly appears as a sulfide (NIH, 2004), which implies that this form of arsenic is a particularly abundant or persistent form. In water, inorganic arsenic occurs primarily in the "+5" valence state when conditions are oxidizing, such as in surface water. Under reducing conditions, such as may be found in groundwater, the inorganic form of arsenic is predominantly the "+3" valence state. In acidic or neutral waters, As(V) is extensively adsorbed but As(III) is not. At high pH (e.g., pH > 9), neither species of arsenic is tightly adsorbed (NIH, 2004). The mobility of arsenic is low to moderate in clay but higher in loamy or sandy soils, such as those found at the CBP. As(V) is adsorbed most strongly at pH 5 in clay minerals. As pH increase, more As(III) is adsorbed. Arsenic adsorbs strongly to sediments. If conditions change sufficiently from oxidizing to reducing, arsenic may be released from sediments.

Bacterial and fungal activity can convert inorganic arsenic to methyl arsines. These volatile organometallic compounds are mobile and can be transferred from sediments to the surrounding water and ultimately to the atmosphere. The potential for volatilization from moist surfaces varies greatly with local conditions. Tightly sorbed arsenic or complexed arsenic species will be unlikely to volatilize whereas methylated arsenic species can volatilize fairly readily (NIH, 2004). Generation of organometallic arsenic species is not expected to be significant at the observed arsenic concentrations.

Barium, atomic symbol Ba, is not a human health COPC. It was selected as an ecological COPC in surface soil and sediment. This metal is commonly found in nature as a sulfate (Emsley, 2001). It forms hydroxides, carbonates and sulfates in soils. Barium carbonates and sulfates are relatively insoluble (negative logarithm of solubility product, pK_{sp}, constants near 9). By contrast, barium hydroxides (pK_{sp} near 2), and especially nitrates and chlorides of barium, are quite soluble (Lang, 1985). Thus, over time, barium is expected to precipitate out of solution as it migrates to areas containing high carbonate or sulfate concentrations and high concentrations of other anions that form barium precipitates. In the absence of these anions, barium is likely to be moderately mobile. Barium is generally classified as a metal of low mobility (See Table 5-2).

Beryllium, atomic symbol Be, was detected in most of the CBP soil samples with a maximum detection site-wide of 4.2 mg/kg. This metal is reported to have a typical concentration of 6 mg/kg in worldwide soils and was not selected as a human health COPC for the CBP (Emsley, 2001). It was, however selected as an ecological COPC in surface soil and sediment. Beryllium can be taken up by plants. Typical concentrations in plants are too low to exhibit any effects on animals that live off of them, even in plants that have the ability to concentrate the beryllium (Emsley, 2001). The divalent Be^{+2} ion dominates environmental beryllium chemistry at all pH values less than about 4. Above that pH it forms insoluble hydroxides (Dragun, 1988). Consequently, this metal generally exhibits low mobility under typical environmental conditions.

Cadmium, atomic symbol Cd, was detected at concentrations greater than the background limit in several soil sample locations. While cadmium concentrations are typically less then 1 mg/kg in worldwide soils, local hot spots have been shown to contain cadmium concentrations as high as 40 mg/kg (Emsley, 2001). The maximum detection in CBP soils was 2.2 mg/kg and in sediments it was 1.4 mg/kg. This element is widely present in food crops at low levels and can be concentrated by the fungus Amanita muscaria, even when grown in soils containing low cadmium levels. Tobacco and other large leaf crops are also known to contain cadmium. Cadmium is present in sewage and crops grown in sewage land farms can lead to an accumulation of cadmium in animals that eat the crops, including humans. This metal mimics zinc in its chemical behavior, especially in the human body. The lifetime in the human body is reported to be about 30 years (Emsley, 2001). Cadmium is expected to be moderately mobile in soil because it's present under most naturally occurring redox and pH conditions as the "+2" ion. If it is combined with anions such as sulfide, it can be very immobile. At pH values greater than about 8, cadmium tends to form insoluble hydroxides. These conditions are not expected at the CBP, therefore the cadmium mobility is expected to be moderate. Cadmium concentrations did not exceed human health screening levels in any of the investigated environmental media and this chemical was not selected as a human health COPC at the CBP. It was, however, selected as an ecological COPC for surface soil and sediment.

Chromium, atomic symbol Cr, exists primary as two oxidation states: Cr(III) and Cr(VI). Cr(IV) is very mobile in the environment under oxidizing conditions, but Cr(III) is less mobile except at pH values less than about 4. The trivalent metal predominates under all conditions except those that are low pH (e.g., less than 4) and high oxidation potential (e.g., greater than 0.4). This element forms insoluble hydroxides under low to moderately reducing conditions. Under highly oxidizing conditions it forms the soluble chromate ion at pH values greater than about 6 and the bichromate ion at lower pH values (Dragun, 1988). Concentration values in soils worldwide are reported to range from 1 to 450 mg/kg (Emsley, 2001). The maximum CBP detection was 57.3 mg/kg in surface soils. Chromium is mobile in ground and surface water under oxidizing conditions and can move in sediments when adsorbed to sediment grains. The concentrations of this metal were greater than soil screening levels and chromium was selected as a human health COPC for CBP soils. It was also selected as an ecological COPC for surface soil and sediment. Migration is expected to be primarily as adsorbed chromium ion in sediments with some slow leaching to surface waters. As migration continues, the chromium concentrations will be spread over increasingly larger areas and become diluted through natural mechanisms.

Cobalt, atomic symbol Co, (not listed in Table 5-1) is an ecological risk COPC in CBP surface soils and sediments. This metal is an essential nutrient and is found in relatively low abundance (0.1 to 70 mg/kg) in the Earlth's crust (Emsley, 2001). The maximum observed cobalt concentration at the CBP was 22.3 mg/kg in soil. This sample and the next two highest concentrations were located near Lumber Yard Road and the rail line north of the CBP. Terrestrial plants absorb this element from soils. Based on its mean K_d equal to 4 (Dragun, 1988), this element has moderate to low mobility in soils and sediments. It forms insoluble oxides and hydroxides in the environment at pH values greater than about 8, but is otherwise generally present as the Co(II) ion at most redox potentials (Dragun, 1988). The cobalt contamination is expected to move migrate primarily in drainage channel sediments to downgradient areas.

Copper, atomic symbol Cu, is a relatively immobile element in soils (Emsley, 2001). Its affinity for organic matter causes it to be bound tightly in surface soils. Where subsurface releases of copper occur this binding mechanism may not be as important for copper binding because the most organic rich layer of soils is generally the surface layer. Plant uptake varies widely for this element and it is transmitted through the food chain. Most of the copper taken up by plants, however, remains in the roots (Emsley, 2001). At low pH this metal is prevalent as the divalent ion under most redox conditions. At High pH the metal tends to form hydroxides and oxides (Dragun, 1988). The 10 highest concentrations of copper in surface soils ranged from 24.9 to 1260 mg/kg, all locations of which were near Lumber Yard Road and/or the debris pile east of central stretch of Lumber yard Road. The concentrations of this metal were greater than human health soil screening levels and copper was selected as a human health and ecological COPC for CBP surface soils. It was also selected as an ecological COPC for sediment. Copper, is expected to move preferentially via overland runoff into drainage channels and subsequently to downgradient areas. Except at location CBPSD-001, sediment copper concentrations were comparable to background. Location CBPSD-001 is near the head of a drainage channel and within 30 ft of Lumber Yard Road, indicating that migration will be slow. This is attributed to the mild relief in this area of the CBP.

Iron, atomic symbol Fe, is a major component of the Earth's crust being the fourth most abundant element (Emsley, 2001). It occurs widely as in oxide forms and is rarely found in the pure metal state. Iron in soil is readily transformed by organic matter into various oxides and other compounds. The most common oxidation state is "+3". This valence state can, however, be readily altered to the "+2" valence in groundwater and other aqueous environs under chemically reducing conditions. Fe(II) is more mobile than Fe(III). An abundance of iron in the Fe(II) state can serve as a large electron reservoir to electron acceptors during redox reactions. In sediments, iron is expected to travel primarily as an adsorbed or particulate species in surface drainage channels because the water is mixed with oxygen in the air to maintain the Fe(III) state. The most prevalent occurrence of Fe(II), then, is groundwater under reducing conditions. Though not selected as a human health COPC, this metal was selected as an ecological COPC for surface soil and sediments. Except under reducing conditions iron mobility is low. This indicates that iron in surface media where it is exposed to oxygen must migrate preferentially in overland runoff and via drainage channels to downgradient locations.

Lead, atomic symbol Pb, is a very immobile element in the environment. This metal has a relatively high soil-water distribution coefficient (ranging from 4.5 to 7640 mL/g, Dragun, 1988). This indicates that it preferentially binds to soils and sediments rather than dissolving in water. When adsorbed to sediments, this metal will be transported as a bound species. This metal appears in the divalent ("+2") state under most pH and redox conditions. At high pH values (e.g., greater than 8 it readily forms hydroxides and oxides). The concentrations of lead were greater than human health soil screening levels and lead was selected as a COPC for CBP soils. It was selected as an ecological COPC for surface soil and sediment. Lead migration is expected to follow the pathway of copper and other metal migrations, i.e., in overland runoff and via drainage channels. The mild relief of the CBP will result in slow migration rates.

Manganese, atomic symbol Mn (not shown in Table 5-2), exhibits chemistry similar to that of iron. This essential nutrient, the twelfth most abundant element in the Earth's crust, occurs primarily in the "+2" valence state. In soil, manganese occurs as hydroxides and oxides and microbial action plays a role in valence state alteration. The least stable form of manganese, Mn(III), is the most biologically active (Emsley, 2001). Manganese can also exist as Mn(IV). Manganese is most soluble in water in the Mn(II) form, thus it's mobility is greatest under reducing conditions. Under these conditions it is most susceptible to migration in groundwater or uptake by plants (Emsley, 2001). When adsorbed to soil or sediment particles, manganese may migrate in surface water. The concentrations of this metal were greater than human health screening levels in surface soil, surface water, groundwater, and sediments and manganese was selected as a human health COPC for the CBP in these media. Its concentrations in surface soil and sediment also exceeded ecological screening criteria and it selected as an ecological COPC in surface soil and sediment. The fate of this metal is expected to emulate the fate of iron, i.e., migration in overland runoff and via drainage channels.

Mercury, atomic symbol Hg, has a complex environmental chemistry. This metal, under most redox conditions, persists as an immobile species. It can be converted to organometallic species that are much more volatile, especially in wet sediments. The two common valence states are the "+1" and the "2" states with Hg(II) predominating under typical environmental conditions. Mercury, when deposited as the pure liquid metal (e.g. from barometers, manometers, and thermometers), will persist for decades in the environment. The liquid mercury coalesces into globules that can slowly release dissolved mercury to the environment. However, the mercury thus released would be expected to precipitate as a chloride, carbonate, hydroxide or oxide over time. Worldwide, concentrations of mercury in uncontaminated soil are reported to be 0.01 to 0.05 or 0.08 ug/kg (Dragun, 1988; Emsley, 2001). The concentrations of this metal were less than human health screening levels and mercury was not selected as a COPC for the CBP, but it was selected as an ecological COPC for surface soil.

Nickel, atomic symbol Ni, predominates under typical environmental conditions as the Ni(II) species. Under high pH conditions (e.g., pH greater than 8) this metal will tend to precipitate as an oxide or hydroxide, except under very reducing conditions where pure metal may exist (Dragun, 1988). Typical soil concentrations are reported to be approximately 50 mg/kg (Emsley, 2001) or even as high as 1,000 mg/kg (Dragun, 1988). The concentrations of this metal were less than human health screening levels and nickel was not selected as a human health COPC for the CBP, but it was selected as an ecological COPC for surface soil. The mobility of this metal ranges from low in neutral or alkaline conditions to high in acidic environments (See Table 5-2). The typical soil conditions of the CBP are expected to render this metal moderately mobile to nearly immobile.

Selenium, atomic symbol Se, exhibits a chemistry similar to that of arsenic. At moderate to low oxidation potentials this metal may exist as pure selenium although it is more likely to exist as a selenium salt. At neutral to high pH values it forms oxides that are soluble, especially under highly oxidizing conditions (Dragun, 1988). These characteristics render it mobile under most environmental conditions. At low oxidation potentials it is much less mobile (Table 5-2). Typical soil concentrations are reported to be 5 mg/kg (Emsley, 2001). Most bodily intake of selenium occurs by ingestion of grains such as breakfast cereals and bread, especially wholemeal bread (Emsley, 2001). Other sources of selenium include peanuts and molasses, thus indicating that selenium is taken up by plants of various kinds. As with other metals taken up by plants, the amount taken up should be related to the amount in surrounding soils. Methyl derivatives of selenium have been measured in air (Emsley, 2001) although no evidence was provided as to the source(s) of the methyl derivatives. With chemistry similar to arsenic, which is known to yield methyl derivatives through microbial action, it is not unexpected that selenium could exhibit a similar fate. The rate of conversion to methyl derivatives, however, would be expected to be immeasurably low at the selenium concentrations observed at the CBP. The concentrations of this metal were less than human health risk screening levels and selenium was not selected as a human health COPC for the CBP, but it was selected as an ecological COPC in surface soil. The most likely migration route is via overland runoff and drainage channels to downgradient locations. Dissolution into groundwater and surface water is not expected to be a significant migration pathway and this is borne out by the failure to detect selenium in those media.

Silver, atomic symbol Ag, is very insoluble in the environment except at oxidation potentials exceeding 0.4 volts (Dragun, 1988). This low solubility limits its mobility. The adsorption coefficient is reported to range from 10 to 1,000 for silver (Dragun, 1988). This is a moderate to high value. Under conditions of slightly acidic pH and moderate to reducing conditions typical of soils containing moderate to high levels of organic matter, silver is expected not to migrate significantly from the point of release. This metal was not selected as a COPC for the CBP and is not discussed further.

Thallium (atomic symbol Tl) minerals are rare, although thallium (not listed in Table 5-2) is ten times more abundant than silver. This metal commonly appears in two different valence states: Tl(I) and Tl(III). When in the "+1" valence state, it has a behavior similar to potassium and sodium. Thallium salts are used in chemical research and thallium sulfate has been banned as a pesticide in the Western countries (Emsley, 2001). Thallium is absorbed easily by plants and the degree of absorption is proportional to the concentration of thallium in the associated soil. Tl(III) is easily reduced to Tl(I) (redox potential=1.25 V). Thus, thallium is a strong oxidizer and the ease of reduction of Tl(III) explains its rarity in nature. Metallic ions of a single positive charge are characteristically mobile in the environment, thus thallium is not expected to be strongly bound to soils or sediments and it should move easily in aqueous media. CBP thallium concentrations exceeded the ecological screening level for surface soil and this metal was selected as a COPC for CBP in surface soils. It was not selected as COPC for any other media.

Vanadium, atomic symbol V, has a very complex environmental chemistry. It exists as numerous species with an array of oxidation states, depending on ambient conditions. Generally, this element is expected to be immobile at neutral to high pH when redox potentials are negative. At moderately positive redox potentials (e.g., greater than 0.2 V), vanadium is expected to exists as soluble vanadate or other oxoanions at all but he lowest pH values. At pH values less than 4 this metal exists predominantly as positively charged oxocations (Dragun, 1988). Vanadium concentrations exceeded human health screening and ecological levels for surface soil and was selected as a human health COPC in that medium. It was also selected as an human health COPC for sediment. Vanadium migration is expected to follow that of other metals, i.e., primarily in overland runoff and via drainage channels.

Zinc, atomic symbol Zn, is widely detected in worldwide soils at concentrations ranging from 5 to 770 mg/kg (Emsley, 2001). Soil concentrations have also been reported to vary from 10 to 300 mg/kg (Dragun, 1988). Plants can take up zinc from surrounding soils, the amount taken up depending on the amount in the soil (Emsley, 2001). This essential nutrient is vital to proper functioning of enzymes. The only zinc species encountered under environmental conditions is as the divalent Zn(II) ion. At high pH (greater than 8), zinc precipitates as a hydroxide. This metal, is moderately to very mobile in soils under most conditions (Table 5-2). Zinc concentrations were less than human health screening criteria in all media, therefore this metal was not selected as a human health COPC. Zinc was selected as an ecological COPC in surface soil.

5.2.6 Miscellaneous Inorganic Chemicals

Cyanides were analyzed as a miscellaneous chemical for this site. Cyanide compounds occur naturally in a number of foods and plants but also have anthropogenic origins. They are produced by certain bacteria, fungi, and algae. Very small amounts of cyanide, in the form of vitamin B12 (cyanocobalamin), are essential to humans. Most of the cyanide found in the environment comes from industrial processes (ATSDR, 2004b). No documentation of naturally occurring cyanide concentration ranges could be found but they would not expected to be much above normal laboratory detection limits.

The half-life of cyanide in water is unknown. Cyanide does not accumulate in fish. Most cyanide in surface water will form hydrogen cyanide and evaporate but the amounts formed typically do not pose environmental threats (ATSDR, 2004b). This chemical has a half life of 1 to 3 years in the atmosphere (ATSDR, 2004b). Cyanides in soil are fairly mobile but can be removed through several natural processes. Some cyanide compounds in soil can form hydrogen cyanide and evaporate. Some cyanide compounds will be transformed into other chemical forms such as thiocyanates by microorganisms in soil, and others bind tightly to metals such as iron. Consequently, cyanides usually do not seep into groundwater (ATSDR, 20004b) and cyanide was not detected in CBP groundwater. Cyanide was selected as an ecological COPC in surface soil and sediment. This mobile anion will migrate freely until it is complexed by a metal such as iron. From that point onward, the cyanide is expected to migrate as a metal complex adsorbed to soil in overland runoff and adsorbed to sediments in surface water.

5.3 CONTAMINANT TRANSPORT PATHWAYS

A contaminant transport pathway represents the physical path or the mechanism by which a contaminant moves or may move from one location (i.e., the source area) to another. A transport pathway may also involve a phase change for the contaminant (e.g., a contaminant is absorbed to soil, volatilizes to soil gas in the vadose zone, and then migrates into a basement as a gas). In addition, contaminant transport pathways provide mechanisms and conduits for contaminants to migrate to a new location where they may contribute to a human health or ecological risk. The determination of whether a pathway is currently causing a risk or could potentially cause a future risk depends on the combination of chemical characteristics, the existence of a potential pathway, the physical site conditions, and the potential for exposure to occur now or in the future.

This section presents a brief summary of contaminant fate and transport pathways that may exist, or may have existed, at the CBP. The following potential contaminant transport pathways may exist:

- Aerial deposition onto soils and sediments from plumes of smoke to downwind locations (historic deposition);
- Leaching of soil contaminants to groundwater;
- Migration of groundwater contaminants within the soil and bedrock strata;
- Mixing of groundwater (i.e., creek bed seepage) with surface water in adjacent stream channels during storm events;

- Erosion and runoff of contaminated particles from soil and deposition in surface water bodies;
- Leaching of contaminants from creek sediment to surface water;
- Migration of contaminants in surface water as dissolved or sorbed phases during storm events; and
- Volatilization from soil, or groundwater, or surface water.

5.3.1 Aerial Deposition onto Soils

Aerial deposition is only being included to present information regarding potential historical deposition since burning operations ceased almost 40 years ago at CBP.

Open burning operations, as previously conducted at the CBP, generate plumes of smoke and vapors that rise into the atmosphere as a result of buoyancy differences between the plume of hot smoke and vapors and the surrounding air. The plume will rise to an altitude of equilibrium where the plume is no longer less dense than surrounding air. During the rise of the plume and thereafter, wind currents carry the plume away from the source of combustion. At the CBP the predominant wind direction is out of the south southwest (See Figure 5-1). The travel distance of the plume depends on factors such as the meteorological conditions at the time of burning, the combustion temperature and size and elevation above ground of the combustion pile. Dense particles are the first to fall out of the plume onto surface soils, sediments, surface waters, vegetation, and man-made structures. The lighter particulates are carried further downwind to more remote locations.

During transport, the plume spreads over an increasingly larger air volume, resulting in a dilution of the contaminants within it. In addition, there is often an area around the combustion source where the plume rises to its greatest altitude, followed by leveling off or an altitude decrease as the plume cools and migrates further downwind. Eventually, the plume and contaminants return to the Earth's surface. A region typically exists somewhere downwind of the predominant plume center line that exhibits the maximum concentration of contaminants deposited from the plume. Long-term plume transport can best be thought of as being affect by climatological conditions rather than daily meteorological conditions.

A simple air dispersion model, SCREEN3 (USEPA, 1995a and 1995b), was used to predict the region of expected maximum concentration downwind of the CBP burn source under a set of assumptions that conservatively emulate burns at the CBP: 25 ft diameter burn area, approximately 400^{o}C burn temperature, burn pile at ground elevation, and average meteorological conditions. With these assumptions, the expected maximum combustion product location would be along the plume center line approximately 1,500 ft downwind of the combustion source. With larger burns of higher temperature, which would drive the plume higher and farther from the source, this location would be expected to move further downwind from the source. This is illustrated in the small matrix below. The results of the modeling may explain why the concentrations of PAHs and other contaminants are relatively low across the CBP. The entire width of the CBP is approximately equal to this plume travel distance. SCREEN3 was used to predict other maximum concentration regions, assuming other burn temperatures and burn pile sizes. The results for all burn conditions are provided below.

Table 5-5. Average Results of Simple Air Dispersion Model – Region of Maximum Contaminant Concentration (ft downwind of combustion source)

	Burn Temperature = 400 °C	Burn Temperature = 830 °C
Burn Pile Diameter = 25 ft	2600 ft	3900 ft
Burn Pile Diameter = 50 ft	3900 ft	5200 ft

5.3.2 Leaching of Soil Contaminants to Groundwater

Contaminants that adhere to soil particles or have accumulated in soil pore spaces at the CBP can leach and migrate vertically to the groundwater as a result of infiltration of precipitation. The rate and extent of this leaching is influenced by the amount of precipitation, rate of infiltration, the physical and chemical properties of the soil, the physical and chemical properties of the contaminant, and the depth of the water table.

During the selection of COPCs in soil (Section 6.2), the maximum detected concentrations of individual soil contaminants were compared against screening levels and background. The soil screening levels (SSLs) included levels protective of groundwater. The SSLs are derived from assumptions regarding aquifer hydraulic conductivity, hydraulic gradient, infiltration rate, mixing zone height, aquifer thickness, source length, and chemical-specific soil-water K_ds. These SSLs for protection of groundwater are used to conservatively estimate whether a chemical could leach from soil to groundwater at a groundwater concentration above the pertinent risk-based screening level for groundwater.

Based on the results of CBP soil analyses, seven metals (aluminum, arsenic, chromium, copper, lead, manganese, and vanadium) were identified as COPCs in soil (Tables 2.1 and 2.2 of Appendix S). Of these chemicals, chromium and lead were not detected in groundwater samples. Hence, leaching of chromium and lead from soil to groundwater is not considered to be significant. Several other environmentally important metals were detected in groundwater but their concentrations were low enough not to be selected as COPCs for this medium. Those metals are barium, cobalt, copper, iron, nickel, silver, and zinc. For these metals, as well, the soil to groundwater migration pathway evidently plays a limited role in contaminant migration.

Calcium, magnesium, potassium, and sodium were also detected in groundwater. These four metals are essentially non-toxic and of little environmental significance, hence are not discussed further.

Acetone and methylene chloride are the only organic chemicals, including explosives and propellants, to be detected in groundwater (Table 2.4, Appendix S). The detections of these two chemicals were low, indicating that the concentrations detected in soil with sediment do not present enough total mass to yield detectable groundwater concentrations after dilution, dispersion, and other natural mechanisms reduce their concentrations.

This leaves aluminum, arsenic, manganese, and vanadium as COPCs in soil with the potential to leach to groundwater. Arsenic was detected two times in groundwater at concentrations exceeding groundwater background. However, there are several factors that limit the significance of these detections and render the soil to groundwater migration pathway insignificant at the CBP. These are discussed below. Aluminum, manganese, and vanadium, were not detected in groundwater at concentrations that exceeded screening values, therefore, the soil to groundwater migration pathway is evidently insignificant for these metals, regardless of whether leaching is occurring. This is true, in part, because no new contamination is being added to soils. The rates of metal leaching from soils to groundwater will, therefore, not increase unless geological conditions such as pH or oxidation-reduction potentials are changed. This is an unlikely event. If it were to occur, the reservoir of metals in the native minerals would vastly outweigh the amount of site-related contamination. This is described in more detail below.

Aside from geological conditions such as pH and oxidation-reduction potentials, a major factor affecting metal leaching rates is the length of time that the site has been non-operational. Metals are generally most mobile in soil soon after they are released. As time progresses, the assimilation of the metals into the mineral matrix renders them less mobile. If an excess of metals is not present beyond what the soil can readily bind, a steady state sets up. This steady state limits the leaching rates of the metals. Over time, the rates of leaching decrease as the excess metal reservoir is depleted and the more tightly bound metals are the only metals available for leaching. CBP has not been operational for about 40 years, which means that no new contaminants have been generated in the last 40 years and the previously released contaminants have had some time to bind to the mineral matrix. Thus, leaching rates can not be any greater than at the current time unless geologic conditions change.

A second factor is the relatively low concentrations of metals contaminants in soil compared to background. Using arsenic as the example, the site concentrations are only slightly greater than the background values. The background concentrations for arsenic range from 15.4 to 19.8 mg/kg, depending on soil depth. The maximum site concentration in any soil sample was 32.8 mg/kg. This is about two times the maximum background concentrations. This indicates that the arsenic might not be a true site contaminant but, if it is, the total mass of arsenic contamination is not much greater than what is present naturally.

A third factor is the arsenic spatial distribution. Because most of the CBP soil concentrations were less than the 19.8 background value, the breadth of arsenic contamination is evidently limited to isolated locations. This is inconsistent with an aerial deposition scenario by which arsenic contamination should be spread preferentially along the line of plume travel. Furthermore, the small number of isolated occurrences of screening value exceedances provides a very limited reservoir of contamination that could be transferred to groundwater. In addition, when the vertical profile of arsenic concentrations in soil is considered, it is clear that arsenic concentrations do not differ appreciably with soil depth (Tables 4-1 through 4-4). Instead, the concentration values, after allowing for natural soil sample heterogeneity, appear to be randomly distributed with depth over the entire observed concentration range up to 32.8 mg/kg. This kind of spatial distribution is often an indication that an apparent contaminant is not an actual contaminant. A similar situation exists in the lateral directions. It is also an indication that the site soils are well leached and will not pose a significant risk to groundwater in the future. Consequently, the evidence is strong that the CBP soils are in a steady state condition whereby the rate of leaching of metals into the groundwater will not change over time.

The final factor is the observed groundwater metal concentrations. The well with the greatest arsenic concentration *(35.1* ug/L) was well MW-00l. This well is located upgradient of the soil sampling location with the greatest arsenic concentration, CBPSS-004, and is unaffected by downgradient soil concentrations. Thus, the high arsenic concentration is evidence of a naturally elevated arsenic level in groundwater. All wells downgradient of soil sampling location CBPSS-004 have much lower arsenic concentrations (non-detect to 19.9 ug/L). Furthermore, there is no spatial trend to the groundwater data to suggest that groundwater is leaching arsenic contamination from soils or bedrock at one or more locations and carrying the contamination downgradient. Such a pattern would be evident by high concentrations near the point(s) of leaching (i.e., the source area) and decreasing concentrations in the downgradient direction(s). This last factor supports the notion that the site is in a steady state whereby there is no significant release of metals contamination except that which is available in the natural soils and bedrock. Thus, the rate of arsenic release is constant, aside from variations caused by natural fluctuations such as changes in rainfall. The rates will not increase because contaminants are no longer being released to the CBP.

Although the factors discussed above are focused on arsenic, similar arguments could be made for aluminum, manganese, vanadium, and other metals such as cobalt, thallium, and even cyanide (a non-metal) whose concentrations may have exceeded soil screening levels but were not selected as COPCs. The arguments presented here point out why there is not believed to be any significant potential for contamination of groundwater with metals via soil leaching of site-related contaminants. Any elevated concentrations of the contaminants in groundwater are more likely to be a manifestation of local conditions, such as reducing conditions near the affected wells, which cause metals to dissolve into the groundwater from the native soil or bedrock.

As indicated in Section 5.2.5, many metals detected at the CBP were not selected as COPCs in groundwater. This is evidence that the soil to groundwater leaching pathway is of limited applicability. Furthermore, the leaching potential of metals is expected to decrease over time as the available metals are leached from soils but are not replenished. Because the metal COPC concentrations are not currently much greater than background concentrations, however, it would be difficult or impossible to measure any such rates of decrease.

5.3.3 Migration of Groundwater Contaminants

Organic groundwater contaminants will alternately adsorb to and desorb from organic matter in the soil and bedrock at the molecular level as they migrate with groundwater toward downgradient directions. Groundwater flow is generally northwest toward Sand Creek. Inorganic groundwater contaminants will follow a pathway similar to the organic contaminants. The relative migration rates will depend on individual contaminant adsorption characteristics and rates of degradation that may occur as described in Sections 5.1 and 5.2.

The reservoir of organic contamination in soil that could feed groundwater is very small, based on soil concentrations reported in Tables 2.1 through 2.3 (Appendix S). Therefore, the level of importance of groundwater migration is expected to be minor. This is borne out by the low frequencies of organic contaminant detections for groundwater (Table 2.4, Appendix S).

Volatilization of VOCs, or precipitation of metals as a mineral phase may physically transform contaminants. Contaminants may be chemically transformed through hydrolysis, oxidation/reduction, or biodegradation. Besides biodegradation, dilution from surface recharge is also a factor that causes the concentrations of contaminants to decrease in the downgradient directions.

Nitrocellulose was detected primarily in surface soils but also in subsurface soil samples scattered across the CBP. This material is relatively insoluble so it is expected to persist in soil for a long time. Half-life information could not be found for this chemical. Failure to detect nitrocellulose in groundwater across the site is evidence of its low solubility and the low concentrations observed in soils. Groundwater transport of nitrocellulose is not expected to be a significant migration pathway.

Metals will follow groundwater flow patterns just as the organic contaminants. The metals may migrate in soluble form or as ions or non-ionized organometallic complexes bound to colloidal particles. Migration of soluble metals would be retarded by ion exchange with bedrock and the rate of colloidal flow through the bedrock would depend on particle size with smaller particles moving more quickly than larger particles. In general, highly charged (+3 or greater) metals and complexes will be retarded to the greatest degree and weakly charged species (+1) will be the most mobile. Lead is a notable exception. This metal binds tightly to soil as the Pb^{+2} ion, and is essentially immobile despite its moderate charge of "+2." This ion also binds tightly to sediments but is mobile when the sediments, themselves, migrate. In general, groundwater migration does not appear to be a significant migration pathway for CBP contaminants.

As explained in Section 5.3.2, however, the amount of metals leaching into groundwater, and hence the migration of groundwater metal contaminants, will remain steady or decrease over time relative to the current concentrations.

5.3.4 Mixing of Groundwater (I.E., Creek Bed Seepage) with Surface Water in Adjacent Stream Channels during Storm Events

Groundwater may recharge Sand Creek. Any contaminants that are in the groundwater would be transported to the creek with the groundwater. Rates of transport can not be predicted but, because the concentrations of organic and inorganic contaminants are low in CBP groundwater, the rates can not be significant. Sediments do not appear to be accumulating contaminants because the contaminant concentrations are low in sediments. Low concentrations of any dissolved contaminants become even less concentrated after mixing in the surface water. This migration pathway, therefore, does not appear to be a significant migration pathway.

5.3.5 Migration of Contaminants from Surface Soil to Surface Water

Rainfall, snowmelt, and surface water runoff that come into direct contact with surface soils can leach contaminants from the soils and transport them to drainage channels and Sand Creek via runoff during storm events.

Soil particles containing sorbed contaminants may also be dislodged from the soil surface and be physically transported to drainage channels and creeks via overland runoff. The rate of soil removal and transport is related to the degree of vegetation in the area of interest and the slop of the land.

Well vegetated areas, especially those with thick, tall grasses, impede runoff because the vegetation lessens the impact and flow of precipitation over the land surface.

Fine soil and sediment particles tend to move preferentially to coarse particles because they are not as heavy as the coarse particles. Bends in creeks such as Sand Creek may serve as sediment depositional areas because of changes in water and entrained sediment flow direction and flow rate.

The topographic relief at the CBP is generally minor. This relatively flat terrain limits the migration potential of contaminants. A general limited amount of water in drainage channels is evidence that the driving force for migration is weak. Sand Creek is an exception where the presence of water is prevalent and flow is therefore more continuous. Shallow drainage channels provide conduits for transport of chemicals in particulate form in surface soils to migrate toward downgradient areas. However, virtually no organic chemicals were detected in surface water; hence, migration of dissolved organic contaminants is not viewed to be a significant transport mechanism at this site. Overland runoff and transport within drainage channels is expected to be the most significant migration pathway for nitrocellulose, which will tend to be particulate in nature or adsorbed to sediment particles. More soluble chemicals present at low concentration may dissolve from soils and be transported in the surface water but the observed concentrations have been very low to undetectable. The inorganic chemicals that were detected in surface water were detected at concentrations typical of this medium. No inorganic chemicals were selected as human health or ecological COPCs in surface water. Consequently, while this migration pathway is expected to be significant for the CBP, the level of contamination that has migrated via this pathway has been minimal and the rates of migration are expected to be slow.

5.3.6 Leaching Of Contaminants from Creek Sediment to Surface Water

The reservoir of organic and inorganic contamination in drainage channels and creek sediments is low. This is evident from low or undetectable concentrations of many inorganic chemicals and most organic chemicals in the surface water and sediment samples. Although nitrocellulose was detected at low concentrations in sediments, the low sediment concentrations and low solubility of this chemical evidently are preventing detection of nitrocellulose in surface water. These factors render leaching of contaminants from sediments to surface water an insignificant migration pathway.

5.3.7 Migration of Contaminants in Surface Water as Dissolved or Sorbed Phases during Storm Events

Once contaminants are dislodged from surface soil particles and become dissolved, they may flow with surface water and entrained sediments to downgradient areas. The amount of organic and inorganic contamination available in surface soils and sediments to support this process is low at the CBP. Metals were detected at various concentrations across all samples, however; there are limited spatial patterns that can be used to identify particular sources to downgradient contamination. One exception may be the debris area near the central portion of Lumber Yard road in the center of the CBP. It does not appear that contaminants are migrating in these channels at detectable levels in surface water.

5.3.8 Volatilization from Soil, Groundwater, or Surface Water

Based on the few detections at low concentration, VOC concentrations may be laboratory artifacts, although there is no proof of this. Because the concentrations of VOCs in all media that would be susceptible to volatilization losses were low, this is not a significant organic contaminant loss mechanism. Metals and their compounds are generally non-volatile so this mechanism is also expected to be insignificant for metal losses as well.

5.4 CONCEPTUAL SITE MODEL

The CSM is a description of known site conditions that explain in a conceptual manner how contaminants were or could have been deposited, how these contaminants can or do move in the environment, and the impact they may have on receptors. The focus of this section is on the physical model. Effects and potential effects on environmental organisms, including humans, are discussed in the risk assessment sections.

The CBP is an area where open burning was conducted. Contaminant sources at CBP originate from the residues of the open burning and disposal (open dumping). Contaminants associated with the disposal include explosives, propellants, metals, SVOCs (especially PAHs), and VOCs.

Combustion operations generate organic combustion products such as PAHs when the combustion includes cardboard, paper, wood, cloth, and other discarded domestic and industrial materials. The soils of CBP are of generally low permeability, which suggests that combustion products deposited aerially in downwind directions from the burn pits should have had little opportunity to percolate into the soils. Instead, they would be expected to preferentially run off the soil into drainage ditches. There is no particularly prominent drainage channel for contaminant migration because contaminant concentration are generally low and relatively uniformly distributed in the area of Lumber Yard Road. Contaminants were detected in several environmental media:

- In surface soils, there were analytical detections of metals, VOCs, PAHs and cyanide. Metal contaminants were detected throughout the site. The metals that appear most frequently are naturally occurring metals. Organic compounds are also detected throughout the site. Nitrocellulose, which has an expected long half life in the environment, was detected in several surface soil samples and sediment samples. Soil contamination is generally low and does not constitute a significant reservoir of contaminants. Most surface soil contaminants are expected to migrate as surface runoff because the soils of the CBP are generally of low permeability. Topographical relief, however, is low so migration rates are expected to be slow.
- In soil borings, metals, nitrocellulose, TNT, PAHs, Aroclor 1254, several pesticides, and cyanide were detected. Metals were detected frequently throughout the site. The nitrocellulose, SVOCs, Aroclor 1254, and cyanide detections were more sparsely scattered throughout the site and were generally low.
- In sediment, metals, nitrocellulose, PAHs, two VOCs, and cyanide were detected. Metals and other inorganics were detected throughout the site. The nitrocellulose, PAHs, the VOCs, and the cyanide detections occurred in scattered samples around the site.

- In surface water only metal contaminants were detected. Of the metals detected, aluminum, arsenic, barium, iron, manganese, and zinc have environmental significance.
- In groundwater, inorganics were detected in most of the groundwater samples while acetone and methylene chloride were detected in two samples and one sample, respectively.

Burning operations characteristically deposit combustion products in a downwind direction via aerial deposition. These products would include metals and organic chemicals such as PAHs. They may also include cyanide. In addition, organic solvents and other chemicals are often used to facilitate combustion; hence, soils may become contaminated with these materials. The levels of contamination at the CBP are relatively low. For example, the concentrations of metals exceeding background were typically within one to three times the background and generally fall within worldwide background concentration ranges (See Section 5.2.6).

Except for metals, the contamination at the CBP is generally sporadically dispersed across the site. There are no spatial patterns present to indicate a release from a source that has expanded through contaminant migration. A known debris area could be a minor source of metal and organic contaminants, especially for copper, which had significantly elevated concentrations near the debris piles.

Metals do not degrade in the environment but they can be assimilated into minerals. Their oxidation states can change over time as they migrate from one location to another. Metals in general, however, are relatively immobile except for those with predominantly single positive charges such as sodium and potassium. A few other metals such as calcium and magnesium are also relatively mobile. These four metals, however, generally pose little to no environmental risks to receptors. Receptor exposure and risk are treated more completely in the risk assessment sections (Sections 6.0 and 7.0).

Few organic chemicals, especially nitrocellulose, that are directly related to site operations were selected as COPCs, thus indicating that the concentrations of detected organic chemicals are generally low enough as not to pose a significant threat to the health of receptors.

The primary contaminant migration pathway for contaminants at the CBP is overland runoff and transport in surface drainage channels, including Sand Creek. The topographic high located in the south central portion of the CBP directs overland runoff radially at first and ultimately toward the northwest. Leaching from soils is not expected to be a significant concern. The quantities of contamination present in CBP soils are generally low. Therefore, the mass of contaminants transported by this migration pathway is low. Dilution effects should be large in drainage channels and in Sand Creek, which lies to the northwest of the CBP. This is reflected in the low concentrations of contaminants detected in surface waters and sediments. Similar effects are observed in groundwater.

Overall groundwater flow is to the northwest toward Sand Creek. Virtually no organic chemical detections were observed in groundwater, indicating that leaching and migration within groundwater is not a significant migration pathway. Although inorganic chemicals were detected in groundwater, many detections were within background concentrations levels and arsenic was the only chemical selected as a groundwater COPC (for human health risk). The single maximum detection of arsenic is in the vicinity of Lumber Yard Road but the small amount of arsenic contamination that is present does not appear to present a long term threat because the arsenic reservoir is low.

Surface water drainage channels can transport surface soil contaminants and sediments to downgradient locations, however, the topographical relief is moderate at the CBP so transport pathways are not expected to move sediments rapidly. An exception to this could be during storm events when flow rates increase significantly. Contaminants detected at the CBP will tend to also adsorb to sediments. The total organic carbon content (approximately 1,000 to 57,000 mg/kg) observed in CBP sediments is typical of environmental sediments so adsorption would also be typical.

6.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

This section presents the results of the Baseline Human Health Risk Assessment (BHHRA) conducted to characterize the risks to humans associated with the potential current or future exposures to chemicals in surface soil, subsurface soil, groundwater, surface water, and sediment within the CBP at the RVAAP, Ravenna, Ohio. This assessment evaluates the potential risks to human health if no remedial action is taken and; therefore, represents the "no action" alternative in a Feasibility Study.

6.1 BHHRA INTRODUCTION

The methodology used in the CBP BHHRA is based primarily on the protocol established in the Facility Wide Human Health Risk Assessors Manual (FWHHRAM), U.S. Army Corp of Engineers [USACE], January 2004 and the White Paper – Human Health Risk Assessment Approach for CBP Remedial Investigations, Ravenna Army Ammunition Plant, Ravenna, Ohio (Tetra Tech, 2004).

Technical direction provided during teleconferences with the USACE (March 17, 2004) and Ohio EPA (March 19, 2004) was incorporated into this document. The White Paper has been reviewed by both the USACE and the Ohio EPA.

To a large extent, the guidance presented in the FWHHRAM and the White Paper is based on standard USEPA guidance presented in:

- Risk Assessment Guidance for Superfund (RAGS) Volume I - Human Health Evaluation Manual (Part A) (EPA, 1989a);
- RAGS Part B, (Development of Risk-based Preliminary Remediation Goals) (EPA, 1991a);
- RAGS Part D, (Standardized Planning, Reporting, and Review of Superfund Risk Assessments) (EPA, 2001a); and
- RAGS Part E, Supplemental Guidance for Dermal Risk Assessment) (EPA, 2004a).

Additional methodology was taken from:

- Dermal Exposure Assessment: Principles and Applications (EPA, 1992a);
- Human Health Evaluation Manual, Supplemental Guidance "Standard Default Exposure Factors" (EPA, 1991b);
- Exposure Factors Handbook (EPA, 1997);
- Oak Ridge National Laboratory Risk Assessment Information System internet site at http://risk.lsd.ornl.gov;
- Integrated Risk Information System (EPA, 2004b) (updated approximately monthly); and
- other guidance documents.

The methodology for the BHHRA consists of the following six steps:

- **Step 1**: Data evaluation – The selection of site-related chemicals (SRCs) and COPCs for environmental media.

- **Step 2**: Exposure assessment - The identification of potential current and future human receptors that may be exposed to the COPCs, the evaluation of the pathways by which the receptors may be exposed, and the estimation of chemical intake resulting from exposure.
- **Step 3**: Toxicity assessment – An assessment of toxicity of each COPC including the presentation of the toxicity criteria (i.e., cancer slope factors, reference doses) typically used by USEPA to estimate risk.
- **Step 4**: Risk characterization – The estimation of cancer and noncancer risk using the intakes and toxicity criteria presented in the exposure assessment and toxicity assessment, respectively.
- **Step 5:** Uncertainty analysis – The identification of major uncertainties affecting the interpretation of the BHHRA results.
- **Step 6**: Summary and Conclusions – The summary and conclusions of the BHHRA.

The COPCs identified in Step 1 are evaluated quantitatively (when possible) and discussed qualitatively otherwise. The results of the BHHRA are used to (1) document and evaluate risks to human health; (2) determine the need, if any, for remedial action; and (3) identify chemicals of concern (COCs). COCs are those chemicals that, when evaluated by this BHHRA, are determined to pose a risk to human health exceeding target risk levels for cancer and non-cancer effects and may require the development of chemical-specific remediation levels. Per the protocol established in the White Paper for the CBP, potential COCs are identified for an environmental media when the receptor risk exceeds a cumulative cancer risk benchmark of $1x10^{-5}$ or a total non-cancer HI benchmark of 1 for non-carcinogens.

Three major aspects of chemical contamination and environmental fate and transport were considered to evaluate potential risks: (1) Contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or by human action; (2) potential exposure points must exist; (3) human receptors must be present at the point of exposure. If any of the factors listed above are absent, risks are not quantitatively evaluated for that exposure pathway.

The quantitative BHHRA for the CBP is presented, in large part, using the standard set of tables similar to those suggested in USEPA RAGS Part D (EPA, 2001a). (The tables presented in this BHHRA take into consideration RVAAP specifications. There are minor formatting differences between the tables and the suggested RAGS Part D tables).

6.2 DATA EVALUATION

Data evaluation involves numerous activities, including sorting the data by medium, evaluating the quality of data with respect to qualifiers and codes, and developing a data set for use in the BHHRA (i.e., the selection of COPCs). Section 6.2.1 provides an overview of sample collection and analysis activities and a data quality review that is further detailed in Sections 1.0 through 4.0. Section 6.2.2 summarizes the results of the COPC screening process

6.2.1 Data Collection and Evaluation

Data for this BHHRA consisted of analytical results for surface soil, subsurface soil, surface water, sediment, and groundwater samples collected during the RI for the CBP. For groundwater, filtered samples were collected and analyzed, per Ohio EPA direction. The lab selected the most appropriate analytical result if re-analyses/dilutions were necessary and included the result in the database used to determine SRCs for this risk assessment. Duplicate samples were averaged.

Chemical analyses were performed in accordance with SW-846 methodologies. The analytical results were evaluated, using the National Functional Guidelines (USEPA, 1994a, b) to assess data usability and the laboratory's compliance with the analytical methodology. The analytical data were reviewed, validated, and evaluated using the criteria specified in the data quality objectives. All validated data (and qualifiers, as necessary) are presented in Appendices F, G, J, N, and P. All unqualified positive detections and "J" qualified detections (estimated values) were considered as detected concentrations for this BHHRA. All nondetects (indicated with a "U" qualifier) were retained in the BHHRA data set. No analytical results with a "UR" qualifier (indicating a rejected nondetect result) or "R" qualifier (indicating a rejected positive detection) were found in the BHHRA data set. A complete data quality summary is presented in Appendix R.

The data evaluation included the calculation of basic descriptive statistics for each data set evaluated in the BHHRA. Basic statistics included frequency of detection, range of positive detections, arithmetic mean, normal 95 percent Upper Confidence Level (95 UCL-N) on the mean, and log-normal 95 percent Upper Confidence Level (95 UCL-L) on the mean. Appendix S provides the equations used to determine the UCL-L and the UCL-N on the mean. These descriptive statistics were also used in the determination of the exposure point concentration (EPC) selected in the exposure assessment.

6.2.2 Selection of COPCs

COPCs for the CBP are identified in two steps. SRCs are first identified for each medium and then COPCs are selected from the SRCs based on a toxicity screen. The purpose of the screening process is to eliminate chemicals for which no further risk evaluation is needed. The premise of this screening step is that risk is typically dominated by a few chemicals and that, although dozens may actually be detected, many chemicals may contribute minimally to the total risk. Section 6.2.2.1 describes the SRC selection process and Section 6.2.2.2 describes the COPC screening process.

6.2.2.1 SRC Screens

The following assumptions are used in the determination of the CBP SRCs:

- Physical chemical data (e.g., alkalinity, pH, etc.) are not considered to be SRCs (and, therefore, are not considered to be COPCs) for the CBP.
- Filtered metals data are used in the determination of groundwater SRCs. The filtered metals data are used because such data are typically more indicative of the truly soluble/dissolved (mobile) chemical concentrations in groundwater.

- Soil data are subdivided into three data sets based on the sampling depths for the CBP and the receptors to be evaluated at the CBP. In accordance with the FWHHRAM, the surface soil data set is comprised of data for samples collected from the 0 to 1 ft bgs interval. The deep surface soil data set is comprised of all soil samples collected within the 0 to 4 bgs ft interval. Subsurface soil data is comprised of all sample results for soil samples collected below 1 ft bgs. Consequently, data from the surface soil data set are compared against the surface soil background criteria and data from the subsurface soil data set are compared against the subsurface soil background criteria. The chemical concentrations in the deep surface soil samples are compared to the lower of the RVAAP backgrounds available for the background surface and subsurface soil datasets.

The SRC screening process involves three steps: background characterization, background comparison, and weight-of-evidence screening. The background comparison was conducted to determine if the inorganics detected in the environmental media were naturally occurring or potentially site-related. Organic chemicals were not eliminated as SRCs based on background comparisons.

Backgrounds were characterized for each environmental media at RAAVP as discussed in Section 4. Per the protocol established in the White Paper, the background values for the RVAPP are those presented in the Phase II Remedial Investigation Report for the Winklepeck Burning Ground at Ravenna Army Ammunition Plant, Ravenna, Ohio (USACE, 2001). These values are the 95 percent upper tolerance limit (UTL) (or the maximum detected concentration if the calculated UTL exceeds the maximum detected concentration reported for the background samples) for the background dataset for each environmental media. An inorganic is selected as a potential SRC if the maximum detected concentration exceeds the RVAAP background values. This background screen applies to inorganic chemicals only.

Weight-of-evidence screens are also used, including:

- Chemicals with a frequency of detection of less than 5 percent of the samples analyzed in any media may not considered to be site-related for that media if:
  - The chemical was not detected at high concentrations (e.g., relative to the detection limit, background);
  - The chemical was not detected in another media; and
  - There is no reason to believe that the chemical may be present (e.g., based on site history, process knowledge). Any explosive detected in any medium at the CBP is considered to be site-related regardless of frequency of detection.

This screen only applies to datasets containing at least 20 samples.

Naturally occurring essential elements, including calcium, chloride, iodine, iron, magnesium, potassium, phosphorous, and sodium, are typically considered to be toxic at high concentrations only and are typically not selected as SRCs. As detailed in the FWHHRAM, these inorganics are an integral part of the human food supply and are often added to food as supplements. USEPA recommends that these chemicals not be evaluated as COPCs as long as they are (1) present at low concentrations (i.e., only slightly elevated above naturally occurring levels), and (2) only toxic at very high doses (i.e., much higher than those that could be associated with contact at a site).

Recommended daily allowance (RDA) and recommended daily intake (RDI) values are available for seven of these inorganics. Based on the RDA/RDI values, a receptor ingesting 100 mg of soil per day would receive less than the RDA/RDI of calcium, magnesium, phosphorous, potassium, and sodium, even if the soil consisted of the pure mineral (i.e., soil concentrations greater than 1,000,000 mg/kg). Receptors ingesting 100 mg of soil per day would require soil concentrations of 1,500 mg/kg of iodine and 100,000 to 180,000 mg/kg of iron to meet their RDA/RDI for these metals. Concentrations of these inorganics in the environmental media at the CBP do not exceed these levels. Consequently, these essential nutrients were not selected as potential SRCs.

The list of SRCs is further evaluated using the toxicity screen described in Section 6.2.2.2 to develop a list of human health COPCs. For efficiency purposes, the results of both the SRC and COPC screens are shown on the same table for each medium and are presented in Tables S.2.1 through S.2.6 (Appendix S).

6.2.2.2 COPC Toxicity Screen

The purpose of the COPC screens is to eliminate SRCs for which no further risk evaluation is needed. COPCs are selected for each medium. COPCs for the BHHRA are limited to those chemicals that exceed a selection criterion. For this risk assessment, risk-based and health-based criteria were used to reduce the number of chemicals and exposure routes considered in a risk assessment. The COPCs were defined as chemicals that were positively detected in an environmental medium at a maximum concentration exceeding screening values.

Environmental sampling results are compared to risk-based screening concentrations (RBSCs) based on USEPA Region IX PRG (EPA, 2004c) and federal Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) (for groundwater only). The USEPA Region IX risk-based PRGs represent a risk level of $1x\ 10^{-6}$ for carcinogenic effects (i.e., a one-in-one million excess chance of developing cancer over a lifetime) and a hazard index level of 1.0 for noncarcinogenic effects (i.e., adverse noncarcinogenic health effects are not anticipated at or below this concentration). The USEPA Region IX PRGs for soil were calculated for a human receptor hypothetically exposed to chemicals in soil assuming a residential land use scenario. The USEPA Region IX PRGs for tap water were calculated for a human receptor hypothetically using a groundwater or surface water resource as a domestic water supply. Conservatively, RBSCs for noncarcinogens are one-tenth these PRGs to further account for potential cumulative noncarcinogenic effects (Section 4.0 comparisons were against total PRGs). The RBSCs for carcinogens are the PRGs and represent the $1x10^{-6}$ cancer risk level. If RBSCs exists for a chemical for both carcinogenic and non-carcinogenic effects, the lower of the two values is used as the COPC selection criteria.

The maximum detected concentration for each SRC in each medium is compared against the risk screens as follows:

- Chemicals in surface soil, subsurface soil, and sediment are screened against their respective RBSCs (based on the Region IX PRGs for soil [assuming residential land use]). For informational purposes only, data from the same three media were also compared to their respective USEPA Region IX industrial soil PRGs.

- Chemicals in groundwater are screened against the lesser of the RBSCs based on the USEPA Region IX tap water PRGs and federal SDWA MCLs.
- Chemicals in surface water are screened against the RBSCs based on the USEPA Region IX tap water PRGs.

USEPA Region IX PRGs can be found at http://www.epa.gov/region09/waste/sfund/prg/index. htm. Drinking water MCLs are obtained from http://www.epa.gov/safewater/mcl.html#1. SRCs that exceed toxicity screening levels and those lacking screening levels are retained as COPCs. Chemicals that were not detected, not selected as SRCs, or were not detected at maximum concentrations exceeding toxicity screening levels were not retained as COPCs.

The COPCs are then classified as quantitative COPCs when U.S. EPA-approved toxicity information (i.e., cancer slope factors, reference doses) is available and as qualitative when no toxicity information is available. The qualitative COPCs are further evaluated in the uncertainty section of the BHHRA. The quantitative COPCs are further discussed in the toxicity assessment (Section 6.4). Toxicity profiles are presented for all COPCs in Section 6.8.

Tables 2.1 through 2.6 (Appendix S) present the COPC screens for surface soil, subsurface soil, deep surface soil (i.e., the 0 to 4 foot interval), groundwater, surface water, and sediments, respectively. These tables include:

- Summary statistics, including the frequency of detection, range of nondetected values, maximum and minimum detected concentrations, location of maximum concentration, arithmetic average concentration, and upper 95 percent confidence limit (UCL95) on the mean concentration;
- Screening values (background concentrations, RBSCs, and MCLs, as appropriate);
- SRC determination; and
- COPC determination.

The datasets evaluated for each environmental media are presented in Tables 6-1 through 6-6. Table 6-7 summarizes the COPC list for each medium and indicates which COPCs will be addressed quantitatively and qualitatively for each medium.

6.2.2.3 Screening for Lead

USEPA approved toxicity criteria (i.e., cancer slope factors, reference doses) have not been published for lead. Consequently, a calculated, toxicity-criteria-based PRG is not available for this inorganic. The lead concentrations in soil and sediment at the CBP (see Appendix S, Tables 2.1, 2.2, 2.3 and 2.6) are compared to the lead soil screening guidance concentration of 400 mg/kg for residential soil published in OSWER Directive #9355.4-12 (EPA 1994c). This value is presented as the PRG in the U.S. EPA Region IX table. Lead was selected as a COPC for surface soil and deep surface soil at the CBP. Lead was not detected in groundwater or surface water at the CBP. Consequently, a COPC screening level for lead in groundwater and surface water was not required for this BHHRA. (The SDWA Action Level of 15 μg/L would be used as the screening level if lead had been detected in groundwater or surface water samples).

Table 6-1. Human Health Risk Assessment Dataset for Surface Soils

Sample ID	Depth bgs
CBPSS-001-0001-SO	0-1
CBPSS-002-0001-FD	0-1
CBPSS-002-0001-SO	0-1
CBPSS-003-0001-SO	0-1
CBPSS-004-0001-SO	0-1
CBPSS-005-0001-SO	0-1
CBPSS-006-0001-FD	0-1
CBPSS-006-0001-SO	0-1
CBPSS-007-0001-SO	0-1
CBPSS-008-0001-SO	0-1
CBPSS-009-0001-SO	0-1
CBPSS-010-0001-SO	0-1
CBPSS-011-0001-SO	0-1
CBPSS-012-0001-SO	0-1
CBPSS-013-0001-SO	0-1
CBPSS-014-0001-FD	0-1
CBPSS-014-0001-SO	0-1
CBPSS-015-0001-SO	0-1
CBPSS-016-0001-SO	0-1
CBPSS-017-0001-SO	0-1
CBPSS-018-0001-SO	0-1
CBPSS-019-0001-SO	0-1
CBPSS-020-0001-SO	0-1
CBPSS-021-0001-SO	0-1
CBPSS-022-0001-SO	4"
CBPSS-023-0001-FD	0-1
CBPSS-023-0001-SO	0-1
CBPSS-024-0001-SO	0-1
CBPSS-025-0001-SO	0-1
CBPSS-026-0001-SO	0-1
CBPSS-027-0001-SO	0-1
CBPSS-028-0001-SO	0-1
CBPSS-029-0001-FD	0-1
CBPSS-029-0001-SO	0-1
CBPSS-030-0001-SO	0-1
CBPSS-031-0001-SO	0-1
CBPSS-032-0001-FD	0-1
CBPSS-032-0001-SO	0-1
CBPSS-033-0001-SO	0-1
CBPSS-034-0001-SO	0-1
CBPSB-001-0001-SO	0-1
CBPSB-002-0001-SO	0-1
CBPSB-003-0001-SO	0-1
CBPSB-003A-0001-SO	0-1
CBPSB-003A-0001-FD	0-1
CBPSB-004-0001-SO	0-1
CBPSB-004-0001-FD	0-1

Table 6-1. Human Health Risk Assessment Dataset for Surface Soils (continued)

Sample ID	Depth bgs
CBPSB-005-0001-SO	0-1
CBPSB-006-0001-SO	0-1
CBPSB-007-0001-SO	0-1
CBPSB-008-0001-SO	0-1

Table 6-2. Human Health Risk Assessment Dataset for Subsurface Soils

Sample ID	Depth bgs
CBPSB-005-0002-SO	17-18
CBPSB-004-0002-SO	18-20
CBPSB-008-0002-SO	18-20
CBPSB-006-0002-SO	20-22
CBPSB-003A-0002-SO	21-23
CBPSB-002-0002-SO	22-24
CBPSB-007-0002-SO	22-24
CBPSB-001-0002-SO	28-30
CBPSS-001-0002-SO	1-3
CBPSS-003-0002-SO	1-3
CBPSS-004-0002-SO	1-3
CBPSS-005-0002-SO	1-3
CBPSS-007-0002-SO	1-3
CBPSS-008-0002-FD	1-3
CBPSS-008-0002-SO	1-3
CBPSS-009-0002-SO	1-3
CBPSS-010-0002-SO	1-3
CBPSS-011-0002-SO	1-3
CBPSS-012-0002-SO	1-3
CBPSS-014-0002-SO	1-3
CBPSS-015-0002-SO	1-3
CBPSS-017-0002-SO	1-3
CBPSS-018-0002-SO	1-3
CBPSS-019-0002-SO	1-3
CBPSS-020-0002-SO	1-3
CBPSS-021-0002-SO	1-3
CBPSS-023-0002-SO	1-3
CBPSS-024-0002-SO	1-3
CBPSS-025-0002-SO	1-3
CBPSS-026-0002-SO	1-3
CBPSS-027-0002-SO	1-3
CBPSS-028-0002-SO	1-3
CBPSS-029-0002-SO	1-3
CBPSS-030-0002-SO	1-3
CBPSS-031-0002-SO	1-3
CBPSS-032-0002-SO	1-3
CBPSS-033-0002-SO	1-3
CBPSS-034-0002-SO	1-3

1 **Table 6-3. Human Health Risk Assessment Dataset for Deep Surface Soils**

Sample ID	Depth bgs
CBPSS-001-0001-SO	0-1
CBPSS-002-0001-FD	0-1
CBPSS-002-0001-SO	0-1
CBPSS-003-0001-SO	0-1
CBPSS-004-0001-SO	0-1
CBPSS-005-0001-SO	0-1
CBPSS-006-0001-FD	0-1
CBPSS-006-0001-SO	0-1
CBPSS-007-0001-SO	0-1
CBPSS-008-0001-SO	0-1
CBPSS-009-0001-SO	0-1
CBPSS-010-0001-SO	0-1
CBPSS-011-0001-SO	0-1
CBPSS-012-0001-SO	0-1
CBPSS-013-0001-SO	0-1
CBPSS-014-0001-FD	0-1
CBPSS-014-0001-SO	0-1
CBPSS-015-0001-SO	0-1
CBPSS-016-0001-SO	0-1
CBPSS-017-0001-SO	0-1
CBPSS-018-0001-SO	0-1
CBPSS-019-0001-SO	0-1
CBPSS-020-0001-SO	0-1
CBPSS-021-0001-SO	0-1
CBPSS-022-0001-SO	4"
CBPSS-023-0001-FD	0-1
CBPSS-023-0001-SO	0-1
CBPSS-024-0001-SO	0-1
CBPSS-025-0001-SO	0-1
CBPSS-026-0001-SO	0-1
CBPSS-027-0001-SO	0-1
CBPSS-028-0001-SO	0-1
CBPSS-029-0001-FD	0-1
CBPSS-029-0001-SO	0-1
CBPSS-030-0001-SO	0-1
CBPSS-031-0001-SO	0-1
CBPSS-032-0001-FD	0-1
CBPSS-032-0001-SO	0-1
CBPSS-033-0001-SO	0-1
CBPSS-034-0001-SO	0-1
CBPSB-001-0001-SO	0-1
CBPSB-002-0001-SO	0-1
CBPSB-003-0001-SO	0-1
CBPSB-003A-0001-SO	0-1

Table 6-3. Human Health Risk Assessment Dataset for Deep Surface Soils (continued)

Sample ID	Depth bgs
CBPSB-003A-0001-FD	0-1
CBPSB-004-0001-SO	0-1
CBPSB-004-0001-FD	0-1
CBPSB-005-0001-SO	0-1
CBPSB-006-0001-SO	0-1
CBPSB-007-0001-SO	0-1
CBPSB-008-0001-SO	0-1
CBPSS-001-0002-SO	1-3
CBPSS-003-0002-SO	1-3
CBPSS-004-0002-SO	1-3
CBPSS-005-0002-SO	1-3
CBPSS-007-0002-SO	1-3
CBPSS-008-0002-FD	1-3
CBPSS-008-0002-SO	1-3
CBPSS-009-0002-SO	1-3
CBPSS-010-0002-SO	1-3
CBPSS-011-0002-SO	1-3
CBPSS-012-0002-SO	1-3
CBPSS-014-0002-SO	1-3
CBPSS-015-0002-SO	1-3
CBPSS-017-0002-SO	1-3
CBPSS-018-0002-SO	1-3
CBPSS-019-0002-SO	1-3
CBPSS-020-0002-SO	1-3
CBPSS-021-0002-SO	1-3
CBPSS-023-0002-SO	1-3
CBPSS-024-0002-SO	1-3
CBPSS-025-0002-SO	1-3
CBPSS-026-0002-SO	1-3
CBPSS-027-0002-SO	1-3
CBPSS-028-0002-SO	1-3
CBPSS-029-0002-SO	1-3
CBPSS-030-0002-SO	1-3
CBPSS-031-0002-SO	1-3
CBPSS-032-0002-SO	1-3
CBPSS-033-0002-SO	1-3
CBPSS-034-0002-SO	1-3

Table 6-4. Human Health Risk Assessment Dataset for Groundwater

CBPGW-001-0001-GW
CBPGW-002-0001-GW
CBPGW-003-0001-GW
CBPGW-004-0001-GW
CBPGW-005-0001-FD
CBPGW-005-0001-GW
CBPGW-006-0001-GW
CBPGW-007-0001-GW
CBPGW-008-0001-GW

Table 6-5. Human Health Risk Assessment Dataset for Surface Water

CBPSW-005-0001-SW
CBPSW-006-0001-SW
CBPSW-008-0001-FD
CBPSW-008-0001-SW

Table 6-6. Human Health Risk Assessment Dataset for Sediments

Sample ID	Depth bgs*
CBPSD-001-0001-SD	0-0.5
CBPSD-002-0001-SD	1
CBPSD-003-0001-SD	1
CBPSD-004-0001-SD	0-0.5
CBPSD-005-0001-SD	0-1
CBPSD-006-0001-SD	0-1
CBPSD-007-0001-SD	0-0.5
CBPSD-008-0001-FD	0-0.5
CBPSD-008-0001-SD	0-0.5
CBPSD-009-0001-SD	4"

Table 6-7. Summary of Quantitative and Qualitative COPCs for Environmental Media

Analyte	Surface Soil	Subsurface Soil	Deep Surface Soil	Groundwater	Surface Water	Sediment
Quantitative COPCs						
Inorganics						
Aluminum	X	X	X			X
Arsenic	X	X	X	X		X
Chromium	X	X	X			
Copper	X		X			
Lead	X		X			
Manganese	X	X	X			X
Vanadium	X		X			X
Organics						
Aroclor-1254	X		X			
Benzo(a)pyrene	X		X			
Qualitative COPCs						
Organics						
Nitrocellulose	X	X	X			X

COPC =Chemical of Potential Concern
Quantitative OCPCs are those COPCs for which risks and/or hazards have been calculated.
Qualitative COPCs are those COPCs for which risks and/or hazards have not been calculated, based on a lack of reliable toxicity data.

6.2.2.4 COPC Screening Assumptions

The following assumptions are made regarding the use of toxicity criteria surrogates and PRG surrogates for those SRCs lacking specific toxicity criteria or PRGs:

- The samples were analyzed for total chromium and results are evaluated conservatively by screening maximum detected concentrations against the USEPA Region IX PRGs for hexavalent chromium. This is a conservative assumption because hexavalent chromium is more toxic than trivalent chromium but is a less commonly occurring form of the metal.
- As specified in the White Paper for the CBP, detected concentrations of phenanthrene are screened against 1/10th the USEPA Region IX PRGs for pyrene.
- As specified in the White Paper for the CBP, detected concentrations of endosulfan I and endosulfan II are screened against 1/10th the USEPA Region IX PRGs for endosulfan.

6.2.3 COPCs for Central Burn Pits

Sections 6.2.3.1 through 6.2.3.6 identify the CBP COPCs in surface soil, subsurface soil, deep surface soil (i.e., the 0 to 4 foot interval), groundwater, surface water, and sediment, respectively. In overview, arsenic was determined to be a COPC in all media at the CBP except surface water. Carcinogenic PAH (cPAHs) (benzo[a]pyrene) and Aroclor-1254 were only determined to be COPCs in soils and/or sediment. No COPCs were identified for surface water.

6.2.3.1 Surface Soil

Twenty four inorganics, nine PAH compounds, eight pesticides/PCBs, and three explosives/propellants were detected in the surface soil samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-1; sampling locations are depicted in Figures 3-1 and

3-2. The results of the COPC selection for surface soils are summarized in Appendix S, Table 2.1. The following chemicals were identified as COPCs:

- Inorganics (aluminum, arsenic, chromium, copper, lead, manganese, and vanadium)
- Organics (benzo[a]pyrene, Aroclor-1254)
- Nitrocellulose

Five aluminum detections and three vanadium detections only exceed the RVAAP's background for surface soil. The maximum vanadium concentration in the surface soil (37 mg/kg) exceeds the background for surface soil (31.1 mg/kg). The maximum detected concentrations of aluminum, copper, and vanadium exceed the RBSCs (set at an HI equal to 0.1); however, they do not exceed the Region IX PRGs for soil. Arsenic was detected in nine samples at concentrations exceeding the RVAAP background for surface soil. However, the concentrations detected are within the literature background values (less than 0.1 to 97 mg/kg) reported in the USEPA Region IX PRG guidance document (USEPA, 2004c). Arsenic is a component of herbicides commonly used in the United States in the past and is, consequently, often detected at concentrations exceeding naturally occurring background concentrations. Lead only exceeded the screening level in one sample. Benzo(a)pyrene was selected as a COPC for surface soil and is likely associated with past operations at the CBP; however, the detected concentration (0.24 mg/kg) is similar to anthropogenic background concentrations reported in the literature. For example, the Agency for Toxic Substances Disease Registry (ATSDR) reports background benzo(a)pyrene concentrations of 0.002 to 1.3 mg/kg in rural soils and 0.0046 to 0.9 mg/kg in agricultural soils (ATSDR, 1995). Anthropogenic background considerations that potentially impact COPC selection for the CBP are further discussed in Section 6.7, Uncertainty Analysis.

Nitrocellulose was selected as a COPC only because a RBSC (Region IX PRG) is not available for this chemical. However, according to the USEPA Office of Drinking Water, nitrocellulose is essentially nontoxic (USEPA, 2004d). Nitrocellulose will be further discussed in the Uncertainty Section.

No chemicals were eliminated as COPCs for surface soil on the basis of the background screen only or frequency of detection.

6.2.3.2 Subsurface Soil

Twenty three inorganics and two explosives/propellants were detected in the subsurface soil samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-2; sampling locations are depicted in Figure 3-2. The results of the COPC selection for subsurface soils are summarized in Appendix S, Table 2.2. The following chemicals were identified as COPCs:

- Inorganics (aluminum, arsenic, chromium, and manganese)
- Nitrocellulose

Three aluminum detections, five arsenic detections, one chromium detection, and one manganese detection only exceed the RVAAP's background for subsurface soil. The maximum detected concentration of aluminum exceeds the RBSC (set at an HI equal to 0.1); however, does not exceed the Region IX PRGs for soil. As noted above, the arsenic concentrations detected are within the literature background values reported in the USEPA Region IX PRG guidance document (USEPA, 2004c) and arsenic is a component of herbicides commonly used in the United States in the past.

Nitrocellulose was selected as a COPC only because a RBSC (Region IX PRGs) is not available for this chemical. However, according to the U.S. EPA Office of Drinking Water, nitrocellulose is essentially nontoxic (USEPA, 2004d). Nitrocellulose will be further discussed in the Uncertainty Section.

Vanadium was the only chemical eliminated as a COPC for subsurface soil on the basis of the background screen only. Thallium, which was detected in only one of 37 samples, was the only chemical eliminated as a COPC on the basis of frequency of detection. The detected concentration of thallium exceeds the RBSC (set at an HI equal to 0.1); however, does not exceed the Region IX PRGs for soil. In addition, thallium was not detected in groundwater, surface water, or sediment samples.

6.2.3.3 Deep Surface (0 to 4 ft bgs) Soil

Twenty four inorganics, nine PAH compounds, eight pesticides/PCBs, and three explosives/propellants were detected in the deep surface (0 to 4 foot bgs) soil samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-3; sampling locations are depicted in Figures 3-1 and 3-2. The results of the COPC selection for deep surface soil are summarized in Appendix S, Table 2.3. The following chemicals were identified as COPCs:

- Inorganics (aluminum, arsenic, chromium, copper, lead, manganese, and vanadium)
- Organics (benzo[a]pyrene, Aroclor-1254)
- Nitrocellulose

The maximum detected concentrations of aluminum, copper, and vanadium exceed the RBSCs (set at an HI equal to 0.1); however, they do not exceed the Region IX PRGs for soil. Arsenic was detected in 12 of 72 samples at concentrations exceeding the RVAAP background for surface soil. However, as noted above, the concentrations detected are within the literature background values reported in the U.S. EPA Region IX PRG guidance document (USEPA, 2004c). Benzo(a)pyrene was selected as a COPC for deep surface soil and is likely associated with past operations at the CBP; however, the maximum concentration detected (0.24 mg/kg) is similar to anthropogenic background concentrations referenced in the preceding section. Aroclor-1254 was detected in three of 30 deep surface soil samples; however, only the maximum reported concentration (0.24 mg/kg) exceeds the RBSC (0.22 mg/kg).

Nitrocellulose was selected as a COPC only because a RBSC (Region IX PRG) is not available for these chemicals. However, as noted above, nitrocellulose is essentially nontoxic (USEPA, 2004d). Nitrocellulose will be further discussed in the Uncertainty Section.

No chemicals were eliminated as COPCs for deep surface soil on the basis of the background screen. Thallium, which was detected in only three of 73 samples, was the only chemical eliminated as a

COPC on the basis of frequency of detection. The detected concentration of thallium exceeds the RBSC (set at an HI equal to 0.1); however, does not exceed the Region IX PRGs for soil. In addition, thallium was not detected in groundwater, surface water, or sediment samples.

6.2.3.4 Groundwater

Sixteen inorganics and two VOCs were detected in the eight groundwater samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-4; sampling locations are depicted in Figure 3-3. The results of the COPC selection for groundwater are summarized in Appendix S, Table 2.4. Arsenic was the only chemical identified as a COPC in groundwater.

Seven arsenic detections exceed the RBSC; however, only two detected concentrations (35.1 µg/L and 19.9 µg/L) exceed the SDWA primary MCL (10 µg/L).

Manganese was the only chemical eliminated as a COPC for groundwater on the basis of the background screen only. The maximum detected concentration of manganese exceeds the RBSC (set at an HI equal to 0.1); however, does not exceed the Region IX PRGs for tap water. No chemicals were eliminated as COPCs on the basis of frequency of detection.

6.2.3.5 Surface Water

Ten inorganics were detected in the three surface water samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-5; sampling locations are depicted in Figure 3-4. The results of the COPC selection for surface water are summarized in Appendix S, Table 2.5. No chemical was identified as a COPC for surface water.

Arsenic and manganese were the only chemicals eliminated as COPCs on the basis of the background screen only. Two arsenic detections exceed the RBSC; however, both detected concentrations were less than the SDWA primary MCL (10 µg/L). The maximum detected concentration of manganese exceeds the RBSC (set at an HI equal to 0.1); however, does not exceed the Region IX PRGs for tap water. No chemicals were eliminated as COPCs on the basis of frequency of detection.

6.2.3.6 Sediment

Twenty three inorganics, two VOCs, eight PAH compounds, and nitrocellulose were detected in the sediment samples collected at the CBP. The samples evaluated in this BHHRA are listed in Table 6-6; sampling locations are depicted in Figure 3-5. The results of the COPC selection for sediments are summarized in Appendix S, Table 2.6. The following chemicals were identified as COPCs:

- Inorganics (aluminum, arsenic, manganese, and vanadium)
- Organics (benzo[a]pyrene)
- Nitrocellulose

Two aluminum detections, one arsenic detection, one manganese detection, and two vanadium detections only exceed the RVAAP's background for sediments. The maximum detected concentrations of aluminum and vanadium exceed the RBSCs (set at an HI equal to 0.1); however, they do not exceed the Region IX PRGs for soil. As noted above, the arsenic concentrations detected are within the literature background values reported for soils in the USEPA Region IX PRG guidance document (USEPA, 2004c) and arsenic is a component of herbicides commonly used in the United States in the past. Benzo(a)pyrene was selected as a COPC for sediments and is likely associated with past operations at the CBP; however, the maximum concentration detected (0.21 mg/kg) is similar to anthropogenic background concentrations referenced in the preceding section. Anthropogenic background considerations that potentially impact COPC selection for the CBP are further discussed in Section 6.7, Uncertainty Analysis.

Nitrocellulose was selected as a COPC only because a RBSC (Region IX PRG) is not available for this chemical. However, according to the USEPA Office of Drinking Water, nitrocellulose is essentially nontoxic (USEPA, 2004d). Nitrocellulose will be further discussed in the Uncertainty Section.

No chemicals were eliminated as COPCs for sediment on the basis of the background screen only or frequency of detection.

6.2.3.7 Summary of COPC Selection

The COPCs selected for the CBP are summarized in Table 6.7. Several COPCs were detected at maximum concentrations only slightly above background and may actually represent background conditions. The average concentrations and the 95 percent UCL on the mean are less than the background values for many inorganics in soil (surface soil, subsurface soil, and sediment).

6.3 EXPOSURE ASSESSMENT

The exposure assessment defines and evaluates the current and potential future exposures experienced by receptor populations. More specifically, an exposure assessment identifies the pathways by which humans are potentially exposed to COPCs, the magnitude of the potential human exposure, and the frequency and duration of exposure. This process involves several steps:

- Characterization of the exposure setting in terms of physical characteristics and the populations that may potentially be exposed to site-related chemicals.
- Identification of potential exposure pathways and receptors.
- Quantification of exposure for each receptor in terms of the amount of chemical that is ingested, inhaled, or absorbed through the skin from all potentially complete exposure pathways.

The output of the exposure assessment (an estimate of COPC intake) is used in conjunction with toxicity criteria (i.e., cancer slope factors and reference doses) identified in the toxicity assessment (Section 6.4) to quantify risks and hazards to receptors during risk characterization (Section 6.5).

6.3.1 Exposure Setting

The exposure setting was described in the RVAAP's FWHHRAM and the White Paper for CBP (Tetra Tech, 2004). Section 2.0 presents a description of the area surrounding RVAAP.

6.3.1.1 Land Use

The land use immediately surrounding the facility is primarily farmland with sparse private residences. Residential groundwater use occurs outside of the facility. Residential wells in the vicinity of the RVAAP are completed in both the unconsolidated unit and bedrock (SAIC 2001). The last of the process production wells on the facility were abandoned in 1992. Two groundwater production wells in the central portion of the facility remain in operation to provide sanitary water to the remaining site personnel. An additional production well is not in operation but could be activated in the future.

Land use within the facility is restricted access. In 1992, the land use changed from "inactive-maintained" status to "modified (unmaintained) caretaker" status (Department of the Army, Environmental Assessment, 1993). This new status indicated that the facility was no longer needed to mobilize for war efforts. The only remaining federally mandated mission for the facility was identified as ammunition and bulk explosives storage. Funding decreased for building maintenance and maintenance activities such as mowing (SAIC 2001).

The CBP, which lies within the east-central portion of the facility, are outside of any of the proposed ammunition storage areas. Site workers (security guard/maintenance workers) infrequently visit the CBP; no mowing takes place. On-site surface water consists of Sand Creek along the western edge and surface water drainage ditches. There are no groundwater/production wells located at the CBP. The topography is generally flat. There are no structures at the site.

The CBP (approximately 20 acres) was utilized primarily for the burning of non-explosive waste. The start date of activities is unknown but activities continued through the mid-1970s. Burn marks and debris (e.g., wiring, insulation, pieces of lead) are visible at the site.

Currently, the CBP is an inactive facility maintained by a contracted caretaker, MKM, Inc. Site workers infrequently visit the CBP for security purposes. However, the future goal at RVAAP is to be able to hunt (mainly deer), fish, and trap anywhere suitable habitat exists. The portion of Sand Creek at the CBP does not support fishing at this time. The creek is shallow except for a few riffle pools and flows through a ravine 15-30 ft deep.

National Guard training operations are very likely to occur in the CBP area in the future. The OHARNG proposed land-use for the CBP is "Dismounted Training – No Digging". Direct contact with soil, surface water, and sediments by the National Guardsman would be permitted for 24 days a year on inactive duty and 15 days a year during training.

Because the CBP are currently identified as an AOC (along with other considerations), the short-term future use of the CBP is expected to remain "institutional maintained." As noted above, the most plausible long-term use is a combination of OHARNG training use and controlled recreational use. Although other uses of the CBP area are unlikely, this BHHRA will also evaluate additional potential future land uses that reflect a more open use of the land, including residential farm use, and a more intensive use of the area by the National Guard (e.g., a National Guard resident-trainer). The trainer will be expected to have similar exposures as the trainee, but the days-per-year exposure frequency is anticipated to be greater because the trainer would be in charge of several groups of trainees. In summary, the land uses and receptors that will be evaluated as part of the BHHRA are listed below in Table 6-8.

Table 6-8. Potential Receptors for the CBP BHHRA

Land Use Designation	Description	Potential Receptors
Modified Caretaker Managed Recreational	Light maintenance Managed hunting/trapping	Security guard/maintenance worker Permitted visitor: hunter/trapper
National Guard Training Area Managed Recreational	Ohio National Guard training activities Managed hunting/trapping	National Guard trainee National Guard resident/trainer Permitted visitor: hunter/ trapper
Open Residential	Unrestricted residential housing and farming	On-site resident farmer

6.3.1.2 Receptors

The potential receptors listed for each land use scenario are further presented in Table 6-9.

6.3.2 Exposure Pathways

The exposure pathways for each receptor and environmental medium evaluated are also listed in Table 6-9 and reflect the protocol established in the RVAAP FWHHRAM and the White Paper developed for CBP. The exposure assumptions used to estimate COPC intake for each receptor are shown in Table 6-10. The current and likely future land use scenarios and receptors identified in Section 6.3.1.1 are discussed below. Release mechanisms and transport pathways are discussed in detail in Section 5.0 of this report.

Table 6-9. Receptors and Exposure Pathways for RVAAP Central Burn Pits

	Exposure Media					
Exposure Pathways	**Groundwater**	**Surface Water**	**Sediment**	**Surface Soil**[a]	**Deep Surface Soil**[b]	**Subsurface Soil**[c]
National Guard - Trainee						
Ingestion						
Incidental				X	--	--
Drinking water	X	--	--	--	--	--
Dermal	X	X	X	X	--	--
Inhalation						
Vapor	X[d]	--	X[d]	X[d]	--	--
Dust	--	--	X	X	--	--
Ingestion of food	--	--	--	--	--	--
National Guard - Trainer/Resident						
Ingestion						
Incidental	--	X	X	X	X	--
Drinking water	X	--	--	--	--	--
Dermal	X	X	X	X	X	--
Inhalation						
Vapor	X[d]	--	X[d]	X[d]	X[d]	--
Dust	--	--	X	X	X	--
Ingestion of food	--	--	--	--	--	--
Future Hypothetical Resident						
Ingestion						
Incidental	--	X	X	X	X	X
Drinking water	X	--	--	--	--	--
Dermal	X	X	X	X	X	X
Inhalation						
Vapor	X[d]	--	X[d]	X[d]	X[d]	X[d]
Dust	--	--	X	X	X	X
Ingestion of beef, milk, and vegetables	X	--	--	X	--	--
Ingestion of waterfowl and fish	--	--	--	--	--	--
Ingestion of venison	--	--	--	X	--	--
Recreators - Hunter/Trapper						
Ingestion						
Incidental	--	X	X	X	--	--
Drinking water	--	--	--	--	--	--
Dermal	--	X	X	X	--	--
Inhalation						
Vapor	--	--	X[d]	X[d]	--	--
Dust	--	--	X	X	--	--
Ingestion of waterfowl and fish	--	--	--	--	--	--
Ingestion of venison	--	--	--	X	--	--

Table 6-9. Receptors and Exposure Pathways for RVAAP Central Burn Pits (continued)

Exposure Pathways	**Exposure Media**					
	Groundwater	**Surface Water**	**Sediment**	**Surface Soil**[a]	**Deep Surface Soil**[b]	**Subsurface Soil**[c]
Security and Maintenance Personnel						
Ingestion						
Incidental	--	--	--	X	--	--
Drinking water	--	--	--	--	--	--
Dermal	--	--	--	X	--	--
Inhalation						
Vapor	--	--	--	X[d]	--	--
Dust	--	--	--	X	--	--
Ingestion of food	--	--	--	--	--	--

[a] Surface soil is defined as 0-1 ft bgs.

[b] Deep surface soil for the National Guard is defined as 0-3 ft bgs.

[c] Subsurface soil for the resident is defined as 1-30 feet bgs.

[d] VOCs only, if applicable.

Qualitative COPCs are those COPCs for which risks and/or hazards have not been calculated, based on a lack of reliable toxicity data.

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits

Parameter	Units	Security Guard/ Maintenance Worker	National Guard Trainee	National Guard Trainer/Resident	Hunter/ Trapper	Resident Farmer (child/adult)
Note: Resident farmer is chosen instead of resident because the property would be used for farming in the unlikely event it was released from military use. Further, the resident farmer is expected to result in greater, more conservative exposure intake when compared to the resident.						
Pathway						
Surface Soil is defined as 0-1 for all receptors except the National Guard Trainee, where it is 0 to 4 feet bgs due to nature of ground training activities.						
Incidental ingestion						
Soil ingestion rate (Adult)	kg/day	0.0001[a]	0.0001[a]	**0.0001[a]**	0.0001[a]	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	**NA**	NA	0.0002[a]
Exposure time	hours/day	1[b]	24[b]	**24[e]**	6	24[a]
Exposure frequency	days/year	250[a]	39[b]	**250[e]**	2	350[a]
Exposure duration (Adult)	years	25[a]	25[b]	**25[b]**	30[a]	30[a]
Exposure duration (Child)	years	NA	NA	**NA**	NA	6[a]
Body weight (Adult)	kg	70[a]	70[a]	**70[a]**	70[a]	70[a]
Body weight (Child)	kg	NA	NA	**NA**	NA	15[a]
Carcinogen averaging time	days	25550[a]	25550[a]	**25550[a]**	25550[a]	25550[a]
Noncarcinogen averaging time (Adult)	days	9125[a]	9125[a]	**9125[a]**	10950[a]	10950[a]
Noncarcinogen averaging time (Child)	days	NA	NA	**NA**	NA	2190[a]
Fraction ingested	unitless	1[b]	1[b]	**1[b]**	1[b]	1[a]
Conversion factor	days/hour	**0.0625[z]**	0.042	**0.042**	**0.0625[z]**	0.042
Dermal contact						
Skin area	m^2/event	0.33[d]	0.33[d]	**0.33[d]**	0.57[d]	0.22[h]/0.57[d]
Adherence factor	mg/cm^2	0.7[c]	0.3[c]	**0.3[c]**	0.3[c]	0.2[h] /0.4[c]
Absorption fraction	Unitless	Chem. Spec[p]	Chem. Spec[p]	**Chem. Spec[p]**	Chem. Spec[p]	Chem. Spec[p]
Exposure frequency	events/year	250[a]	39[b]	**250[e]**	2	350[a]
Exposure duration	years	25[a]	25[b]	**25[b]**	30[a]	6[a] /30[a]
Body weight	kg	70[a]	70[a]	**70[a]**	70[a]	15[a] /70[a]
Carcinogen averaging time	days	25550[a]	25550[a]	**25550[a]**	25550[a]	25550[a]
Noncarcinogen averaging time	days	9125[a]	9125[a]	**9125[a]**	10950[a]	2190[a] /10950[a]
Conversion factor	(kg-cm^2)/(mg-m^2)	0.01	0.01	**0.01**	0.01	0.01
Inhalation of VOCs and dust						
Inhalation rate	--	0.83[a]m^3/hr	44.4 m^3/day	**44.4 m^3/day**	1.47[r]m^3/hr	10[q] /20[a]m^3/day
Exposure time	hours/day	1[b]	24[b]	**24[e]**	6	24/24[a]
Exposure frequency	days/year	250[a]	39[b]	**250[e]**	2	350[a]
Exposure duration	years	25[a]	25[b]	**25[b]**	30[a]	6[a] /30[a]
Body weight	kg	70[a]	70[a]	**70[a]**	70[a]	15[a]/ 70[a]
Carcinogen averaging time	days	25550[a]	25550[a]	**25550[a]**	25550[a]	25550[a]
Noncarcinogen averaging time	days	9125[a]	9125[a]	**9125[a]**	10950[a]	2190[a]/ 10950[a]

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits (continued)

Parameter	**Units**	**Security Guard/ Maintenance Worker**	**National Guard Trainee**	**National Guard Trainer/Resident**	**Hunter/ Trapper**	**Resident Farmer (child/adult)**
Conversion factor	days/hour	**NA**	0.042	**0.042**	**NA**	0.042
Particulate Emission Factor	m^3/kg	9.24E+08[v]	1.67E+06[w]	**9.24E+08[v]**	9.24E+08[v]	9.24E+08[v]
SUBSURFACE SOIL for the National Guard Resident and Resident Farmer may be 1-30 feet bgs unless rock is encountered at a depth less than 30 ft.						
Incidental ingestion						
Soil ingestion rate (Adult)	kg/day	NA	NA	**0.0001[a]**	NA	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	**NA**	NA	0.0002[a]
Exposure time	hours/day	NA	NA	**24[e]**	NA	24
Exposure frequency	days/year	NA	NA	**250[e]**	NA	350[a]
Exposure duration (Adult)	years	NA	NA	**25[b]**	NA	30[a]
Exposure duration (Child)	years	NA	NA	**NA**	NA	6[a]
Body weight (Adult)	kg	NA	NA	**70[a]**	NA	70[a]
Body weight (Child)	kg	NA	NA	**NA**	NA	15[a]
Carcinogen averaging time	days	NA	NA	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	NA	**9125[a]**	NA	10950[a]
Noncarcinogen averaging time (Child)	days	NA	NA	**NA**	NA	2190[a]
Fraction ingested	unitless	NA	NA	**1[b]**	NA	1[a]
Conversion factor	days/hour	NA	NA	**0.042**	NA	0.042
Dermal contact						
Skin area	m^2/event	NA	NA	**0.33[d]**	NA	0.22[h] /0.57[d]
Adherence factor	mg/cm^2	NA	NA	**0.3[c]**	NA	0.2[h] /0.4[c]
Absorption fraction	unitless	NA	NA	**Chem. Spec[p]**	NA	chem. Spec[p]
Exposure frequency	events/year	NA	NA	**250[e]**	NA	350[a]
Exposure duration	years	NA	NA	**25[b]**	NA	6[a]/30[a]
Body weight	kg	NA	NA	**70[a]**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	NA	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	**9125[a]**	NA	2190[a] /10950[a]
Conversion factor	(kg-cm^2)/(mg-m^2)	NA	NA	**0.01**	NA	0.01
Inhalation of VOCs and dust						
Inhalation rate	--	NA	NA	**44.4 m^3/day**	NA	10[q] /20[a]m^3/day
Exposure time	hours/day	NA	NA	**24[e]**	NA	24[a]
Exposure frequency	days/year	NA	NA	**250[e]**	NA	350[a]
Exposure duration	years	NA	NA	**25[b]**	NA	6[a] /30[a]
Body weight	kg	NA	NA	**70[a]**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	NA	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	**9125[a]**	NA	2190[a] /10950[a]
Conversion factor	days/hour	NA	NA	**0.042**	NA	0.042

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits (continued)

Parameter	**Units**	**Security Guard/ Maintenance Worker**	**National Guard Trainee**	**National Guard Trainer/Resident**	**Hunter/ Trapper**	**Resident Farmer (child/adult)**
Particulate Emission Factor	m^3/kg	NA	NA	**9.24E+08**[v]	NA	9.24E+08[v]
SEDIMENT						
Incidental ingestion						
Soil ingestion rate (Adult)	kg/day	NA	0.0001[a]	**0.0001**[a]	0.0001[a]	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	**NA**	NA	0.0002[a]
Exposure time	hours/day	NA	24[b]	**24**[e]	6	24[a]
Exposure frequency	days/year	NA	39[b]	**250**[e]	2	**75**[b]
Exposure duration (Adult)	years	NA	25[b]	**25**[b]	30[a]	30[a]
Exposure duration (Child)	years	NA	NA	**NA**	NA	6[a]
Body weight (Adult)	kg	NA	70[a]	**70**[a]	70[a]	70[a]
Body weight (Child)	kg	NA	NA	**NA**	NA	15[a]
Carcinogen averaging time	days	NA	25550[a]	**25550**[a]	25550[a]	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	9125[a]	**9125**[a]	10950[a]	10950[a]
Noncarcinogen averaging time (Child)	days	NA	NA	**NA**	NA	2190[a]
Fraction ingested	unitless	NA	1[b]	**1**[b]	1[b]	1[a]
Conversion factor	days/hour	NA	0.042	**0.042**	**0.0625**[z]	0.042
Dermal contact						
Skin area	m^2/event	NA	0.33[d]	**0.33**[d]	0.52[d]	0.22[h] /0.57[d]
Adherence factor	mg/cm^2	NA	0.3[c]	**0.3**[c]	0.3[c]	0.2[h] /0.4[c]
Absorption fraction	unitless	NA	chem. Spec[p]	**chem. Spec**[p]	chem. Spec[p]	chem. Spec[p]
Exposure frequency	events/year	NA	39[b]	**250**[e]	2	**75**[b]
Exposure duration	years	NA	25[b]	**25**[b]	30[a]	6[a] /30[a]
Body weight	kg	NA	70[a]	**70**[a]	70[a]	15[a] /70[a]
Carcinogen averaging time	days	NA	25550[a]	**25550**[a]	25550[a]	25550[a]
Noncarcinogen averaging time	days	NA	9125[a]	**9125**[a]	10950[a]	2190[a] /10950[a]
Conversion factor	(kg-cm^2)/(mg-m^2)	NA	0.01	**0.01**	0.01	0.01
Inhalation of VOCs and dust						
Inhalation rate	--	NA	44.4 m^3/day	**44.4 m^3/day**	0.83[a]m^3/hr	10[q] /20[a]m^3/day
Exposure time	hours/day	NA	24[b]	**24**[e]	6	24[a]
Exposure frequency	days/year	NA	39[b]	**250**[e]	2	**75**[b]
Exposure duration	years	NA	25[b]	**25**[b]	30[a]	6[a] /30[a]
Body weight	kg	NA	70[a]	**70**[a]	70[a]	15[a] /70[a]
Carcinogen averaging time	days	NA	25550[a]	**25550**[a]	25550[a]	25550[a]
Noncarcinogen averaging time	days	NA	9125[a]	**9125**[a]	10950[a]	2190[a] /10950[a]
Conversion factor	days/hour	NA	0.042	**0.042**	**0.0625**[z]	0.042
Particulate Emission Factor	m^3/kg	NA	1.67E+06[w]	**9.24E+08**[v]	9.24E+08[v]	9.24E+08[v]

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits (continued)

Parameter	Units	Security Guard/ Maintenance Worker	National Guard Trainee	National Guard Trainer/Resident	Hunter/ Trapper	Resident Farmer (child/adult)
GROUNDWATER						
Drinking Water Ingestion						
Drinking water ingestion rate	L/day	NA	2[a]	**2[a]**	NA	1.5[h] /2[a]
Exposure frequency	days/year	NA	39[b]	**250[e]**	NA	350[a]
Exposure duration	years	NA	25[b]	**25[b]**	NA	6[a] /30[a]
Body weight	kg	NA	70[a]	**70[a]**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	25550[a]	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time	days	NA	9125[a]	**9125[a]**	NA	2190[a] /10950[a]
Dermal contact while showering						
Skin area	m^2	NA	1.94[g]	**1.94[g]**	NA	0.866[s] /1.94[g]
Exposure time	hours/day	NA	0.25[a]	**0.25[a]**	NA	0.25[a]
Exposure frequency	days/year	NA	39[b]	**250[e]**	NA	350[a]
Exposure duration	years	NA	25[b]	**25[b]**	NA	6[a] /30[a]
Body weight	kg	NA	70[a]	**70[a]**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	25550[a]	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time	days	NA	9125[a]	**9125[a]**	NA	2190[a] /10950[a]
Conversion factor	(m/cm)(L/m^3)	NA	10	**10**	NA	10
Inhalation of VOCs during household water use (Only if applicable)						
Inhalation rate	--	NA	0.83[a]m^3/hr	**0.83[a]m^3/hr**	NA	10[q] /20[a]
Exposure time	hours/day	NA	24	**24**	NA	24
Exposure frequency	days/year	NA	39[b]	**250[e]**	NA	350[a]
Exposure duration	years	NA	25[b]	**25[b]**	NA	6[a] /30[a]
Body weight	kg	NA	70[a]	**70[a]**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	25550[a]	**25550[a]**	NA	25550[a]
Noncarcinogen averaging time	days	NA	9125[a]	**9125[a]**	NA	2190[a] /10950[a]
Volatilization factor	L/m^3	NA	0.5[a]	**0.5[a]**	NA	0.5[a]
FOODSTUFFS						
Ingestion of venison						
Conversion factor	unitless	NA	NA	**NA**	**1.25**	1.25
Browse ingestion rate	kg dry weight/day	NA	NA	**NA**	**0.87[b]**	0.87[b]
Fraction browse ingested from site	unitless	NA	NA	**NA**	**0.15**	**0.15**
Fat ratio (venison to beef)	unitless	NA	NA	**NA**	**0.2**	0.2
Venison ingestion rate	kg/day	NA	NA	**NA**	**0.03[b]**	0.03[b]
Fraction ingested	unitless	NA	NA	**NA**	**1[b]**	1[b]
Exposure frequency	days/year	NA	NA	**NA**	**365[b]**	365[b]
Exposure duration	years	NA	NA	**NA**	**30[a]**	6[a] /30[a]
Body weight	kg	NA	NA	**NA**	**70[a]**	15[a] /70[a]
Carcinogen averaging time	days	NA	NA	**NA**	**25550[a]**	25550[a]

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits (continued)

Parameter	**Units**	**Security Guard/ Maintenance Worker**	**National Guard Trainee**	**National Guard Trainer/Resident**	**Hunter/ Trapper**	**Resident Farmer (child/adult)**
Noncarcinogen averaging time	days	NA	NA	**NA**	**10950**[a]	2190[a] /10950[a]
Ingestion of beef						
Resuspension multiplier	unitless	NA	NA	**NA**	NA	0.25[i]
Quantity of pasture ingested	kg dry weight/day	NA	NA	**NA**	NA	7.2[j]
Fraction of year cow is on-site	unitless	NA	NA	**NA**	NA	**1**
Fraction of cow's food from on-site	unitless	NA	NA	**NA**	NA	0.9[b]
Quantity of soil ingested by cow	kg/day	NA	NA	**NA**	NA	1[k]
Beef ingestion rate	kg/day	NA	NA	**NA**	NA	0.0094/0.044[l]
Fraction ingested	unitless	NA	NA	**NA**	NA	1[b]
Exposure frequency	days/year	NA	NA	**NA**	NA	365[b]
Exposure duration	years	NA	NA	**NA**	NA	6[a] /30[a]
Body weight	kg	NA	NA	**NA**	NA	15[a] /70[a]
Carcinogen averaging time	days	NA	NA	**NA**	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	**NA**	NA	2190[a] /10950[a]
Ingestion of milk products						
Resuspension multiplier	unitless	NA	NA	**NA**	NA	0.25[i]
Quantity of pasture ingested	kg dry weight/day	NA	NA	**NA**	NA	16.1[j]
Fraction of year cow is on-site	unitless	NA	NA	**NA**	NA	1[b]
Fraction of cow's food from on-site	unitless	NA	NA	**NA**	NA	0.6[b]
Quantity of soil ingested by cow	kg/day	NA	NA	**NA**	NA	1[k]
Milk ingestion rate (Adult)	kg/day	NA	NA	**NA**	NA	0.305[l]
Milk ingestion rate (Child)	kg/day	NA	NA	**NA**	NA	0.509[m]
Fraction ingested	unitless	NA	NA	**NA**	NA	1[b]
Exposure frequency	days/year	NA	NA	**NA**	NA	365[b]
Exposure duration (Adult)	years	NA	NA	**NA**	NA	30[a]
Exposure duration (Child)	years	NA	NA	**NA**	NA	6[a]
Body weight (Adult)	kg	NA	NA	**NA**	NA	70[a]
Body weight (Child)	kg	NA	NA	**NA**	NA	15[a]
Carcinogen averaging time	days	NA	NA	**NA**	NA	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	NA	**NA**	NA	10950[a]
Noncarcinogen averaging time (Child)	days	NA	NA	**NA**	NA	2190[a]
Ingestion of vegetables						
Resuspension multiplier	unitless	NA	NA	**NA**	NA	0.26[n]
Vegetable ingestion rate	kg/day	NA	NA	**NA**	NA	0.043/0.2[l]
Fraction ingested	unitless	NA	NA	**NA**	NA	0.4[l]
Exposure frequency	days/year	NA	NA	**NA**	NA	365[a]
Exposure duration	years	NA	NA	**NA**	NA	6[a] /30[a]

Table 6-10. Exposure Assumptions for RVAAP Central Burn Pits (continued)

Parameter	Units	Security Guard/ Maintenance Worker	National Guard Trainee	National Guard Trainer/Resident	Hunter/ Trapper	Resident Farmer (child/adult)
Body weight	kg	NA	NA	**NA**	NA	15^a /70^a
Carcinogen averaging time	days	NA	NA	**NA**	NA	25550^a
Noncarcinogen averaging time	days	NA	NA	**NA**	NA	2190^a /10950^a

Bold indicates values that differ than those presented in the Facility Wide Human Health Risk Assessors Manual.

NA = not applicable for this scenario.

a RAGS, Part B (EPA 1991a).

b Site-specific (value assumed for site or value obtained from site personnel). National Guard Trainee is assumed to be on –site 24 hrs/d for 24 d/yr for inactive duty training and 24 hrs/d for 15 d/yr for annual training. Both National Guard receptors are assumed to remain at RVAAP and at the AOC of interest for their entire 25 year enlistment. The Hunter is assumed to be on-site 6 hours/day for 2 days/year. The trapper will be exposed less (i.e., 0.5 hours/day for 6 days/year); therefore, the hunter exposure is used as the more conservative scenario. No fishing takes place at Load Line 11. The hunter is assumed to hunt as long as he/she resides in the area, so the residential default exposure duration is used. The Security Guard/Maintenance Worker is assumed to visit each AOC for 1 hour/day for a standard worker default of 250 days/yr and 25 years.

National Guard Trainee, National Guard Resident, and Resident Farmer are assumed to ingest 0.05 L/hour [per RAGS Part A (EPA 1998)] for approximately 2 hours/day spent in the surface water. Hunter/trappers are assumed to ingest 0.05 L/day due to splashing while setting traps.

c Security Guard/Maintenance Worker = Adult Groundskeeper (95th percentile); Hunter/Trapper = Residential Default; National Guard Trainee = Construction Worker (95th percentile); Resident Farmer Adult= Adult Farmer (95th percentile) (RAGS, Vol. 1 Part E, Supplemental Guidance for Dermal Risk Assessment, Interim) EPA/540/R/99/005.

d Security Guard/Maintenance Worker, National Guard Trainee = Industrial Default; Hunter/Trapper and Resident Farmer = Adult Residential Default. Exposure Factors Handbook (EPA 1997a) (Note dermal contact for Hunter/trapper during wading is 0.52 based on head, hands, forearms and lower legs from Exposure Factors Handbook.)

f RAGS, Part A (EPA 1989a).

g Average total body surface area for an adult (EPA 1992b).

h Per Ohio EPA comment 2002.

i Plant mass loading factor for pasture (Hinton 1992).

j International Atomic Energy agency 1994.

k Soil ingestion by dairy cattle (Darwin 1990).

l Exposure Factors Handbook (EPA 1997). 50th percentile beef ingestion 0.626 g/kg-day = 44 g/day for a 70 kg adult and 9.4 for a 15 kg child. 50th pecentile vegetable ingestion rate = 2.86 g/kg/day = 200 g/day for a 70 kg adult and 43 g/day for a 15 kg child. Ingestion rates for the total population and not any age-specific group.

m Pao et al. (1982).

n Plant mass loading factor for vegetables (Pinder 1989).

p Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment, Interim), EPA/540/R/99/005.

q Recommended value for child age 6-8 (EPA 1997a).

r The inhalation rate for hunter/trapper is based on an adult engaged in light activities 4 hours/day, moderate activities 1 hour/day, and heavy activities 1 hour/day.

s 50th percentile value for male child age 6-7 (EPA 1997a).

u Ecological Risk Assessment. Ohio EPA/DERR. February 2003

w Based on a dust loading factor of 600 ug/m^3 (DOE, 1993).

x A site specific value will be developed following methodology in EPA's Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, December 2002, OSWER 9355.4-24.

y Based on a 16 hour day.

6.3.2.1 Modified Caretaker – Managed Recreational

This land use scenario describes the current land use at the CBP. Receptor/exposure activities under the current land use scenario are expected to be as described in the FWHHRAM and the White Paper for CBP (Tetra Tech, 2004). Consequently, the exposure assumptions presented in Table 6-9 for the current land use scenario are those suggested in those reports. The evaluation of the following authorized receptors provides "reasonable worst case" risk estimates that may be used to make risk management decisions assuming that no land use changes occur at the CBP.

6.3.2.2 Security Guard – Maintenance Worker

Current activities at the CBP include occasional security patrols. Consequently, a security guard or maintenance worker may contact environmental media (i.e., surface soil) at the CBP. However, the contact is likely to be limited because maintenance activities are not routinely scheduled for the CBP and the individual performing a security patrol is not likely to intentionally contact environmental media on a regular basis. Use of the shallow aquifer for a potable water supply and contact with subsurface soil, surface water, and sediment were not considered likely. Exposure parameter values used to assess this receptor in the BHHRA are found in Table 6-9.

6.3.2.3 Hunter/Trapper

Information regarding hunting, trapping, and fishing activities at RVAAP is summarized in the FWHHRAM and from communication with base personnel. A future goal for the RVAAP is to be able to hunt, fish, and trap anywhere suitable habitat exists. According to the RVAAP FWHHRAM, a hunter is assumed to be within any particular RVAAP area for only a couple of days per year (e.g., 6 hours/day for 2 days/year). The trapper is assumed to be exposed less intensely (i.e., 0.5 hours/day for 6 days/year); therefore, the hunter exposure is used as the more conservative scenario. The fisherman is assumed to be within a particular area at RVAAP no more than 8 hours/day for 10 days/year. The hunter/fisherman is assumed to hunt/fish as long as he/she resides in the area, so the residential default exposure duration (30 years) is used. A hunter/trapper operating in the vicinity of the CBP may be exposed to COPCs in surface soil, surface water, and sediments as well as through the ingestion of deer meat. Exposure parameter values used to assess the hunter/trapper receptor are found in Table 6-9.

Note that Sand Creek as it flows through the CBP is not amenable to fishing. Also, waterfowl hunting is not likely at the CBP (i.e., the surface water resource at the CBP is minimal).

6.3.2.4 National Guard – Managed Recreational

Three receptors are expected under the National Guard – Managed Recreational land use scenario. In addition to the hunter/trapper discussed under the Modified Caretaker-Managed Recreational land-use scenario (Section 6.3.2.1), a National Guard training participant and a National Guard resident/trainer are possible. Although National Guard units typically participate in training two weeks a year with some weekend training, instructors and other National Guard personnel managing the training activities could be expected to be on-site more frequently. The National Guard trainee is assumed to be on–site 24 hrs/day for 24 days/year for inactive duty training and 24 hrs/day for 15 days/year for annual training, for a total of 39 days/year. The National Guard trainer (or resident) is assumed to reside on-site during the week (i.e., 24 hours/day, 5 days/week, 50 weeks/year) and go home on weekends for a total of 250 days/year. Both National Guard receptors are assumed to remain at RVAAP and at the AOC of interest for their entire 25 year enlistment. It should be noted that the National Guard trainer/resident receptor is not included in the RVAAP FWHHRAM. Given the anticipated future land use for the CBP, the ***National Guard trainee is the critical receptor for the CBP***. The National Guard trainer/resident was included in the White Paper for CBP, and in this BHHRA after discussions with both the USACE and the Ohio EPA because risk estimates for this receptor may assist the risk managers for RVAAP when making certain risk management decisions (e.g., deed restriction decisions).

The National Guard receptors may be exposed to COPCs in surface soil, subsurface soil, sediment, and surface water during various training activities such as those detailed in the FWHHRAM. Due to nature of ground training activities surface soil is defined as 0 - 4 ft bgs (i.e., deep surface soil) for the National Guard trainee. It is unlikely that National Guard personnel would utilize the groundwater underlying the CBP as a potable water resource; however, this BHHRA will evaluate risks incurred by the National Guard receptors assuming that this scenario is possible. Exposure parameter values used in this BHHRA to evaluate the National Guard receptors are found in Table 6-9.

6.3.2.5 Open Residential

This potential scenario was evaluated to provide risk information assuming a future residential land use of the CBP area. Conservatively, a resident-farmer adult and child are the receptors of concern. However, based on current and anticipated future land use information, it is unlikely that the CBP area will be used for residential purposes. The scenario is included principally for purposes of completeness and to provide information to risk managers regarding the need for institutional land use controls.

The adult resident farmer may come into direct contact with COPCs in all media and may also be exposed via indirect exposure pathways (i.e., ingestion of venison, beef, milk, and vegetables). Exposure parameters used to represent receptor activities patterns are listed in Table 6-9 and generally come from the FWHHRAM, with exceptions as outlined in the White Paper for CBP (Tetra Tech 2004).

6.3.3 Exposure Quantification

Intake or dose is defined as the amount of COPC that could be in contact with the body per unit body weight per unit time. For the CBP BHHRA, the surface soil, subsurface soil, sediment, surface water, and groundwater ingestion, dermal, and inhalation intakes for each receptor as well as for the ingestion of homegrown vegetables, milk, meat, and venison were calculated using standard intake equations from USEPA guidance (e.g., USEPA, 1989) which are presented in the FWHHRAM with exceptions as outlined in the White Paper for CBP (Tetra Tech 2004).

The standard tables published in the USEPA RAGS Part D are used to present the exposure assumptions, intake equations, dose estimates, toxicity criteria (i.e., cancer slope factors, reference doses), and cancer and noncancer risk estimates for receptors evaluated in this BHHRA. These tables also include references for exposure assumptions. The RAGS Part D tables and example calculations for each receptor and exposure pathway are presented in Appendix S.

6.3.3.1 Exposure to Surface Soil

Tables 4.1, 4.2, 4.5, 4.9, 4.12, and 4.20 in Appendix S provide the dose equations used to estimate chemical intake for security guard/maintenance workers, National Guard trainee, National Guard trainer/resident, hunter/trappers, child resident farmers, and adult resident farmers hypothetically exposed to COPCs in surface soil, respectively. Where available, the exposure assumptions used to calculate COPC intake were those suggested by standard U.S. EPA guidance documents and given in the FWHHRAM. Exposure assumptions for the National Guard trainer/resident were presented in the White Paper for CBP (Tetra Tech 2004). Professional judgment was used to select the exposure parameter values in some cases. For example, it was assumed that the conversion factor for ingestion of soils/sediments should be 0.0625 days/hour (not 0.042 days/hour) for receptors that are not onsite for 24 hours a day: the security guard/maintenance workers and the hunter/trapper. The change was made to reflect the fact that the receptors are typically not exposed to soils/dusts while they are sleeping; the suggested parameter is more conservative than the value given in the FWHHRAM.

Intake values for security guard/maintenance workers, National Guard trainee, National Guard trainer/resident, hunter/trappers, child resident farmers, and adult resident farmers exposure to the CBP surface soil noncarcinogens and carcinogens are provided in Appendix S, Tables 7.1, 7.2, 7.3, 7.4, 7.5, and 7.6 respectively.

6.3.3.2 Exposure to Subsurface Soil

Two receptors, the National Guard trainer/resident and the resident farmer are assumed to be exposed to both surface soil and subsurface soil. The National Guard trainer/resident may be exposed to shallow subsurface soil (aka deep surface soil) during certain training activities. Although unlikely, this BHHRA was prepared assuming that the future resident farmer may also come in contact with subsurface soils excavated and spread across the surface of the site. This scenario is included primarily for purposes of completeness.

Tables 4.7, 4.14, and 4.22 in Appendix S provide the dose equations used to estimate chemical intake for the National Guard trainer/resident, child resident farmers, and adult resident farmers, respectively, exposed to COPCs in subsurface soil. Where available, the exposure assumptions used in the equations were those suggested by standard U.S. EPA guidance documents and given in the FWHHRAM. Exposure assumptions for the National Guard trainer/resident are not in the FWHHRAM but were presented in the White Paper for CBP (Tetra Tech 2004).

Intake values for National Guard trainer/resident, child resident farmers, and adult resident farmer’s exposure to the CBP subsurface soil noncarcinogens and carcinogens are provided in Appendix S, Tables 7.3, 7.5, and 7.6, respectively.

6.3.3.3 Exposure to Surface Soil, Subsurface Soil, and Sediment

When exposure to both surface and subsurface soil is anticipated, total receptor risk estimates are calculated separately for receptor exposure to surface and subsurface soil to avoid an overestimation of risk (i.e., risk estimates for COPCs in surface soil will not be added to risk estimates developed for COPCs in subsurface soil).

6.3.3.4 Exposure to Groundwater

Tables 4.4, 4.8, 4.15, and 4.23 in Appendix S provide the dose equations used to estimate chemical intake for National Guard trainees, National Guard trainer/residents, child resident farmers, and adult resident farmers, respectively, hypothetically exposed to COPCs in groundwater. Where available, the exposure assumptions used in the equations were those suggested by standard U.S. EPA guidance documents and given in the FWHHRAM. Exposure assumptions for the National Guard trainer/resident are presented in the White Paper for CBP (Tetra Tech 2004).

Intake values for National Guard trainees, National Guard trainer/residents, child resident farmers, and adult resident farmer’s exposure to the CBP groundwater noncarcinogens and carcinogens are provided in Appendix S, Tables 7.2, 7.3, 7.5, and 7.6, respectively.

6.3.3.5 Exposure to Sediment

Tables 4.3, 4.6, 4.10, 4.13, and 4.21 in Appendix S provide the dose equations used to estimate chemical intake for National Guard trainees, National Guard trainer/resident, hunter/trappers, child resident farmers, and adult resident farmers, respectively, exposed to COPCs in sediments. Where available, the exposure assumptions used in the equations were those suggested by standard U.S. EPA guidance documents and given in the FWHHRAM. Exposure assumptions for the National Guard trainer/resident are presented in the White Paper for CBP (Tetra Tech 2004). However, professional judgment was used to select exposure parameter values in some cases.

Intake values for National Guard trainees, National Guard trainer/resident, hunter/trappers, child resident farmers, and adult resident farmers, exposure to the CBP sediment noncarcinogens and carcinogens are provided in Appendix S, Tables 7.2, 7.3, 7.4, 7.5, and 7.6, respectively.

6.3.3.6 Exposure to Venison

Tables 4.11, 4.16, and 4.24 in Appendix S provide the dose equations used to estimate chemical intake for venison consumption by hunter/trappers, the child resident farmers, and adult resident farmers, respectively. Where available, the exposure assumptions used in the equations were those suggested by the FWHHRAM. No exposure assumptions were given in the FWHHRAM for the hunter/trapper; therefore, values were recommended in the White Paper for CBP. Site-specific information for the CBP was used to determine an exposure parameter as outlined in the FWHHRAM. For example, the fraction of the animals food from the site was adjusted to 0.15 to reflect the size of the site (approximately 27 ha) compared to the home range of a white tailed deer (175 ha) (USEPA 1993).

Intake values for hunter/trappers, the child resident farmers, and adult resident farmer's exposure to the CBP noncarcinogens and carcinogens in venison are provided in Appendix S, Tables S.7.4, S.7.5, and S.7.6, respectively.

6.3.3.7 Exposure to Beef

Tables 4.17 and 4.25 in Appendix S provide the dose equations used to estimate chemical intake for beef consumption by child resident farmers and adult resident farmers, respectively. The exposure assumptions used in the equations were those suggested by the FWHHRAM. Site-specific information for the CBP was used to determine an exposure parameter as outlined in the FWHHRAM. For example, the fraction of the year the animals are on site was presumed to be 1.0.

As explained in the White Paper for CBP, the FWHHRAM recommends that COPC concentrations in beef products consider contaminant uptake as a result of the animal ingesting contaminated ground or surface water. The contribution from this pathway is considered minor for the CBP and was not considered in the BHHRA. Note the water ingestion contribution is shown in the intake equation given in the FWHHRAM but no exposure parameter is given in Table 5 of the FWHHRAM.

Intake values for child resident farmers and adult resident farmer's exposure to the CBP noncarcinogens and carcinogens in beef are provided in Appendix S, Table 7.5 and 7.6.

6.3.3.8 Exposure to Milk

Tables 4.18 and 4.26 in Appendix S provide the dose equations used to estimate chemical intake for milk consumption by child resident farmers and adult resident farmers, respectively. The exposure assumptions used in the equations were those suggested by the FWHHRAM. However, as explained in the White Paper for CBP, the FWHHRAM recommends that COPC concentrations in milk products consider contaminant uptake as a result of the animal ingesting contaminated ground or surface water. The contribution from this pathway is considered minor and was not considered in the BHHRA. Note the water ingestion contribution is shown in the intake equation given in the FWHHRAM but no exposure parameter is given in Table 5 of the FWHHRAM.

Intake values for child resident farmers and adult resident farmer's exposure to the CBP noncarcinogens and carcinogens in milk are provided in Appendix S, Tables 7.5 and 7.6, respectively.

6.3.3.9 Exposure to Vegetables

Tables 4.19 and 4.27 in Appendix S provide the dose equations used to estimate chemical intake for vegetable consumption by child resident farmers and adult resident farmers. Where available, the exposure assumptions used in the equations were those suggested in the FWHHRAM.

Intake values for child resident farmers and adult resident farmer's exposure to the CBP noncarcinogens and carcinogens in vegetables are provided in Appendix S, Tables 7.5 and 7.6.

6.3.4 Exposure Point Concentrations

The EPC is the concentration of a COPC used to best estimate the intake of a COPC detected in an environmental media. Ideally the EPC should be the true average concentration within the exposure unit for the media. However, because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent UCL of the arithmetic mean is selected as the EPC. The following protocol was used to determine EPCs in the BHHRA for the CBP:

- If there were less than 10 samples or fewer than 50 percent positive detections, the maximum concentration was chosen as the EPC because the UCL does not provide a good estimation of the upper bound of the mean concentration for small data sets or for data sets that contain a large number of non-detected values.
- If there were more than 10 samples and greater than 50 percent detections, each data set was evaluated using the Shapiro-Wilk W test (Gilbert 1987) to determine if the dataset more closely reflected a normal or lognormal distribution. If results were inconclusive, the data were assumed to be lognormally distributed. The 95 UCL-L and 95 UCL-N were calculated for each analyte in each medium and data set using one-half the reporting limit for non-detect results and the average for samples with duplicates. Example calculations are found in Appendix S. The UCL-N was used as the EPC if the Shapiro-Wilk W test indicated a normal distribution, and the UCL-L was used as the EPC if the Shapiro-Wilk W test indicated a lognormal distribution or if the distribution was undefined. If the calculated 95 UCL exceeded the maximum detected concentration, the maximum detected concentration was selected as the EPC.

EPCs were calculated for analytes in surface soil (0-1 ft bgs), deep surface soil (0-4 ft bgs), subsurface soil, groundwater, and sediment samples located in the CBP. These EPCs are presented in Appendix S (RAGS Part D, Table 3s).

Route-specific EPCs were also calculated for the inhalation of particulates/vapors migrating from soil and sediment to air, the inhalation of VOCs volatilizing from groundwater, and for consumption of foodstuffs. The methodology used for calculation of the route-specific EPCs is presented in Appendix S, Tables 4.1 through 4.27.

6.4 TOXICITY ASSESSMENT

The toxicity assessment for the COPCs examines information concerning the potential human health effects of exposure to COPCs. For each COPC, the goal of the toxicity assessment is to provide a quantitative estimate of the relationship between the magnitude and type of exposure and the severity or probability of human health effects. The toxicity values presented in this section are integrated with the exposure assessment (Section 6.3) to characterize the potential for the occurrence of adverse health effects.

6.4.1 Toxicity Information and EPA Guidance for Noncarcinogens

For noncarcinogens, it is assumed that a dose exists below which no adverse health effects will be seen. Below this "threshold" dose, exposure to a chemical can be tolerated without adverse effects. The potential for noncarcinogenic health effects resulting from exposure to chemicals is assessed by comparing the intake dose with this "threshold" dose, or reference dose (RfD). The RfD is determined using available dose-response data for individual chemicals. Uncertainty factors are applied to the highest no-observed-adverse-effect level (NOAEL) to adjust for inter- and intraspecies variation, deficiencies in the toxicological database, and use of subchronic rather than chronic animal studies. Additional uncertainty factors may be applied to estimate a NOAEL from a lowest-observed-adverse-effect level (LOAEL) if the key study failed to determine a NOAEL. When chemical-specific data are not sufficient, an RfD may be derived from data for a chemical with structural and toxicologic similarity.

The RfD is expressed in units of mg/kg/day and represents a daily intake of contaminant per kilogram of body weight that is not sufficient to cause the threshold effect of concern. An RfD is specific to the chemical, the route of exposure, and the duration over which the exposure occurs. Separate RfDs are presented for ingestion and inhalation pathways. In particular, Reference Concentrations (RfCs) in units of [mg/m^3] are typically presented for the inhalation pathway. Because characterization of noncarcinogenic effects requires an estimate of dose in units of mg/kg/day, the inhalation RfC must be converted to an inhalation RfD. The conversion is performed by assuming that humans weigh 70 kg and inhale 20 m^3 of air per day (i.e., the inhalation RfC (mg/m^3) is multiplied by 20 m^3/day and divided by 70 kg to yield an inhalation RfD with units of [mg/kg-day]) (USEPA, 1995a). The RfDs used to evaluate the COPCs at the CBP are presented in Appendix S, Table 5.1. The toxicity values were selected using the hierarchy from the FWHHRAM:

- Tier 1- USEPA's IRIS (Integrated Risk Information System)
- Tier 2- USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) – The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis when requested by U.S. EPA's Superfund program.
- Tier 3- Other Toxicity Values – Tier 3 includes additional USEPA and non-USEPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

6.4.2 Toxicity Information and EPA Guidance for Carcinogens

The toxicity information considered in the assessment of potential carcinogenic risks includes a weight-of-evidence classification and a slope factor. The weight-of-evidence classification qualitatively describes the likelihood that a chemical is a human carcinogen and is based on an evaluation of the available data from human and animal studies. Historically, a chemical was placed in one of three groups in U.S. EPA's classification system to denote its potential for carcinogenic effects:

- Group A - known human carcinogen
- Group B1 or B2 - probable human carcinogen
- Group C - possible human carcinogen

Chemicals that cannot be classified as human carcinogens because of a lack of data are placed in Group D, and those for which there is evidence of noncarcinogenicity in humans are in Group E. More recently, the USEPA is evaluating the use of the following categories to describe the carcinogenic potential of a chemical:

- Carcinogenic to humans
- Likely to be carcinogenic to humans
- Suggestive evidence of carcinogenic potential
- Inadequate information to assess carcinogenic potential
- Not likely to be carcinogenic to humans

For carcinogens, risks are estimated as the probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. The cancer slope factor (CSF) is the toxicity value used to quantitatively express the carcinogenic hazard of cancer-causing chemicals. It is defined as the upper-bound estimate of the probability of cancer incidence per unit dose averaged over a lifetime. Slope factors are specific to a chemical and route of exposure and are expressed in units of $[\text{mg/kg-day}]^{-1}$ for both oral and inhalation routes. Inhalation cancer toxicity values are usually expressed as inhalation unit risks in units of reciprocal $\mu g/m^3$ $[1/(\mu g/m^3)]$. The inhalation unit risk must be converted to an inhalation slope factor. This is done by assuming that humans weigh 70 kg and inhale 20 m^3 of air per day (i.e., the inhalation unit risk $(1/\mu g/m^3)$ is divided by 20 m^3/day, multiplied by 70 kg, and multiplied by 1,000 µg/mg to yield the mathematical equivalent of an inhalation slope factor $[\text{mg/kg-day}]^{-1}$) (USEPA, 1995a). CSFs used to evaluate the COPCs at the CBP are presented in Appendix S in Table 6.1 and were selected as described for the RfDs.

6.4.3 Estimation of Toxicity Values for Dermal Exposure

Dermal RfDs and dermal CSFs are derived from the corresponding oral values. In the derivation of a dermal CSF, the oral CSF is divided by the gastrointestinal absorption factor (GAF) to determine a CSF based on an absorbed dose rather than an administered dose. The oral CSF is divided by the GAF because CSFs are expressed as reciprocal doses. A dermal RfD is derived by multiplying an oral RfD by the GAF. Dermal CSFs and RfDs are in Appendix S in Tables 5.1 and 6.1. Values for GAF (or ABS_{GI}) were taken from RAGS Part E, Supplemental Guidance for Dermal Risk Assessment (U.S. EPA 2004a). For chemicals with greater than 50 percent ABS_{GI} absorption, it is recommended that the default value of complete (i.e., 100 percent) oral absorption be assumed, thereby eliminating the need for oral toxicity-value adjustment. Dermal adjustments to the oral CSF or RfD were made for chromium, manganese and vanadium.

6.4.4 Toxicity Criteria Assumptions

Assumptions regarding the toxicity criteria selected for the evaluation of aluminum and chromium are as follows:

- A provisional RfD is available for aluminum from the National Center for Environmental Assessment (NCEA); however, it is based on typical allowable intakes rather than adverse effect levels and is not considered strictly risk-based.
- Chromium was evaluated assuming that all of this metal was present in an environmental medium in the hexavalent state. This is a conservative assumption because hexavalent chromium is more toxic than trivalent chromium. However, hexavalent chromium is typically a less commonly occurring form of the metal (the trivalent form is more common).

6.4.5 Chemicals Lacking USEPA Toxicity Criteria

Toxicity criteria are not available the CBP COPC nitrocellulose. Therefore, cancer and noncancer risk estimates are not provided for this COPC.

Because of the absence of published dose-response parameters for lead, exposure to lead will be assessed by comparison of the lead EPC with the screening level of 400 mg/kg in soil. Lead exposure is evaluated in Section 6.6.

Toxicity profiles for these and other the CBP COPCs are presented in Section 6.9.

6.5 RISK CHARACTERIZATION

The risk characterization evaluates the information obtained through the exposure and toxicity assessments to estimate cancer risks and hazard indices. Total noncarcinogenic and carcinogenic risk estimates for each exposure route, as well as the cumulative risks for each receptor are presented in Tables 9.1 through 9.7 in Appendix S.

The risk characterization is presented in three sections; the methodology is presented in Section 6.5.1, while the results are presented in Section 6.5.2. Remedial Goal Options (RGOs) are presented for potential chemicals of concern in Section 6.5.3.

6.5.1 Methodology

6.5.1.1 Methodology for Estimation of Carcinogenic Risks

Carcinogenic risks can be estimated by combining information on the strength or potency of a known or suspected carcinogen (Carcinogenic Slope Factor [CSF]) with an estimate of the individual exposure doses (or intakes) of a chemical. Carcinogenic risk may be estimated as follows:

$$Risk = CSF \times Dose$$

Where:

CSF = Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$.
Dose = Amount of a contaminant absorbed by a receptor in mg/kg-day.

The equation presented above, however, is valid only at risk levels less than or equal to 1×10^{-2}. When the risk estimate is expected to be greater than 1×10^{-2}, an alternate equation, such as the following one-hit equation may be used to estimate risk (EPA, 1989a):

$$Risk = 1 - \exp(-Dose \times CSF)$$

The resultant cancer risk value (e.g., 1×10^{-6} or a 1-in-1,000,000 chance of developing cancer) can be applied to a given population to determine the number of excess cases of cancer that could be expected to result from exposure (e.g., 1×10^{-6} is one additional case of cancer in 1,000,000 exposed persons).

The total risk resulting from exposure of an individual receptor to multiple compounds in a particular medium is the sum of the cancer risks for the individual contaminants in that medium. Cancer risks will be summed across media for an individual receptor if the following assumptions are met:

- There are no antagonist/synergistic effects between chemicals.
- All chemicals produce the same result (cancer).
- Cancer risks from various exposure routes (e.g., ingestion and dermal) are additive, if the exposed populations are the same (EPA, 1989a).

To interpret the quantitative risk estimates and to aid risk managers in determining the need for remediation, quantitative risk estimates are compared to typical EPA and Ohio EPA risk benchmarks. The U.S.EPA has defined a "target cancer risk" range of 1E-04 to 1E-06. ILCRs below 1E-06 are generally considered acceptable risks. ILCRs above 1E-04 are generally considered unacceptable risks. Risk management decisions are necessary for ILCRs between 1E-06 and 1E-04. The Ohio EPA cumulative cancer risk benchmark is 1E-05.

6.5.1.2 Methodology for Estimation of Noncarcinogenic Risks

Potential health risks resulting from exposure to noncarcinogenic compounds are estimated by comparing the reasonable maximum daily intake dose calculated for an exposure to an acceptable intake dose, such as a chronic or subchronic reference dose (RfD). The ratio of the exposure dose (intake) to the RfD is referred to as the Hazard Quotient (HQ):

$$\text{Hazard Quotient} = \text{Dose}/\text{RfD}$$

If the HQ exceeds unity, there is a potential health risk associated with exposure to that chemical (EPA, 1989a). The Dose/RfD ratio is not a mathematical prediction of the severity or probability of toxic effects; it is simply a numerical indicator of the potential for adverse effects. The summation of HQs for several compounds is referred to as the Hazard Index (HI).

Conservatively, a total HI for any exposure route is calculated by summing the Dose/RfD ratios (HQs) for the individual chemicals of concern (EPA, 1989a). To provide a better indication of risks, Dose/RfD ratios are summed according to the target organ affected. For example, the Dose/RfD ratios for those chemicals affecting the liver should be summed separately from those chemicals affecting the central nervous system. An HI greater than 1 indicates potential adverse noncarcinogenic health effects (EPA 1989a).

The COCs for a given medium are defined as those contaminants that contribute total cancer risk for a receptor greater than 10^{-5} and/or HIs greater than 1.0 within a land use scenario, and that are not eliminated during the uncertainty analysis.

6.5.2 Risk Characterization Results

A summary of the risk characterization for CBP is presented in this section. Total non-carcinogenic and carcinogenic risks for each exposure route, as well as the cumulative risks for each receptor, are presented in Tables 9.1 through 9.7 in Appendix S and summarized in Table 6-11. The following receptors were evaluated:

- The security guard/maintenance worker.
- The National Guard trainee.
- The National Guard resident.
- The Hunter/Trapper.
- The hypothetical future resident farmer (adult and child).

Example calculations and relevant risk calculation spreadsheets are presented in Appendix S. It should be noted that although the risk estimates provided in Appendix S are presented using two significant figures, ***final receptor risk estimates*** are presented in the following narrative in terms of one significant figure as recommended by USEPA RAGS Part A.

Table 6-11. Summary of Cancer Risks and Hazard Indices

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks $> 10^{-4}$	Chemicals with Cancer Risks $> 10^{-5}$ and £ 10^{-4}	Chemicals with Cancer Risks $> 10^{-6}$ and £ 10^{-5}	Hazard Index	Chemicals with HI > 1
Security Guard/ Maintenance Worker	Surface Soil (0 to 1 feet)	Incidental Ingestion	6E-07	- -	- -	- -	8E-03	- -
		Dermal Contact	8E-06	- -	- -	Arsenic, Benzo(a)pyrene	1E-01	- -
		Inhalation	3E-09	- -	- -	- -	1E-03	- -
		Total	8E-06	- -	- -	Arsenic, Benzo(a)pyrene	1E-01	- -
National Guard Trainee	Deep Surface Soil (0 to 4 feet)	Incidental Ingestion	1E-06	- -	- -	- -	2E-02	- -
		Dermal Contact	5E-07	- -	- -	- -	6E-03	- -
		Inhalation	1E-05	- -	Chromium	Arsenic	4E+00	Manganese
		Total	2E-05	- -	Chromium	Arsenic	4E+00	Manganese
	Sediment	Incidental Ingestion	2E-06	- -	- -	Arsenic	2E-02	- -
		Dermal Contact	6E-07	- -	- -	- -	6E-03	- -
		Inhalation	8E-09	- -	- -	- -	1E-02	- -
		Total	2E-06	- -	- -	Arsenic	4E-02	- -
	Groundwater	Ingestion	6E-05	- -	Arsenic	- -	4E-01	- -
		Dermal Contact	1E-07	- -	- -	- -	9E-04	- -
		Inhalation	0E+00	- -	- -	- -	0E+00	- -
		Total	6E-05	- -	Arsenic	- -	4E-01	- -
		Total All Media	8E-05				5E+00	

Table 6-11. Summary of Cancer Risks and Hazard Indices (continued)

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks $> 10^{-4}$	Chemicals with Cancer Risks $> 10^{-5}$ and £ 10^{-4}	Chemicals with Cancer Risks $> 10^{-6}$ and £ 10^{-5}	Hazard Index	Chemicals with HI > 1
National Guard Resident	Surface Soil (0 to 1 feet)	Incidental Ingestion	9E-06	- -	- -	Arsenic	1E-01	- -
		Dermal Contact	3E-06	- -	- -	Arsenic	4E-02	- -
		Inhalation	1E-07	- -	- -	- -	4E-02	- -
		Total	1E-05	- -	- -	Arsenic, Benzo(a)pyrene	2E-01	- -
	Subsurface Soil (> 1 feet)	Incidental Ingestion	8E-06	- -	- -	Arsenic	8E-02	- -
		Dermal Contact	2E-06	- -	- -	Arsenic	2E-02	- -
		Inhalation	1E-07	- -	- -	- -	3E-02	- -
		Total	1E-05	- -	- -	Arsenic	1E-01	- -
	Sediment	Incidental Ingestion	1E-05	- -	- -	Arsenic	2E-01	- -
		Dermal Contact	4E-06	- -	- -	Arsenic	4E-02	- -
		Inhalation	4E-08	- -	- -	- -	6E-02	- -
		Total	2E-05	- -	- -	Arsenic	3E-01	- -
	Groundwater	Ingestion	4E-04	Arsenic	- -	- -	2E+00	Arsenic
		Dermal Contact	9E-07	- -	- -	- -	6E-03	- -
		Inhalation	0E+00	- -	- -	- -	0E+00	- -
		Total	4E-04	Arsenic	- -	- -	2E+00	Arsenic
		Total All Media	4E-04				3E+00	

Table 6-11. Summary of Cancer Risks and Hazard Indices (continued)

Receptor	**Media**	**Exposure Route**	**Cancer Risk**	**Chemicals with Cancer Risks $> 10^{-4}$**	**Chemicals with Cancer Risks $> 10^{-5}$ and £ 10^{-4}**	**Chemicals with Cancer Risks $> 10^{-6}$ and £ 10^{-5}**	**Hazard Index**	**Chemicals with HI > 1**
Hunter	Surface Soil (0 to 1 feet)	Incidental Ingestion	3E-08	- -	--	- -	4E-04	- -
		Dermal Contact	6E-08	- -	- -	- -	6E-04	- -
		Inhalation	3E-10	- -	- -	- -	9E-05	- -
		Total	9E-08	- -	- -	- -	1E-03	- -
	Sediment	Incidental Ingestion	4E-08	- -	- -	- -	5E-04	- -
		Dermal Contact	6E-08	- -	- -	- -	5E-04	- -
		Inhalation	5E-11	- -	- -	- -	8E-05	- -
		Total	1E-07	- -	- -	- -	1E-03	- -
	Venison	Ingestion	1E-08	- -	- -	- -	2E-04	- -
		Total All Media	2E-07				2E-03	

Table 6-11. Summary of Cancer Risks and Hazard Indices (continued)

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks $> 10^{-4}$	Chemicals with Cancer Risks $> 10^{-5}$ and £ 10^{-4}	Chemicals with Cancer Risks $> 10^{-6}$ and £ 10^{-5}	Hazard Index	Chemicals with HI > 1
Child Resident Farmer	Surface Soil (0 to 1 feet)	Incidental Ingestion	NA	- -	- -	- -	2E+00	- -
		Dermal Contact	NA	- -	- -	- -	1E-01	- -
		Inhalation	NA	- -	- -	- -	3E-03	- -
		Total	NA	- -	- -	- -	2E+00	- -
	Subsurface Soil (> 1 feet)	Incidental Ingestion	NA	- -	- -	- -	1E+00	- -
		Dermal Contact	NA	- -	- -	- -	6E-02	- -
		Inhalation	NA	- -	- -	- -	2E-03	- -
		Total	NA	- -	- -	- -	1E+00	- -
	Sediment	Incidental Ingestion	NA	- -	- -	- -	4E-01	- -
		Dermal Contact	NA	- -	- -	- -	2E-02	- -
		Inhalation	NA	- -	- -	- -	1E-03	- -
		Total	NA	- -	- -	- -	5E-01	- -
	Groundwater	Ingestion	NA	- -	- -	- -	1E+01	Arsenic
		Dermal Contact	NA	- -	- -	- -	2E-02	- -
		Inhalation	NA	- -	- -	- -	0E+00	- -
		Total	NA	- -	- -	- -	1E+01	Arsenic
	Venison	Ingestion	NA	- -	- -	- -	1E-03	- -
	Beef	Ingestion	NA	- -	- -	- -	8E-01	- -
	Milk	Ingestion	NA	- -	- -	- -	8E+00	Aroclor-1254
	Vegetables	Ingestion	NA	- -	- -	- -	4E+01	Aluminum, Arsenic, Chromium, Manganese, Vanadium, Aroclor-1254
		Total All Media	NA				7E+01	

Table 6-11. Summary of Cancer Risks and Hazard Indices (continued)

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks $> 10^{-4}$	Chemicals with Cancer Risks $> 10^{-5}$ and £ 10^{-4}	Chemicals with Cancer Risks $> 10^{-6}$ and £ 10^{-5}	Hazard Index	Chemicals with HI > 1
Adult Resident Farmer	Surface Soil (0 to 1 feet)	Incidental Ingestion	NA	- -	- -	- -	2E-01	- -
		Dermal Contact	NA	- -	- -	- -	1E-01	- -
		Inhalation	NA	- -	- -	- -	1E-03	- -
		Total	NA	- -	- -	- -	3E-01	- -
	Subsurface Soil (> 1 feet)	Incidental Ingestion	NA	- -	- -	- -	1E-01	- -
		Dermal Contact	NA	- -	- -	- -	7E-02	- -
		Inhalation	NA	- -	- -	- -	1E-03	- -
		Total	NA	- -	- -	- -	2E-01	- -
	Sediment	Incidental Ingestion	NA	- -	- -	- -	5E-02	- -
		Dermal Contact	NA	- -	- -	- -	3E-02	- -
		Inhalation	NA	- -	- -	- -	5E-04	- -
		Total	NA	- -	- -	- -	7E-02	- -
	Groundwater	Ingestion	NA	- -	- -	- -	3E+00	Arsenic
		Dermal Contact	NA	- -	- -	- -	8E-03	- -
		Inhalation	NA	- -	- -	- -	0E+00	- -
		Total	NA	- -	- -	- -	3E+00	Arsenic
	Venison	Ingestion	NA	- -	- -	- -	2E-04	- -
	Beef	Ingestion	NA	- -	- -	- -	8E-01	- -
	Milk	Ingestion	NA	- -	- -	- -	1E+00	- -
	Vegetables	Ingestion	NA	- -	- -	- -	4E+01	Aluminum, Arsenic, Chromium, Manganese, Vanadium, Aroclor-1254
		Total All Media	NA				5E+01	

Table 6-11. Summary of Cancer Risks and Hazard Indices (continued)

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks > 10^{-4}	Chemicals with Cancer Risks > 10^{-5} and £ 10^{-4}	Chemicals with Cancer Risks > 10^{-6} and £ 10^{-5}	Hazard Index	Chemicals with HI > 1
Lifelong Resident Farmer (Child and Adult)	Surface Soil (0 to 1 feet)	Incidental Ingestion	4E-05	- -	Arsenic	Benzo(a)pyrene	NA	- -
		Dermal Contact	2E-05	- -	- -	Arsenic, Benzo(a)pyrene	NA	- -
		Inhalation	8E-09	- -	- -	- -	NA	- -
		Total	6E-05	- -	Arsenic	Benzo(a)pyrene	NA	- -
	Subsurface Soil (> 1 feet)	Incidental Ingestion	4E-05	- -	Arsenic	- -	NA	- -
		Dermal Contact	1E-05	- -	- -	Arsenic	NA	- -
		Inhalation	8E-09	- -	- -	- -	NA	- -
		Total	5E-05	- -	Arsenic	- -	NA	- -
	Sediment	Incidental Ingestion	1E-05	- -	- -	Arsenic	NA	- -
		Dermal Contact	4E-06	- -	- -	Arsenic	NA	- -
		Inhalation	5E-10	- -	- -	- -	NA	- -
		Total	2E-05	- -	- -	Arsenic	NA	- -
	Groundwater	Ingestion	1E-03	Arsenic	- -	- -	NA	- -
		Dermal Contact	2E-06	- -	- -	Arsenic	NA	- -
		Inhalation	0E+00	- -	- -	- -	NA	- -
		Total	1E-03	Arsenic	- -	- -	NA	- -
	Venison	Ingestion	2E-08	- -	- -	- -	NA	- -
	Beef	Ingestion	9E-05	- -	Arsenic, Benzo(a)pyrene	Aroclor-1254	NA	- -
	Milk	Ingestion	3E-04	Benzo(a)pyrene	Arsenic, Aroclor-1254	- -	NA	- -
	Vegetables	Ingestion	5E-03	Arsenic, Benzo(a)pyrene	Aroclor-1254	- -	NA	- -
		Total All Media	6E-03				NA	

6.5.2.1 Noncarcinogenic Risks

HIs developed for the aforementioned receptors are summarized in Table 6-12.

Table 6-12. Summary of Risk Characterization Results for Noncarcinogens

Receptor[(1)]	**Media and Hazard Index**	**Table in Appendix S**
Security Guard/Maintenance Worker (Current/Future)	Surface soil (SS) 1E-01	9.1
National Guard Trainee	Deep surface soil 4E+00	9.2
(Future)	Sediments 4E-02	9.2
	Groundwater (GW) 4E-01	9.2
Total (All Media)	5E+00	9.2
Total (Minus deep surface soil)	4E-01	9.2
National Guard Resident	Surface soil 2E-01	9.3
(Future)	Subsurface soil (SB) 1E-01	9.3
	Sediment 3E-01	9.3
	Groundwater 2E+00	9.3
Total (All Media)	3E+00	9.3
Total (All Media minus groundwater)	6E-01	9.3
Hunter/Trapper	Surface soil 1E-03	9.4
(Current/Future)	Sediments 1E-03	9.4
	Venison 2E-04	9.4
Total (All Media)	2E-03	9.4
Hypothetical Child Resident Farmer	Surface soil 2E+00	9.5
(Future)	Subsurface soil 1E+00	9.5
	Sediments 5E-01	9.5
	Venison 1E-03	9.5
	Groundwater 1E+01	9.5
Total (All Media)	14E+00	9.5
Total (Minus GW)	4E+00	9.5
Total (Minus GW and SS)	2E+00	9.5
Total (Minus GW and SB)	3E+00	9.5
Adult	Surface soil 3E-01	9.6
	Subsurface soil 2E-01	9.6
	Sediment 7E-02	9.6
	Venison 3E-04	9.6
	Groundwater 3E+00	9.6
Total (All Media)	4E+00	9.6
Total (Minus GW)	6E-01	9.6
Total (Minus GW and SS)	3E-01	9.6
Total (Minus GW and SB)	4E-01	9.6

(1) More than one total risk estimate has been presented for several receptors to demonstrate the relative contribution of an environmental medium to the total risk for a receptor and because of the potential overestimation of risk that may occur when a receptor is assumed to be exposed to both surface and subsurface soils and sediments at a similar daily ingestion rate (e.g., the National Guard Trainee National Guard Resident, the hypothetical future farm resident). Also, risk estimates have been presented for domestic use of groundwater; however, it is very unlikely that the shallow groundwater resource at CBP would be used for domestic purposes.

HIs calculated for the security guard/maintenance worker and the hunter/trapper are less than 1 indicating that adverse noncarcinogenic health effects are not anticipated under the conditions established in the exposure assessment.

HIs calculated for the hypothetical National Guard resident exceed 1 only if it is assumed the receptor is using the shallow groundwater resource for domestic purposes. (As discussed in Section 4, the use of the shallow groundwater at CBP for domestic purposes is considered unlikely.) Only the target organ-specific HI for the skin/cardiovascular system exceeds unity; arsenic is the primary risk driver. HIs calculated for other target organs and COPCs do not exceed unity. The National Guard resident receptor was not required by the RVAAP FWHHRAM. The receptor was added to this HHRA per discussions with the USACE and Ohio EPA because risk estimates for this receptor may assist the risk management team when making risk management decisions for the CBP.

The HIs calculated for the National Guard trainee receptor exposed to COPCs in groundwater (4E-01) and sediments (5E-02) do not exceed 1. The HI for the National Guard trainee exposed to COPCs in deep surface soil (0 to 4 foot bgs) is 4. Manganese (inhalation of air particulates route of exposure) was the only significant contributor to the non-carcinogenic risk (i.e., risk driver) for the National Guard trainee. The HI calculated by summing the HIs calculated for all other COPCs does not exceed 1; only the HI calculated for the central nervous system (the target organ for manganese) exceeds 1. The non-cancer risk estimates for manganese are strongly affected by the PEF specified for the National Guard trainee receptor in the RVAAP FWHHRAM. This PEF and the inhalation reference dose for manganese are further discussed in Section 6.7, the Uncertainty Analysis. The EPC calculated for manganese in the deep surface soil (1,418 mg/kg) does not exceed the RVAAP surface soil background value (1,450 mg/kg) or the RVAAP subsurface soil background value (3,030 mg/kg).

The HI calculated for the adult resident farmer routinely exposed to COPCs in surface soil, sediment, and groundwater or routinely exposed to COPCs in subsurface soil, sediment, and groundwater via the direct contact pathways exceed 1 only when it is assumed that the shallow groundwater is used for domestic purposes. Arsenic is the only risk driver. However, as discussed in Section 4 and Section 6.7, the spatial distribution of the arsenic detections in the shallow groundwater does not strongly suggest that the arsenic detections in this environmental medium are site-related. HIs calculated for the adult resident farmer routinely exposed via indirect exposure pathways (i.e., consumption of foodstuffs) and also presented in Table 9.6 do exceed 1. However, there are significant uncertainties attached to the risk estimates developed for the ingestion of foodstuffs exposure pathways. Consequently these risk assessment results are presented and discussed in the Section 6.7, the Uncertainty Analysis. HIs calculated for the adult resident farmer consumption of venison do not exceed 1.

The HI calculated for the child resident farmer routinely exposed to COPCs in surface soil, sediment, and groundwater or routinely exposed to COPCs in subsurface soil, sediment, and groundwater via the direct contact exposure pathways exceed 1. The HIs calculated for the COPCs in groundwater, surface soil, or subsurface soils equal or exceed 1. The HI calculated for sediments do not exceed 1. Arsenic is the primary risk driver; HIs calculated for other COPCs evaluated do not exceed 1. The target-organ-specific HI calculated for the skin and cardiovascular system (the target organs for arsenic) exceed 1; however, target-organ-specific HIs for the other COPCs do not exceed 1. If groundwater is not evaluated as a medium of concern, the target-organ-specific HIs developed for the combined exposure to surface soil and sediment or for the combined exposure to subsurface soil and sediment do not exceed 1. The HIs calculated for the child resident farmer routinely exposed via indirect exposure pathways (i.e., consumption of foodstuffs) and also presented in Table 9.5 do exceed 1. However, there are uncertainties attached to the risk estimates developed for the ingestion of foodstuffs exposure pathways. Consequently these risk assessment results are presented and discussed in the Section 6.7, Uncertainty Analysis. HIs calculated for the child resident consumption of venison do not exceed 1.

6.5.2.2 Carcinogenic Risks

Incremental lifetime cancer risk (ILCR) estimates calculated for the aforementioned receptors are summarized in Table 6-13.

Table 6-13. Summary of Risk Characterization Results for Carcinogens

Receptor(1)	**Media and Hazard Index**	**Table in Appendix S**
Security Guard/Maintenance Worker (Current/Future)	Surface soil (SS) 8E-06	9.1
National Guard Trainee	Deep surface soil 2E-05	9.2
(Future)	Sediments 2E-06	9.2
	Groundwater (GW) 6E-05	9.2
Total (All Media)	8E-05	9.2
Total (Minus GW)	2E-05	9.2
National Guard Resident	Surface soil 1E-05	9.3
(Future)	Subsurface soil (SB) 1E-05	9.3
	Sediment 2E-05	9.3
	Groundwater 4E-04	9.3
Total (All Media)	4E-04	9.3
Total (All Media minus groundwater)	4E-05	9.3
Hunter/Trapper	Surface soil 9E-08	9.4
(Current/Future)	Sediments 1E-07	9.4
	Venison 1E-08	9.4
Total (All Media)	2E-07	9.4
Hypothetical Resident	Surface soil 6E-05	9.7
(Future)	Subsurface soil 5E-05	9.7
	Sediments 2E-05	9.7
	Groundwater 1E-03	9.7
Total (All Media)	1E-03	9.7
Total (Minus GW)	1E-04	9.7
Total (Minus GW and SS)	7E-05	9.7
Total (Minus GW and SB)	8E-05	9.7

(1) More than one total risk estimate has been presented for several receptors to demonstrate the relative contribution of an environmental medium to the total risk for a receptor and because of the potential overestimation of risk that may occur when a receptor is assumed to be exposed to both surface and subsurface soils and sediments at a similar daily ingestion rate (e.g., the National Guard Trainee National Guard Resident, the hypothetical future farm resident). Also, risk estimates have been presented for domestic use of groundwater; however, it is very unlikely that the shallow groundwater resource at CBP would be used for domestic purposes.

ILCR estimates calculated the hunter/trapper do not exceed 1E-06, the conservative end of the USEPA target risk range. The cancer risk estimates for the security guard/maintenance worker are within the USEPA target risk range of 1E-04 to 1E-06 and do not exceed the Ohio EPA cancer risk benchmark of 1E-05. Only the cancer risk estimate calculated for arsenic exceeds 1E-06.

Cancer risk estimates for the National Guard trainee are within the USEPA target risk range of 1E-04 to 1E-06, but do exceed 1E-05 when the deep surface soil and groundwater are evaluated as media of concern. Risk estimates summed for receptor exposure to sediment do not exceed 1E-05. Although arsenic, chromium, benzo(a)pyrene, and Aroclor 1254, were evaluated as COPCs, only the cancer risk estimates for arsenic and chromium exceed 1E-06. Risk estimates for the deep surface soil exceed 1E-05 only when it is assumed that chromium is present in the hexavalent form. Also, the cancer risk estimates for chromium are strongly affected by the Particulate Emission Factor (PEF) specified for the National Guard trainee receptor in the RVAAP FWHHRAM and the assumption that all chromium exists as hexavalent chromium. This PEF is further discussed in Section 6.7, the Uncertainty Analysis.

The ILCR calculated for the National Guard resident exceeds the USEPA target cancer risk range of 1E-04 to 1E-06 only when it is assumed the shallow groundwater is used as a domestic water supply and arsenic is evaluated as a COPC for groundwater. The cancer risk estimates developed for COPC concentrations in surface soil, subsurface soil, or sediments do not exceed or only marginally exceed 1E-05. Although arsenic, chromium, benzo(a)pyrene, and Aroclor-1254, are evaluated as COPCs, only the risk estimates for arsenic (surface soil, subsurface soil, sediment, and groundwater) and benzo(a)pyrene (subsurface soils, sediments) exceed 1E-06. Only the risk estimates developed for arsenic exceed 1E-05. The National Guard resident receptor was not required by the RVAAP FWHHRAM. The receptor was added to this HHRA per discussions with the USACE and Ohio EPA because risk estimates for this receptor may assist the risk management team when making risk management decisions for the CBP.

Cancer risk estimates for the hypothetical future resident farmer (combined adult and child) exceed the USEPA target risk range when groundwater is evaluated as a potential domestic water supply resource. Risk estimates developed for groundwater, surface soils, subsurface soils, or sediment exceed the Ohio EPA 1E-05 risk benchmark. Only the risk estimates developed for groundwater exceed 1E-04. A review of the media and chemical-specific risk results indicates the following chemicals are primary contributors to the estimated cancer risk:

- Arsenic is the primary risk driver in surface soil, subsurface soil, sediments, and groundwater. However, only the risk estimates calculated for arsenic in groundwater exceed 1E-04. The risk estimate for arsenic in soils exceeds 1E-05; risk estimate for arsenic in sediments equals 1E-05.
- The risk estimates for benzo(a)pyrene in surface soil and sediments exceed 1E-06, but do not exceed 1E-05.
- The risk estimates for Aroclor-1254 in surface soils and sediments exceed 1E-06 but are less than 1E-05.

The cancer risk estimates presented for the environmental media are subject to several significant sources of uncertainty which are further discussed in Section 6.7, the Uncertainty Analysis. Section 6.7 also presents an evaluation of the foodstuffs exposure pathways.

6.5.2.3 Summary of COCs Across All Media/Receptors

COCs are the COPCs that significantly contribute to a pathway in a use scenario for a receptor that either exceeds the 1E-05 cumulative cancer risk benchmark or exceeds a noncarcinogenic hazard index (target organ specific) of 1.0. A summary of COCs for each of the land use/receptor/medium combinations with COCs is presented in Table 6-14. Remedial Goal Options (RGOs) are calculated and presented in Section 6.5.3 for the potential COCs identified in the risk evaluation.

Table 6-14. Potential Land Use/Receptor/Medium Pathway COCs

Pathway	Surface Soil		Subsurface Soil	Soil			Sediment	Groundwater	Soil - Beef			Soil - Milk			Soil - Vegetables						
	As	B(a)P	As	As	Cr	Mn	As	As	As	B(a)P	A-1254	As	A-1254	B(a)P	Al	As	Cr	Mn	V	B(a)P	A-1254
Security Guard/Maintenance Worker			--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--
National Guard Trainee	--	--	--	X	X	X		X	--		--	--	--	--	--	--	--	--	--	--	--
National Guard Resident				--	--	--	X	X	--		--	--	--	--	--	--	--	--	--	--	--
Hunter				--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--
Child Resident Farmer				--	--	--		X					X		X	X	X	X	X		
Adult Resident Farmer				--	--	--		X							X	X	X	X	X		X
Lifelong Resident Farmer	X	X	X	--	--	--	X	X	X	X	X	X	X	X		X				X	X

No COCs were identified for direct contact with surface water and ingestion of venison.
A-1254 - Aroclor-1254
As - Arsenic
Al - Aluminum
B(a)P - Benzo(a)pyrene
DEHP - Bis(2-ethylhexyl)phthalate
Cr - Chromium
Mn - Manganese
V - Vanadium
"X" indicates chemical is a COC for receptor/medium
"--" indicates pathway not applicable in this BHHRA.
A blank indicates chemical is not identified as a COC for receptor/medium.

6.5.3 Remedial Goal Options

RGOs are developed for each direct-contact exposure COC (i.e., not for COCs identified for the foodstuff exposure pathways). The RGOs are risk-based concentrations that may be used in future risk-based decision making. RGOs are determined using the methods, equations, and parameters for determining intake shown in Tables 4.1 through 4.27 in Appendix S, as well as the CSFs and RfDs shown in Table 5.1 and Table 6.1 of Appendix S. The risk (or hazard) equation was rearranged to determine the concentration that would result in a specified risk or hazard. As discussed in Section 6.5.1, the cancer risk estimate and noncancer hazard indices are calculated as:

$$\text{Cancer Risk Estimate} = \text{Intake x CSF}$$
$$\text{Hazard Index} = \text{Intake/RfD}$$

Therefore, for a specified risk or hazard, the allowable intake may be determined as follows:

$$\text{Intake} = \text{Cancer Risk Estimate/CSF}$$
$$\text{Intake} = \text{Hazard Index x RfD}$$

The intake equations shown in Tables 4.1 through 4.27 of Appendix S are then rearranged to determine the allowable concentration, or RGO, for a specified risk level (e.g., the RGO associated with the 1E-06 risk level).

RGOs are determined for each medium and land use/receptor scenario. For example, the RGO for arsenic in surface soil at the cancer risk level of 1E-04 for the National Guard trainee is the concentration of arsenic that produces a risk of 1E-04 when using the exposure parameters specified for the National Guard trainee receptor, as shown in Table S.4.2 of Appendix S.

For the ingestion of surface soil, the RGO is determined as:

$$Cs = TR \text{ x } BW \text{ x } AT/IR \text{ x } FI \text{ x } ET \text{ x } EF \text{ x } ED \text{ x } (CSF \text{ or } 1/RfD)$$

where:

Cs = Concentration in soil (RGO)
TR = Target risk (or hazard)
BW = Body weight
AT = Averaging time
IR = Ingestion rate of soil
FI = Fraction ingested
ET = Exposure time
EF = Exposure frequency
ED = Exposure duration
CSF = Cancer slope factor
RfD = Reference dose

Calculated RGOs that are not physically possible (e.g. the calculated value exceeds 1E+06 mg/kg) are adjusted accordingly. RGOs are calculated for each exposure route (e.g., ingestion), as well as the total risk or hazard for each chemical identified as a COC in an environmental medium. Carcinogenic RGOs are calculated for risk levels of 1E-04, 1E-05, and 1E-06. Noncarcinogenic RGOs are calculated for hazard levels of 0.1 and 1.0.

The COCs identified for surface soil, deep surface soil (0-4), subsurface soil, groundwater, and sediments are shown in Table 6-11. RGOs are calculated for all receptor/medium combinations that have been evaluated in this BHHRA. For example, although arsenic is not a surface soil COC for the National Guard trainer/resident receptor, surface soil RGOs for arsenic are calculated for the National Guard trainer/resident.

RGOs for the direct-exposure surface soil COCs [arsenic and benzo(a)pyrene] were calculated for all receptors and presented in Table 6-15. RGOs for the direct-exposure National Guard trainee deep surface soil (0-4 ft bgs) COCs (arsenic, chromium, and manganese) were calculated for the National Guard trainee and presented in Table 6-16. RGOs for the subsurface soil COC (arsenic) were calculated for the National Guard trainer/resident and the resident farmer receptors and presented in Table 6-17. RGOs for the groundwater COC (arsenic) were calculated for the National Guard trainee, the National Guard trainer/resident, and the resident farmer receptors and presented in Table 6-18. RGOs for the sediment COC (arsenic) were calculated for the hunter/trapper, the National Guard trainee, the National Guard trainer/resident, and the resident farmer receptors and presented in Table 6-19.

RGOs are for direct contact exposure pathways (i.e., ingestion, inhalation, dermal contact) and do not consider potential migration to groundwater. The potential for COPCs to leach and migrate to groundwater is evaluated in Section 5 and is summarized below:

Soil contamination is generally low and does not constitute a significant reservoir of contaminants.

Operations at CBP began in the 1940's and ceased in the mid 1970's. COPCs in soil do not appear to have contributed to groundwater contamination in the 60 years since operations began. Arsenic is the only groundwater COPC identified at this site.

The EPCs (95%UCL or maximum detected concentration) of all soil (surface, deep surface, and subsurface) COPCs are < soil screening levels (SSLs) for protection of groundwater for all COPCs except arsenic in surface soil. The EPC for arsenic in deeper soils (which are more likely to contribute to groundwater contamination) are < SSLs (see Appendix S, Tables 2.1, 2.2, and 2.3).

RGOs are calculated for 3 COCs (arsenic, chromium, and benzo(a)pyrene). Direct contact RGOs for chromium and benzo(a)pyrene are < SSLs as noted below:

Benzo(a)pyrene: RGO for the security guard (surface soil) is 1.28 mg/kg at a 10^{-5} risk level. The SSL is 8.2 mg/kg.

Chromum: RGO for National guard trainee (deep surface soil) is 16.3 mg/kg at a 10^{-5} risk level. The SSL is 42 mg/kg.

RGOs for arsenic (25.2, 30.6, and 14.6 mg/kg for security guard/surface soil, National guard trainee/deep surface soil, and National guard resident/subsurface soil respectively) at a 10-5 risk level exceed the SSL (5.8 mg/kg). However, background concentrations of arsenic (15.4 mg/kg surface, 19.8 subsurface soil) also exceed the SSL.

Based on the above analysis, RGOs calculated for direct contact are adequate for protection of groundwater.

Table 6-15. Surface Soil (0-1 ft BGS) RGOs

	Ingestion					**Dermal**					**Inhalation**					**Total Across All Pathways**				
COC	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4
Security Guard/Maintenance Worker																				
Arsenic	4.91E+02	4.91E+03	3.05E+01	3.05E+02	3.05E+03	4.42E+01	4.42E+02	2.75E+00	2.75E+01	2.75E+02			2.12E+04	2.12E+05	1.00E+06	4.06E+01	4.06E+02	2.52E+00	2.52E+01	2.52E+02
Benzo(a)pyrene			6.27E+00	6.27E+01	6.27E+02			1.31E-01	1.31E+00	1.31E+01			1.03E+05	1.00E+06	1.00E+06			1.28E-01	1.28E+00	1.28E+01
Hunter/Trapper																				
Arsenic	1.02E+04	1.02E+05	5.30E+02	5.30E+03	5.30E+04	7.47E+03	7.47E+04	3.87E+02	3.87E+03	3.87E+04			2.07E+05	1.00E+06	1.00E+06	4.32E+03	4.32E+04	2.24E+02	2.24E+03	2.24E+04
Benzo(a)pyrene			1.09E+02	1.09E+03	1.09E+04			1.84E+01	1.84E+02	1.84E+03			1.00E+06	1.00E+06	1.00E+06			1.57E+01	1.57E+02	1.57E+03
National Guard Trainer																				
Arsenic	3.04E+01	3.04E+02	1.89E+00	1.89E+01	1.89E+02	1.03E+02	1.03E+03	6.42E+00	6.42E+01	6.42E+02			5.73E+02	5.73E+03	5.73E+04	2.35E+01	2.35E+02	1.46E+00	1.46E+01	1.46E+02
Benzo(a)pyrene			3.89E-01	3.89E+00	3.89E+01			3.05E-01	3.05E+00	3.05E+01			2.78E+03	2.78E+04	2.78E+05			1.71E-01	1.71E+00	1.71E+01
Resident Child Farmer																				
Arsenic	2.33E+00	2.33E+01				3.56E+01	3.56E+02									2.18E+00	2.18E+01			
Benzo(a)pyrene																				
Resident Adult Farmer																				
Arsenic	2.17E+01	2.17E+02				3.20E+01	3.20E+02									1.29E+01	1.29E+02			
Benzo(a)pyrene																				
Resident Farmer																				
Arsenic			3.93E-01	3.93E+00	3.93E+01			1.41E+00	1.41E+01	1.41E+02			3.54E+02	3.54E+03	3.54E+04			3.07E-01	3.07E+00	3.07E+01
Benzo(a)pyrene			8.07E-02	8.07E-01	8.07E+00			6.67E-02	6.67E-01	6.67E+00			1.72E+03	1.72E+04	1.72E+05			3.65E-02	3.65E-01	3.65E+00

RGO = Remedial Goal Option
COC = Chemical of Concern
HQ = Hazard Quotient
HI = Hazard Index
All units in mg/kg

Table 6-16. National Guard Trainee Deep Surface Soil (0-4 ft BGS) RGOs

	Ingestion					Dermal					Inhalation					Total Across All Pathways				
COC	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4
National Guard Trainee																				
Arsenic	1.95E+02	1.95E+03	1.21E+01	1.21E+02	1.21E+03	6.62E+02	6.62E+03	4.12E+01	4.12E+02	4.12E+03			4.55E+00	4.55E+01	4.55E+02	1.51E+02	1.51E+03	3.06E+00	3.06E+01	3.06E+02
Chromium	1.95E+03	1.95E+04				4.96E+03	4.96E+04				6.98E+01	6.98E+02	1.63E+00	1.63E+01	1.63E+02	6.65E+01	6.65E+02	1.63E+00	1.63E+01	1.63E+02
Manganese	4.55E+04	4.55E+05				1.00E+05	1.00E+06				3.49E+01	3.49E+02				3.49E+01	3.49E+02			

RGO = Remedial Goal Option
COC = Chemical of Concern
HQ = Hazard Quotient
HI = Hazard Index
All units in mg/kg

Table 6-17. Subsurface Soil RGOs

	Ingestion					Dermal					Inhalation					Total Across All Pathways				
COC	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4
National Guard Trainer																				
Arsenic	3.04E+01	3.04E+02	1.89E+00	1.89E+01	1.89E+02	1.03E+02	1.03E+03	6.42E+00	6.42E+01	6.42E+02			5.88E+02	5.88E+03	5.88E+04	2.35E+01	2.35E+02	1.46E+00	1.46E+01	1.46E+02
Resident Child Farmer																				
Arsenic	2.33E+00	2.33E+01				3.56E+01	3.56E+02									2.18E+00	2.18E+01			
Resident Adult Farmer																				
Arsenic	2.17E+01	2.17E+02				3.20E+01	3.20E+02									1.29E+01	1.29E+02			
Resident Farmer																				
Arsenic			3.93E-01	3.93E+00	3.93E+01			1.41E+00	1.41E+01	1.41E+02			3.54E+02	3.54E+03	3.54E+04			3.07E-01	3.07E+00	3.07E+01

RGO = Remedial Goal Option
COC = Chemical of Concern
HQ = Hazard Quotient
HI = Hazard Index
All units in mg/kg

Table 6-18. Groundwater RGOs

	Ingestion					Dermal					Inhalation					Total Across All Pathways				
COC	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4
National Guard Trainee																				
Arsenic	9.83E+00	9.83E+01	6.11E-01	6.11E+00	6.11E+01	4.05E+03	4.05E+04	2.52E+02	2.52E+03	2.52E+04						9.80E+00	9.80E+01	6.10E-01	6.10E+00	6.10E+01
National Guard Trainer																				
Arsenic	1.53E+00	1.53E+01	9.54E-02	9.54E-01	9.54E+00	6.32E+02	6.32E+03	3.94E+01	3.94E+02	3.94E+03						1.53E+00	1.53E+01	9.52E-02	9.52E-01	9.52E+00
Resident Child Farmer																				
Arsenic	3.13E-01	3.13E+00				2.17E+02	2.17E+03									3.12E-01	3.12E+00			
Resident Adult Farmer																				
Arsenic	1.10E+00	1.10E+01				4.52E+02	4.52E+03									1.09E+00	1.09E+01			
Resident Farmer																				
Arsenic			3.34E-02	3.34E-01	3.34E+00			1.65E+01	1.65E+02	1.65E+03								3.33E-02	3.33E-01	3.33E+00

RGO = Remedial Goal Option
COC = Chemical of Concern
HQ = Hazard Quotient
HI = Hazard Index
All units in ug/L

Table 6-19. Sediment RGOs

	Ingestion					Dermal					Inhalation					Total Across All Pathways				
COC	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4	HQ = 0.1	HQ = 1.0	Risk = 10-6	Risk = 10-5	Risk = 10-4
Hunter/Trapper																				
Arsenic	1.02E+04	1.02E+05	5.30E+02	5.30E+03	5.30E+04	8.19E+03	8.19E+04	4.25E+02	4.25E+03	4.25E+04			3.67E+05	1.00E+06	1.00E+06	4.55E+03	4.55E+04	2.36E+02	2.36E+03	2.36E+04
National Guard Trainee																				
Arsenic	1.95E+02	1.95E+03	1.21E+01	1.21E+02	1.21E+03	6.62E+02	6.62E+03	4.12E+01	4.12E+02	4.12E+03			2.52E+03	2.52E+04	2.52E+05	1.51E+02	1.51E+03	9.34E+00	9.34E+01	9.34E+02
National Guard Trainer																				
Arsenic	3.04E+01	3.04E+02	1.89E+00	1.89E+01	1.89E+02	1.03E+02	1.03E+03	6.42E+00	6.42E+01	6.42E+02			5.73E+02	5.73E+03	5.73E+04	2.35E+01	2.35E+02	1.46E+00	1.46E+01	1.46E+02
Resident Child Farmer																				
Arsenic	1.09E+01	1.09E+02				1.66E+02	1.66E+03									1.02E+01	1.02E+02			
Resident Adult Farmer																				
Arsenic	1.01E+02	1.01E+03				1.49E+02	1.49E+03									6.04E+01	6.04E+02			
Resident Farmer																				
Arsenic			1.83E+00	1.83E+01	1.83E+02			6.56E+00	6.56E+01	6.56E+02			1.65E+03	1.65E+04	1.65E+05			1.43E+00	1.43E+01	1.43E+02

RGO = Remedial Goal Option
COC = Chemical of Concern
HQ = Hazard Quotient
HI = Hazard Index
All units in mg/kg

6.6 LEAD EXPOSURE ANALYSIS

The maximum lead concentration (493 mg/kg) in surface soil and deep surface soil exceeded the OSWER soil screening level of 400 mg/kg for residential land use (USEPA, 1994c). Lead was not selected as a COPC in any other medium. Concentrations of lead only exceeded the residential screening level in one soil sample (CBPSS-018-0001-SO). Exposures to lead are evaluated using arithmetic mean concentrations (USEPA, 1994c). The mean concentrations of lead in surface soil (59.3 mg/kg) and deep surface soil (43.4 mg/kg) are well below the residential screening level of 400 mg/kg. Consequently, no adverse health effects are anticipated from exposures to lead in surface and deep surface soil at the CBP.

6.7 UNCERTAINTY ANALYSIS

This section presents a brief summary of uncertainties inherent in the risk assessment and includes a discussion of how they may affect the quantitative risk estimates and conclusions of the risk analysis. This BHHRA for the CBP was performed in accordance with current USEPA and RVAAP guidance and the aforementioned White Paper developed for the CBP. However, there are varying degrees of uncertainty associated with the BHRRA. The following sections discuss general uncertainties in risk assessment and uncertainties specific to the risk assessment for the CBP.

Uncertainty in the selection of COPCs is related to the current status of the predictive databases, the grouping of samples, and the procedures used to include or exclude constituents as COPCs. Uncertainty associated with the exposure assessment includes the values used as input variables for a given intake route/scenario, the assumptions made to determine exposure point concentrations, and the predictions regarding future land-use and population characteristics. Uncertainty in the toxicity assessment includes the quality of the existing toxicity data needed to support dose-response relationships and the weight-of-evidence used for determining the carcinogenicity of COPCs. Uncertainty in the risk characterization includes that associated with exposure to multiple chemicals and the cumulative uncertainty from combining conservative assumptions made in earlier steps of the risk assessment process.

Whereas there are various sources of uncertainty, the direction of uncertainty can be influenced by the assumptions made throughout the risk assessment, including selection of COPCs and selection of values for dose-response relationships. In general, assumptions, which consider safety factors, are made so that the final calculated risks are overestimated.

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the process can be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions made are protective of sensitive subpopulations or the maximum exposure individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, thereby producing a much larger uncertainty for the final result. This uncertainty is biased toward over predicting both carcinogenic and noncarcinogenic risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

The evaluation of uncertainty is especially relevant when risk estimates exceed the point-of-departure for defining "acceptable" risk. For example, when risks calculated using a high degree of uncertainty are less than an acceptable risk level (e.g., 10^{-6}), the interpretation of no significant risk is typically straightforward. However, when risk calculated using a high degree of uncertainty exceed an "acceptable" risk level; a conclusion can be difficult unless uncertainty is considered especially when the exceedance of acceptable risk is relatively "marginal".

6.7.1 Uncertainties Associated with COPC Selection

The following issues may contribute to uncertainty in COPC selection for the CBP: the existing database, the inclusion of chemicals potentially attributable to background, the screening levels used, the absence of screening levels for a few chemicals detected in the site media, and frequency of detection. A brief discussion of each of these issues is provided in the remainder of this section.

6.7.1.1 Existing Databases

All data used for this evaluation have been validated according to guidelines. Therefore, uncertainties associated with the quality of the data are considered to be minimal. For some media (surface water), few samples (less than 10) were collected. The use of small datasets may result in additional uncertainty both in the COPC selection and in the calculated risks. However, the field sampling program was biased towards areas most likely to demonstrate contamination thus; risks based on these biased data may be over estimated.

6.7.1.2 Chemicals Potentially Attributable to Background

The background values for RVAAP were determined as described in RVAAP WBG Phase II Remedial Investigation (SAIC 2001). Outliers, results exceeding an upper cutoff limit, were removed from the background data set. The upper cutoff limit was the third quartile (the 75th percentile) plus 1.5 times the inter-quartile range. An outlier might indicate a mistake in the dataset; however, it but might also represent a perfectly valid but rare result. Therefore, some higher background values were conservatively removed from the data set.

Although manganese detections reported for 8 surface soil sampling locations exceed the RVAAP background for manganese in surface soils (1,450 mg/kg, the maximum detected manganese concentrations in the background surface soil sample dataset), only the detections reported for locations SS-006 and SS-010 exceed the calculated 95 percent upper tolerance limit (lognormal distribution) for surface soils (3,050 mg/kg) reported in Table 4-5 of WBG RI report (SAIC, 2001). Additionally, a review of the background soils data set ***before*** the outliers were culled from the dataset (as described above) indicates that, in most cases, the actual maximum detected manganese concentrations in the background surface soil dataset exceed or are similar to the manganese concentrations detected in the CBP surface soil dataset (see Appendix S). This is an important consideration because manganese was the only non-cancer risk driver for the National Guard trainee receptor. Likewise a comparison of arsenic concentrations in sediment indicates that the actual maximum detected arsenic concentrations in the background sediment dataset exceed or are similar to arsenic concentrations detected in the CBP sediment dataset. Finally, benzo(a)pyrene was detected in background soil samples at a maximum concentration of 100 ug/kg. The maximum detected concentration in site surface and subsurface soils was 220 ug/kg. As indicated previously, the PAH concentrations detected in the CBP soils and sediments are within the range of background anthropogenic concentrations reported in literature. In addition, as the concentrations of these constituents are similar to or just slightly greater than background, the risk also is similar to or just slightly greater than that associated with background.

As shown in Figures 6-1 and 6-2, risks are primarily driven by exposures to groundwater. Arsenic was the only COPC identified for groundwater at the CBP. Arsenic was detected in samples from two of eight monitoring well samples at concentrations exceeding the current federal SDWA MCL (MW-001 and MW-003). However, the spatial pattern of contamination does not strongly suggest that the reported detections are site related. Specifically, the maximum detected concentration (35.1 ug/L) was reported for a sample collected from MW-001 which is up-gradient of the primary source areas at the Central Burn Pit. In addition, groundwater in the overburden aquifer is not suitable as a drinking water source as indicated by low yields and high turbidity.

6.7.1.3 COPC Screening Levels

The use of risk-based screening values should ensure that the significant contributors to risk from a site are not eliminated but are retained for risk evaluation. COPC screening values were based on conservative land-use scenarios (e.g., residential land use for soil) and protective levels of risk corresponding to an ILCR of 10^{-6} and an HI of 0.1. For example, as discussed in Section 6.2, several non-carcinogenic chemicals (e.g., aluminum and vanadium in surface soils) selected as COPCs were not detected in environmental media at concentrations exceeding the Region IX PRGs.

In addition, the toxicity values used in the derivation of PRGs are subject to change, as additional information (from scientific research) becomes available; these periodic changes in toxicity values may cause the PRG values to change as well.

6.7.1.4 Absence of COPC Screening Levels

Essential human nutrients (e.g., magnesium, potassium, calcium, and sodium) do not have screening levels listed in this report. These nutrients were eliminated from consideration as COPCs. Exclusion of these chemicals as COPCs is not expected to add significant uncertainty to the risk estimates.

Several chemicals did not have screening levels listed in this report but were screened using a surrogate screening value, i.e., a screening value for a similar chemical. Chromium was evaluated as hexavalent chromium. Phenanthrene was screened using the RBSCs for pyrene. Endosulfan I and Endosulfan II were screened using the RBSCs for Endosulfan. In each case, the surrogate screening value is conservative and is not expected to add significant uncertainty to the risk. However, per recent comments from Ohio EPA, the use of surrogate screening values for PAHs detected at the CBP will be discussed during the response-to-comment period for this BHHRA.

6.7.1.5 Frequency of Detection

Thallium was eliminated a COPC on the basis of frequency of detection in subsurface soil and deep surface soil. Thallium was detected in only one of 37 subsurface soil samples and in only three of 73 deep surface soil samples. The maximum detected concentrations of thallium in subsurface soil and deep surface soil exceeds the RBSC (set at an HI equal to 0.1); however, do not exceed the Region IX PRGs for soil.

A few chemicals with low frequency of detection (FOD), although greater than 5%, were retained as SRCs and COPCs. These include the cPAHs (benzo[a]pyrene) detected in 1 of 9 subsurface soil samples, and Aroclor-1254 detected in 3 of 30 samples and PAHs (benzo[a]pyrene) detected in 1 of 10 deep surface soil samples. These were retained as COPCs leading to possible overestimation of risk.

6.7.1.6 Data Analysis

Uncertainty can be added to the risk estimates by limitations in the analytical methods. Some current analytical methods are limited in their ability to achieve detection limits at or below the PRG concentrations. Risks may be overestimated when some analyte concentrations are reported as nondetected at the method detection limit but the actual concentration is much less than the method detection limit. Conversely, risks may be underestimated when some analytes are present, even at concentrations exceeding the PRG, but are not detected because of limitations in the analytical methods and are therefore removed from the SRC list.

6.7.2 Uncertainties Associated with the Exposure Assessment

Uncertainty in the exposure assessment arises because of the methods used to calculate exposure point concentrations, the selection of receptors, the selection of land-use scenarios to be evaluated, and the selection of exposure parameters.

6.7.2.1 Land-Use

The current land use patterns of the CBP are established, thereby reducing the uncertainty associated with current land use assumptions. The anticipated future land use patterns of the CBP are described in the RVAAP FWHHRAM. This BHHRA is based on these known and anticipated future land use scenarios; therefore, the land-use assumptions presented herein are not expected to lead to an underestimation of risk.

6.7.2.2 Exposure Point Concentration

The maximum concentration of some COPCs was used as the EPC to quantify potential risks (e.g., benzo[a]pyrene and Aroclor-1254 in soils, arsenic in groundwater, and benzo(a)pyrene, aluminum, arsenic, manganese, and vanadium in sediment). Risk estimates are likely to be overestimated when the maximum detected concentration is selected as the EPC because it is unlikely that potential receptors would be exposed to the maximum concentration over the entire site for the assumed exposure period.

6.7.2.3 Exposure Parameters

The exposure assessment factors, e.g., exposure frequency and duration, are based on reasonable maximum exposure (RME) assumptions. Generally, exposure factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of potential risks, RME exposure factors values were used in this risk evaluation. Therefore, the risk is not likely to be underestimated for reasonably maximum exposed individuals and is more likely to be overestimated for the general populations exposed to the chemicals in the environmental media at the sites.

A particulate emission factor (PEF) of 9.24E+08 m^3/kg was calculated using the methods in USEPA Soil Screening Guidance (EPA 1996) using site-specific factors for Cleveland, Ohio, the city nearest Ravenna for which EPA had provided parameters to estimate PEF and volatilization factors (VF) values. This value was used to evaluate most receptors in this BHHRA. However, the RVAAP recommends a PEF of 1.67E+06 m^3/kg for the National Guard trainee, whose activities are considered more likely to generate more airborne dust than the activities of other receptors. The FWHHRAM states that this PEF was calculated from a dust loading factor (DLF) of 600 ug/m^3. This value greatly exceeds the National Ambient Air Quality Standards (NAAQS) PM 10 24-hour and annual standard of 150 ug/m^3 and 50 ug/m^3, respectively. While it is possible that National Guard activities could generate significant PM10 concentrations for short periods of time and at locations adjacent to vehicles, it is very unlikely that these activities would generate ambient air particulate emissions for extended periods of time and across the entire site, especially at concentrations which exceed the NAAQS. As a point of comparison, the use of the methodology and default values for estimating dust emissions associated with construction activities in the U.S. EPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, December 2002, results in a DLF of 364 ug m^3. The HI for the National Guard trainee calculated for manganese concentrations in the CBP deep surface soils and sediments using this guidance would be approximately half those presented in Section 6.5.

For the dermal contact with soil pathway, no exposure time is included in the equation. This would indicate the receptor did not bathe (i.e., remove the soil on the skin surface) for the full day. This may overestimate the risk associated with dermal contact with soil. This fact is especially important when the dermal pathway is the major contributor to the risks and/or hazards.

Given climatic conditions in the eastern Ohio region, the assumption of 250 day per year and 350 day per year exposure frequency for the National Guard trainer/resident and the hypothetical future resident, respectively, for soils and sediments likely results in an overestimation of risk because no exposure is likely to occur when these media are covered with snow or frozen solid. Consequently, risks calculated using these exposure assumptions are likely over estimated.

6.7.2.4 Selection of Receptor Groups

Exposures to site media by recreational users were not evaluated in this HHRA because the site is not currently being used for recreational use nor is recreational use anticipated to occur in the future. If recreational use of the site did occur potential cancer risks and hazard indices are expected to be within acceptable levels. For example, assuming an adult recreational user would visit the site for 75 days a year over a 30 year period results in an ILCR of 6E-06 for potential exposures to surface soil and 7E-06 for exposures to sediment. Hazard indices would be 0.07 and 0.09 for potential exposures to surface soil and sediment, respectively. Consequently, potential exposures to surface soil and sediment by a hypothetical recreational user would be within USEPA and Ohio EPA acceptable risk levels.

6.7.3 Uncertainties Related to Toxicity Information

Uncertainties associated with the toxicity assessment include the derivation of the RfDs and CSFs from which the PRGs are calculated and limitations associated with the use of available criteria as presented in this section.

6.7.3.1 Derivation of Toxicity Criteria

Uncertainty is associated with hazard assessment and dose-response evaluations. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will also induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using the USEPA methods. Positive animal cancer test data suggest that humans contain tissue(s) which may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of noncancer effects, however, the positive animal data often suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated for humans.

Uncertainty in hazard assessment arises from the nature and quality of the animal and human data. Uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when pharmacokinetic data indicate a similar fate in humans and animals; when postulated mechanisms of toxicity are similar for humans and animals; and when the chemical of concern is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose-response evaluation is associated with the determination of a CSF for the carcinogenic assessment and derivation of an RfD or RfC for the noncarcinogenic assessment. Uncertainty introduced from interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Uncertainty also results from intraspecies variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal, but the human population of concern may reflect a great deal of heterogeneity including unusual sensitivity or tolerance to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals sufficiently healthy to attend work regularly (the healthy worker effect) and those not unusually sensitive to the chemical are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study from which the quantitative estimate is derived and the database. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty in carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a non-threshold assumption of carcinogenesis. Evidence suggests, however, that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Williams and Welsburger, 1991); therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD or RfC to mitigate poor quality of the key study group or gaps in the database. Uncertainty factors are usually applied to the estimate of a no-effects level when lowest-adverse-effect level data are available. Additional uncertainty arises in estimation of an RfD or RfC for chronic exposure from subchronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the subchronic study. Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors that normally range between 3 and 10. The resulting combination of uncertainty and modifying factors are used to proportionally adjust the RfD downwards and thereby intentionally often introduce a conservative bias in the RfD by a factor of 1000 or more.

The derivation of dermal RfDs and CSFs from oral values may cause uncertainty. This is particularly the case when no gastrointestinal absorption rates are available in the literature or when only qualitative statements regarding absorption are available.

6.7.3.2 Toxicity Criteria for Chromium

Some uncertainty is associated with the evaluation of chromium, which was assumed to be present in its hexavalent state. The estimated risks for the National Guard Trainee only exceeded 1E-05 because chromium was assumed to be present in the hexavalent form. Because hexavalent chromium is considered to be more toxic than trivalent chromium, while the latter is more commonly found in the environment, risks for this chemical are probably overestimated.

6.7.3.3 Toxicity Criteria for Arsenic

The toxicity criteria for arsenic are a major source of uncertainty for this baseline risk assessment. While conventional risk assessment methodology suggests that there is no “zero risk concentration” for a carcinogen such as arsenic, the human body does have a limited capacity to methylate arsenic and this limit is not generally reached until the body’s intake of arsenic exceeds 500 µg/day. Most environmental exposures result in intakes lower than 500 µg/day. Additionally, the USEPA suggests that an order of magnitude adjustment of risk (downward) may be appropriate for arsenic in some cases (USEPA 1987a).

6.7.3.4 Toxicity Criteria for Manganese

The USEPA’s inhalation reference dose for manganese (1.4 mg/kg/day) is very restrictive when compared to most inhalation reference doses presented in IRIS and is based on an epidemiological study where workers are exposed to manganese in its oxide form in an alkaline battery plant. Manganese may or may not be present in this form at the CBP.

6.7.4 Uncertainties and Assumptions in the Risk Characterization

Uncertainty in risk characterization often results from the lack of toxicity criteria and from assumptions made regarding additivity of effects from exposure to multiple COPCs from various exposure routes. For example, high uncertainty exists when summing cancer risks for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often compounds affect different organs, have different mechanisms of action, and differ in the fate in the body; therefore, additivity may not be an appropriate assumption. However, the assumption of additivity is often made to provide a conservative estimate of risk. The risk characterization also does not consider antagonistic or synergistic effects of COPCs.

6.7.4.1 Unavailable Toxicity Criteria or Provisional Toxicity Criteria

Risk-based screening levels and/or toxicity criteria are not available for nitrocellulose in soil and sediment. According to the USEPA Office of Drinking Water, nitrocellulose is essentially nontoxic (USEPA 2000b).

A provisional RfD is available for aluminum (a COPC in soils and sediment) from the National Center for Environmental Assessment (NCEA); however, it is based on typical allowable intakes rather than adverse effect levels and is not considered risk-based. This is unlikely to be a significant source of uncertainty to the risk assessment because aluminum is not a significant COPC for the CBP (i.e., the maximum detected concentration does not exceed the Region IX PRG and the metal was detected infrequently at concentrations exceeding the RVAAP background).

6.7.4.2 Evaluation of Foodstuffs Pathway

As indicated in Section 6.5.2, there is a significant amount of uncertainty attached to the risk assessment evaluation of the ingestion-of-foodstuffs exposure pathways discussed in the RVAAP FWHHRAM (i.e., ingestion of home-grown beef, ingestion of milk, and ingestion of homegrown vegetables). Frequently, risk estimates based on background concentrations of chemicals exceed the risk benchmarks when these pathways are evaluated. However, conservatively, risk estimates were developed for the hypothetical future resident farmer assuming the receptor is routinely consuming homegrown beef and homegrown vegetables, and consuming milk from dairy cattle raised on-site. COPC concentrations in these media are modeled based on the COPC concentrations detected in the surface soils at the CBP and the equations presented in the RVAAP FWHHRA Manual. The risk estimates are included in Tables 9.5, 9.6, and 9.7 of Appendix S and discussed in the following paragraphs.

Cancer risk estimates for the ingestion of beef, ingestion of milk, and ingestion of vegetables exposure pathways were 2E-04, 3E-04, and 7E-03, respectively. Chemical-specific risk estimates for arsenic and benzo(a)pyrene, the two carcinogenic COPCs selected for surface soil, exceed 1E-05 in all cases presented in Table 9.7, Appendix S. Chemical-specific risk estimates for Aroclor-1254 exceed 1E-05 for the ingestion of milk and ingestion of vegetables exposure pathways.

HIs developed for the adult resident farmer and child resident farmer exposed via the ingestion of beef, ingestion of milk, and ingestion of vegetables exposure pathways are presented in Tables 9.5 and 9.6, Appendix S. HIs calculated for child resident farmer and adult resident farmer exceed 1 for all non-carcinogenic COPCs (aluminum, arsenic, manganese, vanadium) when risks are summed across these three exposure pathway. However, risks calculated for the ingestion of vegetables exposure pathway exceed those developed for the ingestion of beef and ingestion of milk exposure pathways by an order of magnitude.

The ingestion rates present in the FWHHRAM for consumption of beef and vegetables are based on exposures by an adult. These same ingestion rates are also recommended by the FWHHRAM for a child consuming beef and vegetables. However, it is very unlikely that a child would be consuming the same amount of beef and vegetables as an adult. USEPA’s Exposure Factor Handbook (USEPA, 1997) and Example Exposure Scenarios (USEPA, 2004) presents ingestion rates for different age groups. Overall, the ingestion rates present in these documents for adults are higher than those presented for children. Using adult ingestion rates for the evaluation of exposures to children will most likely result in an overestimation of the risks.

Also, there is uncertainty associated with the input parameters used in the food chain modeling. The site is not currently used for farming; consequently site-specific values were not available for the input parameters to the food chain models so literature values were used. The literature values were obtained from the RAIS (ORNL 2002) and may not be representative of actual site conditions. The literature values represent upper bound values and are selected as to not underestimate exposures. Therefore, the use of literature values in the place of site-specific values are not expected to underestimate site exposures and may overestimate site exposures.

Bioaccumulation of contaminants into various biological media (i.e., plants, mammals) depends on characteristics of the media such as pH, organic carbon, etc. Therefore, actual bioaccumulation factors at the site may be different than the ones used in the food chain modeling that were obtained from the literature. Also, the site-specific bioavailability of the chemicals are not taken into account in the food chain modeling. All of the chemicals are assumed to be 100 percent bioavailable at the detected concentrations, which would not occur for most chemicals.

The equations for the calculation of the concentration of a chemical in beef/pork, milk, and vegetables include a mass loading factor. The mass loading factor represents the mass of soil that is lying on top of the plants/vegetables/fruit that is consumed by animals or human receptors. The mass loading factor assumes that surface soil can be resuspended in air by wind or mechanical disturbances. The resuspended particles may then be deposited on the surfaces of vegetation. The equations assume a mass loading factor of 0.25 which means that 25 percent of the chemical in soil will end up deposited on the vegetation and then consumed by either an animal or human receptor. There are numerous factors that will affect the mass loading factor including humidity, vegetative cover, and rainfall. Humidity may reduce the resuspension of particles relative to that which takes place in arid or semi-arid regions because humid areas typically have a denser vegetative cover. Vegetative cover will reduce the likelihood of wind erosion and therefore reduce the potential for particles to be deposited on plants. Rainfall will wash the soil particles off of the vegetation. Vegetative cover will reduce the likelihood of wind erosion and therefore reduce the potential for particles to be deposited on plants. Also human receptors will most likely clean any home grown vegetables before eating. Consequently, the use of a mass loading factor of 0.25 will most likely overestimate the actual concentration of the chemical that is ingested by a receptor by as a result of consumption of beef/pork, milk, and vegetables.

6.7.4.3 Summation of Risk

There are uncertainties concerning the summation of hazards and carcinogenic risk estimates across chemicals and pathways. These include the possibility of synergistic or antagonistic reactions and the varying levels of accuracy and precision of the RfDs or CSFs. In addition, the target organ for carcinogens may be different and therefore summation of the risk may not be appropriate in all cases.

6.8 SUMMARY AND CONCLUSIONS

A human health risk assessment was performed for the RVAAP CBP study area based on analytical data for groundwater, soil, sediment and surface water collected in the summer of 2001 The methodology used in the CBP BHHRA is based primarily on the protocol established in the RVAAP FWHHRAM (USACE, January 2004) and the White Paper for the CBP.

The following five human receptors were evaluated:

- The Security Guard/Maintenance Worker
- The National Guard Trainee
- The National Guard Resident

- The Hunter/Trapper
- The Hypothetical Future Resident Farmer (adult and child)

The National Guard trainee is a critical receptor because it is anticipated that the Central Burn Pit area will be used by the Ohio Army National Guard for training activities described in the FWHHRAM as "Dismounted Training by Ohio National Guard Soldiers – No Digging Allowed". The planned training activities would involve potential exposure to soils (no deeper than 4 foot below ground surface), as well as to the other environmental media at the CBP. The hunter/trapper receptor is an important receptor because a long-term goal for RVAAP is to be able to hunt, fish, and trap anywhere suitable habitat exists for recreational fishing and hunting. (Please note that fishing and waterfowl hunting do not currently occur at the CBP.) The National Guard resident and the hypothetical future resident farmer are included in the BHHRA for purposes of completeness and because risk estimates for these receptors may be useful to the risk managers for the RVAAP. For example, the need for deed restrictions at a site (or a portion of a site) may be eliminated if minimal risks are established for these receptors. The security guard/maintenance receptor is included as a receptor because of the routine activities (e.g., security patrols) currently occurring at the site by personnel who visit the site for short periods of time.

The following chemicals were selected as COPCs for quantitative human health risk assessment:

Soils	**Groundwater**	**Sediment**
Arsenic	Arsenic	Arsenic
Aluminum	--	Aluminum
Chromium	--	Manganese
Copper	--	Vanadium
Lead	--	Benzo(a)pyrene
Manganese	--	--
Vanadium	--	--
Aroclor 1254	--	--
Benzo(a)pyrene	--	--

The COPC selection protocol included a conservative toxicity screen (based on the U.S.EPA Region IX PRGs) and a background screen. The following should be considered when evaluating this list of COPCs:

- Arsenic was detected in samples from two of eight monitoring well samples at concentrations exceeding the current federal SDWA MCL (MW-001 and MW-003). However, the spatial pattern of contamination does not strongly suggest that the reported detections are site related Specifically, the maximum detected concentration (35.1 ug/L) was reported for a sample collected from MW-001 (filtered overburden), which is located upgradient of the primary source areas at the CBP. Arsenic is a naturally occurring metal in groundwater. RVAAP backgrounds for arsenic in bedrock and overburden wells are 11 ug/L (filtered overburden), 215 ug/L (unfiltered overburden), 19.1 ug/L (unfiltered bedrock), and 0 ug/L (filtered bedrock). Based on the site-history and the spatial pattern of arsenic concentrations in the environmental media, arsenic is not expected to be a strong site-related/process-related contaminant for the CBP.

- Aluminum, copper, and vanadium were selected as COPCs because these chemicals exceed conservative COPC screening levels for non-carcinogenic chemicals. However, these chemicals were not detected at concentrations exceeding the U.S.EPA Region IX PRGs.
- Although manganese detections reported for 8 surface soil sampling locations exceed the RVAAP background for manganese in surface soils (1,450 mg/kg, the maximum detected manganese concentrations in the background surface soil sample dataset), only the detections reported for locations SS-006 and SS-010 exceed the calculated 95 percent upper tolerance limit (lognormal distribution) for surface soils (3,050 mg/kg) reported in Table 4-5 of WBG RI report (USACE, 1999).
- The benzo(a)pyrene concentrations detected in soils and sediments are similar to anthropogenic background concentrations reported in the scientific literature and concentrations reported to background soil samples collected at RVAAP.
- Maximum arsenic concentrations detected in soils at CBP do exceed backgrounds established for RIs at RVAAP. As noted above, based on the site-history and the spatial pattern of arsenic concentrations in the soils, arsenic is not expected to be a strong site-related/process-related contaminant for the CBP. Also, the arsenic concentrations detected at CBP are within background concentrations reported by the U.S.EPA and in the scientific literature.
- The Aroclor-1254 concentrations detected in soils are less than the 1 mg/kg action level published in OSWER Directive 9355.4-01 titled, Guidance on Remedial Actions for Superfund Sites with PCB Contamination (U.S.EPA, 1990) for residential areas.

6.8.1 Summary of Risk Characterization Results

A summary of the risk characterization for the CBP is presented in Table 6-14 and in the following items:

- Noncancer risk estimates (HIs) developed for the security guard/maintenance worker and the hunter/trapper are less than 1 indicating that adverse noncarcinogenic effects are not anticipated under the exposure conditions considered in the risk assessment. The cancer risk estimates for the security guard/maintenance worker and the hunter/trapper do not exceed 1E-05 and 1E-06, respectively. No potential COCs are identified for these receptors.
- The HIs developed for the National Guard trainee exposure to COPCs in sediments and groundwater are less than 1 indicating that adverse noncarcinogenic health effects are not anticipated (for these media) under the conditions evaluated in the risk assessment. However, the HI developed for the National Guard trainee exposure to COPCs in deep surface soils is 4. Manganese is the primary risk driver; only the HIs developed for the intake of manganese via the inhalation for airborne particulates exposure pathway exceeded 1. This risk assessment result is very conservative and reflects: 1) an assumption that the receptor is exposed to an atmosphere that is heavily loaded with air-borne soil particulate matter for long periods of time, 2) the use of a conservative inhalation rate, and 3) the use of a conservative inhalation reference dose. Consequently, the potential for non-cancer risk is likely over-estimated; adverse non-carcinogenic health effects are unlikely. Additionally, as noted above, few manganese concentrations in soils exceed RVAAP background.
- The total cancer risk estimate for National Guard trainee exposure to all media (8E-05) is within the USEPA target cancer risk range (1E-04 to 1E-06) but exceeds the Ohio EPA cumulative cancer risk benchmark of 1E-05. The risk estimates for deep surface soils and groundwater exceed 1E-05; the cancer risk estimate for sediments does not exceed 1E-05. Arsenic and chromium are the primary contributors to the cancer risk estimate. However, cancer risk estimates for the deep surface soil exceed 1E-05 only when it is assumed that all

chromium is present in the hexavalent state, an unlikely scenario. Also, as noted above for the non-cancer risk estimates for manganese, the risk estimates for the trainee (and thus for the inhalation of chromium in airborne soil particulates) are strongly influenced by the assumption that the receptor is exposed to an atmosphere that is heavily loaded with air-borne soil particulate matter for long periods of time. As noted in Section 6.7, this is a significant source of uncertainty.

- The total HI for the National Guard resident is 3. The HI calculated for receptor exposure to groundwater is 2. The HI for exposure to all other media combined (soils, sediments) is 0.6. Arsenic is the only chemical identified as a potential COC.
- The total cancer risk estimate for the National Guard resident (4E-04) exceeds the USEPA target risk range (1E-04 to 1E-06). However, only the cancer risk estimate for groundwater (4E-04) exceeds 1E-04; the media-specific cancer risk estimate for the surface soil, subsurface soil, or sediments is 1E-05, 1E-05, and 2E-05, respectively. It should be noted that, because of the small size of the sediment dataset, the maximum arsenic concentration in sediments (20.1 mg/kg) was evaluated as the EPC. However, the maximum detected background concentration reported for the sediments is 19.5 mg/kg. Thus, the arsenic concentrations in the sediments at the CBP likely reflect background conditions.
- The total HIs calculated for the hypothetical adult resident farmer routinely exposed to COPCs in surface soil, subsurface soil, and sediment via the direct contact exposure pathways (i.e., incidental ingestion, dermal contact, inhalation exposure pathways) were less than 1. The HI calculated for receptor exposure to groundwater is 3; arsenic is the only chemical identified as a potential COC. However, HIs calculated for the adult resident farmer exposed via the indirect exposure pathways (i.e., consumption of vegetables, beef, and milk raised on-site) do exceed 1. Non-cancer risk estimates for the consumption of vegetables exposure pathway (HI = 40) are an order of magnitude greater than risk estimates developed for the ingestion of beef (HI = 0.8) and ingestion of milk (HI = 1) exposure pathways. Aluminum, arsenic, chromium, manganese, vanadium, and Aroclor-1254 are potential COCs for the indirect exposure pathways. However, the food chain modeling used to characterize risk for the indirect exposure pathways is very conservative. HIs exceeding 1 would also be predicted for the naturally occurring or anthropogenic background concentrations of these parameters. HIs calculated for adult resident consumption of venison do not exceed 1.
- The HI calculated for the child resident farmer routinely exposed to COPCs in groundwater, surface soil, subsurface soil, and sediments via the direct contact exposure pathways are 10, 2, 1, and 0.5, respectively. However, only the total target-organ-specific HI (summed across all media) calculated for the skin and cardiovascular systems exceed 1. The total target-organ-specific HI would not exceed 1 if domestic use of the shallow groundwater medium is not evaluated. Arsenic is the only COPC identified as a potential COC for these direct contact exposure pathways. However, HIs calculated for the child resident farmer exposed via the indirect exposure pathways (i.e., consumption of vegetables, beef, and milk raised on-site) do exceed 1. The non-cancer risk estimates for the consumption of vegetables exposure pathway (HI = 40) are an order of magnitude greater than risk estimates developed for the ingestion of beef (HI = 0.8) and ingestion of milk (HI = 8) exposure pathways. Aluminum, arsenic, chromium, manganese, vanadium, and Aroclor-1254 are potential COCs for the indirect exposure pathways. However, as noted above, the food chain modeling used to characterize risk is very conservative. HIs exceeding 1 would also be predicted for the naturally occurring or anthropogenic background concentrations of these parameters. HIs calculated for child resident consumption of venison do not exceed 1.
- The ILCR estimates for the hypothetical future resident farmer are 6E-05, 5E-05, 2E-05, and 1E-03 for direct contact exposure pathways for surface soil, subsurface soil, sediment, and groundwater, respectively. The total cancer risk (summed for exposure to surface soils, sediments, and groundwater or for exposure to subsurface soils, sediments, and groundwater)

for the direct contact exposure pathways only exceeds 1E-04 when it is assumed that the groundwater is used for domestic purposes. Arsenic, benzo(a)pyrene, and Aroclor-1254 in soils or sediments, and arsenic in groundwater are identified as potential COCs for the direct contact exposure pathway. The cancer risk estimates calculated for the indirect exposure pathways (i.e., consumption of beef, milk, and vegetables raised on site) exceed 1E-04. Arsenic, benzo(a)pyrene, and Aroclor-1254 are identified as potential COCs for the indirect exposure pathways. However, the uncertainties highlighted in the previous items are also relevant for the risk estimates presented for the future hypothetical resident farmer exposed via the indirect, ingestion-of-foodstuffs exposure pathways. Cancer risk estimates for resident consumption of venison do not exceed 1E-06.

Table 6-14 presents a summary of all receptors evaluated in this BHHRA and identifies the contaminants that produce risks greater than 1E-06, 1E-05, and 1E-04 or hazards greater than 1.0.

6.8.2 Conclusions of BHHRA

The conclusions of the BBHRA for the CBP are provided in the following items:

- The total cancer risk estimate (summed across all media) for the critical receptor of concern (the National Guard trainee) does not exceed 1E-04 and only the cancer risk estimates developed for arsenic in groundwater (assuming domestic use) and chromium in deep surface soil (assuming chromium is present in the hexavalent state) exceeds 1E-05. The total non-cancer risk (HI) estimate (summed across all media) only exceeds 1 when manganese is evaluated as a COPC. However, as discussed in the preceding narrative, significant uncertainties were identified for the risk estimates for arsenic (in groundwater) and manganese/chromium (in soils) and should be considered by the risk management team for RVAAP when making further remedial decisions for the CBP.
- The total cancer risk estimate (summed across all media) and the total HI (summed across all media) for the National Guard Resident exceeds 1E-04 and 1, respectively, only when the future domestic use of the shallow groundwater resource is evaluated. Cancer risk estimates and HIs for all other media for the National Guard Resident do not exceed 2E-05 and 1, respectively. As noted above, significant uncertainties were identified for the risk estimates for arsenic (in groundwater and sediments) and should be considered by the risk management team for RVAAP when making further remedial decisions for the CBP.
- The total cancer risk estimate (summed for exposure to groundwater, surface soil, and sediments or for exposure to groundwater, subsurface soils, and sediments) for the hypothetical future resident exposed by the direct contact exposure pathways exceeds 1E-04 only when future domestic use of the shallow groundwater resource is evaluated. Cancer risk estimates for soils and sediments evaluated for the direct contact exposure pathways exceed 1E-05 but do not exceed 1E-04. Total non-cancer risk estimates (HI) calculated on a target-organ-specific basis exceed 1 only when future domestic use of the shallow groundwater resource is evaluated (arsenic is the risk driver). However, cancer and non-cancer risk estimates developed for the indirect exposure pathways (i.e., consumption of home-grown food stuffs) exceed both cancer and non-cancer risk benchmarks (i.e., 1E-04 and HI = 1, respectively). Significant uncertainties were identified for the risk estimates for arsenic (in groundwater and sediments) and for the evaluation of the indirect, ingestion-of-foodstuffs exposure pathways, and should be considered by the risk management team for RVAAP when making further remedial decisions (e.g., deed restriction decisions) for the CBP.

Cancer and non-cancer risk estimates for the security guard/maintenance and the hunter trapper do not exceed 1E-05 and an HI of 1, respectively.

7.0 SCREENING ECOLOGICAL RISK ASSESSMENT

7.1 INTRODUCTION

The goal of this screening-level ecological risk assessment (SERA) is to determine whether adverse ecological impacts are present as a result of exposure to chemicals released to the environment through past site operations at RVAAP Central Burn Pits (CBP). This SERA provides information to scientists and managers that will enable them to conclude either that ecological risks at the site are most likely negligible or that further information is necessary to evaluate potential ecological risks at the site. The SERA methodology follows the guidance presented in the RVAAP Facility Wide Ecological Risk Work Plan (USACE, 2003d) and Guidance for Conducting Ecological Risk Assessments (Ohio EPA, 2003).

This SERA consists of the first two of the eight steps required by the RVAAP, Ohio EPA and USEPA. The first two steps are the screening-level assessment. Step 3a is the first step of the Baseline Ecological Risk Assessment (BERA) and consists of refining the list of COPCs that are retained following the SERA. This step further refines the screening-level risk assessment and has been included in this SERA. Steps 3b through 7 are conducted if additional evaluations or investigations are necessary but were not conducted as part of this report. Finally, Step 8, Risk Management, is incorporated throughout the ERA process, in cooperation with Ohio EPA.

7.2 PRELIMINARY PROBLEM FORMULATION

The preliminary problem formulation includes identification of potential receptor groups, COPCs, and the mechanisms for fate and transport and toxicity. Determination of the complete exposure pathways that exist at a site is accomplished at this point to facilitate receptor selection. As part of receptor identification, site habitats and potential ecological receptors are described.

7.2.1 Habitat Types and Ecological Receptors

The dominant cover types at RVAAP are forest and old field. Roads and former railroad spurs cross and surround the CBP site. Portions of RVAAP meets the regulatory definition of wetland because of poorly drained hydric soils, a seasonally high water table and numerous beaver impoundments (USACE, 2003). Three major creeks drain RVAAP – Sand Creek, the south fork of Eagle Creek and Hinkley Creek.

Sand Creek flows through the center of the installation and is the principal recipient of surface drainage from the plant. Sand Creek is immediately adjacent to and receives surface water runoff from the CBP site. At CBP, the creek is approximately 15-20 ft wide, slow moving due to numerous active beaver dams, and as its name implies, has a sandy bottom substrate. Beavers are actively downing trees along the stream bank producing scattered open areas with lush herbaceous wetland plants.

Sand Creek at Central Burn Pit.

At CBP, Sand Creek lies in a forested floodplain valley or ravine approximately 200 feet across and 20-30 ft lower than the site. The steep sides of the valley are shown in the above paragraph.

The steep valley slopes of Sand Creek at Central Burn Pits.

Habitat at the CBP is diverse with second-growth forest in old fields, open grassy areas, riparian floodplain and perennial stream. The burn pits are actually bare mounds of debris and slag surrounded by shrub and pole-sized trees. Willow, aspen and cottonwood are common along the edges of the barren area. Soil sample forms that describe sample locations report burn or ashy odors (SS-005 and SS-017), compressed slag (SS-006), concrete burn pile (SS-022), solidified molten lead (SS-013) and slag (SS-034) Sample locations in the burn pile were observed to contain gravel and cobbles mixed with fine silt and various proportions of clay or sand. The physical nature of the substrate provides low quality habitat to plant or soil invertebrates.

**Bare ground and sparse vegetation of the Central Burn Pits in the foreground.
Photograph taken looking east with MW-004 in the background.**

A grassy open area with fescue, lespedeza and goldenrod is maintained along a sewer line right-of-way. Serviceberry and witch hazel were common shrub species observed.

The maintained sewer line right of way dissecting Central Burn Pits.
Photo taken looking south from north boundary road.

Several fruit-bearing apple trees are scattered near a concrete slab reported to be a former home site. Hardwoods planted in rows suggest a former woodlot.

During a site visit to nearby Cobbs Pond, several wildlife species were observed especially along the water's edge. Wood duck, mallards and deer were common at Cobbs Pond while evidence of beavers was abundant along the streams. Although not observed, cottontail rabbit, raccoon, red fox, meadow voles, shrews and hawks are expected to frequent the site.

Two separate ephemeral drainage ditch systems are present at CBP. One system is associated with a former railroad track spur (Track 33A). The other drains water from the central bare areas toward the northeast corner of the site. No standing water was observed in the drainage ditches during the site visit. All ditches at CBP discharge to Sand Creek.

A number of rare species are found at the RVAAP (Appendix B), several of which are of federal and state interest (ODNR, 1993). No known federally-listed threatened, endangered, or candidate species or critical habitat have been documented on the RVAAP. The federal endangered Indiana bat (*Myotis sodalis*) has been documented nearby, but not on-site as reported in a 1998 bat survey at RVAAP. State-listed endangered species include eight birds, a lamprey, a butterfly, and two plants. One state-listed threatened plant species is found on RVAAP.

Rare species from a 1993 Inventory include:

- Northern Harrier (*Circus cyancus*);
- Common Barn Owl (*Tyto alba*);
- Yellow-bellied Sapsucker (*Sphyrapicus varius*);
- Little blue heron (*Egretta caerulea*);

- American Bittern (*Botaurus lentiginosu*);
- Canada warbler (Wilsonia canadensis);
- Osprey (Junco hyemalis);
- Trumpeter Swan (*Cygnus buccinator*);
- Mountain Brook Lamprey (*Ichthyomyzon greeleyi*);
- Graceful Underwing (*Catocala gracilis*);
- Northern Monkshood (Aconitum noveboracense);
- White-stemmed Pondweed; and
- Woodland horsetail (*Equisetum sylvaticum*).

The great variety of habitats at RVAAP (i.e., many stages of forest succession, streams, ponds, grassy open spaces) leads to a high diversity of animal species. Some of these species include (but are not limited to) mammals such as white-tailed deer, beaver, coyote, hawks, red fox, rabbits, raccoons, mice; birds such as ducks, geese, wild turkey, bobwhite quail, red-tailed hawks, and American robins; and various amphibians, reptiles, fish, and invertebrates.

7.2.2 Major Chemical Sources and Migration Pathways

The Central Burn Pits (also called the Central Burn Scrap or C.B.S. Yard on Plot Plan for Sand Creek Area, Drawing B-1003, 1956)(Fig. 7-1) were used for the burning of non-explosive, scrap materials (USACHPM, 1998). The dates of operation are unknown. Railroad tracks 25 and 33 comprise the site's north and south boundary. Track 33A divides the site into east and west. Sand Creek is the west boundary and Paris-Windham road the east boundary.

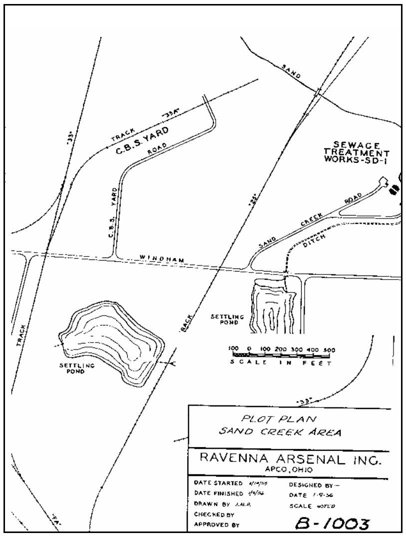

Figure 7-1. 1956 Plot Plan of Central Burn Pits, formerly Central Burn Scrap Yard. North is to the reader's right.

In the Relative Risk Site Evaluation report (USACHPM, 1998), an area of "slag, small metal and ceramic debris" is identified with a "gravelly distressed area" along the east side of Lumber Yard Road (Fig 7-2) . Two railroad spurs are shown – one unnamed spur entering from the north and ending at the west bend of the road, another labeled as Track 33A diagonally dividing the site southeast to northwest. A single area labeled "discolored soil" is located on the west side of the Lumber Yard road but east of Track 33A

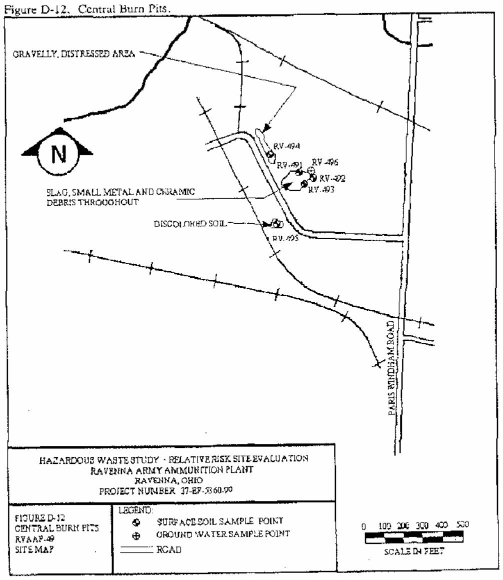

Figure 7-2. Early map of Central Burn Pits showing approximate locations of burn piles and discolored soil area.

The elevated rail bed of Track 33A divides the site and may prevent or minimize westward migration of site contaminants deposited at known locations along the road. Drainage ditches along the east and west side of Track 33A discharge to Sand Creek through culverts under the road and at the end of the ditch. The northeast drainage ditch system begins at the southeast corner of the site, west of Paris-Windham Road. It carries surface water northward and eventually flows into Sand Creek. A small feeder ditch starts at the burn pits, runs east and then joins the northeast ditch.

No load lines are immediately adjacent to the Central Burn Pits, but Load Lines 3 and 12 are closest to CBP. Since the name of the road leading into the CBP is Lumber Yard Road, a sawmill may have been present prior to its use as a burning ground. Sawdust was used extensively in the load lines for clarification of wastewater to remove residual explosive dusts and burned as a waste. Upper Cobbs Pond is immediately east of the CBP and may have received annealing process wastes due to chromium concentrations in sediments. A glass and ceramic disposal site was observed in the northwest corner of the Central Burn Pit at the upland edge of the ravine for Sand Creek. The glass appears to be laboratory ware. A former lab associated with the ammonium nitrate production at the nearby Load Line 12 may be the source of this glass.

Glass and ceramic disposal site in northwest corner of Central Burn Pit.

A fish kill occurred at nearby Cobbs Pond in 1966 and was attributed to improper handling of aluminum chloride at Load Line 12. It is reported that the aluminum chloride and sediment from the ponds were disposed at Ramsdell Quarry landfill. In the description of the spill cleanup, it is stated that "contaminated metals involved were flashed at a burning ground to a 5x condition, then sold as scrap" (USATHMA, 1978, pg. 37). The proximity of CBP to Cobbs Pond and the use of "non-explosive" contaminated waste at CBP suggest it may have been the unnamed burning ground for this contaminated metal.

The major contaminant migration pathways from the Central Burn Pit are:

- Erosion of contaminated soils from small mounds, pits or dump sites and deposited as sediments in drainage ditches or on down-slope soils;
- Intermittent surface water runoff of dissolved or adsorbed contaminants in drainage ditches;
- Transport of contaminated ditch sediments to Sand Creek and offsite;
- Dissolved or adsorbed contaminants in rainwater percolating through the soil column into surficial groundwater aquifers; and
- Discharge of surficial groundwater to springs, seeps, ditches and/or Sand Creek.

Shallow groundwater exists on RVAAP in both the primary bedrock aquifer and in unconsolidated geologic material (soil). Eight monitoring wells were sampled during the CBP remedial investigation activities in the fall of 2001 and groundwater varied from 8.9 to 18.1 ft below ground surface. This shallow groundwater may discharge either directly to Sand Creek or to seeps or springs in floodplain wetlands adjacent to Sand Creek. A preferential subsurface drainage path may be present in a sewer pipeline trench that intersects the site.

Based on historical site data and sampling, the following parameters are among the site-related chemical contaminants that were detected at CBP. Note that not all the chemicals mentioned in the following bullets were detected or analyzed in each sample:

- Explosives and Propellants
- Metals
- Chlorinated volatile organic compounds (VOCs)
- Semivolatile organic compounds (SVOCs)
- PCBs
- Pesticides

Surface soil was sampled at 34 sites at two intervals. Sediment was sampled at 9 sites – 3 in Sand Creek and 6 in the drainage ditches. No surface water was available for sampling in the drainage ditches, but 3 samples were collected in Sand Creek.

Organic analyses were not performed on all surface water, sediment and soil samples. SVOCs (PAHs) were analyzed at 7 surface soil sites (SS-002, -006, -008, -014, -023, -029, and –032) and PCBs at 13 of a total 34 surface soil sample sites. Organic compounds were analyzed at 2 of 9 sediment sample sites (SD-002 and SD-008) and at 1 of 3 (SW-008) surface water sample sites. Explosive-related compounds (Method 8330) were analyzed at all surface water, sediment and soil sample sites.

The results of the surface soil, surface water, and sediment sampling are presented in earlier sections of this report. Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include the organic carbon partition coefficient, octanol water partition coefficient, and vapor pressure.

This SERA uses various bioaccumulation factors (BAF) to estimate contaminant loading in plants, soil invertebrates, fish, and benthic invertebrates from chemical concentrations in surface soil and sediment.

For soil to plant uptake, two separate BAFs are used to predict the biological transfer of contaminants from soil to vegetative (foliage) or reproductive and storage (berries and roots) plant parts (Baes et al, 1984 and HAZWRAP, 1994). Additional transfer factors include soil to animal (assumed earthworm), animal to animal (earthworm to shrew), and sediment to biota (HAZWRAP, 1994; Travis and Arms, 1988). All factors were from the RVAAP Facility Wide Eco-Risk Guidance (USACE, 2003d) and Winklepeck Burning Grounds (WBG) Remedial Investigation (USACE, 1999). Contaminants that do not have BAFs are assigned a default value of 1. Appendix T presents two tables with the all the transfer factors for soil to plant, soil to invertebrate, and diet to animal.

7.2.3 Exposure Routes

The potential pathways by which ecological receptors may be exposed to COPCs were identified, along with the species that could be adversely affected by these chemicals. Several potential exposure pathways may exist. For example, terrestrial animals may be exposed to soil contaminants through ingestion of contaminated food items. Animals can also incidentally ingest soil while grooming fur, preening feathers, digging, grazing close to the soil, or feeding on items to which soil has adhered (such as roots and tubers).

Terrestrial vegetation may be exposed to contaminants via direct aerial deposition and root translocation. Terrestrial animal receptors may also come into contact with contaminants in surface water by drinking the water, although this exposure route typically represents a negligible portion of total exposure for most receptors because of the relatively low contaminant concentrations in surface water as compared to other media. Aquatic and semi-aquatic organisms may be exposed to contaminants via direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. Aquatic and semi-aquatic organisms may also be exposed to constituents from contaminated ground water that flows into surface water.

7.2.3.1 Surface Soil

Several groups of terrestrial ecological receptors can be exposed to contaminants in the soil (0-4 ft), although most of the exposure is expected to occur in the top 12 inches. Invertebrates, such as earthworms, are exposed to the contaminants as they move through the soil and ingest soil particles while searching for food. Plants are exposed to the contaminants via direct contact as contaminants are absorbed through the roots, which may then translocate to different parts of the plants (i.e., leaves, seeds).

Small mammals may be exposed to contaminants in the soil via several exposure routes. They may be exposed by direct contact as they search for food or burrow into the soil. However, exposure of terrestrial wildlife to contaminants in the soil via dermal contact is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons are expected to minimize transfer of contaminants across dermal tissue. Therefore, the dermal pathway is not evaluated in this SERA. Small mammals also may be exposed to contaminants in the soil via incidental ingestion of soil and ingestion of plants and/or invertebrates that have accumulated contaminants from the soil. These pathways are evaluated in this SERA.

Larger predatory species, such as the red fox, barn owl and red-tailed hawk, can be exposed to site contaminants in the soil by ingesting small mammals that have accumulated contaminants from the soil. This pathway is evaluated in this SERA.

7.2.3.2 Ground Water

Ecological receptors are not directly exposed to contaminants in the ground water, so this exposure pathway is not complete. According to USACE (2003d), because groundwater is more than 2 feet deep, exposure to ground water after it discharges to a surface water body does not need to be evaluated as part of the surface water pathway.

7.2.3.3 Surface Water/Sediment

Contaminants in the soil may enter the intermittent streams or ditches via overland flow. All of the surface water conveyances at CBP are small drainage ditches that have poor ecological habitat and probably do not support an invertebrate population. Sand Creek is adjacent to the CBP and supports a small fish population. Aquatic receptors could be exposed to contaminants in the water or sediment by direct contact and incidental ingestion of water. Although not likely to support fishing by people, piscivorous wildlife may consume fish that have accumulated chemicals from the surface water or sediment. Because the section of Sand Creek that lies adjacent to CBP is relatively small, these pathways, while complete, are not expected to account for a significant portion of this pathway.

7.2.3.4 Air

Although inhalation of particulates may be a complete pathway, it is expected to be insignificant compared to other pathways such as ingestion of food items that have accumulated contaminants from soil. Also, inhalation pathways typically are not evaluated in SERAs because of the uncertainty in exposures and effects concentrations. Therefore, this pathway was not evaluated.

7.2.4 Preliminary Assessment and Measurement Endpoints

One of the major tasks in the screening-level problem formulation is the selection of assessment and measurement endpoints.

7.2.4.1 Assessment Endpoints

Assessment endpoints are explicit expressions of the environmental value that is to be protected (USEPA, 1997a). The selection of these endpoints is based on the habitats present, the migration pathways of probable contaminants, and the routes that contaminants may take to enter receptors.

The habitat at and adjacent to the site consists of forested areas, open fields with grasses, and aquatic habitats. For this SERA, the assessment endpoints are the protection of the following groups of receptors from adverse effects of contaminants on their growth, survival, and reproduction:

- Soil invertebrates
- Terrestrial vegetation
- Herbivorous mammals
- Herbivorous birds
- Soil and sediment invertebrate-eating mammals
- Carnivorous mammals
- Carnivorous birds
- Omnivorous mammals
- Omnivorous birds
- Benthic invertebrates
- Fish

The following paragraphs discuss why the above assessment endpoints are selected for this SERA.

<u>Soil Invertebrates</u> - Soil invertebrates are expected to be present in the soil at the site. They aid in the formation of soil and redistribution and decomposition of organic matter in the soil and serve as a food source for higher trophic level organisms. They also can accumulate some contaminants that can then be transferred to the higher trophic level organisms that consume invertebrates.

Terrestrial Vegetation - Terrestrial vegetation at the site consists of grasses, shrubs, and trees. They serve as a food source, provide shade and cover for many organisms and help prevent soil erosion, among other important functions. They also can accumulate some contaminants that can then be transferred to higher trophic level organisms that consume plants.

Herbivorous Birds and Mammals - Herbivorous birds and mammals (animals that consume only plant tissue) may be present at the site because of the vegetative habitats. Their role in the community is essential because, without them, higher trophic levels could not exist. They may be exposed to and accumulate contaminants that are present in the plants they consume.

Carnivorous Birds and Mammals - Carnivorous birds and mammals consist of birds and mammals that consume invertebrates, fish, and other mammals and birds. Soil invertebrate-eating birds and mammals (invertivores) are present throughout RVAAP in different terrestrial habitats (i.e., forested, open field). These are considered first-level carnivores and they serve as a food source for higher trophic level carnivores. Piscivorous birds and mammals may be present along some of the larger water bodies, if significant fish populations are present. Although the drainage ditches are small and intermittent, piscivorous wildlife were included as assessment endpoints to be conservative. Finally, carnivorous birds and mammals that feed on other birds and mammals are at the top of the food chain. The top carnivores typically are less densely distributed than the herbivores and first-level carnivores because they require a larger area to hunt for their food. Large carnivorous mammals (i.e., red fox) and birds (i.e., barn owl and red-tailed hawk) are evaluated in this SERA although the area of CBP is relatively small and well below the typical home and feeding ranges of carnivorous animals. The highest exposure to site contaminants is expected to occur to the small insectivorous mammals and birds that ingest earthworms or plants. All of the carnivores may be exposed to and accumulate contaminants that are present in the food items they consume.

Omnivorous Birds and Mammals - Omnivorous birds and mammals (that consume both plant and animal tissue) are present throughout RVAAP in the different terrestrial habitats (i.e., forested, open field). They may be exposed to and accumulate contaminants that are present in the plants and animals they consume.

Benthic Macroinvertebrates - Benthic macroinvertebrates are similar to the soil invertebrates in that they serve as a food source for higher trophic level organisms (i.e., fish, amphibians, birds, mammals). They also can accumulate some contaminants that can then be transferred to the higher trophic level organisms that consume invertebrates.

Fish - Fish are present in Sand Creek at CBP, but absent in the drainage ditches. Fish are exposed to contaminants and can accumulate contaminants from the food items they consume or from the sediment.

All the initial assessment endpoints are not evaluated in the SERA. As indicated in USEPA guidance (USEPA, 1997a), “it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site. Instead, assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site.” Therefore, the SERA focuses on the endpoints that will tend to yield the highest risks, which should then account for endpoints that will have lower risks.

7.2.4.2 Measurement Endpoints

Measurement endpoints are estimates of biological impacts (e.g., mortality and reduction in growth or reproduction) that are used to evaluate the assessment endpoints. The following measures of effects are used to evaluate the assessment endpoints in this SERA, where applicable.

- Soil screening values - Mortality, growth, and reproduction of plants and soil invertebrates are evaluated by comparing the measured concentrations (maximum) of chemicals in the surface soil to screening values designed to be protective of ecological receptors.
- No-observed-adverse effects levels (NOAELs) for surrogate wildlife species - Mortality, reproductive, and/or developmental effects of birds and mammals are evaluated by comparing the estimated ingested dose from contaminants (maxima and averages) in the surface water, sediment, surface soil, plants, invertebrates, and/or fish to these levels.
- Sediment screening values - Mortality and other adverse effects (e.g., growth, feeding rates, and behavioral changes) of benthic macroinvertebrates are evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the sediment to screening values designed to be protective of ecological receptors.
- Surface water screening values - Mortality and other adverse effects (e.g., growth, feeding rates, behavioral changes) of aquatic organisms are evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the surface water to screening values designed to be protective of ecological receptors.

7.2.5 Selection of Receptor Species

Many receptors in the soil and aquatic environments are adequately described in general categories such as soil invertebrates, vegetation, and sediment-dwelling (benthic) invertebrates. This is due to the nature of the threshold values, effects values, or water-quality criteria that are typically used to characterize risk for such organisms. For vertebrate wildlife receptors, selection of particular species may be required so that intake through eating, drinking, and other routes can be estimated.

Receptor identification is influenced by the contaminants, their likely mode of transport, ultimate fate, and toxicity. For example, most metals (with notable exceptions of cadmium and mercury) typically do not bioaccumulate. For contaminants that bioaccumulate, such as mercury compounds and chlorinated pesticides, effects on upper trophic level receptors need to be assessed. For contaminants that do not bioaccumulate, organisms that are in direct contact with soil and sediment (i.e., sediment- and soil-dwelling organisms and plants) and animals that may incidentally ingest soil particles are selected as receptors for metals if exposure pathways are complete. Sensitivity to particular contaminants is also considered. For example, birds and mammals may have different sensitivities to organic compounds, so each group, or the most sensitive group for a particular contaminant, is assessed.

For most receptor species, ingestion is the primary route of exposure. Indicator species are selected for their preferred habitat, body size, sensitivity, home range, abundance, commercial or sport utilization, legal status, and functional role (e.g., predators). For conservativeness, indicator species may be small and have small home ranges. The availability of exposure parameters such as body mass, feeding rate, and drinking rate may also be a factor in selecting indicator species. The following indicator species are used for the food chain modeling:

- Herbivorous mammal: meadow vole
- Invertivorous mammal: short-tail shrew
- Invertivorous bird: American robin
- Carnivorous bird: Barn owl and Red-tailed hawk
- Carnivorous mammals: fox

7.3 PRELIMINARY ECOLOGICAL EFFECTS EVALUATION

The preliminary ecological effects evaluation is an investigation of the relationship between the magnitude of exposure to a chemical and the nature and magnitude of adverse effects resulting from exposure. As the first step in the ecological effects evaluation, chemicals of potential concern (COPCs) are selected by comparing the contaminant concentrations in the surface water, sediment, and surface soil samples to ecological screening values (ESVs). A hierarchy of ESVs has been specified by Ohio EPA and RVAAP. The first available screening value is used in the hierarchy regardless of whether it may be greater or lesser than other screening values.

Surface water chemical concentrations are compared to chemical criteria for the protection of aquatic life - Outside Mixing Zone Maximum (OMZM) criteria in the Lake Erie Basin from Ohio Administrative Codes (OAC) 3745-1.

Sediment concentrations are screened using the site-specific background concentrations and Ohio Specific Sediment Reference Values (SRVs) (Appendix H in Ohio EPA, 2003) then using a sediment screening hierarchy of: (1) consensus-based threshold effect concentrations (TECs) (MacDonald et al., 2000) and (2) Region 5 ecological data quality levels (EDQLs) (EPA Region 5, 1999).

Soil concentrations are screened using the site-specific background concentrations then using a soil screening value hierarchy in the order given in the guidance, as follows: (1) preliminary remediation goals (PRGs) (Efroymson et al., 1997a); (2) toxicological benchmarks for soil and litter invertebrates (Efroymson et al., 1997b); (3) toxicological benchmarks for terrestrial plants (Efroymson et al., 1997c); and (4) Region 5 EDQLs (EPA Region 5, 1999).

Although the EDQLs have since been updated by the Ecological Screening levels (ESLs) (EPA, 2003a), they were not used as soil or sediment screening levels based on guidance from Ohio EPA.

7.4 PRELIMINARY RISK CALCULATION AND SELECTION OF COPCS

This initial selection of COPCs uses conservative assumptions to screen out chemicals detected during the remedial investigation at concentrations below those levels reported in the literature to cause adverse effects on growth, survival or reproduction. Screening combines a preliminary exposure estimate with a preliminary risk calculation.

The first step in selecting initial COPCs is to select a conservative exposure point concentration (EPCs) for comparison with background and ESVs. The maximum concentration is used as the initial EPC for screening. Screening-level risk calculations compare the conservative exposure estimate to ecological effect values estimated by ESVs. The ratio of the initial EPC to the ESV is called a Hazard Quotient (HQ) and is defined as follows:

$$HQ_I = \frac{EPC_I}{ESV_I}$$

Where:

HQ_I = Hazard Quotient for analyte "I" (unitless)
EPC_I = Exposure Point Concentration for analyte "I" (ug/L or mg/kg)
ESV_I = Ecological Screening Value for analyte "I" (ug/L or mg/kg)

When the ratio of the exposure point concentration to its respective screening value or benchmark exceeds 1.0, adverse impacts are possible, and the chemical is considered for selection as a COPC. The HQ is not probabilistic but a numerical indicator of the extent to which an EPC exceeds an ESV.

Note that calcium, magnesium, potassium, and sodium are not retained as COPCs in any medium because of their relatively low toxicity to ecological receptors and their high natural variability in concentrations.

7.4.1 Soil for Invertebrates, Plants, and Terrestrial Wildlife

The following bullets summarize the procedures that are used in the SERA for CBP to select COPCs.

Inorganic contaminants whose maximum concentrations do not exceed the site-specific background concentrations are not selected as COPCs.

Inorganic and organic contaminants whose maximum concentrations do not exceed soil screening levels are not retained as COPCs, unless the chemicals are bioaccumulative. Inorganic and organic contaminants that are bioaccumulative are selected as COPCs even if their maximum concentration does not exceed a screening level. A chemical was considered to be bioaccumulative if it is included in the list of important bioaccumulative chemicals in USEPA (2000).

Inorganic and organic contaminants without screening values are selected as COPCs.

Table 7-1 summarizes the screening of soil COPCs. Three analytes are retained as COPCs because no screening values are available including 2,4,6-TNT, nitrocellulose, and nitroguainidine. The following analytes were selected as COPCs because their maximum concentrations exceeded their respective ESVs: aluminum, arsenic, barium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. Several bioaccumulative analytes were retained as COPCs although maximums did not exceed soil screening levels including: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, 4,4'-DDE, 4,4'-DDT, Aroclor-1254, endosulfan I and endosulfan II, endrin, gamma-chlordane, heptachlor epoxide, cadmium and silver.

Table 7-1. COPC Selection Table for Surface Soil

Parameter	FOD	Max Conc.	Avg. Conc	Selected Upper Confidence Level	Bkg. Conc.	Max Conc. > Bkg. Conc.	Soil Screening Level		HQ	Bio. Chemical	PBT Chemical	Selected as a COPC?	Rationale
							Value	Source					
Semivolatile Organics (mg/kg)													
BENZO(A)ANTHRACENE	2/10	0.21	0.053	0.195	NA	NA	5.21	d	0.040	YES	NO	YES	BIO
BENZO(A)PYRENE	1/10	0.24	0.054	0.22	NA	NA	1.52	d	0.16	YES	NO	YES	BIO
BENZO(B)FLUORANTHENE	1/10	0.31	0.088	0.275	NA	NA	59.8	d	0.005	YES	NO	YES	BIO
BENZO(K)FLUORANTHENE	2/10	0.36	0.10	0.24	NA	NA	148	d	0.002	YES	NO	YES	BIO
CHRYSENE	2/10	0.26	0.054	0.23	NA	NA	4.73	d	0.055	YES	NO	YES	BIO
FLUORANTHENE	1/10	0.33	0.082	0.3	NA	NA	122	d	0.003	YES	NO	YES	BIO
INDENO(1,2,3-CD)PYRENE	1/10	0.16	0.076	0.145	NA	NA	109	d	0.001	YES	NO	YES	BIO
PHENANTHRENE	1/10	0.093	0.045	0.0653	NA	NA	45.7	d	0.002	YES	NO	YES	BIO
PYRENE	1/10	0.3	0.11	0.265	NA	NA	78.5	d	0.004	YES	NO	YES	BIO
Pesticides PCBs (mg/kg)													
4,4'-DDE	1/10	0.0018	0.00081	0.0016	NA	NA	0.596	d	0.003	YES	YES	YES	BIO
4,4'-DDT	1/10	0.0027	0.00052	0.00155	NA	NA	0.0175	d	0.15	YES	YES	YES	BIO
AROCLOR-1254	3/30	0.24	0.0090	0.142	NA	NA	0.371 (1)	a	0.65	YES	YES	YES	BIO
ENDOSULFAN I	1/10	0.001	0.00034	0.000613	NA	NA	0.119	d	0.008	YES	YES	YES	BIO
ENDOSULFAN II	2/10	0.0034	0.00067	0.003	NA	NA	0.119	d	0.029	YES	YES	YES	BIO
ENDRIN	1/10	0.0024	0.00066	0.00215	NA	NA	0.01	d	0.24	YES	YES	YES	BIO
GAMMA-CHLORDANE	1/10	0.0047	0.00062	0.0046	NA	NA	0.224 (3)	d	0.021	YES	YES	YES	BIO
HEPTACHLOR EPOXIDE	1/10	0.00058	0.00018	0.000335	NA	NA	0.152	d	0.004	YES	YES	YES	BIO
Energetics (mg/kg)													
2,4,6-TNT	2/69	0.18	0.020	0.18	NA	NA	NA	NA	NA	NO	NO	YES	NTX
NITROCELLULOSE	8/10	1.8	1.1	1.24	NA	NA	NA	NA	NA	NO	NO	YES	NTX
NITROGUANIDINE	1/10	0.071	0.12	0.066	NA	NA	NA	NA	NA	NO	NO	YES	NTX
Inorganics (mg/kg)													
ALUMINUM	72/72	31100	13751	15030	17700	YES	50	c	622	NO	NO	YES	ASL
ANTIMONY	22/72	1.8	0.18	1.8	0.96	YES	5	a	0.36	NO	NO	NO	BSL
ARSENIC	71/72	32.8	11.5	15.3	15.4	YES	9.9	a	3.31	YES	NO	YES	ASL,BIO
BARIUM	72/72	417	113	126	88.4	YES	283	a	1.47	NO	NO	YES	ASL
BERYLLIUM	72/72	4.2	1.00	1.11	0.88	YES	10	a	0.42	NO	NO	NO	BSL
CADMIUM	45/72	2.2	0.28	0.393	NA	NA	4	a	0.55	YES	NO	YES	BIO
CALCIUM	72/72	205000	32813	93391	15800	YES	NA	NA	NA	NO	NO	NO	NUT
CHROMIUM	72/72	57.3	16.3	18.0	17.4	YES	0.4	a	143	YES	NO	YES	ASL, BIO
COBALT	70/72	22.3	7.52	8.40	10.4	YES	20	a	1.1	NO	NO	YES	ASL
COPPER	72/72	1260	35.4	25.8	17.7	YES	60	a	21	YES	NO	YES	ASL,BIO

Table 7-1. COPC Selection Table for Surface Soil (continued)

Parameter	FOD	Max Conc.	Avg. Conc	Selected Upper Confidence Level	Bkg. Conc.	Max Conc. > Bkg. Conc.	Soil Screening Level		HQ	Bio. Chemical	PBT Chemical	Selected as a COPC?	Rationale
							Value	Source					
CYANIDE, TOTAL	24/72	99	1.88	92.4	NA	NA	1.33	d	74	NO	NO	YES	ASL
IRON	72/72	107000	21794	26560	23100	YES	200 (2)	b	535	NO	NO	YES	ASL
LEAD	72/72	493	43.4	44.0	26.1	YES	40.5	a	12	YES	NO	YES	ASL,BIO
MAGNESIUM	72/72	22900	4583	5063	3030	YES	NA	NA	NA	NO	NO	NO	NUT
MANGANESE	72/72	6150	979	1215	1450	YES	100 (2)	b	61.5	NO	NO	YES	ASL
MERCURY	71/72	0.079	0.032	0.035	0.04	YES	0.00051	a	155	YES	YES	YES	ASL,BIO
NICKEL	72/72	33.7	13.6	16.3	21.1	YES	30	a	1.1	YES	NO	YES	ASL,BIO
POTASSIUM	72/72	2630	1249	1359	927	YES	NA	NA	NA	NO	NO	NO	NUT
SELENIUM	40/72	2.7	0.69	0.949	1.4	YES	0.21	a	13	YES	NO	YES	ASL,BIO
SILVER	7/72	0.32	0.11	0.32	NA	NA	2	a	0.16	YES	NO	YES	BIO
SODIUM	56/72	1160	175	217	123	YES	NA	NA	NA	NO	NO	NO	NUT
THALLIUM	3/72	4.1	0.33	4.1	NA	NA	1	a	4.1	NO	NO	YES	ASL
VANADIUM	72/72	37	19.9	24.2	31.1	YES	2	a	19	NO	NO	YES	ASL
ZINC	72/72	1500	113	117	61.8	YES	8.5	a	176	YES	NO	YES	ASL,BIO

Notes:

- Average concentration includes positive detections and non-detected results. Detection limits are divided by two.
- Frequency of detection refers to number of times compound was detected among all samples versus total number of samples analyzed for that parameter.
- Number of samples may vary based on the number of usable results.
- Shaded cells are chemicals that are retained as COPCs

Footnotes:

1 - Total PCB value
2 - Based on toxicity to microorganisms
3 - Based on chlordane value

Abbreviations:

Avg. Conc.: Average Concentration
Bio.: Bioaccumulative
Bkg. Conc.: Background Concentration
COPC: Chemical of Potential Concern
FOD: Frequency of Detection
HQ: Hazard Quotient = (Maximum Concentration)/(Surface Soil Screening Level)
Max. Conc.: Maximum Concentration
NA: Not available/Not applicable
PBT: Persistent, Bioaccumulative, and Toxic
PCB: Polychlorinated Biphenyl

Sources of Screening Levels and Heirarchy for Selection:

a - Preliminary Remediation Goals (Efroymson et al., 1997a)
b - Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes (Efroymson et al., 1997b)
c - Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants (Efroymson et al., 1997c)
d - Ecological Data Quality Level (USEPA Region 5, 1999)

7.4.2 Sediment for Benthic Macroinvertebrates, Fish, and Piscivorous Wildlife

The following bullets summarize the procedures that are used in the SERA for CBP to select COPCs:

- Inorganic contaminants whose maximum concentrations do not exceed Ohio Specific SRVs and site-specific background are not selected as COPCs.
- Inorganic and organic contaminants whose maximum concentrations do not exceed screening levels are not selected as COPCs unless they are persistent, bioaccumulative, and toxic (PBT) chemicals as defined in the Ohio EPA ERA guidance (Ohio EPA, 2003). PBT chemicals are selected at COPCs even if their maximum concentration does not exceed a screening level.
- Inorganic and organic contaminants without screening values are selected as COPCs.

Table 7-2 summarizes the initial selection of sediment COPCs. The following analytes are retained as sediment COPCs because no screening values are available: nitrocellulose, barium, beryllium, and manganese. The following contaminants had concentration that exceed their ESVs and are retained as COPCs: benzo(a)anthracene, benzo(a)pyrene, chrysene, pyrene, total PAHs, cadmium, copper, cyanide and lead. The only PBT chemical, mercury, was not selected as a COPC because it was detected at a concentration below the Ohio SRV.

Table 7-2. COPC Selection Table for Sediment

Parameter	FOD	Max Conc.	Avg. Conc	Selected Upper Confidence Level	Bkg. Conc.	Ohio Sediment Reference Value (SRV)(1)	Max Conc. > Bkg. Conc. and Ohio SRV	Sediment Screening Level Value	Sediment Screening Level Source	HQ	PBT Chemical	Selected as a COPC?	Rationale
Volatile Organics (mg/kg)													
ACETONE	1/2	0.016	0.008	NA(2)	NA	NA	NA	0.709	b	0.023	NO	NO	BSL
METHYLENE CHLORIDE	2/2	0.01	0.007	NA(2)	NA	NA	NA	1.26	b	0.008	NO	NO	BSL
Semivolatile Organics (mg/kg)													
BENZO(A)ANTHRACENE	1/2	0.18	0.11	NA(2)	NA	NA	NA	0.108	a	1.7	NO	YES	ASL
BENZO(A)PYRENE	1/2	0.21	0.13	NA(2)	NA	NA	NA	0.15	a	1.4	NO	YES	ASL
BENZO(B)FLUORANTHENE	1/2	0.25	0.16	NA(2)	NA	NA	NA	10.4	b	0.024	NO	NO	BSL
BENZO(K)FLUORANTHENE	1/2	0.21	0.15	NA(2)	NA	NA	NA	0.24	b	0.875	NO	NO	BSL
CHRYSENE	1/2	0.24	0.13	NA(2)	NA	NA	NA	0.166	a	1.4	NO	YES	ASL
INDENO(1,2,3-CD)PYRENE	1/2	0.14	0.11	NA(2)	NA	NA	NA	0.2	b	0.70	NO	NO	BSL
PHENANTHRENE	1/2	0.17	0.11	NA(2)	NA	NA	NA	0.204	b	0.833	NO	NO	BSL
PYRENE	1/2	0.35	0.23	NA(2)	NA	NA	NA	0.195	a	1.8	NO	YES	ASL
TOTAL PAHs	1/2	1.75	1.12	NA(2)	NA	NA	NA	1.61	a	1.1	NO	YES	ASL
Energetics (mg/kg)													
NITROCELLULOSE	2/2	1.1	0.74	NA(2)	NA	NA	NA	NA	NA	NA	NO	YES	NTX
Inorganics (mg/kg)													
ALUMINUM	9/9	19100	9750	NA(2)	13900	29000	NO	NA	NA	NA	NO	NO	BKG
ANTIMONY	1/9	0.32	0.16	NA(2)	NA	1.3	NO	NA	NA	NA	NO	NO	BKG
ARSENIC	9/9	20.1	10.8	NA(2)	19.5	25	NO	9.79	a	2.1	NO	NO	BKG
BARIUM	9/9	214	87.7	NA(2)	123	190	YES	NA	NA	NA	NO	YES	NTX
BERYLLIUM	8/9	1.3	0.7	NA(2)	0.38	0.8	YES	NA	NA	NA	NO	YES	NTX
CADMIUM	5/9	1.4	0.46	NA(2)	NA	0.79	YES	0.99	a	1.4	NO	YES	ASL
CALCIUM	9/9	32600	10787	NA(2)	5510	21000	YES	NA	NA	NA	NO	NO	NUT
CHROMIUM	9/9	21.6	12.9	NA(2)	18.1	29	NO	43.4	a	0.5	NO	NO	BSL,BKG

Table 7-2. COPC Selection Table for Sediment (continued)

Parameter	FOD	Max Conc.	Avg. Conc	Selected Upper Confidence Level	Bkg. Conc.	Ohio Sediment Reference Value (SRV)(1)	Max Conc. > Bkg. Conc. and Ohio SRV	Sediment Screening Level		HQ	PBT Chemical	Selected as a COPC?	Rationale
								Value	Source				
COBALT	9/9	14.2	8.0	NA(2)	9.1	12	YES	50	b	0.284	NO	NO	BSL
COPPER	9/9	141	29.2	NA(2)	27.6	32	YES	31.6	a	4.5	NO	YES	ASL
CYANIDE, TOTAL	4/9	1.2	0.50	NA(2)	NA	NA	NA	0.0001	b	12000	NO	YES	ASL
IRON	9/9	65700	22043	NA(2)	28200	41000	YES	NA	NA	NA	NO	NO	NUT
LEAD	9/9	79.5	29.2	NA(2)	27.4	47	YES	35.8	a	2.2	NO	YES	ASL
MAGNESIUM	9/9	4820	2611	NA(2)	2760	7100	NO	NA	NA	NA	NO	NO	NUT,BKG
MANGANESE	9/9	2590	739	NA(2)	1950	1500	YES	NA	NA	NA	NO	YES	NTX
MERCURY	6/9	0.11	0.04	NA(2)	0.06	0.12	NO	0.18	a	0.611	YES	NO	BSL, BKG
NICKEL	9/9	25.8	16	NA(2)	17.7	33	NO	22.7	a	1.1	NO	NO	BKG
POTASSIUM	9/9	3300	1301	NA(2)	1950	6800	NO	NA	NA	NA	NO	NO	NUT,BKG
SELENIUM	2/9	1.1	0.28	NA(2)	1.7	1.7	NO	NA	NA	NA	NO	NO	BKG
SILVER	3/9	0.39	0.19	NA(2)	NA	0.43	NO	0.5	b	0.78	NO	NO	BSL,BKG
SODIUM	9/9	260	129	NA(2)	112	NA	YES	NA	NA	NA	NO	NO	NUT
VANADIUM	9/9	30.4	16.2	NA(2)	26.1	40	NO	NA	NA	NA	NO	NO	BKG
ZINC	9/9	490	192	NA(2)	532	160	NO	121	a	4.0	NO	NO	BKG

Table 7-2. COPC Selection Table for Sediment (continued)

Parameter	FOD	Max Conc.	Avg. Conc	Selected Upper Confidence Level	Bkg. Conc.	Ohio Sediment Reference Value (SRV)(1)	Max Conc. > Bkg. Conc. and Ohio SRV	Sediment Screening Level		HQ	PBT Chemical	Selected as a COPC?	Rationale
								Value	Source				
Miscellaneous Parameters (mg/kg)													
TOTAL ORGANIC CARBON	9/9	5700	20576.000	NA(2)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

- Average concentration includes positive detections and non-detected results. Detection limits are divided by two.

- Frequency of detection refers to number of times compound was detected among all samples versus total number of samples analyzed for that parameter.

- Number of samples may vary based on the number of usable results.

Acronyms:

1 - Erie/Ontario Lake Plain value is used.

2 - An Upper Confidence Level was not calculated because the pararameter was analyzed for in less than 10 samples.

Abbreviations:

Avg. Conc.: Average Concentration
Bkg. Conc.: Background Concentration
COPC: Chemical of Potential Concern
FOD: Frequency of Detection
HQ: Hazard Quotient = (Maximum Concentration)/(Sediment Screening Level)
Max. Conc.: Maximum Concentration
NA: Not available/Not applicable
PBT: Persistent, Bioaccumulative, and Toxic

Sources of Screening Levels and Heirarchy for Selection:

a - Threshold Effects Concentration from McDonald et al., (2000)
b - Ecological Data Quality Level (USEPA Region 5, 1999)

Rationale Codes:

For Selection as a COPC:

ASL = Above Sediment Screening Level
BIO = Bioaccumulative
NTX = No Toxicity Data Available/Screening Level not Available

For Elimination as a COPC:

BSL = At or Below COPC Screening Level
BKG = At or less than the Background Concentration or Ohio Sediment Reference Value
NUT = Essential Nutrient

7.4.3 Surface Water for Protection of Aquatic Life

The following bullets summarize the procedures that are used in the SERA for CBP to select COPCs:

- Inorganic contaminants whose maximum concentrations do not exceed background are not selected as COPCs.
- Inorganic and organic contaminants whose maximum concentrations do not exceed water quality criteria in OAC 3745-1 are not retained as COPCs
- Inorganic and organic contaminants without screening values are retained as COPCs.

Table 7-3 summarizes the screening of surface water COPCs. No analytes were selected as surface water COPCs.

Table 7-3. COPC Selection for Surface Water

Parameter	FOD	Max Conc.	Avg. Conc	Bkg. Conc.	Max Conc. > Bkg. Conc.	Surface Water Screening Level		HQ	PBT Chemical	Selected as a COPC?	Rationale
						Value	Source				
Inorganics (ug/L)											
Aluminum	2/3	98.6	50.08	3370	NO	NA	NA	NA	NO	NO	BKG
Arsenic	2/3	3.2	2.03	3.2	NO	340 (1)	a	0.0094	NO	NO	BSL,BKG
Barium	3/3	44.5	42.35	47.5	NO	2000 (1)	a	0.0223	NO	NO	BSL,BKG
Calcium	3/3	76600	71183.33	41400	YES	NA	NA	NA	NO	NO	NUT
Iron	3/3	706	458.17	2560	NO	1000	b	0.7060	NO	NO	BSL,BKG
Magnesium	3/3	21200	20433.33	10800	YES	NA	NA	NA	NO	NO	NUT
Manganese	3/3	180	148.00	391	NO	NA	NA	NA	NO	NO	BKG
Potassium	3/3	2200	1851.67	3170	NO	NA	NA	NA	NO	NO	NUT,BKG
Sodium	3/3	7480	7091.67	21300	NO	NA	NA	NA	NO	NO	NUT,BKG
Zinc	3/3	12.6	9.32	42	NO	210 (1,2)	a	0.0600	NO	NO	BSL,BKG

Notes:

- Average concentration includes positive detections and non-detected results. Detection limits are divided by two.
- Frequency of detection refers to number of times compound was detected among all samples versus total number of samples analyzed for that parameter.
- Number of samples may vary based on the number of usable results.

Footnotes:

1 - Outside Mixing Zone Maximum value.
2 - Based on water hardness of 200 mg/L and using dissolved criteria.

Abbreviations:

Avg. Conc.: Average Concentration
Bkg. Conc.: Background Concentration
COPC: Chemical of Potential Concern
FOD: Frequency of Detection
HQ: Hazard Quotient = (Maximum Concentration)/(Surface Water Screening Level)
Max. Conc.: Maximum Concentration
NA: Not available/Not applicable
PBT: Persistent, Bioaccumulative, and Toxic

Sources of Screening Levels and Heirarchy for Selection:

a - Ohio Water Quality Criteria (Reg 3745-1-07)
b - USEPA Recommended Water Quality Criteria (USEPA, 2002)

Rationale Codes:

For Elimination as a COPC:

BSL = At or Below COPC Screening Level
BKG = At or less than the Background Concentration
NUT = Essential Nutrient

7.5 REFINEMENT OF CONSERVATIVE EXPOSURE ASSUMPTIONS METHODOLOGY

As discussed in Section 7.1, Step 3a is technically the first step of a BERA (although it is included in this SERA) and consists of refining the conservative exposure assumptions/concentrations when evaluating potential risks to ecological receptors (i.e., plants, invertebrates, and wildlife receptors) and re-evaluating the analytical data using benchmarks that may be more appropriate for the assessment endpoints. The objective of the Step 3a evaluation is to further reduce the number of chemicals retained as COPCs, if possible, to focus any additional efforts on those chemicals causing ecological concern. The Step 3a evaluation is designed to eliminate chemicals from further evaluation for certain groups of receptors. For example, a chemical may not be retained as a COPC in soil based on risks to soil invertebrates but may be retained for evaluating risks to plants or wildlife. Therefore, chemicals are evaluated during Step 3a in order of plants/invertebrates, aquatic receptors, and wildlife. The following sections present the methodology for evaluating risks to these receptors.

7.5.1 Surface Soil

Chemicals that were initially selected as COPCs in surface soil were carried through three independent flow paths: 1) to further evaluate risks to plants, 2) to further evaluate risks to invertebrates, and 3) to further evaluate risks to wildlife (i.e., mammals and birds). This further evaluation was conducted to determine if there are potential risks to all three receptor groups (i.e., plants, invertebrates, and wildlife), or to only one or two of the receptor groups. This is important because if the site proceeds further in a BERA, the studies in the BERA should only focus on the receptors that are potentially at risk. The first step in the Step 3a evaluation was to compare the maximum and average chemical concentrations in the soil to toxicity benchmarks that are based on effects to earthworms and plants. Tables 7-4 and 7-5 present this comparison for earthworms and plants, respectively.

The following hierarchy was used to select the earthworm benchmark in Table 7-4:

- USEPA Eco-SSLs for earthworms (EPA, 2000b; 2003a-f). These values were selected first because they are USEPA values and are the most recent values.
- The greater of the values from the following two sources. Because both of the following sources are typically used as screening levels in ERAs, the values from either source should be protective of earthworms. For that reason, the greater value was selected to refine the list of chemicals retained as COPCs.
- Canadian Soil Quality Guidelines (EC, 1999a-d).
- Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (Efroymson, et al., 1997b).

Table 7-4. Direct Toxicity to Earthworms

Parameter	FOD	Maximum Concentration	Average Concentration	Selected Upper Confidence Level	Earthworm Toxicity Benchmarks	Source	Maximum > TRV?	Average > TRV?
Energetics (mg/kg)								
2,4,6-TNT	2/69	0.18	0.02	0.18	No TRV	NA	No TRV	No TRV
Nitrocellulose	8/10	1.8	1.07	1.24	No TRV	NA	No TRV	No TRV
Nitroguanidine	1/10	0.071	0.12	0.066	No TRV	NA	No TRV	No TRV
Inorganics (mg/kg)								
Aluminum	72/72	31100	13750.8	15030.3	No TRV	NA	No TRV	No TRV
Arsenic	71/72	32.8	11.5	15.3	60	b	NO	NO
Barium	72/72	417	113	126	330	a	YES	NO
Chromium	72/72	57.3	16.3	18.0	78	c	NO	NO
Cobalt	70/72	22.3	7.52	8.40	No TRV	NA	No TRV	No TRV
Copper	72/72	1260	35.4	25.8	63	c	YES	NO
Cyanide, Total	24/72	99	1.88	92.4	0.9	c	YES	YES
Iron	72/72	107000	21794	26560	pH(1)	NA	NA	NA
Lead	72/72	493	43.4	44.0	1700	a	NO	NO
Manganese	72/72	6150	979	1215	No TRV	NA	No TRV	No TRV
Mercury	71/72	0.079	0.03	0.035	12	c	NO	NO
Nickel	72/72	33.7	13.6	16.3	200	b	NO	NO
Selenium	40/72	2.7	0.69	0.949	70	b	NO	NO
Thallium	3/72	4.1	0.33	4.1	1.4	c	YES	NO
Vanadium	72/72	37	19.9	24.2	130	c	NO	NO
Zinc	72/72	1500	113	117	200	b,c	YES	NO

Notes:

- Average concentration includes positive detections and non-detected results. Detection limits are divided by two.
- Frequency of detection refers to number of times compound was detected among all samples versus total number of samples analyzed for that parameter.
- Number of samples may vary based on the number of usable results.

1 - Benchmark for iron is based on the pH of the soil.

Sources of Earthworm Toxicity Benchmarks:

a - Ecological Soil Screening Level (Eco-SSL) from USEPA, (2003a-e).
b - Earthworm toxicity benchmark from Efroymson et al., 1997b.
c - Canadian Soil Quality Guideline (SQG) from Environment Canada (EC, 1999a-d).

The following hierarchy was used to select the plant benchmark in Table 7-5:

- USEPA Ecological Soil Screening Levels (Eco-SSLs) for plants (EPA, 2000b, USEPA 2003a-e). These values were selected first because they are USEPA values and are the most recent values.
- The greater of the values from the following two sources. Because both of the following sources are typically used as screening levels in ERAs, the values from either source should be protective of plants. For that reason, the greater value was selected to refine the list of chemicals retained as COPCs.
  - Canadian Soil Quality Guidelines (EC, 1999a-d).
  - ORNL Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision (Efroymson, et al., 1997c).

Table 7-5. Direct Toxicity to Plants

Parameter	Frequency Of Detection	Maximum Concentration	Average Concentration	Selected Upper Confidence Level	Plant Toxicity Benchmarks	Source	Maximum > TRV?	Average > TRV?
Energetics (mg/kg)								
2,4,6-TNT	2/69	0.18	0.02	0.18	No TRV	NA	No TRV	No TRV
Nitrocellulose	8/10	1.8	1.07	1.24	No TRV	NA	No TRV	No TRV
Nitroguanidine	1/10	0.071	0.12	0.066	No TRV	NA	No TRV	No TRV
Inorganics (mg/kg)								
Aluminum	72/72	31100	13750.8	15030.3	pH(1)	a	NA	NA
Arsenic	71/72	32.8	11.5	15.3	17.1	c	YES	NO
Barium	72/72	417	113	126	500	b	NO	NO
Chromium	72/72	57.3	16.3	18.0	78	c	NO	NO
Cobalt	70/72	22.3	7.52	8.40	13	a	YES	NO
Copper	72/72	1260	35.4	25.8	100	b	YES	NO
Cyanide, Total	24/72	99	1.88	92.4	0.9	c	YES	YES
Iron	72/72	107000	21794	26560	pH(1)	a	NA	NA
Lead	72/72	493	43.4	44.0	115	a	YES	NO
Manganese	72/72	6150	979	1215	500	b	YES	YES
Mercury	71/72	0.079	0.03	0.035	12	c	NO	NO
Nickel	72/72	33.7	13.6	16.3	50	c	NO	NO
Selenium	40/72	2.7	0.69	0.949	1	b,c	YES	NO
Thallium	3/72	4.1	0.33	4.1	1.4	c	YES	NO
Vanadium	72/72	37	19.9	24.2	130	c	NO	NO
Zinc	72/72	1500	113	117	200	c	YES	NO

Notes:

- Average concentration includes positive detections and non-detected results. Detection limits are divided by two.
- Frequency of detection refers to number of times compound was detected among all samples versus total number of samples analyzed for that parameter.
- Number of samples may vary based on the number of usable results.

1 - Benchmarks for aluminum and iron are based on the pH of the soil.

Sources of Plant Toxicity Benchmarks:

a - Ecological Soil Screening Level (Eco-SSL) from USEPA, (2003a-e).
b - Plant toxicity benchmark from Efroymson et al., 1997c.
c - Canadian Soil Quality Guideline (SQG) from Environment Canada (EC, 1999a-d).

If the chemical concentration is less than the benchmarks for earthworms and/or plants, it was concluded that the chemical is not causing an unacceptable risk to that receptor group and the chemical was not evaluated further in Step 3a for that receptor group.

If the chemical concentration was greater than the benchmarks for earthworms and/or plants (or the chemical does not have a benchmark), the chemical was further evaluated in Step 3a to determine if the risks are great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, etc.].

Concurrent with the evaluation of risks to plants and invertebrates, bioaccumulative chemicals that were retained as COPCs were further evaluated to determine if there are unacceptable risks to wildlife. If the chemical is not bioaccumulative, it was not carried through the food chain model and it was concluded that the chemical is not causing an unacceptable risk to wildlife. If the chemical is bioaccumulative, it was carried through the food chain model. The following bullets outline decisions that were made based on the results of the food chain model:

- If the HQ is less than 1.0 using average contaminant concentrations and the NOAEL as the TRV, it was concluded that the chemical is not causing an unacceptable risk to wildlife and the chemical was not evaluated further in Step 3a.
- If the HQ is greater than 1.0 using average contaminant concentrations and the NOAEL as the TRV, the chemical was further evaluated in Step 3a to determine if the risks are great enough to warrant additional evaluations (i.e., proceed to a BERA, develop cleanup levels, etc.).

For chemicals evaluated further in Step 3a, the other Step 3a factors described below in Section 7.5.4 were used to determine if the risks are great enough to warrant additional evaluations (i.e., proceed to a BERA, develop cleanup levels, etc.).

7.5.2 Sediment

Chemicals selected as COPCs in sediment were evaluated for risks to benthic invertebrates in the Step 3a evaluation. No PBT chemicals were retained as COPCs in sediment so dietary risks to piscivorous wildlife were not evaluated in Step 3a. The risk to benthos was evaluated by comparing the average chemical concentrations in the sediment to the benthos screening level, and then to compare the maximum and average chemical concentrations in the sediment to higher effects-levels (as described below). Table 7-6 presents this comparison.

Table 7-6. Step 3a Table for Evaluating Risks to Sediment Invertebrates

				Screening Level Comparison		**Higher Effects-Level Comparison**			
Chemical of Potential Concern (COPC)(1)	**FOD**	**Maximum Concentration**	**Average Concentration**	**Screening Level(2)**	**Average > Screening Level**	**Higher Effects Level**	**Source**	**Maximum > Higher Effects Level**	**Average > Higher Effects Level**
Semivolatile Organics (mg/kg)									
Benzo(a)Anthracene	1/2	0.18	0.11	0.108	YES	1.1	a	NO	NO
Benzo(A)Pyrene	1/2	0.21	0.13	0.15	NO	1.5	a	NO	NO
Chrysene	1/2	0.24	0.13	0.166	NO	1.3	a	NO	NO
Pyrene	1/2	0.35	0.23	0.195	YES	1.5	a	NO	NO
Total PAHs	1/2	1.75	1.12	1.61	NO	23	a	NO	NO
Energetics (mg/kg)									
Nitrocellulose	2/2	1.1	0.74	No TRV	NA	No TRV	NA	NA	NA
Inorganics (mg/kg)									
Barium	9/9	214	87.7	No TRV	NA	48	c	YES	YES
Beryllium	8/9	1.3	0.66	No TRV	NA	No TRV	NA	NA	NA
Cadmium	5/9	1.4	0.46	0.99	NO	5.0	a	NO	NO
Copper	9/9	141	29.2	31.6	NO	149	a	NO	NO
Cyanide, Total	4/9	1.2	0.50	0.0001	YES	No TRV	NA	NA	NA
Lead	9/9	79.5	29.2	35.8	NO	128	a	NO	NO
Manganese	9/9	2590	739	460(3)	YES	1100	b	YES	NO

Footnotes:

1 - This table only presents that chemicals that were retained as COPCs because the maximum detected concentration exceeded the screening level or the chemical did not have a screening level.

2 - Table 7-2 presents the source of the screening levels.

3 - This value was not used as a screening level because it was not in the hiearchy provided in the Ohio EPA ERA Guidance (Ohio EPA, 2003).

The value is the lowest effects level from OMOE (1993).

Sources of Higher Effects Levels:

a - Probable Effects Concentration from MacDonald et al., 2000.

b - Severe Effect Level from OMOE, 1993.

c - Apparent Effect Threshold from Buchman 1999.

As discussed in Section 7.3, the TEC from MacDonald el al., (2000) was used as the primary source of the sediment screening, followed by the USEPA Region 5 EDQL (EPA Region 5, 1999). TECs are considered "lower effects-levels" because they are intended to identify contaminant concentrations below which harmful effects on benthos are not expected. Probable effects concentrations (PECs) are considered "higher effects-levels" because they are intended to identify concentrations above which harmful effects are expected to occur. Therefore, the PECs were selected first as the higher effects-level in Table 7-6. Because there is no corresponding higher effects-levels for the EDQLs, the severe effects-level (SEL) from the Ontario sediment quality guidelines (OMOE, 1993) was selected next followed by the apparent effects threshold (AET) in Buchman (1999).

All of the chemicals that were selected as COPCs were evaluated further in Step 3a using the benchmarks described above along with the other Step 3a factors described below to determine if the risks are great enough to warrant additional evaluations (i.e., proceed to a BERA, develop cleanup levels, etc.).

7.5.3 Surface Water

No chemicals were selected as COPCs in surface water.

7.5.4 Other Step 3a Factors

For chemicals that are evaluated further in Step 3a, the following factors were evaluated, as appropriate, to determine if the risks are great enough to warrant additional evaluations (i.e., proceed to a BERA, develop cleanup levels, etc.).

- Magnitude of criterion exceedance: Although the magnitude of the risks may not relate directly to the magnitude of a criterion exceedance, the magnitude of the criterion exceedance may be one item used in a lines-of-evidence approach to determine the need for further site evaluation. The greater the criterion exceedance, the greater the probability and concern that an unacceptable risk exists.

- Frequency of chemical detection and spatial distribution: A chemical detected at a low frequency typically is of less concern than a chemical detected at higher frequency if toxicity and concentrations and spatial areas represented by the data are similar. All else being equal, chemicals detected frequently were given greater consideration than those detected relatively infrequently.

- Contaminant bioavailability: Many contaminants (especially metals) are present in the environment in forms that are typically not bioavailable, and the limited bioavailability was considered when evaluating the exposures of receptors to site contaminants. Contaminants with generally less bioavailability are considered to be less toxic than the more bioavailable contaminants, all other factors being equal.

- Habitat: Although exceedances of criteria may occur, potential risks to ecological receptors may be minimal if there is little habitat for those receptors. Therefore, the extent of habitat was used qualitatively when considering additional evaluation. Areas with little habitat were less of a concern than areas with suitable habitat to support the receptors of interest.

- Alternate benchmarks: Use of alternate benchmarks ensures that more realistic exposure assumptions are evaluated. However, some of the alternate benchmarks are overly protective for some receptors and may not have been used in some cases. For example, the EDQLs and PRGs for soil may be based on risks to small mammals. Therefore, an exceedance of that EDQL does not necessarily indicate that potential risks to plants or invertebrates exist, so other more appropriate benchmarks were used to evaluate potential risks to those receptors. Use of these alternate benchmarks was case-specific.

7.5.5 Terrestrial Food Chain Modeling

In order to evaluate potential risks to terrestrial wildlife ingestion of the soil, surface water, plants, invertebrates, and small mammals, terrestrial intake modeling was used to estimate the exposure of the COPCs to terrestrial wildlife receptors. Chemicals evaluated in the terrestrial food-chain model were limited to those identified by the USEPA as bioaccumulative (EPA, 2000). The primary reason for including only bioaccumulative chemicals in the food chain model is based on the assumption that although wildlife can be exposed to chemicals that do not accumulate in food items (i.e., plants, invertebrates), via direct ingestion of the media (i.e., soil), the exposure of the animal consuming that chemical will be low if the chemical is not accumulating in the food item.

Risk to terrestrial receptors from COPCs in the soil, surface water and prey is determined by estimating the chronic daily intake (CDI) and comparing the CDI to TRVs representing acceptable daily doses in mg/kg/day. The TRVs are developed from NOAELs and lowest-observed-adverse-effect-levels (LOAELs) obtained from wildlife studies, if available. The majority of the TRVs are obtained from the ORNL Toxicological Benchmarks for Wildlife: 1996 Revision (Sample et al., 1996). Other sources for NOAELs and LOAELs were used as necessary. Appendix T presents the TRVs that are used in this report and the derivation of the TRVs using the body-weight scaling equation presented below.

For avian species, the NOAEL (or LOAEL) for the test species is used as the NOAEL (or LOAEL) for the surrogate species in accordance with Sample et al. (1996). For mammalian species, the NOAEL (or LOAEL) from one species is adjusted to a NOAEL (or LOAEL) for the surrogate species using the following body-weight scaling equation from Sample et al. (1996):

$$\text{NOAELw} = \text{NOAELt} * (\text{bwt/bww})\,)^{0.25}$$

Where:

NOAELw = no-observed-adverse-effect-level for the surrogate wildlife species
NOAELt = no-observed-adverse-effect-level for the test species
bwt = body weight of the test species
bww = body weight of the surrogate test species

The body-weight scaling is done because studies have shown that, for mammals, numerous physiological functions such as metabolic rate, as well as responses to toxic chemicals, are a function of body size (Sample et al., 1996). However, Sample et al. (1996) indicated that physiological scaling factors may not be appropriate for birds. Therefore, no body-weight scaling was conducted for the bird TRVs. No avian TRVs were available for PAHs so a default of 2 mg/kg/d was used for the NOAEL. Appendix T presents the body weights that are used for the surrogate and potential test species.

If LOAELs were derived, then NOAELs were calculated by dividing by 10. If NOAELs were derived, then LOAELs were estimated by multiplying the NOAEL by 10. NOAELs or LOAELs were derived in WBG Remedial Investigation (USACE, 1999)

7.5.5.1 Characterization of Exposure

This section describes the potential or actual contact or co-occurrence of the contaminants with the receptors to determine their exposure dose.

Terrestrial soil invertebrates and plants are exposed to contaminants in the surface soil through direct contact and/or ingestion. The maximum or selected upper confidence level (UCL) and average soil, and surface water concentrations are used in the food chain model to obtain a range of exposure from ingestion of soil and surface water.

Exposure of the terrestrial receptors to the COPCs in the surface soil and surface water is determined by estimating the daily doses in mg/kg/day using exposure equations. The contaminant concentrations in the surface soil and surface water are used to calculate the CDI doses. The following equation presents the food chain model that is used for the surrogate species that are selected for modeling:

$$\text{CDI Dose (mg/kg/day)} = (\text{FI} * \text{FC}) + (\text{WI} * C_{\text{Sw}}) + (\text{SI} * C_{\text{Ss}})$$

Where:

CDI = Chronic daily intake (mg/kg/day)
FI = Food ingestion rate (kg/day)
FC = Food concentration (mg/kg)
WI = Surface water ingestion rate (L/day)
C_{Sw} = Contaminant concentration in surface water (mg/L)
BW = Body weight (kg)
SI = Incidental soil ingestion rate (kg/day)
C_{Ss} = Contaminant concentration in surface soil (mg/kg)

For inorganic and organic constituents in surface soil, the contaminant concentration of the prey items (i.e., earthworms) is calculated using the following equation:

$$\text{FC} = C_{\text{SO}} * \text{BAF}$$

Where:

FC = Contaminant concentration in food (mg/kg)

C_{SO} = Contaminant concentration in soil (mg/kg)
BAF = Bioaccumulation Factor (chemical-specific)

For inorganic and organic constituents in small mammal tissue, the contaminant concentration of the prey items is calculated using the following equation:

$$FC = C_{SO} * BAF_{si} * BAF_{dm}$$

Where:

FC = Contaminant concentration in food (mg/kg)
C_{So} = Contaminant concentration in soil (mg/kg)
BAF_{si} = Bioaccumulation Factor for soil to invertebrate (chemical-specific)
BAF_{dm} = Bioaccumulation Factor for diet to mammal (chemical-specific)

The exposure assumptions (i.e., ingestion rate, body weight) are obtained from the RVAAP Ecological Risk guidance (USACE, 2003a). Appendix T presents the exposure parameters that are used in the SERA. Note that the receptors home ranges are not used quantitatively in the food chain model. However, the home ranges are discussed qualitatively in the Step 3a evaluation and uncertainty analysis section, when applicable.

7.5.5.2 Ecological Risk Characterization

The risk characterization is the final phase of a risk assessment that compares the exposure to the ecological effects. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated. The HQ approach (as described in Section 7.4) is used to characterize the risk to terrestrial receptors. This approach characterizes the potential effects by comparing exposure concentrations with the effects data. An HQ greater than 1.0 is considered to indicate a potential risk. The HQ is not an expression of probability, and the meaning of values greater than 1.0 must be interpreted in light of attendant uncertainties in risk management.

The HQ for the terrestrial wildlife model is calculated as follows:

$$HQ = \frac{Dose}{TRV}$$

Where:

HQ = Hazard Quotient (unitless)
Dose = Daily Intake Dose (mg/kg/day)
TRV = Toxicity Reference Value (NOAEL or LOAEL) (mg/kg/day)

7.6 STEP 3A REFINEMENT

Subsequent to the initial screening, other factors are considered to further refine COPCs, as discussed in Section 7.5. The following sections present the results of the Step 3a refinement.

7.6.1 Risks to Terrestrial Plants and Invertebrates

Potential risks to terrestrial plants and terrestrial invertebrates from exposure to COPCs were evaluated using the methodologies described in Section 7.5.1. The following subsections discuss whether the chemicals initially selected as COPCs should be retained for further evaluation of risks to soil invertebrates and terrestrial vegetation. Note that bioaccumulative chemicals that were detected at concentrations less than their respective screening levels are not discussed below, because the chemicals are not COPCs for risks to plants and invertebrates (see Table 7-1).

Tables 7-4 and 7-5 summarize the results of potential direct toxicity of chemicals in soil to earthworms and plants, respectively. The tables only list the chemicals that were retained as COPCs because they were detected at concentrations that exceeded screening levels or they did not have screening levels. Chemicals that were only retained as COPCs because they were bioaccumulative are not listed on the table. Both maximum and average concentrations are compared to the toxicity benchmarks for earthworms. Barium, copper, cyanide, thallium and zinc were the chemicals with maximum detected concentrations greater than the earthworm toxicity benchmarks; only the average chemical concentration for cyanide was greater than the benchmarks. The maximum concentrations of arsenic, cobalt, copper, cyanide, lead, manganese, selenium, thallium and zinc were greater than the plant toxicity benchmarks; only the averages for cyanide and manganese were greater than the benchmarks. Earthworm and/or plant benchmarks were not available for several of the chemicals including 2,4,6-TNT, nitrocellulose, nitroguanidine, aluminum, and iron. Initial COPCs that indicate no direct toxicity to plants or soil invertebrates include chromium, mercury, nickel and vanadium. The following text presents the Step 3a evaluation for the chemicals listed above that were detected at concentrations greater than the earthworm or plant toxicity benchmarks and chemicals that do not have earthworm or plant toxicity benchmarks.

7.6.1.1 2,4,6-TNT, Nitrocellulose and Nitroguanidine

These chemicals were initially selected as COPCs because screening levels were not available. For 2,4,6-TNT, there is an earthworm TRV of 140 mg/kg and a plant TRV of 30 mg/kg (Talmage et al., 1999). The maximum concentration of 0.18 mg/kg was much less than either TRV. Therefore, 2,4,6-TNT is not retained as a COPC for risks to earthworms or plants. Nitrocellulose and nitroguanidine are typically considered to be a relative inert compound so are unlikely to impact plants or invertebrates. As such, neither compound is retained as a COPC for risks to plants or invertebrates.

7.6.1.2 Aluminum

Aluminum was selected as a COPC because the soil screening level was exceeded. However, the screening value is the toxicological benchmark to protect plants and is based on laboratory toxicity testing using soluble aluminum added to soils. The standard analytical measurement of aluminum in soils is total recoverable aluminum (soluble + fixed). Comparison of total aluminum concentration in soils to soluble aluminum-based benchmarks and screening values is probably not appropriate. EPA has proposed an alternative screening procedure (EPA, 2003a) that aluminum should be identified as a COPC only at sites where the soil pH is less than 5.5. No soil pH was collected at CBP but the average soil pH levels at Load Lines 2, 3, and 4 were greater than 5.5 (USACE, 2003a, 2003b, and 2003c). Potential impacts from aluminum are unlikely because of the soil pH and consequently, the risks to plants and invertebrates from aluminum are acceptable, and it is not retained as a COPC for risks to plants or invertebrates.

7.6.1.3 Arsenic

This inorganic chemical was initially selected as a COPC because the maximum detected concentration (32.8 mg/kg) exceeded the ORNL PRG (9.9 mg/kg) (Efroymson, et al., 1997a). The PRG is based on risks to wildlife (short-tail shrew) and plants. The maximum detected arsenic concentration in soil is greater than the Canadian SQG of 17.1 mg/kg (EC, 1999a), which is based on plant and earthworm toxicity data. No direct toxicity to earthworms is expected based on the ORNL earthworm benchmark (Efroymson et al., 1997b) of 60 mg/kg (see Table 7-4), but impacts to plants are possible at SS-001, -002, -004, -008, -009, -018, and -031 based on exceedance of the SQG (EC, 1999a). These sample sites are not clustered around the known piles but the site of the maximum (SS-004) is in an area west of the Lumber Yard Rd and south of the burn pits identified as "discolored soil" in the Relative Risk Site Evaluation (USACHPM, 1998) and described as hard-packed during sampling. Since potential risks to plants are possible at a relatively small number of sample sites (7/33), the risks are not great enough to warrant retaining arsenic as a COPC for further evaluation in the ERA for several reasons. The maximum detected arsenic concentration of 32.8 mg/kg is only slightly greater than two times the background concentration (15.4 mg/kg) and does not indicate a "hot spot." Therefore, the average arsenic concentration of 11.5 mg/kg was compared to the Canadian SQG to determine if potential risks are wide spread. The average arsenic concentration was less than the Canadian SQG and the background concentration so further evaluation of risk to plants in the BERA is not necessary. In summary, risks to plants and invertebrates from arsenic are acceptable and arsenic is not retained as a COPC for risks to plants or invertebrates. However, because arsenic is a bioaccumulative chemical, risks to wildlife from arsenic are evaluated in Section 7.7 of this ERA.

7.6.1.4 Barium

This inorganic was initially selected as a COPC because the maximum detected concentration (417 mg/kg) exceeded the ORNL PRG (283 mg/kg) (Efroymson, et al., 1997a) and background (88.4 mg/kg). The PRG is based on risks to wildlife (woodcock). No direct toxicity to plants is expected based on the ORNL plant toxicity benchmark (500 mg/kg) (Efroymson, et al., 1997c) but impacts to soil invertebrates are possible based on exceedance of the Eco-SSL (330 mg/kg)(EPA, 2003b). Potential risks to earthworms are indicated at only 2 of 34 sites (SS-006 and SS-013) with the maximum occurring at SS-013 at the south end of the burn piles. Since the potential impact to soil invertebrates is indicated in a small area, the risks from barium are expected to be acceptable and barium is not retained as a COPC for risks to plants and invertebrates.

7.6.1.5 Cobalt

Initially retained as a COPC due to exceedance by the maximum detected concentration (22.3 mg/kg) of the ORNL PRG (20 mg/kg) for plants (Efroymson, et al., 1997c), the cobalt maximum also exceeded the Eco-SSL for plants (13 mg/kg)(EPA, 2003c). No TRV for earthworms was available. The maximum is only slightly greater than twice the background (10.4 mg/kg) and so the average cobalt concentration was compared to the plant TRV. The average concentration (7.52 mg/kg) is less than the Eco-SSL indicating that the potential impacts are not widespread. Five of the 34 sample sites exceeded the Eco-SSL (SB-005, SS-009, -019, -027 and -030). These sample sites were not clustered near the burn piles and do not appear to be site-related. Since the potential impact to plants is not widespread, the risk from cobalt is acceptable and it is not retained as a COPC.

7.6.1.6 Copper

Copper was selected as an initial COPC due to the exceedance of the ORNL PRG (60 mg/kg) by the maximum detected concentration (1260 mg/kg). The PRG is based on earthworm toxicity (Efroymson, et al., 1997a). The draft Eco-SSL of 61 mg/kg (EPA, 2000b) and the ORNL plant toxicity benchmark (100 mg/kg) (Efroymson, et al., 1997c) were also exceeded. Again, the Eco-SSL was exceeded by only 4/34 sample sites (SS-013, SS-014, SS-018, and SS-030) and the plant TRV was exceeded by only 2 (SS-013 and SS-014). All of these exceedances were grouped near the known burn piles and indicate potential impacts to plants and soil invertebrates from site-related activities. The area potentially impacted is small but clustered at the soil piles. Potential impacts are not widespread, since the average concentration (35.4 mg/kg) does not exceed either TRV. However, localized impacts are indicated and copper is retained as COPC since potential risks are indicated to soil invertebrates and plants. Because copper is a bioaccumulative chemical, risks to wildlife from copper are also evaluated in Section 7.7 of this ERA

7.6.1.7 Cyanide

Cyanide was retained as an initial COPC in soil because the maximum (92 mg/kg) at SS-006 exceeded the EPA Region 5 EDQL (1.33 mg/kg)(EPA Region 5, 1999) which is based on risks to wildlife (meadow vole). The only alternate benchmark for risks to plants and invertebrates was the Canadian SQG (EC, 1999b). This value was determined based on a LOEC of 1.8 mg/kg for radish seed emergence with an uncertainty factor of 2 applied. Note that the NOEC for the same study, however, was 0.9 mg/kg. Cyanide exceeded the LOEC at eight sample locations (SS-006, -001, -004, -010, -017, -022, -026, and -027) north and south of the burn piles. Except for the maximum concentration at SS-006, most of concentrations exceeding the LOEC ranged from 2.2 mg/kg (SS-001) to 6.1 mg/kg (SS-022). The sample location with the maximum detection (at SS-006) was southeast of the pile and west of the Lumber Yard Road in the “discolored soil” area. SS-006 is well bounded by other samples with low concentrations of cyanide, so any potential impacts, if any, would be limited to a small area. The SQG is based on free cyanide and although it is not known whether the cyanide present at the site is in the free form, it is not likely to be very bioavailable after years of weathering. Also, as presented in EC (1999b), the high volatility of cyanide and the action of soil microbes ensure that high levels of cyanide do not persist or accumulate in soil under natural conditions. Although other detected concentrations of cyanide were greater than the Canadian SQG, it is not likely that they would pose a risk to terrestrial receptors because the cyanide in not likely “free” after years of weathering and microbial activities. Therefore, any potential risks to plants and invertebrates from cyanide are not considered to be significant so cyanide is not retained as a COPC for risks to lower trophic level receptors.

7.6.1.8 Iron

Iron was initially retained as a COPC because both the maximum (107,000 mg/kg) and average (21,794 mg/kg) soil concentration greatly exceeded the screening level based on toxicity to microorganisms (200 mg/kg). According to the ECO-SSL for iron (EPA, 2003c), iron is essential for plant growth, and is generally considered to be a micronutrient. Because plants regulate its uptake, iron is not expected to be toxic to plants in well aerated soils with pH levels between 5 and 8 S.U. Although soil pH data has not been collected at CBP, the average soil pH levels at Load Lines 2, 3, and 4 were within the pH range of 5 to 8 S.U. (USACE, 2003a, 2003b, and 2003c). Therefore, iron is not expected to be toxic to plants at the site. No toxicity data was located to evaluate risks to invertebrates from iron, however, because iron is generally considered a non-toxic metal, it is highly unlikely that soil invertebrates are being impacted by iron at the site. For these reasons, any potential risks to plants and invertebrates from iron are acceptable and iron is not retained as a COPC for risks to these receptors.

7.6.1.9 Lead

Lead was retained as an initial COPC since the maximum detected concentration (493 mg/kg) exceeded the ORNL PRG (40.5 mg/kg)(Efroymson et al., 1991a). The PRG is based on dietary toxicity to the woodcock. The plant TRV (Eco-SSL = 115 mg/kg) (EPA, 2003b) was exceeded but not the soil invertebrate TRV (Eco-SSL = 1700 mg/kg). The maximum was much greater than twice the RVAAP background (26.1 mg/kg). The plant TRV was exceeded at 6 of 34 sample sites (SB-004, SS-002, -013, -014, -018, and -020) with the maximum at SS-018 in the center of the burn piles. The SS-013 field sampling report noted “solidified molten lead” in the vicinity of the sample location. Since the majority of the exceedances were located in the location of the burn piles but the average concentration does not exceed the TRV, potential impacts appear site-related but not widespread. Lead is retained as a COPC because potential risks to plants are indicated especially in the area of the burn piles. Because lead is a bioaccumulative chemical, risks to wildlife from lead are also evaluated in Section 7.7 of this ERA

7.6.1.10 Manganese

Manganese like iron was initially selected as a soil COPC because the maximum soil concentration (6150 mg/kg) exceeded the screening level based on toxicity to microorganisms (100 mg/kg). No benchmark for earthworms was available but the maximum soil concentration exceeds the plant toxicity benchmark (500 mg/kg)(Efroymson et al., 1997b). However, this benchmark is less than the background concentration of manganese of 1,450 mg/kg. Eleven (11) of 34 sample locations had concentrations greater than the background concentration. The pattern of these eleven sample locations was not associated with other exceedances or with areas of known site activities. Both the average (979 mg/kg) and UCL concentrations (1,250 mg/kg) were below background. Risks to earthworms cannot be determined because of the lack of toxicity data, but risks to invertebrates are not likely because manganese is typically not considered to be very toxic. In summary, site-related risks to plants and invertebrates from manganese are acceptable and manganese is not retained as a COPC for risks to plants or invertebrates.

7.6.1.11 Selenium

Selenium was selected as an initial COPC since the maximum detected concentration (2.7 mg/kg) exceeded the ORNL PRG (0.21 mg/kg) (Efroymson et al., 1997a). The PRG is based on dietary toxicity to the mouse. The maximum did not exceed the earthworm TRV (70 mg/kg) (Efroymson et al., 1997b) but did exceed the plant TRV (1 mg/kg) (Efroymson et al., 1997c). The plant TRV was less than background (1.4 mg/kg). Exceedances of background were identified at 8 of the 34 sample locations. The maximum concentration at SS-010 (-002) was less than twice the RVAAP background (1.4 mg/kg) so the average was compared to the TRV. The average concentration of selenium (0.69 mg/kg) was less than the plant TRV. Risks to soil invertebrates and plants from selenium are acceptable and selenium is not retained as a COPC for risks to plants and soil invertebrates.

7.6.1.12 Thallium

Since the maximum detected concentration of thallium (4.1 mg/kg) exceeded the ORNL PRG (1 mg/kg) (Efroymson et al., 1997a) which is based on toxicity to plants, thallium was initially selected as a COPC. Thallium was detected infrequently (3/72). And the plant and earthworm TRV (1.4 mg/kg)(EC, 1999c) were exceeded by only one sample (SS-003) so potential impacts are localized and likely not significant. Risks to plants and invertebrates from thallium are acceptable and it is not retained as a COPC.

7.6.1.13 Zinc

Zinc was initially selected as a COPC because the maximum soil concentration (1500 mg/kg) exceeded the soil screening level of 8.5 mg/kg and was greater than the RVAAP background concentration (62 mg/kg). The soil screening level is the ORNL PRG based on dietary toxicity to wildlife (woodcock)(Efroymson et al., 1997a). The TRV for plants and invertebrates was the Canadian SQG (EC, 1999e). The maximum detected concentration exceeded the Canadian SQG (200 mg/kg) at 7 of 34 sample sites mostly located in and around the burn piles (SB-004, SS-002, -013, -014, -018, -020, and -034). The zinc Canadian SQG of 200 mg/kg is the lowest LOEC of the plants and invertebrate data set and is based on an effect on seedling emergence for radish. As presented in Appendix VI of the Canadian SQG document (EC, 1999e), all of the earthworm effects and no-effects data (with the exception of one test in one study) were equal to or greater than 200 mg/kg, indicating that earthworms appear to be less sensitive to zinc than plants.

The sample with the maximum detection (SS-013 = 1500 mg/kg) is in the middle of the burn piles in an area of sparse vegetation. Additional sample sites with elevated concentrations of zinc are also in and near the burn piles including SS-018 (762 mg/kg), SS-020 (517 mg/kg), and SS-014 (310 mg/kg). One sample site (SS-004 = 229 mg/kg) exceeding the SQG is near the "discolored soil" area west of the Lumber Yard Rd. The remaining two sample sites (SS-002 = 240 mg/kg and SS-034 = 496 mg/kg) with concentrations that exceeded the SQG, lie west of the railroad bed and removed from the burning activity.

The soil at location SS-002 was a silty sand with gravel, rocks, and slag while the soil at SS-034 was a gravelly sand with slag. Therefore, the soil in these areas does not appear very conducive to plants or invertebrates so significant numbers of these receptors would not be expected. The area of potential impact appears to be limited to the burn pile area and is not widespread since the average zinc concentration (113 mg/kg) does not exceed the earthworm and plant TRV.

In summary, site-related risks to plants and invertebrates from zinc are not acceptable by the burn area and zinc is retained as a COPC for risks to plants or invertebrates. Because zinc is a bioaccumulative chemical, risks to wildlife from zinc are also evaluated in Section 7.7 of this ERA.

7.6.2 Benthic Invertebrates

Potential risks to benthic invertebrates from exposure to COPCs were evaluated using the methodologies described in Section 7.5.2. The following subsections discuss whether the chemicals initially selected as COPCs should be retained for further evaluation of risks to benthic invertebrates. Note that bioaccumulative chemicals that were detected at concentrations less than their respective screening levels are not discussed below, because the chemicals are not COPCs for risks to benthic invertebrates.

Table 7-6 summarizes the results of potential direct toxicity of chemicals in sediment to benthic invertebrates. The table only lists the chemicals that were retained as COPCs because they were detected at concentrations that exceeded screening levels or they did not have screening levels. Chemicals that were only retained as COPCs because they were bioaccumulative are not listed on the table. Table 7-6 presents the average chemical concentrations compared to the same screening levels that were used to select chemicals as COPCs because the COPC screening table (Table 7-2) only presented the comparison of the maximum concentrations to the screening levels. Table 7-6 also presents the maximum and average concentrations compared to the higher effects levels (i.e., the PEC as discussed in Section 7.5.2) for benthic invertebrates to presents the range of probability of effects. The following text presents the Step 3a evaluation for the chemicals listed in Table 7-6.

7.6.2.1 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs were analyzed in 2 of the 9 sediment sample locations: SD002 at the burn piles and the source of the northeast trending drainage ditch and SD008 where Sand Creek enters (upstream) the AOC boundary for CBP. As presented on Table 7-6, the average concentrations of benzo(a)anthracene and pyrene are only slightly greater than their respective screening levels (Consensus-based TECs). However, because SD002 was located in a dry drainage ditch with little aquatic habitat while SD008 was located in Sand Creek where there is a viable aquatic habitat, it may not be appropriate to use the comparison of the average chemical concentrations to screening levels to eliminate chemicals as COPCs. Therefore, total PAHs were evaluated along with the individually detected PAHs because the toxicity of PAHs may be additive and there are sediment benchmarks for total PAHs. The maximum total PAH concentration (SD-002 = 1.75 mg/kg) is slightly greater than the lower-effects level of 1.61 mg/kg (the TEC from MacDonald et al., 2000) but is much lower than the higher effects level of 23 mg/kg (the PEC from MacDonald et al., 2000). Only 2 of the 9 sediment samples were analyzed for PAHs so their distribution across the site is not known. However, because SD-002 was located at the burn pile drainage ditch, this location should have some of the greatest PAH concentrations at the site. Because the concentrations of PAHs at this location were only slightly greater than the screening levels, it is expected that PAH concentrations at other sediment locations, especially those in Sand Creek, which is approximately 1,000 feet west of SD-002, would be much lower. This is supported by the fact that concentrations of metals in the samples from Sand Creek are lower than the concentrations at SD-002. Typically, the site ditches contain water only during wet weather events (i.e., rain, snowmelt, etc) and are not likely to have a significant benthic invertebrate population to be impacted. For this reason, along with the relatively low concentrations compared to the screening levels and the higher effects levels, PAHs are not present in the ditch at concentrations that warrant further evaluation for risks to benthic invertebrates. Therefore, benzo(a)anthracene and pyrene are eliminated as COPCs for risks to benthic invertebrates.

7.6.2.2 Barium

Barium was initially selected as a COPC because no sediment screening value is available and the maximum detected concentration (214 mg/kg) exceeded the RVAAP background concentration (123 mg/kg) and the Ohio SRV (190 mg/kg). Barium concentrations at three sample sites exceeded the RVAAP background concentration; these sites contained intermittent aquatic habitat of the drainage ditches near (SD-002 = 169 mg/kg) or immediately down gradient (SD-003 = 214 mg/kg) of the burn piles and discolored soil area (SD-001 = 129 mg/kg). The barium concentration in only one of the samples was greater than the Ohio SRV. The maximum concentration exceeded the higher-level effects value (48 mg/kg) – the apparent effects threshold (AET) from the NOAA SQRTable (Buchman, 1999), implying potential risks to benthos are possible. However, all of the barium concentrations in the samples collected from Sand Creek were lower than the AET, and much lower than the RVAAP background concentration and the Ohio SRV. Because the habitat quality is poor and benthic invertebrates are likely to be absent at the locations where barium concentrations were greater than the background concentrations, and the concentrations were less than the AET and the background concentrations at locations where there is viable aquatic habitat, risks to benthic invertebrates from barium are not expected. Therefore, barium is eliminated as a COPC for risks to sediment-dwelling invertebrates.

7.6.2.3 Cyanide

Cyanide, which was detected in less than half of the samples (SD-001, -002, -005, and -007), was initially selected as a COPC because the maximum (1.2 mg/kg) exceeded the EPA Region 5 EDQL (0.0001 mg/kg). As presented in EPA, 2003a, the source of the EDQL for cyanide is OMOE, (1993), which is based on parameters carried over from the open waters disposal guidelines. The value in OMOE (1993) however, is 0.1 mg/kg so there appears to be a unit error in the EDQL. The detected concentrations are all greater than this 0.1 mg/kg, including one sample collected in Sand Creek; however, the toxicological basis of the guideline is not known. Cyanide, being a negatively charged ion is relatively mobile by itself, however, if forms very strong complexes with iron and other metals in the environment that effectively immobilize it. These complexes dramatically reduce the availability of cyanide to organisms because the complexes are difficult to decompose (EC, 1999b). Therefore, it is not likely that the cyanide in the sediment at is causing a risk to aquatic receptors in Sand Creek at the relatively low concentration of 1 mg/kg. For this reason, cyanide is not retained as a COPC.

7.6.2.4 Manganese

Manganese was initially selected as a COPC because the maximum detected concentration (SD-001 = 2,590 mg/kg) exceeded the RVAAP background (1,950 mg/kg) and the Ohio SRV (1,500 mg/kg) but no sediment screening level was available. The OMOE sediment quality guidelines lists LELs and SELs for manganese of 460 mg/kg and 1,100 mg/kg, respectively, both of which are less than background and Ohio SRV concentrations. Only one sediment sample (SD-001) had a manganese concentration that exceeded the background concentration and the SEL; SD-001 is located southeast of the burn piles near the intersection of Lumber Yard Rd and Paris-Wyndham Road. The manganese concentrations at all of the other sediment locations were less than the background concentrations and the manganese concentrations in the samples collected from Sand Creek were less than the LEL. Since potential impacts are limited to one site where there is no habitat for benthic invertebrates (as discussed above), the risks from manganese to benthic receptors at CBP are acceptable and it was not retained as a COPC for risks to sediment invertebrates.

7.6.3 Surface Water

No chemicals were initially selected in surface water as COPCs after the screening.

7.7 RISKS TO TERRESTRIAL WILDLIFE

The discussions in previous sections were not designed to evaluate dietary risks to wildlife through ingestion of food items, drinking water, and incidental ingestion of soil or sediment. Instead, a food-chain model was used to evaluate potential risks posed by COPCs to upper-level terrestrial wildlife receptors. Section 7.5.5 describes the food-chain model methodology. Chemicals evaluated in the terrestrial food-chain model were limited to those identified by the USEPA as bioaccumulative (EPA, 2000a). Separate discussions are provided below for evaluations of potential risk to insectivorous/herbivorous and carnivorous receptors. The maximum (or 95% UCL) chemical concentrations detected in the surface soil, and the maximum concentrations in the surface water are used as the EPCs for the conservative food chain model. The average concentration detected in the surface soil and surface water samples are used as the EPCs for the average food chain model. Appendix T presents the spreadsheets used to calculate the doses and HQs.

7.7.1 Risks to Insectivorous/Herbivorous Species

Table 7-7 presents the terrestrial wildlife model HQs based on conservative input parameters for terrestrial surrogate species (meadow vole, short-tailed shrew, and American robin). For all PAHs, the NOAEL HQs in the conservative models are less than 1.0. However, the HQs in the conservative scenario exceed 1.0 for the following analytes and receptors:

- Aroclor-1254 NOAEL for the robin and shrew;
- arsenic NOAEL for the vole and shrew;
- cadmium NOAEL for the robin and shrew;
- chromium NOAEL for the robin;

- lead NOAEL for the robin and shrew;
- lead LOAEL for the robin;
- zinc NOAEL for the robin; and
- zinc LOAEL for the robin.

The CBP is relatively small (33 acres) and considerably less than the home range (>100 acres) for the barn owl, hawk and fox. The area of maximum concentrations at the burn piles and discolored soil area is likely less than 1 acre. The home range for some individual smaller mammals such as voles and shrews is approximately 1 acre. However, because it is more important to protect populations of these receptors versus single individuals, the food chain models were calculated using the average. Also, the average COPC concentrations are more realistic EPCs for most wildlife receptors than maximum concentrations because receptors are exposed to COPC concentrations throughout the AOC, rather than at a single location. Surface samples were collected at 34 soil borings scattered throughout the 33 acre site so there is adequate spatial coverage within the exposure area making it appropriate to calculate an average concentration as the EPC.

Table 7-8 presents the HQs based on average exposure input parameters for the insectivorous and herbivorous species. Note that Table 7-8 only list the chemicals that had NOAEL HQs greater than 1.0 using the maximum (or 95% UCL) concentrations. HQs in the average scenario are greater than 1 for the following analytes and receptors:

- arsenic NOAEL for the vole and shrew;
- cadmium NOAEL for the robin;
- chromium NOAEL for the robin;
- lead NOAEL for the robin and shrew;
- lead LOAEL for the robin; and
- zinc NOAEL for the robin.

Arsenic was detected in 71 of 72 soil samples with a UCL of 15.3 mg/kg and an average concentration of 11.5 mg/kg. Although arsenic concentrations in approximately 17% of the samples (12/72) were greater than the RVAAP background concentration (15.4 mg/kg), most only slightly exceeded the background concentration and the greatest concentration (SS-004 = 32.8 mg/kg) was only slightly greater than twice the background soil concentration. Therefore, arsenic may not be related to site activities. Also, because the average and UCL concentration of arsenic that was used in the food chain model is less than the background concentration, the dietary risks from arsenic are similar to background risks. For these reasons, it is not likely that potential risks to small mammals are great enough to warrant further evaluation of arsenic in the BERA. Therefore, arsenic is eliminated as a COPC for risks to insectivorous and herbivorous wildlife.

Cadmium was detected in 63% (45/72) of the soil samples with a UCL of 0.39 mg/kg and an average concentration of 0.28 mg/kg. No RVAAP background concentration is available for cadmium. In the initial screening, none of the detected concentrations exceeded the soil screening level (4 mg/kg) which is the ORNL PRG based on risks to plants and woodcocks. The ORNL PRGs use LOAELs in wildlife FCMs to back-calculate soil concentrations that are protective of wildlife receptors. LOAELs were used instead of NOAELs because (1) LOAELs are presumed to be the threshold levels at which effects are evident; (2) LOAELs have less uncertainty associated with them; and (3) the higher level effects of LOAELs on individual wildlife are expected to correspond to no-effect or negligible effect levels on wildlife populations (Efroymson et al., 1997). The conservative scenario estimated exceedances of the robin and shrew NOAEL and the average scenario exceeded only the robin NOAEL. No LOAELs were exceeded in either scenario for cadmium. Also, the Eco-SSL for wildlife is 1.0 mg/kg for avian and 0.38 mg/kg for mammalian wildlife. Several of the sample locations had cadmium concentrations that exceeded the avian and mammalian Eco-SSLs, however, the UCL was just slightly greater than the mammal Eco-SSL and the average concentration was lower than the Eco-SSL. Therefore, because the HQs based on the LOAELs were less than 1.0, and because the average cadmium concentration was less than the Eco-SSL for birds and mammals, risks from cadmium are acceptable and cadmium is eliminated as a COPC for risks to insectivorous and herbivorous wildlife.

Chromium was detected in all 72 samples with a UCL of 18 mg/kg and an average concentration of 16.3 mg/kg. Although chromium concentrations in approximately 35% (25/72) of the samples were greater than the RVAAP background concentration (17.4 mg/kg), most of those detected concentrations only slightly exceeded (≤1.5X) the background concentration but the maximum concentration (SS-004-002 = 57.3 mg/kg) was greater than 3X the background concentration. The conservative and average scenario resulted in exceedance of only the robin NOAEL but not the LOAEL. Since the average chromium concentration that was used in the food chain model is less than the background concentration, the risks from chromium are similar to background risks. For these reasons, it is not likely that potential site-related risks to small mammals are great enough to warrant further evaluation of chromium in the BERA. Therefore, chromium is eliminated as a COPC for risks to small mammals.

Lead was detected in all 72 samples with a UCL of 44 mg/kg and an average concentration of 43.4 mg/kg. Lead concentrations were greater than the RVAAP background concentration (26.1 mg/kg) in approximately 32% of the samples (23/72). Sample locations with greater than twice background lead concentrations define the burn pile and the discolored soil area (SB-003, -004, SS-002, -013, -014, -018, and -020) with one exception SS-002 (117.3 mg/kg) which is located west of the railroad bed and distant from the areas of known site activities. The conservative and average scenarios of the FCM exceed the lead NOAEL for the robin and shrew and the LOAEL for the robin. However, using the RVAAP background concentration, the HQs for the robin are 29 based on the NOAEL and 2.9 based on the LOAEL, and 1.6 for the shrew based on the NOAEL. This illustrates the conservative nature of the food chain model. As stated above, the samples with the greatest lead concentrations were collected in the burn area. Based on the habitat, few earthworms would inhabit this area so robins or shrews would not obtain much, if any, food from this area. Therefore, the average lead concentration was recalculated by removing the five shallow surface soil samples associated with this area at SS013, -014, -019, -018, and -020). The recalculated average is 25 mg/kg, which is less than the RVAAP background concentration. For this reason, although it is possible that birds and mammals would be at risks from lead in the soil, it is likely that any risks would be within background risks. For that reason, lead is eliminated as a COPC for risks to small mammals and birds.

Zinc was detected in all 72 samples with a UCL of 117 mg/kg and an average concentration of 113 mg/kg. The RVAAP background for zinc (61.8 mg/kg) was exceeded in 32 detects in 72 samples representing approximately 44% of the samples. For zinc in the diet of robins, the conservative scenario using the UCL exceeded both NOAEL and LOAEL but the average scenario exceeded only the NOAEL. These results indicate potential slight impacts at sample locations with a zinc concentration near the UCL (117 mg/kg). Sample locations with zinc concentrations above the UCL define the area of known site activities (SB-003, SB-004, SS-002, -013, -014, -018, -020 and -034) with the exception of SS-034 which is located at the western-most boundary of the CBP AOC more than 1,000 ft from the burn piles. The maximum zinc concentration (SS-013 = 1500 mg/kg) was located in the center of the known site activities. However, using the RVAAP background concentration, the HQ for the robin is 5.3 based on the NOAEL. This illustrates the conservative nature of the food chain model. As stated above, the samples with the greatest zinc concentrations were collected in the burn area. Based on the habitat, few earthworms would inhabit this area so robins or shrews would not obtain much, if any, food from this area. Therefore, the average zinc concentration was recalculated by removing the five shallow surface soil samples associated with this area at SS013, -014, -019, -018, and -020). The recalculated average is 73 mg/kg, which is just slightly greater than the RVAAP background concentration. For this reason, although it is possible that birds and mammals would be at risks from zinc in the soil, it is likely that any risks would be within or just slightly greater than background risks. For that reason, zinc is eliminated as a COPC for risks to small mammals and birds

In summary, using average exposure concentrations, the HQs based on the NOAEL exceeded 1.0 for several chemicals and receptors, but the HQs based on the LOAEL only exceeded 1.0 for lead in the robin model. However, as discussed, most of the risks are similar to or just slightly greater than background risks. Therefore, it is possible that there may be some limited risks to small mammals and birds at the site based only on the HQs. When the additional following factors are considered, it is unlikely that receptors will be impacted:

- Although CBP is large enough to be within the home range of individual small mammals and birds, populations of the receptors would encompass an area much larger than CBP, or at least much larger than the burn area, where most of the elevated concentrations of metals were detected.
- The chemicals in soil will likely be less bioavailable than the form of the chemicals used to conduct the toxicity test to establish the NOAELs and LOAELs so the risks are overestimated.

Table 7-7. Terrestrial Food Chain Model – Conservative Scenario Insectivorous, Herbivorous, and Carnivorous Receptors

Chemical	Herbivorous Receptors HQs		Insectivorous Receptors HQs				Carnovorous Receptors HQs					
	Meadow Vole		American Robin		Short-tailed Shrew		Barn Owl		Red Fox		Red-Tailed Hawk	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Semivolatile Organics												
BENZO(A)ANTHRACENE	1.4E-02	1.4E-03	9.9E-03	9.9E-04	1.7E-02	1.7E-03	NC	NC	NC	NC	NC	NC
BENZO(A)PYRENE	1.3E-02	1.3E-03	1.1E-02	1.1E-03	1.9E-02	1.9E-03	NC	NC	NC	NC	NC	NC
BENZO(B)FLUORANTHENE	1.6E-02	1.6E-03	1.3E-02	1.3E-03	2.3E-02	2.3E-03	NC	NC	NC	NC	NC	NC
BENZO(K)FLUORANTHENE	1.4E-02	1.4E-03	1.2E-02	1.2E-03	2.0E-02	2.0E-03	NC	NC	NC	NC	NC	NC
CHRYSENE	1.7E-02	1.7E-03	1.2E-02	1.2E-03	2.0E-02	2.0E-03	NC	NC	NC	NC	NC	NC
FLUORANTHENE	3.5E-02	3.5E-03	1.7E-02	1.7E-03	2.6E-02	2.6E-03	NC	NC	NC	NC	NC	NC
INDENO(1,2,3-CD)PYRENE	2.8E-01	2.8E-02	5.0E-02	5.0E-03	2.1E-02	2.1E-03	NC	NC	NC	NC	NC	NC
PHENANTHRENE	1.3E-02	1.3E-03	4.7E-03	4.7E-04	5.9E-03	5.9E-04	NC	NC	NC	NC	NC	NC
PYRENE	3.5E-02	3.5E-03	1.7E-02	1.7E-03	2.6E-02	2.6E-03	NC	NC	NC	NC	NC	NC
Pesticides PCBs												
4,4'-DDE	2.1E-03	2.1E-04	9.6E-01	9.6E-02	9.1E-04	9.1E-05	2.6E-01	2.6E-02	4.5E-04	4.5E-05	1.1E-01	1.1E-02
4,4'-DDT	2.0E-03	2.0E-04	5.5E-01	5.5E-02	3.8E-04	3.8E-05	8.5E-02	8.5E-03	1.6E-04	1.6E-05	3.5E-02	3.5E-03
AROCLOR-1254	1.3E-01	1.3E-02	2.8E+00	2.8E-01	6.4E+00	6.4E-01	2.3E-01	2.3E-02	6.6E-01	6.6E-02	9.6E-02	9.6E-03
ENDOSULFAN I	7.6E-04	7.6E-05	2.1E-04	2.1E-05	5.3E-03	5.3E-04	6.9E-08	6.9E-09	2.2E-05	2.2E-06	2.8E-08	2.8E-09
ENDOSULFAN II	3.7E-03	3.7E-04	1.0E-03	1.0E-04	2.6E-02	2.6E-03	3.4E-07	3.4E-08	1.1E-04	1.1E-05	1.4E-07	1.4E-08
ENDRIN	2.9E-03	2.9E-04	8.8E-03	8.8E-04	2.0E-02	2.0E-03	2.5E-05	2.5E-06	2.4E-04	2.4E-05	1.0E-05	1.0E-06
GAMMA-CHLORDANE	1.9E-03	1.9E-04	3.5E-03	3.5E-04	8.1E-04	8.1E-05	9.2E-04	9.2E-05	3.9E-04	3.9E-05	3.8E-04	3.8E-05
HEPTACHLOR EPOXIDE	1.3E-04	1.3E-05	No TRV	No TRV	6.8E-04	6.8E-05	No TRV	No TRV	1.5E-05	1.5E-06	No TRV	No TRV
Energetics												
2,4,6-TNT	5.2E-01	5.2E-02	No TRV	No TRV	4.7E-02	4.7E-03	NC	NC	NC	NC	NC	NC
NITROCELLULOSE	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
NITROGUANIDINE	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
Inorganics												
ARSENIC	6.4E+00	6.4E-01	1.9E-01	1.9E-02	8.1E+00	8.1E-01	NC	NC	NC	NC	NC	NC
CADMIUM	5.3E-02	5.3E-03	1.8E+00	1.8E-01	1.0E+00	1.0E-01	NC	NC	NC	NC	NC	NC

Table 7-7. Terrestrial Food Chain Model – Conservative Scenario Insectivorous, Herbivorous, and Carnivorous Receptors (continued)

Chemical	Herbivorous Receptors HQs		Insectivorous Receptors HQs				Carnovorous Receptors HQs					
	Meadow Vole		American Robin		Short-tailed Shrew		Barn Owl		Red Fox		Red-Tailed Hawk	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
CHROMIUM	1.4E-04	1.4E-05	2.8E+00	2.8E-01	4.7E-04	4.7E-05	NC	NC	NC	NC	NC	NC
COPPER	1.7E-01	1.7E-02	1.0E-01	1.0E-02	1.2E-01	1.2E-02	NC	NC	NC	NC	NC	NC
LEAD	1.6E-01	1.6E-02	4.9E+01	4.9E+00	2.7E+00	2.7E-01	NC	NC	NC	NC	NC	NC
MERCURY	5.4E-03	5.4E-04	2.2E-02	2.2E-03	3.1E-03	3.1E-04	9.2E-02	9.2E-03	1.5E-02	1.5E-03	3.8E-02	3.8E-03
NICKEL	1.3E-02	1.3E-03	4.3E-02	4.3E-03	3.6E-02	3.6E-03	NC	NC	NC	NC	NC	NC
SELENIUM	1.2E-01	1.2E-02	9.9E-01	9.9E-02	9.9E-01	9.9E-02	NC	NC	NC	NC	NC	NC
SILVER	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
ZINC	2.4E-01	2.4E-02	1.0E+01	1.0E+00	3.3E-01	3.3E-02	NC	NC	NC	NC	NC	NC

Cells are shaded if the value is greater than 1.0

NC - Not calculated because the food chain model for carnivorous receptors is only done for persistent, bioaccumulative, and toxic chemicals.

Table 7-8. Terrestrial Food Chain Model – Average Scenario Insectivorous, Herbivorous, and Carnivorous Receptors

Chemical	Herbivorous Receptors HQs		Insectivorous Receptors HQs				Carnovorous Receptors HQs					
	Meadow Vole		American Robin		Short-tailed Shrew		Barn Owl		Red Fox		Red-Tailed Hawk	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Semivolatile Organics												
BENZO(A)ANTHRACENE	3.9E-03	3.9E-04	2.7E-03	2.7E-04	4.5E-03	4.5E-04	NC	NC	NC	NC	NC	NC
BENZO(A)PYRENE	3.2E-03	3.2E-04	2.6E-03	2.6E-04	4.6E-03	4.6E-04	NC	NC	NC	NC	NC	NC
BENZO(B)FLUORANTHENE	5.1E-03	5.1E-04	4.2E-03	4.2E-04	7.4E-03	7.4E-04	NC	NC	NC	NC	NC	NC
BENZO(K)FLUORANTHENE	6.0E-03	6.0E-04	5.0E-03	5.0E-04	8.7E-03	8.7E-04	NC	NC	NC	NC	NC	NC
CHRYSENE	4.0E-03	4.0E-04	2.7E-03	2.7E-04	4.6E-03	4.6E-04	NC	NC	NC	NC	NC	NC
FLUORANTHENE	9.6E-03	9.6E-04	4.8E-03	4.8E-04	7.2E-03	7.2E-04	NC	NC	NC	NC	NC	NC
INDENO(1,2,3-CD)PYRENE	1.4E-01	1.4E-02	2.6E-02	2.6E-03	1.1E-02	1.1E-03	NC	NC	NC	NC	NC	NC
PHENANTHRENE	9.2E-03	9.2E-04	3.2E-03	3.2E-04	4.0E-03	4.0E-04	NC	NC	NC	NC	NC	NC
PYRENE	1.2E-02	1.2E-03	6.1E-03	6.1E-04	9.2E-03	9.2E-04	NC	NC	NC	NC	NC	NC

Table 7-8. Terrestrial Food Chain Model – Average Scenario Insectivorous, Herbivorous, and Carnivorous Receptors (continued)

Chemical	Herbivorous Receptors HQs		Insectivorous Receptors HQs				Carnovorous Receptors HQs					
	Meadow Vole		American Robin		Short-tailed Shrew		Barn Owl		Red Fox		Red-Tailed Hawk	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Pesticides PCBs												
4,4'-DDE	1.0E-03	1.0E-04	4.9E-01	4.9E-02	4.7E-04	4.7E-05	1.3E-01	1.3E-02	2.3E-04	2.3E-05	5.4E-02	5.4E-03
4,4'-DDT	6.7E-04	6.7E-05	1.9E-01	1.9E-02	1.3E-04	1.3E-05	2.9E-02	2.9E-03	5.3E-05	5.3E-06	1.2E-02	1.2E-03
AROCLOR-1254	8.0E-03	8.0E-04	1.8E-01	1.8E-02	4.0E-01	4.0E-02	1.5E-02	1.5E-03	4.2E-02	4.2E-03	6.1E-03	6.1E-04
ENDOSULFAN I	4.2E-04	4.2E-05	1.2E-04	1.2E-05	3.0E-03	3.0E-04	3.8E-08	3.8E-09	1.2E-05	1.2E-06	1.6E-08	1.6E-09
ENDOSULFAN II	8.3E-04	8.3E-05	2.3E-04	2.3E-05	5.8E-03	5.8E-04	7.5E-08	7.5E-09	2.4E-05	2.4E-06	3.1E-08	3.1E-09
ENDRIN	8.8E-04	8.8E-05	2.7E-03	2.7E-04	6.3E-03	6.3E-04	7.8E-06	7.8E-07	7.5E-05	7.5E-06	3.2E-06	3.2E-07
GAMMA-CHLORDANE	2.6E-04	2.6E-05	4.7E-04	4.7E-05	1.1E-04	1.1E-05	1.2E-04	1.2E-05	5.2E-05	5.2E-06	5.1E-05	5.1E-06
HEPTACHLOR EPOXIDE	6.9E-05	6.9E-06	No TRV	No TRV	3.7E-04	3.7E-05	No TRV	No TRV	8.0E-06	8.0E-07	No TRV	No TRV
Energetics												
2,4,6-TNT	5.8E-02	5.8E-03	No TRV	No TRV	5.2E-03	5.2E-04	NC	NC	NC	NC	NC	NC
NITROCELLULOSE	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
NITROGUANIDINE	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
Inorganics												
ARSENIC	4.8E+00	4.8E-01	1.4E-01	1.4E-02	6.1E+00	6.1E-01	NC	NC	NC	NC	NC	NC
CADMIUM	3.9E-02	3.9E-03	1.3E+00	1.3E-01	7.5E-01	7.5E-02	NC	NC	NC	NC	NC	NC
CHROMIUM	1.3E-04	1.3E-05	2.5E+00	2.5E-01	4.2E-04	4.2E-05	NC	NC	NC	NC	NC	NC
COPPER	2.3E-01	2.3E-02	1.4E-01	1.4E-02	1.7E-01	1.7E-02	NC	NC	NC	NC	NC	NC
LEAD	1.6E-01	1.6E-02	4.8E+01	4.8E+00	2.7E+00	2.7E-01	NC	NC	NC	NC	NC	NC
MERCURY	5.0E-03	5.0E-04	2.1E-02	2.1E-03	2.9E-03	2.9E-04	8.6E-02	8.6E-03	1.4E-02	1.4E-03	3.5E-02	3.5E-03
NICKEL	1.1E-02	1.1E-03	3.6E-02	3.6E-03	3.0E-02	3.0E-03	NC	NC	NC	NC	NC	NC
SELENIUM	8.6E-02	8.6E-03	7.1E-01	7.1E-02	7.2E-01	7.2E-02	NC	NC	NC	NC	NC	NC
SILVER	No TRV	No TRV	No TRV	No TRV	No TRV	No TRV	NC	NC	NC	NC	NC	NC
ZINC	2.3E-01	2.3E-02	9.7E+00	9.7E-01	3.2E-01	3.2E-02	NC	NC	NC	NC	NC	NC

Cells are shaded if the value is greater than 1.0

NC - Not calculated because the food chain model for carnivorous receptors is only done for persistent, bioaccumulative, and toxic chemicals.

7.7.2 Risks to Carnivorous Species

Tables 7-7 and 7-8 presents the carnivorous wildlife model HQs based on conservative and average input parameters for surrogate species (barn owl, red fox, and red-tailed hawk). Note that only PBT COPCs were carried through the carnivorous wildlife food chain model according with the Ohio EPA ERA guidance (Ohio EPA, 2003). No chemicals resulted in exceedance of NOAELs or LOAELs for carnivorous species so no chemicals were retained as COPCs for risks to carnivorous wildlife.

7.8 ECOLOGICAL RISK UNCERTAINTY ANALYSIS

The uncertainty analysis presented in this section presents the uncertainties associated with this SERA at CBP.

7.8.1 Measurement and Assessment Endpoints

Measurement endpoints are used to evaluate the assessment endpoints that are selected for the SERA. For this SERA, the measures of effects are not the same as the assessment endpoints. Therefore, the measures are used to predict effects to the assessment endpoints by selecting surrogate species that will be evaluated. For example, a decrease in reproduction of a shrew is used to assess a decrease in reproduction of the small mammal population. However, predicting a decrease in reproduction of a shrew may either under- or overprotect the small mammal population, resulting from differences in ingestion rates, toxicity, food preferences, etc. among different species.

Several assessment endpoints were selected for this risk assessment, including the selection of piscivorous wildlife as an assessment endpoint. The ditches at CBP are narrow and shallow and unlikely to contain a significant fish population. Therefore, risks to piscivorous wildlife are overestimated.

Risks to reptiles and amphibians are not quantitatively evaluated because exposure factors are not established for most species and toxicity data are very limited. Using aquatic organisms as a surrogate species, risks to amphibians exposed to the surface water and sediment are expected to be low based on the Step 3a evaluations. However, potential risks to reptiles cannot be further evaluated in this SERA because of a lack of toxicity and exposure data.

7.8.2 Exposure Characterization

The contaminant dose to terrestrial wildlife is calculated using an equation that incorporates ingestion rates, body weights, bioaccumulation factors, and other exposure factors. These exposure factors are obtained from literature studies or are predicted using various equations. Ingestion rates and body weights vary among species, especially among species inhabiting different areas.

Bioaccumulation of contaminants into various biological media (i.e., plants, invertebrates, small mammals) depends on characteristics of the media such as pH, organic carbon, etc. Therefore, actual bioaccumulation factors at the site may be different than those used in the SERA that were obtained from the guidance. Also, the bioavailability of the chemicals is not taken into account in this SERA. All the chemicals are assumed to be 100 percent bioavailable at the detected concentrations, which is unlikely to occur for contaminants in the environment.

There is uncertainty in the chemical data that are collected at the site. Measured levels of chemicals are only estimates of the true site chemical concentrations. For samples that are deliberately biased toward known or suspected high concentrations, predicted doses probably will be higher than actual doses.

Finally, under the food chain model exposure scenario, terrestrial wildlife are assumed to live and feed only at the site. These assumptions will tend to over predict risk because it is unlikely that most receptors will obtain all their food from within the site boundaries and from the most contaminated areas.

7.8.3 Ecological Effects Data

There is uncertainty in the ecological toxicity value comparison. The water quality criteria developed by USEPA in theory protects 95 percent of the exposed species. Therefore, some sensitive species may be present that are not protected by the use of these criteria. There also may be situations where the SWSLs are over-predictive of risk if the sensitive species used to develop the criteria do not inhabit the site. Finally, with the exception of hardness for a few metals, the SWSLs do not account for site-specific factors, such as TOC or pH that may affect toxicity.

Potential adverse impacts to aquatic receptors from constituents in the sediment are evaluated by comparing the COPC concentration to SdSLs. The SdSLs have more uncertainty associated with them than do the SWSLs for the following reasons: The procedures for developing them are not as well established, so screening levels have been developed using different methodologies and there are fewer sediment toxicity data than surface water toxicity data. Sediment characteristics (i.e., pH, acid volatile sulfides, total organic carbon) also will have a large impact on the bioavailability and toxicity of constituents.

Potentially adverse impacts to terrestrial plants and invertebrates from constituents in the surface soil are evaluated by comparing the COPC concentration to SSSLs. The SSSLs are similar to the sediment screening levels in that they are less established than the SWSLs. Fewer studies and fewer data are available for establishing SSSLs than SdSLs and many of the SSSLs are based on the results of only a few studies. In addition, the SSSLs are based on different endpoints, depending on the preference of the agency that developed them. Therefore, they have more uncertainty than surface water and sediment screening values.

The NOAELs and LOAELs that were selected for the wildlife endpoint species were based on species other than the endpoint species (i.e., rats, mice, ducks). There is uncertainty in the application of toxicity data across species because the contaminant may be more or less toxic to the endpoint species than it was to the test study species.

The toxicity of chemical mixtures is not well understood. All the toxicity information used in the SERA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals because of synergistic or antagonistic effects.

Toxicological data for a few of the COPCs are limited or do not exist. Therefore, there is uncertainty in any conclusions involving the potential impacts to ecological receptors from these constituents.

Several alternative benchmark values were used to gain a better understanding of the relationship between the maximum concentrations of the selected COPCs to the overall ecological risks of the site. There is some uncertainty involved when using these alternative benchmarks. The Canadian SQG, which are used as alternative benchmarks for both plants and invertebrates, are based on effects to either plants or invertebrates and thus, differentiation of risk to plants versus risk to invertebrates cannot be made using the Canadian guidelines. The ORNL values are separated into guidelines for plants and guidelines for invertebrates. However, the values are limited to only a few chemicals.

7.8.4 Risk Characterization

Risks are possible if an HQ is greater than or equal to unity regardless of the magnitude of the HQ. However, the magnitude of effects to ecological receptors cannot be inferred based on the magnitude of the HQ. Rather, an HQ greater than 1.0 simply indicates that the dose used to derive the toxicity reference value was exceeded. Finally, there is uncertainty in how the predicted risks to a species at the site translate into risk to the population in the area as a whole.

7.9 CONCLUSIONS

Based on the SERA and the first step of the BERA (Step 3a), the following conclusions were made.

7.9.1 Terrestrial Plants and Soil Invertebrates

After the initial screening (Table 7-1), sixteen inorganics (aluminum, arsenic, barium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc) and three energetics (2,4,6-TNT, nitrocellulose, and nitroguanidine), were detected at concentrations that exceeded RVAAP background and soil screening levels or did not have soil screening levels. Other chemicals were retained as COPCs only because they were bioaccumulative including seven pesticides (4,4'-DDE, 4,4'-DDT, endosulfan I, endosulfan II, endrin, gamma-chlordane, and heptachlor epoxide), one polychlorinated biphenyl (aroclor-1254), seven polycyclic aromatic hydrocarbons [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene], and two inorganics (cadmium and silver). These bioaccumulative chemicals were not included in the evaluation of risks to plants and invertebrates because they were not detected at concentrations that exceeded soil screening levels.

Tables 7-4 and 7-5 summarize the results of potential direct toxicity of chemicals in soil to earthworms and plants, respectively. Arsenic, barium, cobalt, copper, cyanide, lead, manganese, thallium and zinc were the only chemicals with maximum concentrations that were greater than the plant or earthworm toxicity benchmarks; the average chemical concentrations for cyanide and manganese were greater than the benchmarks.

Arsenic was eliminated as a COPC because its average concentration did not exceed the Canadian SQG or background concentration so it was concluded that potential impacts to plants are not widespread. Barium was not retained due to the small area exceeding the earthworm TRV. Cobalt was eliminated based on the distribution of samples exceeding the plant TRV. Cyanide, was eliminated as a COPC because it is not likely that toxic levels of free cyanide are present in the soil after years of weathering and microbial activities. Iron is not expected to impact plants or invertebrates at the site because the soil pH is likely to be within 5 to 8 S.U., based on pH data from Load Lines 2, 3, and 4, thus decreasing its bioavailability. Therefore, iron was eliminated as a COPC. Although manganese concentrations were greater than background concentrations in three samples. a maddox was needed to sample one of the locations because of the hard-packed soil, and refusal was encountered at 12 inches at one location and 6 to 8 inches at other location because of cobbles and/or slag. Therefore, the area is not conducive for most plants and invertebrates so those receptors are unlikely to be present in significant number to be impacted. Also, it is likely that the screening levels for manganese are conservative based on the fact that the background concentration of manganese is almost four times greater than the plant benchmark and almost 20 times greater than the microorganism benchmark. For these reasons, manganese was eliminated as a COPC. Selenium was eliminated because the maximum only slightly exceeded the plant TRV and the average was less than the TRV. Thallium was eliminated because it was detected infrequently and exceeded the TRVs in only one sample.

Copper, lead, and zinc were retained as COPCs because of the relatively high concentrations at a few samples in the center of the burn piles (SS-0013, SS-014, and SS-018). This area is not suitable habitat because ash from the burning operations covers the area. Therefore, impacts to terrestrial receptors will occur from the physical stressors (i.e., the ash which limits the habitat) as well as chemical stressors. In fact, the physical hazard may be more important than the chemical hazard because the presence of the ash limit the numbers of receptors that will be present and thus exposed to the chemicals. For example, if is not likely that significant numbers of earthworms will inhabit this area then earthworms will not be exposed to the chemicals in the soil samples.

In summary, copper, lead, and zinc were retained as COPCs for risks to plants or invertebrates in the burn area. However, the impacts from the presence of the ash at the site may be more important than the presence of chemicals in the soil samples. Several COPCs are bioaccumulative, risks to wildlife from the bioaccumulative chemicals were evaluated in Section 7.7 of this ERA.

7.9.2 Sediment Invertebrates

After the initial screening (Table 7-2), four individual PAHs [benzo(a)anthracene, benzo(a)pyrene, chrysene, and pyrene], Total PAHs and five inorganics (cadmium, copper, cyanide, lead, and manganese) were detected at concentrations that exceeded Ohio SRV and sediment screening levels or were bioaccumulative (mercury). Chemicals without screening values were initially retained as COPCs including three inorganics (barium, beryllium, and manganese) and one energetic compound (nitrocellulose).

Table 7-6 summarizes the results of potential direct toxicity of chemicals in sediment to benthic invertebrates and includes the average chemical concentrations compared to the same screening levels and the maximum and average concentrations compared to the higher effects levels.

Benzo(a)anthracene and pyrene were eliminated as COPCs since the concentrations of total PAHs were only slightly greater than the screening level at a locations where there is limited, if any, aquatic habitat. Although PAHs were only analyzed for in two samples, the location of the maximum concentrations of PAHs were closer to the source area so concentrations of PAHs in other sediment samples would be expected to be much lower.

Barium was eliminated as a COPC because the barium concentrations in all three sediment samples that were collected from Sand Creek were less than the AET and less than background concentrations. Only one of the drainage ditch samples had a barium concentration that exceeded the Ohio SRV and there is limited, if any, aquatic habitat at that location. Cyanide was not retained as a COPC in sediments because it is not likely present in a bioavailable form. Manganese was eliminated as a COPC because manganese concentrations in all three sediment samples that were collected from Sand Creek, were less than the LEL and less than background concentrations. Also, only one of the drainage ditch samples had a manganese concentration that exceeded the Ohio SRV and RVAAP background concentration and there is limited, if any, aquatic habitat at that location.

In summary, no chemicals were retained as COPCs for risks to sediment invertebrates for the reasons discussed above.

A facility-wide biology and surface water investigation is ongoing by USACE with cooperation of Ohio EPA. In the investigation, water and sediment samples were taken from locations along major stream and tributaries, ponds, and wetlands throughout RVAAP at locations that could have been impacted by former facility activities and sites where the streams entered RVAAP. Fish were caught, identified, and released in the sampling locations corresponding to the water and sediment sample locations. Invertebrate biota was collected by Hester-Dendy samplers set in the same locations and by qualitative sampling of organic debris and rocks in the stream reach. Funnel traps were additionally placed in ponds and wetlands for further invertebrate sampling. Sand Creek near CBP was among the sampled water bodies. The details of the study, locations, techniques, and results from this study are published in the Ravenna Facility-wide Surface Water Study: Streams and Ponds (USACE 2005).

By way of summary of surface water quality, for all eight of the Sand Creek sampling locations, including the one near CBP, there were no exceedences of the Ohio WQS aquatic life maximum or average water quality criteria. None of the chemicals measured in this study exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but one [bis(2-ethylhexyl) phthalate] of the organic parameters tested (explosives, semi-volatiles, pesticides, and PCBs) were reported as non-detect. (Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common laboratory contaminants.) In addition, metals concentrations were very low, with many of the results less than lab oratory detection limits. Parameters with measurable concentrations were below applicable Ohio WQS aquatic life criteria. All ammonia-N measurements were less than lab detection limits (0.10 mg/l), and nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below Erie Ontario Lake Plain ecoregion 75th percentile value). Low nutrient and dissolved solids levels in Sand Creek were largely reflective of the undeveloped condition of the watershed.

For the sediment summary, sediment collected from all eight locations in Sand Creek reflected non-contaminated conditions. All metals tested in sediments were below Ohio sediment reference values (Ohio EPA 2003) – levels established from chemical results collected at biological reference sites. All tested explosive compounds, pesticides, PCBs, and most semi-volatile organic compounds were not detected in sediment samples collected from Sand Creek. The few detected semi-volatile compounds were measured at low levels. Di-n-butyl phthalate was detected (estimated concentration) at four of eight Sand Creek sediment sites; however, all values were below ecological screening levels (ESLs). Phthalates are potential lab contaminants. (Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common laboratory contaminants.) Ammonia and total phosphorus levels were measured in all Sand Creek sediment samples below screening guidelines (Persaud et. al. 1993). Cyanide was not detected above ESLs at the Sand Creek location near CBP.

All eight Sand Creek sites evaluated in this survey revealed very good to excellent stream habitats. Qualitative Habitat Evaluation Index (QHEI) scores for Sand Creek sites ranged between 70.0 and 85.5, with an average score of 75.2. These scores demonstrate the potential to support Warmwater Habitat (WWH) biological communities. Sand was a predominating bottom substrate at nearly all of the sampling sites, with gravel and cobble prevalent at half of the locations. Muck, along with sand, predominated at River Mile (RM) 2.4 (near RBP and upstream WWTP tributary). The stream channel was natural within the study area and was represented by pool, run, and riffle areas, with minor amounts of glide habitat. Instream channel development was good, and surrounding land use was largely forest and shrub. Of the eight sites sampled in Sand Creek, the site close to CBP (RM 2.4) was partially impounded by a beaver dam.

Macroinvertebrate communities were very good to exceptional in Sand Creek. Invertebrate Community Index (ICI) scores ranged between 44 and 54. These ICI values achieved the ecoregional biocriterion established for the designated WWH use, as well as meeting the Exceptional Warmwater Habitat (EWH) criterion. The macroinvertebrate community results from the eight Sand Creek sites indicated no biological impairment.

7.9.3 Aquatic Organisms

After the initial screening (Table 7-3), no chemicals were selected as COPCs.

The facility-wide biology and surface water study included fish sampling at RM 2.4 near CBP. The surface water quality, sediment chemistry, physical habitat, and macroinvertebrate community assessment are defined in Section 7.9.2 and not repeated here. The new material summarizes the fish community.

Fish communities ranged from marginally good to good in Sand Creek, one sampling location of which is near CBP. Index of Biotic Integrity (IBI) scores ranged between 36 and 44. These IBI values achieved the ecoregional biocriterion established for WWH streams and rivers in Ohio. Mountain brook lamprey, an Ohio Endangered Species, were collected in Sand Creek at the lower three sampling locations (RMs 1.9, 1.5, and 0.8) and could be present at RM 2.4 near CBP. Based on the fish community results from the eight Sand Creek sites, no biological impairment associated with chemical contaminants was observed.

7.9.4 Risk to Terrestrial Wildlife

The potential risks to mammals and birds associated with all the COPCs in the surface soil, sediment, and/or surface water were further evaluated to determine whether site-related risks from the chemicals were acceptable or whether the risks were great enough to warrant retaining the chemicals as COPCs and proceeding further into the BERA.

7.9.4.1 Risk to Insectivores/Herbivores

Based on the conservative modeling and the no effect benchmark (NOAEL), the vole had an HQ greater than 1.0 for arsenic; the robin had an HQ>1.0 for aroclor-1254, cadmium, chromium, lead and zinc; and the shrew had an HQ>1.0 for aroclor-1254, arsenic, cadmium and lead. The robin had LOAEL HQs>1.0 for lead and zinc. No PAHs or pesticides resulted in NOAEL HQs exceeding 1.0 in the conservative scenario.

Based on the average scenario and the no effect benchmark (NOAEL), the vole had an HQ>1.0 for arsenic; the robin for cadmium, chromium, lead and zinc; and the shrew for arsenic and lead. Only the robin had a LOAEL HQ>1.0 for lead using the average soil concentration as an EPC.

The conservative assumption of total bioavailability, exclusive use of CBP as habitat, the few LOAEL exceedances, lack of habitat in areas with greatest chemical concentrations, and similarity of site average concentrations to background concentrations were used to conclude that impacts to invertivorous and herbivorous receptors is unlikely, especially compared to background risks. Therefore, risks to wildlife are acceptable from aroclor-1254, arsenic, cadmium, chromium, lead and zinc. And these analytes are not retained as a COPC for further evaluation regarding risks to wildlife.

7.9.4.2 Risk to Carnivorous Species

Based on the conservative scenario and the no-effect benchmark (NOAEL), no chemicals had HQs that were greater than one. Consequently, risks to carnivorous wildlife are acceptable and no chemicals are retained as COPCs for further evaluation regarding risks to carnivorous wildlife.

8.0 RESULTS AND CONCLUSIONS

This section briefly summarizes the existing CBP conditions that were found during the RI, the possible fate and transport of contaminants detected at the AOC, and the risk assessment tasks that were completed.

8.1 SUMMARY

This section summarizes Sections 4.0 through 7.0 of the RI document.

8.1.1 Nature and Extent of Contamination

The nature and extent of contamination is examined in four media: soil, sediment, surface water, and groundwater. Contaminants were detected in all environmental media sampled; however very few constituents other than inorganics were detected. Organics were detected in very few samples. For example, explosives were detected in only one soil sample location and SVOCs were detected in one shallow soil boring sample and in one sediment sample. Therefore, no inferences can be made regarding contaminant distribution in any of the media because of the low frequency of detection. In summary:

- Contaminants detected in soil above background and/or PRG values included:
    - metals and other inorganics (arsenic, manganese, iron, chromium, and lead);
    - one explosive (TNT);
    - two propellants (nitrocellulose and nitroguanidine);
    - one PCB (Aroclor 1254); and
    - several pesticides and SVOCs.
- In sediment, inorganics, two VOCs (acetone and methylene chloride), and SVOCs were detected at concentrations above background and/or PRG values.
- In surface water, only calcium, magnesium, and arsenic were detected above background and/or PRG values. The three samples collected were all taken from Sand Creek. Although the samples follow a progression in the creek (up gradient, middle gradient, and down gradient), the concentrations are so similar that no inference can be made regarding impacts from CBP.
- In groundwater, only inorganics and one VOC (acetone) were detected. No inference can be made regarding the distribution of inorganic constituents based upon the detections in monitoring wells.

8.1.2 Fate and Transport

Fate and transport modeling was used to evaluate the vertical migration of contaminants to groundwater and horizontal transport of contaminants from source areas to receptor populations within groundwater, soil, and sediment.

The physical paths or mechanisms by which CBP contaminants could migrate and the significance of those pathways are:

- Leaching from soil to groundwater – Because the number of contaminants and associated concentrations found in soil are low, the mass that can be transported by this pathway is low. Likewise, the low groundwater concentrations suggest that past leaching has not been significant.
- Groundwater migration – Due to the low concentrations of contaminants detected and the impermeable nature of the soil, this pathway is expected to be insignificant.
- Mixing of groundwater and surface water – There is potential for groundwater to discharge to surface water, however due to the low concentrations of contaminants and the dilution that would occur in the surface water, this pathway is expected to be insignificant.
- Soil discharge to surface water – This pathway, along with transport within surface water, is potentially one of the most significant migration pathways at CBP. However, the overall impact would likely be minimized by the low concentrations in soil and the flat topography that limits transport.
- Sediment to surface water – Again, due to the low concentrations seen in sediment, and the low solubility of many of the COCs, this pathway is expected to be insignificant.
- Volatilization from soil and/or surface water – Since VOCs were not a concern at CBP, this pathway is not expected to be of any consequence.

8.1.3 Baseline Human Health Risk Assessment

A BHHRA was conducted to evaluate the risks and hazards associated with the human exposure to contaminated media at CBP. The BHHRA included:

- Data evaluation and selection of COPCs;
- Exposure assessment to identify potential receptors, evaluate potential exposure pathways and estimate the chemical intake resulting from the exposure;
- Toxicity assessment to evaluate the toxicity of each COCP and summarize the toxicity criteria that were used;
- Risk characterization to estimate the carcinogenic and non-carcinogenic risk(s); and
- Uncertainty analysis to identify significant uncertainties that could impact the BHHRA results.

The COPCs identified from the quantitative BHHRA are:

Soils	**Groundwater**	**Sediment**
Arsenic	Arsenic	Arsenic
Aluminum	--	Aluminum
Chromium	--	Manganese
Copper	--	Vanadium
Lead	--	Benzo(a)pyrene
Manganese	--	--
Vanadium	--	--
Aroclor 1254	--	--
Benzo(a)pyrene	--	--

The receptors evaluated included a security guard/maintenance worker; a National Guard trainee; a National Guard resident; a hunter/trapper; and hypothetical future farm residents (adult and child). The risk assessment showed the following results.

Table 8-1. Summary of BHRRA Potential Risk

Receptor	Non-Carcinogenic	Incremental Lifetime Cancer Risk
Security guard/maintenance worker	HI <1 (no adverse non-carcinogenic health effects)	Within USEPA target risk range of 1E-04 to 1E-06, does not exceed Ohio EPA's target of 1E-05.
Hunter/Trapper	HI <1 (no adverse non-carcinogenic health effects)	<1E-06; does not exceed USEPA or Ohio EPA target risk ranges.
National Guard resident	HI >1 ***only*** if it is assumed that groundwater is used for domestic purposes. Arsenic the primary driver.	Exceeds USEPA target risk only if shallow groundwater is used for domestic purposes; exceeds Ohio EPA target risk value. Arsenic is primary risk driver.
National Guard trainee	HI >1 for shallow soil. Risk is driven by inhalation of manganese. HI for no other contaminant exceeded 1. See the Uncertainty section.	Within USEPA target risk range of 1E-04 to 1E-06. Arsenic is primary risk driver.
Adult resident farmer	HI>1 for all media combined ***only*** if it is assumed that receptor is using shallow groundwater for domestic purposes. See the Uncertainty section.	Not applicable
Child resident farmer	HI >1 for groundwater, surface soil, and subsurface soil. However, target-organ specific HI > 1 ***only*** if it is assumed that groundwater is used for domestic purposes and the ingestion of foodstuffs pathways are evaluated. Arsenic is the primary risk driver. See the Uncertainty discussion.	Not applicable
Lifelong resident farmer	Not applicable.	Exceeds USEPA target risk range only if it is assumed that shallow groundwater is used for domestic purposes. Exceeds Ohio EPA target risk value. Arsenic is primary driver.

Several significant uncertainties associated with the risk assessment were identified as outlined in Section 6.7. These uncertainties should be considered when making any risk management decisions. For example, in many cases conservative exposure and toxicity assumptions were applied, that may have resulted in overly conservative estimates of potential risk. In addition, as the concentrations of these constituents are similar to or just slightly greater than background, the risk also is similar to or just slightly greater than that associated with background.

The total cancer risk estimate (summed across all media) for the critical receptor of concern (the National Guard trainee) does not exceed 1E-04. However, the risk for shallow soils and groundwater exceed 1E-05. The cancer risk estimate for sediments does not exceed 1E-05. Arsenic and chromium are the primary contributors to the cancer risk estimate. The cancer risk estimates for the shallow soil exceed 1E-05 only when it is assumed that all chromium is present in the hexavalent state, an unlikely scenario. The HIs for sediment and groundwater are less than 1. The total non-cancer risk (HI) estimate (summed across all media) only exceeds 1 when manganese in soil is evaluated as a COPC. However, as discussed in Section 6, significant uncertainties were identified for the risk estimates for arsenic (in groundwater) and manganese (in soils). These uncertainties are significant because the conservative exposure and toxicity assumptions may have led to conservative conclusions about potential risk and should be considered by RVAAP's risk management team when making further remedial decisions for CBP.

The total cancer risk estimate (summed across all media) and the total HI (summed across all media) for the National Guard Resident exceeds 1E-04 and 1, respectively, only when the future domestic use of the shallow groundwater resource is evaluated. Cancer risk estimates and HIs for all other media for the National Guard Resident do not exceed 1E-05 and 1, respectively. These uncertainties are significant because the conservative exposure and toxicity assumptions may have led to conservative conclusions about potential risk and should be considered by RVAAP's risk management team when making further remedial decisions for CBP.

The total cancer risk estimate (summed across all media) for the hypothetical future resident exposed by the direct contact exposure pathways exceeds 1E-04 only when future domestic use of the shallow groundwater resource is evaluated. Cancer risk estimates for soils and sediments evaluated for the direct contact exposure pathways exceed 1E-05 but do not exceed 1E-04. Total non-cancer risk estimates (HI) calculated on a target-organ-specific basis exceed 1 only when future domestic use of the shallow groundwater use is evaluated. However, cancer and non-cancer risk estimates developed for the indirect exposure pathways (i.e., consumption of home-grown foodstuffs) exceed both cancer and non-cancer risk benchmarks (i.e., 1E-04 and HI = 1, respectively). Several uncertainties were identified for the risk estimates for arsenic in groundwater and for the evaluation of the indirect exposure pathways. These uncertainties are significant because the conservative exposure and toxicity assumptions may have led to conservative conclusions about potential risk and should be considered by RVAAP's risk management team when making further remedial decisions (e.g., deed restriction decisions) for CBP.

Total non cancer risk estimates calculated for the child resident farmer exceeds 1. Only the target-organ-specific HI (summed across all media) calculated for the skin and cardiovascular systems exceed 1. The total target-organ-specific HI would not exceed 1 if domestic use of the shallow groundwater medium is not evaluated. HIs calculated for the child resident farmer exposed via the indirect exposure pathways (i.e., consumption of vegetables, beef, and milk raised on-site) exceed 1. The food chain modeling used to characterize risk is very conservative. HIs exceeding 1 would also be predicted for the naturally occurring or anthropogenic background concentrations of these parameters. HIs calculated for child resident consumption of venison do not exceed 1.

Cancer and non-cancer risk estimates for the security guard/maintenance and the hunter/trapper do not exceed 1E-05 or an HI of 1, respectively.

8.1.4 Screening Ecological Risk Assessment

An SERA was performed to assess whether adverse ecological impacts are present as a result of site-related contaminants found in CBP. The BHHRA included completing Steps 1 through 3a of the eight steps that comprise a Baseline Ecological Risk Assessment. The ecological risk assessment steps are stipulated in U.S. EPA, Ohio EPA and the RVAAP FWERWP (USACE 2003). The steps that were completed as part of the CBP SERA are described below:

- Formulating the preliminary problem by identifying potential receptor groups and complete exposure pathway.
- Comparing the contaminant concentrations for the chemicals found in CBP surface water, sediment and surface soil samples to ecological screening values (ESVs) to initially select COPCs. The ESVs used in this risk assessment were stipulated by Ohio EPA and RVAAP guidance.
- Refining the list of COPCs by comparing exposure point concentrations to toxicity benchmarks established for specific specific receptor groups, by conducting food chain modeling for mammals and birds, and by evaluating other factors such as presence of suitable habitat, frequency of detection, spatial distribution, etc.

Ecological impact was evaluated for plants, soil and sediment invertebrates, aquatic organisms and terrestrial wildlife. Two types of mammals and birds were evaluated: insectivores /herbivores and carnivores. Table 8-2 summarizes the ecological risk.

Table 8-2. Ecological Risk Results

Type of Species	Screening Results	Notes
Terrestrial plants and soil invertebrates	Copper, lead and zinc retained as COPC's.	Several COPCs, though not retained, are potentially bioaccumulative, so they were evaluated further in wildlife.
Sediment Invertebrates	No COPC's retained.	None of the COPCs were bioaccumulative, so no further evaluation was conducted.
Aquatic Organisms	No COPC's retained.	None of the COPCs were bioaccumulative, so no further evaluation was conducted.
Terrestrial Wildlife – Carnivores	Conservative scenario and NOAEL resulted in no chemicals having an HQ >1. No COPCs retained.	Because conservative scenario and NOAEL did not result in HQ >1, the risk was determined to be acceptable.
Terrestrial Wildlife – Insectivores/ Herbivores	Average scenario and NOAEL resulted in HQ>1 for: arsenic (vole and shrew); lead (robin and shrew), cadmium, chromium, and zinc (robin only)	Because conservative bioavailability assumptions were made, few LOAEL exceedances, lack of habitat in areas with greatest chemical concentrations, and similarity of site average concentrations to background concentrations, risks were determined to be acceptable.

No unacceptable ecological risks were identified at the CBP.

8.1.5 Summary of Conclusions

Future planned uses for National Guard training, hunting, and trapping do not pose a risk to potential human health receptors. No unacceptable ecological risks were identified at the CBP.

9.0 RECOMMENDATIONS

Conservative toxicity and exposure values were used to calculate the potential risk. The BHHRA indicated that potential risk to a National Guard trainee due to exposure to manganese via the inhalation exposure pathway. The risk estimates presented likely overestimate the actual potential for non-carcinogenic risk. Additionally, the manganese concentrations detected may represent background conditions. It is recommended that the risk management team carefully consider the need for further investigation or remedial action based on the risk assessment results for this receptor taken at face value.

RVAAP's risk management team should evaluate the need for institutional controls such as deed restrictions to limit the future use of the CBP area. Deed restrictions can be used to prevent residential and/or farmland use in the future. The same mechanism can be used to prevent the use of shallow groundwater for domestic purposes. Additionally, the uncertainties presented in Section 6.7 of this RI should be carefully considered in the overall risk management decisions that are made for CBP.

For example, the primary risk driver for groundwater at CBP is arsenic. However, arsenic is a naturally occurring metal and was detected in soils and groundwater at concentrations similar to or slightly above RVAAP background criteria but within the range of naturally occurring background. The RVAAP background reported arsenic concentrations ranging from 11 ug/L (filtered overburden) to 215 ug/L (unfiltered overburden). The maximum arsenic concentration detected in CBP monitoring wells was 35.1 ug/L.

During the RI, debris piles/berms of soil like materials were observed in the west and north portions of the CBP AOC. These were not evaluated during this RI, recommend characterization of these debris piles/berms be conducted.

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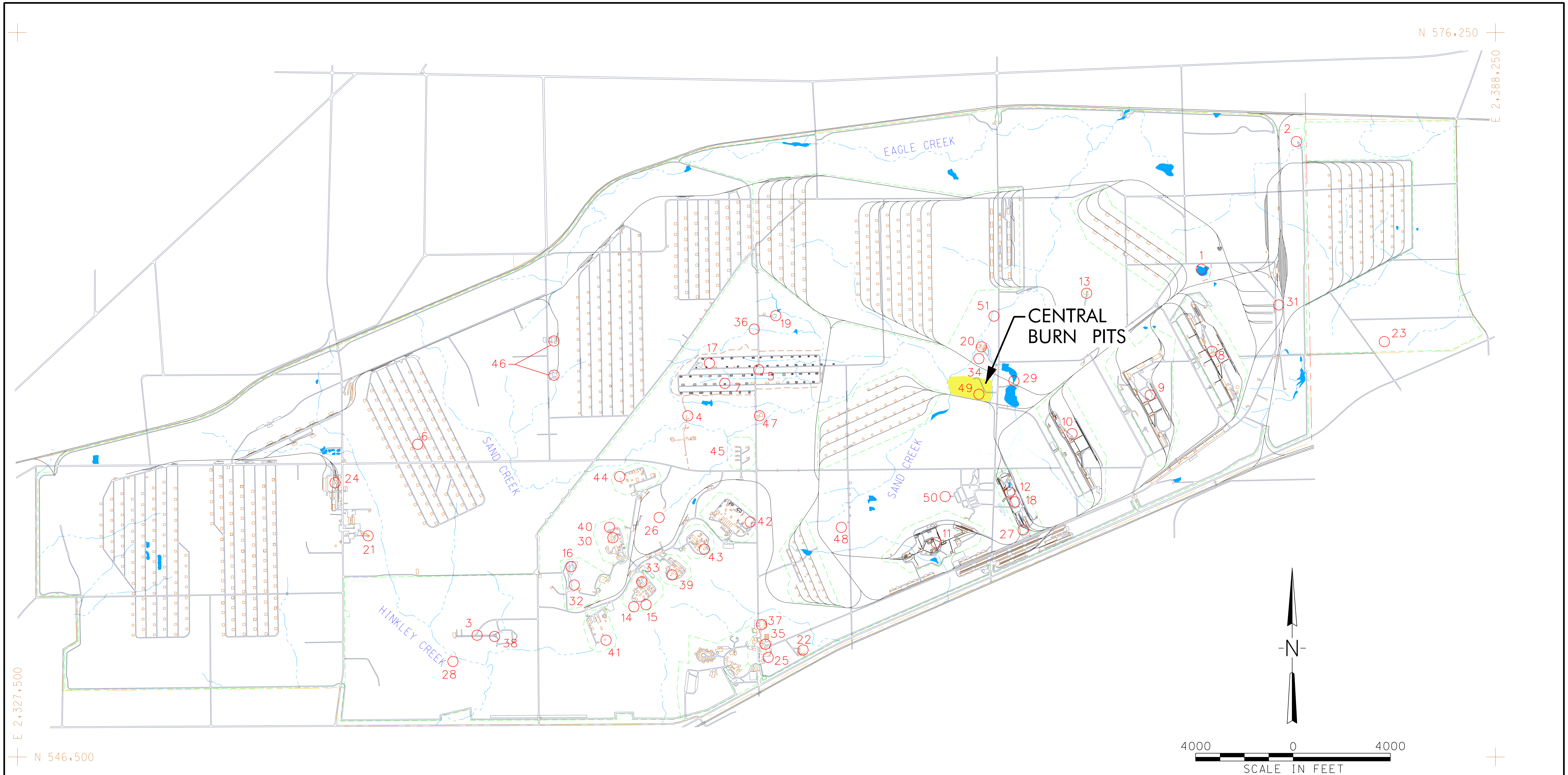
FIGURES

Figure 1-1. Ravenna Army Ammunition Plant Location Map



LEGEND OF SITES:

1	RAMSDELL QUARRY LANDFILL
2	ERIE BURNING GROUNDS
3	DEMOLITIONS AREA #1
4	DEMOLITIONS AREA #2
5	WINKLEPECK BURNING GROUNDS
6	C BLOCK QUARRY
7	BLDG 1601 HAZARDOUS WASTE STORAGE
8	LOAD LINE 1 AND DILUTION/SETTLING POND
9	LOAD LINE 2 AND DILUTION/SETTLING POND
10	LOAD LINE 3 AND DILUTION/SETTLING POND
11	LOAD LINE 4 AND DILUTION/SETTLING POND
12	LOAD LINE 12 AND DILUTION/SETTLING POND
13	BLDG 1200 AND DILUTION/SETTLING POND
14	LOAD LINE 6, EVAPORATION UNIT
15	LOAD LINE 6, TREATMENT PLANT
16	QUARRY LANDFILL/FORMER FUZE & BOOSTER BURNING PITS
17	DEACTIVATION FURNACE
18	LOAD LINE 12 PINK WASTE WATER TREATMENT
19	LANDFILL NORTH OF WINKLEPECK BURNING GROUND
20	SAND CREEK SEWAGE TREATMENT PLANT
21	DEPOT SEWAGE TREATMENT PLANT
22	GEORGE ROAD SEWAGE TREATMENT PLANT
23	UNIT TRAINING SITE WASTE OIL TANK
24	RESERVE UNIT MAINTENANCE AREA WASTE OIL TANK
25	BLDG 1034 MOTOR POOL WASTE OIL TANK
26	FUZE BOOSTER AREA SETTLING TANKS
27	BLDG 854-PCB STORAGE
28	MUSTARD AGENT BURIAL SITE
29	UPPER AND LOWER COBBS POND COMPLEX
30	TREATMENT PLANT LOAD LINE 7 PINK WASTEWATER
31	ORE PILE RETENTION POND
32	40 AND 60 MM FIRING RANGE
33	FIRESTONE TEST FACILITY
34	SAND CREEK DISPOSAL ROAD LANDFILL
35	1037 BUILDING-LAUNDRY WASTEWATER SUMP
36	PISTOL RANGE
37	PESTICIDE BUILDING S-4452
38	NACA TEST AREA
39	LOAD LINE 5/FUZE LINE 1
40	LOAD LINE 7/BOOSTER LINE 1
41	LOAD LINE 8/BOOSTER LINE 1
42	LOAD LINE 9/DETONATOR LINE
43	LOAD LINE 10/PERCUSSION ELEMENT
44	LOAD LINE 11/ARTILLERY PRIMER
45	WET STORAGE AREA
46	BUILDINGS F-15 AND F-16
47	BUILDING T-5301 DECONTAMINATION
48	ANCHOR TEXT AREA
49	CENTRAL BURN PITS
50	ATLAS SCRAP YARD
51	DUMP ALONG PARIS - WINDHAM ROAD
┼┼┼┼┼┼┼┼┼	RAILROAD TRACKS
— — — —	FENCELINE
— — —	PROPERTY BOUNDARY
〰	STREAM OR CREEK
◌ 20	AREAS OF CONCERN

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RAVENNA ARMY AMMUNITION PLANT
RAVENNA OHIO

FIGURE 1-2
CENTRAL BURN PITS REMEDIAL INVESTIGATION FACILITY LOCATION MAP

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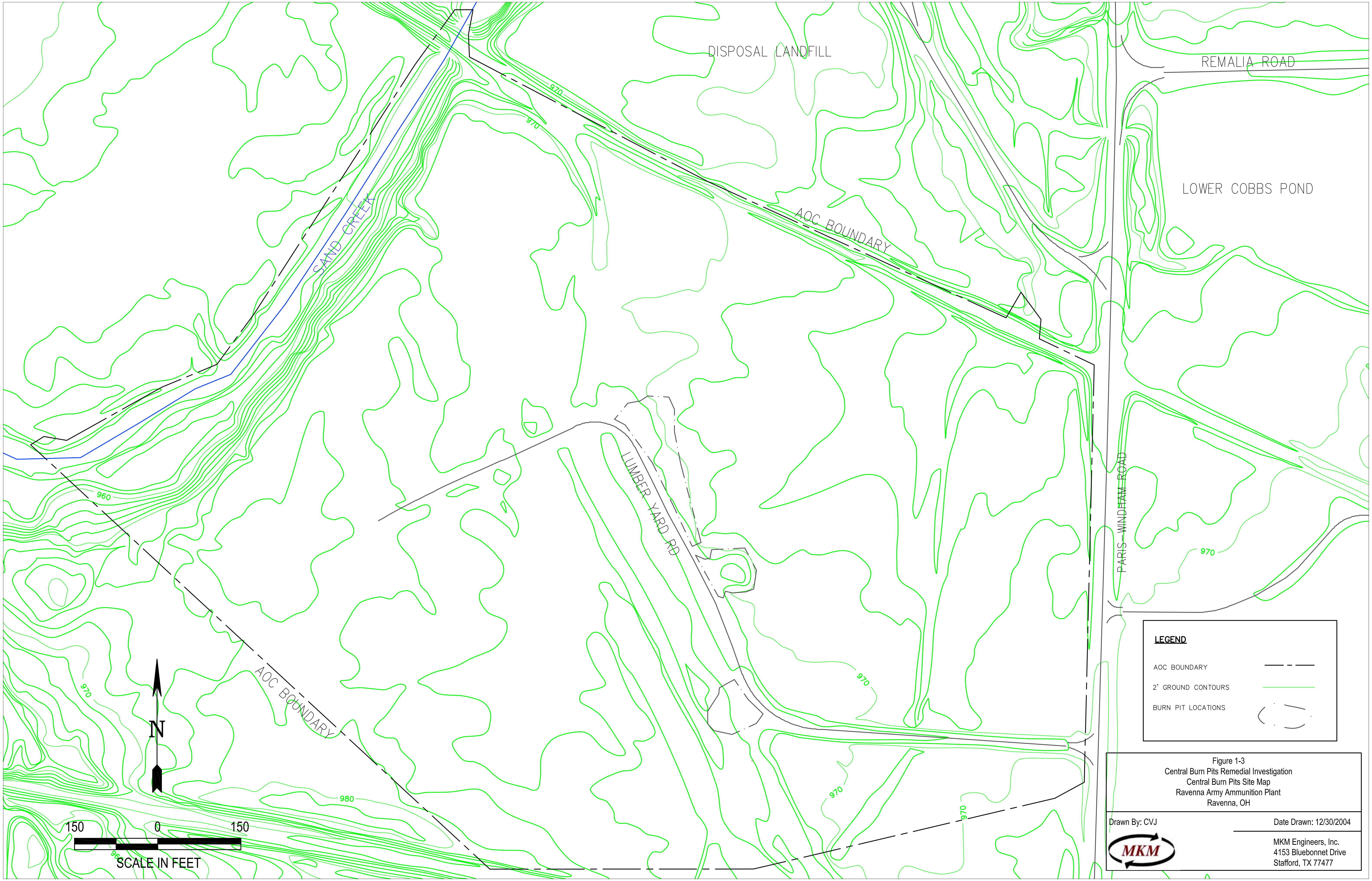

Figure 1-3
Central Burn Pits Remedial Investigation
Central Burn Pits Site Map
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

Date Drawn: 12/30/2004

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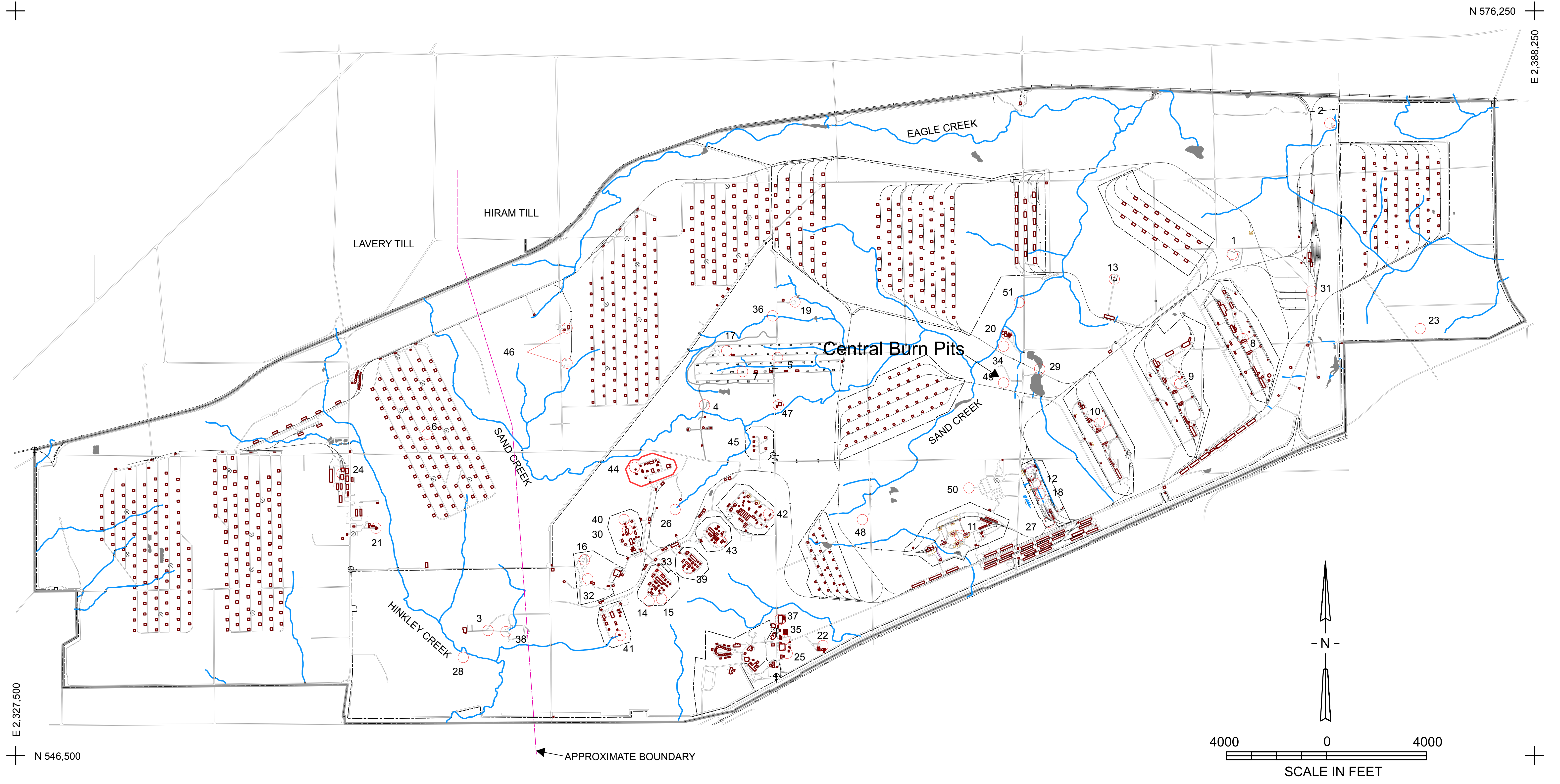

LEGEND OF SITES:

1	RAMSDELL QUARRY LANDFILL
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3	DEMOLITIONS AREA #1
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10	LOAD LINE 3 AND DILUTION/SETTLING POND
11	LOAD LINE 4 AND DILUTION/SETTLING POND
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25	BLDG 1034 MOTOR POOL WASTE OIL TANK
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27	BLDG 854-PCB STORAGE
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29	UPPER AND LOWER COBBS POND COMPLEX
30	TREATMENT PLANT LOAD LINE 7 PINK WASTEWATER
31	ORE PILE RETENTION POND
32	40 AND 60 MM FIRING RANGE
33	FIRESTONE TEST FACILITY
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48	ANCHOR TEXT AREA
49	CENTRAL BURN PITS
50	ATLAS SCRAP YARD
51	DUMP ALONG PARIS - WINDHAM ROAD
┼┼┼┼┼┼┼┼┼	RAILROAD TRACKS
—	FENCELINE
—	PROPERTY BOUNDARY
	STREAM OR CREEK
○ 20	AREAS OF CONCERN

Figure 2-1
Central Burn Pits Remedial Investigation
Glacial Till Map (White, 1982)

Ravenna Army Ammunition Plant
Ravenna, OH

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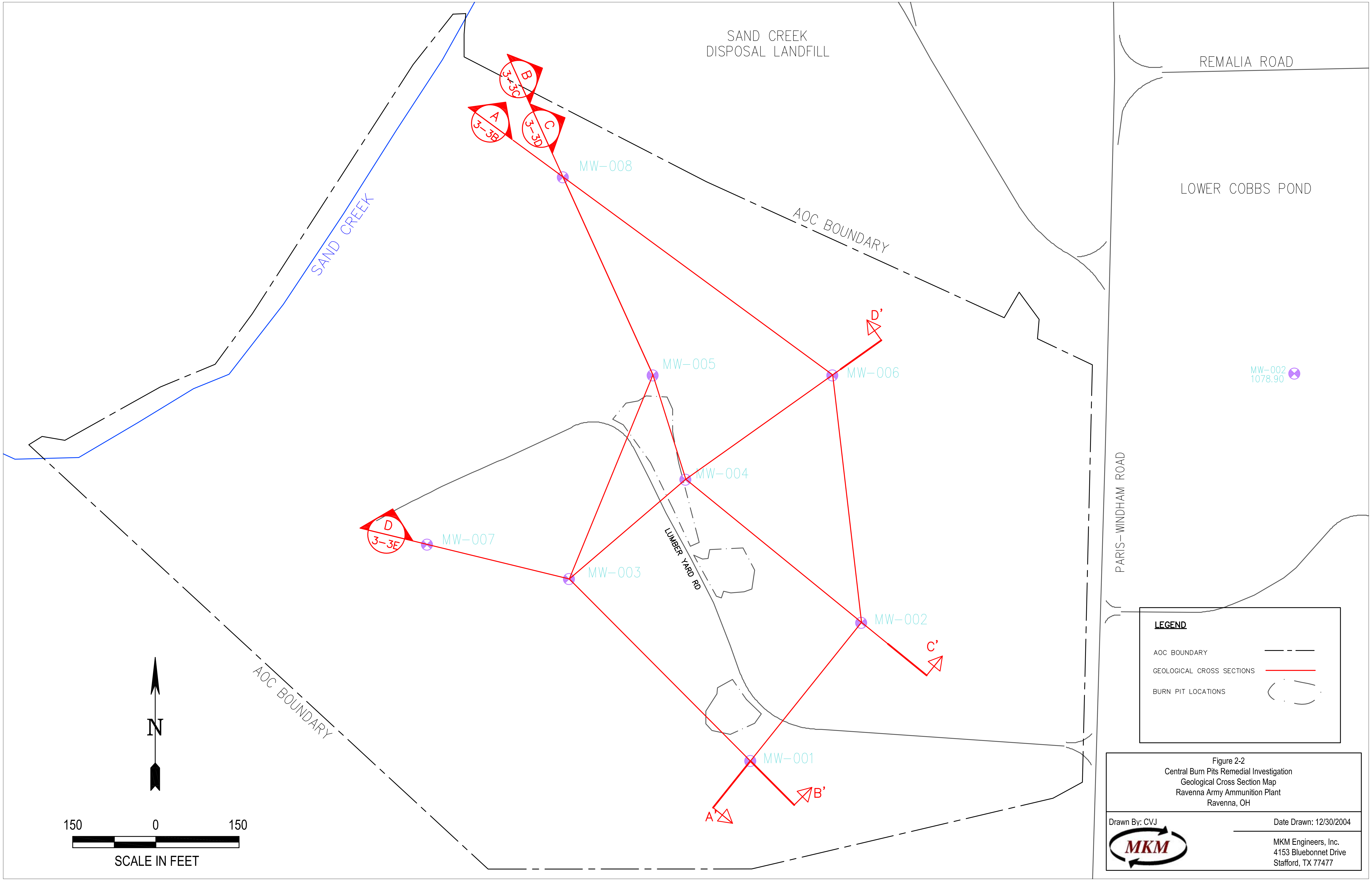

Figure 2-2
Central Burn Pits Remedial Investigation
Geological Cross Section Map
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

Date Drawn: 12/30/2004

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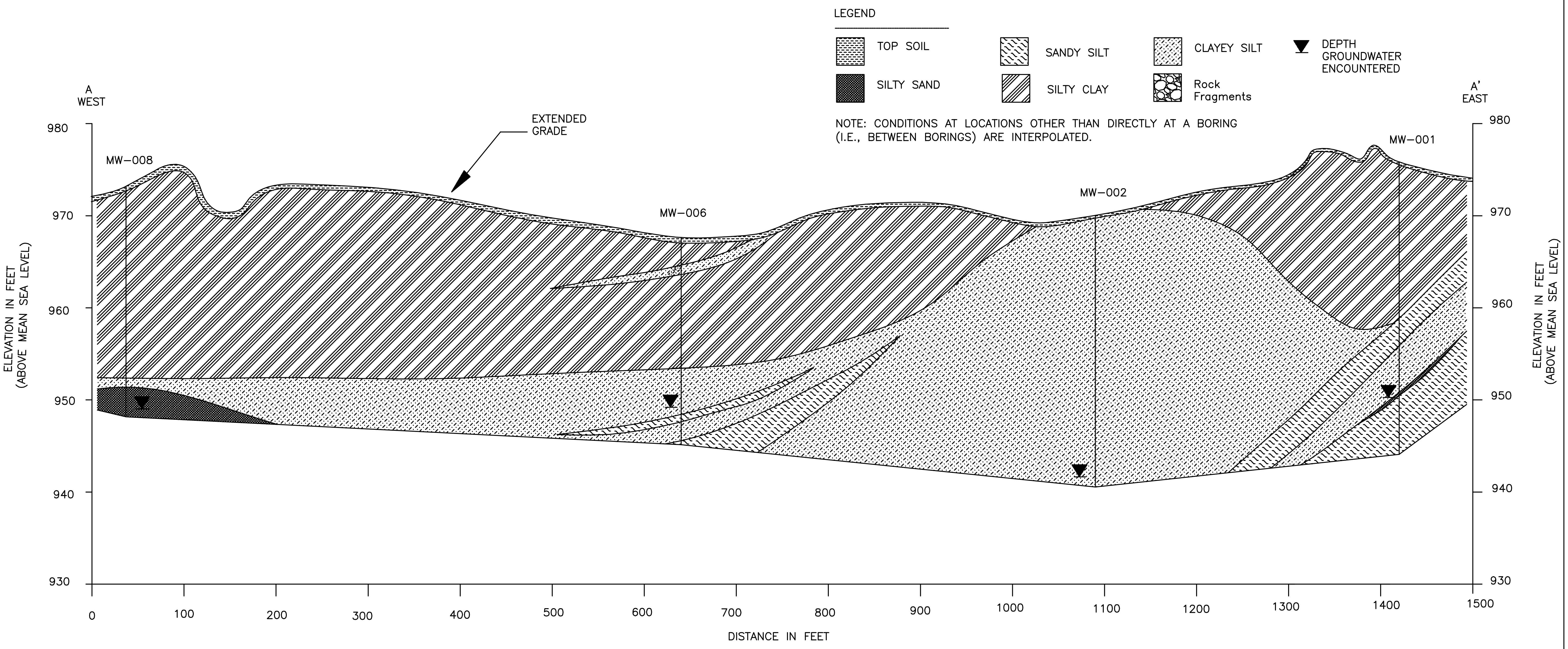

NOTE: CONDITIONS AT LOCATIONS OTHER THAN DIRECTLY AT A BORING (I.E., BETWEEN BORINGS) ARE INTERPOLATED.

CROSS SECTION A

HORIZONTAL 1"=100'
VERTICAL 1"=10'

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

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FIGURE 2–3
CENTRAL BURN PITS
GEOLOGIC CROSS SECTION A
RVAAP, RAVENNA, OH

SIZE	PROJECT NO.	DWG NO.	REV
D		2–3	

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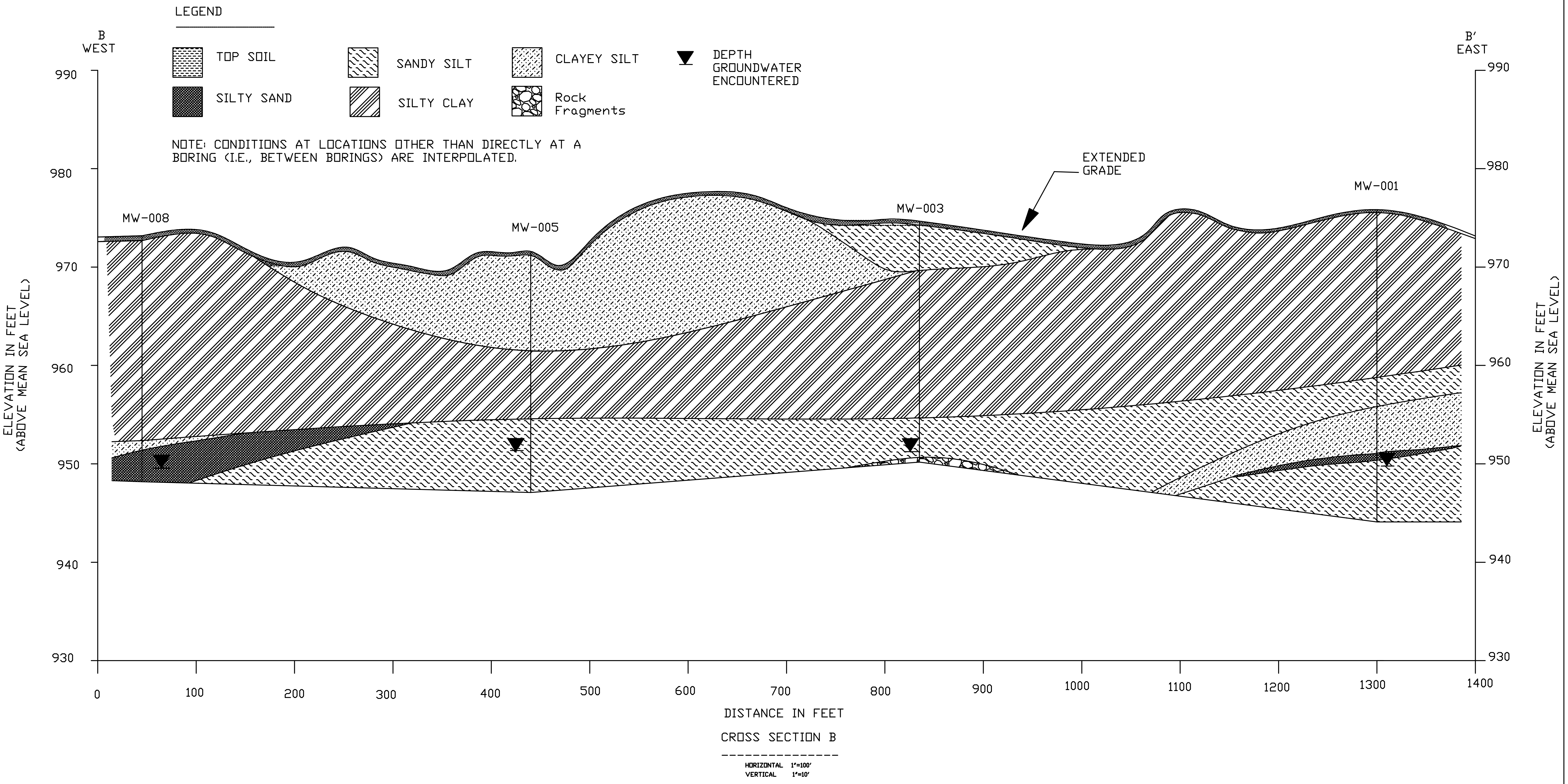

REVISIONS				
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FIGURE 2-4
CENTRAL BURN PITS
GEOLOGIC CROSS SECTION B
RVAAP, RAVENNA OHIO

SIZE	PROJECT NO.	DWG NO.	REV
D		2-4	

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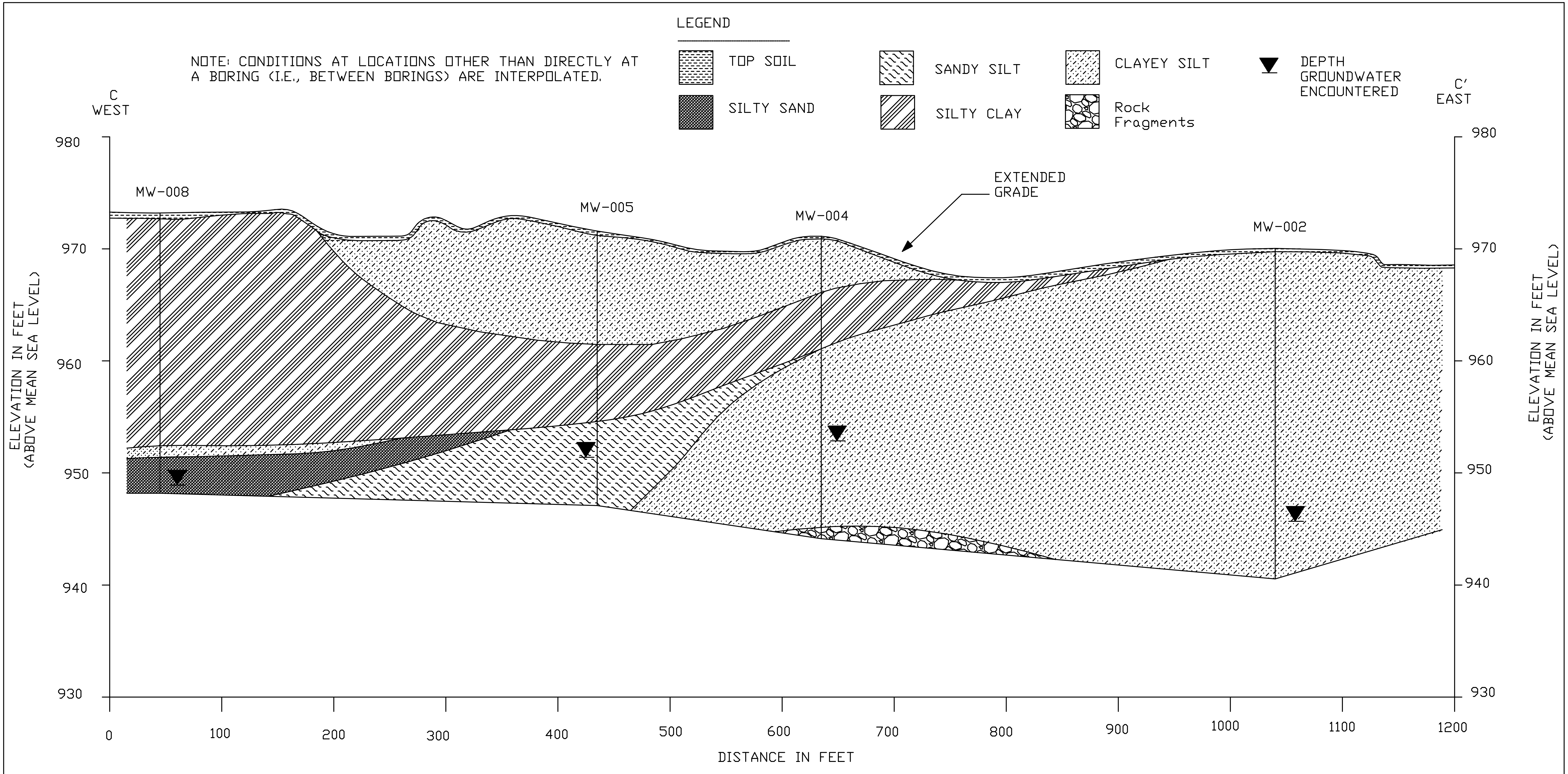
NOTE: CONDITIONS AT LOCATIONS OTHER THAN DIRECTLY AT A BORING (I.E., BETWEEN BORINGS) ARE INTERPOLATED.



CROSS SECTION C

HORIZONTAL 1"=100'
VERTICAL 1"=10'

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

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FIGURE 2-5
CENTRAL BURN PITS
GEOLOGIC CROSS SECTION C
RVAAP, RAVENNA OHIO

SIZE	PROJECT NO.	DWG NO.	REV
D		2-5	

DRAWN BY ST
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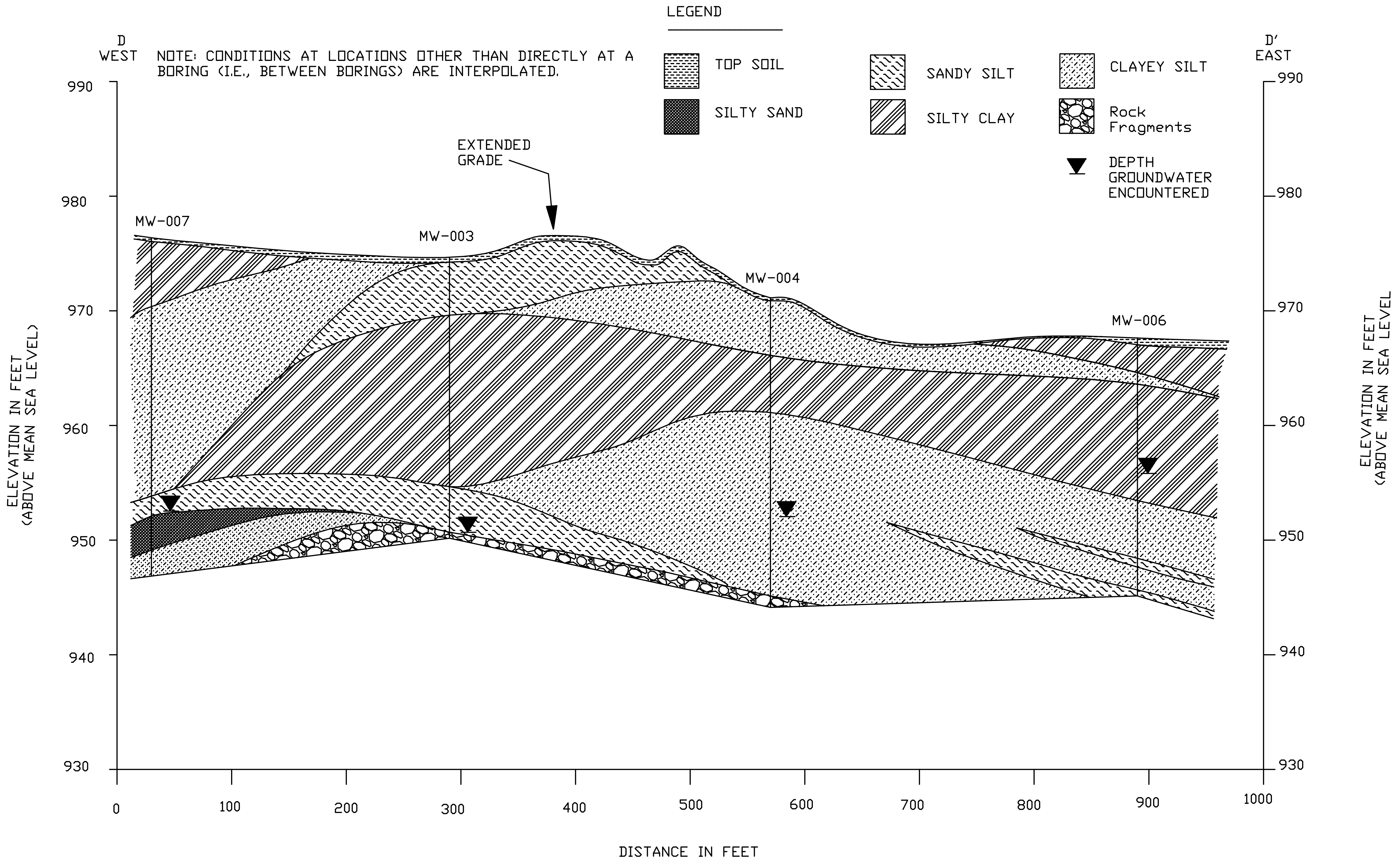

CROSS SECTION D

HORIZONTAL 1"=100'
VERTICAL 1"=10'

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

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FIGURE 2-6
CENTRAL BURN PITS
GEOLOGIC CROSS SECTION D
RVAAP, RAVENNA OHIO

SIZE	PROJECT NO.	DWG NO.	REV
D		2-6	

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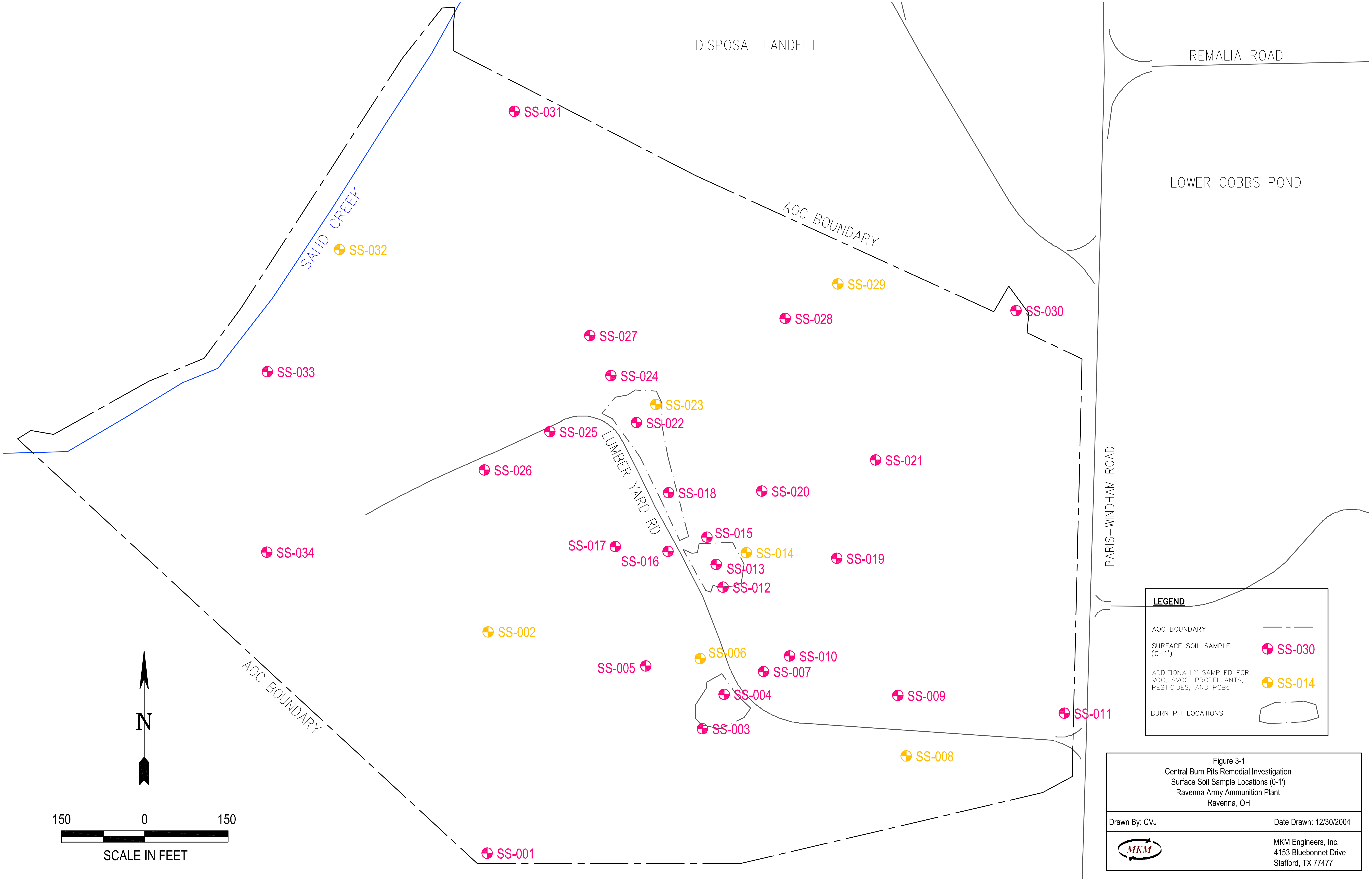

Figure 3-1
Central Burn Pits Remedial Investigation
Surface Soil Sample Locations (0-1')
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

Date Drawn: 12/30/2004

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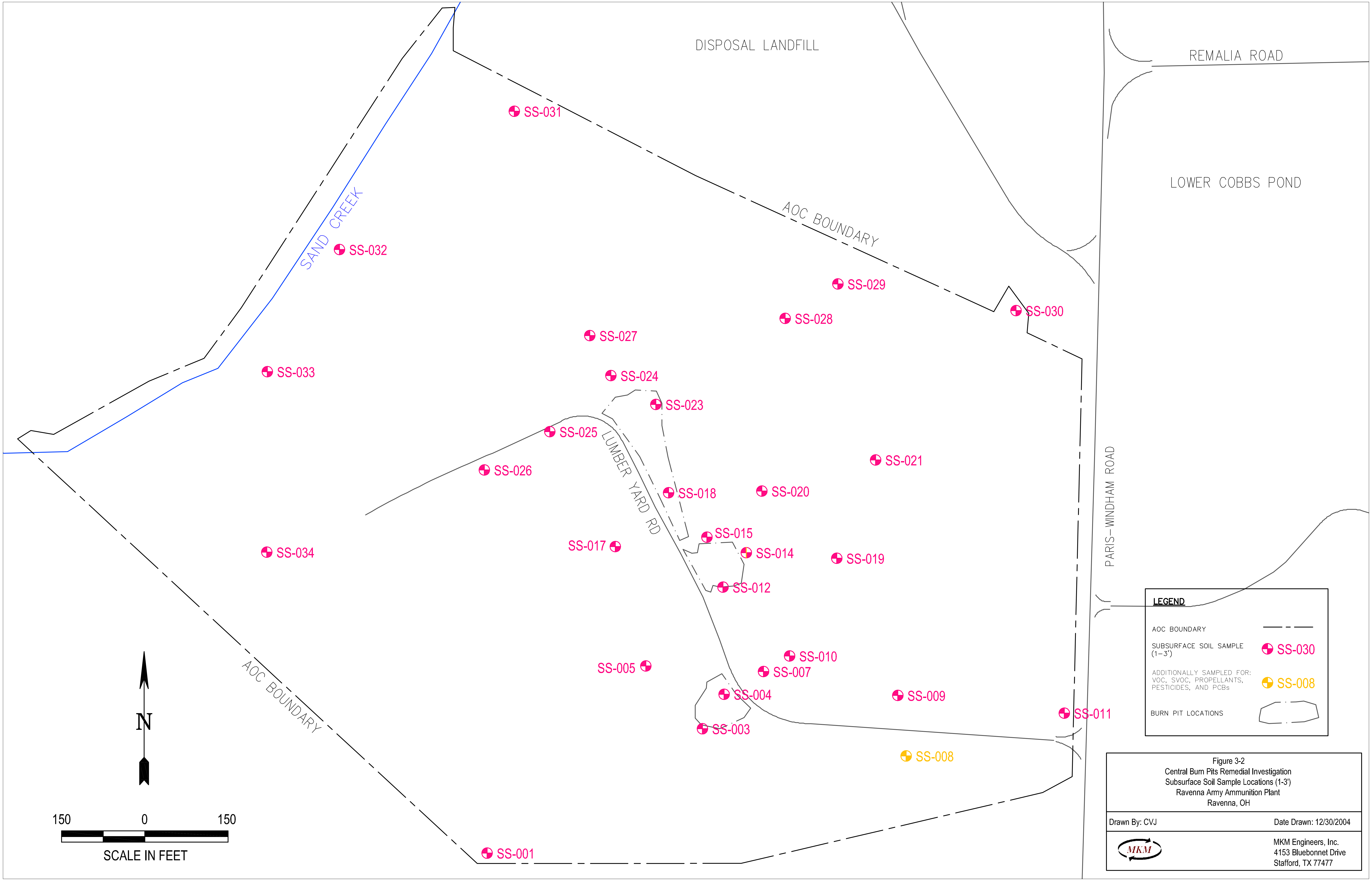

Figure 3-2
Central Burn Pits Remedial Investigation
Subsurface Soil Sample Locations (1-3')
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

Date Drawn: 12/30/2004

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Figure 3-3
Central Burn Pits Remedial Investigation
Soil Boring Surface Sample Locations (0-1')
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

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Figure 3-4
Central Burn Pits Remedial Investigation
Soil Boring Subsurface Sample Locations (>3')
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

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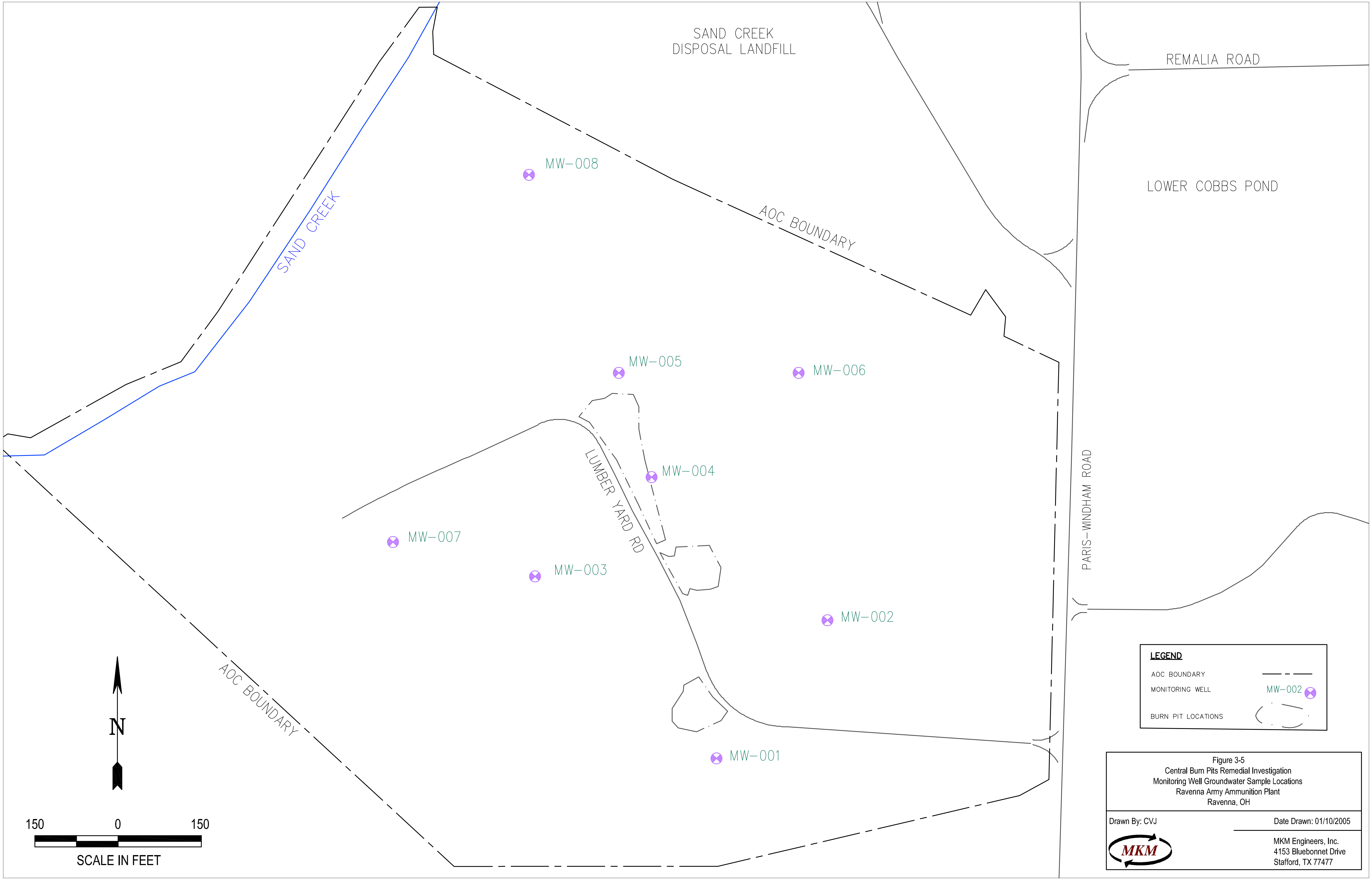

Figure 3-5
Central Burn Pits Remedial Investigation
Monitoring Well Groundwater Sample Locations
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 01/10/2005

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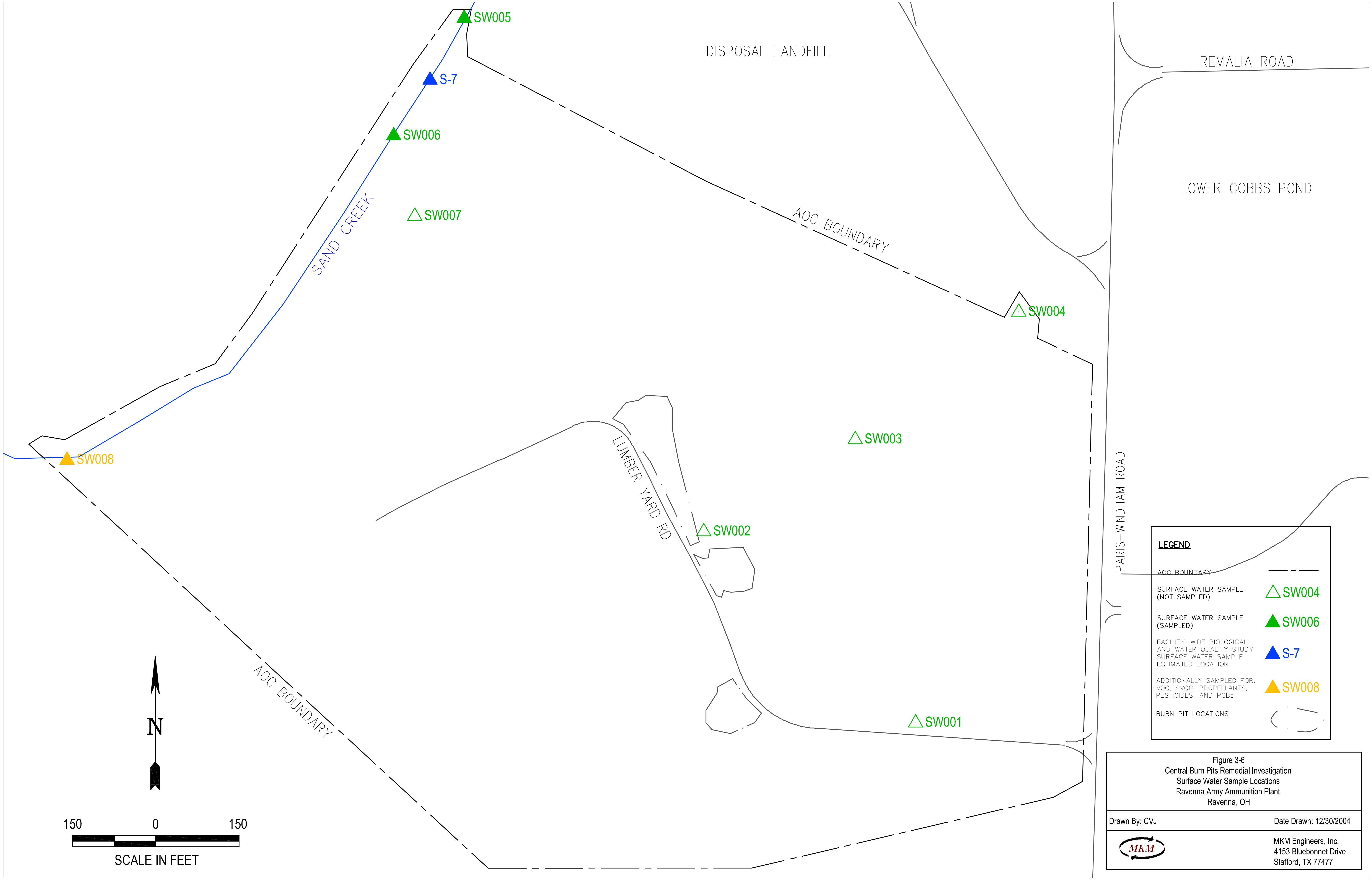

Figure 3-6
Central Burn Pits Remedial Investigation
Surface Water Sample Locations
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

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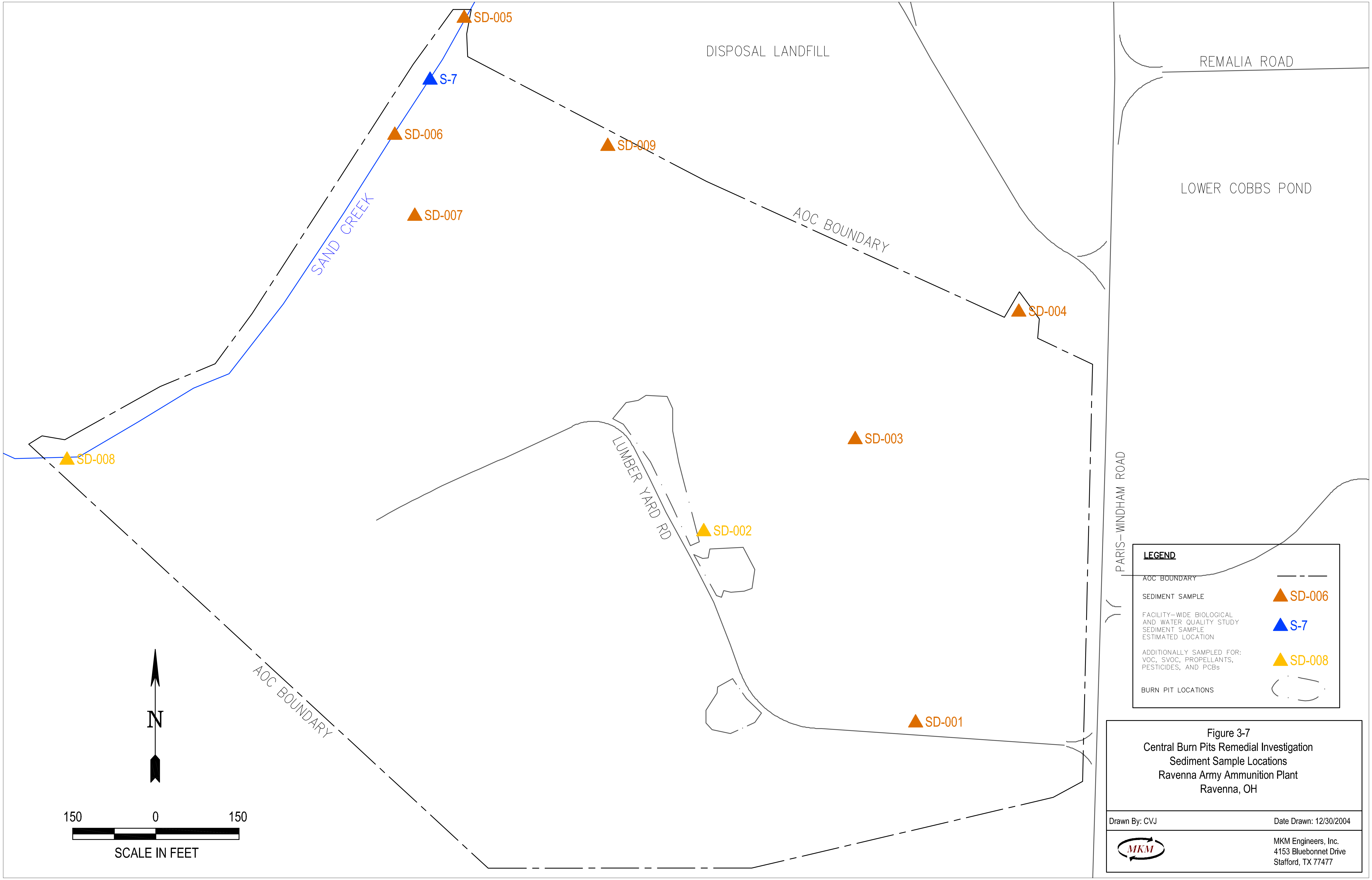

Figure 3-7
Central Burn Pits Remedial Investigation
Sediment Sample Locations
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

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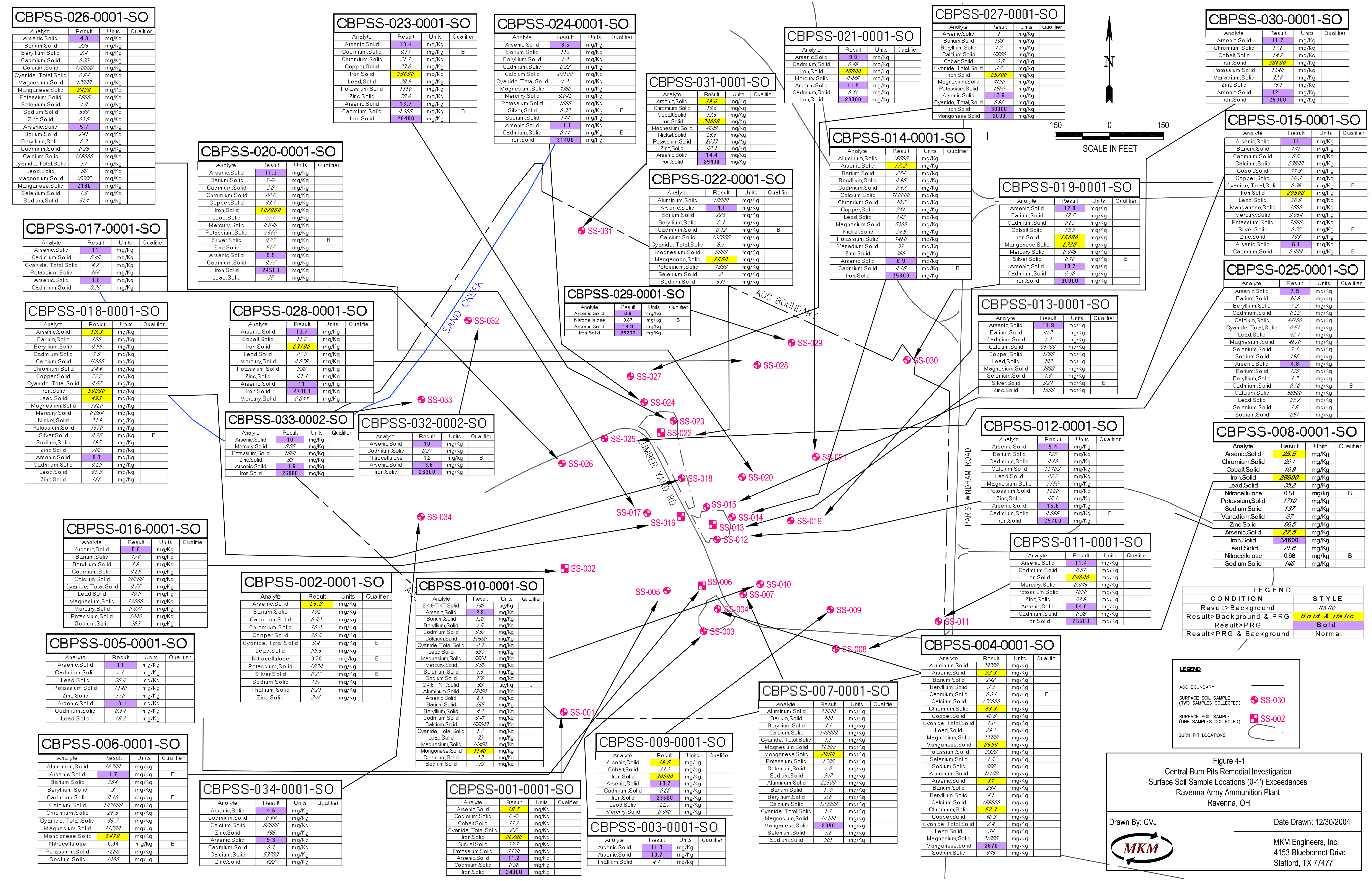


CBPSS-026-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**4.3**	mg/Kg	
Barium,Solid	*225*	mg/Kg	
Beryllium,Solid	*2.4*	mg/Kg	
Cadmium,Solid	*0.33*	mg/Kg	
Calcium,Solid	*170000*	mg/Kg	
Cyanide, Total,Solid	*0.64*	mg/Kg	
Magnesium,Solid	*12000*	mg/Kg	
Manganese,Solid	***2420***	mg/Kg	
Potassium,Solid	*1680*	mg/Kg	
Selenium,Solid	*1.8*	mg/Kg	
Sodium,Solid	*589*	mg/Kg	
Zinc,Solid	*63.8*	mg/Kg	
Arsenic,Solid	**5.7**	mg/Kg	
Barium,Solid	*241*	mg/Kg	
Beryllium,Solid	*2.2*	mg/Kg	
Cadmium,Solid	*0.25*	mg/Kg	
Calcium,Solid	*126000*	mg/Kg	
Cyanide, Total,Solid	*3.1*	mg/Kg	
Lead,Solid	*60*	mg/Kg	
Magnesium,Solid	*10300*	mg/Kg	
Manganese,Solid	**2180**	mg/Kg	
Selenium,Solid	*1.6*	mg/Kg	
Sodium,Solid	*514*	mg/Kg	

CBPSS-017-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11**	mg/Kg	
Cadmium,Solid	*0.45*	mg/Kg	
Cyanide, Total,Solid	*4.7*	mg/Kg	
Potassium,Solid	*966*	mg/Kg	
Arsenic,Solid	**8.6**	mg/Kg	
Cadmium,Solid	*0.28*	mg/Kg	

CBPSS-018-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***19.3***	mg/Kg	
Barium,Solid	*288*	mg/Kg	
Beryllium,Solid	*0.99*	mg/Kg	
Cadmium,Solid	*1.5*	mg/Kg	
Calcium,Solid	*41000*	mg/Kg	
Chromium,Solid	*24.4*	mg/Kg	
Copper,Solid	*77.2*	mg/Kg	
Cyanide, Total,Solid	*0.57*	mg/Kg	
Iron,Solid	***50200***	mg/Kg	
Lead,Solid	***493***	mg/Kg	
Magnesium,Solid	*3820*	mg/Kg	
Mercury,Solid	*0.054*	mg/Kg	
Nickel,Solid	*23.9*	mg/Kg	
Potassium,Solid	*1570*	mg/Kg	
Silver,Solid	*0.25*	mg/Kg	B
Sodium,Solid	*197*	mg/Kg	
Zinc,Solid	*762*	mg/Kg	
Arsenic,Solid	**8.1**	mg/Kg	
Cadmium,Solid	*0.29*	mg/Kg	
Lead,Solid	*65.9*	mg/Kg	
Zinc,Solid	*122*	mg/Kg	

CBPSS-016-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**5.8**	mg/Kg	
Barium,Solid	*174*	mg/Kg	
Beryllium,Solid	*2.6*	mg/Kg	
Cadmium,Solid	*0.25*	mg/Kg	
Calcium,Solid	*90200*	mg/Kg	
Cyanide, Total,Solid	*0.77*	mg/Kg	
Lead,Solid	*40.9*	mg/Kg	
Magnesium,Solid	*11000*	mg/Kg	
Mercury,Solid	*0.071*	mg/Kg	
Potassium,Solid	*1000*	mg/Kg	
Sodium,Solid	*363*	mg/Kg	

CBPSS-005-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11**	mg/Kg	
Cadmium,Solid	*1.1*	mg/Kg	
Lead,Solid	*35.6*	mg/Kg	
Potassium,Solid	*1140*	mg/Kg	
Zinc,Solid	*110*	mg/Kg	
Arsenic,Solid	**10.1**	mg/Kg	
Cadmium,Solid	*0.64*	mg/Kg	
Lead,Solid	*19.2*	mg/Kg	

CBPSS-006-0001-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*26700*	mg/Kg	
Arsenic,Solid	**1.7**	mg/Kg	B
Barium,Solid	*354*	mg/Kg	
Beryllium,Solid	*3*	mg/Kg	
Cadmium,Solid	*0.18*	mg/Kg	B
Calcium,Solid	*182000*	mg/Kg	
Chromium,Solid	*26.5*	mg/Kg	
Cyanide, Total,Solid	*85.7*	mg/Kg	
Magnesium,Solid	*21200*	mg/Kg	
Manganese,Solid	***5410***	mg/Kg	
Nitrocellulose	0.94	mg/kg	B
Potassium,Solid	*1260*	mg/Kg	
Sodium,Solid	*1000*	mg/Kg	

CBPSS-020-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.3**	mg/Kg	
Barium,Solid	*246*	mg/Kg	
Cadmium,Solid	*2.2*	mg/Kg	
Chromium,Solid	*22.6*	mg/Kg	
Copper,Solid	*98.1*	mg/Kg	
Iron,Solid	***107000***	mg/Kg	
Lead,Solid	*371*	mg/Kg	
Mercury,Solid	*0.045*	mg/Kg	
Potassium,Solid	*1560*	mg/Kg	
Silver,Solid	*0.22*	mg/Kg	B
Zinc,Solid	*517*	mg/Kg	
Arsenic,Solid	**9.5**	mg/Kg	
Cadmium,Solid	*0.37*	mg/Kg	
Iron,Solid	**24500**	mg/Kg	
Lead,Solid	*35*	mg/Kg	

CBPSS-028-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.7**	mg/Kg	
Cobalt,Solid	*11.2*	mg/Kg	
Iron,Solid	***23100***	mg/Kg	
Lead,Solid	*27.9*	mg/Kg	
Mercury,Solid	*0.079*	mg/Kg	
Potassium,Solid	*936*	mg/Kg	
Zinc,Solid	*63.4*	mg/Kg	
Arsenic,Solid	**11**	mg/Kg	
Iron,Solid	**27800**	mg/Kg	
Mercury,Solid	*0.044*	mg/Kg	

CBPSS-033-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10**	mg/Kg	
Mercury,Solid	*0.05*	mg/Kg	
Potassium,Solid	*1660*	mg/Kg	
Zinc,Solid	*69*	mg/Kg	
Arsenic,Solid	**11.6**	mg/Kg	
Iron,Solid	**26000**	mg/Kg	

CBPSS-032-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10**	mg/Kg	
Cadmium,Solid	*0.21*	mg/Kg	
Nitrocellulose	1.2	mg/kg	B
Arsenic,Solid	**13.6**	mg/Kg	
Iron,Solid	**26300**	mg/Kg	

CBPSS-002-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***25.2***	mg/Kg	
Barium,Solid	*102*	mg/Kg	
Cadmium,Solid	*0.52*	mg/Kg	
Chromium,Solid	*18.2*	mg/Kg	
Copper,Solid	*20.5*	mg/Kg	
Cyanide, Total,Solid	*0.4*	mg/Kg	B
Lead,Solid	*99.6*	mg/Kg	
Nitrocellulose	0.76	mg/kg	B
Potassium,Solid	*1070*	mg/Kg	
Silver,Solid	*0.27*	mg/Kg	B
Sodium,Solid	*137*	mg/Kg	
Thallium,Solid	*0.21*	mg/Kg	
Zinc,Solid	*246*	mg/Kg	

CBPSS-034-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**4.6**	mg/Kg	
Cadmium,Solid	*0.44*	mg/Kg	
Calcium,Solid	*62500*	mg/Kg	
Zinc,Solid	*496*	mg/Kg	
Arsenic,Solid	**5.3**	mg/Kg	
Cadmium,Solid	*0.3*	mg/Kg	
Calcium,Solid	*53700*	mg/Kg	
Zinc,Solid	*422*	mg/Kg	

CBPSS-023-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.4**	mg/Kg	
Cadmium,Solid	*0.11*	mg/Kg	B
Chromium,Solid	*21.1*	mg/Kg	
Copper,Solid	*23.6*	mg/Kg	
Iron,Solid	***29600***	mg/Kg	
Lead,Solid	*29.9*	mg/Kg	
Potassium,Solid	*1350*	mg/Kg	
Zinc,Solid	*70.6*	mg/Kg	
Arsenic,Solid	**13.7**	mg/Kg	
Cadmium,Solid	*0.085*	mg/Kg	B
Iron,Solid	**26400**	mg/Kg	

CBPSS-024-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**8.6**	mg/Kg	
Barium,Solid	*115*	mg/Kg	
Beryllium,Solid	*1.2*	mg/Kg	
Cadmium,Solid	*0.22*	mg/Kg	
Calcium,Solid	*23100*	mg/Kg	
Cyanide, Total,Solid	*1.2*	mg/Kg	
Magnesium,Solid	*4360*	mg/Kg	
Mercury,Solid	*0.042*	mg/Kg	
Potassium,Solid	*1090*	mg/Kg	
Silver,Solid	*0.32*	mg/Kg	B
Sodium,Solid	*144*	mg/Kg	
Arsenic,Solid	**11.1**	mg/Kg	
Cadmium,Solid	*0.11*	mg/Kg	B
Iron,Solid	**31400**	mg/Kg	

CBPSS-010-0001-SO

Analyte	Result	Units	Qualifier
2,4,6-TNT,Solid	*180*	ug/Kg	
Arsenic,Solid	**2.9**	mg/Kg	
Barium,Solid	*120*	mg/Kg	
Beryllium,Solid	*1.5*	mg/Kg	
Cadmium,Solid	*0.57*	mg/Kg	
Calcium,Solid	*50600*	mg/Kg	
Cyanide, Total,Solid	*2.3*	mg/Kg	
Lead,Solid	*59.7*	mg/Kg	
Magnesium,Solid	*5620*	mg/Kg	
Mercury,Solid	*0.05*	mg/Kg	
Selenium,Solid	*1.6*	mg/Kg	
Sodium,Solid	*276*	mg/Kg	
2,4,6-TNT,Solid	*66*	ug/Kg	J
Aluminum,Solid	*27000*	mg/Kg	
Arsenic,Solid	2.7	mg/Kg	
Barium,Solid	*255*	mg/Kg	
Beryllium,Solid	*4.2*	mg/Kg	
Cadmium,Solid	*0.41*	mg/Kg	
Calcium,Solid	*156000*	mg/Kg	
Cyanide, Total,Solid	*1.7*	mg/Kg	
Lead,Solid	*33*	mg/Kg	
Magnesium,Solid	*16400*	mg/Kg	
Manganese,Solid	***3340***	mg/Kg	
Selenium,Solid	*2.7*	mg/Kg	
Sodium,Solid	*733*	mg/Kg	

CBPSS-001-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***19.7***	mg/Kg	
Cadmium,Solid	*0.43*	mg/Kg	
Cobalt,Solid	*11.2*	mg/Kg	
Cyanide, Total,Solid	*2.2*	mg/Kg	
Iron,Solid	***26700***	mg/Kg	
Nickel,Solid	*22.1*	mg/Kg	
Potassium,Solid	*1190*	mg/Kg	
Arsenic,Solid	**11.2**	mg/Kg	
Cadmium,Solid	*0.38*	mg/Kg	
Iron,Solid	**24300**	mg/Kg	

CBPSS-031-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***19.6***	mg/Kg	
Chromium,Solid	*19.6*	mg/Kg	
Cobalt,Solid	*12.6*	mg/Kg	
Iron,Solid	***28800***	mg/Kg	
Magnesium,Solid	*4680*	mg/Kg	
Nickel,Solid	*26.6*	mg/Kg	
Potassium,Solid	*2630*	mg/Kg	
Zinc,Solid	*62.9*	mg/Kg	
Arsenic,Solid	**14.4**	mg/Kg	
Iron,Solid	**29400**	mg/Kg	

CBPSS-022-0001-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*18800*	mg/Kg	
Arsenic,Solid	**4.1**	mg/Kg	
Barium,Solid	*225*	mg/Kg	
Beryllium,Solid	*2.3*	mg/Kg	
Cadmium,Solid	*0.12*	mg/Kg	B
Calcium,Solid	*132000*	mg/Kg	
Cyanide, Total,Solid	*6.1*	mg/Kg	
Magnesium,Solid	*9660*	mg/Kg	
Manganese,Solid	***2550***	mg/Kg	
Potassium,Solid	*1690*	mg/Kg	
Selenium,Solid	*2*	mg/Kg	
Sodium,Solid	*581*	mg/Kg	

CBPSS-029-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**8.9**	mg/Kg	
Nitrocellulose	0.87	mg/kg	B
Arsenic,Solid	**14.3**	mg/Kg	
Iron,Solid	**26200**	mg/Kg	

CBPSS-009-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***19.5***	mg/Kg	
Cobalt,Solid	*22.3*	mg/Kg	
Iron,Solid	***30000***	mg/Kg	
Arsenic,Solid	**10.7**	mg/Kg	
Cadmium,Solid	*0.26*	mg/Kg	
Iron,Solid	**23600**	mg/Kg	
Lead,Solid	*22.7*	mg/Kg	
Mercury,Solid	*0.046*	mg/Kg	

CBPSS-003-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.3**	mg/Kg	
Arsenic,Solid	**10.7**	mg/Kg	
Thallium,Solid	*4.1*	mg/Kg	

CBPSS-021-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**9.8**	mg/Kg	
Cadmium,Solid	*0.49*	mg/Kg	
Iron,Solid	***25800***	mg/Kg	
Mercury,Solid	*0.046*	mg/Kg	
Arsenic,Solid	**11.9**	mg/Kg	
Cadmium,Solid	*0.41*	mg/Kg	
Iron,Solid	**23000**	mg/Kg	

CBPSS-027-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	7	mg/Kg	
Barium,Solid	*108*	mg/Kg	
Beryllium,Solid	*1.2*	mg/Kg	
Calcium,Solid	*15900*	mg/Kg	
Cobalt,Solid	*10.5*	mg/Kg	
Cyanide, Total,Solid	*3.7*	mg/Kg	
Iron,Solid	***25700***	mg/Kg	
Magnesium,Solid	*4190*	mg/Kg	
Potassium,Solid	*1560*	mg/Kg	
Arsenic,Solid	**13.6**	mg/Kg	
Cyanide, Total,Solid	*0.62*	mg/Kg	
Iron,Solid	**30000**	mg/Kg	
Manganese,Solid	**2090**	mg/Kg	

CBPSS-014-0001-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*19500*	mg/Kg	
Arsenic,Solid	***17.2***	mg/Kg	
Barium,Solid	*274*	mg/Kg	
Beryllium,Solid	*0.98*	mg/Kg	
Cadmium,Solid	*0.47*	mg/Kg	
Calcium,Solid	*160000*	mg/Kg	
Chromium,Solid	*20.2*	mg/Kg	
Copper,Solid	*241*	mg/Kg	
Lead,Solid	*142*	mg/Kg	
Magnesium,Solid	*5380*	mg/Kg	
Nickel,Solid	*24.5*	mg/Kg	
Potassium,Solid	*1480*	mg/Kg	
Vanadium,Solid	*32*	mg/Kg	
Zinc,Solid	*368*	mg/Kg	
Arsenic,Solid	**6.9**	mg/Kg	
Cadmium,Solid	*0.15*	mg/Kg	B
Iron,Solid	**25800**	mg/Kg	

CBPSS-013-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.9**	mg/Kg	
Barium,Solid	*41.7*	mg/Kg	
Cadmium,Solid	*1.2*	mg/Kg	
Calcium,Solid	*95700*	mg/Kg	
Copper,Solid	*1260*	mg/Kg	
Lead,Solid	*392*	mg/Kg	
Magnesium,Solid	*3980*	mg/Kg	
Selenium,Solid	*1.8*	mg/Kg	
Silver,Solid	*0.21*	mg/Kg	B
Zinc,Solid	*1500*	mg/Kg	

CBPSS-012-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**9.4**	mg/Kg	
Barium,Solid	*125*	mg/Kg	
Cadmium,Solid	*0.28*	mg/Kg	
Calcium,Solid	*33100*	mg/Kg	
Lead,Solid	*27.2*	mg/Kg	
Magnesium,Solid	*3150*	mg/Kg	
Potassium,Solid	*1220*	mg/Kg	
Zinc,Solid	*65.1*	mg/Kg	
Arsenic,Solid	**15.6**	mg/Kg	
Cadmium,Solid	*0.099*	mg/Kg	B
Iron,Solid	**29700**	mg/Kg	

CBPSS-007-0001-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*23600*	mg/Kg	
Barium,Solid	*208*	mg/Kg	
Beryllium,Solid	*3.1*	mg/Kg	
Calcium,Solid	*149000*	mg/Kg	
Cyanide, Total,Solid	*1.5*	mg/Kg	
Magnesium,Solid	*16300*	mg/Kg	
Manganese,Solid	***2860***	mg/Kg	
Potassium,Solid	*1700*	mg/Kg	
Selenium,Solid	*1.8*	mg/Kg	
Sodium,Solid	*947*	mg/Kg	
Aluminum,Solid	*22500*	mg/Kg	
Barium,Solid	*179*	mg/Kg	
Beryllium,Solid	*2.8*	mg/Kg	
Calcium,Solid	*129000*	mg/Kg	
Cyanide, Total,Solid	*1.1*	mg/Kg	
Magnesium,Solid	*14300*	mg/Kg	
Manganese,Solid	**2390**	mg/Kg	
Selenium,Solid	*1.8*	mg/Kg	
Sodium,Solid	*901*	mg/Kg	

CBPSS-004-0001-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*29700*	mg/Kg	
Arsenic,Solid	***32.8***	mg/Kg	
Barium,Solid	*242*	mg/Kg	
Beryllium,Solid	*3.9*	mg/Kg	
Cadmium,Solid	*0.34*	mg/Kg	B
Calcium,Solid	*172000*	mg/Kg	
Chromium,Solid	***48.8***	mg/Kg	
Copper,Solid	*43.8*	mg/Kg	
Cyanide, Total,Solid	*1.2*	mg/Kg	
Lead,Solid	*29.1*	mg/Kg	
Magnesium,Solid	*22300*	mg/Kg	
Manganese,Solid	***2590***	mg/Kg	
Potassium,Solid	*2320*	mg/Kg	
Selenium,Solid	*1.5*	mg/Kg	
Sodium,Solid	*999*	mg/Kg	
Aluminum,Solid	*31100*	mg/Kg	
Arsenic,Solid	***31***	mg/Kg	
Barium,Solid	*294*	mg/Kg	
Beryllium,Solid	*4.1*	mg/Kg	
Calcium,Solid	*166000*	mg/Kg	
Chromium,Solid	***57.3***	mg/Kg	
Copper,Solid	*46.9*	mg/Kg	
Cyanide, Total,Solid	*2.4*	mg/Kg	
Lead,Solid	*34*	mg/Kg	
Magnesium,Solid	*21800*	mg/Kg	
Manganese,Solid	**2670**	mg/Kg	
Sodium,Solid	*946*	mg/Kg	

CBPSS-019-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**12.8**	mg/Kg	
Barium,Solid	*97.7*	mg/Kg	
Cadmium,Solid	*0.63*	mg/Kg	
Cobalt,Solid	*13.9*	mg/Kg	
Iron,Solid	***26000***	mg/Kg	
Manganese,Solid	***2720***	mg/Kg	
Mercury,Solid	*0.045*	mg/Kg	
Silver,Solid	*0.16*	mg/Kg	B
Arsenic,Solid	**10.7**	mg/Kg	
Cadmium,Solid	*0.48*	mg/Kg	
Iron,Solid	**30000**	mg/Kg	

CBPSS-011-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.4**	mg/Kg	
Cadmium,Solid	*0.51*	mg/Kg	
Iron,Solid	***24800***	mg/Kg	
Mercury,Solid	*0.045*	mg/Kg	
Potassium,Solid	*1090*	mg/Kg	
Zinc,Solid	*62.6*	mg/Kg	
Arsenic,Solid	**14.6**	mg/Kg	
Cadmium,Solid	*0.38*	mg/Kg	
Iron,Solid	**25500**	mg/Kg	

CBPSS-030-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.7**	mg/Kg	
Chromium,Solid	*17.6*	mg/Kg	
Cobalt,Solid	*14.7*	mg/Kg	
Iron,Solid	***30600***	mg/Kg	
Potassium,Solid	*1540*	mg/Kg	
Vanadium,Solid	*32.6*	mg/Kg	
Zinc,Solid	*76.3*	mg/Kg	
Arsenic,Solid	**12.1**	mg/Kg	
Iron,Solid	**25000**	mg/Kg	

CBPSS-015-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11**	mg/Kg	
Barium,Solid	*141*	mg/Kg	
Cadmium,Solid	*0.5*	mg/Kg	
Calcium,Solid	*28900*	mg/Kg	
Cobalt,Solid	*11.6*	mg/Kg	
Copper,Solid	*30.3*	mg/Kg	
Cyanide, Total,Solid	*0.36*	mg/Kg	B
Iron,Solid	***29500***	mg/Kg	
Lead,Solid	*28.9*	mg/Kg	
Manganese,Solid	*1500*	mg/Kg	
Mercury,Solid	*0.054*	mg/Kg	
Potassium,Solid	*1060*	mg/Kg	
Silver,Solid	*0.22*	mg/Kg	B
Zinc,Solid	*108*	mg/Kg	
Arsenic,Solid	**6.1**	mg/Kg	
Cadmium,Solid	*0.098*	mg/Kg	B

CBPSS-025-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**7.9**	mg/Kg	
Barium,Solid	*96.6*	mg/Kg	
Beryllium,Solid	*1.2*	mg/Kg	
Cadmium,Solid	*0.22*	mg/Kg	
Calcium,Solid	*44100*	mg/Kg	
Cyanide, Total,Solid	*0.51*	mg/Kg	
Lead,Solid	*42.1*	mg/Kg	
Magnesium,Solid	*4670*	mg/Kg	
Selenium,Solid	*1.4*	mg/Kg	
Sodium,Solid	*192*	mg/Kg	
Arsenic,Solid	**4.8**	mg/Kg	
Barium,Solid	*125*	mg/Kg	
Beryllium,Solid	*1.7*	mg/Kg	
Cadmium,Solid	*0.12*	mg/Kg	B
Calcium,Solid	*58500*	mg/Kg	
Lead,Solid	*23.7*	mg/Kg	
Selenium,Solid	*1.6*	mg/Kg	
Sodium,Solid	*251*	mg/Kg	

CBPSS-008-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***25.5***	mg/Kg	
Chromium,Solid	*20.1*	mg/Kg	
Cobalt,Solid	*10.9*	mg/Kg	
Iron,Solid	***29800***	mg/Kg	
Lead,Solid	*35.2*	mg/Kg	
Nitrocellulose	0.81	mg/kg	B
Potassium,Solid	*1710*	mg/Kg	
Sodium,Solid	*137*	mg/Kg	
Vanadium,Solid	*37*	mg/Kg	
Zinc,Solid	*66.5*	mg/Kg	
Arsenic,Solid	***27.5***	mg/Kg	
Iron,Solid	**34600**	mg/Kg	
Lead,Solid	*21.8*	mg/Kg	
Nitrocellulose	0.68	mg/kg	B
Sodium,Solid	*146*	mg/Kg	

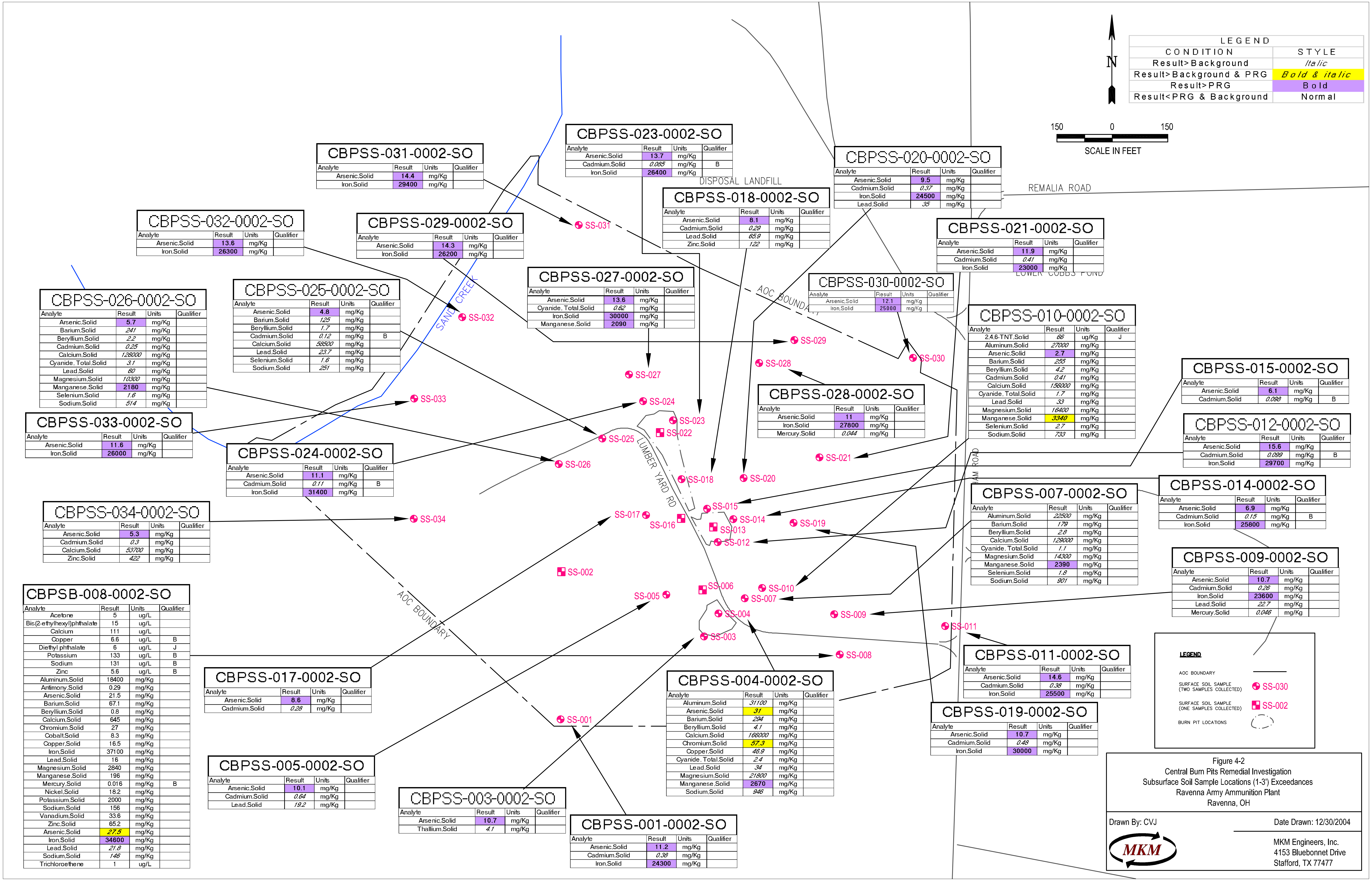
LEGEND

CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

Figure 4-1
Central Burn Pits Remedial Investigation
Surface Soil Sample Locations (0-1') Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



LEGEND	
CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

CBPSS-031-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**14.4**	mg/Kg	
Iron,Solid	**29400**	mg/Kg	

CBPSS-023-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.7**	mg/Kg	
Cadmium,Solid	*0.085*	mg/Kg	B
Iron,Solid	**26400**	mg/Kg	

CBPSS-020-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**9.5**	mg/Kg	
Cadmium,Solid	*0.37*	mg/Kg	
Iron,Solid	**24500**	mg/Kg	
Lead,Solid	*35*	mg/Kg	

CBPSS-018-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**8.1**	mg/Kg	
Cadmium,Solid	*0.29*	mg/Kg	
Lead,Solid	*65.9*	mg/Kg	
Zinc,Solid	*122*	mg/Kg	

CBPSS-032-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.6**	mg/Kg	
Iron,Solid	**26300**	mg/Kg	

CBPSS-029-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**14.3**	mg/Kg	
Iron,Solid	**26200**	mg/Kg	

CBPSS-021-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.9**	mg/Kg	
Cadmium,Solid	*0.41*	mg/Kg	
Iron,Solid	**23000**	mg/Kg	

CBPSS-027-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.6**	mg/Kg	
Cyanide, Total,Solid	*0.62*	mg/Kg	
Iron,Solid	**30000**	mg/Kg	
Manganese,Solid	**2090**	mg/Kg	

CBPSS-030-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**12.1**	mg/Kg	
Iron,Solid	**25000**	mg/Kg	

CBPSS-026-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**5.7**	mg/Kg	
Barium,Solid	*241*	mg/Kg	
Beryllium,Solid	*2.2*	mg/Kg	
Cadmium,Solid	*0.25*	mg/Kg	
Calcium,Solid	*126000*	mg/Kg	
Cyanide, Total,Solid	*3.1*	mg/Kg	
Lead,Solid	*60*	mg/Kg	
Magnesium,Solid	*10300*	mg/Kg	
Manganese,Solid	**2180**	mg/Kg	
Selenium,Solid	*1.6*	mg/Kg	
Sodium,Solid	*514*	mg/Kg	

CBPSS-025-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**4.8**	mg/Kg	
Barium,Solid	*125*	mg/Kg	
Beryllium,Solid	*1.7*	mg/Kg	
Cadmium,Solid	*0.12*	mg/Kg	B
Calcium,Solid	*58500*	mg/Kg	
Lead,Solid	*23.7*	mg/Kg	
Selenium,Solid	*1.6*	mg/Kg	
Sodium,Solid	*251*	mg/Kg	

CBPSS-010-0002-SO

Analyte	Result	Units	Qualifier
2,4,6-TNT,Solid	*66*	ug/Kg	J
Aluminum,Solid	*27000*	mg/Kg	
Arsenic,Solid	**2.7**	mg/Kg	
Barium,Solid	*255*	mg/Kg	
Beryllium,Solid	*4.2*	mg/Kg	
Cadmium,Solid	*0.41*	mg/Kg	
Calcium,Solid	*156000*	mg/Kg	
Cyanide, Total,Solid	*1.7*	mg/Kg	
Lead,Solid	*33*	mg/Kg	
Magnesium,Solid	*16400*	mg/Kg	
Manganese,Solid	***3340***	mg/Kg	
Selenium,Solid	*2.7*	mg/Kg	
Sodium,Solid	*733*	mg/Kg	

CBPSS-015-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**6.1**	mg/Kg	
Cadmium,Solid	*0.098*	mg/Kg	B

CBPSS-028-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11**	mg/Kg	
Iron,Solid	**27800**	mg/Kg	
Mercury,Solid	*0.044*	mg/Kg	

CBPSS-012-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**15.6**	mg/Kg	
Cadmium,Solid	*0.099*	mg/Kg	B
Iron,Solid	**29700**	mg/Kg	

CBPSS-033-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.6**	mg/Kg	
Iron,Solid	**26000**	mg/Kg	

CBPSS-024-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.1**	mg/Kg	
Cadmium,Solid	*0.11*	mg/Kg	B
Iron,Solid	**31400**	mg/Kg	

CBPSS-007-0002-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*22500*	mg/Kg	
Barium,Solid	*179*	mg/Kg	
Beryllium,Solid	*2.8*	mg/Kg	
Calcium,Solid	*129000*	mg/Kg	
Cyanide, Total,Solid	*1.1*	mg/Kg	
Magnesium,Solid	*14300*	mg/Kg	
Manganese,Solid	**2390**	mg/Kg	
Selenium,Solid	*1.8*	mg/Kg	
Sodium,Solid	*901*	mg/Kg	

CBPSS-014-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**6.9**	mg/Kg	
Cadmium,Solid	*0.15*	mg/Kg	B
Iron,Solid	**25800**	mg/Kg	

CBPSS-034-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**5.3**	mg/Kg	
Cadmium,Solid	*0.3*	mg/Kg	
Calcium,Solid	*53700*	mg/Kg	
Zinc,Solid	*422*	mg/Kg	

CBPSS-009-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10.7**	mg/Kg	
Cadmium,Solid	*0.26*	mg/Kg	
Iron,Solid	**23600**	mg/Kg	
Lead,Solid	*22.7*	mg/Kg	
Mercury,Solid	*0.046*	mg/Kg	

CBPSB-008-0002-SO

Analyte	Result	Units	Qualifier
Acetone	5	ug/L	
Bis(2-ethylhexyl)phthalate	15	ug/L	
Calcium	111	ug/L	
Copper	6.6	ug/L	B
Diethyl phthalate	6	ug/L	J
Potassium	133	ug/L	B
Sodium	131	ug/L	B
Zinc	5.6	ug/L	B
Aluminum,Solid	18400	mg/Kg	
Antimony,Solid	0.29	mg/Kg	
Arsenic,Solid	21.5	mg/Kg	
Barium,Solid	67.1	mg/Kg	
Beryllium,Solid	0.8	mg/Kg	
Calcium,Solid	645	mg/Kg	
Chromium,Solid	27	mg/Kg	
Cobalt,Solid	8.3	mg/Kg	
Copper,Solid	16.5	mg/Kg	
Iron,Solid	37100	mg/Kg	
Lead,Solid	16	mg/Kg	
Magnesium,Solid	2840	mg/Kg	
Manganese,Solid	196	mg/Kg	
Mercury,Solid	0.016	mg/Kg	B
Nickel,Solid	18.2	mg/Kg	
Potassium,Solid	2000	mg/Kg	
Sodium,Solid	156	mg/Kg	
Vanadium,Solid	33.6	mg/Kg	
Zinc,Solid	65.2	mg/Kg	
Arsenic,Solid	***27.5***	mg/Kg	
Iron,Solid	**34600**	mg/Kg	
Lead,Solid	*21.8*	mg/Kg	
Sodium,Solid	*146*	mg/Kg	
Trichloroethene	1	ug/L	

CBPSS-017-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**8.6**	mg/Kg	
Cadmium,Solid	*0.28*	mg/Kg	

CBPSS-011-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**14.6**	mg/Kg	
Cadmium,Solid	*0.38*	mg/Kg	
Iron,Solid	**25500**	mg/Kg	

CBPSS-004-0002-SO

Analyte	Result	Units	Qualifier
Aluminum,Solid	*31100*	mg/Kg	
Arsenic,Solid	***31***	mg/Kg	
Barium,Solid	*294*	mg/Kg	
Beryllium,Solid	*4.1*	mg/Kg	
Calcium,Solid	*166000*	mg/Kg	
Chromium,Solid	***57.3***	mg/Kg	
Copper,Solid	*46.9*	mg/Kg	
Cyanide, Total,Solid	*2.4*	mg/Kg	
Lead,Solid	*34*	mg/Kg	
Magnesium,Solid	*21800*	mg/Kg	
Manganese,Solid	**2670**	mg/Kg	
Sodium,Solid	*946*	mg/Kg	

CBPSS-019-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10.7**	mg/Kg	
Cadmium,Solid	*0.48*	mg/Kg	
Iron,Solid	**30000**	mg/Kg	

CBPSS-005-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10.1**	mg/Kg	
Cadmium,Solid	*0.64*	mg/Kg	
Lead,Solid	*19.2*	mg/Kg	

CBPSS-003-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10.7**	mg/Kg	
Thallium,Solid	*4.1*	mg/Kg	

CBPSS-001-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.2**	mg/Kg	
Cadmium,Solid	*0.38*	mg/Kg	
Iron,Solid	**24300**	mg/Kg	

LEGEND

AOC BOUNDARY	———
SURFACE SOIL SAMPLE (TWO SAMPLES COLLECTED)	⊕ SS-030
SURFACE SOIL SAMPLE (ONE SAMPLES COLLECTED)	▚ SS-002
BURN PIT LOCATIONS	◌

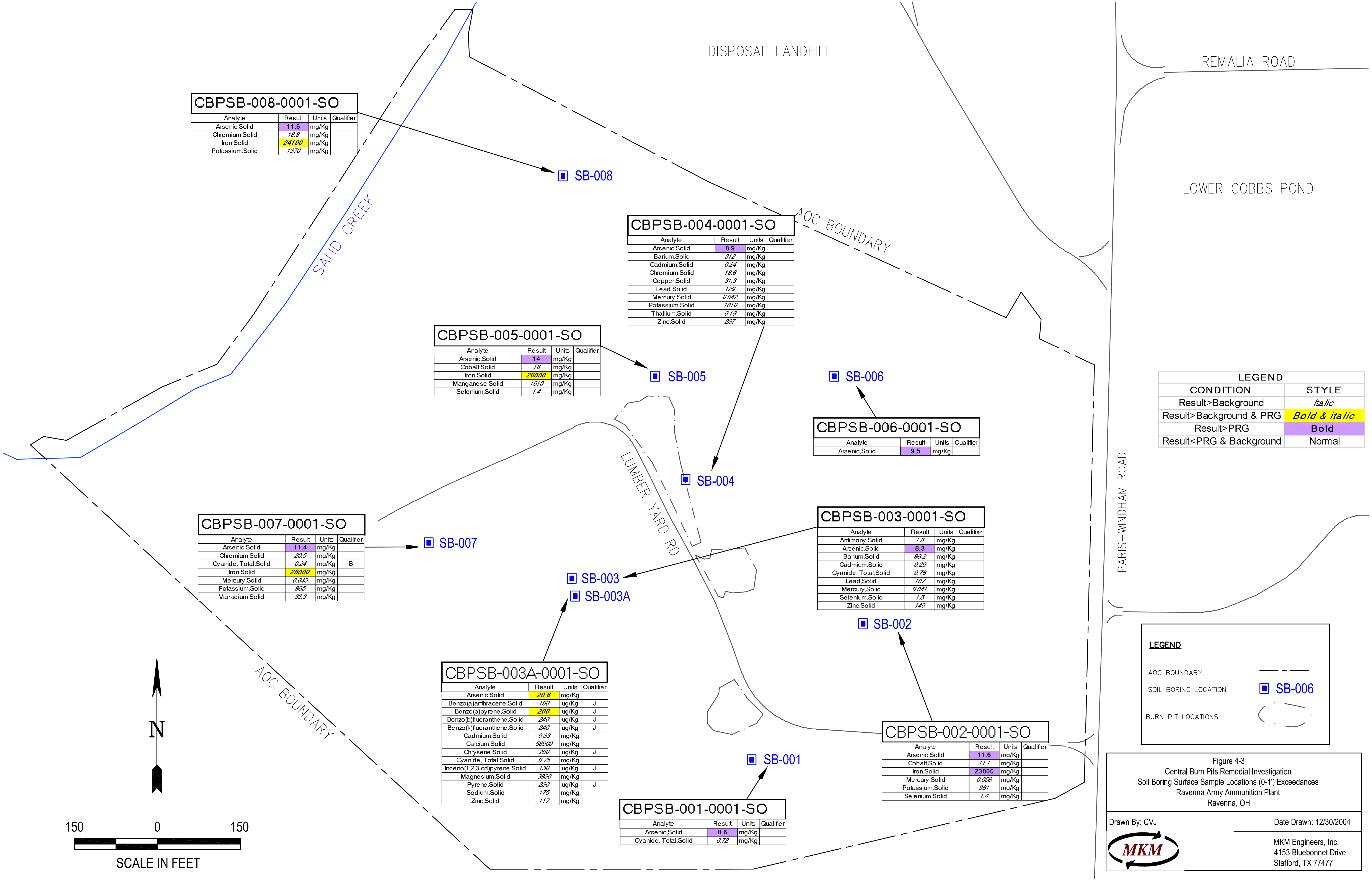
Figure 4-2
Central Burn Pits Remedial Investigation
Subsurface Soil Sample Locations (1-3') Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

Date Drawn: 12/30/2004

MKM

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



CBPSB-008-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.6**	mg/Kg	
Chromium,Solid	*18.8*	mg/Kg	
Iron,Solid	***24100***	mg/Kg	
Potassium,Solid	*1370*	mg/Kg	

CBPSB-004-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	8.9	mg/Kg	
Barium,Solid	*312*	mg/Kg	
Cadmium,Solid	*0.24*	mg/Kg	
Chromium,Solid	*18.6*	mg/Kg	
Copper,Solid	*31.3*	mg/Kg	
Lead,Solid	*129*	mg/Kg	
Mercury,Solid	*0.042*	mg/Kg	
Potassium,Solid	*1010*	mg/Kg	
Thallium,Solid	*0.18*	mg/Kg	
Zinc,Solid	*237*	mg/Kg	

CBPSB-005-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**14**	mg/Kg	
Cobalt,Solid	*16*	mg/Kg	
Iron,Solid	***26000***	mg/Kg	
Manganese,Solid	*1610*	mg/Kg	
Selenium,Solid	*1.4*	mg/Kg	

CBPSB-006-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**9.5**	mg/Kg	

CBPSB-007-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.4**	mg/Kg	
Chromium,Solid	*20.5*	mg/Kg	
Cyanide, Total,Solid	*0.24*	mg/Kg	B
Iron,Solid	***28000***	mg/Kg	
Mercury,Solid	*0.043*	mg/Kg	
Potassium,Solid	*985*	mg/Kg	
Vanadium,Solid	*33.3*	mg/Kg	

CBPSB-003-0001-SO

Analyte	Result	Units	Qualifier
Antimony,Solid	*1.8*	mg/Kg	
Arsenic,Solid	8.3	mg/Kg	
Barium,Solid	*98.2*	mg/Kg	
Cadmium,Solid	*0.29*	mg/Kg	
Cyanide, Total,Solid	*0.76*	mg/Kg	
Lead,Solid	*107*	mg/Kg	
Mercury,Solid	*0.041*	mg/Kg	
Selenium,Solid	*1.5*	mg/Kg	
Zinc,Solid	*140*	mg/Kg	

CBPSB-003A-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***20.6***	mg/Kg	
Benzo(a)anthracene,Solid	*180*	ug/Kg	J
Benzo(a)pyrene,Solid	***200***	ug/Kg	J
Benzo(b)fluoranthene,Solid	*240*	ug/Kg	J
Benzo(k)fluoranthene,Solid	*240*	ug/Kg	J
Cadmium,Solid	*0.33*	mg/Kg	
Calcium,Solid	*56900*	mg/Kg	
Chrysene,Solid	*200*	ug/Kg	J
Cyanide, Total,Solid	*0.75*	mg/Kg	
Indeno(1,2,3-cd)pyrene,Solid	*130*	ug/Kg	J
Magnesium,Solid	*3930*	mg/Kg	
Pyrene,Solid	*230*	ug/Kg	J
Sodium,Solid	*175*	mg/Kg	
Zinc,Solid	*117*	mg/Kg	

CBPSB-002-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**11.6**	mg/Kg	
Cobalt,Solid	*11.1*	mg/Kg	
Iron,Solid	**23000**	mg/Kg	
Mercury,Solid	*0.058*	mg/Kg	
Potassium,Solid	*961*	mg/Kg	
Selenium,Solid	*1.4*	mg/Kg	

CBPSB-001-0001-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**8.6**	mg/Kg	
Cyanide, Total,Solid	*0.72*	mg/Kg	

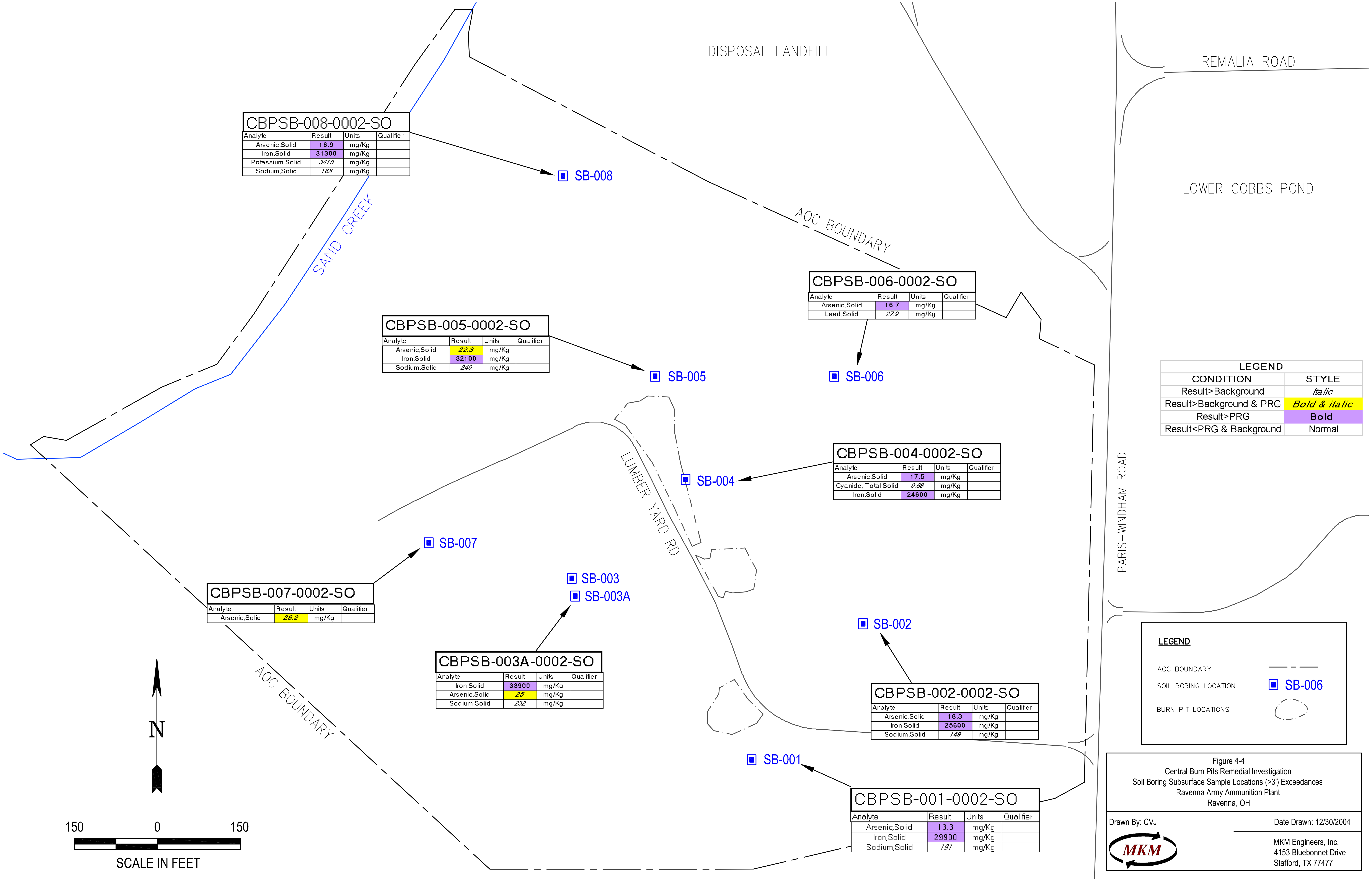
LEGEND

CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

Figure 4-3
Central Burn Pits Remedial Investigation
Soil Boring Surface Sample Locations (0-1') Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



CBPSB-008-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**16.9**	mg/Kg	
Iron,Solid	**31300**	mg/Kg	
Potassium,Solid	*3410*	mg/Kg	
Sodium,Solid	*168*	mg/Kg	

CBPSB-006-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**16.7**	mg/Kg	
Lead,Solid	*27.9*	mg/Kg	

CBPSB-005-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***22.3***	mg/Kg	
Iron,Solid	**32100**	mg/Kg	
Sodium,Solid	*240*	mg/Kg	

CBPSB-004-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**17.5**	mg/Kg	
Cyanide, Total,Solid	*0.68*	mg/Kg	
Iron,Solid	**24600**	mg/Kg	

CBPSB-007-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	***26.2***	mg/Kg	

CBPSB-003A-0002-SO

Analyte	Result	Units	Qualifier
Iron,Solid	**33900**	mg/Kg	
Arsenic,Solid	***25***	mg/Kg	
Sodium,Solid	*232*	mg/Kg	

CBPSB-002-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**18.3**	mg/Kg	
Iron,Solid	**25600**	mg/Kg	
Sodium,Solid	*149*	mg/Kg	

CBPSB-001-0002-SO

Analyte	Result	Units	Qualifier
Arsenic,Solid	**13.3**	mg/Kg	
Iron,Solid	**29900**	mg/Kg	
Sodium,Solid	*191*	mg/Kg	

LEGEND

CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

LEGEND

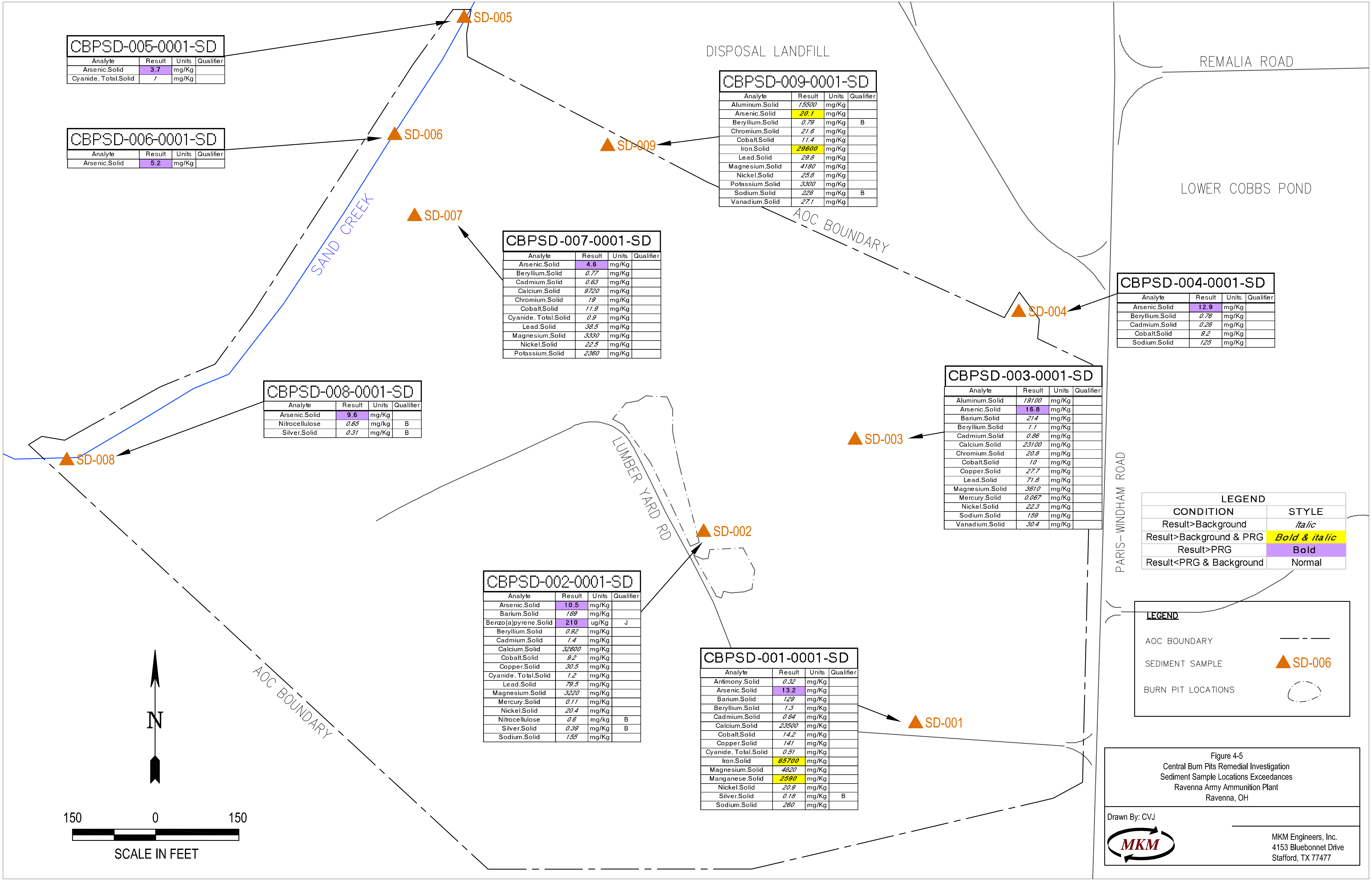
AOC BOUNDARY	— - —
SOIL BORING LOCATION	▣ SB-006
BURN PIT LOCATIONS	◌

Figure 4-4
Central Burn Pits Remedial Investigation
Soil Boring Subsurface Sample Locations (>3') Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

MKM

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



CBPSD-005-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**3.7**	mg/Kg	
Cyanide, Total,Solid	*1*	mg/Kg	

CBPSD-006-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**5.2**	mg/Kg	

CBPSD-009-0001-SD

Analyte	Result	Units	Qualifier
Aluminum,Solid	*15500*	mg/Kg	
Arsenic,Solid	***20.1***	mg/Kg	
Beryllium,Solid	*0.79*	mg/Kg	B
Chromium,Solid	*21.6*	mg/Kg	
Cobalt,Solid	*11.4*	mg/Kg	
Iron,Solid	***29600***	mg/Kg	
Lead,Solid	*29.8*	mg/Kg	
Magnesium,Solid	*4180*	mg/Kg	
Nickel,Solid	*25.8*	mg/Kg	
Potassium,Solid	*3300*	mg/Kg	
Sodium,Solid	*226*	mg/Kg	B
Vanadium,Solid	*27.1*	mg/Kg	

CBPSD-007-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**4.6**	mg/Kg	
Beryllium,Solid	*0.77*	mg/Kg	
Cadmium,Solid	*0.63*	mg/Kg	
Calcium,Solid	*9720*	mg/Kg	
Chromium,Solid	*19*	mg/Kg	
Cobalt,Solid	*11.9*	mg/Kg	
Cyanide, Total,Solid	*0.9*	mg/Kg	
Lead,Solid	*38.5*	mg/Kg	
Magnesium,Solid	*3330*	mg/Kg	
Nickel,Solid	*22.5*	mg/Kg	
Potassium,Solid	*2360*	mg/Kg	

CBPSD-008-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**9.6**	mg/Kg	
Nitrocellulose	*0.65*	mg/kg	B
Silver,Solid	*0.31*	mg/Kg	B

CBPSD-004-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**12.9**	mg/Kg	
Beryllium,Solid	*0.76*	mg/Kg	
Cadmium,Solid	*0.26*	mg/Kg	
Cobalt,Solid	*9.2*	mg/Kg	
Sodium,Solid	*125*	mg/Kg	

CBPSD-003-0001-SD

Analyte	Result	Units	Qualifier
Aluminum,Solid	*19100*	mg/Kg	
Arsenic,Solid	**16.8**	mg/Kg	
Barium,Solid	*214*	mg/Kg	
Beryllium,Solid	*1.1*	mg/Kg	
Cadmium,Solid	*0.86*	mg/Kg	
Calcium,Solid	*23100*	mg/Kg	
Chromium,Solid	*20.8*	mg/Kg	
Cobalt,Solid	*10*	mg/Kg	
Copper,Solid	*27.7*	mg/Kg	
Lead,Solid	*71.8*	mg/Kg	
Magnesium,Solid	*3610*	mg/Kg	
Mercury,Solid	*0.067*	mg/Kg	
Nickel,Solid	*22.3*	mg/Kg	
Sodium,Solid	*159*	mg/Kg	
Vanadium,Solid	*30.4*	mg/Kg	

LEGEND	
CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

CBPSD-002-0001-SD

Analyte	Result	Units	Qualifier
Arsenic,Solid	**10.5**	mg/Kg	
Barium,Solid	*169*	mg/Kg	
Benzo(a)pyrene,Solid	**210**	ug/Kg	J
Beryllium,Solid	*0.92*	mg/Kg	
Cadmium,Solid	*1.4*	mg/Kg	
Calcium,Solid	*32600*	mg/Kg	
Cobalt,Solid	*9.2*	mg/Kg	
Copper,Solid	*30.5*	mg/Kg	
Cyanide, Total,Solid	*1.2*	mg/Kg	
Lead,Solid	*79.5*	mg/Kg	
Magnesium,Solid	*3220*	mg/Kg	
Mercury,Solid	*0.11*	mg/Kg	
Nickel,Solid	*20.4*	mg/Kg	
Nitrocellulose	*0.6*	mg/kg	B
Silver,Solid	*0.39*	mg/Kg	B
Sodium,Solid	*155*	mg/Kg	

CBPSD-001-0001-SD

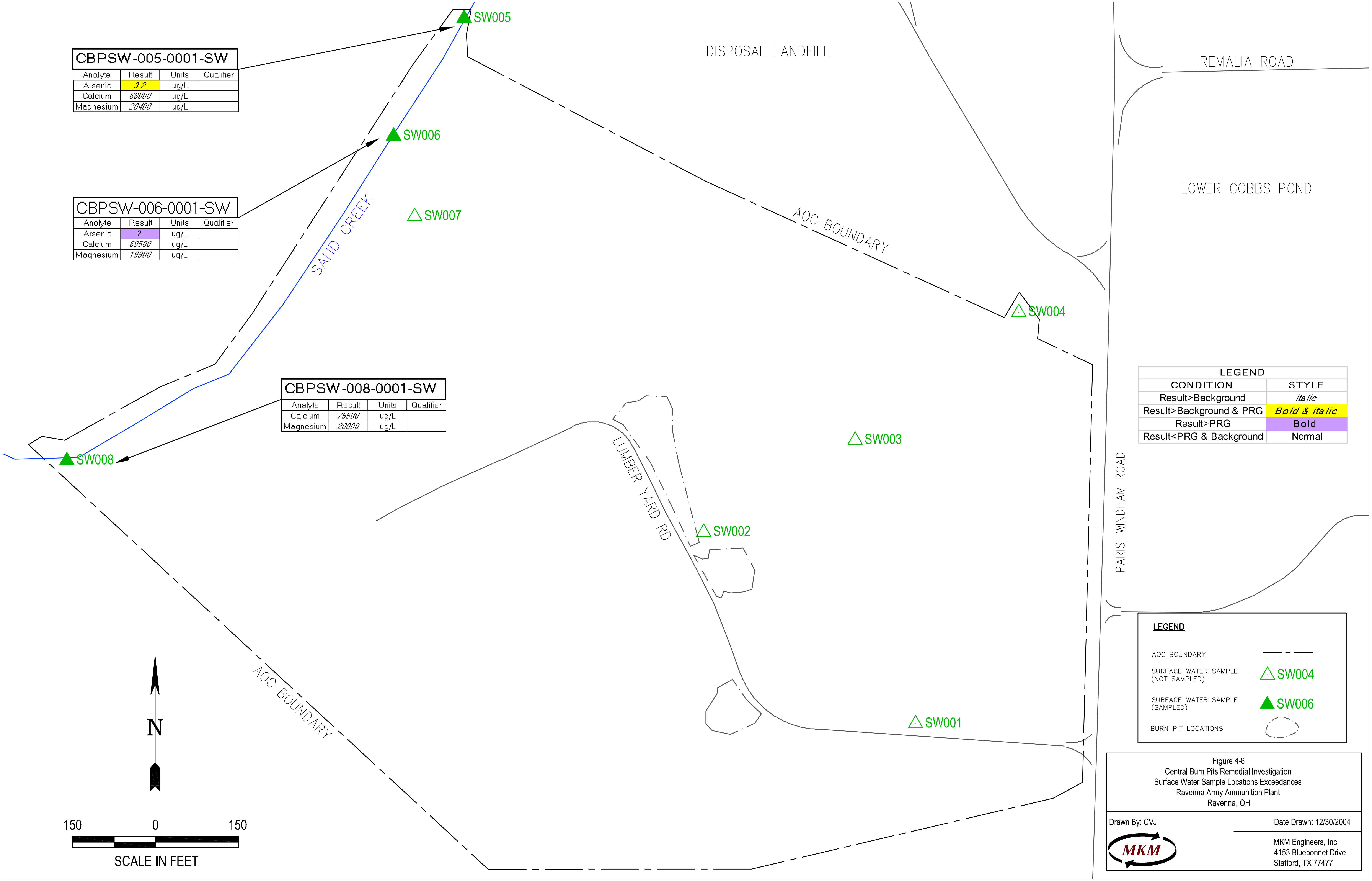
Analyte	Result	Units	Qualifier
Antimony,Solid	*0.32*	mg/Kg	
Arsenic,Solid	**13.2**	mg/Kg	
Barium,Solid	*129*	mg/Kg	
Beryllium,Solid	*1.3*	mg/Kg	
Cadmium,Solid	*0.64*	mg/Kg	
Calcium,Solid	*23500*	mg/Kg	
Cobalt,Solid	*14.2*	mg/Kg	
Copper,Solid	*141*	mg/Kg	
Cyanide, Total,Solid	*0.51*	mg/Kg	
Iron,Solid	***65700***	mg/Kg	
Magnesium,Solid	*4820*	mg/Kg	
Manganese,Solid	***2590***	mg/Kg	
Nickel,Solid	*20.9*	mg/Kg	
Silver,Solid	*0.18*	mg/Kg	B
Sodium,Solid	*260*	mg/Kg	

Figure 4-5
Central Burn Pits Remedial Investigation
Sediment Sample Locations Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ

MKM

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



CBPSW-005-0001-SW

Analyte	Result	Units	Qualifier
Arsenic	***3.2***	ug/L	
Calcium	*68000*	ug/L	
Magnesium	*20400*	ug/L	

CBPSW-006-0001-SW

Analyte	Result	Units	Qualifier
Arsenic	**2**	ug/L	
Calcium	*69500*	ug/L	
Magnesium	*19900*	ug/L	

CBPSW-008-0001-SW

Analyte	Result	Units	Qualifier
Calcium	*75500*	ug/L	
Magnesium	*20800*	ug/L	

LEGEND

CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

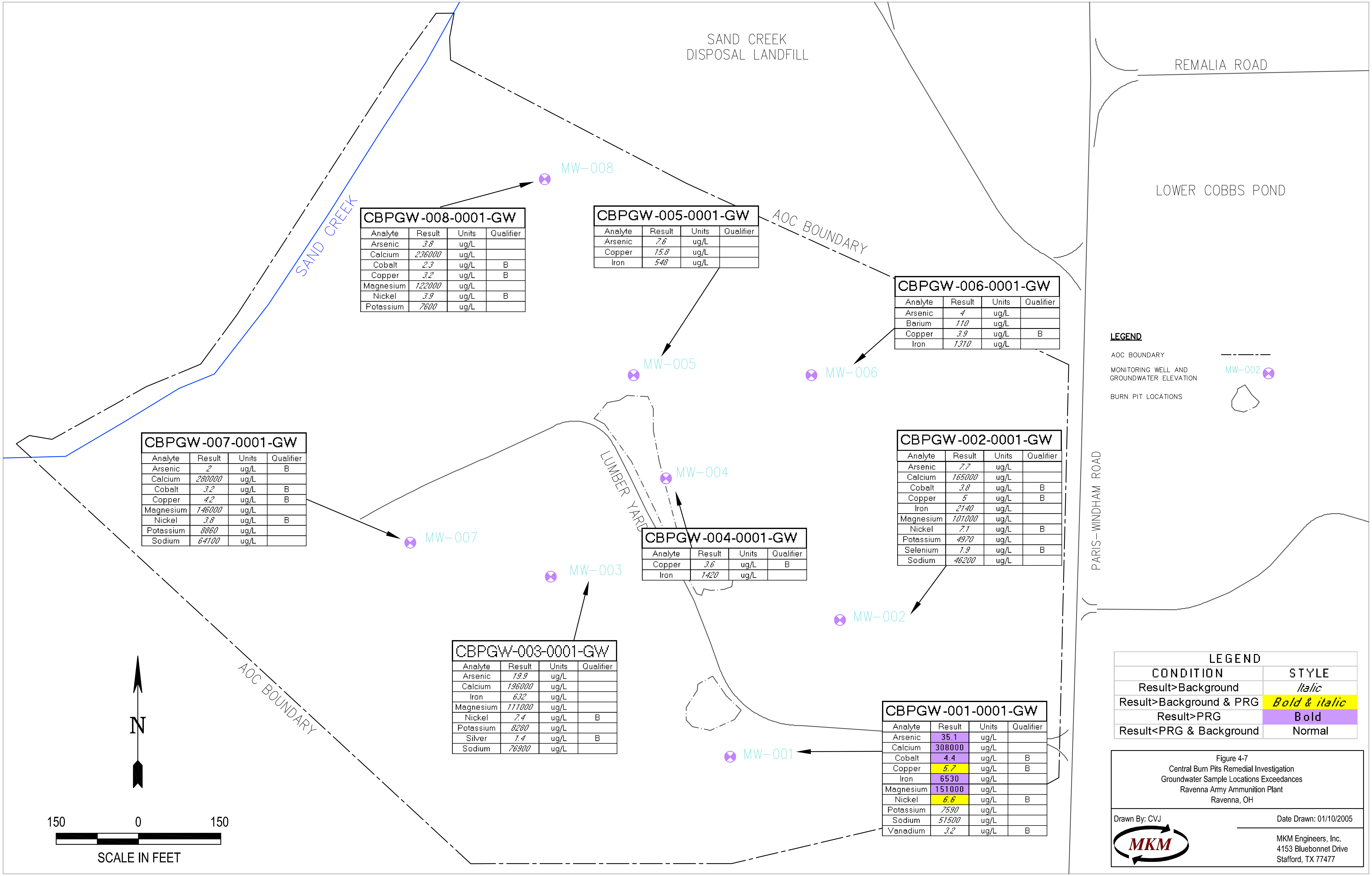
LEGEND

AOC BOUNDARY	— - —
SURFACE WATER SAMPLE (NOT SAMPLED)	△ SW004
SURFACE WATER SAMPLE (SAMPLED)	▲ SW006
BURN PIT LOCATIONS	◌

Figure 4-6
Central Burn Pits Remedial Investigation
Surface Water Sample Locations Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 12/30/2004

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477



CBPGW-008-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*3.8*	ug/L	
Calcium	*236000*	ug/L	
Cobalt	*2.3*	ug/L	B
Copper	*3.2*	ug/L	B
Magnesium	*122000*	ug/L	
Nickel	*3.9*	ug/L	B
Potassium	*7600*	ug/L	

CBPGW-005-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*7.6*	ug/L	
Copper	*15.8*	ug/L	
Iron	*548*	ug/L	

CBPGW-006-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*4*	ug/L	
Barium	*110*	ug/L	
Copper	*3.9*	ug/L	B
Iron	*1310*	ug/L	

CBPGW-007-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*2*	ug/L	B
Calcium	*280000*	ug/L	
Cobalt	*3.2*	ug/L	B
Copper	*4.2*	ug/L	B
Magnesium	*146000*	ug/L	
Nickel	*3.8*	ug/L	B
Potassium	*8860*	ug/L	
Sodium	*64100*	ug/L	

CBPGW-002-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*7.7*	ug/L	
Calcium	*165000*	ug/L	
Cobalt	*3.8*	ug/L	B
Copper	*5*	ug/L	B
Iron	*2140*	ug/L	
Magnesium	*101000*	ug/L	
Nickel	*7.1*	ug/L	B
Potassium	*4970*	ug/L	
Selenium	*1.9*	ug/L	B
Sodium	*46200*	ug/L	

CBPGW-004-0001-GW

Analyte	Result	Units	Qualifier
Copper	*3.6*	ug/L	B
Iron	*1420*	ug/L	

CBPGW-003-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	*19.9*	ug/L	
Calcium	*196000*	ug/L	
Iron	*632*	ug/L	
Magnesium	*111000*	ug/L	
Nickel	*7.4*	ug/L	B
Potassium	*8280*	ug/L	
Silver	*1.4*	ug/L	B
Sodium	*76900*	ug/L	

CBPGW-001-0001-GW

Analyte	Result	Units	Qualifier
Arsenic	**35.1**	ug/L	
Calcium	**308000**	ug/L	
Cobalt	**4.4**	ug/L	B
Copper	***5.7***	ug/L	B
Iron	**6530**	ug/L	
Magnesium	**151000**	ug/L	
Nickel	***6.6***	ug/L	B
Potassium	*7590*	ug/L	
Sodium	*51500*	ug/L	
Vanadium	*3.2*	ug/L	B

LEGEND	
CONDITION	STYLE
Result>Background	*Italic*
Result>Background & PRG	***Bold & italic***
Result>PRG	**Bold**
Result<PRG & Background	Normal

Figure 4-7
Central Burn Pits Remedial Investigation
Groundwater Sample Locations Exceedances
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: CVJ
Date Drawn: 01/10/2005

MKM

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477

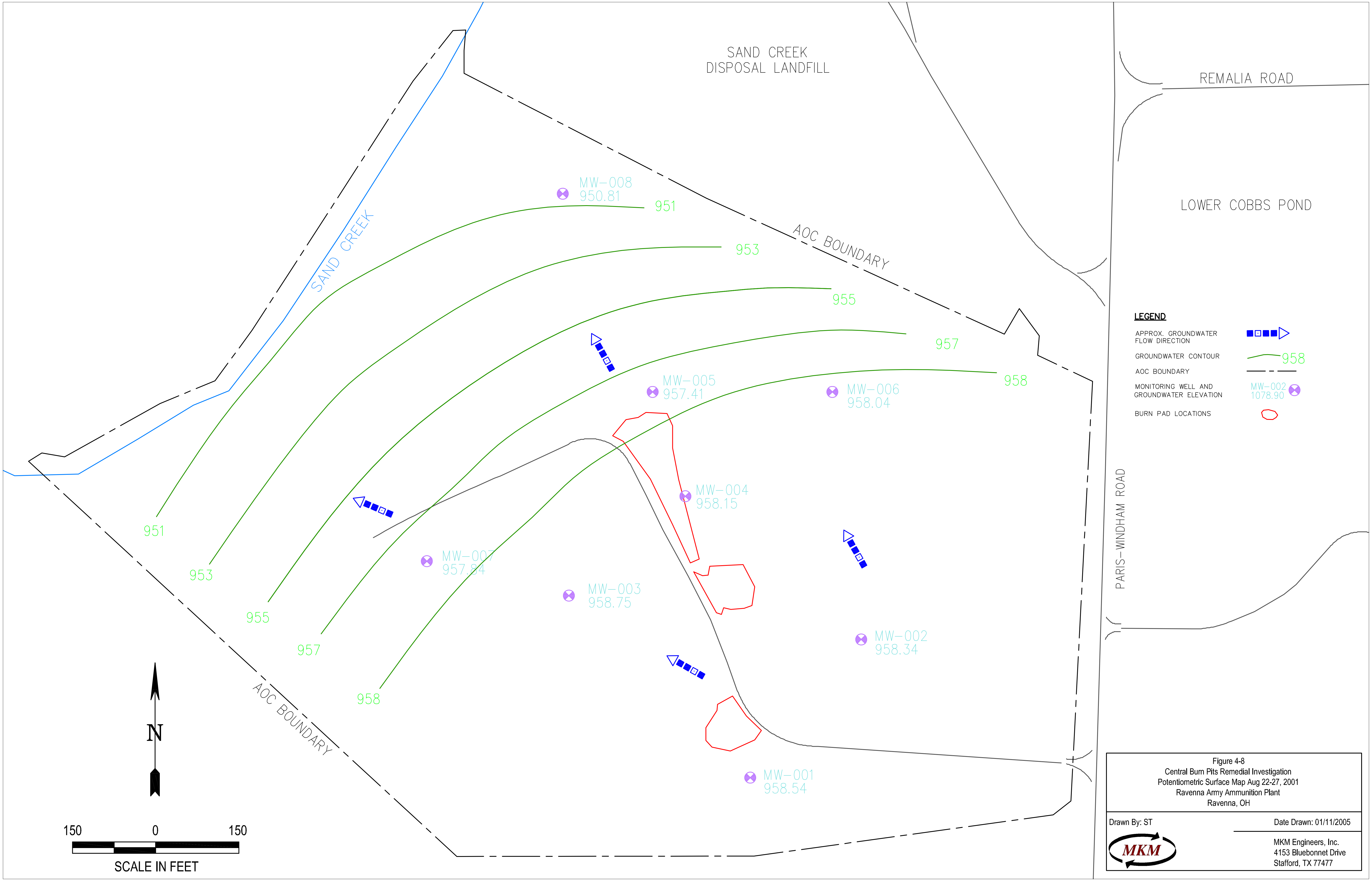


Figure 4-8
Central Burn Pits Remedial Investigation
Potentiometric Surface Map Aug 22-27, 2001
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: ST
Date Drawn: 01/11/2005

MKM

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4153 Bluebonnet Drive
Stafford, TX 77477

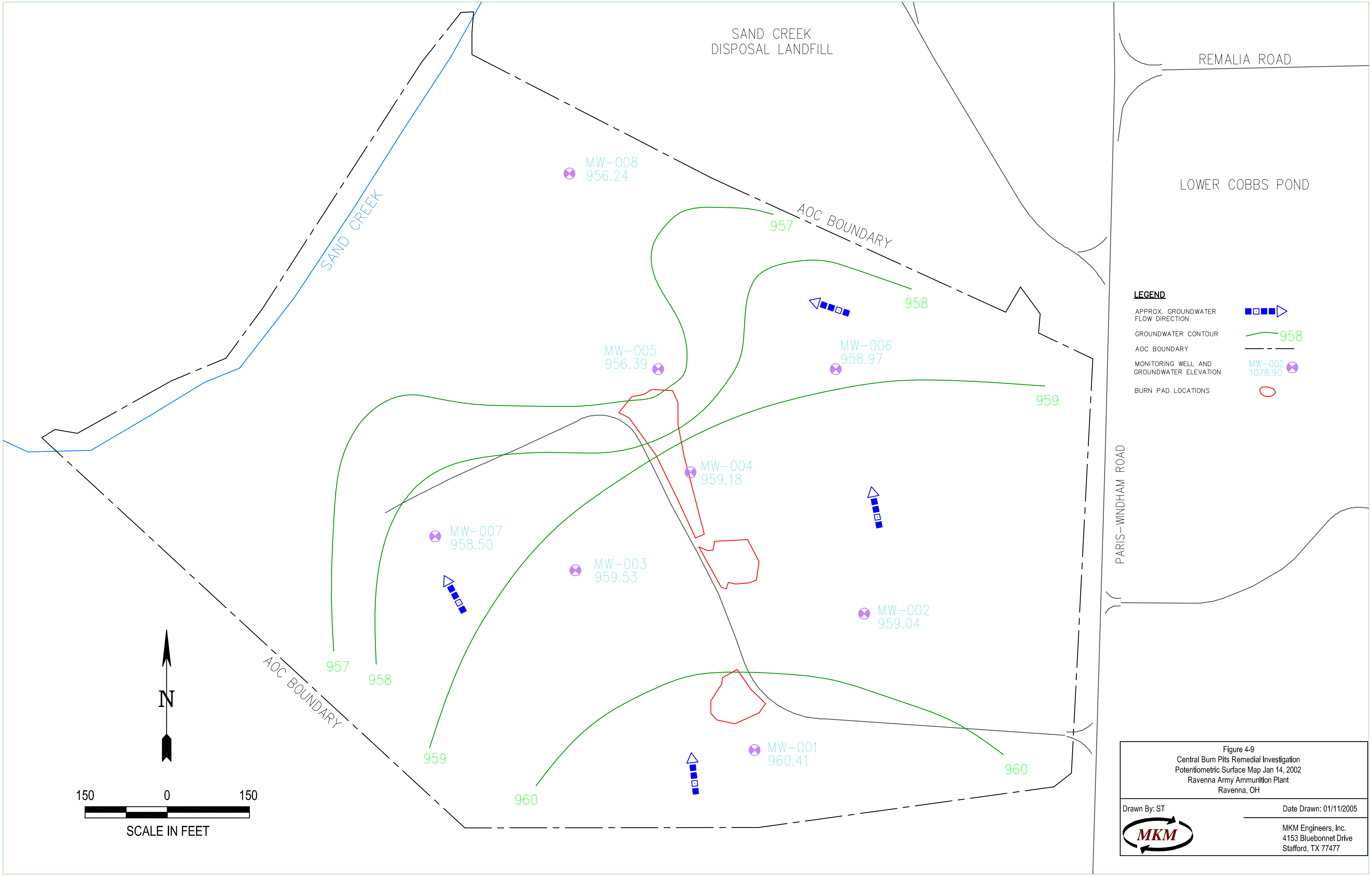

Figure 4-9
Central Burn Pits Remedial Investigation
Potentiometric Surface Map Jan 14, 2002
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: ST

Date Drawn: 01/11/2005

MKM

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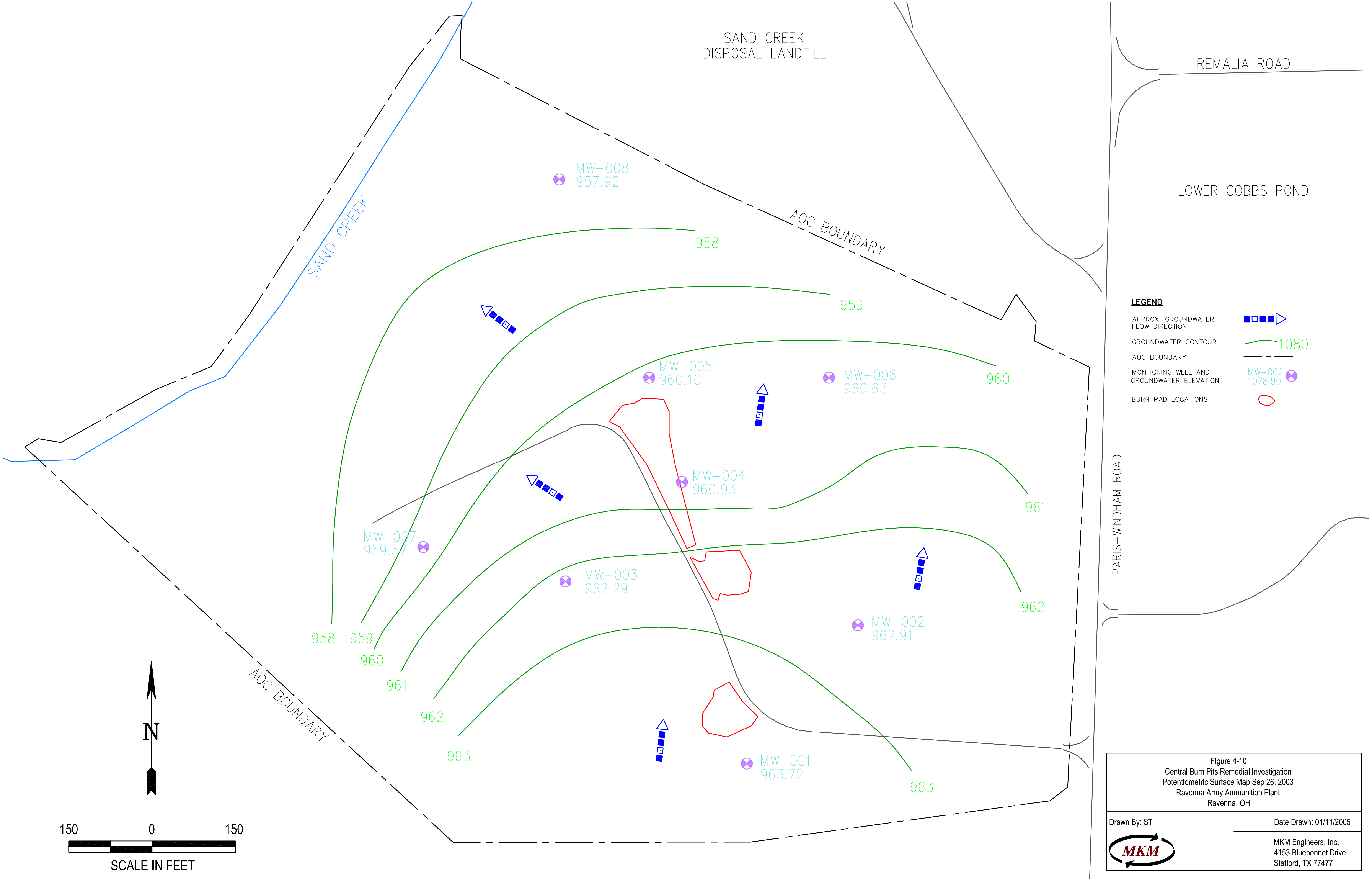


Figure 4-10
Central Burn Pits Remedial Investigation
Potentiometric Surface Map Sep 26, 2003
Ravenna Army Ammunition Plant
Ravenna, OH

Drawn By: ST

Date Drawn: 01/11/2005

MKM Engineers, Inc.
4153 Bluebonnet Drive
Stafford, TX 77477

Figure 5-1
1991 Windrose for Akron Canton Airport
Central Burn Pits Remedial Investigation
Ravenna Army Ammunition Plant, Ravenna, OH

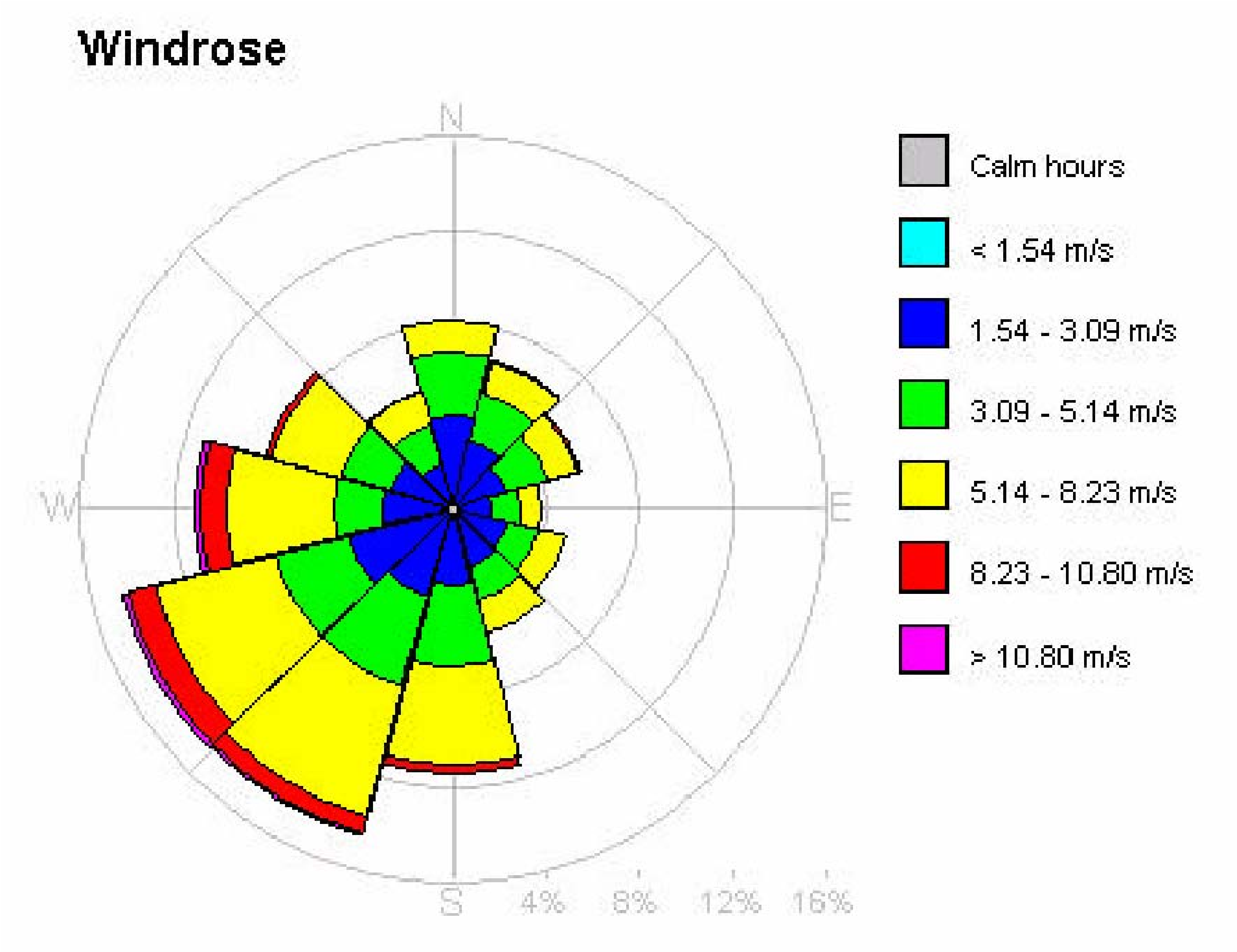


FIGURE 6-1
SUMMARY OF CANCER RISKS
CENTRAL BURN PIT REMEDIAL INVESTIGATION
RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OH

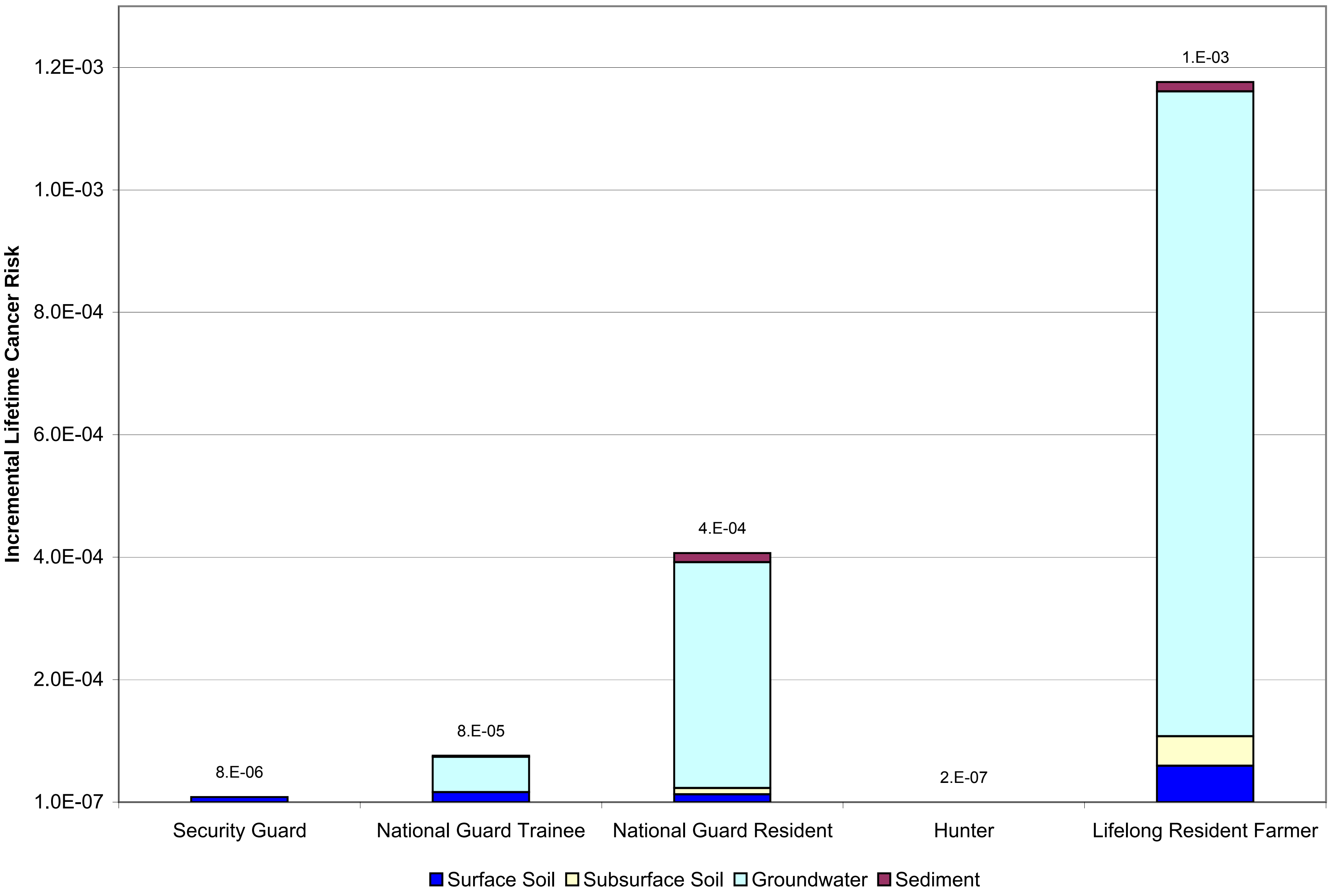
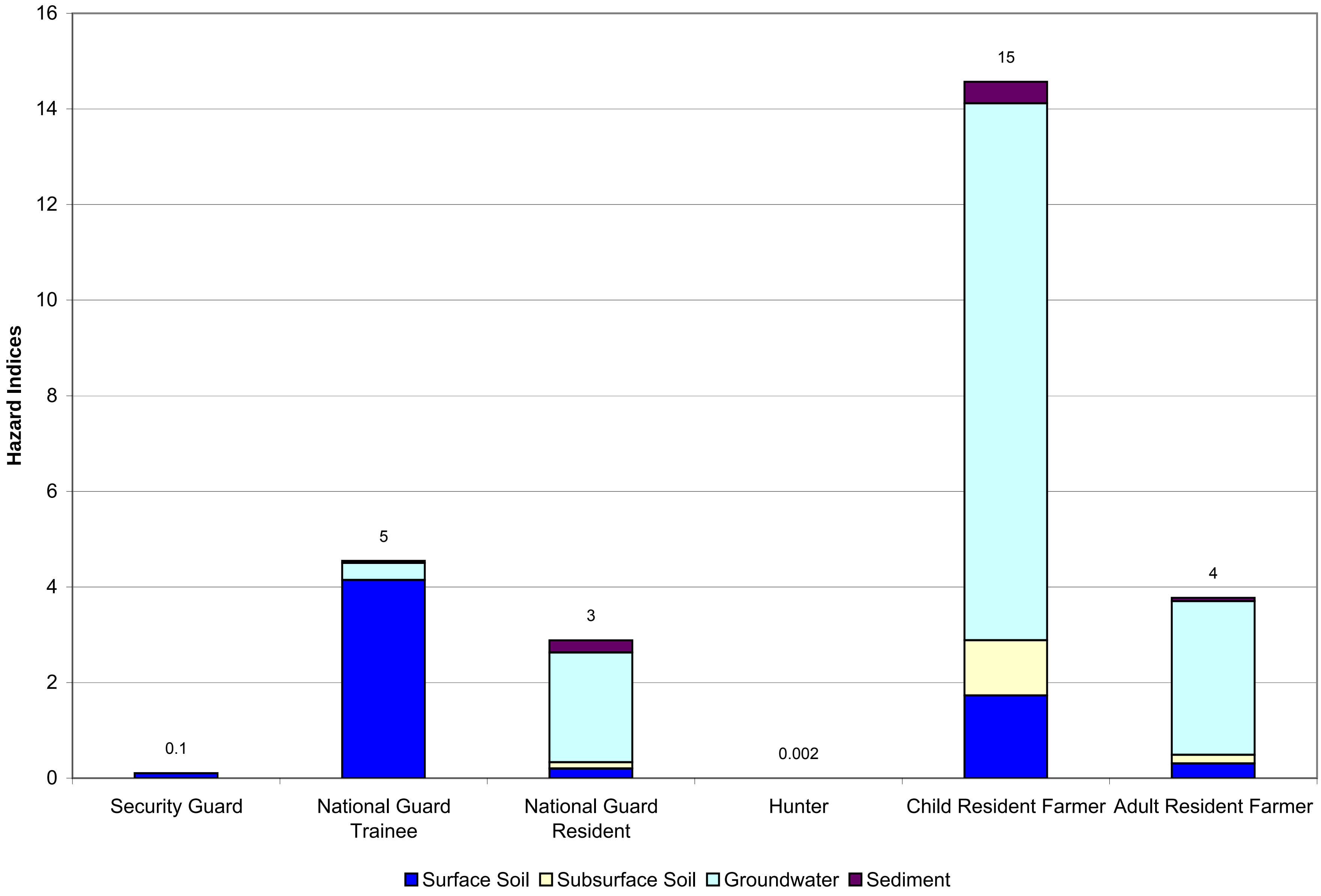


FIGURE 6-2
SUMMARY OF HAZARD INDICES
CENTRAL BURN PIT REMEDIAL INVESTIGATION
RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OH



DRAFT REMEDIAL INVESTIGATION REPORT FOR CENTRAL BURN PITS AT THE RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO
COMMENT RESPONSE TABLE
September 20, 2005

Comment Number	Page or Sheet	Comment	Recommendation	Response
		Ohio EPA NEDO, DERR and DDAGW (V. Deppisch, L. Moore)		
1.	General	The comment response table (CRT) indicates the background table was inserted into the RI report. Please specific the location, as this table cannot be located.		Clarification. The Background Table is presented as *Table 4-1 RVAAP Facility Wide Background Criteria* on page 4-2 of the draft report.
2.	General	The CRT indicates qualifiers and definitions were added to Tables 4-1 through 4-7. They were not added to table 4-1. Please add.		Clarification. Tables 4-1 through 4-7 in the pre-draft report become Tables 4-2 through 4-8 in the draft report as a result of the insertion of the requested background table (Table 4-1). Qualifiers and definitions were added to Tables 4-2 through 4-8.
3.	Section 1.2.1 General Facility Description, page 1-2.	Issue = Consistency. As a result of the discussion on the August 3, 2005 conference call regarding the "Proposed General Facility Description" language (see email from Martha dated 08/03/2005 10:18am), this section may need to be replaced with standard language circulated by SAIC to the Ravenna team for consensus. After the team reaches consensus on this issue, this section should be revised to reflect the agreed upon language (long version).		Agree. Revised text included in Final Report as Section 1.2.1 General Site Description.

Comment Number	**Page or Sheet**	**Comment**	**Recommendation**	**Response**
4.	Table 6-3, page 6-9	Issue = consistency/terminology. Please remove the term "shallow soils" and revise the title of this table to read "*Human Health Risk Assessment Dataset for <u>Deep Surface</u> Soils*". Also, this terminology change is needed in the fourth column of Table 6-7 on page 6-12; also in Table 6-11 in the row for National Guard Trainee, under the media column on page 6-38 change "shallow soil (0-4')" to "deep surface soil (0-4').		Agree. Tables revised as follows: Table 6-3. Human Health Risk Assessment Dataset for ~~Shallow~~ Deep Surface Soils Table 6-7 Column headers changed from "Shallow Soil" to "Deep Surface Soil" Table 6-11 Row callout changed from "Shallow Soil (0 to 4 feet)" to "Deep Surface Soil (0 to 4 feet)."
5.	Table 6-9, page 6-19	Issue = consistency/terminology. Please remove the term "shallow" and revise to surface soil in the second to last column. Also, add a column to represent subsurface soil exposure, where appropriate depending on the receptor.		Agree. Table 6-9 revised as requested and included in the Final Report.
6.	Section 6.5.3 Remedial Goal Options, page 6-50	New Comment. Issue = CERCLA vs. RCRA terminology. Per conference call on Aug 3, 2005 and Aug 9, 2005, please use the term Preliminary PRGs when referring to the proposed chemical specific clean up levels for COCs identified in this risk assessment. The term "Remedial Action Objectives (RAO's)" should be used instead of "Remedial Goal Options (RGO's)" when discussing the written remediation objectives. Text changes may be needed elsewhere in the report. Please revise report as appropriate.		Acknowledged. Per the 01 September 2005 RQL/CBP Draft RI Report CRT teleconference, RGO terminology will remain in RI Reports consistent with previous versions and other published documents. SAIC will strictly adhere to utilization of CERCLA terminology in the FS with transitions clearly explained.

Comment Number	Page or Sheet	Comment	Recommendation	Response
7.	Section 6.5.3 Remedial Goal Options, page 6-51	Issue = Typo. Line 28, revise "96% UCL" to 95% UCL. Verify that this is a typo and make corrections. If this is not a typo, please explain.		Agree. "96% UCL" is a typo. Text revised as follows: "The EPCs (95~~6~~%UCL or maximum detected concentration) of all soil (surface, deep surface, and subsurface) COPCs are < soil screening levels (SSLs) for protection of groundwater for all COPCs except arsenic in surface soil."
8.	Summary of May 31, 2005 CRT	Summary of the risk review of the revised report and resolution of comments from CRT (May 31, 2005) table: CRT #1 = Change made in revised report and text per comment response. Please note that there are some areas where this change is still needed and Ohio EPA has tried to point those areas out in the above comments. CRT #2 = Change made in revised report and text per comment response. CRT #3 = Change made in revised report and text per comment response. CRT #4 = Change made in revised report and text per comment response.		Acknowledged. With respect to pre-draft CRT #1 (Ohio EPA Laurie Moore), SAIC also has re-reviewed the document to identify additional instances requiring revision – none were noted.

Comment Number	Page or Sheet	Comment	Recommendation	Response
Army (Brancato, Druck, Jent, Watson, Zorko)				
1.	Page xviii, line 3	Please take out reference to background, since there is no background value for 2,4,6 TNT.		Agree. Text revised as follows: "One explosive compound (2,4,6-trinitrotoluene) was detected ~~above the background value~~ in one surface soil sample (SS-010) in each sample interval (0 to 1 ft and 1 to 3 ft)."
2.	Page xviii, line 6	Please take out reference to background, since there is no background value for nitrocellulose.		Agree. Text revised to "One propellant (nitrocellulose) was detected ~~above the background value~~ at five sample locations in the 0 to 1 ft interval."
3.	Page xviii, line 36	Please take out reference to background, since there is no background value for nitrocellulose.		Agree. Text revised to "A propellant (nitrocellulose) was detected ~~above background~~ in two sediment locations."
4.	Page 4-12, line 10	Please take out reference to background, since there is no background value for propellants.		Agree. Bullet revised as follows: "The propellants detected ~~are shown as exceeding background since background for propellants is zero. However, none of the concentrations exceeded PRGs.~~ do not exceed PRGs."
5.	Table 4-9	In the last column, please change to 'Hydraulic Conductivity (cm/s) Based on Slug Testing'.		Agree. Table 4-9 column heading revised as follows: "**Hydraulic Conductivity (cm/s) Based on Slug Testing.**"

Comment Number	Page or Sheet	Comment	Recommendation	Response
6.		**Once the FWSW Report is finalized, please add to this report the results associated with the location of the FWSW Study that was along Sand Creek, at the downstream end of the Central Burn Pits.**		Agree. Summaries from the FWSW Report (USACE 2005) will be incorporated into Section 7.9.2 on sediment invertebrates and Section 7.9.3 on aquatic organisms. The summaries address surface quality, sediment chemistry, physical habitat, and the macroinvertebrate community (Section 7.9.2) as well as aquatic organisms, especially fish (Section 7.9.3). Please also see response to USACE Comment #9. Note the full citation of the biology and surface water study (FSWS) for the reference section: USACE (United States Army Corps of Engineers). 2005. *Facility-wide Biological and Water Quality Study 2003, Ravenna Army Ammunition Plant, Part 1 – Streams and Part II – Ponds*. U.S. Army Corps of Engineers, Louisville District, with the State of Ohio Environmental Protection Agency, Division of Surface Water. Pp. 144 and several appendices.
7.	Table 6-8	Please add the trespasser scenario.		Per 01 Sept. 2005 RQL/CBP Draft RI Report CRT teleconference, the trespasser scenario will not be included in the Draft RI Report and will be included in the FS as an appendix. Ohio EPA will raise the topic to dispute for resolution starting with the Tiger Team.
8.	Page 6-63, line 25	If there is no toxicity associated with nitrocellulose, why are we testing for it?		Comment withdrawn per 01 Sept. 2005 RQL/CBP Draft RI Report CRT teleconference

Comment Number	**Page or Sheet**	**Comment**	**Recommendation**	**Response**
9.	Chapter 7	Please add the results of the FWSW study for the location along Sand Creek at the downstream end of the CBP as further support to Paragraphs 7.9.2 and 7.9.3.		Agree. Text was incorporated into Section 7.9.2 Sediment Invertebrates and Section 7.9.3 Aquatic Organisms.
10.	Figures 2-(3-6)	A Please add a note that conditions at locations other than directly at a boring are interpolated. B Please delete the portions of the profiles that extend below the bottoms of borings, as for instance the portion of the profile on Figure 2-4 at MW-008 below the bottom of that boring shown at about elevation 948.		A. Agree. The following notation will be added to the legend of Figures 2-3 through 2-6: "Conditions at locations other than directly at a boring (i.e., between borings and below the boring) are interpolated." B. Agree. Portions of the profiles that extend below the bottoms of borings will be cropped.
11.	Figures 3-6 and 3-7	Please add the location from the FWSW study at the downstream end of Sand Creek along the Central Burn Pits.		Agree. The sampling location (RM 2.4) downstream CBP has been added to Figures 3-6 and 3-7. The following text was added to Section 3.1.3 "In addition, the downstream stream sample from CBP (S-7) collected as part of the *Facility-wide Biological and Water Quality Study 2003 (USACE, 2005*) is shown on Figure 3-6." The following text was added to Section3.1.4: "In addition, the downstream stream sample from CBP (S-7) collected as part of the *Facility-wide Biological and Water Quality Study 2003 (USACE, 2005*) is shown on Figure 3-7."
12.	Page 6-48, line 5; page 6-50, section 6.5.3	Recommend the use of CERCLA language Remedial Action Objective (RAO) in lieu of Remedial Goal Option (RGO)	Needs team discussion; decision will be applicable throughout the program	Acknowledged. Please see response to Ohio EPA Comment #6.

Comment Number	**Page or Sheet**	**Comment**	**Recommendation**	**Response**
13.	Page xix, line 19	Suggested language change: "…the primary contaminant migration pathway**s** of concern …"		Agree. Text revised as follows: "The primary contaminant migration~~s~~ pathways of concern for contaminants at CBP are ~~is~~ overland runoff and transport in surface drainage channels, including Sand Creek."
14.	Page xxi, line 9	Suggested language change: "…indicated **a** potential risk to…"		Agree. Text revised as follows: "The BHHRA indicated ~~that~~ a potential risk to a National Guard trainee due to exposure to manganese via the inhalation exposure pathway."
15.	Page xxii, line 4	Suggested language change: "…background benchmarks reported arsenic concentrations ranging from…" Line 6: Recommend that the data point (35.1 ug/L) be put in the context of filtered or unfiltered, overburden or bedrock for understanding it's potential significance.		Agree. Text revised as follows: "The RVAAP background benchmarks reported ~~that~~ arsenic concentrations ranging from 11 ug/L (filtered overburden) to 215 ug/L (unfiltered overburden). The maximum arsenic concentration detected in CBP monitoring wells was 35.1 ug/L (filtered overburden)."
16.	Page 1-1, line 3	Suggested language change: Recommend deletion of "U. S. Army Industrial Operations Command (IOC)" because of the re-organization/name change and lack of relevance. Suggest using "U.S. Army…" only.		Agree. Text revised as follows: "which is located at the U.S. Army's ~~Industrial Operations Command's (IOC)~~ Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio (Figure 1-1)."
17.	Page 1-2, line 13	Recommend deletion of "JMC" and change verb in next statement from "is" to "are." Lines 23-34: Suggested language change: "jointly operated by the U.S. Army Rock Island BRAC Field Office and the OHARNG."	Delete Bureau—the National Guard Bureau is a separate entity.	Agree. Text revised as requested and in conjunction with Ohio EPA Comment #3. Updated text attached to CRT – see reference to Ohio EPA Comment #3.

Comment Number	Page or Sheet	Comment	Recommendation	Response
18.	Page 1-3, lines 20-24	Please reword this sentence to indicate that while the debris piles were not investigated during this RI effort that they will be addressed during the upcoming field work and presented as a portion of the FS report. Line 33: I believe that "excessor" should be trespasser? Also, "…hunters **are** potential receptors…"		Agree. Text revised as follows: "The investigation and characterization of these debris piles/berms was not included in the original scope of work and therefore, not ~~conducted~~ addressed in this report. ~~These materials should be evaluated.~~ These materials will be evaluated during the Fall of 2005 and results will be presented in the Feasibility Study." Text revised as follows consistent with information presented on page xix, lines 22-27: "The report indicates that hunters and trespassers are ~~excessors to be~~ potential receptors for exposure to soil contamination."
19.	Tables 4-2 thru 4-8	Tables 4-2 thru 4-8 are titled "Summary of…Exceedances" It is not clear what the title means because data which does not exceed the BKG or PRG is also presented.	Suggest that the actual exceedances be bold.	Agree. Table titles revised as follows: "Summary of … *media*…~~Exceedances~~ Data Screening Results." Exceedances of PRGs and background will be highlighted by *italics*, **bolding**, and ***bold italics***.
20.	Page 6-6	The link given for USEPA Region 9's PRG table is not correct.	Here is the correct link: http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf	Disagree. Per 01 Sept. 2005 RQL/CBP Draft RI Report CRT teleconference, the link provided in the RI Report is consistent with the link provided in the FW Human Health Risk Assessor's Manual.
21.	Page 6-66, line 24	Recommend that the data point (35.1 ug/L) be put in the context of the follow on information (filtered or unfiltered, overburden or bedrock) for understanding it's potential significance. Same comment applies to page 9-1, line 20.		Agree. Text revised as follows: "Specifically, the maximum detected concentration (35.1 ug/L) was reported for a sample collected from MW-001 (filtered overburden) which is located upgradient of the primary source areas at the CBP.

Comment Number	Page or Sheet	Comment	Recommendation	Response
22.	Page 6-67, line 18	Suggested language change: "…concentrations detected in soils **are** less…"		Agree. Text revised as follows: "The Aroclor-1254 concentrations detected in soils ~~is~~ are less than the 1 mg/kg action level."
23.	line 28, p 6-51	Why was 96%UCL referenced on line 28, p 6-51? It should be 95%UCL.		Agree. "96% UCL" is a typo. Text revised as follows: "The EPCs (95~~6~~%UCL or maximum detected concentration) of all soil (surface, deep surface, and subsurface) COPCs are < soil screening levels (SSLs) for protection of groundwater for all COPCs except arsenic in surface soil."