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April 16, 2007

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Subject: Final Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans, Acid Areas 2 and 3, Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio

Dear Kathy,

Enclosed find four (4) copies of the above referenced document.

This is a required deliverable for Contract DACW62-03-D-0004-0004, "Acid Areas 2 and 3, Remedial Investigation Part 1: Site Characterization at the Former Plum Brook Ordnance Works, Sandusky, Ohio".

If you have any question please contact me at 865-220-6043 or al.hardesty@jacobs.com.

Sincerely yours,

Al Hardesty

Al Hardesty

Attachments

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Final Baseline Human Health Risk Assessment Work Plan
Acid Areas 2 and 3

Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

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

Prepared by:

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April 2007

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

Jacobs Engineering Group, Inc. has completed the Final Baseline Human Health Risk Assessment Work Plan, Acid Areas 2 & 3, 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		4/13/07
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Independent Technical Review Team Leader and Team Members		
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Jacobs Baseline Human Health Risk Assessment Work Plan Author		

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

Responses to comments from the PBOW Team review are provided as appendices to the document and changes have been incorporated as appropriate.

All concerns resulting from independent technical review of the project have been considered.

Al Hardesty
(Signature)

April 12, 2007
(Date)

(Project Manager)

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List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
°F	degrees Fahrenheit
μg/L	micrograms per liter
μg/mg	micrograms per milligram
AA	Acid Area
ABS	dermal absorption factor
AF	adherence factor
amsl	above mean sea level
AT	averaging time
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
BTEX	benzene, toluene, ethylbenzene, and xylenes
BW	body weight
CDI	chronic daily intake
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
COC	chemical of concern
COPC	chemical of potential concern
CSEM	conceptual site exposure model
D&M	Dames & Moore, Inc.
DA	dose absorbed per unit body surface area per event
DAD	dermal absorbed dose
DERP-FUDS	Defense Environmental Restoration Program – Formerly Used Defense Sites
DM	dry matter
DNT	dinitrotoluene
DOE	U.S. Department of Energy
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
HHEM	human health evaluation manual
HI	hazard index
HQ	hazard quotient
I	intake
ILCR	incremental lifetime cancer risk
IR	ingestion rate
IRIS	Integrated Risk Information System

IT	IT Corporation
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
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PC	permeability coefficient
PCB	polychlorinated biphenyl
PEF	particulate emission factor
RA	risk assessment
RBC	risk-based criteria
RBRC	risk-based remediation criteria
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.
STC	source-term concentration
SVOC	semivolatile organic compound
TAL	target analyte list
TNT	trinitrotoluene
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

1.0 INTRODUCTION

This baseline human health risk assessment (BHHRA) work plan was prepared to describe the protocol for evaluating human health risks associated with exposure to soil, groundwater, surface water, and sediment associated with Acid Areas 2 and 3 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 #4. This work is being conducted for the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP). The PBOW site is a formerly used defense site (FUDS) under DERP, currently being managed by the Corps of Engineers, Huntington District and technically overseen by the Corps of Engineers, Nashville District. As the lead agency for environmental response actions at PBOW, the USACE is responsible for site investigation and evaluation, as well as any remedial activities.

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

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 2 (AA2) site is located in the northwestern portion of PBOW, south of Patrol Road and west of Campbell Street (Figure 1-2). The Acid Area 3 (AA3) site is located approximately 1 mile east of AA2, northwest of the intersection of Ransom Road and Maintenance Road (Figure 1-2).

The AA2 site is an open field with two drainage ditches running west to east; one on the northern perimeter of the site, and one on the southern perimeter of the site. 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 an old railroad grade with a few railroad ties and loose track are still evident at the site. Former building foundations can be observed on the north side of the site. A paved service road completes a loop around the perimeter of the site. AA2 covers approximately 25 acres. The ground surface is relatively flat, with minimal slope toward the east and southeast. Elevations at the site range from 639.6 feet (ft) above mean sea level (amsl) near the southeastern portion of the site to 643.8 ft amsl in the western portion. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Small wooded areas have developed throughout the site and tend to be thickest in the western portion. The areas outside of the site boundary are heavily wooded.

The Acid Area 3 (AA3) site physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. A large diameter concrete culvert discharges into the ditch on the east side of the bank, near the center of the site. Running water was heard through the drainage grates during the Round 1 groundwater sampling effort. Several rail lines are still present at the site, oriented in a north–south direction. A paved service road borders the northern and western perimeter of the site, while Ransom Road and Maintenance Road serve as boundaries for the eastern and southern perimeter, respectively. AA3 covers approximately 40 acres. The ground surface is relatively flat, with elevations ranging from 632.6 to 637.0 ft amsl. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass or small shrubs and occasional wooded areas.

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.

The National Aeronautics and Space Administration (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. Army's General Services Administration to use 604 acres of the facility.

The acid areas were used to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. The AA2 site contained eight buildings, 24 above-ground acid storage tanks, and a rail line. The AA3 site contained 10 buildings, 46 above-ground tanks, and a rail line. A review of the 1958 and 1968 aerial photos indicates that the above-ground features including buildings and storage tanks were dismantled between these dates. The AA2 and AA3 sites are currently open fields and are not being utilized, with the exception of storage use at two remaining buildings.

Recent investigations at AA2 and AA3 have identified chemical contamination in the soil and sediment, which is related to former U.S. Department of Defense (DOD) activities. Concentrations of polychlorinated biphenyls (PCBs) and semivolatile organic compounds (SVOCs) exceed the screening criteria.

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 General Services Administration 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 3 through 7 are speculative and no negotiations have been scheduled to define future land use.

1.3.1 Acid Areas Land Use

The Acid Areas were used as early as 1941. Acid production likely ceased in 1945 when TNT production was discontinued. Previous investigation reports and records searches do not indicate dates for construction, operation, and dismantlement of the Acid Areas. Removal of buildings and above-ground tanks occurred between 1958 and 1968 based on aerial photography. The only remaining building at AA2 is the easternmost building adjacent to the former rail line, which currently is used for storage of deer traps. The only remaining building at AA3 is the northernmost building adjacent to the rail line, which is locked and used by NASA for storage of unknown materials. 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 gpm from the shale aquifer and overlying discontinuous sand and gravel deposits. The northwest portion of PBOW, including all of AA2 and most or all of AA3, 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. A wedged-shape area extending from

the northwest boundary of PBOW and pinching out just south of AA3 is mapped as an area in which yields of five to 25 gpm may be developed from wells drilled in limestone. The boundary of this area runs near to or includes the southeastern-most extent of AA3 (Ohio Department of Natural Resources, 2007).

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 (SAIC, 1991). The nearest recorded well is at 6115 Schenk Road, approximately 1950 ft north of AA2 and 3600 ft west of AA3; however, a closer well was observed at 1810 Schenk Road, located approximately 1400 ft northeast of AA2 and 2700 ft west of AA3.

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, 1993, *Closure Plan Review Guidance for RCRA Facilities*, Interim Final, OEPA Division of Hazardous Waste Management, September 1.
- 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. 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. Army Corps of Engineers (USACE), 1999, *Risk Assessment Handbook, Volume I: Human Health Evaluation*, Engineer Manual EM 200-1-4.

- 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.

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 (EPC); 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 each acid area. Risks associated with exposure to all appropriate media at each acid area 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 Criteria Development: Describes the development of risk-based remediation criteria (RBRC), 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 each acid area will be selected based on the representativeness and quality of the data. For inorganics in groundwater, the sampling method can affect the representativeness of the analytical data; thus, the sampling method will also be considered in selection of the analytical data set. Sampling methods and data usability considerations are presented in Section 2.1.2. The evaluation of data quality is presented in Section 2.1.3. Surface and subsurface soil sample locations, surface water and sediment sample locations, bedrock wells, and overburden wells considered for the evaluation of the respective Acid Areas, as well as downgradient locations, are identified on Tables 2-1 and 2-2.

2.1.1 Available Data

A Site Investigation (SI) was performed at the Acid Areas in 1998 (IT 1998), which identified surface and subsurface soil contamination above EPA Region III Risk Based Criteria (RBC). Thirty soil samples were collected at 15 locations at AA2. Thirty-eight soil samples were collected at 20 locations at AA3. Organic contaminants in surface and subsurface soil exceeding the RBCs included PCBs and semivolatile organic compounds (SVOCs).

Groundwater monitoring wells were installed at AA2 and AA3 as part of a site-wide groundwater investigation beginning as early as 1993. Five wells installed at or adjacent to AA2 were sampled at various times during the period 1993 through 2004. Two wells installed at AA3 were sampled from 1997 through 2002. These wells were included in the 2005 investigation, which is summarized below.

A Remedial Investigation (RI) was performed in 2004 – 2005, which involved additional surface and subsurface soil sampling, surface water and sediment sampling, and groundwater sampling from shallow and bedrock monitoring wells.

Soil samples were collected from 13 locations in AA2 and 14 locations in AA3. Surface soil samples were collected from 0.5 to 1.5 ft bgs at all locations. Subsurface samples were collected from three to five ft bgs at all locations and from eight to ten ft bgs at specific locations. All samples were analyzed for volatile organic compounds (VOCs), SVOCs, nitroaromatics, taget analyte list (TAL) metals, and PCBs.

Three shallow overburden monitoring wells and two bedrock monitoring wells were installed at AA3 in December 2004. No monitoring wells were installed at AA2 since there were five existing wells at the site. All newly installed wells were developed and slug tested. Two rounds of groundwater samples were collected from the newly installed wells and existing wells in January and April 2005. Samples for metals analysis were filtered in the field during the January 2005 sampling round in addition to unfiltered metals. Based on the BHHRA technical memorandum submitted 23 May 2005 (Shaw, 2005) no filtered data will be used in risk assessment.

Three surface water and sediment samples were collected from the drainage ditches at each site. Samples were collected from the drainage ditch along the southern perimeter of AA2 and

from the drainage ditch along the western perimeter of AA3. Sediment samples were collected 27 October 2004. Surface water samples were collected at the same locations 29 April 2005, once sufficient discharge was present at all locations. Sample locations at both sites included one upstream location, one location adjacent to the site, and one downstream location.

RI sample collection and data evaluation are discussed in detail in the Interim Final Site Characterization Report (Jacobs, 2006). Sufficient soil data have been collected for the AA2 and AA3 soil to support a risk assessment. Sufficient data have also been collected to evaluate impacts to the groundwater at both sites.

Thirty additional surface water and sediment samples were collected in the spring of 2006. The locations include co-located surface water and sediment sampling as follows:

- Twelve locations at the southern drainage ditch at AA2, including one upstream location, eight locations adjacent to the site, and three downstream locations.
- Eight locations at the northern drainage ditch at AA2, including six locations adjacent to the site and two downstream locations.
- Ten additional locations at the AA3 drainage ditch, including seven locations adjacent to the site and 3 downstream locations.

These data are discussed in the Interim Final Site Characterization Report (Jacobs, 2006).

2.1.2 Sampling Method Considerations

Surface soil and subsurface soil sampling was performed utilizing a Geoprobe® 5400 DPT rig equipped with a Macrocore sampling device. VOC samples were collected from the undisturbed soil cores using an Encore® sampler or Terracore® sample kit. Remaining soil was homogenized in a glass bowl prior to sample collection with a stainless steel spoon.

Surface water samples were collected by direct-fill methods from the center of the stream and upstream of the sampler to ensure no sediment disturbance. Sampling began at the downstream location and proceeded upstream to avoid any sediment disturbance. Sample containers with preservatives were filled first by transfer from a clean sample container with no preservatives.

Sediment samples were collected with a stainless steel hand auger equipped with dedicated disposable stainless steel liners. VOC samples were collected from the undisturbed stainless steel liners using an Encore® sampler or Terracore® sample kit. Remaining sediment was homogenized in a glass bowl prior to sample collection with a stainless steel spoon.

Groundwater sampling prior to 2001 was performed with a bailer. Low-flow sampling techniques were employed for all other sampling rounds when possible. Low-flow sampling could not be performed at monitoring well IT-MW10, due to an obstruction in the casing near ground surface. A ½-inch diameter disposable bailer was used to purge the well dry and to collect samples after the well had recovered. Turbidity in both 2005 sampling rounds was not an issue as both samples were very clear; however, based on conclusions documented in a

technical memorandum, inorganics from the 1998 sample at monitoring well IT-MW10 will not be used in the risk assessment due to elevated concentrations resulting from turbidity (Shaw, 2005b).

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 five times 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 ten times 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. 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 semivolatile organic compounds. 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 5 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 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. 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, potentially capable of contributing significantly to risk, and are carried forward to quantitative evaluation in the RA. The following subsections describe their identification. Prior to initiation of the RA, a list of chemicals present in site samples will be compiled. This initial list will include all chemicals detected in any site medium. COPCs will be selected from this list as discussed in the following sections.

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.

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 9 preliminary remediation goals (PRG) tables (EPA, 2004b).

PRG 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, the threshold at (or below) which adverse noncancer effects are regarded as unlikely to occur. For this BHHRA, the noncancer values listed in the PRG tables will be multiplied by a factor of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals (EPA, 2004c, 1995). This results in RBSC values associated with an HQ of 0.1. For cancer risk, the PRG values will be used directly as RBSCs in the BHHRA, as 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." Cancer risks associated with PRG 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.

A number of the chemicals may have MDCs that exceed RBSCs but are part of normal background concentrations. Such chemicals may include inorganics and polycyclic aromatic hydrocarbons (PAH), a class of organic compounds which 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 xylenes (BTEX) compounds may also be associated with background concentrations due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW (see Section 2.2.5).

Site concentrations of chemicals will be compared to those of PBOW background using a 2-step approach: 1) background screening and 2) statistical data set testing. This second step (Section 2.2.4) will only be used in cases where the concentration used for background screening is exceeded (refer to Section 2.2.3) and will be addressed after the risk characterization (Section 5.0) in the uncertainty analysis (Section 6.0) of the BHHRA report. No suitable background data set exists for overburden wells, so no comparison to background concentrations will be made for perched groundwater.

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 9 PRGs 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 of Inorganics

Background screening will be applied to each inorganic 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 BSCs is described in the 2004 groundwater report (Shaw, 2005). BSCs were calculated for use at PBOW based on concentrations found in background bedrock monitoring wells installed upgradient of PBOW sources. Each BSC either the MDC or the calculated 95th percent upper tolerance limit of the background data set (based on unfiltered samples collected using low-flow sampling), whichever value is lower (Shaw, 2005). Background values for soil, established as part of the acid areas investigation (IT, 1998), will be used for this RA.

Screening will consist of comparing the MDC of the site data set to the BSC. A chemical will be considered for further evaluation if its MDC exceeds the BSC for that chemical; further evaluation would 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 the BSC.

2.2.4 Statistical Data Set Testing of Inorganics

Statistical testing of site inorganics data against the PBOW background data set (identified in Appendix M of the 2004 groundwater data summary and evaluation report [Shaw, 2005]) may be performed for chemicals whose MDCs exceed the 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 analyte tested. As mentioned in Section 2.2.1, statistical testing will be performed after the risk characterization (Section 5.0) as part of the uncertainty analysis (Section 6.0). 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. Analytes 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, unless a qualitative chemical-specific explanation will be presented in the uncertainty analysis (Section 6.0) of the BHHRA report as to why the analyte should not be regarded as site related.

2.2.5 Treatment of Organics

As mentioned in Section 2.2.1, 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 2.1.4). A discussion of background contribution of organics will be presented in the uncertainty analysis (Section 6.0) 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 each acid area 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,
- Appropriate RBSC,
- Appropriate BSC, and
- Selection/exclusion of chemical as a COPC.

Similar tables will be provided for each medium at each acid area for data summary purposes. However, because overburden groundwater is not regarded as a potential source of tap water (Section 1.3), chemicals with MDCs exceeding the RBSCs will be indicated on the tables but will not be identified as COPCs. Likewise, a comparison to background concentrations will not be included on the tables for the overburden wells, because no background data exist for overburden groundwater at PBOW (Section 2.2.1).

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 AA2 and AA3 will characterize potential exposures to COPCs in soil, groundwater, surface water and sediment associated with the respective site areas. Estimation of risk from potential exposure will be described in the BHHRA risk characterization for each COPC (refer to Chapter 5.0). The Scope of Work (USACE, 2001) requires the summation of potential risks from all environmental media evaluated in the risk characterization (see Section 5.4). Therefore, the respective CSEMs described in Section 3.1 include all environmental media evaluated for each acid area.

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 the acid areas. The receptors and pathways on the figure reflect plausible scenarios developed from information on 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 AA2 site physical features include an open field with two drainage ditches running west to east: one on the northern perimeter of the site, and one on the southern perimeter of the site. 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 an old railroad grade with a few railroad ties and loose track are still evident at the site. Former building foundations can be observed on the north side of the site. A paved service road completes a loop around the perimeter of the site. AA2 covers approximately 25 acres. The ground surface is relatively flat, with minimal slope toward the east and southeast. Elevations at the site range from 639.6 ft amsl near the southeastern portion of the site to 643.8 ft amsl in the western portion. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Small wooded areas have developed throughout the site and tend to be thickest in the western portion. The areas outside of the site boundary are heavily wooded.

The AA3 site physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. A large diameter concrete culvert discharges into the ditch on the east side of the bank, near the center of the site. Running water was heard through the drainage grates during the Round 1 groundwater sampling effort. Several rail lines are still present at the site oriented in a north–south direction. A paved service road borders the northern and western perimeter of the site, while Ransom Road and Maintenance Road serve as boundaries for the eastern and southern perimeter, respectively. AA3 covers approximately 40 acres. The ground surface is relatively flat, ranging from 632.6 to 637.0 ft amsl. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass

or small shrubs and occasional wooded areas.

AA2 Geology: Overburden thickness at AA2 ranges from 18 to 21.5 ft. The overburden consists of clay and silty clay, with frequent discontinuous zones of silt and occasional sandy silt or silty fine grained sand zones. The discontinuous silts and sands are limited to the upper 10 ft of the overburden. The lower 10 to 12 ft of overburden consists of clay and silty clay, with occasional silt layers. Silt content tends to be greater in the southern half of the site. The northern half of the site contains a greater amount of highly plastic clays in the bottom half of the overburden. The Delaware Limestone subcrops beneath these unconsolidated deposits over the entire site. A small amount of Plum Brook shale may be present on top of the Delaware Limestone in the extreme eastern end of the site.

AA3 Geology: Overburden thickness at AA3 ranges from 21.0 to 25.9 ft. The overburden consists of clay and silty clay, with frequent discontinuous zones of silt in the upper 10 feet of the overburden. The lower 5 to 7 ft of overburden consists of a fairly continuous layer of highly plastic clay, which is present at most locations. There are deposits of sandy silt and silty sand on the east side of the site at depths ranging from 8 to 18 ft, with a maximum thickness of 5 ft. The Plum Brook Shale subcrops beneath these unconsolidated deposits over the entire site. The thickness of this shale ranges from 4.5 to 14 ft, with thickness decreasing to the northwest. The Delaware Limestone underlies the Plum Brook Shale.

AA2 Surface Water: Two drainage ditches border the AA2 site: one on the northern perimeter of the site and one on the southern perimeter. The drainage ditches are both approximately 1900 ft on-site, discharging to Pipe Creek approximately one-quarter mile downgradient (east) of the site. The southern drainage ditch channel is approximately six to eight ft wide and four to six feet deep, with width and depth increasing downstream. The northern drainage ditch channel is approximately three ft wide and two to three feet deep. Both drainage systems are ephemeral and flow only during the wet season and following precipitation events, remaining dry from mid-summer through the fall. The average annual precipitation for Sandusky is 34.5 inches per year.

AA3 Surface Water: The only surface water feature within AA3 is a drainage ditch on the western perimeter of the site, which flows from north to south. The drainage ditch is approximately 1800 ft on-site, discharging to Pipe Creek approximately one-half mile downgradient of the site. The drainage ditch makes a 90-degree bend at the southwest corner of the site and then flows westward toward Pipe Creek. The channel is approximately six to eight ft wide and four to five ft deep at the upstream end north of the site, increasing to 15 ft wide and eight ft deep at the downstream location. The upstream portion of the drainage ditch is ephemeral and flows only during the wet season and following precipitation events, remaining dry from mid-summer through the fall. The lower half of the drainage ditch maintains six to twelve inches of water on a continuous basis. A 24" culvert discharges into the drainage ditch on the east side of the channel near the center of the site. An underground drainage system is present within the interior of the AA3 site, which likely discharges shallow groundwater through the 24" culvert. A series of drainage grates are present on the east side of the easternmost rail line.

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 less than one ft below ground surface (bgs) to six ft bgs during wet season and fluctuate up to four 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 northerly trend. Shallow groundwater at AA3 generally flows toward the center of the site, where underground drainage tiles divert shallow groundwater directly to the drainage ditch west of the site.

Bedrock groundwater has been subdivided into two separate units at PBOW: 1) the Plum Brook Shale and Ohio Shale, and 2) the Delaware Limestone. 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 Limestone 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 Limestone is dependant on the frequency, orientation, density, and connectivity of the fractures. Groundwater flow in the Delaware Limestone 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 AA2 and AA3 to support the production of oleum, sulfuric acid, and nitric acid used in manufacturing TNT. Contamination involved the inadvertent release of oleum, sulfuric acid, nitric acid, contaminants, and residues. Releases occurred to the surface soil as spills and to the subsurface soil from leaking or damaged underground pipes. Releases may also have occurred during decontamination or during the building and equipment removal processes. 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 Areas 2 and 3, 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 level 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 (1991) guidance, 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 (1986) policy of carcinogen evaluation, although it introduces considerable uncertainty into the cancer RA.

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 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 the acid areas 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 not quantitatively 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 the acid areas.

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 the acid areas 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 resident receptor represent an upper bound on exposure for all potential receptors.

The potential exposure scenarios evaluated for acid area 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 each acid area will be 1.0 for each receptor. Exposure parameters and parameter values are summarized in Table 3-1.

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, 2004c). 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 (EPA, 1991a) will be used for adult and child residential pathways.

Drinking water ingestion rates for the adult of 2 liters per day (L/day) (EPA, 1991a) and for the child of 1 L/day (EPA, 2004c) will be assumed. 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 per hour (m^3/hour) for the adult (EPA, 1991a) and 0.416 m^3/hour for the child (EPA, 2004c) will be used. Because the *Exposure Factors Handbook* (EPA, 1997a) 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.

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 ingestion rate will be assumed to be 1 L/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) (EPA, 2004a), would be exposed intermittently for up to 1 hour per day. Because exposure was assumed to be intermittent, rather than continuous, organic chemical uptake across the dermis would not reach steady state, which guides selection of the EPA (2004a) model to be used to quantify this pathway (Section 3.3.3).

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 the acid areas.

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 3-1.

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-kilogram adult who works 8 hours per day (hours/day), approximately 5 days per week (days/week) year-round on site for a total of 250 days/year for 25 years (EPA, 1991). The respiratory rate for the groundskeeper will be assumed to be 20 m^3/8-hour workday (2.5 cubic meters per hour [m^3/hour]), and the soil incidental ingestion rate will be assumed to be 100 milligrams per day (mg/day), 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 (1997a). Measurements of soil adherence to hands, arms, legs, feet, and face for 29 groundskeepers revealed AFs ranging from 8E-4 milligrams per square centimeters (mg/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 includes approximately 11,300 cm^2 (EPA, 1997a).

Because infiltration and dissipation over time reduce VOC concentrations at the surface (i.e., first few centimeters) from which volatilization would occur, VOC-contaminated surface soil that has been in place 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-kilogram adult nearby resident (exposure duration of 30 years) (EPA, 1991). 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 ingestion rate will be assumed to be 100 mg/day (EPA, 1991). 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 ingestion rates and inhalation rate for the child when expressed on a BW basis.

The adult resident will be assumed to be a 70-kilogram person with an incidental soil ingestion rate of 100 mg/day, an inhalation rate of 20 m^3/day (0.83 m^3/hour) (EPA, 1991). 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 1 through 6 year-old with an average BW of 15 kilograms, a soil ingestion rate 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, 1991, 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 be developed to 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-kilogram 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, 1991). His soil incidental ingestion rate 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 be developed to evaluate short-term exposure to surface and subsurface soil (total soil) in either the current or future site-use scenario. Construction projects are expected to be infrequent. 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-kilogram adult who works 8 hours per day (hours/day), approximately 5 days per week (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 3 months; for the remaining 3 months, construction activities are assumed to result in less intensive soil contact. Soil ingestion rates of 480 mg/day (EPA 1991a) and 100 mg/day, similar to an agricultural worker, are assumed for the intensive and less intensive contact periods, respectively. The resulting time-weighted average soil ingestion rate 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 using the same method as previously described for the groundskeeper, combining EPA (1997a) data for construction workers, utility workers, and equipment operators to capture the full range of activities likely to be performed by this receptor. The body regions evaluated for construction workers total approximately 11,300 cm^2. An inhalation rate of 20 m^3/day (EPA, 1991a) for potential exposures to VOCs and air borne dust will be assumed.

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 the acid areas.

Current on-site: The only potential current on-site receptors are construction workers. 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 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 3-1.

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 the acid areas.

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. 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 3-1.

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 the acid areas. 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 to be evaluated will be dermal contact with surface water. Approximately 30 percent of the adults and child's total body SAs, 5,450 cm^2 and 2,100 cm^2, respectively, are available for exposure to surface water. It will be assumed that dermal uptake of organic chemicals from water does not reach steady state. Incidental ingestion of surface water in a wading scenario is 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, so that this pathway is expected to less significant than dermal contact, which is 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 subsurface soil. The construction worker may also be exposed to surface water during projects such as installation of underground utilities or rerouting stream flow. Dermal contact is the most significant pathway for exposure to surface water. Incidental ingestion of surface water is also 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 work day. It will be assumed that the arms, forearms and hands (an SA of approximately 3,100 cm^2 [EPA, 1997a]) are exposed to surface water. 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 is 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 the acid areas.

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 3-1.

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 the acid

areas and could be exposed to sediment. 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 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 ingestion rate 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,

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 subsurface soil. The construction worker may also 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 that dermal contact. Dermal exposure to sediment will be assumed to occur for 4 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 (EPA, 1997a), are exposed to sediment 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 the acid areas.

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 3-1.

Hunters: This scenario will be developed to evaluate the potential for contaminants in soil to affect food-chain pathways. Both acid areas provide 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, 2000c). 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 kilograms) of venison per year (Sharp, 1995). This consumption rate corresponds to 0.013 kg/day (0.186 g/kg-day) of venison for each of the 350 days per year (EPA, 1991) that the hunter spends at home.

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 ingestion rate for children. EPA (1997a) 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) 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). 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 ingestion rate of 0.335 g/kg-day will be estimated for the young child from the venison ingestion rate 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 kilograms (EPA, 2000), the child venison ingestion rate may be expressed as 0.005 kg/day.

3.2 Quantification of Exposure-Point Concentrations

The EPC is a conservative estimate of the average concentration of a COPC, 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, surface water 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 (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 mean is generally 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. Inclusion of outliers increases the overall conservatism of the risk estimate. The following paragraphs describe the statistical approaches and the models used to derive EPCs.

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 or 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 the previously mentioned 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):

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

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):

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

where:

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

$\bar{Y}$ = $\Sigma y/n$ = 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):

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

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 grams per cubic meter (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 (1996) 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:

$$PEF = Q/C \times \frac{3600}{0.036 \times (1-V) \times \left(U_m/U_t\right)^3 \times F(x)}$$ **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 m/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 (1997b) 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.

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 (1996) methodology for particulate emission factor (PEF), and to impart a conservative bias to the evaluation. 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* (EPA, 1996) to maintain consistency with the other models described in Section 3.2.1.

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/cm^3, calculated)

H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H·· 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 (1997b) 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. 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·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 cm, default [EPA, 1997b])

D^{crack} = effective diffusion coefficient through cracks (cm^2/second, assumed to be equivalent to D^{eff} [EPA, 1997b])

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

The building characteristics were obtained from EPA (1997a), which reviewed several studies of the volumes of houses and recommends 369 cubic meters as a central estimate of the volume of a house. Assuming the house has 8 ft (2.44 meters) ceilings and exists on one level, an area of 151.3 square meters, 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 (EPA, 1997a), which is equivalent to 4.61E+4 cm^2/second.

EPA (1997b) assumes that the only crack available for the entry of soil gas is a 0.1-centimeter (cm) wide gap at the interface of the floor and foundation. As noted above, it is assumed that the area of the basement floor is 151.3 square meters. Assuming that the house is square, the length of one side would be 12.3 meters, and the total length of the wall would be 49.2 meters (4,920 centimeters). 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 (1997b) provides default depths of 15 cm for buildings on slabs and 200 centimeters for buildings on foundations. 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 (4920 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, 1997b). 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, 1997b])

ρ_w = density of water (0.999 g/cm^2, [EPA, 1997b])

g = acceleration due to gravity (980.665 cm/$second^2$ [EPA, 1997b]).

Soil saturation hydraulic conductivity is related to soil texture. Site-specific data will be used in conjunction with Table 4 of EPA (1997b) to estimate an approximate value for K_s.

Relative air permeability is estimated as follows:

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

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 (1997b) 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 [1997b])

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 provided by 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·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·· 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 volatile organic compounds (VOC) 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 cubic meter (m^3) per mole and a molecular weight less than 200 grams 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) (EPA, 1991b) will be used in the BHHRA. This model was selected based on correspondence between the OEPA (2004) and the USACE. 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:

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

where:

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

C_{gw} = Groundwater EPC (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 (1997a) *Exposure Factors Handbook* lists values different from some of these assumed by HHEM Part B. 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 (Cd), 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 do not exist 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 in either of the Acid Areas 2 or 3; 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 (0.04 and 0.06 for AA2 and AA3, respectively, unitless, see below)

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 each of the COPCs evaluated in the RA. The toxicity profiles briefly describe the uses of the chemical, its physical properties, behavior in environmental media, biotransfer capability, and toxicity values.

The Acid Areas 2 and 3 sites cover approximately 25 and 40 acres, respectively. The home range of a deer is approximately 630 acres. Therefore, FI_e will be set equal to 0.04 and 0.06 for AA2 and AA3, respectively.

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 (1989a) unless otherwise indicated. Intakes will be calculated for both cancer and noncancer evaluations. 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, 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, 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 (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, 2004b). A default K_p value of 0.001 cm/hour (EPA, 2004b) 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 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 (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, 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 slope factor 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 slope factor 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 $\mu g/m^3$.

The slope factor 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 slope factor 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 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 slope factors (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 (1989a) 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.

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 (1989a) 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. 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." Two common examples of Tier 3 values are the EPA's Health Effects Assessment Summary Tables (EPA, 1997c) and the California Environmental Protection Agency (2005) Office of Environmental Health Hazard Assessment Toxicity Criteria Database.

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 (1989a), as modified by more recent information and guidance. 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 incremental lifetime cancer risk (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 (1986) 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). 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. Cancer risks above 1E-4 are considered to be clearly 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 (1989a), 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). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ as follows:

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

where:

$TotalHI_a$ = total hazard index for target organ "a" (unitless, calculated)

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

5.3 Risk Characterization Results

Separate risk characterization results for potential exposures at AA2 and AA3 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 AA2 and AA3 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 risk management range) and that of scenario "B" given as 5E-4 (exceeding the 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 the 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 overviews 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 CRITERIA

RBRCs are derived to provide support for risk management decisions. They are developed only for the COC in media that are associated with unacceptable risk that may potentially warrant corrective action. RBRCs are site-specific risk-based concentrations that reflect the exposure and toxicity assumptions applied in the baseline RA. Consequently, the RBRCs are source medium-, receptor-, and chemical-specific. Separate sets of RBRC values would be derived for AA2 and AA3. The development of RBRCs would involve a balance of cancer risk and noncancer hazard estimates separately for each site. The development of RBRCs would be an iterative process with on-going discussion between OEPA and the USACE.

The first step in RBRC 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-6; COCs based on noncancer are selected for any receptor for which the total HI (summed across chemicals and exposure pathways) exceeds 1. An individual COPC in that medium must have an ILCR (summed across exposure pathways) exceeding 1E-6 to be selected as a cancer-based COC. An individual COPC in any medium must have an HI (summed across exposure pathways) exceeding 0.1 to be selected as a noncancer-based COC.

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

$$RBRC_{coc} = \frac{ST_{coc} TR}{ILCR_{coc}} \qquad \textbf{Eq. 7.1}$$

where:

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

ST_{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.

RBRCs for noncancer COCs are estimated as follows:

$$RBRC_{coc} = \frac{ST_{coc} THI}{HI_{coc}} \qquad \textbf{Eq. 7.2}$$

where:

$RBRC_{coc}$ = risk-based remediation criterion for a given COC, receptor and source medium (calculated) ST_{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 RBRC units will be the same as the concentration units of the source-term concentration. RBRCs are not final remedial concentrations. RBRCs 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 and feasibility study begins.

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.

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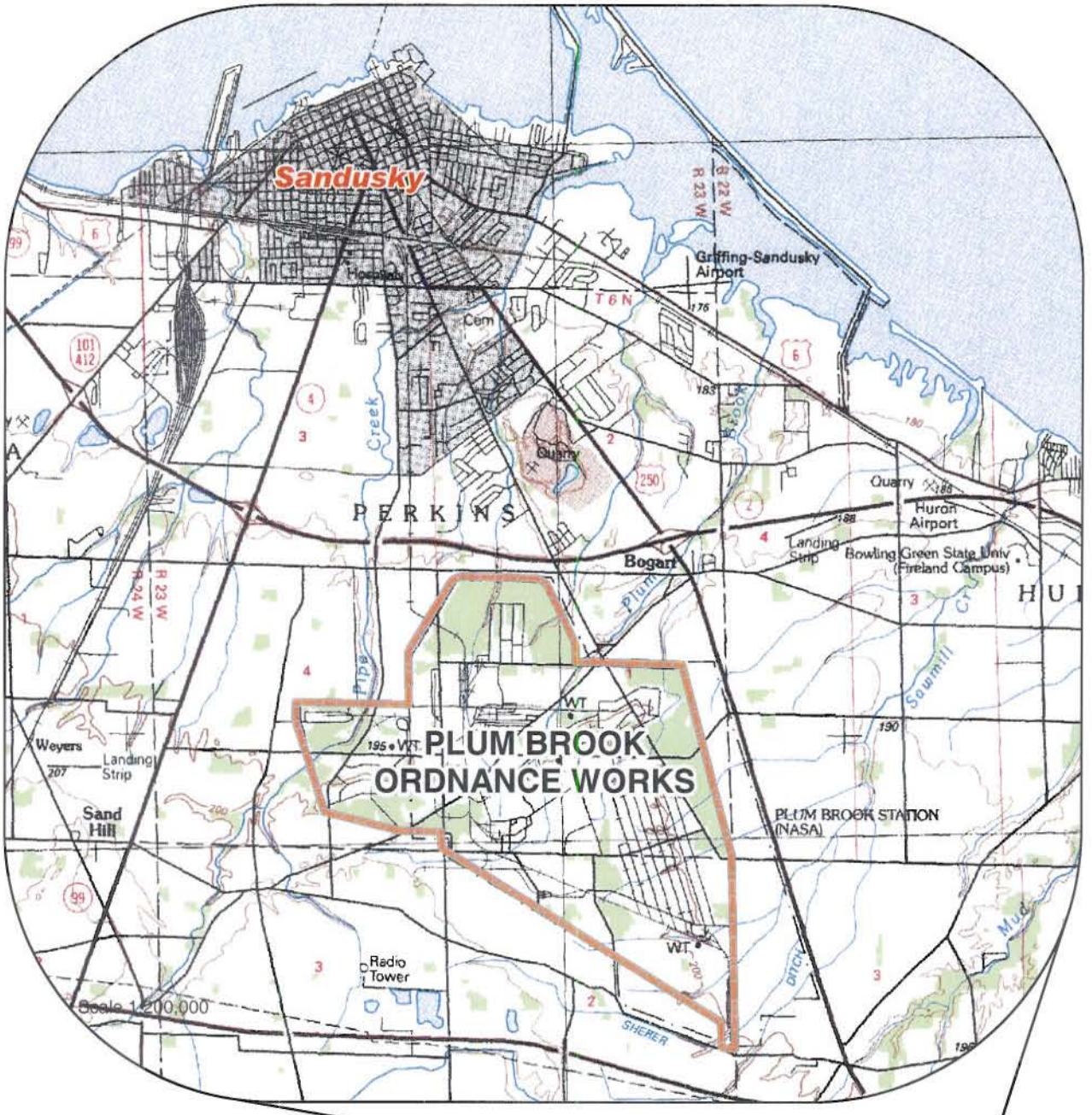

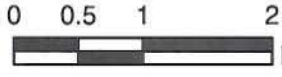

Legend

Plum Brook Ordnance Works Boundary

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JACOBS

Location Map,
Plum Brook Ordnance Works
Sandusky, Ohio

Plumbrook Ordnance Works
Sandusky, Ohio

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Figure 1-1

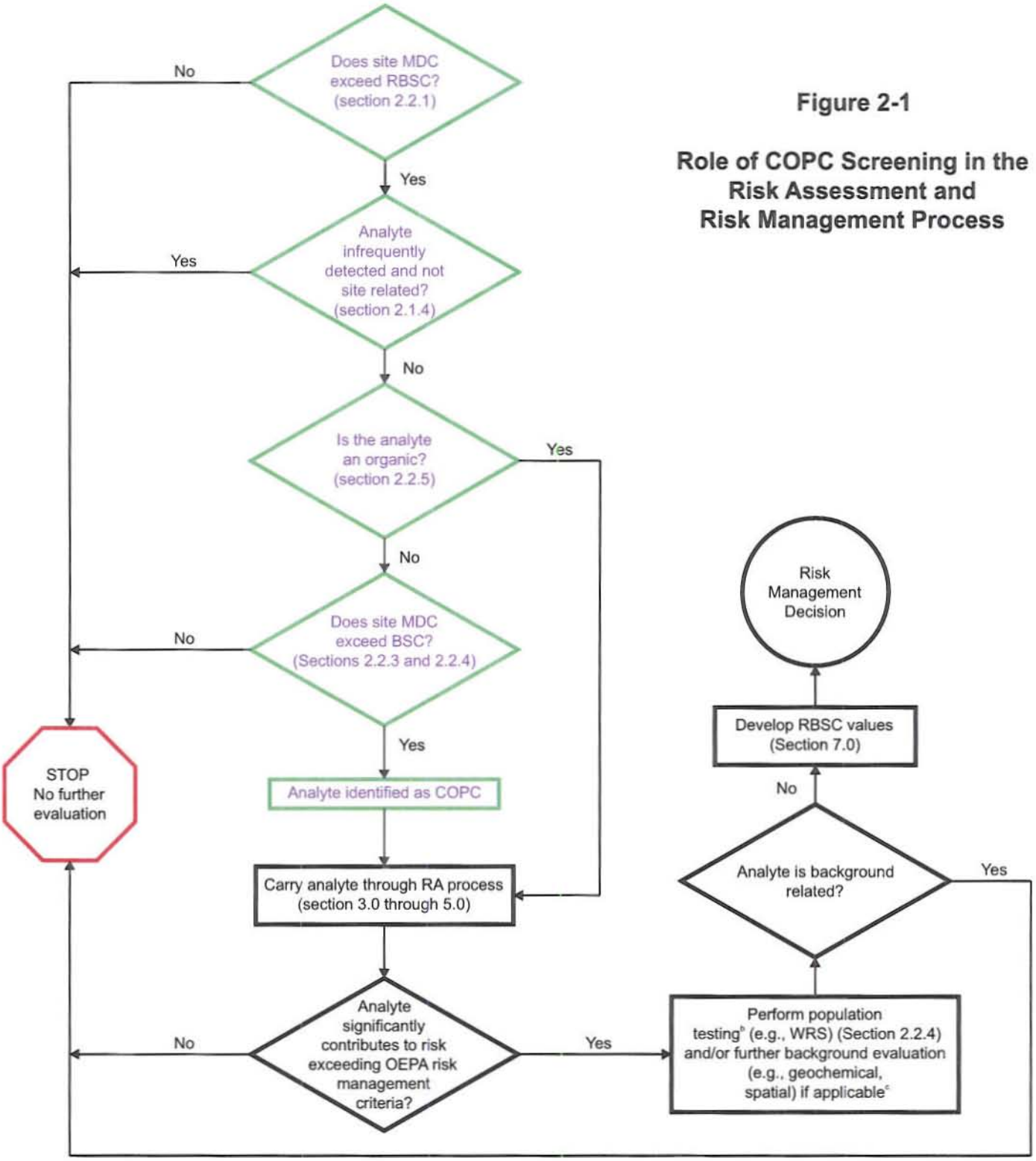
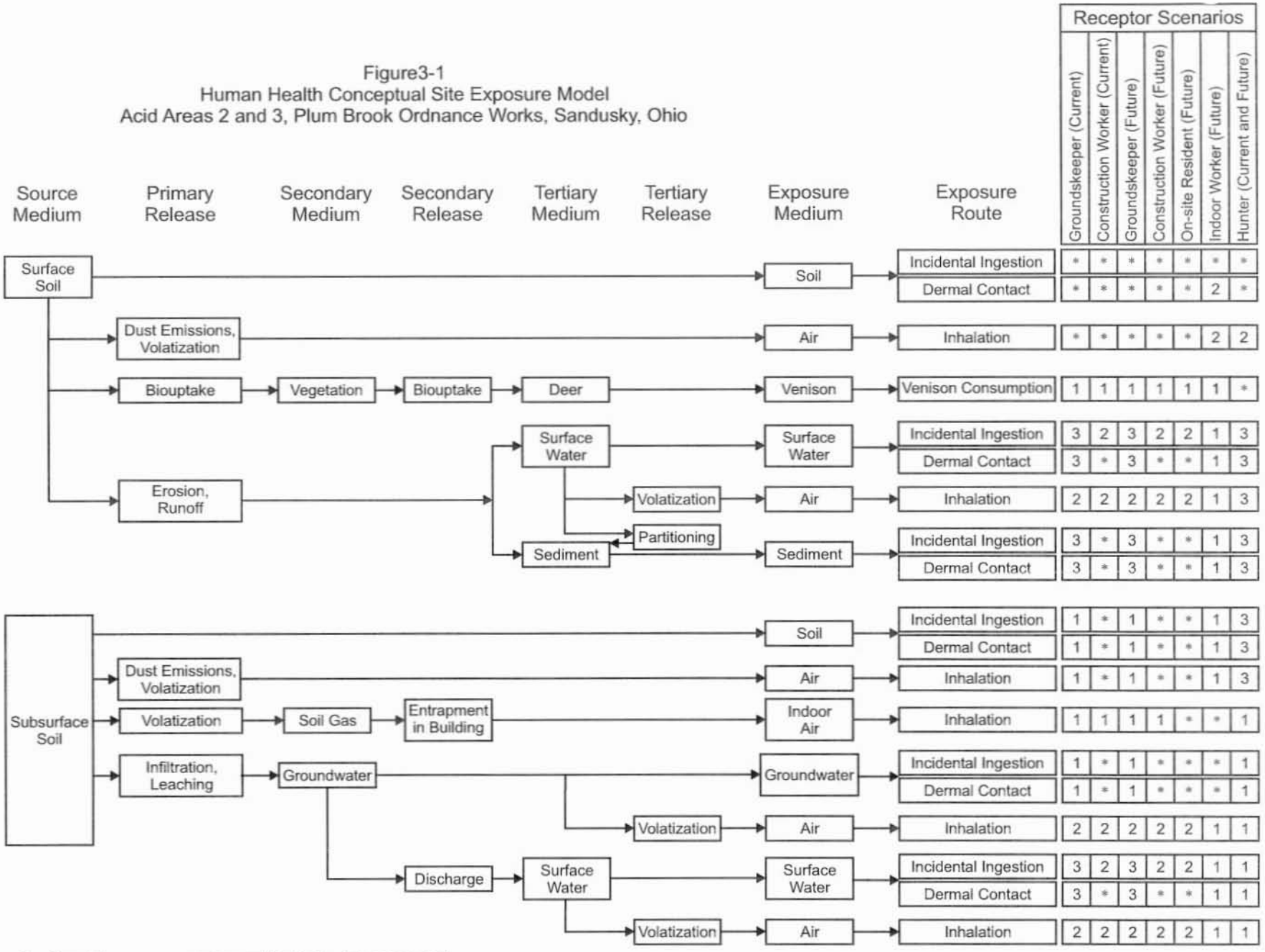


Figure 2-1

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)

Figure3-1
Human Health Conceptual Site Exposure Model
Acid Areas 2 and 3, 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 2, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)
Soil	AA2-SB01	IT, 1998	0-1, 6-8
	AA2-SB02	IT, 1998	0-1, 2-4
	AA2-SB03	IT, 1998	0-1, 4-6
	AA2-SB04	IT, 1998	0-1, 8-10
	AA2-SB05	IT, 1998	0-1, 4-6
	AA2-SB06	IT, 1998	0-1, 4-5.5
	AA2-SB07	IT, 1998	0-1, 4-6
	AA2-SB08	IT, 1998	0-1, 6-8
	AA2-SB09	IT, 1998	0-1, 4-6
	AA2-SB10	IT, 1998	0-1, 8-10
	AA2-SB11	IT, 1998	0-1, 2-4
	AA2-SB12	IT, 1998	0-1, 6-8
	AA2-SB13	IT, 1998	0-1, 2-4
	AA2-SB14	IT, 1998	0-1, 4-6
	AA2-SB15	IT, 1998	0-1, 2-4
	AA2-SB16	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB17	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB18	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB19	Jacobs, 2004	0.5-1.5, 3-5
	AA2-SB20	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB21	Jacobs, 2004	0.5-1.5, 3-5
	AA2-SB22	Jacobs, 2004	0.5-1.5, 3-5
	AA2-SB23	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB24	Jacobs, 2004	0.5-1.5, 3-5
	AA2-SB25	Jacobs, 2004	0.5-1.5, 3-5
	AA2-SB26	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB27	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA2-SB28	Jacobs, 2004	0.5-1.5, 3-5
Surface Water	AA2-SWSD-01	Jacobs, 2005	N/A
	AA2-SWSD-02	Jacobs, 2005	N/A
	AA2-SWSD-03	Jacobs, 2005	N/A
	AA2-SWSD-04	Jacobs, 2006	N/A
	AA2-SWSD-05	Jacobs, 2006	N/A
	AA2-SWSD-06	Jacobs, 2006	N/A
	AA2-SWSD-07	Jacobs, 2006	N/A
	AA2-SWSD-08	Jacobs, 2006	N/A
	AA2-SWSD-09	Jacobs, 2006	N/A
	AA2-SWSD-10	Jacobs, 2006	N/A
	AA2-SWSD-11	Jacobs, 2006	N/A
	AA2-SWSD-12	Jacobs, 2006	N/A
	AA2-SWSD-13	Jacobs, 2006	N/A
	AA2-SWSD-14	Jacobs, 2006	N/A
	AA2-SWSD-15	Jacobs, 2006	N/A
	AA2-SWSD-16	Jacobs, 2006	N/A
	AA2-SWSD-17	Jacobs, 2006	N/A

Table 2-1

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 2, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)
Surface Water (cont)	AA2-SWSD-18	Jacobs, 2006	N/A
	AA2-SWSD-19	Jacobs, 2006	N/A
	AA2-SWSD-20	Jacobs, 2006	N/A
	AA2-SWSD-21	Jacobs, 2006	N/A
	AA2-SWSD-22	Jacobs, 2006	N/A
	AA2-SWSD-23	Jacobs, 2006	N/A
Sediment	AA2-SWSD-01	Jacobs, 2004	0 - 0.75
	AA2-SWSD-02	Jacobs, 2004	0 - 0.75
	AA2-SWSD-03	Jacobs, 2004	0 - 0.75
	AA2-SWSD-04	Jacobs, 2006	0 - 0.75
	AA2-SWSD-05	Jacobs, 2006	0 - 0.75
	AA2-SWSD-06	Jacobs, 2006	0 - 0.75
	AA2-SWSD-07	Jacobs, 2006	0 - 0.75
	AA2-SWSD-08	Jacobs, 2006	0 - 0.75
	AA2-SWSD-09	Jacobs, 2006	0 - 0.75
	AA2-SWSD-10	Jacobs, 2006	0 - 0.75
	AA2-SWSD-11	Jacobs, 2006	0 - 0.75
	AA2-SWSD-12	Jacobs, 2006	0 - 0.75
	AA2-SWSD-13	Jacobs, 2006	0 - 0.75
	AA2-SWSD-14	Jacobs, 2006	0 - 0.75
	AA2-SWSD-15	Jacobs, 2006	0 - 0.75
	AA2-SWSD-16	Jacobs, 2006	0 - 0.75
	AA2-SWSD-17	Jacobs, 2006	0 - 0.75
	AA2-SWSD-18	Jacobs, 2006	0 - 0.75
	AA2-SWSD-19	Jacobs, 2006	0 - 0.75
	AA2-SWSD-20	Jacobs, 2006	0 - 0.75
	AA2-SWSD-21	Jacobs, 2006	0 - 0.75
	AA2-SWSD-22	Jacobs, 2006	0 - 0.75
	AA2-SWSD-23	Jacobs, 2006	0 - 0.75
Overburden Groundwater	IT-MW10	Nov 1997 Feb 2005 Apr 2005	11.8 - 21.8 (feet below TOC)
	MK-MW09	Jun 1993 Nov 19997 May 1998 Jan 2005 Apr 2005	7.85 - 17.85 (feet below TOC)
	AA2-GW002	Jan 2005 Apr 2005	10.75 - 20.75 (feet below TOC)

Table 2-1

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 2, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)
Bedrock Groundwater	PB-BED-MW19	Dec 1994 Oct 1996 Nov 1997 May 1998 Oct 2001 Apr 2002 May 2004 Jan 2005 Apr 2005	26.2 - 51.2 (feet below TOC)
	AA2-BEDGW-001	Nov 1997 May 1998 Oct 2001 Apr 2002 Jan 2005 Apr 2005	30.25 - 45.25 (feet below TOC)

Table 2-2

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)
Soil	AA3-SB01	IT, 1998	0-1, 6-8
	AA3-SB02	IT, 1998	0-1, 6-8
	AA3-SB03	IT, 1998	0-1, 6-8
	AA3-SB04	IT, 1998	0-1, 8-10
	AA3-SB05	IT, 1998	0-1, 8-10
	AA3-SB06	IT, 1998	0-1, 4-6
	AA3-SB07	IT, 1998	0-1, 2-4
	AA3-SB08	IT, 1998	0-1, 4-6
	AA3-SB09	IT, 1998	0-1, 8-10
	AA3-SB10	IT, 1998	0-1, 6-8
	AA3-SB11	IT, 1998	0-1, 2-4
	AA3-SB12	IT, 1998	0-1, 2-4
	AA3-SB13	IT, 1998	0-1, 8-10
	AA3-SB14	IT, 1998	0-1, 2-4
	AA3-SB15	IT, 1998	0-1, 6-8
	AA3-SB16	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB17	Jacobs, 2004	0.5-1.5, 3-5
	AA3-SB18	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB19	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB20	Jacobs, 2004	0.5-1.5, 3-5
	AA3-SB21	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB22	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB23	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB24	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB25	Jacobs, 2004	0.5-1.5, 3-5, 8-10
	AA3-SB26	Jacobs, 2004	0.5-1.5, 3-5
	AA3-SB27	Jacobs, 2004	0.5-1.5, 3-5
	AA3-SB28	Jacobs, 2004	0.5-1.5, 3-5
	AA3-SB29	Jacobs, 2004	0.5-1.5, 3-5
	MNT-SB01	IT, 1998	0-1, 4-6
	MNT-SB02	IT, 1998	0-1, 2-4
	MNT-SB03	IT, 1998	0-1, 6-8
	PSB-SS01	IT, 1998	0-1
	PSB-SS02	IT, 1998	0-1
Surface Water	AA3-SWSD-01	Jacobs, 2005	N/A
	AA3-SWSD-02	Jacobs, 2005	N/A
	AA3-SWSD-03	Jacobs, 2005	N/A
	AA3-SWSD-04	Jacobs, 2006	N/A
	AA3-SWSD-05	Jacobs, 2006	N/A
	AA3-SWSD-06	Jacobs, 2006	N/A
	AA3-SWSD-07	Jacobs, 2006	N/A
	AA3-SWSD-08	Jacobs, 2006	N/A
	AA3-SWSD-09	Jacobs, 2006	N/A
	AA3-SWSD-10	Jacobs, 2006	N/A
	AA3-SWSD-11	Jacobs, 2006	N/A

Table 2-2

Sampling Locations to be Used in the Baseline Human Health Risk Assessment
Acid Area 3, Plum Brook Ordnance Works, Sandusky, Ohio

Sampled Media	Sample Location	Contractor / Sample Date	Sample Intervals (feet bgs)
Surface Water (cont)	AA3-SWSD-12	Jacobs, 2006	N/A
	AA3-SWSD-13	Jacobs, 2006	N/A
Sediment	AA3-SWSD-01	Jacobs, 2004	0 - 0.75
	AA3-SWSD-02	Jacobs, 2004	0 - 0.75
	AA3-SWSD-03	Jacobs, 2004	0 - 0.75
	AA3-SWSD-04	Jacobs, 2006	0 - 0.75
	AA3-SWSD-05	Jacobs, 2006	0 - 0.75
	AA3-SWSD-06	Jacobs, 2006	0 - 0.75
	AA3-SWSD-07	Jacobs, 2006	0 - 0.75
	AA3-SWSD-08	Jacobs, 2006	0 - 0.75
	AA3-SWSD-09	Jacobs, 2006	0 - 0.75
	AA3-SWSD-10	Jacobs, 2006	0 - 0.75
	AA3-SWSD-11	Jacobs, 2006	0 - 0.75
	AA3-SWSD-12	Jacobs, 2006	0 - 0.75
	AA3-SWSD-13	Jacobs, 2006	0 - 0.75
Overburden Groundwater	AA3-GW002	Nov 1997 May 1998 Jan 2005 Apr 2005	8.25 - 18.25 (feet below TOC)
	AA3-GW003	Jan 2005 Apr 2005	10 - 20 (feet below TOC)
	AA3-GW004	Jan 2005 Apr 2005	10.3 - 20.3 (feet below TOC)
	AA3-GW005	Jan 2005 Apr 2005	10.1 - 20.1 (feet below TOC)
Bedrock Groundwater	AA3-BEDGW-001	Nov 1997 May 1998 Sep 2001 Apr 2002 Jan 2005 Apr 2005	40.25 - 55.25 (feet below TOC)
	AA3-BEDGW-002	Jan 2005 Apr 2005	47.4 - 57.4 (feet below TOC)
	AA3-BEDGW-003	Jan 2005 Apr 2005	42.95 - 52.95 (feet below TOC)

Table 3-1
Receptor/Exposure Scenarios
Acid Areas 2 and 3
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 Areas 2 and 3, 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 at Acid Areas 2 and 3 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 (Fl_{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 (Fl_{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.

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Appendix A

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

COMMENTS RESPONSE MATRIX
DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN
ACID AREAS 2 AND 3
FORMER PLUM BROOK ORDNANCE WORKS, SANDUSKY, OH

Reviewers: CHPPM, OEPA, RAB
Respondent: Jacobs Engineering, Group, Inc. Mark E. Stack

Comment #	Section/ Page	Comment	ECC Response
US Army Center for Health Promotion and Preventive Medicine, L. Tannenbaum			
1	Page 2-5, Section 2.2.1 Risk-based Screening	Comment: The last sentence of the Section's second paragraph could be rewritten for clarity. Recommendation: Please consider rewriting the sentence as: "Risk based screening concentrations (RBSCs used in this BHHRA will be those of the EPA Region 9 preliminary remediation goals (PRG) tables . . ."	The text is correct as currently written; as discussed in the third paragraph of the section, PRGs based on noncancer endpoints will be derived from the Region 9 PRG tables by multiplying the Region 9 PRG by 0.1 as required by OEPA.
2	Page 2-5, Section 2.2.1, Risk-based Screening	The second sentence of the Section's last paragraph is not clear. When the text says: "However, all organics not eliminated on the basis of RBSC exceedance or infrequent detection will be carried through the risk assessment process . . .", this is no different than the process for inorganic compounds (and in concert with the subject paragraph's first sentence). Recommendation: Please rewrite the paragraph so that the distinction the text intends on making (with regard to how organic compounds are handled differently that inorganic compounds) is apparent to the reader.	The treatment of inorganic and organic constituents with regard to background is described in the subsequent sections of the report. The paragraph in question has been deleted in response to this comment.
3	Page 3-3. Section 3.1.1, AA2 Surface Water / AA3 Surface Water	The lengths of these two drainage ditches are not provided, but they should be. Such information can very much influence the ecological risk assessment. By way of example, if one or both ditches are not sufficiently large, it can become apparent that intended receptors to evaluate are not spatially relevant for study. Recommendation: In the revised work plan, please have the text supply the lengths of the ditches.	The approximate length of the two ditches has been added to the text in these sections. The drainage ditches at AA2 are both approximately 1900 ft on-site, discharging to Pike Creek approximately one-quarter mile downgradient of the site. The drainage ditch at AA3 is approximately 1800 ft on-site, discharging to Pike Creek approximately one-half mile downgradient of the site.
4	Page 3-20, Section 3.2.6 Concentra-tions of Contami-nants of	The page's two bulleted paragraphs (at the page bottom) are disturbing. The implication is that the ingestion of venison by hunters is a worthwhile pathway to evaluate. There are clear indications however, that such is not the case. The average home range of a White-tailed deer is about 630 acres. At just 25 acres in size, Acid Area 2 (AA2) constitutes just 4% of a deer's home range, and essentially then, no real opportunity for any one deer to sufficiently bioaccumulate site contaminants (in soil) so as to pose a realistic	The term FI_e in Equation 3.22 represents the areal portion of the site compared to the deer's home range. The description of the parameter and the subsequent text has been revised for clarification in response to this comment to address the size of the sites relative to the home range of deer. The pathway needs to be retained in order to be consistent with previous risk assessments.

COMMENTS RESPONSE MATRIX
DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN
ACID AREAS 2 AND 3
FORMER PLUM BROOK ORDNANCE WORKS, SANDUSKY, OH

Comment #	Section/ Page	Comment	ECC Response
	Potential Concern (COPCs) in Venison	health concern for a would-be venison consumer. Same would be true for the AA3 site. Additionally, neither site affords high quality habitat, such that deer would be attracted to such locations; in the main, both areas are dotted by buildings and former building foundations. Recommendation: For the reasons expressed in the Comment, please consider withdrawing the proposed venison consumption pathway evaluation of the forthcoming human health risk assessment. A useful reference that defends the non-applicability of deer for the sites in question is: Tannenbaum, L.V., 2005. Two Simple Algorithms for Refining Mammalian Receptor Selection in Ecological Risk Assessments. Integrated Environmental Assessment and Management, Volume 1(3): 290-298. See Comment #7.	
Ohio Environmental Protection Agency, Bonnie Buthker			
1	Page 2-1	On Page 2-1, it states that subsurface soil samples were collected from 3-5 feet below ground surface. In the table, there are some intervals that were collected from 2-4 feet BGS. Are these also going to be included in the subsurface soil data set? Please clarify. In addition, please clarify why exposure to surface soils is not being evaluated for the on-site resident.	The text refers to soil samples collected during the 2004-2005 Remedial Investigation. The samples in question were collected during a previous investigation. However, all samples will be used in the Risk Assessment. As depicted in the Conceptual Site Model, on-site residents will be evaluated for exposure to surface soil. Additional subsections (3.1.3.3 Surface Soil, 3.1.3.4 Subsurface Soil, 3.1.3.5 Surface Water, 3.1.3.6 Sediment, and 3.1.3.7 Game Animals) have been added to the work plan to briefly discuss the potential receptors to be evaluated.
2	Figure 2-1	Figure 2-1 is incorrect. There is no background screening concentration established for organics, so analytes cannot be screened out if the maximum concentration detected does not exceed the background screening concentration. Please correct.	The figure has been revised by switching the "Yes" and "No" at the "Is the analyte and Organic?" diamond.
RAB, Bennett & Williams			
1	General Comments 1.2 Background	This section contains a nice summary of the various entities who utilize the PBOW facility and the history behind their acquisitions.	Comment noted.

COMMENTS RESPONSE MATRIX
DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN
ACID AREAS 2 AND 3
FORMER PLUM BROOK ORDNANCE WORKS, SANDUSKY, OH

Comment #	Section/ Page	Comment	ECC Response
2	1.5 Organiza-tion of the Baseline Human Health Risk Assessment	This section has a good discussion on the various parts of the baseline human health risk assessment and what each part does. For the lay reader, this set of descriptions will make the much more technical sections easier to understand.	Comment noted.
3	2.1.1 Available Data	This section presents a good summary of the data that is available to the team as historic sampling information for completing the risk assessment.	Comment noted.
4	2.1.4 Frequency of Detection	The information in this section is important to the RAB. It documents the position of ACOE to preserve the infrequent but higher levels of contamination hits, preserves the data from possible "hot spots" that may be located above or to the side of the specific sampling location and therefore, not continuous contributors to the water or air being sampled at the sampling points. Retaining the infrequent but high sampling results is a protective position.	Comment noted.
5	3.2 Quantificati on of Exposure-Point Concentra-tions	This section provides a well written, straight forward technical explanation of the premises and formulas behind the risk assessment evaluations.	Comment noted.
6	Specific Comments 1.1 Facility Description	Please refer to our last review on Acid Areas 2 & 3 regarding the new Erie County Watershed Groups and their activities on Pipe Creek. It would be advisable to coordinate the work efforts on Acid Area 2, especially, with the Pipe Creek Watershed Group and with the Erie Soil and Water Conservation District. The person who should be contacted at the District is Breann Hohman, the new Firelands Coastal Tributaries Watershed Coordinator. She attended the PBOW field day held last December so is somewhat familiar with the facility. She can be reached at 419-626-5211.	The contact for the Pipe Creek Watershed Group has been added to the RAB mailing list.
7	1.3.2 Ground-water Use	The second paragraph of this section simply does not agree with the information presented on the Ohio Department of Natural Resources (ODNR) Ground-water Resources of Erie County map which was developed by Alfred Walker in 1986. The map can be viewed on ODNR's Division of Water web page at http://www.dnr.state.oh.us/water/gwrmaps/counties/Erie.htm. A	The paragraph has been revised using information from the ODNR Division of Water web page provided in the comment.

Comment #	Section/ Page	Comment	ECC Response
		version that can be enlarged enough to read all the text on the map can be downloaded in a pdf format from http://www.dnr.state.oh.us/water/gwrmaps/pdfs/Erie_GWR_36x23.pdf. If this map is the source of the information presented in this paragraph, then this paragraph needs to be rewritten to reflect the information presented. If this map is NOT the source of this information, then the source needs to be identified and referenced here. In addition, there needs to be a discussion as to why this ground water section does not follow the ODNR map since ODNR is the referenced source in the paragraph (e. g. "The carbonate aquifer is subdivided into two zones by the Ohio Department of Natural Resources based on usage and yields").	
8	2.2.2 Evaluating Essential Nutrients	This section needs to have a sentence added that states that the acceptable rate of exposure will be based on the lowest "safe" exposure rates for an "at risk" population. This clarification is important because the levels of "safe" exposure for one person may not be a "safe" level for someone else. An example of this is the exposure to sodium and chloride (table salt) in drinking water. While the Safe Drinking Water Act Secondary Maximum Contaminant Level (MCL) of 250 mg/l for chloride was established for taste, there are portions of the general population for which 250 mg/l of chloride, present as dissolved sodium chloride in the water, would be too high an elevation to serve as a source of potable water. That person would be unable to drink the water because the extra salt included could cause their blood pressure to rise and/or might affect other systems in their body adversely.	The work plan indicates that the potential dose to a receptor will be compared to "levels known or expected to be safe or toxic, and/or with daily allowances, depending on the availability of data." MCLs are for total constituent concentrations in water but do not address the potential dose an individual might receive. A child ingesting 1L of water containing 250 mg/L of Chloride would have a daily dose of chloride of 0.32 mg/kg-d, whereas an adult ingesting 2L of the same water would have a daily dose of 0.29 mg/kg-d. These daily dose estimates will be compared to the United States Reference Daily Intake values for the individual constituents.
9	2.2.5 Treatment of Organics	Has the petroleum in the Delaware Limestone been fingerprinted yet to establish the source? If so, what are the findings of the study? If not, when will it be done?	This study will be conducted by NASA. The timing for the study is not known at this time.
10	3.1.1 Physical Setting – Ground-water: 2nd paragraph page 3-4	No, the water levels in the Delaware Limestone are NOT hydraulically isolated from the Plum Brook / Ohio Shale. Please see our last memo on Acid Areas 2 & 3 that discusses the potential of dewatering in the Delaware Limestone from the dewatering activities at the Wagner Quarry.	The phrase "suggesting that this unit is hydrologically isolated from the overlying units" has been deleted in response to this comment.
11	3.2.2 COPC Concen-trations in Indoor Air –	While this equation is basically correct, the methodology used to determine Ks can have significant impacts on the accuracy of the output of this formula. We know that in fine grained geologic settings and soils secondary porosity may well equal and/or exceed primary porosity (see Tornes and others, 2000;	Efforts will be to make reasonably conservative assumptions for this pathway. The potential over- or under-estimation of vapor concentrations in indoor air will be addressed in the

Comment #	Section/ Page	Comment	ECC Response
	Equation 3.12, page 3-15	Kim and Christy, 2006 as introductory references to this topic). However, if the Ks values used for these equations are taken from small diameter samples that have been tested in a laboratory setting, there is an extremely high likelihood that the only porosity measured is that of primary porosity. To provide a meaningful evaluation, the total effective porosity (both primary and secondary), must be established and used to determine Ks . Methodologies that can be used to achieve meaningful total effective porosity and soil saturation hydraulic conductivity are discussed in Haefner (2000) and Fausey and others (2000). All of these papers can be found in the two special issues of the Ohio Journal of Science which have been provided to the members of the RAB, to ACOE, and to their consultants. Given that soil intrinsic permeability is a critical component in calculating the exposure levels for both inside air and for ambient air (see 3.2.3 VOC Concentrations from Subsurface Soil in Ambient Air), it may be necessary to retest this parameter in the field using a more appropriate sampling methodology. See McMahon and Christy (2000) for a preliminary discussion of the importance of macropores in soil gas exchange. Haefner (2000) and Fausey and others (2000) includes suggestions on how to better measure the total effective porosity of the site's soils.	Uncertainty Analysis.
12	Figure 3-1 Human Health Conceptual Site Exposure Model	For Hunter (Current and Future) in Surface Soil: Surface Water Dermal Contact, Sediment Dermal Contact, and Subsurface Soil: Surface Water Dermal Contact, the value of 1 is assigned. The note for 1 states "There is no plausible pathway for exposure in this medium". Of course the hunter has the same possible routes of exposure in these settings as does a current or future groundskeeper. Why isn't the hunter assigned the same value of 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.") as the groundskeepers? Please change these 1's to 3's for greater accuracy.	The suggested changes have been made.
13	Table 3-1 (continued)	See comments above and relabel the Hunter under Surface Soil as "not quantified[b]" to parallel the rating given to Groundskeeper. This relabeling could also be applied to Construction Worker.	Rows have been added to the end of the table for Total Soil, Surface water, and Sediment, all of which have been labeled "not quantified[b]."

FINAL BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN

Acid Areas 2 & 3

Former Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

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

Prepared by:

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April 2007

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

Jacobs Engineering Group, Inc. has completed the Final Baseline Ecological Risk Assessment Work Plan, Acid Areas 2 & 3, 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 Handsby	Ecologist	4/13/07
(Signature)	(Discipline)	(Date)

Independent Technical Review Team Leader and Team Members

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(Signature)	(Discipline)	(Date)

Jacobs Baseline Ecological Risk Assessment Work Plan Author

CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

Responses to comments from the PBOW Team review are provided as appendices to the document and changes have been incorporated as appropriate.

All concerns resulting from independent technical review of the project have been considered.

Al Hardesty
(Signature)

April 12, 2007
(Date)

(Project Manager)

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List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
ARP	assessment receptor profile
BAF	bioaccumulation factor
BCF	bioconcentration factor
bgs	below ground surface
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
DNT	dinitrotoluene
DOD	U.S. Department of Defense
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
HQ	hazard quotient
IT	IT Corporation
K_{oc}	soil adsorption coefficient
K_{ow}	octanol-water partition coefficient
LD_{50}	lethal dose 50%
LOAEL	lowest observed adverse effect level
MDC	maximum detected concentration
NASA	National Aeronautics and Space Administration
NOAEL	no observed adverse effect level
OEPA	Ohio Environmental Protection Agency
PBOW	Plum Brook Ordnance Works
RA	risk assessment
RBSEV	risk-based screening ecotoxicity value
RTV	reference toxicity value
SLERA	screening-level ecological risk assessment
STC	source-term concentration
TNT	trinitrotoluene
UCL	upper confidence limit
UCL_{95}	95th percent upper confidence limit on the arithmetic mean
USACE	U.S. Army Corps of Engineers
UTL	upper tolerance limit
WQC	Water Quality Criteria

1.0 INTRODUCTION

This screening level ecological risk assessment (SLERA) work plan was prepared to describe the protocol for evaluating adverse risks posed to ecological receptors from potential hazardous substance releases at Acid Areas 2 and 3, 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 #4. This work is being conducted for the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP). The PBOW site is a formerly used defense site (FUDS) under DERP, currently being managed by the Corps of Engineers, Huntington District and technically overseen by the U.S. Army Corps of Engineers, Nashville District (CELRN). As the lead agency for environmental response actions at PBOW, the USACE is responsible for site investigation and evaluation as well as any remedial activities.

This work plan is consistent with U.S. Environmental Protection Agency (EPA) guidance and with the procedures established in the Baseline Ecological Risk Assessment Work Plan for TNT Areas A & C soil (IT, 2001).

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 2 (AA2) site is located in the northwestern portion of PBOW, south of Patrol Road and west of Campbell Street (Figure 1-2). The Acid Area 3 (AA3) site is located approximately 1 mile east of AA2, northwest of the intersection of Ransom Road and Maintenance Road (Figure 1-2).

The AA2 site is an open field with two drainage ditches running west to east; one on the northern perimeter of the site, and one on the southern perimeter of the site. 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 an old railroad grade with a few railroad ties and loose track are still evident at the site. Former building foundations can be observed on the north side of the site. A paved service road completes a loop around the perimeter of the site. AA2 covers approximately 25 acres. The ground surface is relatively flat, with minimal slope toward the east and southeast. Elevations at the site range from 639.6 feet (ft) above mean sea level (amsl) near the southeastern portion of the site to 643.8 ft amsl in the western portion. The majority of the site is currently an open field, with tall grass and frequent low

shrubs. Small wooded areas have developed throughout the site and tend to be thickest in the western portion. The areas outside of the site boundary are heavily wooded.

The Acid Area 3 (AA3) site physical features include an open field with a drainage ditch running north to south on the western perimeter of the site. A storm sewer system was constructed at the site, as evidenced by existing drainage grates, manhole covers, and open holes with brick lining. A large diameter concrete culvert discharges into the ditch on the east side of the bank, near the center of the site. Running water was heard through the drainage grates during the Round 1 groundwater sampling effort. Several rail lines are still present at the site oriented in a north–south direction. A paved service road borders the northern and western perimeter of the site, while Ransom Road and Maintenance Road serve as boundaries for the eastern and southern perimeter, respectively. AA3 covers approximately 40 acres. The ground surface is relatively flat, with elevations ranging from 632.6 to 637.0 ft amsl. The majority of the site is currently an open field, with tall grass and frequent low shrubs. Some small wooded areas have developed along the former railroad tracks. Much of the area outside of the site boundary is also open terrain with tall grass or small shrubs and occasional wooded areas.

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.

The National Aeronautics and Space Administration (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 Corporation [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. Army's General Services Administration to use 604 acres of the facility.

The acid areas were used to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. The AA2 site contained eight buildings, 24 above-ground acid storage tanks, and a rail line. The AA3 site contained 10 buildings, 46 above ground tanks, and a rail line. A review of the 1958 and 1968 aerial photos indicates that the above ground features including buildings and storage tanks were dismantled between these dates. The AA2 and AA3 sites are currently open fields and are not being utilized, with the exception of storage use at two remaining buildings.

Recent investigations at AA2 and AA3 have identified chemical contamination in the soil and sediment, which is related to former U.S. Department of Defense (DOD) activities. Concentrations of polychlorinated biphenyls (PCBs) and semivolatile organic compounds (SVOCs) exceed the screening criteria.

1.3 Scope and Objectives

A SLERA will be performed to provide an estimate of current ecological risk associated with potential hazardous substance releases at Acid Areas 2 and 3. The results of the SLERA will contribute to the overall characterization of the sites and serve as part of the process used 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], 1997), *Region 5 Biotechnical Assistance Group (BTAG) Ecological Risk Assessment Guidance Bulletin No. 1* (EPA, 1996a), and *Guidance for Conducting Ecological Risk Assessments* (OEPA, 2003). The SLERA fits into Steps 1 and 2 of the ERAGS process (EPA, 1997).

The primary objective of the SLERA is to determine whether unacceptable adverse risks are posed to ecological receptors as a result of potential hazardous substance releases. This objective will be met by characterizing the ecological communities in the vicinity of the sites, determining the particular hazardous substances being released, identifying pathways for receptor exposure, and estimating the magnitude of the likelihood of potential risk to identified receptors. The SLERA will address the potential for adverse effects to the vegetation, wildlife, aquatic life (including both fish and aquatic macroinvertebrates), endangered and threatened species, and wetlands or other sensitive habitats associated with the sites. There is limited habitat for fish in this area of concern as the small streams within and adjacent to the area are intermittent.

Concentrations of chemicals measured in relevant environmental media, including soil, surface water, sediment, and groundwater (Jacobs, 2006) will be used to perform a SLERA, including a problem formulation (Section 2.0); an exposure characterization (Section 3.0); an ecological effects characterization (Section 4.0); a risk characterization (Section 5.0); a 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 sites 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 sites is minimal or nonexistent due to the lack of potential ecological receptors.
- Potential for adverse ecological effects to ecological entities at the sites is minimal or nonexistent due to the lack of potential exposure pathways.
- Potential for adverse ecological effects to ecological entities at the sites 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 sites will be described in sufficient detail to ensure that the CELRN technical specialist can be oriented to the sites. This information will be assembled from existing sources without conducting additional field studies. Natural resource personnel (e.g., federal or state officials) will be contacted to obtain any relevant data or useful ecological information.

2.2 Pre-Assessment Reconnaissance (Biota Checklist)

A site reconnaissance will be performed for the purpose of collecting qualitative information on the type, quality, and location of biological resources at Acid Areas 2 and 3. The assessment duration will typically be about one day per site. 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. Fish and aquatic macroinvertebrates will be collected for identification as necessary, depending on characteristics of the sites.

- 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, and identify protected species or habitats of special concern in the study area.

The site reconnaissance will be performed by two biologists or ecologists. Prior to arrival at the sites, reconnaissance personnel will obtain relevant information on the sites, 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 sites. Additionally, the *Biological Inventory of Plum Brook Station, 1994* (National Aeronautics and Space Administration, 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 similar to that on EPA's *Checklist for Ecological Assessment/Sampling* (EPA, 1997). In situ water column measurements (i.e., pH, temperature, dissolved oxygen, conductivity) will be collected by the field sampling team. The location of known or potential contaminant sources affecting the sites and the probable gradient of the pathway by which contaminants may be released from the sites to the surrounding environment will be identified. Reconnaissance personnel will use the reconnaissance to evaluate the sites 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 the 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 botanist will search for threatened and endangered plant species (two botanical surveys are planned; one in the spring and one in the late summer or early fall). A checklist of biological species present at the sites will be developed using existing site investigation reports, environmental data sources mentioned previously, and information gathered during the 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 sites 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 sites. 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 sites have 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 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.

2.5 Review, Evaluation, and Presentation of Analytical Data

Any relevant historical chemical analytical data will be reviewed and evaluated, as well as all 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 chemicals of potential ecological concern (COPECs) will identify a subset of site related chemicals to be carried through the risk assessment. 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. For ecological impacts, soil from 0 to 2 feet below ground surface (bgs) will be considered. Chemicals that are not detected at least once in a medium will not be included in the risk assessment. Available background data will be determined for each medium. Potential sources of background information will include data from previous and current investigations, as well as monitoring wells in areas unaffected by site activities.

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 5x, 10x rule).

"J" qualified data are used in the risk assessment; "R" and "B" qualified data are not. The handling of "U" qualified data (nondetects) is described below in this work plan.

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. In general, "outliers" are included in the calculation of the UCL because high values in environmental data are seldom true statistical outliers. Inclusion of outliers increases the overall conservatism of the risk estimate and the likelihood of rejecting the null hypothesis.

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, 1992b). 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 or lognormal distribution. For data sets with less than five samples, the maximum detected concentration (MDC) is used as the Exposure Point Concentration (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 chemical of potential concern (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 SLERA report as appropriate.

Analytical results are presented as "nondetects" ("U" qualifier) whenever chemical concentrations in samples do not exceed the reporting limits. To apply the previously mentioned 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 phenomena 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).

Data sets consisting of five or more data points are tested for normality and lognormality with the Shapiro-Wilks 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 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):

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

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, 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 risk assessment (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 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 risk 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. This comparison is generally valid for inorganic chemicals, but not for organic chemicals, because inorganic chemicals are naturally occurring and most organic chemicals are not. Statistical techniques are used as tools to aid the exercise of professional judgment in resolving site-related issues for metals, since metals are naturally present in most environmental media. The statistical techniques generally involve comparing the site data with background data.

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, 1996a). 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) Preliminary Remediation Goals for Ecological Endpoints (Efroymson et. al. 1997a); (2); Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process (Efroymson, Suter, and Will, 1997b); (3) Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants (Efroymson et. al. 1997c); and (4) Ecological Data Quality Levels (EDQLs; EPA, 1999). 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 sites. 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 sites, 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) Ohio EPA Water Quality Criteria [(WQC) OAC Chapter 3745-1] for the protection of aquatic life; (2) Preliminary Remediation Goals for Ecological Endpoints (Efroymson et. al. 1997a); and (3) Ecological Data Quality Levels (EDQLs; EPA, 1999). 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) Ecological Data Quality Levels (EDQLs; EPA, 1999); (2) Preliminary Remediation Goals 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 risk drivers 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. 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 (water fowl 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 on-site 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 sites; (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 sites or that habitats present at the sites 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 individual sites 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 ecological risk assessment (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 risk assessment process, which focuses on individual receptors, the SLERA will focus on populations or groups of interbreeding nonhuman, nondomesticated receptors. In the SLERA process, the risks 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 sites 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 sites. This information may be included in the ARP for appropriate receptors.

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 will be the ecological site conceptual model (ESCM). The ESCM will trace the contaminant pathways through both abiotic components and biotic food web components of the environment. The ESCM will present all potential exposure pathways and will identify those pathways that are complete and incomplete. The ESCM will clearly identify 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. All existing data will be qualitatively reviewed for quality, usefulness, and uncertainty.

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 sites will be developed considering both current and reasonably plausible future uses of the sites. Exposure and chemical uptake will be modeled to produce upper-bound exposure estimates. Exposure characterization is critical in further evaluating the risks of 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 chemical amounts that are bioavailable and the means by which the ecological receptors are 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 surface water, surface soil, 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 risk 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 site receptors. EPA (1993) provides a variety of exposure information for a number of avian, herptile, and mammalian species. 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, 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., raccoons' 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 associated with surface water or sediment pore water in order to modify exposure rates.

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

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

where:

SC = sediment concentration (milligram per kilogram)

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

K_{oc} = chemical-specific organic carbon partition coefficient (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 bioconcentration, bioaccumulation, and biomagnification are used throughout this document. Definitions describing their application are presented in the Glossary of Terms (Appendix A).

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 environmental risk 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 (1995) will be used to assess the possibility of contaminant magnification through site receptors. 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):

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

where:

BCF = Bioconcentration Factor

K_{oc} = 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 (EPA, 1996b) as follows:

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

where:

K_{oc} = the partition constant relative to organic carbon.

K_{ow} = the partition constant of octanol relative to water.

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

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

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 (1988). Soil-to-insect BAFs will be based on log K_{ow} relationships developed by Connell and Markwell (1990). Inorganic constituent BAFs will be based on literature values such as those found in Baes, et al. (1984), International Atomic Energy Agency (1994), and 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 sites. For nonburrowing animal exposure, soil samples obtained from a depth of 0 to 1 foot will be considered, as this would be the point of exposure. For burrowing animals, soil samples obtained from a depth of 0 to 6 feet bgs will be considered. For plant exposure, soil samples taken from 0 to 6 feet 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 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.

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. However, contaminant transport along the shallow groundwater pathway is considered an exposure route to aquatic life, wetlands, and some wildlife where the groundwater discharges to surface water. This pathway is of importance to aquatic and wetland receptors where groundwater discharges to surface water. It should be noted that groundwater concentrations will not be screened against surface water RBSEVs when either surface water data are available or groundwater is not discharging to the surface.

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. 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 ecological risk. 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 reference toxicity values.

4.1 Selection of Literature Benchmark Values

Appropriate sources for literature benchmark values will be consulted, such as (1) *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); and (2) LD_{50} values from data bases such as the Registry of Toxic Effects Concentrations (extrapolated to chronic no observed adverse effect level [NOAEL] or lowest observed adverse effect level [LOAEL] values using recommended Tri-Service [Wentsel, 1996] uncertainty factors). Extrapolation to chronic NOAEL or LOAEL values from LD_{50} values will only be performed when benchmark values are not available from other sources. 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 Reference Toxicity Values

Reference toxicity values (RTV) for the sites will be developed or determined. These RTVs 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 NOAEL and 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 risks 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, RTVs will be calculated for each of the COPECs. RTVs 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 risk assessment. RTVs will be calculated using safety factors

(Wentsel, et al., 1996) specified in Figure 4-1. Interclass toxicity extrapolations will not be performed, as physiological differences between classes are too great to be addressed with the use of simplistic safety factors. Separate factors are recommended to account for extrapolation to the no effects or lowest-effects endpoints, for study duration, and for extrapolation across taxonomic groups (e.g., species, genus, family, order). Additional safety factors will be employed for endangered species, as appropriate. These factors are multiplied together to derive a total safety factor. The reported effects dose is then adjusted to account for potential uncertainties by dividing by the total safety factor. 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, as described by 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 RTVs 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 risks 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. RTVs and exposure rates will be calculated and used to generate hazard quotients (HQ) (Wentsel, et al., 1996) by dividing the receptor exposure rate for each contaminant by the calculated RTV. 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 risk associated with the sites will be estimated. The risk estimation will be performed through a series of quantitative HQ calculations that compare receptor-specific exposure values with RTVs. It is important to note that HQs are not absolute risk measures, are not population-based statistics, and are not linearly scaled statistics. The HQs will be compared to HQ guidelines for assessing the potential risk posed from contaminants. HQs less than or equal to 1 present no probable risk; HQs greater than 1 but less than 10 present a low potential for environmental effects; HQs from 10 up to but less than 100 present a significant potential that effects could result from greater exposure; and HQs greater than 100 present the highest potential for expected effects (Wentsel, et al., 1996). It should be noted that OEPA considers HQs greater than 1.0 to be potentially significant.

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 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 risk analysis 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 risk 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 ecological risk. 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 risk drivers, 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 sites. 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 one brief site reconnaissance 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 risk), 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, 1997). 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 ecological risk associated with the sites; and (2) interpret the ecological significance, which describes the magnitude of the potential risks 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 ecological risks associated with releases from the sites will be summarized. This summary will be supported by the steps performed as described in the previous sections. Additionally, recommendations for further risk investigations will be made if appropriate and cost effective, and site-specific remedial action objectives will be developed for the sites, 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 risk assessment 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 ecological risk.

8.0 REFERENCES

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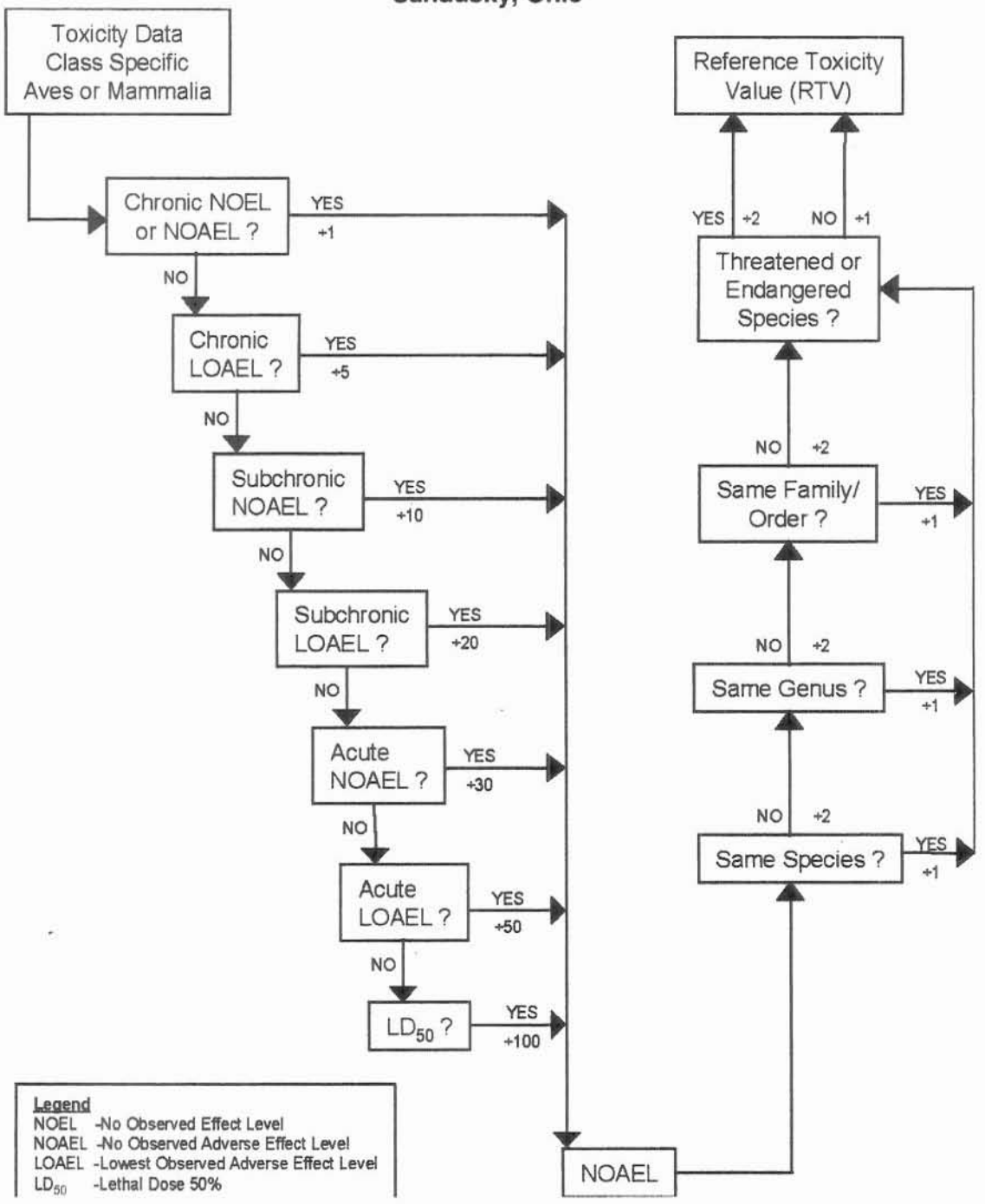
Figure 4-1
Procedural Flow Chart for Deriving Reference Toxicity Values (RTVs) from Class-Specific Toxicity Data
Plum Brook Ordnance Works
Sandusky, Ohio



Credit: Adapted from *Tri-Service Procedural Guidelines for Ecological Risk Assessments*, 1996

Appendix A

Glossary of Terms

Appendix A

Glossary of Terms

Bioconcentration: For aquatic organisms, bioconcentration is the uptake and retention of a substance by an aquatic organism from the surrounding water through gill membranes or other external body surfaces. Terrestrial bioconcentration focuses on uptake and retention of contaminants from the surrounding medium on the organism level (as by the earthworm, for example).

Bioaccumulation: This refers to the uptake and retention of a substance by an aquatic organism from its surrounding medium and food (U.S. Environmental Protection Agency, 1995). Terrestrial bioaccumulation, as with aquatic bioaccumulation, is defined as an organism's uptake and retention of a substance from its surrounding medium and food.

Biomagnification: This refers to the process by which tissue concentrations of bioaccumulated toxic substances increase as the substances pass up through two or more trophic levels. The definition of this term is similar for both terrestrial and aquatic organisms.

References

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Appendix B

Responses to Comments on the
Draft Baseline Ecological Risk Assessment Work Plan

COMMENTS RESPONSE MATRIX
DRAFT BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN
ACID AREAS 2 AND 3
FORMER PLUM BROOK ORDNANCE WORKS, SANDUSKY, OH

Reviewers: HTRW, CHPPM, OEPA, RAB
Respondent: Jacobs Engineering, Group, Inc. Mark E. Stack

Comment #	Section/ Page	Comment	ECC Response
		HTRW Center of Expertise, Terry L. Walker	
1	Section 4, general.	The procedures listed in Wentsel 1996 are not generally applied at the time of this writing. TRVs are available from many sources and extrapolations as shown in Figure 4-1 are not necessary. Consider checking the USACHPPM terrestrial toxicity database (TTD) at: http://chppm-www.apgea.army.mil/tox/HERP.aspx	The extrapolations depicted in Figure 4-1 will be applied only when TRVs from other sources are not available. A statement to this effect has been added to Section 4.1.
2	Section 5.3, page 5-2.	As the only evaluation planned for this SLERA is computation of HQs, there will be no estimate of ecological risks, only the potential for ecological risks to exist (see Section 5.1). Also, any attempt to interpret the ecological significance of the potential for risks cannot be done, unless further work is accomplished. Suggest that this section delineate where the potential for risks exists, the magnitude of the potential problem and the potential implications of the contamination on the applicable populations and communities of effected receptors.	The text has been revised as follows: "(1) summarize the potential ecological risk associated with the sites; and (2) interpret the ecological significance, which describes the magnitude of the potential risks and accompanying uncertainty."
		US Army Center for Health Promotion and Preventive Medicine, L. Tannenbaum	
1	Page 1-2, Section 1.3, Scope and Objectives	The text mentions the intention to estimate future ecological risk. Such an intention overlooks a reality with technically sound supports. Specifically, at historically-contaminated sites such as the two subject sites which ceased operation over 60 years ago, there is no legitimate concern over the well-being of site ecological receptors in the future. Taken together, the many decades that have passed and the life spans of ecological receptors being so very brief, it is far too late to any longer be considering what could happen to site receptors in the future. Instead, now is the time to determine if site ecological receptors display any signs of toxicological stress or impact as a result of their prolonged exposure to site contaminants. See Comment #8. Recommendation: In the revised document, please withdraw any mention of an intent to evaluate potential for future risk to site ecological receptors. We recommend the following two references be incorporated into the new text, as they specifically discuss the points raised in the Comment:	The reference to evaluation of potential future risks to ecological receptors has been eliminated from the document.

Comment #	Section/ Page	Comment	ECC Response
		Tannenbaum, L.V., 2003. Can Ecological Receptors Really Be At Risk? Human and Ecological Risk Assessment, Volume 9(1): 5-13. Tannenbaum, L.V., 2005. A Critical Assessment of the Ecological Risk Assessment Process: A Review of Misapplied Concepts. Integrated Environmental Assessment and Management, Volume 1(1): 66-72.	
2	Page 2-1, Section 2.2, Pre-Assessment Reconnais-sance (Biota Checklist)	Identifying dominant plant species and defining plant communities pursuant to the species identification, could very well amount to unnecessary work. If the two subject sites are adequately vegetated, there is no need to conduct the intended identification work. Such a finding would indicate that the two sites are able to support vegetation, which is all that really needs to be known. Additionally, in the event that either or both of the sites have distinctly different vegetation relative to a reference location, there are no methods available for determining if different plant assemblages found at contaminated sites constitutes an issue that demands attention. In other words, biologically significant thresholds are lacking at the present time. Also, it could be that the contaminated sites might have more biomass per acre than does the background condition, and realistically, the effort is not going to be made to make such a determination anyway. Beyond this, there are numerous reasons why plant assemblages might be expected to be different at contaminated sites relative to the reference/background condition, and these may have nothing to do with site contamination. See Comment 8. Recommendation: Please modify the text to note, in concert with the Comment, that extensive vegetative analysis is not necessary.	The site reconnaissance activities have already been completed. Page 2-2 states: "The purpose of these activities was to select representative receptors, refine exposure scenarios for the risk assessment, and identify protected species or habitats of special concern in the study area." The most important aspect of this activity was the identification of the presence of protected species in the study areas.
3	Page 2-3, Section 2.4, Significant Ecological Threats	From the reading of this brief paragraph, there is the potential for misinterpretation of any field-recorded 'presence or absence' data. The sites are small enough that no individuals of various species might be observed, but this would be a reflection of animals' relatively sparse densities, and also home ranges that far subsume the sites in question. By way of example, at the 25-acre AA2 site, based on the maximum density know for Red fox, not even one fox would be anticipated to be present (to possibly be observed), and same would be true for a 25-acre site in the most pristine (i.e., contaminant-free) area where Red fox is known to be found in the general area. Recommendation: As per the Comment, please have the text of this Section note the potential to wrongly interpret biota presence/absence information.	The site reconnaissance was performed primarily to determine the presence of T&E plant species. Specifically, species of Carex spp were evaluated in wetland areas. Bird and mammal species that were observed during completion of the plant surveys were recorded. Observations were simply noted and no assumptions or interpretations were made regarding the presence or absence of any species.

COMMENTS RESPONSE MATRIX
DRAFT BASELINE ECOLOGICAL RISK ASSESSMENT WORK PLAN
ACID AREAS 2 AND 3
FORMER PLUM BROOK ORDNANCE WORKS, SANDUSKY, OH

Comment #	Section/ Page	Comment	ECC Response
4	Page 2-7, Section 2.6.5, Comparison to Risk-Based Screening Ecotoxicity Values	It's not clear why there would be any screening for the potential effects of contaminant exposure on soil and litter invertebrates. For all intents and purposes, sites are not remediated on the basis of affording (health) protection to soil and litter invertebrates. Additionally, with the two sites having been contaminated and left alone for over 60 years, surely some equilibrium has been established at the site by this late date. Thus, if the site precludes the survival of soil and litter invertebrates, any receptors that might depend on these, will have found ways to adjust to their absence. It is most important to note that exceedances of the intended benchmarks for these soil biota does not indicate that these species are harmed or absent from the site. Regarding the use of plant screening for contaminants effects, there is an important caveat for the plant benchmarks that needs to be called out. Recommendation: In the revised document, please expand this Section to include the points made in the Comment. Consider not screening soil invertebrates for contaminant-posed effects. Regarding plants, please have the text here, note that the plant benchmark guidance specifically notes that should sites be adequately vegetated, the plant benchmarks are poor measures of potential toxicological effects and should not be used.	The last sentence of the paragraph has been revised and an additional sentence has been added so that the paragraph ends as follows: "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 sites. 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." The points made in the comments will be addressed in the uncertainty analysis of the SLERA.
5	Page 3-1, Section 3.1, Exposure Analysis	The page's next-to-last sentence should be modified to clarify the point being made. Recommendation: Please consider rewriting the identified sentence as: ". . . for animal bioaccumulation where both of these are considered as diet items for receptors to be evaluated for ingestion hazard."	The recommended text has been incorporated.
6	Page 5-1, Section 5.2, Uncertainty Analysis	This Section overlooks the entire subject of the limitations of the hazard quotient (HQ) method. Recommendation: In the revised document, please expand the Section to list six limitations of the HQ method, and please supply a brief (1-2 sentence) explanation of each. The limitations are: - 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; - the most miniscule soil concentrations of inorganics can lead to a 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	The recommended text has been incorporated.

Comment #	Section/ Page	Comment	ECC Response
		500 years old (contaminated). An appropriate reference to incorporate in the added HQ method limitation text is: Tannenbaum, L.V., Johnson, M.S., and Bazar, M., 2003. Application of the Hazard Quotient Method in Remedial Decisions: A Comparison of Human and Ecological Risk Assessments. Human and Ecological Risk Assessment, Volume 9 (1): 387-401.	
Ohio Environmental Protection Agency, Bonnie Buthker			
1	General	USACE should consider using Ohio EPA's Guidance for Conducting Ecological Risk Assessments, DERR-00-RR-031, February 2003.	The referenced document has been incorporated as guidance.
RAB, Bennett & Williams			
1	3.1 Exposure Analysis – Soil Exposure Pathway – bottom of page 3-4	"Generally, neutral to alkaline soils (soil pH of 6.5 or greater) restrict the absorption of toxic metals, making pathway completion to plants difficult." The above statement is simply incorrect. While it is true that in a setting with pH levels of 6.5 or higher, toxic metals tend to stay attached to the negatively charged clay minerals and/or dead organic materials in the soil and underlying geologic materials, plants have developed a very effective method of loosening those metals and absorbing them into their cellular structure. The plant forms and releases an acid in the area of its feeder root hairs (i.e. tannic acid from oak trees). This acid changes the pH levels surrounding the root hairs, allows the metals to be released from the negatively charged clay minerals and/or dead organic materials in the soil where they are attached and allows them to move to the negatively charged feeder root hairs where they are then absorbed into the plants as critically important nutrients. Once available, the plant root hairs accept the available metals following the rules of cation exchange. The heavier the metal cation and the higher the valence, the more tightly it binds to the negatively charged root hairs of the plant. Therefore, metals of smaller size and molecular weight with lower valence numbers such as sodium or magnesium are replaced by heavier metals with higher valences such as lead. This is the premise behind the whole field of bioremediation called "phytoremediation". It would be advisable to identify which plants growing at PBOW would have a greater than normal potential for uptake of heavy metals and target them for study and sampling. For	As indicated in the comment, plant uptake of metals from soil is influenced by the pH of the soil whether on a macro- or micro-scale. The statement is correct that at higher pH metals become less available. However, the statement has been removed from the text as it adds little to the overall discussion. A literature search for soil-to-plant transfer factors will be performed to determine appropriate factors for the soil type and plant communities present at the sites as part of the SLERA.

Comment #	Section/ Page	Comment	ECC Response
		instance, plants in the mustard family, such as Yellow Rocket and Dames Rocket are especially prone to absorbing heavy metals and this family of plants is often used in phytoremediation projects. This family of plants is expected to be growing at the PBOW. The ability of plants to chemically weather soil parent materials, including bedrock, is so well recognized that "biota" is listed as one of the five processes identified in basic soil formation. We recommend that the authors of this document visit the basic literature of plant science and soils to better understand these relationships. A copy of the periodic table of chemistry can be located on the web. One such table can be found at http://images.google.com/imgres?imgurl=http://wwwcms. llnl.gov/e113_115/download_images/Periodic_Table.jpg&imgrefurl=http://w wwcms. llnl.gov/e113_115/images.html&h=1717&w=2189&sz=1956&tbnid=7ymj6tl SllMA wM:&tbnh=118&tbnw=150&prev=/images%3Fq%3Dperiodic%2Btable%2 Bof%2Bche mistry&start=2&sa=X&oi=images&ct=image&cd=2.	
2	5.2 Uncertainty Analysis - top of page 5-2	"The use of soil data from 0 to 6 feet bgs may overestimate ecological effects, because many ecological receptors are only exposed to shallower soils." However, MANY ecological receptors are found in the full 6 feet here listed and in addition, other ecological receptors, such as the grasses, have the ability to draw up potentially contaminated soil water from as much as a foot or more below the bottom of their root zone. Grasses in the fescue family, the rye family, and native grasses commonly have feeder roots extending 6 feet or more below the surface of the ground. This is also true of some of the native prairie forbs. It is this deep-rooted feeding system that makes these plants so successful during times of drought and also allows them to successfully hold soil in place and protect it from wind and water erosion. This deep rooted growing pattern is also typical of a number of kinds of shrubs and trees. Furthermore, many soil insects, including earthworms, take advantage of old root channels and fractures to extend their habitat to significant depths. We have seen earthworms exiting from old root channels and fractures into our exploration pits at 6 feet or more in depth. For additional information on these topics, review McMahon and Christy (2000).	The referenced text has been removed as it is inconsistent with text in Section 3.1.