Final Baseline Human Health Risk Assessment Work Plan
Acid Area 1
Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
CONTRACT DACW62-03-D-0004-0009

Prepared by:

JACOBS™

JACOBS ENGINEERING GROUP, INC.
125 BROADWAY AVENUE
OAK RIDGE, TN 37830

April 2009

200-1e
03.04_0502
G05OH001823_03.04_0502_a

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

Jacobs Engineering Group, Inc. has completed the Final Baseline Human Health Risk Assessment Work Plan for Acid Area 1 at the Former Plum Brook Ordnance Works, Sandusky, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

Kraig Kish	geologist	4-6-09
(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

Mark Stacke	toxicologist	4-6-09
(Signature)	(Discipline)	(Date)

Jacobs BHHRA Work Plan Author

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

All reviewer comments have been addressed and responses are included in the appendix.

Al Hardesty 4-7-09

(Signature) (Date)

(Project Manager)

Table of Contents

Section ..... **Page**

List of Figures v

List of Tables v

List of Acronyms and Abbreviations vi

1.0 INTRODUCTION 1-1

1.1 FACILITY DESCRIPTION 1-1

1.2 BACKGROUND 1-2

1.3 SITE USE AND GROUNDWATER USE 1-3

1.3.1 Acid Area 1 Land Use 1-3

1.3.2 Groundwater Use 1-4

1.4 PROTOCOL FOR THE BASELINE HUMAN HEALTH RISK ASSESSMENT 1-4

1.5 ORGANIZATION OF THE BASELINE HUMAN HEALTH RISK ASSESSMENT 1-6

2.0 DATA EVALUATION 2-1

2.1 SELECTION OF ANALYTICAL DATA 2-1

2.1.1 Available Data 2-1

2.1.2 Sampling Method Considerations 2-1

2.1.3 Evaluation of Data Quality 2-2

2.1.4 Frequency of Detection 2-3

2.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN 2-3

2.2.1 Risk-Based Screening 2-4

2.2.2 Evaluating Essential Nutrients 2-4

2.2.3 Background Screening 2-5

2.2.4 Statistical Data Set Testing of Inorganics 2-5

2.2.5 Treatment of Organics 2-6

2.2.6 Role of COPC Screening in the Risk Assessment Process 2-6

2.3 DATA EVALUATION SUMMARY 2-6

3.0 EXPOSURE ASSESSMENT 3-1

3.1 CONCEPTUAL SITE EXPOSURE MODEL 3-1

3.1.1 Physical Setting 3-2

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways 3-2

3.1.3 Receptors and Exposure Pathways 3-4

3.1.3.1 Overburden Groundwater 3-5
3.1.3.2 Bedrock Groundwater 3-5
3.1.3.3 Surface Soil 3-6
3.1.3.4 Subsurface Soil 3-9
3.1.3.5 Surface Water 3-10
3.1.3.6 Sediment 3-11
3.1.3.7 Game Animals 3-12
3.2 QUANTIFICATION OF EXPOSURE-POINT CONCENTRATIONS 3-13
3.2.1 COPC Concentrations from Dust 3-16
3.2.2 COPC Concentrations in Indoor Air 3-17
3.2.3 VOC Concentrations from Subsurface Soil in Ambient Air 3-24
3.2.4 Concentrations in Household Air from Groundwater Use 3-25
3.2.5 Concentrations of VOCs in Groundwater: Resident Dermal Uptake 3-26
3.2.6 Concentrations of COPCs in Venison 3-26
3.3 QUANTIFICATION OF CHEMICAL INTAKES 3-28
3.3.1 Inhalation of COPCs in Air 3-29
3.3.2 Incidental Ingestion of COPCs in Soil and Sediment 3-29
3.3.4 Dermal Contact with COPCs in Soil, Sediment, or Water 3-30
3.3.5 Consumption of Venison 3-33
3.3.6 Ingestion of COPCs in Groundwater and Surface Water 3-34
4.0 TOXICITY ASSESSMENT 4-1
4.1 EVALUATION OF CARCINOGENICITY 4-1
4.2 EVALUATION OF NONCARCINOGENIC EFFECTS 4-2
4.3 DERMAL TOXICITY VALUES 4-4
4.4 TARGET ORGAN TOXICITY 4-4
4.5 SOURCES OF TOXICITY INFORMATION USED IN THE RISK ASSESSMENT 4-4
5.0 RISK CHARACTERIZATION 5-1
5.1 CARCINOGENIC EFFECTS OF CHEMICALS 5-1
5.2 NONCANCER EFFECTS OF CHEMICALS 5-2
5.3 RISK CHARACTERIZATION RESULTS 5-4
5.4 SUMMARY 5-4
6.0 UNCERTAINTY ANALYSIS 6-1
6.1 TYPES OF UNCERTAINTY 6-1
6.2 SOURCES OF UNCERTAINTY 6-1

7.0 DEVELOPMENT OF RISK-BASED REMEDIATION LEVELS.....7-1

8.0 SUMMARY AND CONCLUSIONS.....8-1

9.0 REFERENCES.....9-1

List of Appendices

Appendix Response to comments

List of Figures

Figure 1-1 Location Map, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 1-2 Location Map, Acid Area 1
Figure 1-3 Site Layout, Acid Area 1
Figure 2-1 Role of COPC Screening in the Risk Assessment and Risk Management Process
Figure 3-1 Human Health Conceptual Site Exposure Model, Acid Area 1

List of Tables

Table 2-1 Sampling Locations to be used in the Baseline Human Health Risk Assessment, Acid Area 1 Site
Table 3-1 Receptor/Exposure Scenarios
Table 3-2 Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Table 3-3 Variables Used to Estimate Potential Chemical Intake and Contact Intake and Contact Rates from Groundwater

List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
ABS	dermal absorption factor
AF	adherence factor
amsl	above mean sea level
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BHHRA	baseline human health risk assessment
Bldg.	building
BSC	background screening concentration
BTEX	benzene, toluene, ethylbenzene, and xylenes
BW	body weight
CDC	U.S. Centers for Disease Control
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
COC	chemicals of concern
COPC	chemical of potential concern
CSEM	conceptual site exposure model
DA	dose absorbed per unit body surface area per event
DAD	dermal absorbed dose
DERP-FUDS	Defense Environmental Restoration Program – Formerly Used Defense Sites
dl	deciliter
DM	dry matter
DNT	dinitrotoluene
DOE	U.S. Department of Energy
DPT	direct push technology
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
ET	exposure time
FI	fraction of intake
ft	feet
g	gram
g/kg-day	grams per kilogram of body weight per day
GAF	gastrointestinal absorption factor
gpm	gallons per minute
GSA	U.S. General Services Administration
H_2S	hydrogen sulfide
HHEM	human health evaluation manual
HI	hazard index
HQ	hazard quotient
HxCDD	hexachlorodibenzo-P-dioxin compounds
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
ILCR	incremental lifetime cancer risk
IR	ingestion rate

IRIS	Integrated Risk Information System
IT	IT Corporation
Jacobs	Jacobs Engineering Group Inc.
kg	kilogram
K_p	permeability coefficient
L	liter
m	meter
m^2	square meter
m^3	cubic meter
MDC	maximum detected concentration
mg	milligram
mg/cm^2-event	milligrams per square centimeter per event
NASA	National Aeronautics and Space Administration
NCRPM	National Council on Radiation Protection and Measurements
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PC	permeability coefficient
PCB	polychlorinated biphenyl
PEF	particulate emission factor
ppm	parts per million
PRG	preliminary remediation goals
RA	risk assessment
RBC	risk-based concentration
RBRL	risk-based remediation level
RBSC	risk-based screening concentration
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
SA	surface area
SAIC	Science Applications International Corporation
SF	slope factor
Shaw	Shaw Environmental, Inc.
SI	site investigation
STC	source-term concentration
SVOC	semi-volatile organic compound
TNT	trinitrotoluene
TRW	Technical Review Workgroup
UCL	upper confidence limit
UCL_{95}	95th percent upper confidence limit on the arithmetic mean
UF	uncertainty factor
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
WRS	Wilcoxon Rank-Sum
µg	micrograms

1.0 INTRODUCTION

This baseline human health risk assessment (BHHRA) work plan was prepared to describe the protocol for evaluating risk to human health from potential exposure to soil, groundwater, surface water, and sediment associated with Acid Area 1 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio.

This work plan was prepared by Jacobs Engineering Group (Jacobs) under contract DACW62-03-D-0004, Delivery Order #8. This work is being conducted for the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) - Formerly Used Defense Sites (FUDS). Investigations at PBOW under DERP-FUDS are being managed by the USACE, Huntington District and technically overseen by the USACE Nashville District.

This work plan is consistent with U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (OEPA) guidance and with the procedures established in the BHHRA work plan for trinitrotoluene (TNT) Areas A & C soil (IT Corporation [IT], 2001a), the BHHRA work plan for groundwater at PBOW (Shaw Environmental, Inc. [Shaw], 2005a) and the BHHRA work plan for Acid Areas 2 and 3 (Jacobs, 2007).

1.1 Facility Description

PBOW is located approximately 4 miles south of Sandusky, Ohio, and 59 miles west of Cleveland (Figure 1-1). Although located primarily in Perkins and Oxford Townships, the eastern edge of the facility extends into Huron and Milan Townships. PBOW is bounded on the north by Bogart Road, on the south by Mason Road, on the west by Patten Tract Road, and on the east by U.S. Highway 250. The area surrounding PBOW is mostly agricultural and residential (IT, 2001b). The facility is currently surrounded by a chain-link fence and the perimeter is regularly patrolled. Access by authorized personnel is limited to established checkpoints. Public access is restricted, except during the annual deer hunting season.

The Acid Area 1 site is located in the central portion of PBOW, adjacent to Taylor Road, between Maintenance Road and Fox Road (Figure 1-2) (Jacobs, 2006), covering an area approximately 20 acres in size. The site physical features include an open field bounded by a drainage ditch to the south with scattered overgrowth throughout. Two railroad grades run east-west through the site: one on the southern perimeter and one through the northern portion of the site. The original service road encircles the site. The road is in fair condition and clear of vegetation. Buildings (Bldgs) 302, 308, and 310 are the only remaining original structures at the site. All other buildings and tanks have been removed. The National Aeronautics and Space Administration (NASA) constructed a metal building between former Building 301 and Building 302. This building was formerly used by NASA as an incinerator, but is currently used for equipment storage.

The ground surface at Acid Area 1 is relatively flat, with minimal slope toward the drainage ditches to the north, south, and west. Elevations at the site range from 629 to 640 feet (ft) above mean sea level (amsl). Four drainage features are present at the site. The drainage ditch to the south is located approximately 40 ft south of the service road and drains to the west, parallel to the site, discharging into Ransom Brook west of the site. This drainage feature has

little relief adjacent to the site. Another drainage ditch originates on site on the north central portion of the site and drains to the north. This drainage feature is approximately 30 to 40 ft wide and 15 to 18 ft deep just north of the Acid Area 1 site. A third drainage ditch originates in a low swampy area in the west central portion of the site and drains to the west into Ransom Brook. The fourth drainage ditch originates at a ponded area with a man-made dike in the northwest corner of the site, which also drains west into Ransom Brook. Flowing water has been observed in all four drainage ditches during the wet season in early to mid-spring. All but the northern drainage ditch dry up by mid-summer including the ponded area and the swampy area.

1.2 Background

The 9,009-acre PBOW site was built in early 1941 as a manufacturing plant for TNT, dinitrotoluene (DNT), and pentolite. Production of explosives began in December 1941 and continued until 1945. It is estimated that more than one billion pounds of explosives were manufactured during the four-year operating period.

NASA acquired PBOW in 1963 and presently utilizes about 6,400 acres for conducting space research. The site is operated by NASA as the Plum Brook Station of the John Glenn Research Center, which is headquartered in Cleveland, Ohio. In 1978, NASA declared approximately 2,152 acres of land as excess (IT, 1997). The Perkins Township Board of Education acquired 46 acres of the excess property for use as a bus transportation center. The Ohio National Guard has an agreement with the U.S. General Services Administration (GSA) to use 604 acres of the facility.

The acid production areas were in operation from 1941 to 1945 to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. A records review was conducted by IT in preparation for a Site Investigation (SI) of the Acid Areas (IT 1998). The records review indicated that no previous investigations had been conducted at Acid Area 1. Available drawings of the site were used to identify some facility components. A review of the 1958 aerial photographs revealed several buildings and aboveground storage tanks at Acid Area 1. The majority of the site facilities were dismantled between 1958 and 1963. Buildings 302 Sulphuric Acid Concentration Plant, 308 Ammonia Oxidation Plant, and 310 are the only remaining original structures at the site.

Acid Area 1 consisted of eight buildings (Bldgs. 301-304, Bldgs. 306-308, and Bldg. 310), 43 aboveground storage tanks, and two rail lines (Figure 1-3). No information was obtained during the IT records review to indicate the type of process conducted at each building; however, identification of five storage areas was determined from the drawings: Oleum Storage (twelve tanks), Concentrating Mix Storage (six tanks), Sulfuric Acid Sales (twelve tanks), TNT Residual Acid Storage (five tanks), and Mixed Storage (8 horizontal tanks) as shown on Figure 1-3. Based on the location of the Oleum Storage, Sulfuric Acid Sales Storage, and Mixed Storage in close proximity to the rail line, the stored material was likely transferred directly to and from tanker cars or containers on a routine basis.

An SI was performed at Acid Area 1 in 1998, which identified surface and subsurface soil contamination above EPA Region III Risk-Based Criteria (RBC). Organic contaminants in

surface and subsurface soil exceeding the RBCs included polynuclear aromatic hydrocarbons (PAH), and polychlorinated biphenyls (PCB).

A Remedial Investigation (RI) was performed May 2007 through May 2008 to define the extent of soil contamination and to evaluate impacts to the groundwater, surface water, and sediment in the vicinity of Acid Area 1. Two rounds of groundwater sampling were performed; one in November 2007 and one in early May 2008.

1.3 Site Use and Groundwater Use

Prior to acquisition of the site for construction of the PBOW, the area was largely agricultural. During construction of the PBOW, most of the forested areas were cleared. Today, second generation forests have returned to large portions of the site that are not actively used by NASA. Other undeveloped areas of the site are maintained as open fields. The surrounding area is mostly agricultural and residential.

Potential future uses of portions or all of the facility property include:

1. The continuation of NASA activities at PBOW.
2. Recreational uses such as hunting and fishing. PBOW is open to deer hunters during the hunting season.
3. Selling of portions of the site by GSA to other parties (state or local government or private individual).
4. Agricultural uses.
5. Residential uses.
6. Training area for use by National Guard Units.
7. Construction activities.

Items three through seven are speculative and no negotiations have been scheduled to define future land use.

1.3.1 Acid Area 1 Land Use

The Acid Area 1 site was used for the production and storage of various types of acid used for the production of TNT and DNT. The facility was constructed in 1941 and used through 1945. Most of the building and all of the storage tanks were removed between 1958 and 1963. The remaining buildings at Acid Area 1 are used on a limited basis for temporarily storage. No specific future uses of this site have been identified.

1.3.2 Groundwater Use

Two aquifers are utilized for drinking water in the area surrounding PBOW: a carbonate aquifer outcropping in the western portion of Erie County and a shale aquifer outcropping in the eastern portion. PBOW is located within the transition of the two aquifers. Both aquifers are overlain by a veneer of glacial drift, generally less than 20 ft thick, that is considered a poor source of groundwater except in areas of sand and gravel lenses.

Most of PBOW is mapped by the Ohio Department of Natural Resources as an area in which well yields seldom exceed three gallons per minute (gpm) from the shale aquifer and overlying discontinuous sand and gravel deposits. The northwest portion of PBOW, including Acid Area 1, is mapped as an area in which yields of 100 to 500 gpm may be developed from depths of less than 200 ft from cavernous limestone and dolomite. The bedrock monitoring wells installed at Acid Area 1 were completed in limestone with a diverse range in porosity and fracturing. Groundwater yields range from zero gpm from the upgradient well east of Taylor Road to less than a 1 gpm from the downgradient well located at the northwest corner of the site.

Residences to the north and east of PBOW are served by city, county, and rural water departments. Residences south and west of PBOW are supplied by wells. As of 1991, a total of 179 permitted private drinking water wells, listed at the Erie County Health Department, were within a four-mile radius of PBOW (Science Applications International Corporation [SAIC], 1991). The nearest recorded well was at 6115 Schenk Road, approximately 3,800 ft from the site; however, a closer well was observed at 1810 Schenk Road, located approximately 2,250 ft from the site.

1.4 Protocol for the Baseline Human Health Risk Assessment

The BHHRA work plan is based on EPA, USACE, and OEPA guidance, including, but not limited to, the following:

- OEPA, 2004a, *TECHNICAL DECISION COMPENDIUM Methodology for Evaluating Site-specific Background Concentrations of Chemicals Ohio EPA Division of Emergency and Remedial Response Remedial Response Program 14 April 2004.*

- OEPA, 2004b, *TECHNICAL DECISION COMPENDIUM Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight Ohio EPA Division of Emergency and Remedial Response 28 April 2004*

- OEPA, 2005a, *Use of Risk-Based Numbers in the Remedial Response Process Overview DERR-00-RR-038, June 28, 2005.*

- OEPA, 2005b, *TECHNICAL DECISION COMPENDIUM Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment Ohio EPA Division of Emergency and Remedial Response Remedial Response Program August 2005.*

- OEPA, 2007, Remedial Investigation/Feasibility Study Programmatic Recommendations Guidance List; http://www.epa.state.oh.us/derr/rules/guidance.html; *Ohio EPA Division of Emergency and Remedial Response Remedial Response Program April 2007.*

- U.S. EPA, 1989a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/1-89/002.

- U.S. Environmental Protection Agency (EPA), 1989b, *General Quantitative Risk Assessment Guidelines for Noncancer Health Effects*, Prepared by the Office of Health and Environmental Assessment, Cincinnati, OH, for the Risk Assessment Forum, ECAO-CIN-538.

- U.S. EPA, 1991a, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors*, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

- U.S. EPA, 1991b, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual Part B – Development of Risk-Based Preliminary Remediation Goals*, Interim, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/R-92/003, December.

- U.S. EPA, 1992a, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9285.7-081.

- U.S. EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, D.C., EPA/600/891/011B, including Supplemental Guidance dated August 18, 1992.

- U.S. EPA, 1992c, "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

- U.S. EPA, 1997a, *Exposure Factors Handbook*, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., EPA/600/P95/002F, August.

- U.S. EPA, 2004a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)*, Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., EPA/540/R-99/005, July.

- U.S. EPA, 2009, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part F - Supplemental Guidance for Inhalation Risk Assessment)*, Final, Office of Solid Waste and Emergency Response, Washington, D.C., OSWER No. 9285.7-82, January.

- U.S. Army Corps of Engineers (USACE), 1999, *Risk Assessment Handbook, Volume I: Human Health Evaluation*, Engineer Manual EM 200-1-4.

1.5 Organization of the Baseline Human Health Risk Assessment

The BHHRA report will present the methods used, results generated, and the interpretation of these results. The report will be organized as follows:

Data Evaluation: Identifies data sources, evaluates data quality, identifies chemicals of potential concern (COPC), and provides a background screening.

Exposure Assessment: Presents a conceptual site exposure model (CSEM), including contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; describes exposure-point concentrations (EPCs); and presents methods for calculating chemical intake and contact rates.

Toxicity Assessment: Describes the potential for cancer and/or noncancer human health effects, provides an estimate of the quantitative relationship between the magnitude of dose or contact rate and the probability and/or severity of adverse effects, identifies the toxicity values that are used in the BHHRA, and describes the development of dermal toxicity values.

Risk Characterization: Combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor at Acid Area 1. Risks associated with exposure to all appropriate media at Acid Area 1 will be evaluated.

Uncertainty Analysis: Identifies uncertainties in all phases of the BHHRA and discusses their individual effects on the risk assessment results, focusing on those issues that are most likely to have the greatest effect on risk estimates and/or risk management decisions.

Risk-Based Remediation Level Development: Describes the development of risk-based remediation levels (RBRL), based on the methods of the BHHRA and discussion between OEPA and USACE.

Summary/Conclusions: Provides a brief summary of the BHHRA, including quantitative results, uncertainties, and pertinent site information. Summary and discussion is focused on those results and issues that are most likely to directly affect site management decisions.

References: Provides a complete bibliography of all references used and cited in the BHHRA.

2.0 DATA EVALUATION

2.1 Selection of Analytical Data

Analytical data for the Acid Area 1 site will be selected based on the representativeness and quality of the data. The evaluation of data quality is presented in Section 2.1.3. Surface and subsurface soil sample locations, surface water, sediment sample locations, and bedrock wells, considered for the evaluation of the Acid Area 1 site are identified on Table 2-1.

2.1.1 Available Data

An SI of Acid Area 1 was conducted in 1998 by IT to determine the existence and nature of contamination, and to evaluate potential risks to human health and the environment (IT 1998). Fifteen soil borings were completed to characterize lithology and to collect soil samples for off-site laboratory analysis. Total depths of these borings ranged from 4 to 10 ft below ground surface (bgs).

The SI identified surface and subsurface soil contamination above EPA Region III RBCs. Organic contaminants in surface and subsurface soil exceeding the RBCs were identified, including the following:

- PAHs: Benzo(a)pyrene
- PCBs: Aroclor 1260 (surface soil only, subsurface soil not analyzed for PCBs)

Inorganic contaminants in surface and subsurface soil exceeding both the RBCs and the established background values were limited to arsenic, aluminum, and beryllium.

An RI was performed by Jacobs from May 2007 through May 2008 to define the extent of soil contamination and to evaluate impacts to the groundwater, surface water, and sediment in the vicinity of Acid Area 1. Two rounds of groundwater sampling were performed, one in November 2007 and the second in May 2008.

A total of 45 soil samples were collected from 23 locations, placed adjacent to buildings and storage tanks. Contaminants in soil exceeding the EPA Region IX Residential Preliminary Remediation Goals (PRGs) (EPA, 2004b) and established background values for inorganics are primarily limited to surface soil. These contaminants include PCBs, PAHs, and lead.

A total of 15 co-located surface water and sediment samples were collected from the drainage ditches. At least one upgradient and one downgradient sample were collected from each of the four drainage ditches. Contaminants exceeding the EPA Region IX Residential PRGs and established background values for inorganics were primarily limited to sediment. These contaminants include PCBs, PAHs, and lead.

Three shallow groundwater monitoring wells and three bedrock groundwater monitoring wells were installed. Two rounds of groundwater sampling were conducted, one in November 2007 and the other in May 2008. Data from the May 2008 sampling is not yet available. Contaminants in shallow groundwater exceeding the EPA Region IX Tap Water PRGs

(EPA, 2004b) were only present in the upgradient well. These contaminants include benzene and xylene. Contaminants in bedrock groundwater exceeding the EPA Region IX Tap Water PRGs include volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) associated with naturally occurring petroleum and explosives at one well on the north central portion of the site.

2.1.2 Sampling Method Considerations

Soil sampling was performed utilizing a Geoprobe 5400 direct push technology (DPT) rig. VOC samples were collected directly from the sleeve using a 5035 T-Handle Samplesmart Kit or an Encore sampler. Samples for non-VOC analysis were extruded from the sleeve and homogenized in a dedicated disposable glass bowl using a stainless steel spoon.

Sediment samples were collected with a hand auger equipped with dedicated disposable stainless steel sleeves. VOC samples were collected directly from the sleeve using a 5035 T-Handle Samplesmart Kit or an Encore sampler. Samples for non-VOC analyses were extruded from the sleeve and homogenized in a dedicated disposable glass bowl using a stainless steel spoon. Surface water samples were collected by direct-fill methods and therefore did not utilize any sampling equipment.

Groundwater sampling was conducted with a bladder pump using low flow methods. Water quality parameters were measured during purging on a continuous basis using a Horiba equipped with a flow through cell. A dedicated disposable bailer was used for the downgradient shallow overburden groundwater monitoring well during Round 1 sampling because of limited water volume. No water parameters were collected in association with these samples. Due to low well yields, limited available water column, and/or hydrogen sulfide (H_2S) gas, several of the wells were sampled prior to obtaining the required purge volume and/or stabilization of water parameters.

2.1.3 Evaluation of Data Quality

The quality of the analytical data will be evaluated to select data for inclusion in the BHHRA. Data quality is expressed by the assignment of qualifier codes during the analytical laboratory quality control process or during data validation that reflect the level of confidence in the data. The following are some of the more common qualifiers and their meanings (EPA, 1989a):

U — Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.

J — Value is estimated, probably below the contract-required quantitation limit.

N — The analysis indicates an analyte for which there is presumptive evidence to make a tentative identification.

NJ — The analysis indicates a "tentatively identified analyte", and the reported value represents its approximate concentration.

UJ — The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may

not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

R Quality control indicates that the data are unusable (chemical may or may not be present).

B Inorganic chemicals: the concentration is less than the contract-required detection limit but greater than the instrument detection limit. Organic chemicals: the concentration in the sample is not sufficiently higher than concentration in the blank, using the five-times, ten-times (5x, 10x) rule: A chemical is considered a nondetect unless its concentration exceeds 5x the blank concentration. For common laboratory contaminants (acetone, 2-butanone [methyl ethyl ketone], methylene chloride, toluene, and the phthalate esters), the sample concentration must exceed 10x the blank concentration to be considered a detection.

"J", "N", and "NJ" qualified data will be used in the BHHRA; "R" data and "B" qualified data will not be used. The handling of "U" qualified data (nondetects) in the BHHRA is described in Section 3.2. The use of data with other, less-common qualifiers will be evaluated on a case-by-case basis. Generally, data for which the identity of the chemical is unclear are not used in the BHHRA. When confidence is reasonably high that the chemical is present but the actual concentration is somewhat in question, the data generally are used.

Some chemicals may be analyzed under two different analytical programs. For example, the DNT isomers are analyzed by EPA Method 8330 for nitroaromatics as well as EPA Method 8270C for SVOCs. Analytical results from EPA Method 8330 will be used to quantify risks. The potential uncertainties associated with analytical results obtained by EPA Method 8270C will be discussed in the uncertainty analysis (Section 6.0) of the BHHRA report.

2.1.4 Frequency of Detection

As stated above, if confidence is high that a given chemical is present, the data generally are used in the risk assessment (RA). For most chemicals, their identification at concentrations above levels in blanks (considering the 5x, 10x rule; see above) is presumptive evidence of their presence. However, chemicals that are reported infrequently, e.g., in less than five percent of the samples, may be artifacts in the data that do not reflect the presence of the chemical in question. Generally, chemicals that are reported only at low concentrations in less than five percent of the samples from a given medium are dropped from further consideration, unless their presence is expected based on historical information about the site. Chemicals detected infrequently at high concentrations may identify the existence of "hot spots" and are retained in the evaluation.

2.2 Identification of Chemicals of Potential Concern

COPCs are chemicals that are identified as site-related and potentially capable of contributing significantly to risk that are carried forward for quantitative evaluation in the RA. Prior to initiation of the RA, a list of chemicals present in site samples will be compiled. This initial list will include chemicals detected in site media. COPCs will be selected from this list as discussed

in the following sections. Data from the Acid Area 1 site will be presented in tables and discussed in text in the BHHRA report. A CD-ROM of the raw data used in the risk assessment, organized by exposure medium and exposure unit, will be included with the risk assessment report for ease in data manipulation during document review.

2.2.1 Risk-Based Screening

Risk-based screening for human health is introduced to focus the assessment on the chemicals that may contribute significantly to overall risk and to remove from quantification those chemicals whose contribution is clearly inconsequential. In this screening, the maximum detected concentration (MDC) is compared to the appropriate risk-based screening concentration (RBSC). The units of the MDC and RBSC are the same for each chemical in a given medium. The maximum reporting limit for analytes with no reported detections will be compared to the risk-based screening criteria. If the maximum reporting limit exceeds the screening level, the analyte will be retained for qualitative evaluation in the HHRA.

If the MDC of a chemical is less than or equal to its RBSC, then the chemical in this medium is not considered further in the BHHRA because it is unlikely that chemical concentrations at or below the RBSC would contribute significantly to risk. An analyte is identified as a COPC if its MDC exceeds its RBSC. RBSCs used in this BHHRA will be derived from the EPA Region III RBC tables (EPA, 2008). Region IX PRGs are not being used for the screening because the Region IX PRGs are no longer being updated and published. Contaminants that are considered to be related to past activities at the site may be retained as COPCs based on best professional judgment regardless of the results of screening.

RBC values are based on a concentration equal to either an incremental lifetime cancer risk (ILCR) of 1E-6 or a noncancer hazard quotient (HQ) of 1, which is the threshold at (or below) which adverse noncancer effects are regarded as unlikely to occur. For this BHHRA, the noncancer values listed in the RBC tables will be multiplied by a factor of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals (EPA, 2004a and 1995). This will result in RBSC values associated with an HQ of 0.1. For cancer risk, the RBC values will be used directly as RBSCs in the BHHRA because they are based on an ILCR of 1E-6; acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of 1E-6 to 1E-4 (EPA, 1990), referred to as the "risk management range." The OEPA-DERR fixed cumulative human health goals of 1E-5 and HI=1 will be considered during completion of the risk assessment. However, decisions for the site will be based on the EPA risk management range. Cancer risks associated with RBC values represent the lower end of this range. For this BHHRA, the RBSC for a chemical that elicits both cancer and noncancer health effects will be selected based on either a cancer risk of 1E-6 or an HQ of 0.1, whichever associated concentration is lower.

2.2.2 Evaluating Essential Nutrients

Certain elements are essential human nutrients that are generally regarded as innocuous at levels found in environmental media. These include calcium, chloride, iodine, magnesium, phosphorous, potassium, and sodium. There are no Region III RBCs listed for these nutrients. Essential nutrients may be eliminated as COPCs, provided that their presence in a particular medium is shown to be unlikely to cause adverse effects on human health. An exposure

analysis will be performed whereby a daily dose of the essential nutrient from the medium in question is calculated. The dose will be compared with levels known or expected to be safe or toxic, and/or with daily allowances, depending on the availability of data.

2.2.3 Background Screening

Background screening will be applied to each inorganic analyte whose MDC exceeds the RBSC and that cannot be characterized as an infrequently detected analyte. In background screening, the MDC will be compared to the PBOW chemical-specific background screening concentration (BSC). The derivation of groundwater BSCs was described in the 2004 groundwater report (Shaw, 2005b). Groundwater BSCs were calculated for use at PBOW based on concentrations found in background bedrock monitoring wells installed upgradient of PBOW sources. Each groundwater BSC is either the MDC or the calculated 95 percent upper tolerance limit of the background groundwater data set based on unfiltered samples collected using low-flow sampling, whichever value was lower (Shaw, 2005c). BSCs for soil were established as part of the acid areas investigation (IT, 1998). BSCs for soil were reported as the 95 percent upper tolerance limit for lognormal data sets or the 95th percentile for datasets with a nonparametric distribution.

Background screening may also apply to certain organic compounds that are part of normal background concentrations. Such chemicals may include VOCs and PAHs, a class of organic compounds that form from natural or anthropogenic combustion of organic matter including fossil fuels, and are generally ubiquitous in the environment. Airborne PAHs associated with non-Department of Defense sources may be deposited on soil and leach to groundwater. Benzene, toluene, ethylbenzene, and xylene (BTEX) compounds may also be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW.

Background screening for inorganic constituents will consist of comparing the MDC of the site data set to the BSC. An inorganic constituent will be considered for further evaluation if its MDC exceeds the BSC; further evaluation may include either statistical population testing (Section 2.2.4) or immediate inclusion as a COPC and subsequent evaluation in the exposure assessment, toxicity assessment, and risk characterization. The chemical will not be regarded as a COPC if its MDC is equal to or less than its BSC.

2.2.4 Statistical Data Set Testing of Inorganics

Statistical testing of site inorganic data against the PBOW background data set (identified in Appendix M of the 2004 groundwater data summary and evaluation report [Shaw, 2005b]) may be performed for chemicals whose MDC exceeds their respective BSCs and are identified as COPCs based on RBSC comparison (Section 2.2.1) and frequency of detection (Section 2.1.4). This will be performed using the nonparametric Wilcoxon Rank-Sum (WRS) statistical test (also known as the Mann-Whitney U test). Site data sets will be interpreted as being significantly different from PBOW background if the associated p-level is less than 0.05. WRS statistical output and box and whisker plots of the various data sets will also be included for any constituent tested. Statistical testing will be performed after the risk characterization as part of the uncertainty analysis. A WRS test will not necessarily be run on all inorganic COPCs. For instance, if a site data set of a given inorganic has obviously greater concentrations than the

background data set, then the USACE might choose not to run the WRS. Constituents shown by the WRS results to exceed background (or for which the WRS was not run because of obviously higher concentrations in the site data set) will be assumed to be site related or a qualitative chemical-specific explanation as to why the constituent should not be regarded as site related will be presented in the uncertainty analysis of the BHHRA report.

2.2.5 Treatment of Organics

As mentioned in Section 2.2.3, certain organic compounds (BTEX and PAHs) in site media may be attributable to background conditions. The MDC of PAH and BTEX data may also be compared to BSCs (Section 2.2.3) and may be compared to PBOW background data using WRS (Section 2.2.4), but no organic compound will be summarily screened out. Instead, all detected organic compounds will be carried through the risk assessment process (i.e., exposure assessment, toxicity assessment, risk characterization) unless screened out on the basis of comparison to RBSCs (Section 2.2.1) or is characterized as infrequently detected (Section 2.1.3). A discussion of background contribution of organics will be presented in the uncertainty analysis of the BHHRA report.

2.2.6 Role of COPC Screening in the Risk Assessment Process

Figure 2-1 depicts COPC screening as it applies to the risk assessment process. The figure highlights the role of COPC screening, including frequency of detection, risk-based screening, and comparison to background. The figure is not intended as a detailed flow chart of the risk assessment itself, but rather is intended to illustrate how the steps described in Sections 2.1 through 2.2.5 are integrated into the overall risk assessment and the processes that lead to risk management decisions.

2.3 Data Evaluation Summary

A table will be prepared for each medium at Acid Area 1 with the following information for each detected chemical:

- Chemical name,
- Frequency of detection,
- Range of detected concentrations,
- Range of detection limits,
- Arithmetic mean of site concentrations,
- 95th percent upper confidence limit (UCL) on the arithmetic mean (UCL_{95}),
- Appropriate RBSC,
- Appropriate BSC, and

- Selection/exclusion of chemical as a COPC.

3.0 EXPOSURE ASSESSMENT

Exposure is the contact by a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPCs found at or migrating from a site (EPA, 1989a). The following steps are included in an exposure assessment:

- Characterize the physical setting,
- Identify the contaminant sources, release mechanisms, and migration pathways,
- Identify the potentially exposed receptors,
- Identify the potential exposure pathways,
- Estimate EPCs, and
- Estimate chemical intakes or contact rates.

The BHHRA described in this work plan for the Acid Area 1 site will characterize potential exposures to COPCs in soil, groundwater, surface water and sediment associated with the site. Estimation of risk from potential exposure will be described in the BHHRA risk characterization for each medium. The Scope of Work (USACE, 2007) requires the summation of potential risks from all environmental media evaluated in the risk characterization. Therefore, the CSEM described in Section 3.1 includes all environmental media evaluated for Acid Area 1.

3.1 Conceptual Site Exposure Model

A CSEM provides the basis for identifying and evaluating the potential risks to human health in the BHHRA. A CSEM is constructed from plausible site-use scenarios and the potential exposure pathways. The elements of a CSEM include:

- Source,
- Source media (i.e., initially contaminated environmental media),
- Contaminant release mechanisms,
- Contaminant transport pathways,
- Intermediate or transport media,
- Exposure media,
- Plausible receptors, and
- Routes of exposure.

Contaminant release mechanisms and transport pathways are not relevant for direct receptor

contact with a contaminated source medium (e.g., ingestion of or dermal contact with groundwater).

Figure 3-1 depicts the CSEM used for Acid Area 1. The receptors and pathways on the figure reflect plausible scenarios developed from information regarding site background and history, topography, climate, and demographics as presented by the site-wide groundwater investigation (IT, 1997). Exposure pathways that are identified as complete on the CSEM will be addressed in the BHHRA, and additional potential receptors not listed on the CSEM figures are briefly discussed in Section 3.1.3.2 of this work plan.

No current or future exposures by off-site residents will be evaluated. The majority of the off-site residents are serviced by municipal water (from surface water sources), and there are numerous private groundwater wells in the vicinity, including eight within one mile of the facility boundary. Although natural hydrocarbons are known to be present within the bedrock limestone and shale formations, groundwater underlying the sites cannot be summarily excluded for consideration as a tap water source based on natural water quality parameters. Therefore, given the presence of numerous off-site wells and the assumption of unrestricted future land use on site, the development of groundwater for on-site residential (or on-site worker) use as tap water is regarded as plausible.

3.1.1 Physical Setting

The Acid Area 1 site physical features include an open field with three drainage features flowing east to west and one drainage feature flowing to the north. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. The remains of two old railroad grades with a few railroad ties and loose track are still present at the site. Three buildings remain at the site, two in the center of the site and one on the western edge of the site. A paved service road completes a loop around the perimeter of the site, with an additional service road oriented east-west through the center of the site. Acid Area 1 covers approximately 20 acres. The ground surface is relatively flat, with minimal slope toward the west. Elevations at the site range from 629 ft amsl at the lowest point in the drainage ditches to 640 ft amsl. The majority of the site consists of small grassy clearings, surrounded by low shrubs with occasional small trees. The areas outside of the site boundary consist of low growing shrubs with occasional clearings and occasional wooded areas.

Geology: Overburden thickness ranges from 20.25 to 26 ft, with thickness decreasing slightly toward the middle of the site. The overburden is characterized as clay or silty clay with a fairly continuous layer of silt and clayey silt near the surface. The top of this silt layer ranges in depth from four inches to five ft bgs and the bottom of the silt layer ranges from two to sixteen ft bgs. The thickness of the silt layer, where present, ranges from 1.5 to 12 ft with an average thickness of 4.7 ft. No silt was present at monitoring well AA1-BEDGW-003, near the center of the site, where silt thickness and depth tend to decrease. Thickness of silt near the center of the site averages 1.6 feet and total depth of the silt averages 2.9 ft bgs. The clay content of this silt layer varies with location and with depth and is generally marked by gradational changes downward from silt to clay. The lower 10 to 20 ft of the overburden is a highly plastic clay, with decreasing plasticity and increasing angular rock fragments near the bedrock interface.

The Plum Brook Shale subcrops beneath these unconsolidated deposits over the entire site. The thickness of this shale ranges from 12 ft to 20.25 ft, with thickness decreasing to the northwest. The Delaware Limestone and Columbus Limestone underlie the Plum Brook Shale. Average thickness of the limestone at the Acid Area 1 site is unknown, since borings extended no further than 31 ft below the top of the formation. Rock cores collected during the monitoring well installation showed few fractures, low porosity, and occasional zones with naturally occurring oil and hydrogen sulfide gas which are common in the Columbus Limestone (Shaw, 2004).

Surface Water: There are four drainage features at the Acid Area 1 site. The drainage ditch to the south is located approximately 40 ft south of the service road and drains to the west, parallel to the site, discharging into Ransom Brook west of the site. This drainage feature is a grass lined swale with little relief at the upgradient end, increasing in depth downgradient. At the southwest corner of the site, at sampling location SW-07, the depth of the ditch is approximately 7 ft and the width is approximately 15 ft. The drainage ditch at the north central portion of the site drains to the north. This drainage feature is approximately 30 to 40 ft wide and 11 ft deep just north of the Acid Area 1 site at sampling location SW-12. A third drainage ditch originates in a low swampy area in the west central portion of the site and drains to the west into Ransom Brook. This ditch has little relief at the upgradient end increasing in depth downgradient. Depth and width are approximately 6 ft and 15 ft respectively just beyond the site boundary at sampling location SW-04. The fourth drainage ditch, which originates at the ponded area at the northwest corner of the site, also drains west into Ransom Brook. The drainage feature is a grassy swale with approximately 1 to 2 feet of relief. Flowing water has been observed in all four drainage ditches during the wet season in early to mid Spring. All but the northern drainage ditch dry up by mid summer including the ponded area and the swampy area.

Groundwater: Groundwater at PBOW includes the shallow overburden and the bedrock aquifers. Numerous wells have been installed across the site to characterize these two water bearing units (Shaw, 2003). The shallow overburden generally has low yields over most of the site due to the high percentage of silt and clay. Water levels in the shallow overburden range from 2.5 to 5 ft bgs during the wet season and fluctuate up to 5 ft on a seasonal basis. Shallow water levels generally mirror the local topography and flow is typically toward the local surface drainage features with a general westerly trend. Groundwater elevations in the shallow overburden range from 634.1 ft amsl to 639.5 ft amsl during wet season and 630.1 ft amsl to 636.5 ft amsl during dry season.

Groundwater elevation contours for the deeper Delaware Limestone aquifer indicate a linear feature on a regional scale, running northeast-southwest through PBOW, in the vicinity of Acid Area 1, which acts as a preferential flow path (Shaw, 2003). This feature is parallel to the bedrock strike and may represent a fracture system and/or karst development. Groundwater elevations drop steeply toward this zone on either side. The Acid Area 1 site is located approximately 500 ft east of the axis of this feature; however bedrock groundwater data collected from the site indicate a northerly flow direction rather than westward.

Bedrock groundwater has been subdivided into two separate units at PBOW: 1) the Plum Brook Shale and Ohio Shale, and 2) the Delaware and Columbus Limestones. Water levels in the Plum Brook Shale and Ohio Shale closely match those of the shallow overburden suggesting good vertical communication between the two units. Water levels in the Delaware and

Columbus Limestones are on average 30 ft bgs. Water in the limestone typically occurs in fractures, along bedding planes, or in solutionally enlarged openings. The conceptual model indicates that bedrock groundwater flow in the Delaware and Columbus Limestones is dependant on the frequency, orientation, density, and connectivity of the fractures. Bedrock groundwater flow is generally to the north, however there are major fracture zones transecting the site, which influence groundwater flow in several areas (Shaw, 2003).

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways

Numerous buildings, process facilities, and storage tanks were constructed at Acid Area 1 to support the production of oleum, sulfuric acid, and nitric acid used in manufacturing TNT. Contamination involved the inadvertent release of contaminants and residues resulting from the burning of production waste (such as PAHs and dioxin/furan compounds). Releases occurred to the surface soil as spills and to the subsurface soil from infiltration/percolation of unburned waste or residues. Runoff and erosion may have spread contamination over the surrounding surface soil and may have carried contaminants to nearby streams. Infiltration and leaching may have carried contaminants into the subsurface soil and groundwater.

3.1.3 Receptors and Exposure Pathways

Receptors, selected to represent the upper bound on exposure from all plausibly exposed groups of people at Acid Area 1, and the pathways by which they may be exposed to chemicals are summarized in Figure 3-1 and Table 3-1. The exposure variable values used in the contaminant intake models for soil, surface water, and sediment are compiled in Table 3-2. The exposure variable values used in the contaminant intake models for groundwater are compiled in Table 3-3. The receptors to be evaluated in the Human Health Risk Assessment are:

- Current and future groundskeeper,
- Current and future construction worker,
- Future on-site resident,
- Future indoor worker, and
- Current and future hunter.

Most RAs are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989a, 1991a). It is interpreted as reflecting the 90 to 95th percentile on exposure. In keeping with EPA guidance (EPA, 1991a), variables chosen for a baseline RME scenario for ingestion rate (IR), exposure frequency (EF) and exposure duration (ED) are generally upper bounds. Other variables such as body weight (BW) and exposed skin surface area (SA), are generally central or average values. In the case of contact rates consisting of multiple components (e.g., dermal contact with soil or water, which consists of a dermal absorption factor [ABS] and soil-to-skin adherence factor [AF] for soil, and permeability coefficient [PC] and exposure time [ET] for water), only one variable, ABS or PC, needs to be an upper bound. The conservatism built into the individual variables ensures that

the entire estimate for contact rate is sufficiently conservative.

The averaging time (AT) for noncancer evaluation is computed as the product of ED (years) times 365 days per year (days/year), to estimate an average daily dose over the entire exposure period (EPA, 1989a). For cancer evaluation, AT is computed as the product of 70 years, the assumed human lifetime, times 365 days/year, to estimate an average daily dose prorated over a lifetime regardless of the frequency or duration of exposure. This methodology assumes that the risk from short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is generally consistent with the EPA policy of carcinogen evaluation, although it introduces considerable uncertainty into the cancer RA (EPA, 1986).

The chemical intake equations contain a fraction of intake (FI) parameter to account for scenarios in which exposure to a potentially contaminated medium associated with the site is less than the total daily exposure to that medium. For example, if the site of interest is small enough such that a groundskeeper may spend only one-half of his working time at the site, an FI of 0.5 is applied to the soil ingestion and dermal intake equations. An FI is used also if a receptor's exposure is split between two comparable media. For example, if a construction worker is exposed to both soil and sediment, FIs are introduced that apportion his exposure between the two media. The default value of FI is 1.

3.1.3.1 Overburden Groundwater

Shallow groundwater in the vicinity of Acid Area 1 is not regarded as a potential source of potable water because of the high clay content and limited, discontinuous permeable zones, resulting in low yields. It is possible that a construction worker may be exposed to shallow groundwater via direct contact; however, such exposure would likely be sporadic and of short duration. Therefore, the BHHRA will qualitatively evaluate exposure to perched groundwater.

3.1.3.2 Bedrock Groundwater

The following receptors will be evaluated to represent the upper bound on bedrock groundwater exposure for all plausibly exposed groups of people at Acid Area 1.

Current on-site: No current on-site exposure to bedrock groundwater exists.

Future on-site: The evaluation of future on-site exposure to bedrock groundwater will be based on measured concentrations at Acid Area 1 described in this work plan. Future receptors are an on-site worker and on-site resident.

If on-site groundwater were to be developed as a tap water source, other potential future groundwater receptors may include short-term (e.g., construction) workers or site visitors. However, the levels of exposure to these would be shorter in duration and/or frequency than that of an on-site worker or resident. Therefore, the on-site worker and residential receptors represent an upper bound on exposure for all potential receptors.

The potential exposure scenarios evaluated for Acid Area 1 groundwater will be the future on-site resident and the future on-site worker. Exposure assumptions and parameter values specific to the resident and worker are described in the paragraphs that follow. The fraction of

tap water intake/exposure attributed to groundwater from Acid Area 1 will be 1.0 for each receptor. Exposure parameters and parameter values are summarized in Table 3-3.

Resident: The resident will be assumed to be exposed to groundwater as household tap water and, for volatile compounds, to air concentrations that are associated with groundwater use in the residence. Cancer and noncancer assessments will be performed for both an adult and child. The evaluations will assume 30 years of exposure: 24 years as a 70-kilogram (kg) adult (EPA, 1991a) and 6 years as a 15-kg child (EPA, 2004a). For cancer effects, the adult and child effects will be summed together; for noncancer effects, the child and adult will be evaluated separately. An EF of 350 days per year will be used for adult and child residential pathways (EPA, 1991a).

Drinking water IRs for the adult of 2 liters per day (L/day) (EPA, 1991a) and for the child of 1 L/day will be assumed (EPA, 2004a). Both the child and adult resident are assumed to be dermally exposed to COPCs in groundwater while bathing/showering. The child will be assumed to bathe for 20 minutes per day (0.333 hour/day) (EPA, 1997a). The adult will be assumed to shower for 35 minutes per day (0.6 hour/day) (EPA, 2003a). Inhalation rates of 0.833 cubic meters (m^3) per hour for the adult (EPA, 1991a) and 0.416 m^3/hour for the child (EPA, 2004a) will be used. Because the *Exposure Factors Handbook* lists a 90th percentile for time spent in a residence as over 23 hours per day, it will be conservatively assumed that the resident spends 24 hours per day in the house (EPA, 1997a).

On-Site Worker: Under the future land-use scenario, a site worker may be exposed to groundwater, which theoretically could be developed as a source of drinking water. His drinking water IR will be assumed to be 1 liter (L) per day (EPA, 1991a). He may also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it will be assumed that the head, forearms, and hands, approximately 3,300 square centimeters (cm^2), would be exposed intermittently for up to 1 hour per day (EPA, 2004a). Because exposure is assumed to be intermittent rather than continuous, organic chemical uptake across the dermis would not reach steady state, which guides selection of the EPA model to be used to quantify this pathway (Section 3.3.3) (EPA, 2004a).

3.1.3.3 Surface Soil

The following receptors will be evaluated to represent the upper bound on surface soil exposure for all plausibly exposed groups of people at Acid Area 1.

Current on-site: Potential current on-site receptors are construction workers, groundskeepers, and hunters. The evaluation of current on-site exposure to surface soil will be based on current measured concentrations.

Future on-site: Potential future receptors are construction workers, on-site indoor workers, on-site residents, groundskeepers, and hunters. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-2.

Groundskeeper: Under the current and future land-use scenarios, a groundskeeper may be exposed to surface soil. The groundskeeper scenario is designed to evaluate the upper bound for site worker exposure to surface soil in the current and future site-use scenario. Direct

exposure pathways include incidental ingestion and dermal contact. Inhalation of dust raised by operating lawn mowers or other equipment is also evaluated because relatively high dust concentrations may be produced within the groundskeeper's breathing zone, with little opportunity for dilution by ambient air. The groundskeeper will be assumed to be a 70-kg adult who works eight hours per day (hours/day), approximately five days per week (days/week) year-round on site for a total of 250 days/year for 25 years (EPA, 1991a). The respiratory rate for the groundskeeper will be assumed to be 20 m^3/8-hour workday (2.5 m^3 per hour [m^3/hour]), and the soil incidental IR will be assumed to be 100 milligrams (mg) per day, which is comparable to that for an agricultural worker.

Recent studies evaluating soil adherence that consider the nature of the activity performed and the different body regions were reviewed by EPA (EPA, 1997a). Measurements of soil adherence to hands, arms, legs, feet, and face for 29 groundskeepers revealed AFs ranging from 8E-4 mg per cm^2 (legs) to 1.5E-1 mg/cm^2 (hands). The AF weight averaged across these body regions (i.e., adjusted to reflect the different SAs of the different body regions) for males and females is 9E-3 mg/cm^2. The SA of body regions evaluated for groundskeepers is approximately 11,300 cm^2 (EPA, 1997a).

Because infiltration and dissipation over time reduce VOC concentrations at the surface (i.e., the first few centimeters) from which volatilization would occur, VOC-contaminated surface soil that has remained for extended periods is not a significant source of airborne VOCs. The surface soil data set might indicate the presence of VOCs, although volatilization to the air is likely to be insignificant. Therefore, a surface-soil-to-air volatilization model will not be used in addition to the activity-based dust emissions model to estimate airborne concentrations of VOCs. Instead, the airborne concentrations estimated by the dust emissions model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust emissions model treats the VOCs as if they were located at the surface. It will be assumed that VOC emissions from subsurface soil would be attenuated by the overlying soil, so that concentrations in ambient air would not be toxicologically significant.

Hunter: Under the current and future land-use scenarios, a hunter may be exposed to surface soil. The hunter will be assumed to be a 70-kg adult nearby resident (ED of 30 years) (EPA, 1991a). Small children would be unlikely to accompany the hunter afield. Therefore, the direct exposure pathways evaluated for the hunter (incidental ingestion and dermal contact with soil) will not be evaluated for the small child. It will be assumed that he spends his entire 2-week vacation hunting on PBOW; i.e., his EF for incidental soil ingestion and dermal contact is 14 days/year. His incidental soil IR will be assumed to be 100 mg/day (EPA, 1991a). It will be assumed that approximately 25 percent of his body SA, or 4,550 cm^2, is available for exposure to soil (EPA, 1992b). A soil AF of 0.2 mg/cm^2 will be assumed. Inhalation of airborne dust is a potential exposure pathway, however, vegetation reduces dust emissions to insignificant levels, and it will be assumed that the hunter would spend virtually all of his time on vegetated rather than bare soil. Therefore, it will be assumed that inhalation exposure would contribute much less than incidental ingestion and the inhalation exposure pathway will not be evaluated.

Future On-Site Resident: The future on-site resident will be assumed to be exposed to surface soil. The on-site residential scenario will be evaluated using both an adult and a child. Cancer risk will be estimated as the sum of the risks calculated for the adult and the child. Only

the child will be used for the noncancer evaluation. This approach captures the greater conservatism of the larger incidental soil IRs and inhalation rate for the child when expressed on a BW basis.

The adult resident will be assumed to be a 70-kg person with an incidental soil IR of 100 mg/day and an inhalation rate of 20 m^3/day (0.83 m^3/hour) (EPA, 1991a). Approximately 25 percent of his body SA, or 4,500 cm^2, will be assumed as available for exposure to soil (EPA, 1992b). The adult resident will be assumed to be exposed 350 days/year for 24 years (EPA, 2000).

The child resident will be assumed to be a one through six year-old with an average BW of 15 kg, a soil IR of 200 mg/day, and an inhalation rate of 10 m^3/day (EPA, 2000). Approximately 25 percent of his body SA, or 1,750 cm^2, will be assumed to be available for exposure to soil (EPA, 1992b). The child resident will be assumed to be exposed for 350 days/year for six years (EPA, 1991a and 2000). An average soil AF of 0.2 mg/cm^2 will be adopted for the on-site resident (EPA, 1992b).

Evaluation of exposure to VOCs from soil by the future on-site resident will be addressed during evaluation of airborne dust as described for the groundskeeper, above. It will be assumed that 80 percent of the soil surface is covered with pavement or vegetation for evaluating inhalation to airborne dust. Inhalation of VOCs released from soil and entrapped in indoor air will also be evaluated. Inhalation rates of 20 m^3/day for the adult (EPA, 1991a) and 10 m^3/day for the child (EPA, 1999) will be used.

Future On-Site Indoor Worker: Under the future land-use scenario, an on-site worker may be exposed to surface soil. This receptor scenario will evaluate exposure to indoor airborne VOCs entrapped in a building. VOCs released from subsurface soil may enter a building through joints or cracks in the foundation or slab. The indoor worker would also be potentially exposed to surface soil via incidental ingestion. Dermal exposure to surface soil and inhalation of airborne dust and VOCs from surface soil, although plausible, would be expected to be less significant than incidental ingestion because he would spend his work time indoors. Therefore, dermal contact and inhalation of dust and airborne VOCs from surface soil will not be quantified. Exposure to VOCs in ambient (outdoor) air from volatilization from subsurface soil will not be quantified for the reasons given under the discussion of the groundskeeper scenario, above.

The indoor worker will be assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week year-round on the site for a total of 250 days/year for 25 years (EPA, 1991a). His soil incidental IR is assumed to be 50 mg/day, and his inhalation rate will be assumed to be 20 m^3/8-hour workday.

Construction Worker: Under the current and future land-use scenarios, a construction worker may be exposed to surface soil. The construction worker scenario will evaluate short-term exposure to surface and subsurface soil in either the current or future site-use scenario. Construction projects are expected to be infrequent and of short duration. It will be assumed that the construction worker participates in only one construction project on the site. Relevant exposure pathways include incidental ingestion and dermal contact, inhalation of dust raised by operating construction equipment, and inhalation of airborne VOCs released from subsurface soil during excavation and grading.

The construction worker will be assumed to be a 70-kg adult who works 8 hours/day, approximately five days/week for six months. Potential exposure pathways are incidental ingestion and dermal contact, inhalation of dust raised by operating construction equipment, and inhalation of airborne VOCs released from subsurface soil during excavation and grading. Excavation and soil grading activities, which result in intensive soil contact, are assumed to last for three months; for the remaining three months, construction activities are assumed to result in less intensive soil contact. Soil IRs of 480 mg/day and 100 mg/day, similar to an agricultural worker, are assumed for the intensive and less intensive contact periods, respectively (EPA, 1991a). The resulting time-weighted average soil IR will be 290 mg/day.

Construction workers would also experience dermal contact with soil adhered as dust or from direct contact with the soil. An AF for soil for the construction worker of 8E-2 mg/cm^2 will be estimated as previously described for the groundskeeper, combining EPA data for construction workers, utility workers, and equipment operators to capture the full range of activities likely to be performed by this receptor (EPA, 1997a). The body regions evaluated for construction workers total approximately 11,300 cm^2. An inhalation rate of 20 m^3/day for potential exposures to VOCs and air borne dust will be assumed (EPA, 1991a).

3.1.3.4 Subsurface Soil

The following receptors will be evaluated to represent the upper bound on surface soil exposure for all plausibly exposed groups of people at Acid Area 1.

Current on-site: The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to subsurface soil will be based on current measured concentrations.

Future on-site: Potential future receptors are construction workers and on-site residents. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-2.

Groundskeeper: Under the current and future land-use scenarios, contact with subsurface soil would be infrequent and sporadic, since such contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to subsurface soil will not be evaluated.

Future On-Site Resident: Exposure parameters for the future on-site resident are identical to those described above for surface soil (Section 3.1.3.3). Future on-site residents are assumed to be exposed to subsurface soil as a result of residential development that would involve excavation and grading, which would bring subsurface soil to the surface.

Future On-Site Indoor Worker: Under the future land-use scenario, an on-site worker may be exposed to indoor airborne VOCs entrapped in a building. VOCs released from subsurface soil may enter a building through joints or cracks in the foundation or slab. The exposure parameters for the on-site indoor worker are the same as described above for surface soil (Section 3.1.3.3).

Construction Worker: Under the current and future land-use scenarios, a construction worker may be exposed to subsurface soil. Exposure parameters for the construction worker are

identical to those described above for surface soil (Section 3.1.3.3).

3.1.3.5 Surface Water

The following receptors will be evaluated to represent the upper bound on surface water exposure for all plausibly exposed groups of people at Acid Area 1. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-2. There are four drainage features at the Acid Area 1 site. The drainage ditch to the south is located approximately 40 ft south of the service road and drains to the west, parallel to the site, discharging into Ransom Brook west of the site. The drainage ditch at the north central portion of the site drains to the north. A third drainage ditch originates in a low swampy area in the west central portion of the site and drains to the west into Ransom Brook. The fourth drainage ditch, which originates at the ponded area at the northwest corner of the site, also drains west into Ransom Brook. Potential exposure to surface water in each of these drainages will be evaluated individually using only the data from samples collected within the specific drainage.

Current on-site. The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to surface water will be based on current measured concentrations.

Future on-site. Potential future receptors are construction workers and on-site residents. The evaluation of future on-site exposure to surface water will be based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, a groundskeeper may be exposed to surface water. However, such exposure would be infrequent and sporadic, since such contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to surface water will not be quantified.

Hunters. Under the current and future land-use scenarios, a hunter may be exposed to surface water. However, such exposure would be infrequent and sporadic, since such contact would not be part of the hunter's regular or activities. Therefore, exposure to surface water will not be quantified.

Future On-Site Resident. The future on-site resident will be assumed to be exposed to surface water. The resident could have access to the surface water bodies associated with Acid Area 1. It will be assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident will be assumed to wade for 3 hours/day on 52 days/year. The exposure pathway evaluated will be dermal contact with surface water. Approximately 30 percent of the adult's and child's total body SAs, 5,450 cm^2 and 2,100 cm^2, respectively, will be assumed to be available for exposure to surface water. The dermal absorbed dose will be calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a). Incidental ingestion of surface water in a wading scenario will be considered to be less significant than dermal contact and will not be quantified. Inhalation of VOC emissions from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations

such that this pathway would be less significant than dermal contact, which will be quantified. For these reasons, inhalation of VOC emissions from surface water will not be quantified.

On-Site Indoor Worker. Under the future land-use scenario, an on-site indoor worker would not be expected to be exposed to surface water. Therefore, exposure to surface water will not be quantified.

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to surface water during projects such as installation of underground utilities or rerouting stream flow. Dermal contact would be the most significant pathway for exposure to surface water. Incidental ingestion of surface water would also be possible, but would be expected to be much less significant than dermal contact. Dermal exposure to surface water will be assumed to occur for 4 hours/day, or one-half the normal workday. It will be assumed that the arms, forearms and hands (an SA of approximately 3,100 cm^2 [EPA, 1997a]) would be exposed to surface water. Dermal absorbed dose will be calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a). Inhalation of VOCs from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations, so that this pathway would be less significant than dermal contact, which was quantified. For these reasons incidental ingestion and inhalation of VOCs from surface water will not be quantified.

3.1.3.6 Sediment

The following receptors will be evaluated to represent the upper bound on sediment exposure for all plausibly exposed groups of people at Acid Area 1. As with surface water, potential exposure to sediment from the four drainages will be evaluated individually using only the data from samples collected within the specific drainage.

Current on-site: The only potential current on-site receptors are construction workers. The evaluation of current on-site exposure to sediment will be based on current measured concentrations.

Future on-site: Potential future receptors are construction workers and on-site residents. Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-2.

Groundskeeper: Under the current and future land-use scenarios, a groundskeeper may be exposed to sediment. However, such exposure would be infrequent and sporadic, since such contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to sediment will not be quantified.

Hunters: Under the current and future land-use scenarios, a hunter may be exposed to sediment. However, such exposure would be infrequent and sporadic, since such contact would not be part of the hunter's regular or activities. Therefore, exposure to sediment will not be quantified.

Future On-Site Resident: The future on-site resident will be assumed to be exposed to sediment. The resident could have access to the sediment bodies associated with Acid Area 1

and could be exposed to sediment. It will be assumed that the resident would visit the streams for eight hours/day, two days/week during the warmer half of the year. The resident will be assumed to wade for 3 hours/day on 52 days/year. The exposure pathway to be evaluated is dermal contact with sediment. The mechanisms of exposure to soil and sediment are likely to be similar; therefore, the incidental soil IR of 100 mg/day will be also applied to sediment. Approximately 25 percent of the adults and child's total body SAs, 4,500 cm^2 and 1,750 cm^2, respectively, will be used.

On-Site Indoor Worker: Under the future land-use scenario, an on-site indoor worker would not be expected to be exposed to sediment. Therefore, exposure to sediment will not be quantified.

Construction Worker: Under the current and future land-use scenarios, a construction worker may be exposed to sediment during projects such as installation of underground utilities or rerouting stream flow. Dermal contact is the most significant pathway for exposure to sediment. Incidental ingestion of sediment is also possible, but would be expected to be much less significant than dermal contact. Dermal exposure to sediment will be assumed to occur for four hours/day, or one-half the normal work day. It will be assumed that the arms, forearms and hands, an SA of approximately 3,100 cm^2, are exposed to sediment (EPA, 1997a). Inhalation of VOCs from sediment would also be possible; but the large volume of outdoor air and natural air currents would be expected to dilute airborne concentrations, so that this pathway would be less significant than dermal contact, which is quantified. For these reasons incidental ingestion and inhalation of VOCs from sediment will not be quantified.

3.1.3.7 Game Animals

The following receptors will be evaluated to represent the upper bound on exposure via ingestion of game animals taken at Acid Area 1.

Current and future on-site: The potential current and future on-site receptors are hunters. The evaluation of current on-site exposure to game animals will be based on current measured concentrations.

Exposure assumptions and parameter values specific to the potential current and future receptors are described in the paragraphs that follow. Exposure parameters and parameter values are summarized in Table 3-2.

Hunters: This scenario will be developed to evaluate the potential for contaminants in soil to affect food-chain pathways. The Acid Area 1 site provides habitat for deer and other wildlife, and deer hunting is permitted on the PBOW facility. Therefore, a hunter who consumes his game is a plausible scenario requiring evaluation. Many kinds of game animals may be hunted and consumed (e g., squirrel, pheasant and other upland birds, turkey, deer); however, the deer is the species most likely to contribute meaningfully to the diet. Therefore, the evaluation will be limited to a deer hunter.

Data were not located regarding the rate of venison ingestion; therefore, a hypothetical scenario is adapted from the assumptions applied to a similar site in West Virginia (IT, 2000). A highly conservative but plausible scenario consists of a hunter who kills a deer each year. It will be assumed that the hunter eats 10 pounds (4.5 kg) of venison per year (Sharp, 1995). This

consumption rate corresponds to 0.013 kg/day (0.186 grams (g) per kg of body weight per day [g/kg-day]) of venison for each of the 350 days per year that the hunter spends at home (EPA, 1991a).

It is likely that the successful hunter would share his venison with the rest of the family, which may include small children. The hunter's child is referred to as a child venison consumer for the purposes of this evaluation. Data regarding the rate of venison ingestion by small children were not located. However, if it will be assumed that venison may replace beef in the diet, the differences in beef consumption between adults and children can be used to estimate a venison IR for children. EPA provides per capita beef intake data for less than one- to five-year-old children ranging from 0.941 to 1.46 g/kg-day (time-weighted average of 1.296 g/kg-day) (EPA, 1997a). EPA provides per capita beef intake data for 12- to 70+-year-old adults ranging from 0.568 to 0.83 g/kg-day (time-weighted average of 0.727 g/kg-day) (EPA, 1997a). From these data, it can be estimated that the beef consumption of small children, expressed on a BW basis, is approximately 1.8 times that of an adult. Therefore, a venison IR of 0.335 g/kg-day will be estimated for the young child from the venison IR of 0.186 g/kg-day for the adult. Assuming that the child is zero to six years old with an average BW of 15 kg, the child venison IR may be expressed as 0.005 kg/day (EPA, 2000).

3.2 Quantification of Exposure-Point Concentrations

The EPC is a conservative estimate of the average concentration of a COPC, which is statistically calculated from the analytical results of all samples for a particular environmental medium to which a receptor may be exposed over the duration of the exposure. An EPC may be based on media concentrations that have been directly measured or it may be derived based on environmental medium-to-medium transport modeling. The EPCs of COPCs in soil, groundwater, and sediment will be statistically derived values based on measured analytical data. Concentrations of COPCs in air will not be measured (and in the case of groundwater volatilization or future exposure scenarios, cannot reasonably be measured), but will be based on models, which use the EPCs of COPCs in groundwater as input values.

Exposure to an environmental medium is generally assumed to be random, and the EPC should be the arithmetic average encountered over the ED (EPA, 1989a). Therefore, the population mean concentration, if known, would be the ideal value selected as the EPC. The sample mean is an obvious estimate of the population mean. However, because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the UCL on the mean are usually estimated for each COPC in each medium of interest. Therefore, EPA (EPA, 1989a) has recommended the inclusion of the 95 percent upper confidence limit on the sample mean for RME evaluation.

The 95 percent upper confidence limit on the arithmetic mean is referred to as the UCL_{95}. In general, unusually high values are included in the calculation of the UCL_{95} because high values seldom appear as statistical outliers in environmental data. A general discussion of the statistical approaches used to derive EPCs is presented in the following paragraphs. EPA's ProUCL Version 4 software will be used to derive EPCs for all COPCs (EPA, 2007a and 2007b).

The nature of the statistical distribution (normal, lognormal, nonparametric) is determined for COPC data sets having five or more samples with the Shapiro-Wilks test (EPA, 1992d). Either

a normal or lognormal UCL is calculated; whichever provides the better fit in the Shapiro-Wilks test. Where either distribution provides virtually the same level of fit (at $p<0.05$) based on the Shapiro-Wilks test results, a normal distribution is selected because the UCL calculation for the normal distribution has greater mathematical stability (EPA, 1997b; Hardin and Gilbert, 1993).

A nonparametric confidence limit is calculated when the data fit neither a normal nor lognormal distribution. For data sets with less than five samples, the MDC is used as the EPC.

The concentration corresponding to the calculated rank order UCL is used as the EPC for nonparametric data, unless this value is less than the mean concentration. It is theoretically possible using the lognormal and nonparametric methods that the UCL for a given COPC may be less than the arithmetic mean concentration. If such an instance were to occur, the arithmetic mean concentration would be used as the EPC and the COPC data would be specifically discussed in the uncertainty analysis (Section 6.0) of the BHHRA report as appropriate.

Analytical results are presented as "nondetects" ("U" qualifier) whenever chemical concentrations in samples do not exceed the reporting limits. To apply statistical procedures to a data set with nondetects, a concentration value must be assigned to nondetects. Nondetects are assumed to be present at one-half the reporting limit, although judgment is used in those cases where matrix interference or other effects drive the reporting limits unusually high (EPA, 1989a). If any nondetects are eliminated from the data set due to high reporting limits that would otherwise skew the EPC, these samples will be discussed in the uncertainty analysis (Section 6.0) of the BHHRA report.

Data sets consisting of five or more data points are tested for normality and lognormality with the Shapiro-Wilk test as described above. Statistical analysis is performed only on those chemicals identified as background or site-related COPCs. The UCL_{95} is calculated for a normal distribution as follows (EPA, 1992a):

$$UCL_{95} = \bar{x} + t_{1-a,n-1}\left(\frac{s}{\sqrt{n}}\right) \qquad \textbf{Eq. 3.1}$$

where:

UCL_{95} = upper 95th confidence limit on the arithmetic mean concentration (calculated)

$\bar{x}$ = sample arithmetic mean

t_1 = critical value for Student's *t*-test

α= 0.05 (95 percent confidence limit for a one-tailed test)

n = number of samples in the data set

s = sample standard deviation.

The UCL_{95} will be calculated for a lognormal distribution as follows (Gilbert, 1987):

$$UCL_{95} = e^{\left(\bar{Y}+0.5s_y^2+\left[H_{0.95}\frac{s_y}{(n-1)^{0.5}}\right]\right)}$$ **Eq. 3.2**

where:

UCL_{95} = 95 percent upper confidence limit on the arithmetic mean (calculated)

$\bar{Y}$ = Σy/n = sample arithmetic mean of the log-transformed data

s_y = ln x = sample standard deviation of the log-transformed data

n = number of samples in the data set

$H_{0.95}$ = value for computing the one-sided upper 95 percent confidence limit on a lognormal mean from standard statistical tables.

If the data distribution is nonparametric, the data point selected as the nonparametric UCL will be estimated as the 95 percent UCL rank order on the arithmetic mean of the data set. It will be estimated by ranking the data observations from smallest to largest. The arithmetic mean will be converted to a percentile by interpolation. The rank order of the data point selected as the UCL will be estimated from the following equation (Gilbert, 1987):

$$u = p(n+1) + Z_{1-\alpha}\sqrt{np(1-p)}$$ **Eq. 3.3**

where:

u = rank order of value selected as UCL, calculated

p = percentile corresponding to the arithmetic mean

n = number of samples in the data set

α= confidence limit (95 percent)

$Z_{1-\alpha}$ = normal deviate variable.

Analytical data from field duplicates will be averaged with originals to yield one result for use in the statistical manipulations.

Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. Analytical results are presented as nondetects ("U" qualifier) whenever chemical concentrations in samples do not exceed the detection limits for the analytical procedures for those samples. To apply the statistical procedures described above, a concentration value must be assigned to nondetects. Generally, nondetects are assumed to be present at one-half the detection limit (EPA, 1989a). However, judgment is used in those cases where the detection limit is unusually high. For example, elevated detection limits that exceed the MDC due to matrix interference or sample

dilution may be eliminated from the data set and not used in the estimation of the source term concentration (STC).

The UCL or MDC, whichever is smaller, is selected as the STC, and is understood to represent a conservative estimate of average for use in the RA or in various transport models used to estimate EPCs. If the data set consists of fewer than 5 data points, the MDC will be selected as the STC. The impact of eliminated data points on the adequacy of the data sets and the risk estimates will be discussed in the uncertainty analysis (Section 6.0) of the BHHRA report.

3.2.1 COPC Concentrations from Dust

Inhalation exposure to particulate (dust) emissions from soils for the groundskeeper and construction worker evaluations results from activities that raise dust. Therefore, the most appropriate approach to estimating chemical concentrations in ambient air is through the use of an activity-based dust loading equation (U.S. Department of Energy [DOE], 1989):

$$C_a = (D)(C_{so})(CF_1) \qquad \textbf{Eq. 3.4}$$

where:

C_a=contaminant concentration in air (mg/m^3, calculated)

D = dust loading factor (g of soil/m^3 of air)

C_{so} = contaminant concentration in soil (mg/kg)

CF_1 = conversion factor (1E-3 kg/g).

Plausible values for D include 2E-4 g/m^3 for agricultural activity (DOE, 1989), 6E-4 g/m^3 for construction work (DOE, 1983), and 1E-4 g/m^3 for other activity (National Council on Radiation Protection and Measurements [NCRPM], 1984). The value for D of 1E-4 g/m^3 for other activity will be used for the groundskeeper. It will be assumed that construction activities requiring intimate contact with soil, for which D = 6E-4 g/m^3 is appropriate, may last for one-half of a construction period. The remaining one-half of the time is more realistically characterized by D = 1E-4 g/m^3. Therefore, a time-weighted average dust loading factor for construction work of 3.5E-4 g/m^3 will be estimated for the construction worker.

Airborne concentrations of VOCs estimated by the dust loading model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust loading model treats the VOCs as if they were located at the ground surface.

The resident would be more likely to be exposed to dust arising from wind erosion than from dust-raising activities on the site. EPA derived a model for estimating a dust particulate emission factor based on an "unlimited reservoir" model and the assumption that the source area is square (EPA, 1996):

$$PEF = Q/C \times \frac{3600}{0.036 \times (1-V) \times \left(U_m / U_t\right)^3 \times F(x)}$$ **Eq. 3.5**

where:

PEF = particulate emission factor (m^3/kg, calculated)

Q/C = inverse of the mean concentration at center of square source (43.08 g/m^3second per kg/m^3, site-specific value from Table 3 in [EPA, 1996] [Zone 7, Cleveland, 30-acre site])

3600 = seconds/hour

V = fraction of surface covered with vegetation (0.8, unitless, assumed)

U_m = mean annual wind speed (default, 4.69 meters (m) per second)

U_t = equivalent threshold value of wind speed at 7 m (default, 11.32 m/second)

F(x) = function dependent on U_m/U_t (default, 0.194).

The concentration of COPC in air is calculated as follows:

$$C_a = \frac{C_{so}}{PEF}$$ **Eq. 3.6**

where:

C_a = contaminant concentration in air (mg/m^3, calculated)

C_{so} = contaminant concentration in soil (mg/kg)

PEF = particulate emission factor (m^3/kg).

Airborne concentrations of VOCs estimated by the wind erosion model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the wind erosion model treats the VOCs as if they were located at the ground surface.

3.2.2 COPC Concentrations in Indoor Air

An EPA modification of the Johnson and Ettinger model is used to estimate airborne concentrations of VOCs in indoor air from subsurface soil for the indoor worker and resident (EPA, 1997b).

Estimating indoor airborne concentrations from subsurface soil can be considered to consist of three separate steps:

- Estimating VOC concentration in soil gas at source of contamination (C_{source}).
- Estimating an attenuation coefficient that captures the decline in VOC concentration between soil gas at the source and indoor air (α).
- Combining C_{source} and α to estimate VOC concentration in indoor air in the building ($C_{building}$).

An "infinite source" assumption will be selected to maintain consistency with the EPA methodology for PEF, and to impart a conservative bias to the evaluation (EPA, 1996). It will be assumed that both the source of VOC contamination in subsurface soil and the foundation of the building are located above the groundwater saturation zone. It will also be assumed that VOC contamination in soil does not exist in a nonaqueous phase. Because of the strongly conservative bias imparted by the infinite source assumption, average values will be selected for model variables, where possible, if site-specific data are not available. Default values will be taken preferably from *Soil Screening Guidance: Technical Background Document* to maintain consistency with the other models described in Section 3.2.1 (EPA, 1996).

The first step in estimating indoor air concentrations is to relate the concentration of VOC in soil gas at the source of contamination to the concentration of VOC in soil, as follows:

$$C_{source} = \frac{(H')(C_{so})(\rho_b)(CF_2)}{\theta_w + (K_d)(\rho_b) + (H')(\theta_a)} \qquad \textbf{Eq. 3.7}$$

where:

C_{source} = VOC concentration in soil gas at source of contamination (g/cubic centimeter (cm^3), calculated)

H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H·x 41 [EPA, 1996])

H = Henry's law constant (atmosphere-m^3/mole, chemical-specific)

C_{so} = contaminant concentration in soil (mg/kg)

ρ_b = dry soil bulk density (1.5 g/cm^3, default [EPA, 1996], or site-specific)

CF_2 = conversion factor (10^{-6} kg/mg)

θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific)

K_d = soil-water partition coefficient (cm^3/g, chemical-specific, may be estimated as K_{oc} f_{oc})

K_{oc}=soil organic carbon-water partition coefficient (cm^3/g, chemical-specific)

f_{oc} = organic carbon content of soil (0.006 g/g, default [EPA, 1996], or site-specific)

θ_a = air-filled soil porosity (0.28 unitless, default [EPA, 1996], or site-specific estimated as n-θ_w)

n = total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as 1-[ρ_b / ρ_s]).

The next step in calculating indoor air concentrations is the estimation of an attenuation coefficient that reflects factors that reduce concentration in air between the source and the interior of the building. Because of the many factors involved, it is helpful to break this step into several smaller segments.

Diffusion is probably the most important process involved in the transport of VOC vapors from source to building. The EPA modification of the Johnson and Ettinger model provides for multiple layers; i.e., different soil types, each of which would have its own physical properties that affect diffusion, between the contaminant source and the foundation of the building (EPA, 2004d). For the purposes of this evaluation, it will be simplistically assumed that only one soil type – the predominant soil type in the area – intervenes between the source and building foundation. The equation for effective diffusivity through the soil between the source and the building foundation is given as:

$$D^{eff} = D_a\left(\theta_a^{3.33} / n^2\right) + \left(D_w / H'\right)\left(\theta_w^{3.33} / n^2\right) \qquad \textbf{Eq. 3.8}$$

where:

D^{eff} = effective diffusion coefficient across soil (cm^2/second, calculated)

D_a = diffusivity in air (cm^2/second, chemical specific)

θ_a = air-filled soil porosity (0.28 unitless, default [EPA, 1996], or site-specific estimated as $n - \theta_w$)

n = total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as 1-[ρ_b / ρ_s])

D_w = diffusivity in water (cm^2/second, chemical specific)

H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H x 41 [EPA, 1996])

H = Henry's law constant (atmosphere-m^3/mole, chemical-specific)

θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific).

The equation for the attenuation coefficient is given as:

$$\alpha = \frac{\left(\left(\frac{D^{eff} A_B}{Q_{Building} L_T}\right) \times \exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right)}{\left(\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) + \left(\frac{D^{eff} A_B}{Q_{building} L_T}\right) + \left(\frac{D^{eff} A_B}{Q_{soil} L_T}\right)\left(\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right)\right)} \quad \textbf{Eq. 3.9}$$

where:

α = attenuation coefficient (unitless, calculated)

D^{eff} = effective diffusion coefficient across soil (cm^2/second)

A_B = area of enclosed space below grade (1.51E+6 cm^2, see below)

$Q_{building}$ = building ventilation rate (4.61E+4 cm^2/second, see below)

L_T = distance from source to building (site-specific)

Q_{soil} = flow rate of soil gas into enclosed space (cm^2/second, see below)

L_{crack} = foundation or slab thickness (15 centimeters (cm), default [EPA, 2004d])

D^{crack} = effective diffusion coefficient through cracks (cm^2/second, assumed to be equivalent to D^{eff} [EPA, 2004d])

A_{crack} = area of total cracks (492 cm^2, see below).

The building characteristics were obtained from EPA, which reviewed several studies of the volumes of houses and recommends 369 m^3 as a central estimate of the volume of a house (EPA, 2004d). Assuming the house has 8 ft (2.44 m) ceilings and exists on one level, an area of 151.3 square meters (m^2), equivalent to 1.51E+6 cm^2, can be estimated as an upper bound on the area below grade.

An average building ventilation rate of 3,984 m^3/day was estimated for a home, which is equivalent to 4.61E+4 cm^3/second (EPA, 2004d).

EPA assumes that the only crack available for the entry of soil gas is a 0.1-cm wide gap at the interface of the floor and foundation (EPA, 2004d). As noted above, it is assumed that the area of the basement floor is 151.3 m^2. Assuming that the house is square, the length of one side would be 12.3 m, and the total length of the wall would be 49.2 m (4,920 cm). Therefore, the area of the crack would be 492 cm^2.

The equation for the flow rate of soil gas into enclosed space is:

$$Q_{soil} = \frac{2\pi \Delta P k_v X_{crack}}{\mu \ln\left(2 \, Z_{crack} / r_{crack}\right)} \qquad \textbf{Eq. 3.10}$$

where:

Q_{soil} = flow rate of soil gas into enclosed space (cm^2/second, calculated)

ΔP = pressure differential between soil surface and enclosed space (20 g/cm $second^2$)

k_v = soil vapor permeability (cm^2, see below)

X_{crack} = floor-wall seam perimeter (4,920 cm, see above)

μ = viscosity of air (1.83E+5 g/cm-second [EPA, 1992e])

Z_{crack} = crack depth below grade (108 cm, see below)

r_{crack} = equivalent crack radius (0.1 cm, see below).

Data were not located from which to estimate the crack depth below grade. Presumably, however, houses or other buildings may be built on slabs or on full foundations. EPA provides default depths of 15 cm for buildings on slabs and 200 centimeters for buildings on foundations (EPA, 2004d). The average, 108 cm, will be used for this evaluation.

Equation 3.7 assumes that vapor transport occurs solely by pressure-driven air flow to an idealized cylinder buried some distance (Z_{crack}) below grade. The length of the cylinder is assumed to be equal to X_{crack}. Therefore, the equivalent crack radius can be estimated as follows:

$$r_{crack} = \eta \left(\frac{A_B}{X_{crack}} \right) \qquad \textbf{Eq. 3.11}$$

where:

r_{crack} = equivalent crack radius (cm, calculated)

$\eta = A_{crack} / A_B$

A_{crack}= area of total cracks (492 cm^2, see above)

A_B = area of enclosed space below grade (1.51E+6 cm^2, see above)

X_{crack} = floor-wall seam perimeter (4,920 cm, see above).

From the foregoing, a value of 0.1 cm is estimated for r_{crack}.

Soil vapor permeability is a very sensitive parameter associated with convective transport of vapors within the zone of influence of a building (EPA, 2004d). It can be estimated as the product of soil intrinsic permeability and the relative air permeability at the estimated water-filled soil porosity (θ_w). Soil intrinsic permeability is estimated as follows:

$$k_i = \frac{K_s \mu_w}{\rho_w g} \qquad \textbf{Eq. 3.12}$$

where:

k_i = soil intrinsic permeability (cm^2, calculated)

K_s = soil saturation hydraulic conductivity (cm/second, see below)

μ_w = dynamic viscosity of water (0.01307 g/cm-second [EPA, 2004d])

ρ_w = density of water (0.999 g/cm^2, [EPA, 2004d])

g = acceleration due to gravity (980.665 cm/second^2 [EPA, 2004d]).

Soil saturation hydraulic conductivity is related to soil texture. Site-specific data will be used in conjunction with Table 4 of (EPA, 2004d) to estimate an approximate value for K_s.

Relative air permeability is estimated as follows:

$$k_{rg} = (1 - S_{te})^{0.5} \left(1 - S_{te}^{1/M}\right)^{2M} \qquad \textbf{Eq. 3.13}$$

where:

k_{rg} = relative air permeability (positive unitless value, calculated)

S_{te} = effective total fluid saturation (unitless, see below)

M = van Genuchten shape parameter (unitless, see below).

Site-specific data regarding the nature of the soil will be used in conjunction with Table 2 of (EPA, 2004d) to estimate an appropriate van Genuchten shape parameter.

S_{te} is calculated as follows:

$$S_{te} = \frac{\theta_w - \theta_r}{n - \theta_r} \qquad \textbf{Eq. 3.14}$$

where:

S_{te} = effective total fluid saturation (unitless, calculated)

θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific)

θ_r = soil water content (cm^3/cm^3, taken from Table 2 of [EPA, 2004d])

n = total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as 1-[ρ_b / ρ_s]).

Soil vapor permeability is estimated as follows:

$$K_v = (k_i)(k_{rg}) \qquad \textbf{Eq. 3.15}$$

where:

K_v = soil vapor permeability (cm^2, calculated)

k_i = soil intrinsic permeability (cm^2)

k_{rg} = relative air permeability (unitless).

The foregoing permit calculation of the attenuation coefficient, which, in turn permits calculation of the concentration of VOC in indoor air in the building, as follows:

$$C_{building} = \alpha CF_3 C_{source} \qquad \textbf{Eq. 3.16}$$

where:

$C_{building}$ = VOC concentration in indoor air in the building (mg/m^3, calculated)

α = attenuation coefficient (unitless)

CF_3 = conversion factor (1E+9 $mg\text{-}cm^3/g\text{-}m^3$)

C_{source} = VOC concentration in soil gas at source of contamination (g/cm^3).

3.2.3 VOC Concentrations from Subsurface Soil in Ambient Air

The construction worker may be exposed to VOCs released from subsurface soil by volatilization. Exposure-point concentrations of VOCs in ambient air due to volatilization are estimated with a chemical-specific soil volatilization factor calculated from the following equations and defaults (EPA, 1996):

$$VF_s = Q/C \times CF_4 \times \left(\frac{(3.14 \times D_A \times T)^{1/2}}{2 \times \rho_b \times D_A} \right) \qquad \textbf{Eq. 3.17}$$

and

$$D_A = \frac{\left(\theta_a^{10/3} \times D_i \times H' + \theta_w^{10/3} \times D_w \right) / n^2}{\rho_b \times K_d + \theta_w + \theta_a \times H'} \qquad \textbf{Eq. 3.18}$$

where:

VF_s =chemical-from-soil volatilization factor (m^3/kg, calculated)

Q/C =inverse of the mean concentration at center of square source (43.08 g/m^2second per kg/m^3, site-specific value from Table 3 of [EPA, 1996] [Zone 5, Cleveland, 30-acre site])

CF_4 = conversion factor (1E-4 m^2/cm^2)

D_A = apparent diffusivity (cm^2/second, calculated)

T = exposure interval (seconds, receptor-specific, estimated as ED x 3.15E7 seconds/year)

ED = exposure duration (years, receptor-specific)

ρ_b = dry soil bulk density (1.5 g/cm^3, default, or site-specific)

θ_a = air-filled soil porosity (0.28 unitless, default, or site-specific estimated as $n - \theta_w$)

n = total soil porosity (0.43 unitless, default, or site-specific estimated as 1-[ρ_b / ρ_s])

ρ_s = true soil or particle density (2.65 g/cm^3, default, or site-specific)

θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default, or site-specific)

D_i = diffusivity in air (cm^2/second, chemical specific)

H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H x 41)

H = Henry's law constant (atmosphere-m^3/mole, chemical-specific)

D_w = diffusivity in water (cm^2/second, chemical-specific) K_d = soil-water partition coefficient (cm^3/g, chemical-specific, may be estimated as $K_{oc} \cdot f_{oc}$)

K_{oc} = soil organic carbon-water partition coefficient (cm^2/g, chemical-specific)

F_{oc} = organic carbon content of soil (6E-3 g/g, default, or site-specific).

The concentration of a COPC in ambient air is estimated as follows:

$$C_a = \frac{C_{so}}{VF_s} \qquad \textbf{Eq. 3.19}$$

where:

C_a = contaminant concentration in air (mg/m^3, calculated)

C_{so} = contaminant concentration in soil (mg/kg)

VF_s = chemical-from-soil volatilization factor (m^3/kg, chemical-specific, calculated).

3.2.4 Concentrations in Household Air from Groundwater Use

Inhalation of VOCs released from groundwater will be evaluated, as applicable, for the on-site resident scenario. Chemicals that have a Henry's Law value exceeding 1E-05 atmospheres per m^3 per mole and a molecular weight less than 200 g per mole are considered to be VOCs and are subject to evaluation via this pathway. Other groundwater contaminants may be evaluated on a case-by-case basis for their potential contribution to risk via the inhalation pathway based on the degree of departure from the Henry's Law and molecular weight criteria, groundwater concentration, and toxicity.

The simple whole-house tap water-to-air model described in Part B of the human health evaluation manual (HHEM) will be used in the BHHRA (EPA, 1991b). This model was selected based on correspondence between the OEPA and the USACE (OEPA, 2004c). Part B of the HHEM recommends a volatilization constant of 0.0005 for the total concentrations of all VOCs detected in groundwater; the conversion is characterized by the following equation:

$$C_a = C_{gw} \times 0.001 \, {}^{mg}\!/_{\mu g} \times K_{wa} x 1{,}000 \, {}^{L}\!/_{m^3} \qquad \textbf{Eq. 3.20}$$

where:

C_a = Modeled concentration in air (mg/m^3)

C_{gw} = Groundwater EPC micrograms per liter (µg/L)

K_{wa} = tap water-to-air volatilization constant (0.0005 [unitless], [EPA, 1991b])

Implicit in HHEM Part B application of this model are the following: 1) a family of four uses the groundwater as the sole source of household tap water; 2) the volume of the house is 150 m^3; 3) the daily groundwater use is 720 L/day; 4) 50 percent of VOCs in tap water volatilize to household air; and 5) the exchange rate of the house is 0.25 m^3/hour (EPA, 1991b). The EPA *Exposure Factors Handbook* lists values different from some of these assumed by HHEM Part B (EPA, 1997a). As appropriate, this pathway will also be evaluated in the BHHRA using alternate values from the *Exposure Factors Handbook*.

3.2.5 Concentrations of VOCs in Groundwater: Resident Dermal Uptake

Volatilization of VOCs from household water reduces the concentration remaining available for dermal contact. As mentioned in Section 3.2.2, the HHEM Part B whole-house tap water-to-air model assumes that 50 percent of the VOC concentrations are released to household air. Thus, the concentrations of VOCs remaining in the water after volatilization occurs are calculated by difference as follows:

$$C_d = C_{gw} x (1 - F_v) \qquad \textbf{Eq. 3.21}$$

where:

C_d = concentration of VOC in household water available for dermal exposure (mg/L, calculated)

C_{gw} = concentration of VOC in groundwater (mg/L)

F_v = fraction of VOCs volatilized to air (0.5, unitless).

Only the concentration remaining in tap water after volatilization (C_d), as applicable, is assumed to be available for contact with the skin during bathing/showering.

3.2.6 Concentrations of COPCs in Venison

The hunter is assumed to harvest and consume game, and share it with his family, including small children. The game will be assumed to be venison because deer is the species hunted most widely and most likely to provide a regular contribution to the diet. Data are not available to reliably estimate contaminant concentrations in venison, but the following simplifying assumptions permit estimates sufficient for an RA:

- Deer are small ruminants and as such are not unlike cattle; thus, it is reasonable to assume they may have similar physiological processes that could yield similar biotransfer factors. Unlike beef, however, deer meat does not undergo marbling with fat, and deer fat is quite unpalatable and is likely to be trimmed rather than consumed. Therefore, the biotransfer factors for edible venison are derived by adjusting biotransfer factors for beef to account for differences in the fat content of table-ready beef (cooked choice retail cuts trimmed to 0 inches of fat: average 14.4 percent fat) and venison (cooked boneless muscle meats: average 2.9 percent fat) (Nutrient Database, 1997).

- Deer are expected to browse a much larger area than that encompassed by the Acid Area 1 site; therefore the fraction of total browse consumed from the contaminated site would be expected to be small.

- Indirect food-chain pathways may be significant for metals and for those SVOCs that persist in the environment and have the tendency to bioaccumulate. VOCs are generally mobile in the environment and unstable in biological systems and do not tend to bioaccumulate.

To reflect the assumptions previously noted, venison biotransfer factors are estimated by multiplying beef biotransfer factors by 2.9/14.4 (or 0.20), and by a fraction, FI_e. FI_e reflects the areal portion of the site compared to a deer's home range area. These assumptions are captured in the following equation:

$$B_v = 0.20(FI_e)(B_b) \qquad \textbf{Eq. 3.22}$$

where:

B_v = biotransfer factor for venison (unitless, calculated)

0.20 = factor to reflect differences in fat content between beef and venison (0.20, unitless, see above)

FI_e = areal portion of site compared to a deer's home range

B_b = biotransfer factor for beef.

Values for B_b for metals will be provided in the toxicity profiles appended to the RA. Toxicity profiles will be prepared for the COCs identified in the RA. The toxicity profiles will briefly describe the uses of the chemical, its physical properties, behavior in environmental media, biotransfer capability, and toxicity values.

The home range of a deer is approximately 630 acres. Deer will be assumed to be exposed to contaminants by ingesting browse growing on contaminated soil. It will be assumed that deer consume approximately 1.74 kg of browse per day (Sample, et al., 1996), which is approximately 50 percent dry matter (DM), or 0.87 kg browse DM per day (Mautz, et al., 1976). The contaminant concentration in browse will be estimated from the following equation, which

was originally developed for estimating the contaminant concentration in forage to which cattle may be exposed (EPA, 1994):

$$C_p = (CF_7)(C_{so})(B_p) \qquad \textbf{Eq. 3.23}$$

where:

C_p = concentration of contaminant in (plant) forage DM (mg/kg, calculated)

CF_7 = conversion factor to adjust for soil containing 20 percent moisture (1.25 unitless).

C_{so} = concentration of contaminant in soil (mg/kg)

B_p = soil-to-forage biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

Values for B_p will be taken from the toxicity profiles appended to the RA. B_p values for the vegetative parts of plants, rather than the reproductive parts of plants, will be selected, when possible, because deer browse year-round, and the vegetative parts are more available for the greater part of the year.

The concentration of COPC in venison can be estimated from the following equation (adapted from EPA, 1994):

$$C_v = (Q_p)(C_p)(B_v) \qquad \textbf{Eq. 3.24}$$

where:

C_v = contaminant concentration in venison (mg/kg, calculated)

Q_p = browse ingestion rate (0.87 kg DM/day)

C_p = contaminant concentration in browse DM (mg/kg)

B_v = biotransfer factor for venison (days/kg).

3.3 Quantification of Chemical Intakes

This section describes the models used to quantify doses or intakes of the COPC by the exposure pathways identified in Section 3.1.2, using the exposure parameter values described in Section 3.1.3. Models are taken or modified from EPA unless otherwise indicated. Intakes will be calculated for both cancer and noncancer evaluations (EPA, 1989a). Therefore, the AT variable shown in the following equations is replaced with AT_n for noncancer calculations (365 × ED), and with AT_c (25,550 days) for the cancer calculations. Intake values will be based

on the EPCs (Section 3.2) and the equations discussed below for the respective exposure pathways.

3.3.1 Inhalation of COPCs in Air

The following equation will be used to estimate the inhaled dose of COPC in air (groundskeeper, construction worker, on-site resident - inhalation of dust and VOCs in ambient air from surface or total soil; construction worker - inhalation of VOCs in ambient air from subsurface soil; indoor worker and on-site resident - inhalation of VOCs in indoor air from subsurface soil and tap water):

$$I_a = \frac{(C_a)(FI_a)(IR_a)(ET_a)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.25}$$

where:

I_a = inhaled dose of COPC (mg/kg-day, calculated)

C_a = concentration of COPC in air (mg/m^3)

FI_a = fraction of exposure attributed to site media (unitless)

IR_a = inhalation rate (m^3/hour)

ET_a = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

3.3.2 Incidental Ingestion of COPCs in Soil and Sediment

The ingested dose of COPCs in soil (groundskeeper, construction worker, on-site resident, indoor worker, and hunter) will be estimated from the equation:

$$\mathrm{I_{so}} = \frac{(\mathrm{C_{so}})(\mathrm{FI_{so}})(\mathrm{IR_{so}})(\mathrm{EF})(\mathrm{ED})(\mathrm{CF_2})}{(\mathrm{BW})(\mathrm{AT})} \qquad \textbf{Eq. 3.26}$$

where:

I_{so} = ingested dose of COPC in soil (mg/kg-day, calculated)

C_{so} = concentration of COPC in soil (mg/kg)

FI_{so} = fraction of exposure attributed to site soil or sediment (unitless)

IR_{so} = ingestion rate of soil or sediment (mg/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF_2 =conversion factor (1E-6 kg/mg)

BW = body weight (kg)

AT = averaging time (days).

3.3.4 Dermal Contact with COPCs in Soil, Sediment, or Water

Unlike the methodologies for estimating inhaled or ingested doses of COPCs, which quantify the dose presented to the barrier membrane (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as the dose that crosses the skin and is systemically absorbed. For this reason, dermal toxicity values are also based on absorbed dose. The absorbed dose of a COPC is estimated from the equation (EPA, 1992b):

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.27}$$

where:

DAD = average dermal absorbed dose of COPC (mg/kg-day, calculated)

DA = dose absorbed per unit body surface area per day (mg/cm^2-day)

SA = SA_{so} for soil, SA_{sd} for sediment, SA_w for water = surface area of the skin exposed (cm^2)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

DA is calculated differently for dermal uptake from soil or sediment and from water. Dermal uptake of constituents from soil (groundskeeper, construction worker, on-site resident, and

hunter) or sediment (construction worker, on-site resident) assumes that absorption is a function of the fraction of a dermally applied dose that is absorbed. It is calculated from the equation (EPA, 1992b):

$$DA = (C)(FI)(CF_2)(AF)(ABS) \qquad \textbf{Eq. 3.28}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)

C = C_{so} for soil, C_{sd} for sediment = concentration of COPC in medium (mg/kg)

FI = FI_{so} for soil, FI_{sd} for sediment = fraction of exposure attributed to site medium (unitless)

CF_2 = conversion factor (1E-6 kg/mg)

AF = AF_{so} for soil, AF_{sd} for sediment = soil- or sediment-to-skin adherence factor (mg/cm^2-day)

ABS = absorption fraction (unitless, chemical-specific).

ABS values will be provided in the toxicity profiles for each COPC that will be appended to the RA.

Quantification of dermal uptake of constituents from water depends on a permeability coefficient (K_p), which describes the rate of movement of a constituent, from water across the dermal barrier to the systemic circulation (EPA, 1992b). Separate calculation methods are applied to estimate the DA term (defined above) for inorganic and organic chemicals in water. For inorganic chemicals, DA is calculated from the following equation:

$$DA = (C_w)(K_p)(ET_w)(CF) \qquad \textbf{Eq. 3.29}$$

where:

DA = dose absorbed per unit body surface area per event (milligrams per square centimeter per event [mg/cm^2-event], calculated)

C_w = concentration of COPC in water (mg/L)

K_p = permeability coefficient (cm/hour)

ET_w = time of exposure (hours/event)

CF = conversion factor (0.001 L/cm^3).

K_p values are available for some inorganics (EPA, 2004a). A default K_p value of 0.001 cm/hour (EPA, 2004a) will be used for those inorganics for which no chemical-specific values were available.

K_p values for organic chemicals vary by several orders of magnitude, largely dependent on lipophilicity, expressed as a function of the octanol/water partition coefficient (K_{ow}). Because the stratum corneum (the outer skin layer) is rich in lipid content, it may act as a sink, initially reducing the transport of chemical to the systemic circulation. With continued exposure and the attainment of steady state conditions, the rate of transfer to the systemic circulation increases. Therefore, different equations are used to estimate DA, depending on whether the ET is less or greater than the estimated time to reach steady state. Dermal exposure to groundwater would be expected to generally be of relatively short duration (e.g., limited to bathing/showering time and/or intermittent hand and face washing). Therefore, it will be assumed that steady state is not reached, which is the usual case for relatively short ETs. Under these conditions, DA is calculated from the following equation (EPA, 2004a):

$$DA = 2(FA)(K_p)(C_w)(CF_6)\sqrt{\left(\frac{6\tau(ET_w)}{\pi}\right)} \qquad \textbf{Eq. 3.30}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)

C_w = concentration of COPC in water (µg/L) (Note that for volatiles in shower water the C_w should be the concentration remaining after volatilization from the water droplet.)

FA = fraction available post-exposure for absorption in the stratum corneum

K_p = permeability coefficient (cm/hour)

CF_6 = conversion factor (1E-3 L/cm^3)

τ = time for concentration of contaminant in stratum corneum to reach steady state (hours)

ET = time of exposure to water (hours).

When available, values for K_p and τ will be taken from EPA guidance (EPA, 2004a). For organics that have no K_p values listed, the values will be calculated using Equation 3.27 (EPA, 2004a):

$$Log(K_p) = -2.80 + 0.66(LogK_{ow}) - 0.0056(MW) \qquad \textbf{Eq. 3.31}$$

where:

K_p = permeability coefficient (cm/hour, calculated)

$LogK_{ow}$ = log of the octanol/water partition coefficient (unitless)

MW = molecular weight.

Where values for τ are not available, they will be calculated using Equation 3.28 (EPA, 1992a). Values of K_p and τ to be used in the BHHRA will be appended.

$$\tau = \frac{L_{sc}}{6 \times 10^{(-2.72-0.0061 \times MW)}} \qquad \textbf{Eq. 3.32}$$

where:

τ = time for concentration of contaminant in stratum corneum to reach steady state (hours, calculated)

L_{sc} = effective thickness of the stratum corneum (0.001 cm)

MW = molecular weight.

3.3.5 Consumption of Venison

Consumption of venison by the hunter or his child is evaluated by the following equation:

$$I_v = \frac{(C_v)(IR_v)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.33}$$

where:

I_v = ingested dose of COPC in venison (mg/kg-day, calculated)

C_v = concentration of COPC in venison (mg/kg)

IR_v =venison ingestion rate (kg/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

3.3.6 Ingestion of COPCs in Groundwater and Surface Water

The ingested dose of COPCs in groundwater and surface water is estimated from the equation:

$$I_w = \frac{(C_w)(IR_w)(EF)(ED)}{(BW)(AT)} \qquad \textbf{Eq. 3.34}$$

where:

I_w = ingested dose of COPC in groundwater (mg/kg-day, calculated)

C_w = concentration of COPC in groundwater (mg/L)

IR_w = drinking water ingestion rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days).

4.0 TOXICITY ASSESSMENT

Toxicity is defined as the ability of a chemical to induce adverse effects in biological systems. The purpose of the toxicity assessment is two-fold:

- Identify the cancer and noncancer effects that may arise from exposure of humans to the COPC (hazard assessment).
- Provide an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects (dose-response assessment).

The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described in the following section.

4.1 Evaluation of Carcinogenicity

A few chemicals are known, and many more are suspected, to be human carcinogens. The carcinogenic slope factors (SFs), inhalation unit risks, and the accompanying weight-of-evidence classification are used to evaluate potential human carcinogenic risks associated with exposures.

In defining the potential carcinogenicity of a chemical to humans, EPA first evaluates the sufficiency of evidence of carcinogenicity from available animal and human data. If there are sufficient quantitative data and adequate understanding of the carcinogenic process, a biologically based model may be developed to relate dose and response data on an agent-specific basis. Otherwise, as a default procedure, a standard model can be used to curve-fit the data. Once the data are evaluated, the chemical is assigned a weight-of-evidence classification. The EPA recognizes six weight-of-evidence group classifications for carcinogenicity, which are as follows:

- Group A – Human Carcinogenic: human data are sufficient to identify the chemical as a human carcinogen.
- Group B1 – Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.
- Group B2 – Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association.
- Group C – Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.
- Group D – Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate.

- Group E – Evidence of Non-Carcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer.

The weight of evidence narrative developed to characterize potential carcinogenic hazard summarizes the results of the hazard assessment and provides a conclusion with regard to human carcinogenic potential. The weight of evidence narrative includes both a conclusion about the weight-of-evidence of carcinogenic potential and a summary of the data on which the conclusion rests. The narrative explains the kinds of evidence available and how they fit together in drawing conclusions, and points out significant issues/strengths/limitations of the data and conclusions.

EPA derives SF and unit risk values for carcinogens. Slope factors generally represent an upper bound on the average risk in a population or the risk for a randomly selected individual but not the risk for a highly susceptible individual or group. Some individuals face a higher risk and some face a lower risk. The use of upper bounds generally is considered to be a health-protective approach for covering the risk to susceptible individuals, although the calculation of upper bounds is not based on susceptibility data. The SF defines quantitatively the relationship between dose and response as the plausible upper-bound estimate of the probability of a response (i.e., development of cancer) per unit intake of a potential carcinogen over a lifetime. In general, an inhalation unit risk is developed directly from a dose response analysis using equivalent human concentrations already expressed in units of micrograms (µg) per m^3.

The SF is derived by EPA by selecting the most appropriate data set, extrapolating to lower doses, determining equivalent human doses for the appropriate route of exposure. A nonlinear extrapolation method can be used for cases with sufficient data to ascertain the mode of action and to conclude that it is not linear at low doses but with insufficient data to support a toxicodynamic model that may be either nonlinear or linear at low doses. Nonlinear extrapolation having a significant biological support may be presented in addition to a linear approach when the available data and a weight of evidence evaluation support a nonlinear approach, but the data are not strong enough to ascertain the mode of action. The SF is expressed in terms of risk per unit concentration of the chemical (mg) per unit body weight (kg) per unit time (day) or $(mg/kg/day)^{-1}$. Inhalation unit risk estimates express the slope in terms of $\mu g/m^3$ or parts per million (ppm) air.

Cancer toxicity values and sources will be provided in the PBOW BHHRA in table format.

4.2 Evaluation of Noncarcinogenic Effects

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (EPA, 1989b) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical, which may differ depending on the duration (acute or chronic) or route (oral or inhalation) of exposure.

- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased).

- Estimation of the threshold dose for the critical effect for each duration of exposure.

- Development of an uncertainty factor (UF); i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of the critical effect, slope of the dose-response curve, and deficiencies in the database, in regard to developing a reference dose (RfD) for human exposure.

- Identification of the target organ(s) for the critical effect for each route of exposure.

These information points are used to derive an exposure route- and duration-specific toxicity value called an RfD, expressed as mg/kg-day, which is considered to be the dose for humans at which adverse effects are not expected to occur, and includes uncertainty of an order of magnitude or greater. Mathematically, it is estimated as the ratio of the threshold dose to the UF. For purposes of risk assessment, chronic exposure is defined as equal to or greater than seven years, or at least 10 percent of expected lifespan; subchronic exposure is defined as two weeks to seven years.

The EPA Integrated Risk Information System (IRIS) expresses the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m^3. Because noncancer risk characterization requires a reference value expressed as mg/kg-day, the RfC must be converted to an inhalation RfD. Since the inhalation RfC is based on continuous exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the RfC (mg/m^3) by 20 m^3/day and dividing the result by 70 kg.

RfD and RfC values are derived for both chronic and subchronic exposure. Under the assumption of monotonicity (incidence, intensity, or severity of effects can increase, but cannot decrease, with increasing magnitude or duration of exposure), a chronic RfD may be considered sufficiently protective for subchronic exposure, but a subchronic RfD may not be protective for chronic exposure. Currently, subchronic RfD values exist for few chemicals. Subchronic RfD values can be derived from chronic RfD values as follows:

- If the UF applied in the derivation of the chronic RfD does not provide for expansion from subchronic to chronic exposure (e.g., if the chronic RfD was derived from a chronic study), the chronic RfD is adopted as being sufficiently protective for subchronic exposure.

- If the UF applied in the derivation of the chronic RfD contains a component to expand from subchronic to chronic exposure, the subchronic RfD is derived by multiplying the chronic RfD by the factor used to expand from subchronic to chronic exposure (e.g., if a factor of 10 was used to expand from subchronic to chronic exposure, the subchronic RfD will be 10 times larger than the chronic RfD).

Oral and dermal RfDs (discussed in Section 4.3), as well as RfCs and inhalation RfDs will be provided in the BHHRA report in table format.

4.3 Dermal Toxicity Values

Dermal RfDs and SFs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (GAF), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the GAF. The oral SF is divided, rather than multiplied, by the GAF because the SF is expressed as a reciprocal dose.

4.4 Target Organ Toxicity

As a matter of science policy, EPA assumes dose and effect to be additive for noncarcinogenic effects (EPA, 1989a). This assumption provides the justification for adding the HQs or hazard indices (HI) in the risk characterization for noncancer effects (Section 5.2) resulting from exposure to multiple chemicals, pathways, or media. However, EPA acknowledges that adding all HQ or HI values may overestimate hazard, because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism (EPA, 1989a).

Mechanisms of toxicity data sufficient for predicting additivity with a high level of confidence are available for very few chemicals. In the absence of such data, EPA assumes that chemicals that act on the same target organ may do so by the same mechanism of toxicity; that is, the target organ serves as a surrogate for mechanism of toxicity (EPA, 1989a). When total HI for all media for a receptor exceeds 1 due to the contributions of several chemicals, it is appropriate to segregate the chemicals by route of exposure and mechanism of toxicity (i.e., target organ) and estimate separate HI values for each target organ.

As a practical matter, since human environmental exposures are likely to involve near- or sub-threshold doses, the target organ chosen for a given chemical is the one associated with the critical effect. If more than one organ is affected by a given chemical at the threshold, then the affected target organs are selected for this chemical. The target organ is also selected on the basis of duration of exposure (i.e., the target organ for chronic or subchronic exposure to low or moderate doses is selected rather than the target organ for acute exposure to high doses) and route of exposure. Because dermal RfD values are derived from oral RfD values, the oral target organ is adopted as the dermal target organ. For some chemicals, no target organ is identified. This occurs when no adverse effects are observed or when adverse effects such as reduced longevity or growth rate are not accompanied by recognized organ- or system-specific functional or morphologic alteration. Target organs for the oral and inhalation pathway will be provided in the BHHRA report.

4.5 Sources of Toxicity Information Used in the Risk Assessment

Toxicity values will be selected for use in the BHHRA based on the EPA Office of Solid Waste and Emergency Response Directive 9285.7-53 (EPA, 2003b) which prescribes the following hierarchy:

- **Tier 1** values: IRIS (EPA) database.

- **Tier 2** values: EPA's provisional peer-reviewed toxicity values. The provisional peer-reviewed toxicity values are developed by the Office of Research and Development, the National Center for Environmental Assessment, and the Superfund Health Risk Technical Support Center on a chemical-specific basis when requested by the Superfund program.

- **Tier 3** values: Other toxicity values from additional EPA and non-EPA sources of toxicity information. As stated in the EPA Office of Solid Waste and Emergency Response directive, "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." Examples of Tier 3 values recommended by EPA and OEPA (OEPA, 2005d) are the EPA's Health Effects Assessment Summary Tables (HEAST) (EPA, 1997c) and the California Environmental Protection Agency Office of Environmental Health Hazard Assessment Toxicity Criteria Database, toxicity values (California Environmental Protection Agency, 2005) (peer reviewed, U.S. Centers for Disease Control (CDC) - Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, U.S. EPA Criteria Documents).

If lead is retained as a COPC, the potential for exposure of children to potentially harmful concentrations of lead in blood (10 µg lead/deciliters (dl) of blood) will be addressed through the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK model).

Carcinogenicity of dioxin/furan compounds shall be addressed for hexachlorodibenzo-P-dioxin (HxCDD) compounds with the IRIS listed slope factors. For all other dioxin/furan compounds the concentration of individual congeners will be converted to a 2,3,7,8-tetrachlorodibenzo-P-dioxin (TCDD) equivalent (Section 3.2), and assessed by the 1997 HEAST cancer slope factor for 2,3,7,8-TCDD (EPA, 1997c).

GAFs, used to derive dermal RfD values and SFs from the corresponding oral toxicity values, are obtained from the following sources:

- Oral absorption efficiency data compiled by the National Center for Environmental Assessment for the Superfund Health Risk Technical Support Center of EPA.

- Federal agency reviews of the empirical data, such as Agency for Toxic Substances and Disease Registry Toxicological Profiles and various EPA criteria documents.

- Other published reviews of the empirical data.

- The primary literature.

GAFs obtained from reviews are compared to empirical (especially more recent) data, when possible, and are evaluated for suitability for use for deriving dermal toxicity values from oral toxicity values. The suitability of the GAF increases when the following similarities are present in the oral pharmacokinetic study from which the GAF is derived and in the key toxicity study from which the oral toxicity value is derived:

- The same strain, sex, age, and species of test animal were used.
- The same chemical form (e.g., the same salt or complex of an inorganic element or organic compound) was used.
- The same mode of administration (e.g., diet, drinking water, or gavage vehicle) was used.
- Similar dose rates were used.

The most defensible GAF for each chemical will be used in the BHHRA.

5.0 RISK CHARACTERIZATION

Risk characterization is the process of applying numerical methods and professional judgment to determine the potential for adverse human health effects that result from the presence of site-specific contaminants. This is done by combining the intake rates estimated during the exposure assessment with the appropriate toxicity information identified during the toxicity assessment. Noncancer hazards and cancer risks are characterized separately.

Quantitative expressions are calculated during risk characterization that describe the probability of developing cancer (ILCRs), or the nonprobabilistic comparison of estimated dose with an RfD for noncancer effects (HQs and HIs). Quantitative estimates are developed for individual chemicals, exposure pathways, and exposure media for each receptor. These quantitative risk characterization expressions, in combination with qualitative information, are used to guide risk management decisions. Risk characterization, as described in this section, is applied only to COPCs.

Generally, the risk characterization follows the methodology prescribed by EPA, as modified by more recent information and guidance (EPA, 1989a). EPA methods are, appropriately, designed to be health protective and tend to overestimate rather than underestimate risk. The risk results, however, may be overly conservative because risk characterization involves multiplication of the conservative assumptions built into the estimation of source-term concentrations and EPCs, the exposure (intake) estimates, and the toxicity dose-response assessments.

5.1 Carcinogenic Effects of Chemicals

The risk from exposure to potential chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime, and is called the ILCR. In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (EPA, 1989a):

$$ILCR = (CDI)(SF) \qquad \textbf{Eq. 5.1}$$

where:

$ILCR$ = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated

CDI = chronic daily intake, averaged over 70 years (mg/kg-day)

SF = cancer slope factor (risk per mg/kg-day).

The use of Equation 5.1 assumes that chemical carcinogenesis does not exhibit a threshold, and that the dose-response relationship is linear in the low dose range. Because this equation could generate theoretical cancer risks greater than 1 for high dose levels, it is considered to be inaccurate at cancer risks greater than 1E-2. In these cases, cancer risk is estimated by the one-hit model (EPA, 1989a):

$$ILCR = 1 - e^{[(CDI)(SF)]}$$ **Eq. 5.2**

where:

$ILCR$ = incremental lifetime cancer risk, a unitless expression of the probability of developing cancer, adjusted for background incidence, calculated

$e^{[(CDI)(SF)]}$ = the exponential of the risk calculated using Equation 5.1.

As a matter of policy, the EPA considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemicals' mechanisms of toxicity or sites of action (organs of the body) (EPA, 1986). Cancer risk arising from exposure to multiple chemicals in a given exposure medium and pathway is estimated from the following equation (EPA, 1989a):

$$ILCR_p = ILCR_{chem1} + ILCR_{chem2} + ...ILCR_i$$ **Eq. 5.3**

where:

$ILCR_p$ = total pathway risk of cancer incidence, calculated

$ILCR_{chemi}$ = individual chemical cancer risk for the pathway.

Cancer risk for a given receptor across pathways and across media is summed in the same manner.

For risk management purposes, a total cancer risk of 1E-6 is a point of departure below which cancer risks are considered to be insignificant. Cancer risks between 1E-6 and 1E-4 fall within a risk management range. OEPA considers cancer risks above 1E-5 to be unacceptable.

5.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects of chemicals are evaluated by comparing an exposure level or intake with an RfD. The HQ, defined as the ratio of intake to RfD, is estimated as (EPA, 1989a):

$$HQ = I/RfD$$ **Eq. 5.4**

where:

HQ = hazard quotient (unitless, calculated)

I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day)

RfD = reference dose (mg/kg-day).

As shown above, the "I" and the RfD are in units of mg/kg-day. The RfD has been developed to represent a dose that is unlikely to result in an adverse noncancer health effect, even to the most susceptible members of the population. Therefore, if the "I" is equal to or less than the RfD (i.e., HQ<1), an adverse noncancer health effect is unlikely. HQ values exceeding 1 do not indicate that a noncancer health effect is likely to occur, but rather that the occurrence of an adverse noncancer health effect cannot be termed "unlikely". The HQ does not define a particular risk level, nor can it be used to infer information regarding a dose-response curve. That is, an HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than the RfD. This approach is different from the probabilistic approach described in Section 5.1 for the evaluation of cancer risks.

In the case of simultaneous exposure of a receptor to multiple chemicals, or to a given chemical by multiple pathways, a HI is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + HQ_i \qquad \textbf{Eq. 5.5}$$

where:

HI = hazard index (unitless, calculated)

HQ_i = hazard quotient for the ith chemical, or for the ith pathway.

An HI may be calculated across all exposure pathways for a given chemical, across all chemicals for a given exposure pathway, across all chemicals and exposure pathways for a given exposure medium, or across all media to yield the total HI for a given receptor.

Calculating a total HI as the sum of HQ values is based on the assumption that the potential for noncancer effects is additive. EPA, however, acknowledges that the assumption of additivity is probably appropriate only for chemicals that induce adverse effects by the same mechanism (please see Section 4.3) (EPA, 1989a). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ as follows:

$$Total\ HI_a = HI_{p1-a} + HI_{p2-a} + ...HI_{pi-a} \qquad \textbf{Eq. 5.6}$$

where:

$Total\ HI_a$ = total hazard index for target organ "a" (unitless, calculated)

HI_{pi-a} = hazard index for target organ "a" via pathway "i".

Toxicity values are not available for the evaluation of lead. Risk assessment of potential exposures to lead will consist of estimating blood lead levels in children associated with exposure to the environmental media at the site in question, and comparing the estimate with the threshold level of 10 µg/dL.

The EPA IEUBK blood lead model for young children will be used to predict blood lead levels for children hypothetically exposed at the site (EPA, 1994b). The IEUBK is a self-contained DOS-based computer program. Average lead concentrations in the various media are input in the model; default values provided by the IEUBK are used when site-specific data are not available. Arithmetic mean values, rather than conservative estimates of average, are used because the IEUBK contains a statistical module that addresses individual variation in exposure and physiological parameters. The output is a probability density histogram of predicted blood lead levels. The risk assessment is considered to "pass" if the IEUBK predicts that not more than 5 percent of young children exposed in this manner would experience a mean blood lead level above the 10 µg/dL threshold.

Nonresidential exposure scenarios will be addresses for adult exposures to lead in soil using the adult lead methodology (EPA, 1996b). The method focuses on the estimation of blood lead concentrations in fetuses carried by women exposed to average concentrations of lead in soil (EPA, 1999). The method is based on a probability model for blood lead levels in adult women exposed to lead in soil coupled with an estimated constant of proportionality between fetal and maternal blood lead levels, a geometric mean fetal blood lead concentration and empirically determined geometric standard deviation (EPA, 1999). The statistical terms used in the method permit an equation to be used to establish an average adult blood lead concentration such that a fetus has not more than a 5 percent probability of blood lead concentrations exceeding 10 µg/dL (EPA, 1996b). The risk assessment is considered to pass if the average adult blood lead level does not predict an excess of 5 percent probability that fetal blood lead levels exceed 10 µg/dL, as interpreted by the Technical Review Workgroup (TRW) for the established cleanup goal to limit childhood risk of exceeding 10 µg/dL to 5 percent (EPA, 1994c and1996b).

5.3 Risk Characterization Results

Risk characterization results for potential exposures at the Acid Area 1 site will be presented in tables and discussed in text in the BHHRA report. Potential cancer (Section 5.1) and adverse noncancer effects (Section 5.2) for each receptor will be presented separately. Detailed spreadsheet calculations will be appended to the BHHRA.

5.4 Summary

Risk characterization results for the Acid Area 1 site will be briefly summarized in the BHHRA report, with special emphasis on whether or not COPCs, pathways, media, and receptors exceed the cancer risk management range (1E-6 to 1E-4) and noncancer (HI>1) human health-based criteria. This summary will include risks associated with potential exposures to all media.

6.0 UNCERTAINTY ANALYSIS

The primary objective of the BHHRA is to characterize and quantify potential human health risks. However, these risks are estimated using incomplete and imperfect information that introduces uncertainties at various stages of the risk assessment process. Uncertainties associated with earlier stages of the risk assessment become magnified when they are combined with other uncertainties in the latter stages. Reliance on a simplified numerical presentation of dose rate and risk without consideration of uncertainties, limitations, and assumptions inherent in their derivation can be misleading. For example, the calculated ILCR for a given scenario "A" may be 5E-5 (within the cancer risk management range) and that of scenario "B" given as 5E-4 (exceeding the cancer risk management range). However, if the uncertainties associated with scenario "B", for example, span orders of magnitude and the ILCR is regarded as biased high, it is not unlikely that scenario "A" actually presents a higher risk of developing cancer.

The chief goal of this analysis is to evaluate uncertainties and present them in context of their potential impact on the interpretation of the risk assessment results and the types of environmental management decisions that may be based on these results. The uncertainty analysis does not exhaustively describe all potential uncertainties but presents those that have the largest implications for the interpretation of the risk assessment results. This analysis also reviews the types and, as applicable, the magnitude of the uncertainties at each stage of the risk assessment. Although the BHHRA will include generic uncertainties that are common to the state of human health risk assessment practice (e.g., additivity of health effects in the risk characterization), overall, the uncertainty analysis focuses on a set of uncertainties that is peculiar to specific PBOW sites.

6.1 Types of Uncertainty

Uncertainties in risk assessment are categorized into two general types: 1) variability inherent in the (true) heterogeneity of the data set, measurement precision, and measurement accuracy; and 2) uncertainty that arises from data gaps. Estimates of the degree of variability tend to decrease as the sample size increases. This is because larger data sets are less impacted by individual samples/measurements and typically allow for greater accuracy. Uncertainty that arises from data gaps is addressed by applying models and assumptions. Models are applied because they represent a level of understanding to address certain exposure parameters that are impractical or impossible to measure (e.g., COPC concentrations in air that would result from groundwater use that has not yet occurred or may never occur at the site). Assumptions represent an educated estimate to address information that is not available (e.g., additivity of carcinogens).

6.2 Sources of Uncertainty

A discussion will be included in the BHHRA report that presents an overview of general sources of uncertainty and focuses on those most likely to affect the interpretation of the BHHRA results. These sources may include, but are not limited to, the following:

- Representativeness of samples,

- Laboratory procedures and analytical methods,
- Sampling methods,
- Adequacy of background data set,
- Comparisons to background concentrations,
- Land-use and groundwater use assumptions,
- Routes of exposure,
- Exposure assessment values,
- Exposure models,
- Methods of calculating EPCs,
- Toxicity values,
- Form or isomer of chemical, and
- Interactions of multiple contaminants.

The PBOW BHHRA will identify and describe the unique set of uncertainties associated with the site. Special attention may be given to those uncertainties that are thought to have the most significant impact on risk and/or remediation decisions.

7.0 DEVELOPMENT OF RISK-BASED REMEDIATION LEVELS

RBRLs are derived to provide a range of potential remediation levels for the site to support risk management decisions. RBRLs are not mandatory remediation limits, but rather support the evaluation of the cost and benefits of potential remedial actions at a site. RBRLs are developed only for the chemicals of concern (COCs) in media that are associated with unacceptable risk that may potentially warrant corrective action. RBRLs are site-specific risk-based concentrations that reflect the exposure and toxicity assumptions applied in the baseline RA. Consequently, the RBRLs are source-, medium-, receptor-, and chemical-specific. The development of RBRLs would involve a balance of cancer risk and noncancer hazard estimates for the Acid Area 1 site. The development of RBRLs would be an iterative process with ongoing discussion between OEPA and the USACE.

The first step in RBRL development is selection of COCs. Either of two conditions results in designation of a COPC as a COC:

- The concentration of the COPC exceeds its medium-specific ARAR, provided one is available.
- The COPC contributes significantly to cancer risk or hazard as described below.

COCs based on cancer risks are selected for any medium for which the total ILCR for a given receptor (summed across chemicals and exposure pathways) exceeds 1E-4 (EPA, 1991b). For an individual COPC in a given medium to be selected as a cancer-based COC, it must have an ILCR (summed across exposure pathways) exceeding 1E-6. COCs based on noncancer hazards are selected for any receptor for which the total HI (summed across chemicals and exposure pathways) exceeds 1. For an individual COPC in any medium to be selected as a noncancer-based COC, it must have an HI (summed across exposure pathways) exceeding 0.1.

RBRLs are risk- or hazard-specific concentrations of chemicals developed only for the COCs in media selected by the criteria described above. RBRLs for cancer COCs are estimated for a given medium from the following equation (EPA, 2000):

$$RBRL_{coc} = \frac{EPC_{coc} TR}{ILCR_{coc}} \qquad \textbf{Eq. 7.1}$$

where:

$RBRL_{coc}$ = risk-based remediation criterion for a given COC, receptor and source medium (calculated)

EPC_{coc} = source-term concentration of the COC in the given medium

TR = target risk level (1E-6, 1E-5)

$ILCR_{coc}$ = total incremental lifetime cancer risk for a given COC, receptor and source

medium.

RBRLs for noncancer COCs are estimated as follows:

$$RBRL_{coc} = \frac{EPC_{coc} THI}{HI_{coc}} \qquad \textbf{Eq. 7.2}$$

where:

$RBRL_{coc}$ = risk-based remediation criterion for a given COC, receptor and source medium (calculated)

EPC_{coc} = source-term concentration of the COC in the given medium

THI = target hazard index (0.1, 1)

HI_{coc} = total hazard index for a given COC, receptor and source medium.

Concentration units are not provided in Equations 7.1 or 7.2; the RBRL units will be the same as the concentration units of the source-term concentration. RBRLs are not final remedial concentrations. RBRLs are to be used by risk-managers as ballpark values to give an idea of the magnitude of remediation that may be needed. Final remedial goals based on toxicity, carcinogenicity, number and variety of COCs, and other factors as appropriate will be developed before a feasibility study begins.

The procedure described above is not suitable for developing an RBRL for lead. EPA has considerable experience using the IEUBK to develop screening levels for lead in soil (EPA, 1994c,d, 1998, and 2001). The concentration of 400 mg/kg in soil has stood the test of time as a screening level. EPA recommends applying site-specific data to the IEUBK to develop site-specific cleanup levels or RBRLs (EPA, 1998). In general, cleanup levels developed with the IEUBK do not exceed the screening level of 400 mg/kg unless site-specific exposure parameters are available that differ substantially from the defaults provided by the model. The residential scenario developed in this BHHRA work plan was based on standard exposure assumptions. Site-specific information is not available that would permit refinement of these assumptions. Therefore, the 400 mg/kg screening level confirmed by EPA will be adopted as the RBRL (EPA, 1998).

EPA provides a PRG of 750 mg/kg for lead in soil for industrial sites, based on the recommendations of the TRW for lead (EPA, 2004b). The PRG is appropriately considered a screening value for lead for industrial site use. Plausible receptor scenarios for industrial site use include the groundskeeper, the indoor worker and the construction worker. The EPA adult lead methodology may be used to develop RBRLs for lead in soil for the groundskeeper, construction worker, and hunter exposure scenarios (EPA, 1996b). The EPA PRG of 750 mg/kg for lead in industrial soil will be adopted as the RBRL for the indoor worker for this BHHRA work plan (EPA, 2004b).

8.0 SUMMARY AND CONCLUSIONS

This section will briefly summarize the RA protocol and results and interpret the results, in light of the uncertainty about their estimation, to draw realistic conclusions regarding risk to human health.

9.0 REFERENCES

California Environmental Protection Agency, 2005, ***Toxicity Criteria Database***, Office of Environmental Health Hazard Assessment, Sacramento, California, http://www.oehha.co.gov/risk/ChemicalDB/index.asp.

City-Data.com, 2004, on-line data search for Sandusky, Ohio, performed November 11, 2004, http://www.city-data.com/city/Sandusky-South-Ohio.html.

Dames and Moore, Inc. (D&M), 1997, ***TNT Areas Site Investigation Final Report, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Gilbert, R. O., 1987, ***Statistical Methods for Environmental Pollution Monitoring***, New York, New York: Van Nostrand Reinhold.

Hardin, J. W., and R. O. Gilbert, 1993, ***Statistical Tests for Detecting Soil Contamination Greater than Background,*** PNL-8989/UC-630, Pacific Northwest Laboratory, Richland, Washington, December.

IT Corporation (IT), 2001a, ***Baseline Human Health Risk Assessment Work Plan for Trinitrotoluene (TNT), Areas A and C Soil, Former Plum Brook Ordnance Works, Final, Sandusky, Ohio***, April.

IT Corporation (IT), 2001a, ***TNT Areas A and C Remedial Investigation, Volume II – Human Health Risk Assessment, Final, Former Plum Book Ordnance Works, Sandusky, Ohio,*** November.

IT Corporation (IT), 2001b, ***TNT Areas A and C Remedial Investigation, Volume I – Report of Findings, Final, Former Plum Book Ordnance Works, Sandusky, Ohio,*** November.

IT Corporation (IT), 1999b, ***Summary Report, Site-Wide Groundwater Monitoring (1997/1998), Final, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** June.

IT Corporation (IT), 1997, ***Site-Wide Groundwater Investigation Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

Jacobs, 2007, ***Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans, Acid Areas 2 & 3, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, April

Mautz, W. W., H. Silver, and J. B. Holter, 1976, "Digestibility and Related Nutritional Data for Seven Northern Deer Browse Species," ***Journal of Wildlife Management***, 40(4): 630-638.

National Oceanic and Atmospheric Administration, 1990, ***Comparative Climatic Data for***

the United States through 1989, National Climatic Data Center, Asheville, North Carolina.

National Council on Radiation Protection and Measurements (NCRPM), 1984, ***Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment***, NCRP Report No. 76.

Nutrient Database, 1997, Data compiled from U.S. Department of Agriculture releases, and published nutrient information from 71 chain references, on line, http://www.nutribase.com.)

Ohio Department of Natural Resources, map showing Ground-Water Resources of Erie County by Alfred C. Walker, http://www.dnr.state.oh.us/water/gwrmaps/counties/Erie.htm, accessed April 2007.

Ohio Environmental Protection Agency (OEPA) 2007, ***Remedial Investigation/Feasibility Study Programmatic Recommendations Guidance List***; http://www.epa.state.oh.us/derr/rules/guidance.html; *Ohio EPA Division of Emergency and Remedial Response Remedial Response Program,* April 2007.

Ohio Environmental Protection Agency (OEPA), 2004a, ***TECHNICAL DECISION COMPENDIUM Methodology for Evaluating Site-specific Background Concentrations of Chemicals,*** Ohio EPA Division of Emergency and Remedial Response Remedial Response Program, 14 April 2004.

Ohio Environmental Protection Agency (OEPA), 2004b, ***TECHNICAL DECISION COMPENDIUM Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR***, Remedial Response and Office of Federal Facility Oversight Ohio EPA Division of Emergency and Remedial Response, 28 April 2004

Ohio Environmental Protection Agency (OEPA), 2004c, e-mail correspondence from L. Moore (OEPA Risk Assessor) to L. Long (USACE Risk Assessor), December 15.

Ohio Environmental Protection Agency (OEPA), 2005a, ***Use of Risk-Based Numbers in the Remedial Response Process Overview***, DERR-00-RR-038, June 28, 2005.

Ohio Environmental Protection Agency (OEPA), 2005b, ***Technical Decision Compendium Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment,*** Ohio EPA Division of Emergency and Remedial Response Remedial Response Program, August 2005.

Ohio Environmental Protection Agency (OEPA), 2005c, **Methodology for Vapor Intrusion Assessment**, April 2005.

Ohio Environmental Protection Agency (OEPA), 2005d, ***Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment***.

Ohio Environmental Protection Agency (OEPA), 1993, ***Closure Plan Review Guidance for RCRA Facilities***, Interim Final, OEPA Division of Hazardous Waste Management, September 1.

Sample, B. E., D. M. Opresko, and G. W. Suter II, 1996, ***Toxicological Benchmarks for Wildlife: 1996 Revision***, Prepared for the U.S. Department of Energy by Health Sciences Research Division, Oak Ridge National Laboratory.

Science Applications International Corporation (SAIC), 1991, ***NASA Plum Brook Station, Preliminary Assessment***, Volume I, Sandusky, Ohio, June.

Shaw Environmental, Inc. (Shaw), 2005a, ***Baseline Human Health Risk Assessment Work Plan for Groundwater, Former Plum Brook Ordnance Works, Final, Sandusky, Ohio***, April.

Shaw Environmental, Inc. (Shaw), 2005b, ***2004 Groundwater Data Summary and Evaluation Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, April.

Shaw Environmental, Inc. (Shaw), 2005c, ***Technical Memorandum for the Baseline Human Health Risk Assessment for Groundwater at the West Area Red Water Pond, Former Plum Brook Ordnance Works, Sandusky, Ohio***, May.

Shaw Environmental, Inc. (Shaw), 2003, ***2002 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

U.S. Army Corps of Engineers (USACE), 1999, ***Risk Assessment Handbook, Volume I: Human Health Evaluation***, Engineer Manual EM 200-1-4.

U.S. Department of Energy (DOE), 1989, ***A Manual for Implementing Residual Radioactive Material Guidelines***, Argonne National Laboratory, Argonne, IL, ANL/ES-160, DOE/CH/8901.

U.S. Department of Energy (DOE), 1983, ***Pathway Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites***, U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN, DOE ORO-832.

U.S. Environmental Protection Agency (EPA), 2009, **Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part F - Supplemental Guidance for Inhalation Risk Assessment)**, Final, Office of Solid Waste and Emergency Response, Washington, D.C., OSWER No. 9285.7-82, January.

U.S. Environmental Protection Agency (EPA), 2008, ***Region III Risk-Based Concentration (RBC) Table***, Region III, Philadelphia, Pennsylvania, http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

U.S. Environmental Protection Agency (EPA), 2007a, ProUCL Version 4 User Guide, EPA/600/R-07/038, April.

EPA, 2007b, ProUCL Version 4 Technical Guide, EPA/600/R-07/041, April.

U.S. Environmental Protection Agency (EPA), 2005, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, Ohio, <http://cfpub.epa.gov/ncea/iris/index.cfm>.

U.S. Environmental Protection Agency (EPA), 2004a, **Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)**, Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., EPA/540/R-99/005, July.

U.S. Environmental Protection Agency (EPA), 2004b, ***Region IX Preliminary Remediation Goals (PRG) Table***, Region IX, San Francisco, California, October, <http://www.epa.gov/region09/waste/sfund/prg/files/prgtable.pdf>.

U.S. Environmental Protection Agency (EPA), 2004c, ***User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table***, Region 9, San Francisco, California, October, <http://www.epa.gov/region09/waste/sfund /prg/files/04usersguide.pdf>.

U.S. Environmental Protection Agency (EPA), 2004d, **User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings**,U.S. Environmental Protection Agency Office of Emergency and Remedial Response Ariel Rios Building, 5202g 1200 Pennsylvania Avenue, NW Washington, D.C. 20460 Revised February 22, 2004

U.S. Environmental Protection Agency (EPA), 2003a, ***Updated Dermal Exposure Assessment Guidance***, EPA Region 3, Philadelphia, Pennsylvania, June.

U.S. Environmental Protection Agency (EPA), 2003b, ***Human Health Toxicity Values in Superfund Risk Assessments***, Office of Solid Waste and Emergency Response, Washington, D.C., OSWER Directive 9285.7-53, December.

EPA, 2000. **Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment Bulletins**. EPA Region 4, originally published November 1995, Website version last updated May 2000: http://www.epa.gov/region4/waste/ots/healtbul.htm.

U.S. Environmental Protection Agency (EPA), 1997a, ***Exposure Factors Handbook***, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002F, August.

U.S. Environmental Protection Agency (EPA), 1997b, ***The Lognormal Distribution in Environmental Applications***, Technology Support Center Issue Paper, EPA/600/R-97/006, December.

U.S. Environmental Protection Agency (EPA), 1997c, ***Health Effects Assessment Summary Tables, FY 1997 Update,*** Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, NTIS No. PB97-921197.

U.S. Environmental Protection Agency (EPA), 1996, ***Soil Screening Guidance: Technical Background Document***, Office of Solid Waste and Emergency Response, EPA/540/R-95/128, NTIS No. PB96-963502.

U.S. Environmental Protection Agency (EPA), 1995, ***Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment***, Waste Management Division, Atlanta, Georgia, November.

U.S. Environmental Protection Agency (EPA), 1994, ***Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities,*** Office of Solid Waste and Emergency Response, Draft, April, EPA530-R-94-021, including Errata, "Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes," October, and "Modification of Screening Guidance Fate and Transport Equations," November.

U.S. Environmental Protection Agency (EPA), 1992a, ***Supplemental Guidance to RAGS: Calculating the Concentration Term***, Office of Solid Waste and Emergency Response, Washington, D.C., Publication 9285.7-081.

U.S. Environmental Protection Agency (EPA), 1992b, ***Dermal Exposure Assessment: Principles and Applications***, Interim Report, Office of Research and Development, Washington, D.C., EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

U.S. Environmental Protection Agency (EPA), 1992c, "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

U.S. Environmental Protection Agency (EPA), 1992d, ***Statistical Training Course for Groundwater Monitoring Data Analysis***, Office of Solid Waste, EPA/530/R-93/003.

U.S. Environmental Protection Agency (EPA), 1991a, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors***, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

U.S. Environmental Protection Agency (EPA), 1991b, ***Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual Part B – Development of Risk-Based Preliminary Remediation Goals***, Interim, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/R-92/003, December.

U.S. Environmental Protection Agency (EPA), 1990, 40 CFR Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule," ***Federal Register*** 55

(46): 86668865.

U.S. Environmental Protection Agency (EPA), 1989a, ***Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)***, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/1-89/002.

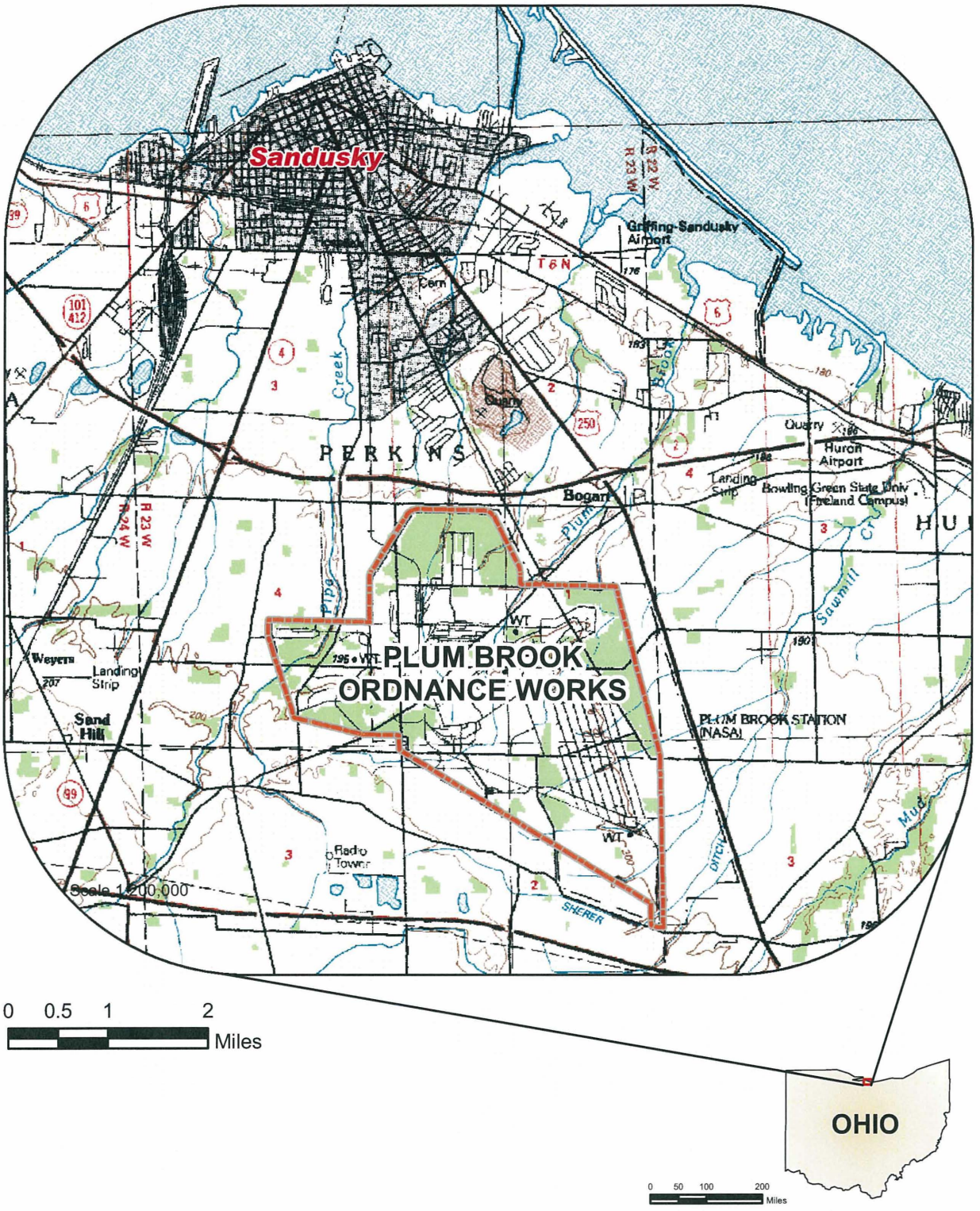
U.S. Environmental Protection Agency (EPA), 1989b, ***General Quantitative Risk Assessment Guidelines for Noncancer Health Effects***, Prepared by the Office of Health and Environmental Assessment, Cincinnati, OH for the Risk Assessment Forum, ECAO-CIN-538.

U.S. Environmental Protection Agency (EPA), 1986, ***Guidelines for Carcinogen Risk Assessment***," Federal Register, 51(185): 33992-34003.

U.S. Geological Survey, 1992, ***Hydraulic Properties of Three Types of Glacial Deposits in Ohio***, Water-Resources Investigation Report 92-4135.

Appendix A

Responses to Comments on the Draft
Baseline Human Health Risk Assessment Work Plan



Legend

Plum Brook Ordnance Works Boundary

N

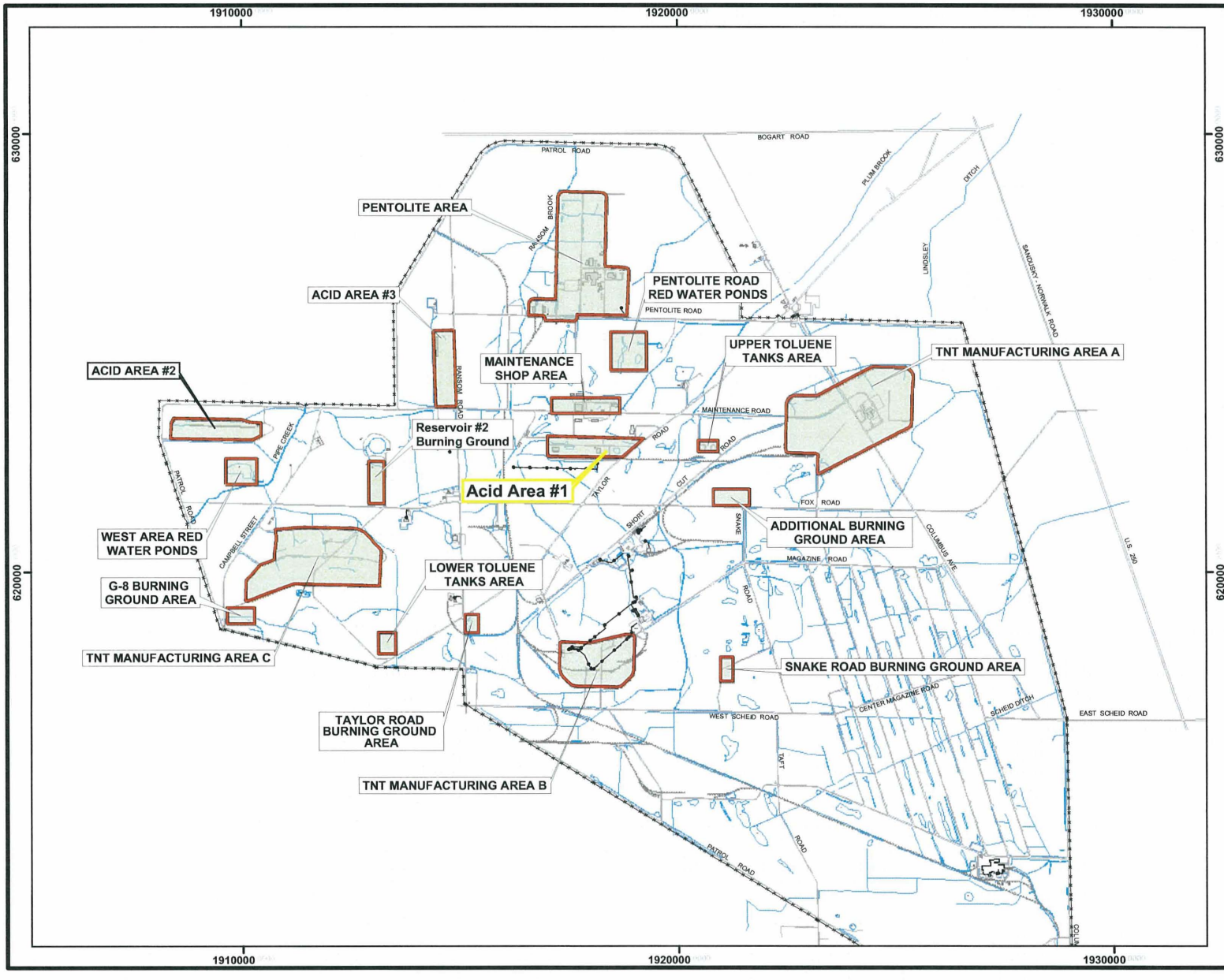
JACOBS

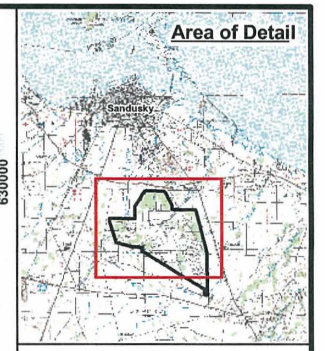
Location Map,
Plum Brook Ordnance Works
Sandusky, Ohio

Plumbrook Ordnance Works
Sandusky, Ohio

08/04/06 NZ D:/GIS/Plumbrook/Projects/
Final_AA2_3_RI/ArcGIS/PBOW_Site_Location.mxd

Figure 1-1





Legend

Area of Concern

Creek, Ditch, Conveyance

N

0 2,000 4,000 Feet

Sources

Data mapped to Ohio State Plane North NAD83, map grid units in feet.

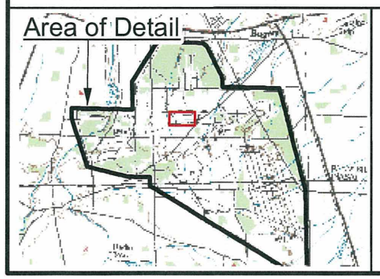
JACOBS

Location Map, Acid Area 1

Plum Brook Ordnance Works
Sandusky, Ohio

07/01/08 JP X:/GIS/Projects/Plumbrook/Projects/AA2_3 HHRA/ArcGIS/AA1_LocMap.mxd

Figure 1-2



Legend

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway
- Monitoring Well
- Piezometer
- Soil Boring
- Surface Water/Sediment

0 50 100 200
Feet

N

Notes: *Aerial Photography from 1958.*
Data mapped to Ohio Stateplane North NAD83, map units are feet.

JE JACOBS

Site Layout

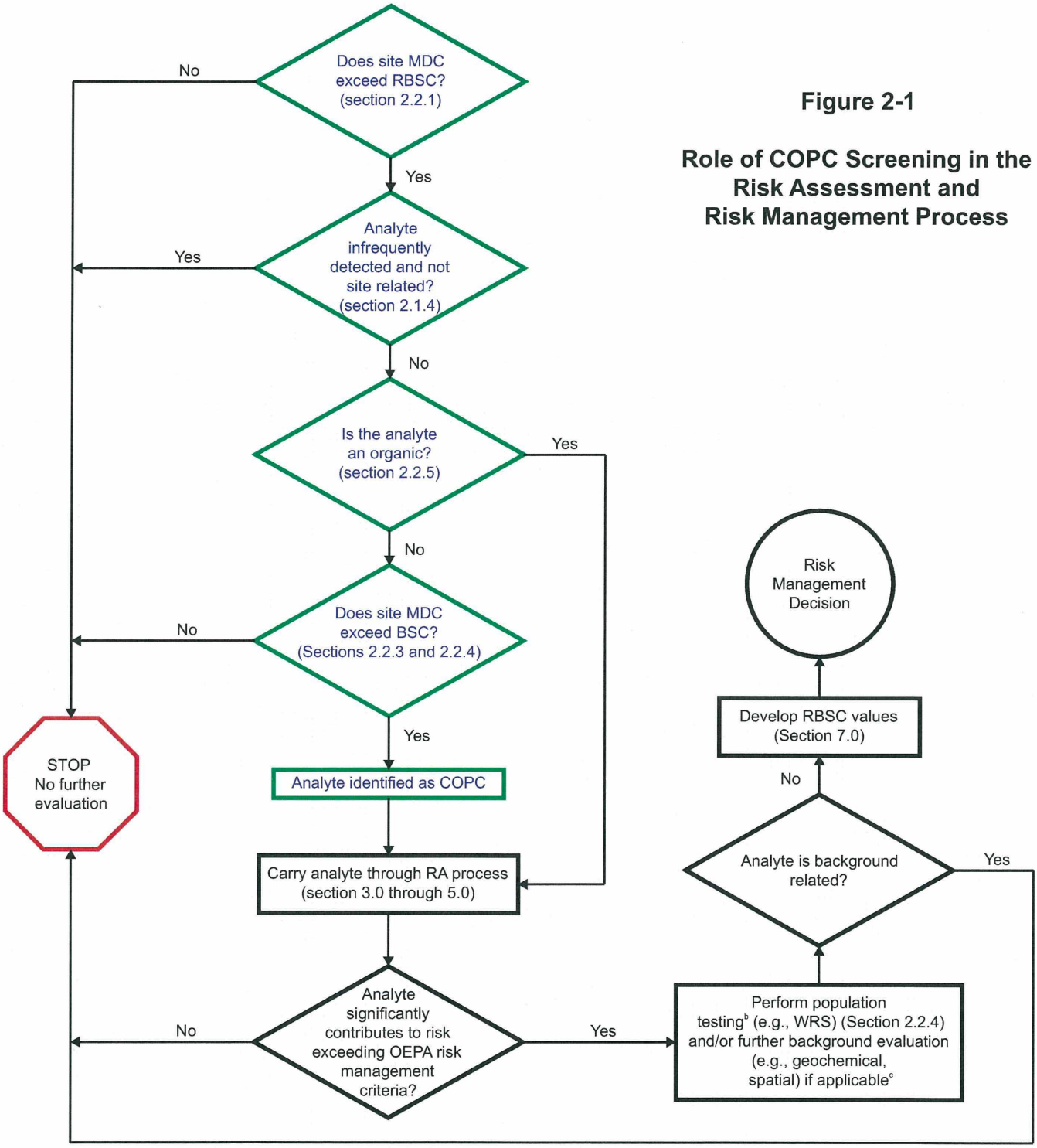
Plum Brook Ordnance Works
Sandusky, Ohio

11/7/08 JP Y:/GIS/Projects/Plumbrook/Projects/AA1_Draft_SAP/ArcMap/Survey/AA1_Locations.mxd

Figure 1-3

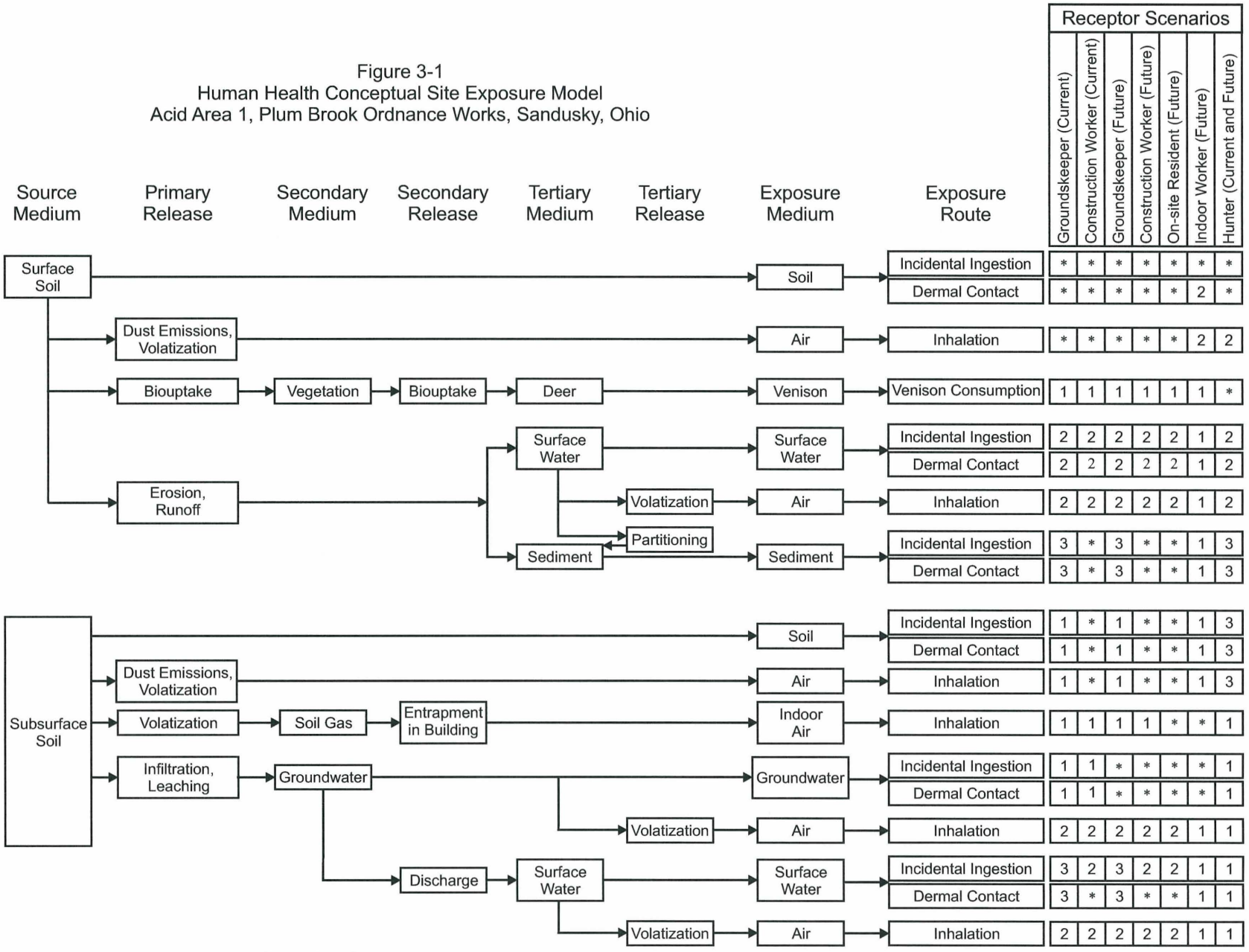
Figure 2-1

Role of COPC Screening in the Risk Assessment and Risk Management Process



Notes:
a - COPC screening steps are shown in blue
b - A judgement may be made at this step to forego or modify population testing if the site data is clearly greater than background and/or individual exceedances suggest the presence of a hot spot
c - Refer to Appendix M of the 2004 Groundwater Data Summary and Evaluation Report (Shaw, 2005)
BSC - background screening concentration
COPC - chemical of potential concern
MDC - maximum detected concentration
OEPA - Ohio Environmental Protection Agency
RA - risk assessment
RBC - risk-based remediation criterion
RBSC - risk-based screening concentration
WRS - Wilcoxon rank sum (test)

Figure 3-1
Human Health Conceptual Site Exposure Model
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio



* = Complete exposure route quantified in the risk assessment.
1 = There is no plausible pathway for exposure in this medium.
2 = Although theoretically complete, this pathway in not quantified as explained in text.
3 = Contact with this medium, although plausible, is not part of this receptor's normal or expected activities; therefore, contact would be sporadic and is not quantified.

Table 2-1

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)	Analysis
Soil	AA1-SB01	IT, 1998	0-1, 8-10	VOCs, SVOCs, PCBs (surface soil only), metals, nitroaromatics
	AA1-SB02	IT, 1998	0-1, 6-8	VOCs, SVOCs, PCBs (surface soil only), metals, nitroaromatics
	AA1-SB03	IT, 1998	0-1, 6-8	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB04	IT, 1998	0-1, 8-10	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB05	IT, 1998	0-1, 6-8	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB06	IT, 1998	0-1, 6-8	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB07	IT, 1998	0-1, 2-4	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB08	IT, 1998	0-1, 2-4	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB09	IT, 1998	0-1, 2-4	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB10	IT, 1998	0-1, 4-6	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB11	IT, 1998	0-1, 4-6	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB12	IT, 1998	0-1, 2-4	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB13	IT, 1998	0-1, 2-4	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB14	IT, 1998	0-1, 8-10	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB15	IT, 1998	0-1, 8-10	VOCs, SVOCs, PCBs (surface soil only), metals
	AA1-SB16	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB17	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB18	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB19	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB20	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB21	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB22	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB23	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB24	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB25	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB26	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB27	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB28	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB29	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs

Table 2-1

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)	Analysis
Soil (cont)	AA1-SB30	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB31	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB32	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB33	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB34	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB35	Jacobs, 2007	0.5-1.5, 3-5	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB36	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB37	Jacobs, 2007	0.5-1.5, 8-10	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SB38	Jacobs, 2007	0.5-1.5	VOCs, SVOCs, nitroaromatics, metals, PCBs
Surface Water	AA1-SWSD-01	Jacobs, 2005	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-02	Jacobs, 2005	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-03	Jacobs, 2005	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-04	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-05	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-06	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-07	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-08	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-09	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-10	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-11	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-12	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-13	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-14	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-15	Jacobs, 2006	N/A	VOCs, SVOCs, nitroaromatics, metals, PCBs
Sediment	AA1-SWSD-01	Jacobs, 2004	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-02	Jacobs, 2004	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-03	Jacobs, 2004	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-04	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-05	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-06	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs

Table 2-1

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)	Analysis
Sediment (cont)	AA1-SWSD-07	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-08	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-09	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-10	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-11	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-12	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-13	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-14	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-SWSD-15	Jacobs, 2006	0 - 0.75	VOCs, SVOCs, nitroaromatics, metals, PCBs
Overburden Groundwater	AA1-GW002	Nov 1997 May 1998 Nov 2007 May 2008	15 - 25 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-GW003	Nov 2007 May 2008	6.85 - 11.85 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-GW004	Nov 2007 May 2008	7 - 12 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-GW005	Nov 2007 May 2008	7 - 12 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
Bedrock Groundwater	AA1-BEDGW-001	Nov 1997 May 1998 Nov 2007 May 2008	26.2 - 51.2 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-BEDGW-002	Nov 2007 May 2008	51.1 - 66.1 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-BEDGW-003	Nov 2007 May 2008	47.4 - 67.4 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs
	AA1-BEDGW-004	Nov 2007 May 2008	46.4 - 71.4 (feet below TOC)	VOCs, SVOCs, nitroaromatics, metals, PCBs

Table 3-1
Receptor/Exposure Scenarios
Acid Area 1
Plum Brook Ordnance Works, Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Pathway
	Groundskeeper		
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Total soil	Not quantified[a]		
Groundwater	Not quantified[a]		
Surface water	Not quantified[b]		
Sediment	Not quantified[b]		
	Indoor Worker		
Surface soil	None	Soil	Incidental ingestion Dermal contact
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Total soil	Not quantified[a]		
Groundwater	None	Groundwater	Ingestion Dermal contact
Surface water	Not quantified[a]		
Sediment	Not quantified[a]		
	Construction Worker		
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Groundwater	Not quantified[b]		
Surface water	None	Surface water	Incidental ingestion Dermal contact
	Volatilization from water	Ambient air	Inhalation
Sediment	None	Sediment	Incidental ingestion Dermal contact

Table 3-1 (continued)

Source Medium	Model	Exposure Medium	Exposure Pathway
	On-Site Resident		
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on wind erosion	Ambient air	Inhalation
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Groundwater	None	Groundwater	Ingestion Dermal contact
	Volatilization from groundwater	Ambient air	Inhalation
Surface water	None	Surface water	Incidental Ingestion Dermal contact
	Volatilization from water	Ambient air	Inhalation
Sediment	None	Sediment	Incidental ingestion Dermal contact
	Hunter		
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Dust, volatilization	Ambient air	Inhalation
	Bio uptake	Venison	Venison consumption
Groundwater	Not quantified[a]		

a There is no plausible pathway for exposure to this medium.

b Although contact with this medium is possible, exposure would be sporadic rather than continuous or predictable. Such exposures do not lend themselves to evaluation under the chronic toxicity paradigm used in a baseline risk assessment. Although theoretically complete, this pathway is not quantified as explained in text.

Table 3-2
Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
General Variables Used in All Intake Models					
Body weight (BW), kg	70[a]	70[a]	Child: 15[b] Adult: 70[a]	70[a]	Child: 15[b] Adult: 70[a]
Averaging time, noncancer (AT), day_{sd}	9125	183	Child: 2190 Adult: 8760	9125	Child: 2190 Adult: 10950
Averaging time, cancer (AT), day_{se}	25550	25550	25550	25550	25550
Inhalation of VOCs and Resuspended Dust from Surface Soil, Total Soil or Subsurface Soil					
Fraction exposed to contaminated medium(FI_a), unitless	1[c]	1[c]	1[c]	NA	NA
Inhalation rate (IR_a), m^3/day	20[a]	20[a]	Child: 10[b] Adult: 20[a]	NA	NA
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	NA
Exposure duration (ED), years	25[a]	0.5[b]	Child: 6[b] Adult: 24[b]	NA	NA
Inhalation of VOCs in Indoor Air from Subsurface Soil					
Fraction exposed to contaminated medium(FI_a), unitless	NA	NA	1[c]	1[c]	NA
Inhalation rate (IR_a), m^3/day	NA	NA	Child: 6.8[c] Adult: 13.7[c]	20[a]	NA
Exposure frequency (EF), days/year	NA	NA	350[a]	250[a]	NA
Exposure duration (ED), years	NA	NA	Child: 6[b] Adult: 24[b]	25[a]	NA
Incidental Ingestion of Soil					
Fraction exposed to contaminated medium(FI_{so}), unitless	1[c]	1[c]	0.9[c]	1[c]	1[c]
Soil incidental ingestion rate (IR_{so}), mg/day	100[a]	290[c]	Child: 200[b] Adult: 100[a]	50[a]	Child: NA Adult: 100[a]
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	250[a]	14[c]
Exposure duration (ED), years	25[a]	0.5[c]	Child: 6[b] Adult: 24[b]	25[a]	30[a]

Table 3-2 (Continued)

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Incidental Ingestion of Sediment					
Fraction exposed to contaminated medium(FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Sediment incidental ingestion rate (IR_{sd}),mg/day	NA	290[c]	Child: 200[b] Adult: 100[a]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Dermal Contact with Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	0.9[c]	NA	1[c]
Body surface area exposed to soil (SA_{so}), cm^2	11,300[f]	11,300[f]	Child: 1750[g] Adult: 4550[g]	NA	Child: NA Adult: 4550[g]
Soil-to-skin adherence factor (AF_{so}),mg/cm^2	0.009[f]	0.08[f]	0.2[g]	NA	0.2[g]
Dermal absorption factor (ABS), unitless	csv	csv	csv	NA	csv
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	14[c]
Exposure duration (ED), years	25a	0.5[c]	Child: 6[b] Adult: 24[b]	NA	30[a]
Dermal Contact with Sediment					
Fraction exposed to contaminated medium(FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Body surface area exposed to sediment(SA_{sd}), cm^2	NA	3100[f]	Child: 1750[g] Adult: 4550[g]	NA	NA
Sediment-to-skin adherence factor (AF_{sd}),mg/cm^2	NA	0.24[f]	0.2[g]	NA	NA
Dermal absorption factor (ABS), unitless	NA	csv	csv	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA

Table 3-2 (Continued)

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Dermal Contact with Surface Water					
Body surface area exposed to surface water (SA_{sw}), cm^2	NA	3100[f]	Child: 2100[g] Adult: 5450[g]	NA	NA
Permeability coefficient (PC), cm/hour	NA	csv	csv	NA	NA
Exposure time (ET_{sw}), hour/day	NA	4[c]	3[c]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	52[c]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Venison Consumption					
Venison ingestion rate (IR_v), kg/day	NA	NA	NA	NA	Child: 0.005[c] Adult: 0.013[c]
Exposure frequency (EF), days/year	NA	NA	NA	NA	350[a]
Exposure duration (ED), years	NA	NA	NA	NA	Child: 6[b] Adult: 30[a]

a U.S. Environmental Protection Agency (EPA), 1991, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.603.

b U.S. Environmental Protection Agency (EPA), 1999, *EPA Region 9: Preliminary Remediation Goals (PRGs) 1999*, 3 December, on-line.

c Assumed; see text.

d Calculated as the product of ED (years) x 365 days/year.

e Calculated as the product of 70 years (assumed human lifetime) x 365 days/year.

f U.S. Environmental Protection Agency (EPA), 1997b, *Exposure Factors Handbook*, Final, National Center for Environmental Assessment, Washington, DC, EPA/600/P-95/002Fa, August.

g U.S. Environmental Protection Agency (EPA), 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

NA = not applicable to this receptor; csv = chemical-specific value.

Table 3-3
Variables Used to Estimate Potential Chemical Intake and Contact Rates from Groundwater
Acid Area 1, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	On-site Worker	Resident
General Variables		
Exposure duration (ED), years	25[a]	Child: 6[b] Adult: 24[b]
Body weight (BW), kg	70[a]	Child: 15[b] Adult: 70[a]
Averaging time, noncancer (AT), days[c]	9125	Child: 2190 Adult: 8760
Averaging time, cancer (AT), days[c]	25550	25550
Inhalation of VOCs from Groundwater		
Exposure time (ET), hours/day	NA	24[d]
Inhalation rate (IR_a), m^3/hour	NA	Child: 0.416[b] Adult: 0.833[b]
Exposure frequency (EF), days/year	250[a]	350[a]
Drinking Water Ingestion of Groundwater		
Fraction exposed to contaminated medium (FI_{gw}), unitless	1[f]	1[f]
Drinking water ingestion rate (IR_{gw}), L/day	1[a]	Child: 1[b] Adult: 2[a]
Exposure frequency (EF), days/year	250[a]	350[a]
Dermal Contact with Groundwater		
Fraction exposed to contaminated medium (FI_{gw}), unitless	1[e]	1[e]
Body surface area exposed to water (Sa_{gw}), cm^2	3300[g]	Child: 6600[f] Adult: 20000[f]
Permeability coefficient (PC), cm/hour	csv	csv
Exposure time (ET_{gw}), hours/day	1[f]	Child: 0.333[g] Adult: 0.2[d]
Exposure frequency (EF), days/year	250[a]	350[a]

cm - Centimeter.
cm^2 - Square centimeter.
csv - Chemical-specific value.
kg - Kilogram.
L - Liters.
m^3 - Cubic meters.
NA - Not applicable to this receptor.
VOC - Volatile organic compound.

[a] U.S. Environmental Protection Agency (EPA), 1991a, *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors* , Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.603.

[b] U.S. Environmental Protection Agency (EPA), 2004c, *User's Guide and Background Technical Document for EPA Region 9 Preliminary Remediation Goals (PRG) Table* , Region 9, San Francisco, California, October.

[c] Calculated as the product of ED (years) x 365 days/year.

[d] The *Exposure Factors Handbook* (see reference g) indicates that the 90th percentile for the amount of

time spent at a residence is more than 23 hours per day.

[e] Assumed; see text.

[f] U.S. Environmental Protection Agency (EPA), 2004a, *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)* , Final, Office of Superfund Remediation and Technology Innovation, Washington, D.C., July, EPA/540/R-99/005.

[g] U.S. Environmental Protection Agency, (EPA), 1997a, *Exposure Factors Handbook* , Final, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002Fa, August.

References

Foster, S. A. and P. C. Chrostowski, 1987, "Inhalation Exposures to Volatile Organic Contaminants in the Shower," Presentation at the ***80th Annual Meeting of the Air Pollution Control Association***, June 21-28.

Ohio Environmental Protection Agency (OEPA), 2004, e-mail correspondence from L. Moore (OEPA Risk Assessor) to L. Long (USACE Risk Assessor), December 15.

U.S. Environmental Protection Agency (EPA), 2004a, ***Risk-Based Concentration Table***, memorandum from Jennifer Hubbard (Region 3 Toxicologist) to RBC Table users, Philadelphia, Pennsylvania, April, <http://www.epa.gov/reg3hwmd/risk/human/index.htm>.

U.S. Environmental Protection Agency (EPA), 2004b, ***User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table***, Region 9, San Francisco, California, October, <http://www.epa.gov/region09/waste/sfund/prg/files/04usersguide.pdg>.

U.S. Environmental Protection Agency (EPA), 1995, ***Supplemental Guidance to RAGS: Region 4 Bulletins Human Health Risk Assessment***, Waste Management Division, Atlanta, Georgia, November.

U.S. Environmental Protection Agency (EPA), 1991b, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim***, Office of Emergency and Remedial Response, Washington, D.C., December (EPA/540/R-92/003).

FINAL SCREENING ECOLOGICAL RISK ASSESSMENT WORK PLAN
Acid Area 1

Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
CONTRACT DACW62-03-D-0004-0009

Prepared by:

JACOBS™

JACOBS ENGINEERING GROUP, INC.
125 BROADWAY AVENUE
OAK RIDGE, TN 37830

April 2009

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

Jacobs Engineering Group, Inc. has completed the Final Screening Level Ecological Risk Assessment Work Plan for Acid Area 1 at the Former Plum Brook Ordnance Works, Sandusky, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

Al Hardesty	geologist	4-6-09
(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

Jon Ross	wildlife biologist	4-6-09
(Signature)	(Discipline)	(Date)

Jacobs SLERA Work Plan Author

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

All reviewer comments have been addressed and responses are included in the appendix.

Al Hardesty 4-6-09

(Signature) (Date)

(Project Manager)

Table of Contents

Section ..... **Page**

List of Appendices iii

List of Figures iii

List of Acronyms and Abbreviations iv

1.0 INTRODUCTION 1-1

1.1 FACILITY DESCRIPTION 1-1

1.2 BACKGROUND 1-2

1.3 SCOPE AND OBJECTIVES 1-3

2.0 PROBLEM FORMULATION 2-1

2.1 ECOLOGICAL SITE DESCRIPTION 2-1

2.2 PRE-ASSESSMENT RECONNAISSANCE (BIOTA CHECKLIST) 2-1

2.3 POTENTIAL RECEPTORS OF SPECIAL CONCERN AND CRITICAL HABITAT ... 2-3

2.4 SIGNIFICANT ECOLOGICAL THREATS 2-3

2.5 REVIEW, EVALUATION, AND PRESENTATION OF ANALYTICAL DATA 2-3

2.6 SELECTION OF CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN 2-3

2.6.1 Data Organization 2-3

2.6.2 Descriptive Statistical Calculations 2-4

2.6.3 Frequency of Detection 2-6

2.6.4 Natural Site Constituents (Background and Essential Nutrients) 2-7

2.6.5 Comparison to Risk-Based Screening Ecotoxicity Values 2-7

2.6.6 Summary of COPEC Selection 2-8

2.7 SELECTION OF ASSESSMENT RECEPTORS 2-9

2.8 ECOLOGICAL ENDPOINT (ASSESSMENT AND MEASUREMENT) IDENTIFICATION 2-10

2.9 ECOLOGICAL SITE CONCEPTUAL MODEL 2-11

3.0 EXPOSURE CHARACTERIZATION 3-1

3.1 EXPOSURE ANALYSIS 3-1

3.2 EXPOSURE CHARACTERIZATION SUMMARY 3-6

4.0 ECOLOGICAL EFFECTS CHARACTERIZATION 4-1

4.1 SELECTION OF LITERATURE BENCHMARK VALUES 4-1

4.2 DEVELOPMENT OF TOXICITY REFERENCE VALUES 4-1

5.0 RISK CHARACTERIZATION 5-1

5.1 RISK ESTIMATION 5-1
5.2 UNCERTAINTY ANALYSIS 5-1
5.3 RISK DESCRIPTION 5-3
6.0 RISK SUMMARY AND IDENTIFICATION OF PRELIMINARY REMEDIAL ACTION OBJECTIVES 6-1
7.0 CONCLUSIONS AND RECOMMENDATIONS 7-1
8.0 REFERENCES 8-1

List of Appendices

Appendix Response to comments

List of Figures

Figure 1-1 Location Map, Plum Brook Ordnance Works, Sandusky, Ohio
Figure 1-2 Location Map, Acid Area 1
Figure 1-3 Site Layout, Acid Area 1
Figure 3-1 Surface Water/Sediment Sampling Locations, Acid Area 1

List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
amsl	above mean sea level
ARP	assessment receptor profile
AST	aboveground storage tank
BAF	bioaccumulation factor
BCF	bioconcentration factor
bgs	below ground surface
Bldg.	building
BTAG	Biological Technical Advisory Group
CELRN	U.S. Army Corps of Engineers, Nashville District
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
DERP-FUDS	Defense Environmental Restoration Program-Formerly Used Defense Sites
DNT	dinitrotoluene
DOD	U.S. Department of Defense
EDQL	ecological data quality levels
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESCM	ecological site conceptual model
FCM	food chain multiplier
ft	feet
HQ	hazard quotient
IT	IT Corporation
Jacobs	Jacobs Engineering Group Inc.
kg	kilograms
K_{oc}	soil adsorption coefficient
K_{ow}	octanol-water partition coefficient
L	liters
LOAEL	lowest observed adverse effect level
MDC	maximum detected concentration
mg	milligrams
NASA	National Aeronautics and Space Administration
NOAEL	no observed adverse effect level
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
RA	risk assessment
RBSEV	risk-based screening ecotoxicity value
RI	remedial investigation
SI	site investigation
SLERA	screening-level ecological risk assessment
TNT	trinitrotoluene

TRV	toxicity reference value
TTD	terrestrial toxicity database
UCL	upper confidence limit
UCL_{95}	95th percent upper confidence limit on the arithmetic mean
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
WQC	water quality criteria
WTA	wildlife toxicity assessments

1.0 INTRODUCTION

This screening level ecological risk assessment (SLERA) work plan presents the protocol for evaluating the potential for adverse effects posed to ecological receptors from suspected hazardous substance releases at Acid Area 1 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio.

This work plan was prepared by Jacobs Engineering Group (Jacobs) under contract DACW62-03-D-0004, Delivery Order #8. This work is being conducted for the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) - Formerly Used Defense Sites (FUDS). Investigations at PBOW under DERP-FUDS are being managed by the USACE, Huntington District and technically overseen by the USACE Nashville District (CELRN).

This work plan is consistent with U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (OEPA) – Division of Emergency and Remedial Response guidance (OEPA, 2008) and with the procedures established in the Baseline Ecological Risk Assessment Work Plan for Trinitrotoluene (TNT) Areas A & C soil (IT Corporation [IT], 2001) and the SLERA work plan for Acid Areas 2 and 3 (Jacobs, 2007).

1.1 Facility Description

PBOW is located approximately 4 miles south of Sandusky, Ohio, and 59 miles west of Cleveland (Figure 1-1). Although located primarily in Perkins and Oxford Townships, the eastern edge of the facility extends into Huron and Milan Townships. PBOW is bounded on the north by Bogart Road, on the south by Mason Road, on the west by Patten Tract Road, and on the east by U.S. Highway 250. The area surrounding PBOW is mostly agricultural and residential (IT, 2001). The facility is currently surrounded by a chain-link fence, and the perimeter is regularly patrolled. Access by authorized personnel is limited to established checkpoints. Public access is restricted, except during the annual deer hunting season.

The Acid Area 1 site is located in the central portion of PBOW, adjacent to Taylor Road, between Maintenance Road and Fox Road (Figure 1-2) (Jacobs, 2006), covering an area approximately 20 acres in size. The site physical features include an open field bounded by a drainage ditch to the south with scattered overgrowth throughout. Two railroad grades run east-west through the site: one on the southern perimeter and one through the northern portion of the site. The original service road encircles the site. The road is in fair condition and clear of vegetation. Buildings 302, 308, and 310 are the only remaining original structures at the site. All other buildings and tanks have been removed. The National Aeronautics and Space Administration (NASA) constructed a metal building between former Building 301 and Building 302. This building was formerly used by NASA as an incinerator, but is currently used for equipment storage.

The ground surface at Acid Area 1 is relatively flat, with minimal slope toward the drainage ditches to the north, south, and west. Elevations at the site range from 629 to 640 feet (ft) above mean sea level (amsl). Four drainage features are present at the site. The drainage ditch to the south is located approximately 40 ft south of the service road and drains to the west,

parallel to the site, discharging into Ransom Brook west of the site. This drainage feature has little relief adjacent to the site. Another drainage ditch originates on site on the north central portion of the site and drains to the north. This drainage feature is approximately 30 to 40 ft wide and 15 to 18 ft deep just north of the Acid Area 1 site. A third drainage ditch originates in a low swampy area in the west central portion of the site and drains to the west into Ransom Brook. The fourth drainage ditch originates at a ponded area with a man-made dike in the northwest corner of the site, which also drains west into Ransom Brook. Flowing water has been observed in all four drainage ditches during the wet season in early to mid Spring. All but the northern drainage ditch dry up by mid summer including the ponded area and the swampy area.

1.2 Background

The 9,009-acre PBOW site was built in early 1941 as a manufacturing plant for trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite. Production of explosives began in December 1941 and continued until 1945. It is estimated that more than one billion pounds of explosives were manufactured during the four-year operating period.

NASA acquired PBOW in 1963 and presently utilizes about 6,400 acres for conducting space research. The site is operated by NASA as the Plum Brook Station of the John Glenn Research Center, which is headquartered in Cleveland, Ohio. In 1978 NASA declared approximately 2,152 acres of land as excess (IT, 1997). The Perkins Township Board of Education acquired 46 acres of the excess property for use as a bus transportation center. The Ohio National Guard has an agreement with the U.S. General Services Administration to use 604 acres of the facility.

The acid production areas were in operation from 1941 to 1945 to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. A records review was conducted by IT Corporation (IT) in preparation for a Site Investigation (SI) of the Acid Areas (IT 1998). The records review indicated that no previous investigations had been conducted at Acid Area 1. Available drawings of the site were used to identify some facility components. A review of the 1958 aerial photographs revealed several buildings and aboveground storage tanks (ASTs) at Acid Area 1. The majority of the site facilities were dismantled between 1958 and 1963.

Acid Area 1 consisted of eight buildings (Buildings (Bldgs.) 301-304, Bldgs. 306-308, and Bldg. 310), 43 ASTs, and two rail lines (Figure 1-3). Buildings 302 Sulphuric Acid Concentration Plant, 308 Ammonia Oxidation Plant, and 310 are the only remaining original structures at the site. No information was obtained during the IT records review to indicate the type of process conducted at each building; however, identification of five storage areas was determined from the drawings: Oleum Storage (12 tanks), Concentrating Mix Storage (six tanks), Sulfuric Acid Sales (12 tanks), TNT Residual Acid Storage (five tanks), and Mixed Storage (eight horizontal tanks) as shown on Figure 1-3. Based on the location of the Oleum Storage, Sulfuric Acid Sales Storage, and Mixed Storage in close proximity to the rail line, the stored material was likely transferred directly to and from tanker cars or containers on a routine basis.

An SI of Acid Area 1 was conducted in 1998 by IT to determine the existence and nature of contamination, and to evaluate potential risks to human health and the environment (IT, 1998).

Fifteen soil borings were completed to characterize lithology and to collect soil samples for off-site laboratory analysis. Total depths of these borings ranged from 4 to 10 ft below ground surface (bgs).

A Remedial Investigation (RI) was performed May 2007 through May 2008 to define the extent of soil contamination and to evaluate impacts to the groundwater, surface water, and sediment in the vicinity of Acid Area 1. A total of 45 soil samples were collected from 23 locations, which were placed adjacent to buildings and storage tanks. A total of 15 co-located surface water and sediment samples were collected from the drainage ditches. At least one upgradient and one downgradient sample was collected from each of the four drainage ditches.

1.3 Scope and Objectives

A SLERA will be performed to provide an estimate of the potential for adverse ecological effects associated with suspected hazardous substance releases at Acid Area 1. The results of the SLERA will contribute to the overall characterization of the site and may be used to determine the need for additional investigations or to develop, evaluate, and select appropriate remedial alternatives. The SLERA will be performed following the general guidelines of the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* (Wentsel, et al., 1996), as well as the *Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments* (U.S. Environmental Protection Agency [EPA], 1997a), *Region V Biotechnical Assistance Group (BTAG) Ecological Risk Assessment Guidance Bulletin No. 1* (EPA, 1996), and *Guidance for Conducting Ecological Risk Assessments* (OEPA, 2008). The SLERA fits into Steps 1 and 2 of the ERAGS process (EPA, 1997a).

The primary objective of the SLERA is to evaluate the potential for adverse ecological effects to ecological receptors from suspected hazardous substance releases. This objective will be met by characterizing the ecological communities in the vicinity of the site, determining the particular hazardous substances present, identifying pathways for receptor exposure, and estimating the magnitude of the likelihood of potential adverse effects to identified receptors. The SLERA will address the potential for adverse effects to the vegetation, wildlife, aquatic life (sediment-dwelling organisms), threatened and endangered species, and wetlands or other sensitive habitats associated with the site. Because of the ephemeral nature of the surface water drainage, it does not support fish.

Concentrations of chemicals measured in relevant environmental media, including soil and sediment (Jacobs, 2006) will be used to perform a SLERA, including problem formulation (Section 2.0); exposure characterization (Section 3.0); ecological effects characterization (Section 4.0); risk characterization (Section 5.0); summary of risks and identification of preliminary remedial action objectives (Section 6.0); and conclusions and recommendations (Section 7.0). These subtasks are described in greater detail in the following sections.

The chemicals of potential ecological concern (COPEC), the ecosystems and receptors at risk, the ecotoxicity of the contaminants known or suspected to be present, and observed or anticipated ecological effects will be evaluated. This evaluation will be conducted in two steps: (1) a screening assessment step and (2) a predictive assessment step. Ecological endpoints to

be addressed in both steps will be identified. The results and conclusions of the screening assessment will determine whether a predictive assessment is needed. The criteria by which the need for a predictive assessment is measured will be formalized as null hypotheses to be accepted (in which case a predictive assessment is not needed) or rejected (in which case a predictive assessment is needed).

2.0 PROBLEM FORMULATION

The screening assessment null hypotheses are as follows:

- Potential for adverse ecological effects to ecological entities at the site is minimal or nonexistent due to the lack of viable habitat for potential ecological receptors.
- Potential for adverse ecological effects to ecological entities at the site is minimal or nonexistent due to the lack of potential ecological receptors.
- Potential for adverse ecological effects to ecological entities at the site is minimal or nonexistent due to the lack of potential exposure pathways.
- Potential for adverse ecological effects to ecological entities at the site is minimal or nonexistent due to the lack of potential chemical stressors.

If one or more of these null hypotheses are accepted, a predictive assessment is not triggered. All four null hypotheses must be rejected for a predictive assessment to be triggered. The first three null hypotheses are tested with the results of the ecological site description (Section 2.1), the pre-assessment reconnaissance (Section 2.2), the documentation of potential receptors of special concern and critical habitats (Section 2.3), and the determination of significant ecological threats (Section 2.4). The fourth null hypothesis will be tested with the results of COPEC selection (Sections 2.5 and 2.6).

If a predictive assessment is triggered, terrestrial and aquatic ecological conceptual site models will be developed, as appropriate, and additional problem formulation tasks will be performed as described in Sections 2.7 to 2.9 of this work plan.

2.1 Ecological Site Description

The site will be described in sufficient detail to ensure that the CELRN technical specialist can be oriented to the site. This information will be assembled from existing sources. Natural resource personnel (e.g., federal or state officials) will be contacted to obtain any relevant data or useful ecological information. Two pre-assessment reconnaissance/ecological survey will be performed to validate the findings as described in Section 2.2. Data from the Acid Area 1 site will be presented in tables discussed in text in the SLERA report.

2.2 Pre-Assessment Reconnaissance (Biota Checklist)

Two site reconnaissances will be performed for the purpose of collecting qualitative information on the type, quality, and location of biological resources at Acid Area 1. The assessment duration will be about one day each. This will be achieved as follows:

- Dominant plant species will be identified by a qualified botanist, and plant communities will be defined based on dominant species observed.

- Observations of fauna will be made by a qualified biologist or ecologist. Mammals will be identified by tracks, scat, burrows, and sightings. Bird, reptile, and amphibian identifications will be made by sightings.

- Areas will be examined for vegetative stress. Stress may be exhibited by stunted growth, poor foliage growth, tissue discoloration, and a loss of leaf coverage. Due to the seasonal component of this evaluation, the survey will be performed during late spring to late summer, as the schedule permits.

The purpose of these activities will be to select representative receptors, refine exposure scenarios for the risk assessment (RA), and identify protected species or habitats of special concern in the study area.

Site reconnaissance will be performed by an expert in the identification of Northern Ohio flora and fauna and one of the onsite personnel. Prior to arrival at the site, reconnaissance personnel will obtain relevant information on the site, including topographic maps; township, county, or other appropriate maps; and location of potential ecological units such as streams, creeks, ponds, grasslands, forest, and wetlands on or near the site. Additionally, the *Biological Inventory of Plum Brook Station, 1994* (NASA, 1995), which identifies and shows the locations of threatened and endangered species at PBOW, as well as results of extensive wildlife surveys, will be reviewed. Reconnaissance personnel will complete a checklist consistent with EPA's *Checklist for Ecological Assessment/Sampling* (EPA, 1997a) and OEPA's Ecological Risk Assessment Guidance (OEPA, 2008). The location of known or potential contaminant sources affecting the site and the probable gradient of the pathway by which contaminants may be released from the site to the surrounding environment will be identified. Reconnaissance personnel will use the reconnaissance to evaluate the site for more subtle clues of potential effects from contaminant release. The designation of any waters potentially impacted by contaminant migration will be determined.

Ecological characterization of the study area will be based on a compilation of existing ecological information and site reconnaissance activities. Methods used to characterize ecological resources will include a site walkover for the identification of existing wildlife and vegetative communities; interviews with local, state, and PBOW resource personnel; and a review of environmental data obtained from various sources (e.g., Nature Conservancy, U.S. Fish and Wildlife Service). A photographic record will be made during each site reconnaissance. Information will be obtained on the presence of state-listed and federal-listed, threatened, and endangered species; species of special concern; and wildlife and fisheries resources. A checklist of biological species present at the site will be developed using existing site investigation reports, environmental data sources mentioned previously, and information gathered during each site reconnaissance. Information on unique and special-concern habitats, preserves, wildlife refuge parks, and natural areas within the general vicinity will also be obtained.

The methods used to characterize natural resources will focus on aquatic and terrestrial resources at the site and within the immediate vicinity. If not already available, general habitat maps will be prepared showing the types and extent of biological communities present within

the immediate vicinity of the site. These maps will be based on information collected during the site reconnaissance previously discussed.

2.3 Potential Receptors of Special Concern and Critical Habitat

A determination will be made as to whether the site has designated wetlands or critical or sensitive habitats for threatened or endangered species. This will be performed, in part, by reviewing National Wetland Inventory Maps and threatened and endangered species information requested from the Ohio Department of Natural Resources Division of Natural Areas and Preserves. The site reconnaissance will not include wetlands delineation activities.

2.4 Significant Ecological Threats

A determination will be made whether significant ecological threats exist and whether these threats are related to chemical contamination caused by U.S. Department of Defense (DOD) activities. The initial screening of whether significant threats exist will be based on the qualitative absence of plant or animal life in areas expected to support these ecological components. The Acid Area 1 site will be evaluated for significant ecological threats.

2.5 Review, Evaluation, and Presentation of Analytical Data

Any relevant historical chemical analytical data will be reviewed and evaluated, as well as all data from previous and ongoing investigations. Data identified as being of acceptable quality for use in the SLERA will be summarized in a manner that presents the pertinent information to be applied. Any data rejected during the data evaluation ("R" qualified data) will be identified along with the rejection rationale. Only validated data are proposed for use in the SLERA.

2.6 Selection of Chemicals of Potential Ecological Concern

The selection of COPECs will identify a subset of site related chemicals to be carried through the RA. The data will be presented in tables in the SLERA report. Screening criteria include analytical detection limit; frequency of detection greater than 5 percent; comparison of inorganic constituent concentrations to naturally-occurring background concentrations; evaluation of site concentrations against ecologically essential nutrient concentrations; and comparison of site concentrations to ecologically relevant screening criteria. The COPEC selection process is described in more detail in the following subsections.

2.6.1 Data Organization

The data for each chemical will be sorted by medium and location and will be presented electronically by exposure unit for each indicator receptor species allowing reviewers to verify the accuracy of the RA findings. The electronic data will be provided upon request. For ecological impacts, soil from 0 to 5 ft bgs will be considered. Chemicals that are not detected at least once in a medium will not be included in the RA. Available background data will be determined for each medium. Potential sources of background information will include data from previous and current investigations. All existing data will be qualitatively reviewed for quality, usefulness, and uncertainty.

The analytical data may have qualifiers from the analytical laboratory quality control or from the data validation process that reflect the level of confidence in the data. Some of the more common qualifiers and their meanings are (EPA, 1989):

U Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.

J Value is estimated, probably below the contract-required quantitation limit.

R Quality control indicates that the data are unusable (chemical may or may not be present).

B Concentration of chemical in sample is not sufficiently higher than concentration in the blank (using the five-times, ten-times [5x, 10x] rule).

"J" qualified data are used in the RA; but "R" and "B" qualified data are not used. The handling of "U" qualified data (nondetects) is described below in this work plan. A CD-ROM of the raw data used in the RA, organized by exposure medium and exposure unit will be included with the RA report for ease in data manipulation during document review.

2.6.2 Descriptive Statistical Calculations

Because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the 95 percent upper confidence limit (UCL) of the mean are usually estimated for each chemical in each medium of interest.

The 95 percent UCL on the arithmetic mean is referred to as the UCL_{95}. In general, unusually high values are included in the calculation of the UCL_{95} because high values seldom appear as statistical outliers in environmental data. A general discussion of the statistical approaches used to derive exposure point concentrations (EPC) is presented in the following paragraphs. EPA's ProUCL Version 4 software will be used to derive EPCs for all COPECs (EPA, 2007a and EPA, 2007b).

The nature of the statistical distribution (normal, lognormal, nonparametric) is determined for chemical of potential concern (COPC) data sets having five or more samples with the Shapiro-Wilks test (EPA, 1992a). Either a normal or lognormal UCL is calculated; whichever provides the better fit in the Shapiro-Wilks test. Where either distribution provides virtually the same level of fit (at $p<0.05$) based on the Shapiro-Wilks test results, a normal distribution is selected because the UCL calculation for the normal distribution has greater mathematical stability (EPA, 1997b; Hardin and Gilbert, 1993).

A nonparametric confidence limit is calculated when the data fit neither a normal nor lognormal distribution. For data sets with less than five samples, the maximum detected concentration (MDC) is used as the EPC.

The concentration corresponding to the calculated rank order UCL_{95} may be used as the EPC for nonparametric data, unless this value is less than the mean concentration. It is theoretically

possible using the lognormal and nonparametric methods that the UCL_{95} for a given COPEC may be less than the arithmetic mean concentration. If such an instance were to occur, the arithmetic mean concentration would be used as the EPC and the COPEC data would be specifically discussed in the uncertainty analysis (Section 5.2) of the SLERA report as appropriate.

Data sets consisting of five or more data points are tested for normality and lognormality with the Shapiro-Wilk test as described above. Statistical analysis is performed only on those chemicals identified as background or site-related COPCs. The UCL_{95} is calculated for a normal distribution as follows (EPA, 1992a):

$$UCL_{95} = \bar{x} + t_{1-a,n-1}\left(\frac{s}{\sqrt{n}}\right) \qquad \textbf{Eq. 2.1}$$

where:

UCL_{95} = upper 95th confidence limit on the arithmetic mean concentration (calculated)

$\bar{x}$ = sample arithmetic mean

t_1 = critical value for Student's *t*-test

α = 0.05 (95 percent confidence limit for a one-tailed test)

n = number of samples in the data set

s = sample standard deviation.

The UCL_{95} will be calculated for a lognormal distribution as follows (Gilbert, 1987):

$$UCL_{95} = e^{\left(\bar{Y}+0.5s_y^2+\left[H_{0.95}\frac{s_y}{(n-1)^{0.5}}\right]\right)} \qquad \textbf{Eq. 2.2}$$

where:

UCL_{95} = 95 percent upper confidence limit on the arithmetic mean (calculated)

$\bar{Y}$ = Σy/n = sample arithmetic mean of the log-transformed data

S_y = ln x = sample standard deviation of the log-transformed data

n = number of samples in the data set

$H_{0.95}$ = value for computing the one-sided upper 95 percent confidence limit on a lognormal mean from standard statistical tables.

If the data distribution is nonparametric, the data point selected as the nonparametric UCL may be estimated as the 95 percent UCL rank order on the arithmetic mean of the data set. It may be estimated by ranking the data observations from smallest to largest. The arithmetic mean is converted to a percentile by interpolation. The rank order of the data point selected as the UCL may be estimated from the following equation (Gilbert, 1987):

$$u = p(n+1) + Z_{1-\alpha}\sqrt{np(1-p)} \qquad \textbf{Eq. 2.3}$$

where:

u = rank order of value selected as UCL, calculated

p = percentile corresponding to the arithmetic mean

n = number of samples in the data set

α = confidence limit (95 percent)

$Z_{1-\alpha}$ = normal deviate variable.

Analytical data from field duplicates will be averaged with originals to yield one result for use in the statistical manipulations.

Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. Analytical results are presented as nondetects ("U" qualifier) whenever chemical concentrations in samples do not exceed the detection limits for the analytical procedures for those samples. To apply the statistical procedures described above, a concentration value must be assigned to nondetects. Generally, nondetects are assumed to be present at one-half the detection limit (EPA, 1989). However, judgment is used in those cases where the detection limit is unusually high. For example, elevated detection limits that exceed the MDC due to matrix interference or sample dilution may be eliminated from the data set and not used in the estimation of the EPC.

The UCL_{95} or MDC, whichever is smaller, will be selected as the EPC and is understood to represent a conservative estimate of average for use in the RA or in various transport models used to estimate EPCs. If the data set consists of fewer than five data points, the MDC will be selected as the EPC. The impact of eliminated data points on the adequacy of the data sets and the risk estimates will be discussed in the uncertainty analysis (Section 6.0) of the SLERA report.

2.6.3 Frequency of Detection

Chemicals that are detected infrequently may be artifacts in the data that do not reflect site-related activity or disposal practices. These chemicals will not be included in the evaluation. Generally, chemicals that are detected only at low concentrations in less than 5 percent of the samples from a given medium are dropped from further consideration unless their presence is expected based on historical information about the site (such as nitroaromatics

in the present case). Chemicals detected infrequently at high concentrations may identify the existence of "hot spots" and will be retained in the evaluation unless other information exists to suggest that their presence is unlikely to be related to site activities.

2.6.4 Natural Site Constituents (Background and Essential Nutrients)

Chemical concentrations will be compared to site-specific background concentrations as an indication of whether a chemical is present from site-related activity or as natural background.

Essential nutrients such as calcium, chloride, iodine, magnesium, phosphorus, potassium and sodium may be eliminated as COPECs, provided that their presence in a particular medium is judged to be unlikely to cause adverse effects on wildlife. However, as most nutrients do not have readily available ecological screening criteria, nutrients will be retained in the SLERA (if not background related) and assessed in an ecological effects characterization (as described in Section 4.0).

2.6.5 Comparison to Risk-Based Screening Ecotoxicity Values

A comparison will be made between MDCs of chemicals in media and risk-based screening ecotoxicity value (RBSEV) for ecological endpoints following recommendations received from OEPA and as discussed in EPA Region V BTAG Bulletin No. 1 (EPA, 1996). Chemicals that exceed the RBSEVs, or for which no RBSEVs are available, will be retained as COPECs. The RBSEVs or RBSEV hierarchy (as noted) described below will be used for the ecological evaluation.

Soil: Soil screening values will be selected using the following hierarchy: (1) EPA Ecological Soil Screening Levels; (2) Preliminary Remediation Goals (PRGs) for Ecological Endpoints (Efroymson et. al., 1997a); (3); Ecological Screening Levels, U.S. EPA, Region V, (EPA, 2003). (4) Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process (Efroymson et. al., 1997b); (5) Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants (Efroymson et. al., 1997c); and (6) Ecological Data Quality Levels (EDQLs) (EPA, 1999a). It should be noted that potential effects on heterotrophic processes based on this screening may not be relevant to ecological receptors of concern at the site. Additionally, it is important to note that exceedances of the benchmarks for soil biota do not indicate that these species are either harmed or absent from the site.

Groundwater: If groundwater is known to impact surface water at the site, surface water RBSEVs will be used as discussed below.

Surface Water: The lowest surface water screening value will be selected from the following three sources: (1) OEPA Water Quality Criteria (WQC) (Ohio Administrative Code [OAC] Chapter 3745-1) for the protection of aquatic life; (2) PRGs for Ecological Endpoints (Efroymson et. al. 1997a); and (3) EDQLs (EPA, 1999a). A hierarchy will not be used because it would potentially eliminate important surface water COPECs, as OEPA WQC do not consider food-chain effects.

Sediment: Sediment screening values will be selected using the following hierarchy: (1) EDQLs (EPA, 1999a); (2) PRGs for Ecological Endpoints (Efroymson et. al. 1997a); and (3) Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (Ontario Ministry of the Environment and Energy; 1993).

Nonchemical stressors will also be assessed, using available surface water data collected on pH, turbidity, conductivity, dissolved oxygen, oxidation-reduction potential, and temperature.

2.6.6 Summary of COPEC Selection

A table of COPECs will be prepared for each medium with the following information:

Chemical name

Frequency of detection

Range of detected concentrations

Range of detection limits

Arithmetic mean (average) of site concentrations

Distribution type

UCL of the mean of the concentration

Source-term concentration

Appropriate RBSEV

The background screening concentrations

COPEC selection conclusion: NO (with rationale for exclusion), or YES (selected).

Footnotes in the table(s) will provide the rationale for selecting or rejecting a chemical as a COPEC.

An evaluation of all constituents eliminated will be performed to determine whether any should be reinstated as COPECs due to other considerations. Examples of these exceptions include potential breakdown products, chemicals with detection limits greater than the RBSEV, chemicals known to have been used onsite historically, and chemicals with high bioconcentration and/or bioaccumulation factors. Chemicals not eliminated using the screening procedures previously presented will be considered COPECs and will be quantitatively evaluated in the SLERA. The physical, chemical, and toxicological properties of the identified COPEC contributing to potential adverse effects will be reviewed from the scientific literature and summarized in COPEC profiles. Where possible, data and information directly relevant to the SLERA will be included in the COPEC profiles. COPEC-specific information pertaining to physiological, biological, or ecological effects that is used directly in the exposure and effects

analysis of this SLERA may be presented and discussed in the COPEC profiles. In addition, justification for the use of surrogate chemical data in the absence of direct chemical data for COPECs may be presented and discussed in the profiles. The COPEC profiles will be included in the final ecological risk assessment (ERA) report as an appendix.

2.7 Selection of Assessment Receptors

Assessment receptors will be selected for evaluation during the SLERA. In order to focus the exposure characterization portion of the SLERA on species or components that are the most likely to be affected and on those that, if affected, are most likely to produce greater effects in the on-site ecosystem, the selection process will focus on species, groups of species, or functional groups, rather than on higher organization levels such as communities or ecosystems. Site biota will be organized into major functional groups and will be based on the findings of the pre-assessment reconnaissance/ecological survey. For terrestrial communities, the major groups are plants and wildlife including terrestrial invertebrates, mammals, and birds. For aquatic and/or wetland communities, the major groups are flora and fauna including vertebrates (waterfowl and fish), aquatic invertebrates, and wetland/terrestrial mammals. Species presence and relative abundance will be determined during the site reconnaissance prior to identification of target species.

Primary criteria for selecting appropriate assessment receptors will include, but will not be limited to, the following:

- The assessment receptor will have a relatively high likelihood of contacting chemicals via direct or indirect exposure.
- The assessment receptor will exhibit marked sensitivity to chemicals.
- The assessment receptor will be a key component of ecosystem structure or function (e.g., importance in the food web, ecological relevance).
- The assessment receptor may be listed as rare, threatened, or endangered by a governmental organization or the receptor will consist of critical habitat for rare, threatened, or endangered species.

Additional criteria for selection of assessment receptors will be used to identify species that offer the most favorable combination of characteristics for determining the implications of onsite contaminants. These criteria may include: (1) limited home range; (2) role in local nonhuman food chains; (3) potential high abundance and wide distribution at the site; (4) sufficient toxicological information available in the literature for comparative and interpretive purposes; (5) sensitivity to COPECs; (6) relatively high likelihood of occurrence onsite following remediation; (7) suitability for long-term monitoring; (8) importance to the stability of the ecological food chain or biotic community of concern; and (9) relatively high likelihood that they will be present at the site or that habitats present at the site could support the species.

It is important that sufficient toxicological information be available in the literature on the receptor species or that a closely related species be selected. While the ecological

communities at the site have species with many desirable characteristics for use as receptor species, not all of these species have been used extensively for toxicological testing.

Results of the assessment receptor selection process will be presented in detailed biological and ecological descriptions called assessment receptor profiles (ARP). Additionally, the biologically relevant criteria used to select each assessment receptor will be discussed and summarized in the ARP. The ARPs will be included in the final ERA report as an appendix.

2.8 Ecological Endpoint (Assessment and Measurement) Identification

The protection of ecological resources such as habitats and species of plants and animals is a principal motivation for conducting the SLERA. Potential ecological assessment and measurement endpoints will be proposed after the site reconnaissance and a thorough review of existing reports and site-related documents. The final assessment and measurement endpoints will be selected by agreement between risk assessors, risk managers, and regulatory agencies.

Unlike the human health RA process, which focuses on individual receptors, the SLERA will focus on populations or groups of interbreeding nonhuman, nondomesticated receptors. In the SLERA process, the potential for adverse effects to individual receptors will be assessed only if they are protected under the Endangered Species Act, are species that are candidates for protection, or are species that are considered rare.

Given the diversity of the biological world and the multiple values placed on it by society, there is no universally applicable list of assessment endpoints. Suggested criteria that may be considered in selecting assessment endpoints suitable for a specific ecological risk assessment are: (1) ecological relevance; (2) susceptibility to the contaminant(s); (3) accessibility to prediction and/or measurement; and (4) definable in clear, operational terms (Suter, 1993). Selected assessment endpoints will reflect environmental values that are protected by law, are critical resources, or have relevance to ecological functions that may be impaired. Both the entity and attribute will be identified for each assessment endpoint.

Assessment endpoints are inferred from effects to one or more measurement endpoints. The measurement endpoint is a measurable response to a stressor that is related to the valued attribute of the chosen assessment endpoint. It serves as a surrogate attribute of the ecological entity of interest (or of a closely related ecological entity) that can be used to draw a predictive conclusion about the potential for effects to the assessment endpoint.

Measurement endpoints for the SLERA will be based on toxicity values from the available literature and not on statistical or arithmetic summaries of actual field or laboratory observations or measurements. Where possible, receptors and endpoints will be concurrently selected by identifying those that are known to be adversely affected by chemicals at the site based on published literature. COPECs for those receptors and endpoints will be identified by drawing on the scientific literature to obtain information regarding potential toxic effects of site chemicals to site species. This process will ensure that a conservative approach is taken in selecting endpoints and evaluating receptors that are likely to be adversely affected by the potentially most toxic chemicals at the site.

2.9 Ecological Site Conceptual Model

A pictorial representation of the exposure characterization will be prepared. This pictorial and any text necessary to clarify the representation make up the ecological site conceptual model (ESCM). The ESCM traces the contaminant pathways through both abiotic components and biotic food web components of the environment. The ESCM presents all potential exposure pathways and identifies those pathways that are complete or incomplete. The ESCM clearly identifies the relationship between the measurement and assessment endpoints. It will be used as a tool for judging the appropriateness and usefulness of the selected measurement endpoints in evaluating the assessment endpoints, and for identifying sources of uncertainty in the exposure characterization.

3.0 EXPOSURE CHARACTERIZATION

An estimate of the nature, extent, and magnitude of potential exposure of assessment receptors to COPECs that are present at or migrating from the site will be developed. Exposure and chemical uptake will be modeled to produce upper-bound exposure estimates. Exposure characterization is critical in further evaluating the potential for adverse effects from chemicals identified as COPECs during the selection process (Section 2.6). The exposure assessments will be conducted by characterizing the magnitude (concentration) and distribution (locations) of the contaminants detected in the media sampled during the investigation, evaluating pathways by which chemicals may be transported through the environment, and determining the points at which organisms found in the study area may contact contaminants.

3.1 Exposure Analysis

An exposure analysis will be performed, which will combine the spatial and temporal distribution of the ecological receptors with those of the COPECs to evaluate exposure. The exposure analysis will focus on the bioavailability of the chemical and the means by which the ecological receptors may be exposed (e.g., exposure pathways). The focus of the analysis will be dependent on the assessment receptors being evaluated as well as the assessment and measurement endpoints.

Calculation of plant uptake values is not necessary as the plant toxicity data are expressed in concentration in the growth medium. For terrestrial faunal receptors, calculation of exposure rates relies upon determination of an organism's exposure to COPECs found in soil, surface water, and sediment. Exposure rates for terrestrial wildlife receptors will be based solely upon ingestion of contaminants from these media and consumption of other organisms. Given the scarcity of available data for wildlife dermal and/or inhalation exposure pathways, potential for adverse ecological effects from these pathways will not be estimated. These pathways are generally considered to be incidental for most species, with the possible exceptions of burrowing animals and dust-bathing birds.

The first step in estimating exposure rates for terrestrial wildlife involves the calculation of feeding and watering rates for receptors species. EPA provides a variety of exposure information for a number of avian, herptile, and mammalian species (EPA, 1993). Information regarding feeding and watering rates and dietary composition are available for many species, or may be estimated using allometric equations (Nagy, 1987). Data will be gathered on incidental ingestion of soil and will be incorporated for the receptor species. This information will be summarized and documented in the ARPs.

Algorithms will be evaluated for calculating exposure for terrestrial vertebrates that account for exposure via ingestion of contaminated water, incidental ingestion of contaminated soil, ingestion of prey items, and ingestion of plants grown in contaminated soil. Singular algorithms will be developed for soil-to-plant uptake and for animal bioaccumulation where both of these are considered as dietary items for receptors to be evaluated for ingestion hazard. An assessment exposure via uptake by carnivores will also be included.

Literature values for animal-specific sediment ingestion will be used, where available. However, such values generally are not available in the literature. Where sediment ingestion rates cannot be found, the animal-specific incidental soil ingestion rate will be used for sediment ingestion as well, if the receptor's life history profile suggests a significant aquatic component (e.g., raccoon's use of surface water in foraging activities).

For aquatic faunal receptors, the calculation of exposure rates will depend on the determination of the contaminant concentration in water and on food-chain multipliers, bioconcentration factors (BCF), and bioaccumulation factors (BAF). If appropriate, an evaluation will be made of the time each organism spends in contact with surface water or sediment pore water in order to modify exposure rates.

For species exposed to organic contaminants found in sediment, calculations will be performed to quantify interstitial (pore) water contaminant concentrations given a known sediment concentration. Suter notes an algorithm to calculate pore water concentrations for nonionic organic chemicals, as follows (Suter, 1993):

$$Pore\ water\ concentration(mg/L) = \left({}^{SC}/_{F_{oc}}\right)\left(K_{oc}\right) \qquad \textbf{Eq. 3.1}$$

where:

SC = sediment concentration (milligram [mg] per kilogram [kg])

F_{oc} = fraction organic carbon in sediment (kg organic carbon/kg sediment)

K_{oc} = chemical-specific soil (sediment) adsorption coefficient (liter [L]/kg).

Ecological routes of exposure for biota may be direct (bioconcentration) or through the food web via the consumption of contaminated organisms (biomagnification). Direct exposure routes include dermal contact, absorption, inhalation, and ingestion. Examples of direct exposure include animals incidentally ingesting contaminated soil or sediment (e.g., during burrowing or dust-bathing activities); animals ingesting surface water; plants absorbing contaminants by uptake from contaminated sediment or soil; and the dermal contact of aquatic organisms with contaminated surface water or sediment.

Food web exposure can occur when terrestrial or aquatic fauna consume contaminated biota. Examples of food web exposure include animals at higher trophic levels consuming plants or animals that bioaccumulate contaminants. The concepts of bioaccumulation, bioconcentration, and biomagnification are used throughout this document. These terms are defined by EPA as follows (EPA, 1997a):

- **Bioaccumulation.** General term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical.

- **Bioconcentration.** A process by which there is a net accumulation of a chemical directly from an exposure medium into an organism.

- **Biomagnification.** Result of the process of bioaccumulation and biotransfer by which tissue concentrations of chemicals in organisms at one trophic level exceed tissue concentrations in organisms at the next lower trophic level in a food chain.

Contamination of biota could result from exposure to one or more COPECs. Bioavailability is an important contaminant characteristic that influences the degree of chemical-receptor interaction. Bioavailable compounds are those that a receptor can take in from the environment. Bioavailability of a chemical is a function of several physical and chemical factors.

Exposure pathways consist of four primary components: source and mechanism of contaminant release, transport medium, potential receptors, and exposure route. A chemical may also be transferred between several intermediate media before reaching the potential receptor. All of these components will be addressed in the SLERA. If any of these components are not complete, then contaminants in those media do not constitute an adverse environmental effect at that specific site. The major fate and transport properties associated with typical site contaminants will be outlined. These properties directly affect a contaminant's behavior for each of the exposure pathway components.

Adjustments will be made for potential biomagnification of contaminants through aquatic trophic levels. Food chain multipliers (FCMs), derived by EPA will be used to assess the possibility of contaminant magnification through site receptors (EPA, 1995). The FCMs are multiplied by chemical-specific BCFs to obtain BAFs. The SLERA will either use laboratory-measured BCF values obtained from the scientific literature or fish BCFs will be calculated for organic compounds using the following equation (EPA, 1995):

$$BCF = K_{ow} \qquad \textbf{Eq. 3.2}$$

where:

BCF = bioconcentration factor

K_{ow} = chemical-specific octanol/water partition coefficient.

When possible, octanol-water partition coefficient (K_{ow}) values for appropriate COPECs will be obtained from the literature or from databases and will be listed among the fate and transport properties within the COPEC profiles.

The BCF is dependent upon a chemical-specific K_{ow} that relates to a chemical's tendency to partition to a polar versus nonpolar solution. EPA has established a relationship between the K_{ow} and the FCM such that as the K_{ow} increases, the FCM increases correspondingly.

For sediment or soil, the percent carbon present is critical to partitioning. For these matrices, the K_{ow} will be converted to a soil adsorption coefficient (K_{oc}) value as follows (EPA, 1996):

$$Log\ K_{oc} = 0.00028 + (0.983x \log K_{ow}) \qquad \textbf{Eq. 3.3}$$

where:

K_{oc} = chemical-specific soil adsorption coefficient

K_{ow} = chemical-specific octanol/water partition coefficient.

This equation was chosen because it is the best fit for site-related compounds (semivolatile, nonionizing organic compounds).

Per EPA guidance, aquatic BAFs will be estimated by one of four methods (in order of preference) (EPA, 1995):

A measured BAF for an inorganic or organic chemical derived from a field study.

A predicted BAF for an organic chemical derived from a field-measured biota-sediment accumulation factor.

A predicted BAF for an inorganic or organic chemical derived from a laboratory-measured BCF and a FCM.

A predicted BAF for an organic chemical derived from a K_{ow} and an FCM.

The EPA guidance notes, however, that for chemicals for which no K_{ow} is available and for which no BCF is calculable, a default FCM of 1.0 should be used. Accordingly, for inorganics not thought to biomagnify and/or for which no literature value is available, the value of 1.0 will be used at each trophic level.

In addition to the aquatic food web, FCMs are also related to an organism's trophic status as predator/prey, producer/consumer, etc. in the terrestrial food web. Although exposures of terrestrial floral and faunal receptors are significant considerations for many hazardous waste sites, well accepted models for predicting the fate of many contaminants in terrestrial systems are less developed. Trophic level compartments and transfer between compartments based on uptake, storage, and loss processes are not as well defined in terrestrial systems as in aquatic systems. In addition, the relationship between K_{ow} and bioconcentration is less well delineated by trophic level in terrestrial ecosystems. For the current SLERA, soil-to-plant and food-to-muscle BAFs will be estimated for organic constituents using the log K_{ow} relationships developed by Travis and Arms (Travis and Arms, 1988). Soil-to-insect BAFs will be based on log K_{ow} relationships developed by Connell and Markwell (Connell and Markwell, 1990). Inorganic constituent BAFs will be based on literature values such as those found in Baes, et al. (Baes et al., 1984), International Atomic Energy Agency (International Atomic Energy Agency,

1994), and Ma (Ma, 1982). Site-specific BAFs from the data reflected in the Red Water Ponds Phase II Ecological Risk Assessment Work Plan (IT, 2000) will be used where available.

Media-Specific Exposure Pathways: Exposure to four categories of environmental media will be addressed in the SLERA, as discussed in the following subsections.

Soil Exposure Pathway: Soil exposure pathways are potentially important for terrestrial plants and animals at the site. For burrowing animals, soil samples obtained from a depth of 0 to 5 ft bgs will be considered. For plant exposure, soil samples taken from 0 to 5 ft bgs (or the water table surface) will be considered because most feeder roots are located within this depth.

Environmental conditions such as soil moisture, soil pH, and cation exchange capacities significantly influence whether potential soil contaminants remain chemically bound in the soil matrix or whether they can be chemically mobilized (in a bioavailable form) and released for plant absorption. Literature values for soil-to-plant transfer rates for inorganic and organic soil contaminants and for organic soil contaminants will be used unless contaminant-specific information is available.

Sediment Exposure Pathway: Sediment generally consists of soil or other material settled out of suspension in surface water or native soils underlying flowing or standing surface water bodies. Potential contaminant sources for sediment include buried or stored waste and contaminated surface water, groundwater, and soil. The release mechanisms include surface water runoff, groundwater discharge, and airborne deposition. Potential receptors of chemicals in contaminated sediment include aquatic flora and fauna. Direct exposure routes for contaminated sediment include contact by benthic-dwelling organisms such as catfish, uptake by aquatic flora, and ingestion by aquatic fauna. Indirect exposure pathways from sediment include consumption of bioaccumulated contaminants by consumers in the food chain. Chemical bioavailability of many nonpolar organic compounds (e.g., polychlorinated biphenyls (PCBs) and pesticides) decreases with increasing concentrations of total organic carbon in the sediment; however, these compounds can still bioaccumulate up the food chain (Landrum and Robbins, 1990).

Surface Water Exposure Pathway: Surface water represents a potential transport medium for COPECs. Potential sources for contaminated surface water include buried or stored waste, stored or spilled fuel, contaminated soil and groundwater, and deposition of airborne contaminants. The release mechanisms include surface runoff, leaching, and groundwater seepage. Potential receptors of contaminated surface water include terrestrial and aquatic fauna and aquatic flora. Exposure routes for contaminated surface water include ingestion by terrestrial fauna and uptake and absorption by aquatic flora and fauna. Consumption of bioaccumulated contaminants constitutes a potential indirect exposure pathway for faunal receptors. Chemical bioavailability of some metals and other chemicals is controlled by water hardness, pH, and total suspended solids.

Four surface water drainage features are present at the site. Flowing water has been observed in all four drainage ditches during the wet season in early to mid Spring. All but the northern drainage ditch dry up by mid summer including the ponded area and the swampy area located to the northwest of Acid Area 1. All surface water/sediment data for the site will be evaluated in

the SLERA. COPECs identified during the site-wide drainage assessment will be evaluated further specific to each drainage.

Groundwater Exposure Pathway: Groundwater represents a potential transport medium for COPECs. Potential contaminant sources for groundwater include contaminated soil and buried or stored waste. The release mechanism for contaminants into groundwater is direct transfer of contaminants from waste materials to water as water passes through the materials.

Groundwater itself is not an exposure point, although contaminant transport along the shallow groundwater pathway may be considered an exposure route to aquatic life, wetlands, and some wildlife were the groundwater to discharge to surface water. This pathway is of importance to aquatic and wetland receptors where groundwater discharges to surface water. Because surface water data is available, groundwater concentrations will not be screened against surface water RBSEVs.

3.2 Exposure Characterization Summary

At the conclusion of the exposure characterization, the estimated chemical intakes for each exposed receptor group under each exposure pathway and scenario will be presented in tabular form for the site. The presentation will include an identification of all pertinent factors. These intake estimates will be combined with the COPEC toxicity values (discussed in the following chapter) to derive estimates and characterize potential for adverse ecological effects. The uncertainties associated with the estimation of chemical intake will be summarized in the uncertainty analysis of the SLERA report. The basis for each uncertainty will be identified, with the degree of uncertainty estimated qualitatively (low, medium, or high) or quantitatively, and the impact of the uncertainty will be estimated qualitatively (overestimate or underestimate, as appropriate).

4.0 ECOLOGICAL EFFECTS CHARACTERIZATION

The ecological effects characterization will include the selection of literature benchmark values and the development of toxicity reference values.

4.1 Selection of Literature Benchmark Values

Appropriate sources for literature benchmark values will be consulted, such as *Toxicological Benchmarks for Wildlife* (Sample et al., 1996); *Development of Toxicity Reference Values for Conducting Ecological Risk Assessments at Naval Facilities in California* (Engineering Field Activity, West, 1998); *Review of the Navy - EPA Region 9 BTAG Toxicity Reference Values for Wildlife* (CH2M-Hill, 2000). The level of effort will be limited to documents that summarize the available ecotoxicological information and will not include review of the primary toxicological literature (i.e., details of toxicity test conditions to determine validity of the tests performed will not be reviewed).

4.2 Development of Toxicity Reference Values

Toxicity reference values (TRV) for the site will be developed or determined. These TRVs will focus on the growth, survival, and reproduction of species and/or populations. Empirical data may be available for the specific receptor-endpoint combinations in some instances. However, for some COPECs, data on surrogate species and/or on endpoints other than the no observed adverse effect level (NOAEL) and lowest observed adverse effect level (LOAEL) may have to be used. The NOAEL is a dose of each COPEC that will produce no known adverse effects in the test species. The NOAEL was judged to be an appropriate toxicological endpoint since it would provide the greatest degree of protection to the receptor species. The LOAEL will be used as a point of comparison for decision-making for risk management purposes. In addition, in instances where data are unavailable for a site-associated COPEC, toxicological information for surrogate chemicals may be used. Safety factors will be used to adjust for these differences and extrapolate effects to the site's receptors at the NOAEL and/or LOAEL endpoint, as described in the following paragraphs.

Toxicity information pertinent to identified receptors will be gathered for those analytes identified as COPECs. Because the measurement endpoint will range from the NOAEL to the LOAEL, preference will be given to chronic studies noting concentrations at which no adverse effects were observed and ones for which the lowest concentrations associated with adverse effects were observed. As previously noted, where data are unavailable for the exposure of a receptor to a COPEC, data for a surrogate chemical (e.g., endrin for endrin aldehyde) will be gathered for use in the SLERA.

Using the relevant toxicity information, TRVs will be calculated for each of the COPECs. TRVs represent NOAELs and LOAELs with safety factors incorporated for toxicity information derived from studies other than no-effects or lowest-effects studies, and studies on species other than the receptors selected for this RA. TRVs will be obtained from the open literature including the wildlife toxicity assessments (WTAs) and terrestrial toxicity database (TTD) from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) available at (http://chppm-www.apgea.army.mil/tox/HERP.aspx) and EPA's *Screening Level Ecological Risk Assessment*

Protocol (EPA, 1999b). Because NOAELs for the selected wildlife receptor species will most likely be based on NOAELs from test species, the latter will be converted to NOAELs specific to the selected wildlife receptors using a power function of the ratio of body weights (Sample et al., 1996). A body weight scaling factor of 0.25 will be used for mammals, whereas a body weight scaling factor of 0 will be used for birds, making the $NOAEL_W$ for birds the same as the $NOAEL_T$, as shown below:

$$NOAEL_W = NOAEL_T \left(\frac{BW_T}{BW_W} \right)^s \qquad \textbf{Eq. 4.1}$$

where:

$NOAEL_w$ = the No Observed Adverse Effect Level for the wildlife indicator species (mg/kg-day)

$NOAEL_T$ = the No Observed Adverse Effect Level for the test species (mg/kg-day)

BW_T = the body weight of the test species (kg)

BW_W = the body weight of the wildlife indicator species (kg)

s = a body weight scaling factor (s = 1/4 for mammals and s = 0 for birds).

Exposure rate TRVs provide a reference point for the comparison of toxicological effects upon exposure to a contaminant. To complete this comparison, receptor exposure to site contaminants must be calculated or, as in the case of plant receptors, exposure is simply calculated as the soil concentration.

The equilibrium partitioning approach has been used by the EPA and Ontario Ministry of the Environment and Energy in the preparation of sediment quality criteria for the protection of aquatic life. These criteria will be used, where available, to assess sediment effects to aquatic receptors.

5.0 RISK CHARACTERIZATION

The risk characterization phase integrates information on exposure, exposure-effects relationships, and defined or presumed target populations. The result is a determination of the likelihood, severity, and characteristics of adverse effects of environmental stressors present at a site. A semiquantitative approach will be taken to estimate the likelihood of adverse effects occurring as a result of exposure of the selected site receptors to COPECs. TRVs and exposure rates will be calculated and used to generate hazard quotients (HQ) by dividing the receptor exposure rate for each contaminant by the calculated TRV (Wentsel et al., 1996). HQs are a means of estimating the potential for adverse effects to organisms of a contaminated site, and for assessing the potential that toxicological effects will occur among site receptors.

5.1 Risk Estimation

The potential for adverse effects associated with the site will be estimated. Estimation of potential effects will be performed through a series of quantitative HQ calculations that compare receptor-specific exposure values with TRVs. It is important to note that HQs are not absolute measures of adverse effects, are not population-based statistics, and are not linearly scaled statistics. The HQs will be compared to HQ guidelines for assessing the potential for adverse ecological effects posed from contaminants.

The simple HQ ratios may be summed, where appropriate and scientifically defensible, to provide hazard index estimates for all chemicals and exposure pathways for a given receptor (e.g., organochlorine pesticides, polynuclear aromatic hydrocarbons (PAHs), and phthalates). The following criterion will be used to determine if HQs will be summed: for a given receptor, only HQs for those chemicals that have a similar mode of toxicological action will be summed. While individual contaminants may affect distinct target organs or systems within an organism, classes of chemicals may act in similar ways, thus being additive in effect.

5.2 Uncertainty Analysis

The results of the SLERA will be influenced to some degree by variability and uncertainty. In theory, investigators might reduce variability by increasing sample size of the media or species sampled. Alternatively, uncertainty within the RA can be reduced by using species-specific and site-specific data (i.e., to better quantify contamination of media, vegetation, and prey through direct field measurements, toxicity testing of site-specific media, field studies using site-specific receptor species). Detailed media, prey, and receptor field studies are costly; thus, the preliminary scoping and predictive analyses of potential adverse effects are conducted to limit the potential use of these resource-intensive techniques to only those COPECs that continue to show a relatively high potential for adverse ecological effects. Since assessment criteria were developed based on conservative assumptions, the results of the screening and predictive assessments will err on the side of conservatism. This has the effect of maximizing the likelihood of accepting a false positive (Type I error: the rejection of a true null hypothesis) and simultaneously minimizing the likelihood of accepting a true negative (Type II error: the acceptance of a false null hypothesis). The uncertainty analysis will assess the soil depth of elevated concentrations of COPECs identified as contributing significantly to the estimate of potential adverse effects, and will evaluate the significance of these findings on the results of

the SLERA (e.g., if COPEC hot spots only occur at deeper soil depths, realistic ecological exposure could be expected to be minimal).

A number of factors contribute to the overall variability and uncertainty inherent in ecological risk assessments. Variability is due primarily to measurement error. Laboratory media analyses and receptor study design are the major sources of this kind of error. Uncertainty, on the other hand, is associated primarily with deficiency or irrelevancy of effects, exposure, or habitat data to actual ecological conditions at the site. Species physiology, feeding patterns, and nesting behavior are poorly predictable; therefore, all toxicity information derived from toxicity testing, field studies, or observation will have uncertainties associated with them. Laboratory studies conducted to obtain site-specific, measured information often suffer from poor relevance to the actual exposure and uptake conditions onsite (i.e., bioavailability, exposure, assimilation, etc., are generally greater under laboratory conditions as compared to field conditions). Calculating an estimated value based on a large number of assumptions is often the only alternative to the accurate (but costly) method of direct field or laboratory observation, measurement, or testing. Finally, habitat- or site-specific species may be misidentified if, for example, the observational assessment results are based on only two brief site reconnaissances performed on a relatively large site.

The calculation of hazard quotients also introduces uncertainty. The following limitations associated with hazard quotients are noted and will be briefly addressed in the final SLERA report.

- HQs are not measures of risk.
- HQs are not population-based.
- HQs are not linearly-scaled.
- HQs are often produced that are unrealistically high and toxicologically impossible.
- Miniscule soil concentrations of inorganics can lead to HQ threshold of 1.0 exceedances.
- HQs are not geared to a temporal scheme (i.e., a HQ of 10 means the same thing for a site that is five years old (contaminated) as it does for a site that is 500 years old (contaminated).

The uncertainty analysis will be presented, in part, as a table listing the assumptions made for the ERA including the direction of bias caused by each assumption (i.e., whether the uncertainty results in an overestimate or underestimate of potential adverse effect), the likely magnitude of impact expressed quantitatively as percent difference or expressed qualitatively as high, medium, low, or unknown], and, where possible, a description of recommendations for minimizing the identified uncertainties if the ERA progresses to higher level assessment phases (EPA, 1997a). The uncertainty analysis will identify and, where possible, quantify the uncertainty in the individual preliminary scoping assessment, problem formulation, exposure and effects assessment, and risk characterization phases of the SLERA.

5.3 Risk Description

As part of the risk description, the following will be completed: (1) summarize the potential adverse ecological effect associated with the site; and (2) interpret the ecological significance, which describes the magnitude of the potential adverse effects and the accompanying uncertainty. The effect of additional data or analyses on uncertainty will also be discussed. A weight-of-evidence approach will be used to interpret the ecological significance of the findings.

6.0 RISK SUMMARY AND IDENTIFICATION OF PRELIMINARY REMEDIAL ACTION OBJECTIVES

The potential adverse ecological effects associated with releases from the site will be summarized. This summary will be supported by the steps performed as described in the previous sections. Additionally, recommendations for further investigations will be made if appropriate and cost effective, and site-specific remedial action objectives will be developed for the site, if warranted.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Only the data, results, and conclusions of the various preliminary scoping and predictive assessment phases will be described. No recommendations concerning types of remedial actions to be conducted will be made other than to present the specific remedial action objectives. Conclusions and recommendations derived from the RA will be based on the responses to the assessment hypotheses. The predictive assessment results will be summarized and presented in table format. These tables may serve as the foci of discussions for risk managers and regulatory agencies concerning the potential need for additional assessment at PBOW to reduce the uncertainty in the estimate of potential adverse ecological effects.

8.0 REFERENCES

Baes, C. F., R. D. Sharp, A. L. Sjoreen and R. W. Shor, 1984, ***A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture***, prepared for the U.S. Department of Energy under Contract No. DE-AC0584OR21400.

CH2M-Hill, 2000, ***Review of the Navy - EPA Region 9 BTAG Toxicity Reference Values for Wildlife***, prepared for US Army Biological Technical Assistance Group (BTAG) and US Army Corps of Engineers, prepared by CH2M-Hill, Sacramento, California, March.

Connell, D. W. and R. D. Markwell, 1990, "Bioaccumulation in the Soil to Earthworm System," ***Chemosphere***, Vol. 20, Nos. 1-2, pp. 91-100.

Dames and Moore, 1997, ***Red Water Ponds Focused Remedial Investigation, Final Report,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones, 1997a, ***Preliminary Remediation Goals for Ecological Endpoints***, Oak Ridge National Laboratory. Report No. ES/ER/TM162/R2.

Efroymson, R.A., G.W. Suter II, and M.E. Will, 1997b, ***Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process, 1997 Revision***, Oak Ridge National Laboratory. Report No. ES/ER/TM-126/R2.

Efroymson, R.A., G.W. Suter II, Wooten, A.C., and M.E. Will, 1997c, ***Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants, 1997 Revision***, Oak Ridge National Laboratory. Report No. ES/ER/TM-85/R3.

Engineering Field Activity, West, 1998, ***Development of Toxicity Reference Values for Conducting Ecological Risk Assessments at Naval Facilities in California***, Interim Final, EFA West, Naval Facilities Engineering Command, United States Navy, San Bruno, California.

Gilbert, R. O., 1987, ***Statistical Methods for Environmental Pollution Monitoring***, van Nostrand Reinhold Co., Inc., New York, New York.

Hardin, J. W., and R. O. Gilbert, 1993, ***Statistical Tests for Detecting Soil Contamination Greater than Background,*** PNL-8989/UC-630, Pacific Northwest Laboratory, Richland, Washington, December.

International Atomic Energy Agency, 1994, ***Handbook of Parameter Values for the Protection of Radionuclide Transfer in Temperate Environments***, Technical Reports Series No. 364, Vienna, Austria.

IT Corporation (IT), 2001, ***Baseline Human Health Risk Assessment (Volume II) and the Ecological Risk Assessment (Volume III) for TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2000, ***Work Plan, Phase 2 Ecological Risk Assessment, Red Water Ponds, Former Plum Brook Ordnance Works, Sandusky, Ohio***, August.

IT Corporation (IT), 1998, ***Site Investigation of Acid Areas, Plum Brook Ordnance Works, Sandusky, Ohio.***

IT Corporation (IT), 1997, ***Site-Wide Groundwater Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

Jacobs Engineering (Jacobs), 2006, ***Interim Final Site Characterization Report, Remedial Investigation Part 1, at Acid Areas 2 & 3 Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

Jacobs, 2007, **Final Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans, Acid Areas 2 & 3, Former Plum Brook Ordnance Works, Sandusky, Ohio**, April

Landrum, P. F. and J. A. Robbins, 1990, "Bioavailability of Sediment-Associated Contaminants to Benthic Invertebrates," in ***Sediments: Chemistry and Toxicity of In-Place Pollutants***, R. Baudo, J. P. Giesy and II, Muntau Eds., Chelsea, Michigan: Lewis, 1990, pp. 237-263.

Ma, W. C. 1982, "The Influence of Soil Properties and Worm-related Factors on the Concentration of Heavy Metals in Earthworms," ***Pedobiologia***, Vol. 24, pp. 109-119.

Nagy, K. A., 1987, "Field Metabolic Rate and Food Requirement Scaling in Mammals and Birds," ***Ecological Monographs***, Vol. 57, pp.111-128.

National Aeronautics and Space Administration (NASA), 1995, ***Biological Inventory of Plum Brook Station, 1994***, Office of Environmental Programs, NASA Lewis Research Center, Cleveland, Ohio.

Ohio Environmental Protection Agency (OEPA) 2008, ***Guidance for Conducting Ecological Risk Assessments***, Division of Emergency and Remedial Response, Columbus, Oh, DERR-00-RR-031.

Ohio Administrative Code (OAC) Chapter 3745-1, Water Quality Criteria (Ohio Environmental Protection Agency).

Ontario Ministry of Environment and Energy, 1993, ***Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario***, ISBN 0-7729-9248-7.

Sample, B. E., D. M. Opresko, and G. W. Suter II, 1996, ***Toxicological Benchmarks for Wildlife: 1996 Revision***, prepared for the U.S. Department of Energy by Health Sciences Research Division, Oak Ridge National Laboratory.

Suter, G. W., 1993, ***Ecological Risk Assessment***, Lewis Publishers, Boca Raton, Florida.

Travis, C. C. and A. D. Arms, 1988, "Bioconcentration of Organics in Beef, Milk, and Vegetation," ***Environmental Science and Technology***, 22:271-274.

U.S. Army Corps of Engineers (USACE), 2000a, ***Scope of Work; Remedial Investigation, Feasibility Study and Decision Document, TNT Area A, Former Plum Brook Ordnance Works (PBOW), Sandusky, Ohio,*** Nashville, Tennessee, 14 February.

U.S. Environmental Protection Agency (EPA), 2007a, ProUCL Version 4 User Guide, EPA/600/R-07/038, April.

U.S. Environmental Protection Agency (EPA), 2007b, ProUCL Version 4 Technical Guide, EPA/600/R-07/041, April.

U.S. Environmental Protection Agency (EPA), 1999a, ***Ecological Data Quality Levels, RCRA Appendix IX Hazardous Constituents***, Region 5, October.

U.S. Environmental Protection Agency (EPA), 1999b, ***Screening Level Ecological Risk Assessment Protocol***, EPA530-D-99-001A. November.

U.S. Environmental Protection Agency (EPA), 1997, ***Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessment***, EPA/540-R97-006.

U.S. Environmental Protection Agency (EPA), 1997b, ***The Lognormal Distribution in Environmental Applications,*** Technology Support Center Issue Paper, EPA/600/R-97/006, December.

U.S. Environmental Protection Agency (EPA), 1996a, ***Region 5 Biological Technical Assistance Group (BTAG) Ecological Risk Assessment Bulletin No. 1***, Chicago, Illinois.

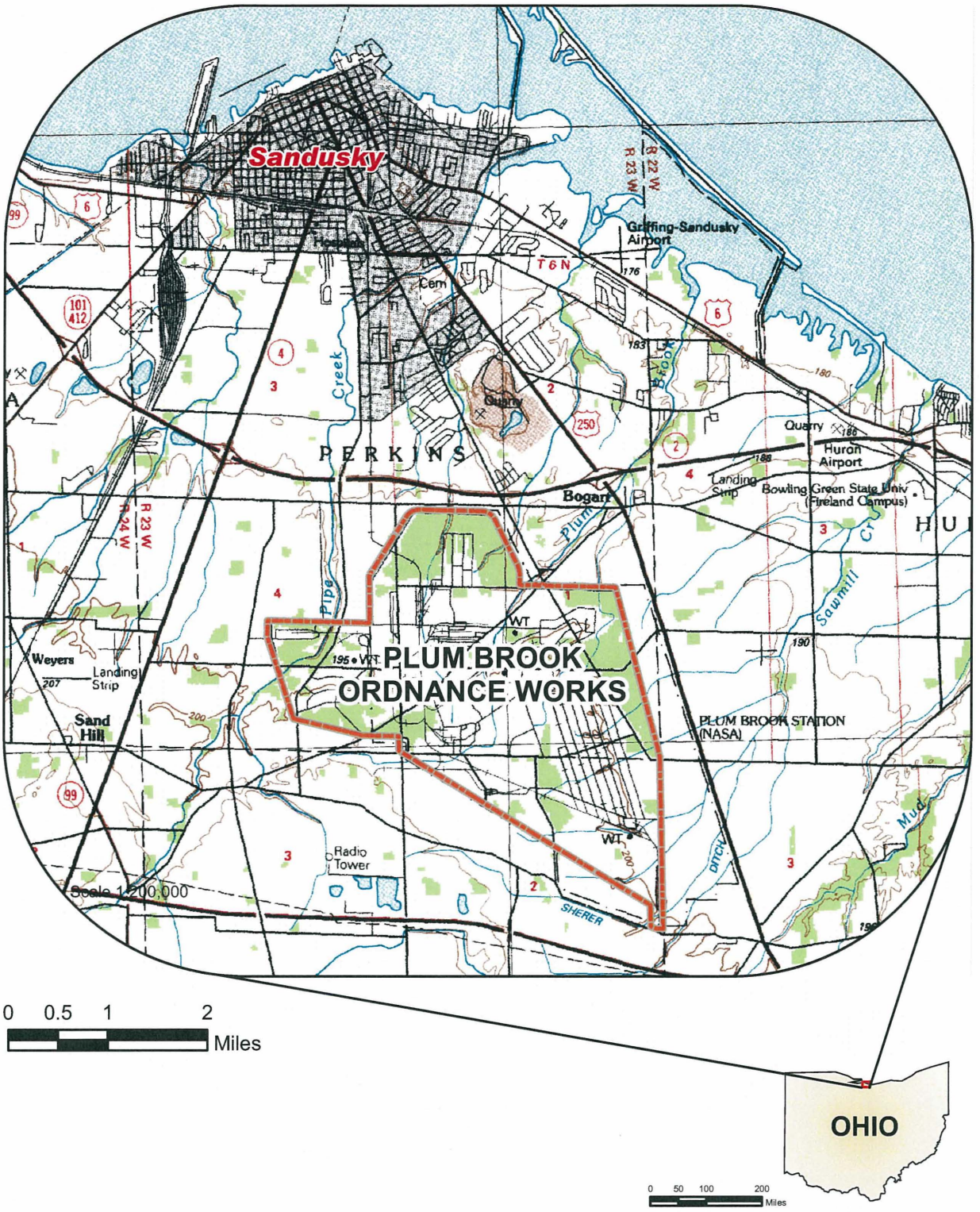
U.S. Environmental Protection Agency (EPA), 1995, ***Final Water Quality Guidance for the Great Lakes System***, 40 CFR Parts 9, 122, 123, 131, and 132.

U.S. Environmental Protection Agency (EPA), 1993, ***Wildlife Exposure Factors Handbook***, Vols. I and II, Office of Research and Development, Washington, DC, EPA/600/R-93/187a.

U.S. Environmental Protection Agency, (EPA), 1992a, ***Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance***, Office of Solid Waste.

U.S. Environmental Protection Agency (EPA), 1989, ***Risk Assessment Guidance for Superfund***, Volume I, Human Health Evaluation Manual (Part A), Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002.

Wentsel, R. S., T. W. LaPoint, M. Simini, R. T. Checkai, D. Ludwig, and L. W. Brewer, 1996, ***Tri-Service Procedural Guidelines for Ecological Risk Assessments,*** U.S. Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Maryland.



Legend

Plum Brook Ordnance Works Boundary

N

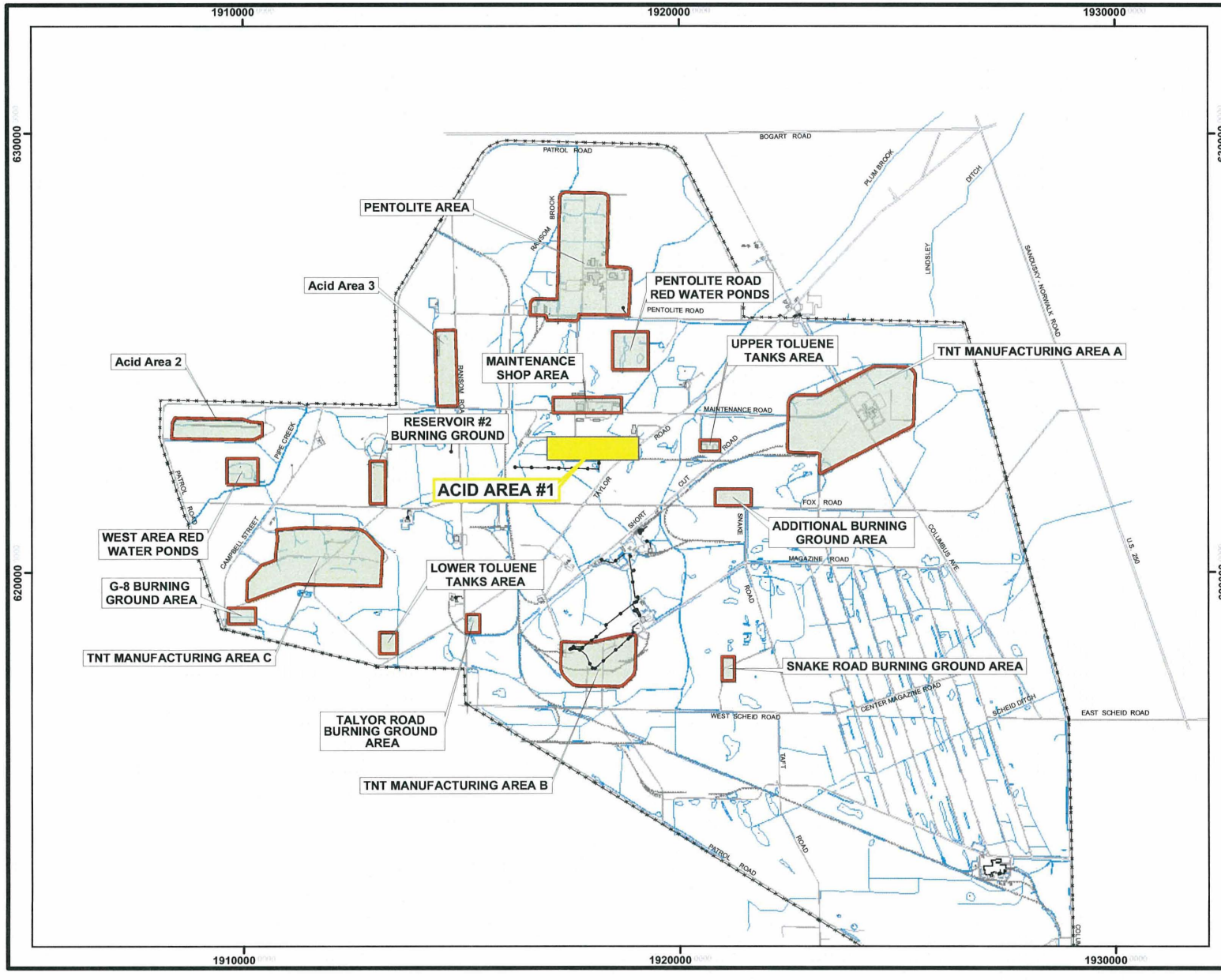
JACOBS™

Location Map,
Plum Brook Ordnance Works
Sandusky, Ohio

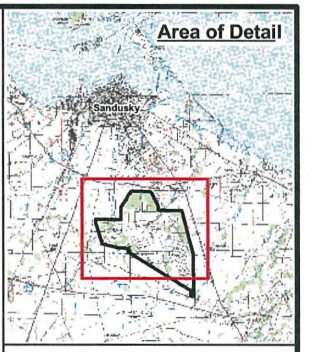
Plumbrook Ordnance Works
Sandusky, Ohio

11/20/08 JP X:/GIS/Projects/Plumbrook/Projects/AA1_Draft_RI/ArcGIS/PBOW_Site_Location_AA1.mxd

Figure 1-1



Area of Detail



Legend

Area of Concern

Creek, Ditch, Conveyance

Sources

Data mapped to Ohio State Plane North NAD83, map grid units in feet.

N
W
E
S

0 2,000 4,000 Feet

JACOBS™

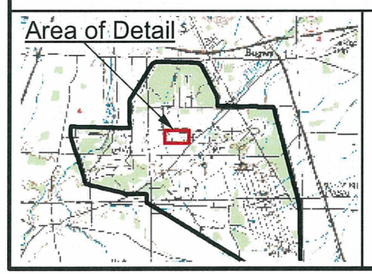
Location Map
Acid Area 1

Plum Brook Ordnance Works
Sandusky, Ohio

11/20/08 JP X:/GIS/Projects/Plumbrook/Projects/AA1_Draft_Rt/ArcGIS/Acid_Area1_LocMap.mxd

Figure 1-2

Area of Detail



Legend

Storage Tank Areas from Engineering Drawings

Buildings from Engineering Drawings

Creek, Ditch, Conveyance

Railway

200 100 0 200
Feet

N

Notes: *Aerial Photography from 1958.*
Data mapped to Ohio State Plane North NAD83, map units are feet.

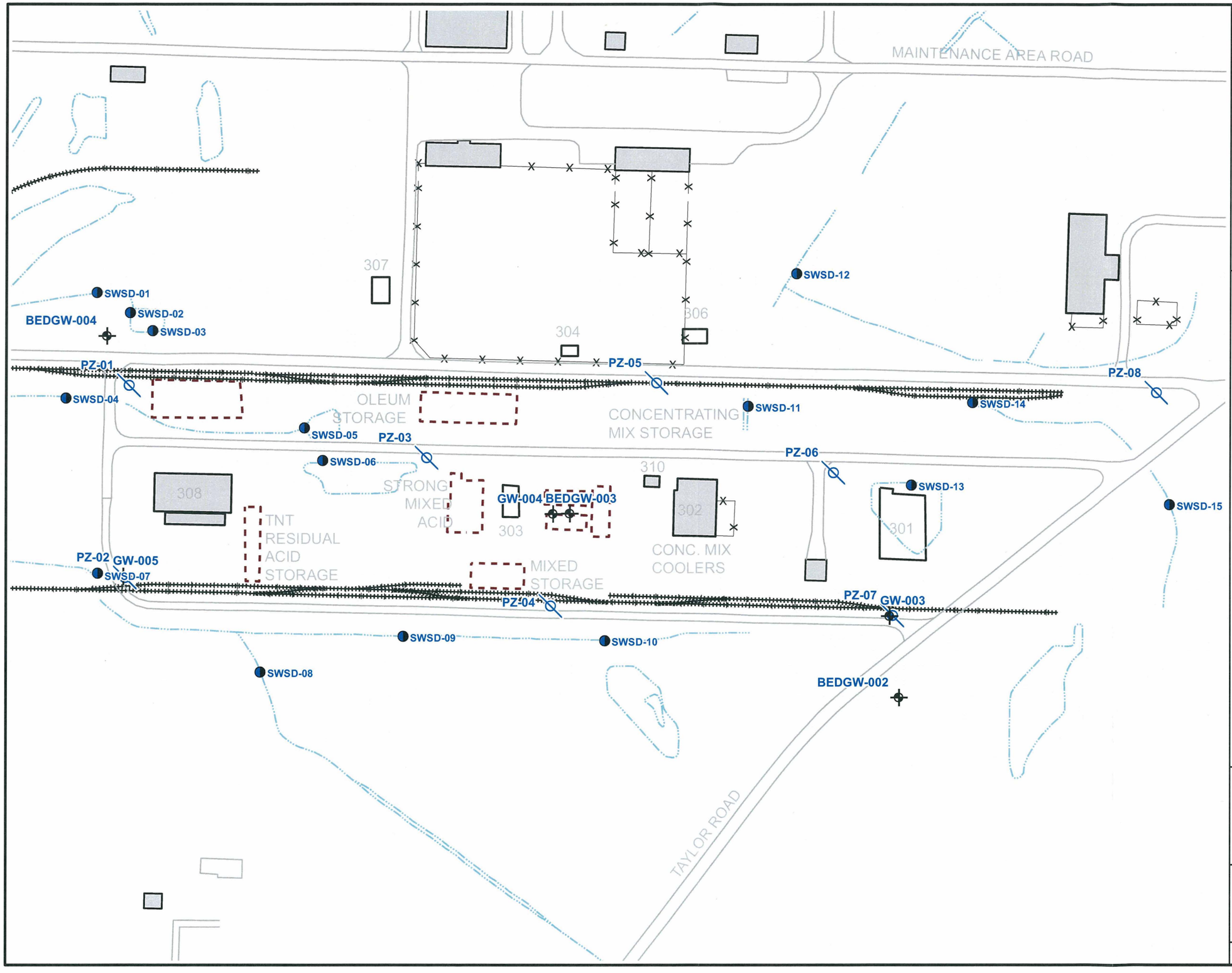
JACOBS™

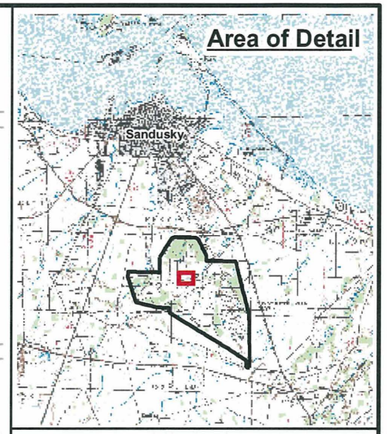
Acid Area 1 — 1958
Aerial Photography

Plum Brook Ordnance Works
Sandusky, Ohio

11/20/08 JP X:/GIS/Projects/Plumbrook/Projects /AA1_Draft_RI/ArcGIS/Acid_Area1_1958_RI.mxd

Figure 1-3





Legend

- Surface Water or Sediment Sampling Locations
- Monitoring Wells
- Piezometers

Note:
bgs = below ground surface
Bkg. = Background Sample (values are provided in units consistent with the reported sample values)
PRG = Preliminary Remediation Goal (values are provided in units consistent with the reported sample values)

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway

0 50 100 200 Feet

N

Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.

JACOBS

Surface Water/Sediment Sampling Locations — Acid Area 1

Plum Brook Ordnance Works
Sandusky, Ohio

4/2/09 JP X:/GIS/Projects/Plumbrook/Projects /AA1_Draft_SLERA/ArcGIS/ AA1_SLERA_sediment_surface.mxd

Figure 3-1

Appendix

Responses to Comments on the Draft
Baseline Human Health Risk Assessment Work Plan and the Draft
Screening Level Ecological Risk Assessment Work Plan

Reviewer Name:	Walker, Terry L.
Discipline	Risk Assessor
CX Project Review No.	71511
Date:	22 January 2009
Project Location	PBOW, Acid Area 1, Sandusky, OH.
Document Name:	Draft - BRA Work Plans.

Comment # 1: Section 2.2.1, HHRA, page 2-4. As R9 is no longer publishing their PRG table, suggest using the Regional Screening Levels instead.

Response: Agreed. The EPA Region III RBCs table updated in September 2008 will be used for the HHRA screening.

Comment # 2: Section 2.2.3, HHRA, page 2-5. The second paragraph indicates that screening will be done with select organic parameters. The third paragraph indicates that only inorganics will be screened. Note that Section 2.2.5 indicates that organics will not be screened out. Please clarify this apparent discrepancy.

Response: The third paragraph of Section 2.2.3 has been revised to indicate that inorganic compounds are being screened against background concentrations per the comment as well as certain organic compounds. Organics will be screened against background but will not be eliminated from further consideration as COPCs based on the results of said screening. They will be carried through the HHRA and the findings of the background screening will be addressed in the uncertainty section for those compounds. This is consistent with HHRA guidance.

Comment # 3: SLERA. No comments required.

USACE – Nashville District
Lannae Long Comments on PBOW Acid Area 1 Draft HHRA and ERA Work Plans

Draft HHRA WP

Comment 1. I have no additional comments to those I made on the internal draft HHRA WP. My previous comments have been addressed sufficiently.

Draft ERA WP

Comment 1. Section 2.6.1: State that sample data tables, broken-up by exposure unit for each indicator receptor, will be supplied by electronic media in the format that was described in previous contracts. This will provide risk assessment reviews the opportunity to easily access the sample results applicable to each exposure unit.

Response: The change to Section 2.6.2 has been made as noted in the comment.

Comment 2. Section 2.6.5 Surface Water sub-section: This section seems to be from Reservoir #2 Burning Ground. Insert correct text for Acid Area 1. Acid Area 1 had four (4) distinct surface water units, and each one should be described here.

Response: The text has been revised to present the surface water features located in Acid Area 1. Section 1.0 and Section 3.1 have been updated per the comment. Section 2.6.5 has been updated to reflect the fact that surface water features are present and surface water quality will be assessed.

Comment 3. Section 3.1 Exposure Analysis Para. 3: Explain how the surface water will be divided up and assessed as discrete units. Include a map showing the sample locations, and exposure units.

Response: Section 3.1 has been updated per the comment and Figure 3-1 has been added showing the surface water and sediment sample locations collected from each of the drainages.

USACE – Nashville District

Jim Beaujon's Comments on PBOW Acid Area 1 Draft Baseline HHRA and ERA Work Plans

I read the general text of the Work Plans and only had the few comments below. I'll leave it to you all to decide whether they're worth passing along to Jacobs.

Comment 1. BHHRA page 2-2, Section 2.1.2 end of 2nd paragraph: Change "did not utilize and sampling equipment" to "did not utilize any sampling equipment".

Response: The change was made as noted.

Comment 2. BHHRA page 3-2, Section 3.1.1, 4th line from end of 1st paragraph: Edit for clarity- "from 629 ft amsl near at the low points".

Response: The text was revised to clarify that "elevations at the site range from 629 ft amsl at the lowest point in the drainage ditches to 640 ft amsl.

Comment 3. BHHRA page 3-2, Section 3.1.1, 4th line of 2nd paragraph: Change "sixteen bgs" to "sixteen ft bgs".

Response: The change was made as noted.

Comment 4. Ecological RA references to figures: Since the Ecological RA doesn't have a set of figures- consider clarifying in the figure references that they can be found in the BHHRA.

Response: Figures have been added to the document per the comment

Comment 5. Ecological RA page 2-7, Section 2.6.5, Surface Water: Edit for relevance to Acid Area 1 site rather than 2BG site.

Response: Text has been revised to present the surface water characteristics at Acid Area 1.

MEMORANDUM

FROM: Julie Weatherington-Rice, Ph.D., RAB TAPP Coordinator

RE: Draft Human Health Risk Assessment and Ecological Risk Assessment Work Plans for Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio – JE Jacobs

General Comments

Please develop a section that discusses the date of the latest thorough literature review of "risk assessment" documents that Jacobs has undertaken. The newest general reference report is dated 2005 but it is not clear from the reports if that is the most recent reference document or if that is the date of the last time that Jacobs updated their general risk assessment templates. Clarification on this issue would be helpful. I have asked for this clarification in the text at least once before in the Reservoir No. 2 Burning Grounds review last year.

Response: Per the comment, references have been verified and updated where appropriate. A new section addressing the updates has not been included.

Specific Comments - Baseline Human Health Risk Assessment Work Plan for Acid Area 1

Page 3-19

1. Page break fault here. Please correct.

Page 3-35

2. Page break fault here. Please correct.

These page break faults were noted in earlier Baseline Human Health Risk Assessment Work Plans, most recently the one for the Reservoir No. 2 Burning Grounds.

Response: The changes have been made as noted.

Specific Comments - Baseline Ecological Risk Assessment Work Plan for Acid Area 1

Page 2-7 Section 2.6.5 Surface Water

1. This paragraph speaks to the issue that surface water at the site is ephemeral and so was dry at the point in time of sampling. The paragraph goes on to state that "Due to the ephemeral natural of the drainage ditch, it does not represent a habitat for aquatic biota or a significant source of drinking water for terrestrial biota." In an earlier e-mail that I sent to Jacobs last month when reviewing this document, I asked if there was any reason to consider the surface water sites at Acid Area 1 to be vernal pools. If not, why not, and if so, would that change the review process? I stated that I would include their responses in this memo, but to date, I have no reply.

Response: The document has been updated to indicate that there are four distinct surface water bodies located on Acid Area 1. All of the surface water bodies are ephemeral with the exception of the drainage to the north-northeast of Acid Area 1.

There has been a vigorous effort on the part of the Ohio EPA Division of Surface Water, the Ohio Department of Natural Resources, and the Ohio Biological Survey to identify and inventory vernal pools in Ohio. There was a recent awareness article in the Columbus Dispatch newspaper on vernal pools which brought my question to mind. In thinking back, I do not remember any mention of vernal pools at Plum Brook in any of the reports. However, I don't know if that is because they were never inventoried or because they were inventoried and do not exist. Please clarify.

Response: The *Final Protected Species Management Strategy for NASA Glenn Research Center at Lewis Field and Plum Brook Station*, prepared by the Ohio Department of Natural Resources, Division of Natural Areas and Preserves (April 2002) does not mention the presence of vernal pools on Plum Brook. The document is based on biological surveys conducted on Plum Brook. The document does not state that vernal pools were addressed and found or not found. However, the surface water and sediment data collected at Acid Area 1 will be evaluated in the SLERA and potential impacts to aquatic and terrestrial receptors addressed.

This concludes my technical comments on these Draft Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans for Acid Area 1, Former Plum Brook Ordnance Works, Sandusky, Ohio documents. If you have any questions and/or need further clarification on any point discussed in this memorandum, please feel free to contact me.

DOCUMENT TITLE: *Draft* ***Baseline Human Health and Screening Ecological Risk Assessments, Work Plans, Acid Area 1***

SITE: US NASA PLUM BROOK, TAYLOR & COLUMBUS Rds., SANDUSKY, OH 44870; ERIE Cnt.; OHID# 322-0552.

DOCUMENT/DATE: Draft /November 2008

Ohio EPA – Division of Emergency and Remedial Response COMMENTS

REVIEWER: Dr. Janusz Z. Byczkowski, DERR, CO; Tel: 614-644-3070; e-mail: jbyczkowski@epa.state.oh.us.

Review/DATE: 12/11/2008

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
1.			**General Remark:** I suggest a minor **revision** of the Document. If you have any questions or need further technical support, please give me a call at: 614-644-3070 or e-mail at jbyczkowski@epa.state.oh.us.	Before OEPA can concur with RA work plan, this Document should be revised to include reference to **OEPA-DERR** - RI/FS programmatic recommendations (available on-line at: http://www.epa.state.oh.us/derr/rules/guidance.html), and to follow the other suggestions as listed below.	The OEPA-DERR reference to the guidance list has been added to the RA Work Plan per the comment.
2.	S. 2.2.1 P. 2-4 L # 25		**Specific Issues:** This Document states: "*…acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of 1E-6 to 1E-4 (EPA, 1990), referred to as "risk management range"…*" **Comment:** While the RI/FS process should follow the U.S. EPA Risk Assessment Guidance for Superfund (RAGS), it should also consider that for multiple chemicals, the fixed cumulative OEPA-DERR (2004b) human health goals (ELCR=**1E-5** and HI=**1**) should be met. The	Instead of using "*risk management range*", please apply and refer to **fixed cumulative excess cancer risk goal of 1E-5**, recommended by Ohio EPA-DERR (2004b).	The text will be revised to state that OEPA applies fixed cumulative risk goals of ELCR=1E-5 and HI=1 for carcinogenic and non-carcinogenic constituents. However, the EPA risk management range referenced in the work plan will remain. It is acknowledged that OEPA recommends using EPA Region 9 PRGs for screening criteria as referenced in the comment. Application of EPA Region 9 PRGs is consistent with the completion of past

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
			OEPA (2004b) guideline has been listed on Page 1-4 among "*Protocols for the Baseline Human Health Risk Assessment*", but apparently not applied in the work plan. Please note, that in the list on Page 1-4, a crucial OEPA-DERR (2004a) technical decision compendium is missing, relevant to toxicity-based screening which may be performed differently than that described in U.S. EPA RAGS. **Reference**: **OEPA – DERR (2004a)** Use of U.S. EPA Region 9 PRGs as screening Values in Human Health Risk Assessments. Technical Decision Compendium, 28 April 2004. On-line: http://www.epa.state.oh.us/derr/rules/screening.pdf **OEPA - DERR (2004b)** Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight. Technical Decision Compendium, 28 April 2004. On-line: http://www.epa.state.oh.us/derr/rules/riskgoal.pdf		risk assessments at Plum Brook. However, we have revised the Acid Area 1 RA Work Plan, based on USACE comment and EPA guidance, to apply EPA Region 3 RBCs rather than Region 9 PRGs. This change is recommended because Region 9 no longer updates their PRGs with updated toxicity values and data. In contrast, Region 3 updates the RBCs twice a year with input from EPA Regions III, VI, and IX. Region 3 values are considered more protective.
3.	S. 2.2.3 P. 2-5 L # 8		This Document states: "*...groundwater BSC is either the MDC or the calculated 95 percent upper tolerance limit of the background groundwater data set...*" and further: "*...BSCs for soil were reported as the 95 percent upper tolerance limit for lognormal data sets or the 95th percentile for datasets with a nonparametric distribution...*" Then, starting in line # 34: "*...This will be performed using the nonparametric Wilcoxon Rank-Sum (WRS) statistical test (also known as the Mann-Whitney U test)...*"	Please **recalculate background levels** in accordance with OEPA-DERR (2004c and d) guidelines.	Background data being used in support of the risk assessment is site-specific data derived for Plum Brook. The background study was completed in 2001 with the approach and generated data being reviewed and accepted by OEPA. The background data has been used in the completion of past investigations and risk assessments for Plum Brook. No background data is being collected or derived in support of the Acid Area 1

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
			Comment: The background sampling should be performed in OEPA-pre-approved location and in media of a similar type and horizon as those evaluated in Baseline Risk Assessment (OEPA-DERR, 2004c). The background levels should be calculated according to the method provided by OEPA-DERR (2004d). Accordingly, instead of "*95% UTL*" and/or "*U test*", the background levels should be calculated as point values, equal to upper quartile + 1.5 × (interquartile range) of the data set. **References:** **OEPA – DERR (2004c)** Methodology for Evaluating Site-specific Background Concentrations of Chemicals. Technical Decision Compendium, 14 April 2004. On-line: http://www.epa.state.oh.us/derr/rules/Methodology.pdf **OEPA-DERR (2004d)** Background Calculation Methodology. Guidance DERR-00-RR-039P, 30 June 2004, Final. On-line: http://www.epa.state.oh.us/derr/rules/RR-039_public.pdf		RA.
4.	Figure 2-1		The paradigm presented in the Human Health Risk Assessment plan on Figure 2-1 does not follow the OEPA – DERR RI/FS Program, and the decision tree, as presented, could be misleading. It is recommended that the Figure 2-1 should not be included at or followed in preparing the Risk Assessment report based on this draft. Instead, the OEPA – DERR (2004e) should be applied along with other relevant technical decision documents (TDCs). **Reference**: **OEPA-DERR (2004**) Use of Risk-Based Numbers in	Please delete fig. 2-1 and follow screening methodology as described in **OEPA-DERR (2004 a and e)**.	The decision process presented in Figure 2-1 is consistent with EPA guidance and the process that has been used throughout the investigations at Plum Brook. It is also consistent with the decision process employed at Acid Areas 2 and 3.

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
			the Remedial Response Process Overview (revised June 28, 2005). Available on-line: http://www.epa.state.oh.us/derr/rules/RR-038.pdf		
5	Table 3-2		This document states in Table 3-2 (On-Site Resident, in several rows): "*...Exposure duration (ED), years* [...] *Adult 24...*" **Comment**: According to U.S EPA (1989) the default **ED is 30 years or more**, unless otherwise justified on Site-specific basis. Quoted from U.S EPA (1989) Page 6-22: "*...the upper-bound value of 30 years can be used for exposure duration when calculating reasonable maximum residential exposures. In some cases, however, lifetime exposure (70 years by convention) may be a more appropriate assumption...*" **Reference:** **U.S. EPA (1989)** Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), Interim Final, EPA/540/1-89/002, December 1989. On-line: http://www.epa.gov/oswer/riskassessment/ragsa/index.htm	Please either justify the applied exposure duration on Site-specific basis (a reference to U.S. EPA Region 9 seems to be inappropriate in this place), or use the default of **30 years**.	An exposure duration of 24 years for the on-site resident is based on EPA 1991 Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Manual, OSWER Directive: 9285.603. The reference notation in the table will be corrected.
6.	Table 3-2		This document states in Table 3-2 (Dermal Contact with Sediment; On-Site Resident): "*...Child: 1750*[g] *Adult: 4550*[g]*...*" **Comment**: The quoted (U.S. EPA, 1992b) reference "g" is obsolete. Please use values recommended by U.S. EPA (2004) in RAGS Part E, (see Exhibit 3-5, page 3-20).	Please either justify the applied exposure duration on Site-specific basis (and delete reference to U.S. EPA 1992b), or use the RAGS E default of **2,800 and 5,700 cm^2**, respectively.	Skin surface areas are based on a wading scenario and assume exposure to the lower legs and feet plus the forearms and hands.

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
			Reference: **U.S. EPA (2004)** Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part E, Supplemental Guidance for DermalRisk Assessment) Final. EPA/540/R/99/005. On-line: http://www.epa.gov/oswer/riskassessment/ragse/index.htm		
7.	Table 3-2		This document states in Table 3-2 (Dermal Contact with Surface Water; On-Site Resident): "*...Child: 2100[g] Adult: 5450[g]...*" **Comment**: The quoted (U.S. EPA, 1992b) reference "g" is obsolete. Please use values recommended by U.S. EPA (2004) in RAGS Part E, (see Exhibit 3-2, page 3-8).	Please either justify the applied exposure duration on Site-specific basis (and delete reference to U.S. EPA 1992b), or use the RAGS E default of **6,600 and 18,000 cm^2**, respectively.	Skin surface areas are based on a wading scenario and assume exposure to the lower legs and feet plus the forearms and hands.
1.	SLER A S. 3.1 PP. 3-3 to 3-4		This Document states in Equation 3.3: "*...K_{OC} = chemical –specific organic carbon partition coefficient.* *K_{OW} = chemical-specific octanol/water partition coefficient...*" The same K_{OC} variable in the Eq. 3.2 is listed as a: "*chemical-specific octanol/water partition coefficient*". **Comment:** To avoid any confusion about K_{OC} vs. K_{OW} the same symbol or acronym should be consistently used throughout the Document to depict the same variable with the same definition.	Please correct symbol used in **equation 3.2.**	The change will be made as noted in the comment
2.	SLER A		The reference to OEPA *(2003)* "*Guidance for Conducting Ecological Risk Assessments*"...	Please **update** reference to OEPA (2003) guidance with	Text has been revised per the comment

Comment Number	Sect. Page/ Line#	Cross Ref.	Comment	Recommendation	PRP Response
	S. 8.0		Seems to be obsolete. The OEPA-DERR revised this guidance in April 2008.	**(2008)** revision.	