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Nashville, Tennessee

Final Baseline Human Health Risk Assessment Acid Area 2

Former Plum Brook Ordnance Works
Sandusky, Ohio

Contract DACW62-03-D-0004-0004

February, 2008

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CERTIFICATION OF INDEPENDENT TECHNICAL REVIEW

Significant concerns and the explanation of the resolution are as follows (Describe the major technical concerns, possible impact, and resolution):

Comment: See Appendix F for responses to PBOW team member review comments on the draft report.

Comment: Ensure that comments addressing specific sections or text are applied to all other relevant sections/text within the document.

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

Al Handesly
(Signature)
(Project Manager)

Feb 14, 2008
(Date)

**Final
Baseline Human Health Risk Assessment**

Acid Area 2

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Sandusky, Ohio**

Prepared for:



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

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February 2008

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List of Acronyms and Abbreviations

5x, 10x	five-times, ten-times
µg/dL	microgram/deciliter
ABS	dermal absorption factor
AF	adherence factor
amsl	above mean sea level
ATSDR	Agency for Toxic Substances and Disease Registry
AT	averaging time
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
BW	body weight
cm ²	square centimeter
COC	chemical of concern
COPC	chemical of potential concern
CSEM	conceptual site exposure model
CT	central tendency
DA	dose absorbed per unit body surface area per event
DERP	Defense Environmental Restoration Program
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	foot/feet
FUDS	Formerly Used Defense Sites
g	gram
g/m ³	grams per cubic meter
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
Jacobs	Jacobs Engineering Group
IEUBK	integrated exposure-uptake biokinetic
ILCR	incremental lifetime cancer risk
IR	ingestion rate
IRIS	Integrated Risk Information System
IT	IT Corporation
kg	kilogram
L	liter
m ³	cubic meter
MDC	maximum detected concentration

mg	milligram
mg/cm ²	milligrams per square centimeter
NASA	National Aeronautics and Space Administration
NCRPM	National Council on Radiation Protection and Measurements
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PC	permeability coefficient
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PRG	preliminary remediation goal
RA	Risk Assessment
RBC	Risk Based Criteria
RBRL	risk-based remediation level
RBSC	risk-based screening concentration
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
SA	surface area
SAIC	Science Applications International Corporation
SF	slope factor
Shaw	Shaw Environmental, Inc.
SI	Site Investigation
SVOC	semivolatile organic compound
TAL	target analyte list
TNT	trinitrotoluene
TRW	Technical Review Workgroup
UCL	upper confidence limit
UCL ₉₅	95th percent upper confidence limit on the arithmetic mean
UF	uncertainty factor
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

EXECUTIVE SUMMARY

This baseline human health risk assessment (BHHRA) report presents the human health risks from potential exposure to soil, groundwater, surface water, and sediment associated with Acid Area 2 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio. This BHHRA was prepared in accordance with the Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans (Jacobs, 2007). It is consistent with U.S. Environmental Protection Agency (EPA) and Ohio EPA guidance and with the procedures established in the BHHRA Work Plan for TNT Areas A & C soil (IT Corporation, 2001a) and the BHHRA work plan for groundwater at PBOW (Shaw Environmental, Inc., 2005a).

Acid Area 2 is located in the northwestern portion of PBOW. The site was used to produce oleum, sulfuric acid, and nitric acid for the manufacture of trinitrotoluene (TNT). Investigations have identified chemical contamination in site media. Acid Area 2 is now an open field with two drainage ditches running west to east. The remains of an old railroad grade are still evident. Former building foundations can be observed on the north side of the site. Acid Area 2 covers approximately 25 acres. The majority of the site is currently covered 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 Acid Area 2 site is currently not being utilized, with the exception of storage use at the remaining building. 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 objective of this BHHRA is to evaluate potential for cancer and noncancer human health effects posed to current and potential future receptors. This objective was met through the process of data evaluation, exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis.

Data evaluation consists of identification of data sources, evaluation of data quality, identification of chemicals of potential concern, and background screening. The exposure assessment consists of development of the conceptual site exposure model including definition of contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; description of exposure-point concentrations (EPCs); and identification of the methods for calculating chemical intake and contact rates. The toxicity assessment defines 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; and identifies the toxicity values that are used in the BHHRA. The risk characterization combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor. The uncertainty analysis identifies uncertainties in all phases of the BHHRA and discusses their individual effects on the risk assessment results.

PBOW is currently classified for industrial use, but future residential use was considered in the risk assessment to support evaluation of all plausible receptor scenarios. Groundskeeper, construction worker and hunter scenarios were evaluated under the current site-use assumptions. Groundskeeper, construction worker, indoor worker, hunter (including a child venison consumer) and on-site residential scenarios were evaluated as plausible future exposure scenarios.

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. The total hazard index (HI) estimate for the groundskeeper receptor equaled the threshold value of 1. The total incremental lifetime cancer risk (ILCR) estimate for the groundskeeper receptor was $5.0E-5$. The HI equaled 1. There were no chemicals of concern (COCs) for the HI; the COCs for the ILCR were arsenic, polychlorinated biphenyl- (PCB-) 1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil. Total HI estimates for the adult hunter and the adult and child venison consumer receptors were below 1. The total ILCR estimate for the adult hunter was $6E-6$. The COCs were benzo(a)pyrene and PCB-1254 in surface soil. Total ILCR estimates for the adult and child venison consumer receptors were below $1E-6$, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. The total HI estimate summed across all media for the construction worker receptor was 10. The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and arsenic, iron, thallium, and PCB-1254 in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was $1E-5$. ILCR sums for surface water and sediment were below $1E-6$. ILCR summed for surface and subsurface soil was $1E-5$. The COCs for the ILCR were PCB-1254 and benzo(a)pyrene in surface soil and benzo(a)pyrene in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. Total HI estimates for the indoor worker for groundwater and surface soil were 2 and 0.4, respectively. The COCs for the groundwater HI were arsenic, iron, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was $5E-5$. The ILCRs for groundwater and surface soil were $7E-4$ and $2E-5$, respectively. The COCs for the ILCR were 1,1,2-trichloroethane, arsenic and benzene in groundwater, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 7 and 31, respectively. HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 7 and 31 for the adult and child, respectively. The groundwater COCs for the HI were aluminum, arsenic, barium, iron, manganese, thallium, vanadium, cyanide, benzene, bromomethane, and nitrobenzene for the adult, and aluminum, arsenic, barium, chromium, iron, manganese, thallium, vanadium, cyanide, 1,1,2-trichloroethane, 2-methylnaphthalene, benzene, bromomethane, nitrobenzene, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, and aluminum, arsenic, iron, thallium, and PCB-1254 for the child. The subsurface soil COCs were aluminum, arsenic, iron, manganese, thallium, and PCB-1254 for the child. There were no HI COCs for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were both $3E-4$. ILCR sums for surface water and sediment were $5E-6$ and $7E-6$ for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil for adult and child residential receptors were both $3E-4$. The groundwater COCs for the ILCR were 1,1,2-trichloroethane, arsenic, bis(2-ethylhexyl)phthalate, and benzene for the adult and 1,1,2-trichloroethane, arsenic, and benzene for the child. The surface soil COCs were arsenic, PCB-

1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the child. The subsurface soil COCs were arsenic, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene for both the adult and child.

Based on analytical results, metals, polynuclear aromatic hydrocarbons (PAHs), and PCBs appear to be widespread but generally at low concentrations in environmental media at Acid Area 2, with isolated areas of elevated PAH or PCB contamination. All inorganic constituents detected in environmental media were carried through the risk assessment to provide a conservative estimate of potential risks associated with exposure to site media. However, the maximum detected concentrations (MDCs) for arsenic and iron in surface soil and aluminum, arsenic, iron, and manganese in subsurface soil were lower than their respective background criteria. The MDC of aluminum exceeded its background criterion, which was based on the maximum concentration detected in background samples. The EPC for aluminum was well below its background criterion. There are no site-specific background data for the PAHs, and several were selected as COCs. PAH concentrations at Acid Area 2 all fall within global background levels for urban areas compiled by the Agency for Toxic Substances and Disease Registry (1997).

HIs for contamination in soil are less than 1 for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, suggesting that adverse effects from exposure are unlikely. Cancer risk for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site are within or below the cancer risk range of 1E-6 to 1E-4.

HIs for the indoor workers were below 1. HIs exceeded 1 for the construction worker, and adult and child residential receptors for exposure to surface soil. The primary contributor to the HIs was PCB-1254. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the construction worker and indoor worker, and just slightly above 1E-4 for the adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for construction workers and adult and child residential receptors exceeded 1 for exposure to subsurface soil. The primary contributor to the HIs was thallium. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the construction worker and the adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for the indoor workers and adult and child residential receptors exceeded 1 for exposure to groundwater. The primary contributor to the HIs was thallium. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the indoor worker, and just slightly above 1E-4 for the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

Cancer risk and noncancer hazard estimates for exposure to surface water were below 1E-6 and 1, respectively, for any receptor evaluated. Cancer risk estimates were within the cancer risk range of 1E-6 to 1E-4 for the construction worker and adult and child residential receptors for exposures to sediment.

Accounting for natural background concentrations of metals and the isolated detections of elevated concentrations of some COCs, potential risks from exposure to contaminants detected in site environmental media appear to be limited.

1.0 INTRODUCTION

This baseline human health risk assessment (BHHRA) report presents the human health risks from potential exposure to soil, groundwater, surface water, and sediment associated with Acid Area 2 located at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio.

This BHHRA 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 Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the USACE Huntington District and technically overseen by the USACE Nashville District.

This BHHRA was prepared in accordance with the *Baseline Human Health Risk Assessment and Ecological Risk Assessment Work Plans* (Jacobs, 2007). It is consistent with U.S. Environmental Protection Agency (EPA) and Ohio EPA (OEPA) guidance and with the procedures established in the BHHRA Work Plan for TNT Areas A & C soil (IT Corporation [IT], 2001a) and the BHHRA work plan for groundwater at PBOW (Shaw Environmental, Inc. [Shaw], 2005a).

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 site is located in the northwestern portion of PBOW, south of Patrol Road and west of Campbell Street (Figure 1-2).

The Acid Area 2 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. Acid Area 2 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 covered 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.

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

Acid Area 2 was used to produce oleum, sulfuric acid, and nitric acid for the manufacture of TNT. The Acid Area 2 site contained 8 buildings, 24 above-ground acid storage 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 Acid Area 2 site is currently not being utilized, with the exception of storage use at the remaining building.

Recent investigations at Acid Area 2 have identified chemical contamination in the soil and sediment related to former U.S. Department of Defense 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. Most of the forested areas were cleared during construction of the PBOW. 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 the General Services Administration to other parties (state or local government or private individuals).
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

Acid Area 2 was 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, or dismantlement. Removal of buildings and above-ground tanks occurred between 1958 and 1968 based on aerial photography. The only remaining building at Acid Area 2 is the easternmost building adjacent to the former rail line, which currently is used for storage of deer traps. 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. The shallow overburden at Acid Area 2 is limited primarily to silt and clay deposits, with occasional discontinuous lenses of silty fine-grained sand. Well yields from the shallow monitoring wells at Acid Area 2 ranged from 210 to 300 ml per minute. Because of the low yields, shallow groundwater could not realistically be used as a potable water source and does not represent a point of exposure for future residents.

Most of PBOW is mapped by the Ohio Department of Natural Resources as an area in which well yields seldom exceed 3 gallons per minute (gpm) from the shale aquifer and overlying discontinuous sand and gravel deposits. The northwest portion of PBOW, including all of Acid Area 2, 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 (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 4-mile radius of PBOW (Science Applications International Corporation [SAIC], 1991). The nearest recorded well is at 6115 Schenk Road, approximately 1950 ft north of Acid Area 2; however, a closer well was observed at 1810 Schenk Road, located approximately 1400 ft northeast of Acid Area 2.

1.4 Protocol for the Baseline Human Health Risk Assessment

This BHHRA was prepared based on EPA, OEPA, and USACE, guidance, including, but not limited to, the following:

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

- OEPA, 2004b, *Technical Decision Compendium, Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight* Ohio EPA Division of Emergency and Remedial Response 28 April 2004
- OEPA, 2005a, *Use of Risk-Based Numbers in the Remedial Response Process Overview* DERR-00-RR-038, June 28, 2005.
- OEPA, 2005b, *Technical Decision Compendium, Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment* Ohio EPA Division of Emergency and Remedial Response Remedial Response Program August 2005.
- 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.
- 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

This BHHRA report presents the methods used, results generated, and the interpretation of these results. The remainder of this report is organized as follows:

Section 2.0, Data Evaluation: Identifies data sources, evaluates data quality, identifies chemicals of potential concern (COPCs), and provides the background screening.

Section 3.0, Exposure Assessment: Presents the conceptual site exposure model (CSEM), including contaminant sources, contaminant release mechanisms, receptors, and exposure pathways; describes exposure-point concentrations (EPCs); and presents methods for calculating chemical intake and contact rates.

Section 4.0, 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.

Section 5.0, Risk Characterization: Combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor. Risks associated with exposure to all appropriate media were evaluated. This section includes the derivation of risk-based remediation levels (RBRLs), which describes their development based on the methods of the BHHRA and discussion between OEPA and USACE.

Section 6.0, 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.

Section 7.0, Summary and Conclusions: Provides a brief summary of the BHHRA, including quantitative results, uncertainties, and pertinent site information. The summary focuses those results and issues that are most likely to directly affect site management decisions.

Section 8.0, References: Provides a complete list of all references used and cited in the BHHRA.

The text of this document is supported by the following appendices:

Appendix A, Dermal Absorbed Dose Calculations

Appendix B, Risk Calculations

Appendix C, Risk-Based Remediation Levels

Appendix D, Toxicological Profiles for Chemicals of Concern

Appendix E, ProUCL Calculations for Exposure-Point Concentrations

Appendix F, Responses to Comments on the Draft Baseline Human Health Risk Assessment

2.0 DATA EVALUATION

A Site Investigation (SI) was performed at Acid Areas 2 and 3 in 1998 (IT, 1998), which identified surface and subsurface soil contamination above EPA Region 3 Risk Based Criteria (RBC). Thirty soil samples were collected at 15 locations at Acid Area 2. Organic contaminants in surface and subsurface soil exceeding the RBCs included PCBs and SVOCs.

Groundwater monitoring wells were installed at Acid Area 2 as part of a site-wide groundwater investigation beginning as early as 1993. Five wells installed at or adjacent to Acid Area 2 were sampled at various times during the period 1993 through 2004. These wells were included in the 2005 investigation (Jacobs, 2006), 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 Acid Area 2. Surface soil samples were collected from 0.5 to 1.5 ft below ground surface (bgs) at all locations. Subsurface samples were collected from 3 to 5 ft bgs at all locations and from 8 to 10 ft bgs at specific locations. All samples were analyzed for volatile organic compounds (VOCs), SVOCs, nitroaromatics, target analyte list (TAL) metals, and PCBs.

No monitoring wells were installed at Acid Area 2 as there were 5 existing wells at the site. Two rounds of groundwater samples were collected from the existing wells in January and April 2005. In addition to the collection of unfiltered samples, samples for metals analysis were filtered in the field during the January 2005 sampling rounds. Based on the BHHRA technical memorandum submitted 23 May 2005 (Shaw, 2005b) no filtered data were used in risk assessment.

Three surface water and sediment samples were collected from the drainage ditch along the southern perimeter of Acid Area 2 on 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 included one upstream location, one location adjacent to the site, and one downstream location.

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

- Twelve locations at the southern drainage ditch, including one upstream location, 8 locations adjacent to the site, and 3 downstream locations.
- Eight locations at the northern drainage ditch, including 6 locations adjacent to the site and 2 downstream locations.

RI sample collection and data evaluation are discussed in detail in the Interim Final Site Characterization Report (Jacobs, 2006). Sufficient data have been collected for Acid Area 2 to support a risk assessment.

2.1 Identification of COPCs

COPCs are the chemicals that are identified as site-related and potentially capable of contributing significantly to risk, and are carried forward to quantitative evaluation in the risk assessment (RA). The following subsections describe the process for their identification. Prior to initiation of the RA, a list of chemicals present in site samples was compiled. This initial list included all chemicals detected in any site medium. COPCs were selected from this list as discussed in the following sections.

2.1.1 Evaluation of Data Quality

The quality of the analytical data was 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 the concentration in the blank, using the five-times, ten-times (5x, 10x) rule, whereby a chemical is considered a nondetect unless its concentration exceeds 5 or 10 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 10 times the blank concentration to be considered a detection.

“J”, “N”, and “NJ” qualified data were used in the BHHRA; “R” data and “B” qualified data were not. The handling of “U” qualified data (nondetects) in the BHHRA is described in Section 3.2. Data for which the identity of the chemical was unclear were not used in the BHHRA. When confidence was reasonably high that the chemical was present but the actual concentration was somewhat in question, the data generally were used.

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

2.1.2 Frequency of Detection

As stated above, if confidence was high that a given chemical was present, the data generally were used in the RA. For most chemicals, their identification at concentrations above levels in blanks (considering the 5x, 10x rule) was presumptive evidence of their presence. However, chemicals that were reported infrequently (i.e., 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. Chemicals that were reported only at low concentrations in less than 5 percent of the samples from a given medium were dropped from further consideration unless their presence would be expected based on site historical information.

2.1.3 Risk-Based Screening

Risk-based screening for human health focuses 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) was 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 was less than or equal to its RBSC, then the chemical in this medium was 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 was identified as a COPC if its MDC exceeded its RBSC. RBSCs used in this BHHRA were derived from the EPA Region 9 preliminary remediation goal (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 were multiplied by a factor of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals resulting in RBSC values associated with an HQ of 0.1. For cancer risk, the PRG values were 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 increased 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 elicited both cancer and noncancer health effects was selected based on either a cancer risk of 1E-6 or an HQ of 0.1, whichever associated concentration was lower.

2.1.4 Evaluating Essential Nutrients

Evaluating essential nutrients is a special form of risk-based screening applied to certain ubiquitous elements that are generally considered to be required human nutrients. Essential nutrients such as calcium, iron, magnesium, potassium, and sodium are usually eliminated as COPCs because they are generally considered innocuous in environmental media. Other

essential nutrients including chloride, iodine, and phosphorus, 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. No members of this latter group were selected as site-related chemicals. Therefore, an exposure analysis was not performed.

2.1.5 Background Screening

For background screening, the MDC was compared to the PBOW chemical-specific background screening concentration (BSC) for groundwater or soil. The derivation of groundwater BSCs was described in the 2004 groundwater report (Shaw, 2005c). BSCs were calculated for use at PBOW based on concentrations found in background bedrock monitoring wells installed upgradient of PBOW sources. Each groundwater BSC is either the MDC or the calculated 95 percent upper tolerance limit of the background groundwater data set based on unfiltered samples collected using low-flow sampling, whichever value is lower (Shaw, 2005c). BSCs for soil established as part of the acid areas investigation (IT, 1998) were used for this RA. BSCs for soil were reported as the 95 percent upper tolerance limit for lognormal data sets or the 95th percentile for datasets with a nonparametric distribution.

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

Background screening was applied to each inorganic constituent whose MDC exceeded the RBSC and that could not be characterized as an infrequently detected analyte. Background screening consisted of comparing the MDC of the site data set to the BSC. Background screening was not used to eliminate COPCs. Comparison of COPC concentrations to background levels are discussed in Section 6.0.

2.2 Developing 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 within an exposure unit.

Because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the upper confidence limit (UCL) on the mean are usually estimated for each COPC in each medium of interest. The upper 95 percent confidence limit on the mean is generally referred to as the 95 percent upper confidence limit on the arithmetic mean (UCL₉₅).

The EPA statistical software package ProUCL Version 3 was used to compute estimated mean and UCL₉₅ concentrations for all data sets containing fewer than 15 percent nondetects. ProUCL Version 3 is inappropriate for data sets containing more than 15 percent nondetects.

For data sets with 15 percent or more nondetects, a combination of the following procedures was used:

- Most statistical computations were made using a FoxPro based statistical package developed by Jacobs and based on a large number of published guidance manuals.
- Kaplan-Meier computations were confirmed using Minitab Version 14 (commercial statistical software from Minitab Inc.).

Data sets consisting of 5 or more data points were tested for normality and lognormality with the Shapiro-Wilk test. Statistical analysis was performed only on those chemicals identified as COPCs. The UCL_{95} was calculated for a normal distribution as follows (EPA, 1992a):

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

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

$\alpha = 0.05$ (95 percent confidence limit for a one-tailed test)

n = number of samples in the data set

s = sample standard deviation.

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

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

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 was nonparametric, the UCL_{95} was estimated using three different methods: Kaplan-Meier (Kaplan and Meier, 1958), simple bootstrap with replacement (Helsel, 2005), and rank order based on the binomial distribution.

The Kaplan-Meier method for UCL_{95} calculation has been used for many years in the medical industry and in manufacturing to estimate summary statistics for censored data sets (data sets with nondetect results). The Kaplan-Meier method estimates the survival probability function for the evaluated data set. The survival function is the probability that any given data value will exceed any specific quantile of the data set. The UCL_{95} is computed by integrating the area under the stair-step survival function curve.

The simple bootstrap UCL_{95} is computed by resampling the data set with replacement a large number of times, computing the mean of each resampling, and computing the UCL_{95} from these computed means using the Students-t approach.

The UCL_{95} rank order on the arithmetic mean of the data set was estimated by ranking the data observations from smallest to largest. The arithmetic mean was converted to a percentile by interpolation. The rank order of the data point selected as the UCL_{95} was estimated from the following equation (Gilbert, 1987):

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

where:

u = rank order of value selected as UCL_{95} , 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 were averaged with original sample results 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 reporting 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 were assumed to be present at one-half the reporting limit (EPA, 1989a). However, professional judgment was used in those cases where the detection limit was unusually high. For example, elevated detection limits that exceed the MDC due to matrix interference or sample dilution may be eliminated from the data set and not used in the estimation of the EPC; however, no data points were eliminated from use in EPC estimation in this evaluation.

The UCL₉₅ or MDC, whichever is smaller, was selected as the EPC and is understood to represent a conservative estimate of average for use in the RA or in various transport models used to estimate exposure.

2.3 Results of the Data Evaluation

Previous investigations at Acid Area 2 confirmed the presence of soil contamination from former PBOW operations. The sampling locations for these investigations are provided in Figure 2-1. The objective of the soil investigation conducted under the RI (Jacobs, 2006) was to evaluate the presence of soil contamination at additional former site facilities not previously sampled. The objective of the groundwater investigation was to characterize the shallow and bedrock aquifers and to evaluate the presence of chemical contamination in groundwater in the vicinity of Acid Area 2. Two rounds of groundwater samples were collected from the shallow and bedrock monitoring wells. Surface water and sediment samples were collected from the drainage ditches bounding Acid Area 2: 15 from the southern drainage ditch and 8 from the northern drainage ditch.

Table 2-1 provides the following information for each detected chemical for each medium at Acid Area 2:

- Chemical name,
- Frequency of detection,
- Range of detected concentrations,
- Range of detection limits,
- Arithmetic mean of site concentrations,
- 95 percent UCL on the arithmetic mean,
- Appropriate RBSC,
- Appropriate BSC, and
- Selection/exclusion of chemical as a COPC.

Surface Soil. A total of 28 surface soil samples have been collected at Acid Area 2, which includes 15 samples collected during the 1998 SI and 13 samples collected during the RI. Contaminants detected include VOCs, nitroaromatics, SVOCs, PCBs, and metals. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) are identified in Table 2-1.

Subsurface Soil. A total of 35 subsurface soil samples have been collected from 28 locations at Acid Area 2, which includes 15 samples from 15 locations during the 1998 SI and 20 samples from 13 locations during the RI. Sample depths for the 1998 SI ranged from 2 to 10 ft bgs. Depths for the samples were limited to the 3 to 5 ft interval and the 8 to 10 ft interval.

Contaminants detected include VOCs, SVOCs, PCBs, and metals. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) are identified in Table 2-1.

Shallow Groundwater. Contaminants detected in shallow groundwater at Acid Area 2 during two rounds of sampling in 2005 include VOCs, SVOCs, and metals. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA, 2004b) for drinking water are identified in Table 2-1. The organic detections were limited to a few locations and a few compounds. SVOC detection was limited to bis(2-ethylhexyl)phthalate, a common lab artifact, which was reported in the sample from monitoring well IT-MW10 during Round 2 only.

The VOCs detected at monitoring well AA2-GW-002 during Round 1 include benzene, cyclohexane, ethylbenzene, isopropylbenzene, methylcyclohexane, and xylenes, all at relatively low levels. The results for benzene, ethylbenzene, and isopropylbenzene were J-flagged because the detections were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate concentrations of the respective analytes in the samples. These contaminants are found in groundwater in most of the bedrock wells, and are associated with naturally occurring petroleum in the Columbus Limestone. AA2-GW-002 was the only shallow well where bladder pump #2 was used during Round 1 sampling. This pump was used for all of the bedrock wells. It is possible that residual amounts of contaminants were left in the pump after decontamination. Precautions were made during Round 2 to ensure that the pump used for sampling bedrock wells was not used in a shallow well, and these contaminants were not detected during Round 2.

Bedrock Groundwater. Contaminants detected in bedrock groundwater during two rounds of sampling include VOCs, nitroaromatics, SVOCs, and metals. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA, 2004b) for drinking water are identified in Table 2-1. SVOCs were detected in 3 bedrock wells and limited to naphthalene and 2-methylnaphthalene, which are compounds associated with naturally occurring petroleum, present in the Columbus Limestone. All of these detections were J-flagged because they were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate concentrations of the respective analytes in the samples. Further characterization of the organic compounds is to be performed by NASA in an attempt to confirm the source of these compounds.

Five nitroaromatic compounds were detected in 4 bedrock wells during Round 2, only. All of these detections were J-flagged because they were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate concentrations of the respective analytes in the samples. The nitroaromatic compound 2-nitrotoluene was not detected during Round 1 and the Round 2 detection was J-flagged because it was between the reporting limit and the detection limit.

Surface Water. Contaminants detected in surface water at Acid Area 2 include SVOCs, PAHs, and metals. Specific compounds exceeding the USEPA Region 9 residential PRGs (EPA 2004b) for drinking water are identified in Table 2-1.

Results for the arsenic, vanadium, and trichloroethene exceedances were J-flagged because the detections were between the reporting limit and the detection limit, indicating that the detections are estimated and the associated numerical values are the approximate

concentrations of the respective analytes in the samples. Other than the J-flagged results, trichloroethene was not otherwise detected. The bis(2-ethylhexyl)phthalate concentration exceeding the PRG was both J-flagged and was detected in the associated trip blank and is recognized as a common laboratory artifact.

Sediment. Contaminants detected in sediment at Acid Area 2 include VOCs, SVOCs, PAHs, nitroaromatics, PCBs, and metal. Specific compounds exceeding the USEPA Region 9 Residential PRGs (EPA, 2004b) for soil are identified in Table 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.

This BHHRA characterizes potential exposures to COPCs in soil, groundwater, surface water and sediment associated with Acid Area 2. Estimation of risk from potential exposure is described in the risk characterization for each COPC (Section 5.0). The Scope of Work (USACE, 2001) requires the summation of potential risks from all environmental media evaluated in the risk characterization.

3.1 Conceptual Site Exposure Model

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

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

Contaminant release mechanisms and transport pathways are not relevant for direct receptor contact with a contaminated source medium (e.g., ingestion of or dermal contact with groundwater).

Figure 3-1 depicts the CSEM used for Acid Area 2. 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 were identified as complete on the CSEM are addressed in the BHHRA. Additional potential receptors not listed on the CSEM figures were briefly discussed in Section 3.1.3.2 of the Work Plan (Jacobs, 2007).

No current or future exposures by off-site residents were evaluated. The majority of the off-site residents are serviced by municipal water. There are numerous private groundwater wells in the vicinity, including 8 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 was regarded as plausible.

3.1.1 Physical Setting

The Acid Area 2 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. Acid Area 2 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 covered 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.

Geology. Overburden thickness at Acid Area 2 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. The Delaware Limestone is underlain by the Columbus Limestone.

Surface Water. Two drainage ditches border the Acid Area 2 site: one on the northern perimeter 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 6 to 8 ft wide and 4 to 6 ft deep, with width and depth increasing downstream. The northern drainage ditch channel is approximately 3 ft wide and 2 to 3 ft deep. Both drainage systems are ephemeral and flow only during the wet season and following precipitation events, which limits potential human exposure to surface water. Both drainages remain dry from mid-summer through the fall, further limiting potential human exposure. The average annual precipitation for Sandusky is 34.5 inches per year.

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 1 ft bgs to 6 ft bgs during wet season and fluctuate up to 4 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.

Bedrock groundwater has been subdivided into two separate units at PBOW: 1) the Plum Brook Shale and Ohio Shale, and 2) the Delaware Limestone and Columbus 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 and Columbus Limestones are on average 30 ft bgs. Water in the limestone typically occurs in fractures, along bedding planes, or in solutionally enlarged openings. The conceptual model indicates that bedrock groundwater flow in the Delaware and Columbus Limestones is dependant on the frequency, orientation, density, and connectivity of the fractures. Groundwater flow in the limestone is generally to the north; however, there are major fracture zones transecting the site, which influence groundwater flow in several areas (Shaw, 2003). Groundwater from the Columbus Limestone at Acid Area 2 is unsuitable as a potable water source due to the presence of naturally occurring hydrogen sulfide gas and petroleum.

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways

Numerous buildings, process facilities, and storage tanks were constructed at Acid Area 2 to support the production of oleum, sulfuric acid, and nitric acid used in manufacturing TNT. Contamination resulted from 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 Area 2, 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 evaluated in this BHHRA 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 90th to 95th percentile on exposure. In keeping with EPA (1991a) guidance, variables chosen for the baseline RME scenario for ingestion rate (IR), exposure frequency (EF) and exposure duration (ED) were generally upper bounds. Other variables such as body weight (BW) and exposed skin surface area (SA), were 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 the noncancer evaluation was 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 was 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 consistent with the EPA (1986) policy of carcinogen evaluation, although it introduces 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 was 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 there, an FI of 0.5 was applied to the soil ingestion and dermal intake equations. An FI was also used if a receptor's exposure was split between two comparable media. For example, if a construction worker is exposed to both soil and sediment, FIs are introduced that apportion his exposure between the two media. The default value of FI is 1.

3.1.3.1 Overburden Groundwater

Shallow groundwater in the vicinity of Acid Area 2 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 did not quantitatively evaluate exposure to perched groundwater.

3.1.3.2 Bedrock Groundwater

The following receptors were evaluated to represent the upper bound on bedrock groundwater exposure for all plausibly exposed groups of people at Acid Area 2.

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 was based on measured concentrations at Acid Area 2 described in this report. Future receptors were the 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 groundwater were 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 was 1.0 for each receptor. Exposure parameters and parameter values are summarized in Table 3-1.

Resident. The resident was assumed to be exposed to groundwater as household tap water and, for volatile compounds, to air concentrations associated with groundwater use in the residence. Cancer and noncancer assessments were performed for both an adult and child. The evaluations assumed 30 years of exposure: 24 years as a 70-kilogram (kg) adult (EPA, 1991a) and 6 years as a 15-kg child (EPA, 1991a). For cancer effects, the adult and child effects were summed together; for noncancer effects, the child and adult were evaluated separately. An EF of 350 days per year (EPA, 1991a) was 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, 1991a) were assumed. Both the child and adult resident were assumed to be dermally exposed to COPCs in groundwater while bathing/showering. The child was assumed to bathe for 20 minutes per day (0.333 hour/day) (EPA, 2004a). The adult was assumed to shower for 35 minutes per day (0.6 hour/day) (EPA, 2004a). Inhalation rates of 0.833 m³/hour for the adult (EPA, 1991a) and 0.416 m³/hour for the child (EPA, 2004a) were 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 was 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 was assumed to be 1 L/day (EPA, 1991a). He could also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it was assumed that the head, forearms, and hands, approximately 3,300 square centimeters (cm²) (EPA, 2004a), would be exposed intermittently for up to 1 hour per day. Dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A).

3.1.3.3 Surface Soil

The following receptors were evaluated to represent the upper bound on surface soil exposure for all plausibly exposed groups of people at Acid Area 2. 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.

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

Future on-site. Potential future receptors are construction workers, on-site indoor workers, on-site residents, groundskeepers and hunters. The evaluation of future on-site exposure to surface soil was based on current measured concentrations.

Groundskeeper. Under the current and future land-use scenarios, a groundskeeper may be exposed to surface soil. The groundskeeper scenario was 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 was 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 was assumed to be a 70-kg 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, 1991a). The respiratory rate for the groundskeeper was assumed to be 20 m³/8-hour workday (2.5 m³/hour), and the soil incidental ingestion rate was 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, ft, and face for 29 groundskeepers revealed AFs ranging from 8E-4 milligrams per square centimeters (mg/cm²) (legs) to 1.5E-1 mg/cm² (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/cm². The SA of body regions evaluated for groundskeepers includes approximately 11,300 cm² (EPA, 1997a).

Hunter. Under the current and future land-use scenarios, a hunter may be exposed to surface soil. The hunter was assumed to be a 70-kg adult nearby resident (exposure duration of 30 years) (EPA, 1991a). Small children would be unlikely to accompany the hunter afield. Therefore, the direct exposure pathways evaluated for the hunter (incidental ingestion and dermal contact with soil) were not evaluated for the small child. It was assumed that the hunter would spend his entire 2-week vacation hunting on PBOW; i.e., his EF for incidental soil ingestion and dermal contact was 14 days/year. His incidental soil ingestion rate was assumed to be 100 mg/day (EPA, 1991a). It was assumed that approximately 25 percent of his body SA, or 4,550 cm², would be available for exposure to soil (EPA, 2004a). A soil AF of 0.2 mg/cm² was assumed. Inhalation of airborne dust would be a potential exposure pathway, however, vegetation would reduce dust emissions to insignificant levels, and it was assumed that the hunter would spend virtually all of his time on vegetated rather than bare soil. Therefore, it was assumed that inhalation exposure would contribute much less than incidental ingestion and the inhalation exposure pathway was not evaluated.

Future On-Site Resident. It was assumed that the future on-site resident would be exposed to surface soil. The on-site residential scenario was evaluated using both an adult and a child. Lifetime cancer risk was estimated as the sum of the risks calculated for the adult and the child.

The adult resident was assumed to be a 70-kg person with an incidental soil ingestion rate of 100 mg/day, and an inhalation rate of 20 m³/day (0.83 m³/hour) (EPA, 1991a). Approximately 25 percent of his body SA, or 4,500 cm², was assumed as available for exposure to soil (EPA, 2004a). The adult resident was assumed to be exposed 350 days/year for 24 years (EPA, 1991a).

The child resident was assumed to be a 1- through 6-year-old with an average BW of 15 kg, a soil ingestion rate of 200 mg/day, and an inhalation rate of 10 m³/day (EPA, 1991a). Approximately 25 percent of his body SA, or 1,750 cm², was assumed to be available for exposure to soil (EPA, 2004a). The child resident was assumed to be exposed for 350 days/year for 6 years (EPA, 1991a).

An average soil AF of 0.2 mg/cm² was adopted for the on-site resident (EPA, 2004a).

Evaluation of exposure to VOCs from soil by the future on-site resident was addressed during evaluation of airborne dust as described for the groundskeeper, above. It was assumed that 80 percent of the soil surface would be covered with pavement or vegetation for evaluating inhalation to airborne dust. Inhalation of VOCs released from subsurface soil and entrapped in indoor air was not evaluated as there were no VOCs detected in the subsurface soil. Inhalation rates of 20 m³/day for the adult (EPA, 1991a) and 10 m³/day for the child (EPA, 1991a) were 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 was developed to evaluate exposure to indoor airborne VOCs entrapped in a building. However, as there were no VOCs detected in the subsurface soil, this pathway was not evaluated. 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, were 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 was not quantified.

The indoor worker was assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week year-round on the site for a total of 250 days/year for 25 years (EPA, 1991a). His soil incidental ingestion rate was assumed to be 50 mg/day, and his inhalation rate was assumed to be 20 m³/8-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 was developed to evaluate short-term exposure to surface and subsurface soil (total soil) in either the current or future site-use scenario. Construction projects were expected to be infrequent. It was assumed that the construction worker would participate 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 was assumed to be a 70-kg adult who works 8 hours per day (hours/day), approximately 5 days per week (days/week) for 6 months. Potential exposure pathways were 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. However, as there were no VOCs detected in the subsurface soil, inhalation of airborne VOCs released from subsurface soil during excavation and grading was not evaluated. Excavation and soil grading activities, which result in intensive soil contact, were assumed to last for 3 months; for the remaining 3 months, construction activities were 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, were assumed for the intensive and less intensive contact periods, respectively. The resulting time-weighted average soil ingestion rate was 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/cm² was 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 cm². An inhalation rate of 20 m³/day (EPA, 1991a) for potential exposures to VOCs and air borne dust was assumed.

3.1.3.4 Subsurface Soil

The following receptors were evaluated to represent the upper bound on subsurface soil exposure for all plausibly exposed groups of people at Acid Area 2. 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.

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

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

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 was not 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 were 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. However, as there were no VOCs retained as COPCs in the subsurface soil, this pathway was not evaluated. 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 were identical to those described above for surface soil (Section 3.1.3.3).

3.1.3.5 Surface Water

The following receptors were evaluated to represent the upper bound on surface water exposure for all plausibly exposed groups of people at Acid Area 2. 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.

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

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

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

Future On-Site Resident. The future on-site resident was assumed to be exposed to surface water. The resident could have access to the surface water bodies associated with Acid Area 2. It was assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident was assumed to wade for 3 hours/day on 52 days/year. The exposure pathway evaluated was dermal contact with surface water. Approximately 30 percent of the adult's and child's total body SAs, 5,450 cm² and 2,100 cm², respectively, were assumed to be available for exposure to surface water. The dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A). Incidental ingestion of surface water in a wading scenario was considered to be less significant than dermal contact and was not quantified. Inhalation of VOC emissions from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations such that this pathway would be less significant than dermal contact, which was quantified. For these reasons, inhalation of VOC emissions from surface water was not 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 was not 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 would be the most significant pathway for exposure to surface water. Incidental ingestion of surface water would also be possible, but would be expected to be much less significant than dermal contact. Dermal exposure to surface water was assumed to occur for 4 hours/day, or one-half the normal workday. It was assumed that the arms, forearms and hands (an SA of approximately 3,100 cm² [EPA, 1997a]) would be exposed to surface water. Dermal absorbed dose was calculated using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix A). Inhalation of VOCs from surface water is also possible, but the large volume of outdoor ambient air and natural air currents would be expected to dilute airborne concentrations, so that this pathway would be less significant than dermal contact, which was quantified. For these reasons incidental ingestion and inhalation of VOCs from surface water were not quantified.

3.1.3.6 Sediment

The following receptors were evaluated to represent the upper bound on sediment exposure for all plausibly exposed groups of people at Acid Area 2. 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.

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

Future on-site. Potential future receptors are construction workers and on-site residents. The evaluation of future on-site exposure to sediment was based on current measured concentrations.

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 contact would not be part of the groundskeeper's regular duties or activities. Therefore, exposure to sediment was not 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 contact would not be part of the hunter's regular or activities. Therefore, exposure to sediment was not quantified.

Future On-Site Resident. The future on-site resident was assumed to be exposed to sediment. The resident could have access to sediments associated with Acid Area 2 and could be exposed to sediment. It was assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident was assumed to wade for 3 hours/day on 52 days/year. The exposure pathway evaluated was 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 was also applied to sediment. Approximately 25 percent of the adults and child's total body SAs, 4,500 cm² and 1,750 cm², respectively, were used.

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

Construction Worker. Under the current and future land-use scenarios, a construction worker may be exposed to sediment. The construction worker may be exposed to sediment during projects such as installation of underground utilities or rerouting stream flow. Dermal contact would be the most significant pathway for exposure to sediment. Incidental ingestion of sediment would also be possible, but would be expected to be much less significant than dermal contact. Dermal exposure to sediment was assumed to occur for 4 hours/day, or one-half the normal work day. It was assumed that the arms, forearms and hands, an SA of approximately 3,100 cm² (EPA, 1997a), would be 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 such that this pathway would be less significant than dermal contact, which was quantified. For these reasons, incidental ingestion and inhalation of VOCs from sediment were not quantified.

3.1.3.7 Game Animals

The following receptors were evaluated to represent the upper bound on exposure via ingestion of game animals taken at Acid Area 2.

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 was 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 was developed to evaluate the potential for contaminants in soil to affect food-chain pathways. Acid Area 2 provides habitat for deer and other wildlife, and deer hunting is permitted on the PBOW facility. Therefore, a hunter who consumes his game is a plausible scenario requiring evaluation. Many kinds of game animals may be hunted and consumed including squirrel, pheasant and other upland birds, turkey and deer; however, the deer is the species most likely to contribute meaningfully to the diet. Therefore, the evaluation was limited to a deer hunter.

Data were not located regarding the rate of venison ingestion; therefore, a hypothetical scenario was 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 was assumed that the hunter eats 10 pounds (4.5 kg) of venison per year (Sharp, 1995). This consumption rate corresponds to 0.013 kg/day (0.186 g/kg-day) of venison for each of the 350 days per year (EPA, 1991a) 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 was 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. It was assumed that venison replaced beef in the diet, and the differences in beef consumption between adults and children were used to estimate a venison ingestion rate for children. EPA (1997a) provides per capita beef intake data for less than 1- to 5-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 was estimated that the beef consumption of small children, expressed on a BW basis, would be approximately 1.8 times that of an adult. Therefore, a venison ingestion rate of 0.335 g/kg-day was estimated for the young child from the venison ingestion rate of 0.186 g/kg-day for the adult. Assuming that the child is 0 to 6 years old with an average BW of 15 kg (EPA, 1991a), 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 were statistically derived values based on measured analytical data. Concentrations of COPCs in air were not measured (and in the case of groundwater volatilization or future exposure scenarios, cannot reasonably be measured), but were based on models that use the EPCs of COPCs in groundwater as input values.

3.2.1 COPC Concentrations from Dust

Inhalation exposure to particulate (dust) emissions from soil 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):

$$C_a = (D)(C_{so})(CF_1) \quad \text{Eq. 3.1}$$

where:

C_a = contaminant concentration in air (mg/m³, calculated)

D = dust loading factor (g of soil/m³ 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/m³) for agricultural activity (DOE, 1989), 6E-4 g/m³ for construction work (DOE, 1983), and 1E-4 g/m³ for other activity (National Council on Radiation Protection and Measurements [NCRPM], 1984). The value for D of 1E-4 g/m³ for other activity was used for the groundskeeper. It was assumed that construction activities requiring intimate contact with soil, for which D = 6E-4 g/m³ 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/m³. Therefore, a time-weighted average dust loading factor for construction work of 3.5E-4 g/m³ was estimated for the construction worker.

Airborne concentrations of VOCs estimated by the dust loading model was 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 (1996a) 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:

$$PEF = \frac{Q}{C} \times \frac{3600}{0.036 \times (1-V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x)} \quad \text{Eq. 3.2}$$

where:

PEF = particulate emission factor (m³/kg, calculated)

Q/C = inverse of the mean concentration at center of square source (43.08 g/m³second per kg/m³, site-specific value from Table 3 in EPA [1996a] [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 COPCs in air are calculated as follows:

$$C_a = \frac{C_{so}}{PEF} \quad \text{Eq. 3.3}$$

where:

C_a = contaminant concentration in air (mg/m³, calculated)

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

PEF = particulate emission factor (m³/kg).

Airborne concentrations of VOCs estimated by the wind erosion model were 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 Concentrations in Household Air from Groundwater Use

Inhalation of VOCs released from groundwater was evaluated, as applicable, for the on-site resident scenario. Chemicals that have a Henry's Law value exceeding 1E-05 atmospheres per cubic meter (m³) per mole and a molecular weight less than 200 grams (g) per mole are considered to be VOCs and are subject to evaluation via this pathway. Other groundwater contaminants may be evaluated on a case-by-case basis for their potential contribution to risk via the inhalation pathway based on the degree of departure from the Henry's Law and molecular weight criteria, groundwater concentration, and toxicity.

The simple whole-house tap water-to-air model described in Part B of the human health evaluation manual (HHEM) (EPA, 1991b) was 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:

$$C_a = C_{gw} \times 0.001 \frac{\text{mg}}{\mu\text{g}} \times K_{wa} \times 1,000 \frac{\text{L}}{\text{m}^3} \quad \text{Eq. 3.4}$$

where:

C_a = Modeled concentration in air (mg/m³)

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 m³; 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 m³/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 was evaluated in the BHHRA using alternate values from the *Exposure Factors Handbook*.

3.2.3 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:

$$C_d = C_{gw} \times (1 - F_v) \quad \text{Eq. 3.5}$$

where:

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

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

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

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

3.2.4 Concentrations of COPCs in Venison

The hunter was assumed to harvest and consume game and share it with his family, including small children. The game was 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 were derived by adjusting biotransfer factors for beef to account for differences in the fat content of table-ready beef (cooked choice retail cuts trimmed to 0 inches of fat: average 14.4 percent fat) and venison (cooked boneless muscle meats: average 2.9 percent fat) (Nutrient Database, 1997).

- Deer are expected to browse a much larger area than that encompassed by Acid Area 2; 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:

$$B_v = 0.20(FI_e)(B_b) \quad \text{Eq. 3.6}$$

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, unitless, see below)

B_b = biotransfer factor for beef.

Values for B_b for metals are provided in the toxicity profiles in Appendix D. Toxicity profiles were prepared for each of the COCs. The toxicity profiles briefly describe the uses of the chemical, its physical properties, behavior in environmental media, biotransfer capability, and toxicity values.

The Acid Area 2 site covers approximately 25 acres. The home range of a deer is approximately 630 acres. Therefore, FI_e was set equal to 0.04.

Deer were assumed to be exposed to contaminants by ingesting browse growing on contaminated soil. It was 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 was estimated from the following equation, which was originally developed for estimating the contaminant concentration in forage to which cattle may be exposed (EPA, 1994a):

$$C_p = (CF_7)(C_{so})(B_p) \quad \text{Eq. 3.7}$$

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 were taken from the toxicity profiles in Appendix D. B_p values for the vegetative parts of plants rather than the reproductive parts of plants were selected, where 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, 1994a):

$$C_v = (Q_p)(C_p)(B_v) \quad \text{Eq. 3.8}$$

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 3.1.3, using the exposure parameter values described in Section 3.1.3. Models are taken or modified from EPA (1989a) unless otherwise indicated. Intakes were calculated for both cancer and noncancer evaluations. Therefore, the AT variable shown in the following equations is replaced with AT_n for noncancer calculations ($365 \times ED$), and with AT_c (25,550 days) for the cancer calculations. Intake values were based on the EPCs (Section 2.2) and the equations discussed below for the respective exposure pathways.

3.3.1 Inhalation of COPCs in Air

The following equation was 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):

$$I_a = \frac{(C_a)(FI_a)(IR_a)(ET_a)(EF)(ED)}{(BW)(AT)} \quad \text{Eq. 3.9}$$

where:

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

C_a = concentration of COPC in air (mg/m³)

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

IR_a = inhalation rate (m³/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) were estimated from the equation:

$$I_{so} = \frac{(C_{so})(FI_{so})(IR_{so})(EF)(ED)(CF_2)}{(BW)(AT)} \quad \text{Eq. 3.10}$$

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).

3.3.3 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, 2004a):

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)} \quad \text{Eq. 3.11}$$

where:

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

DA = dose absorbed per unit body surface area per day (mg/cm²-day)

$SA = SA_{so}$ for soil, SA_{sd} for sediment, SA_w for water = surface area of the skin exposed (cm²)

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, 2004a):

$$DA = (C)(FI)(CF_2)(AF)(ABS) \quad \text{Eq. 3.12}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm²-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/cm²-day)

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

ABS values are provided in the toxicity profiles for each COC.

Quantification of dermal absorbed dose was modeled using the spreadsheet model developed by EPA in conjunction with RAGS Part E (EPA, 2004a) (Appendix C).

3.3.4 Consumption of Venison

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

$$I_v = \frac{(C_v)(IR_v)(EF)(ED)}{(BW)(AT)} \quad \text{Eq. 3.13}$$

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).

3.3.5 Ingestion of COPCs in Groundwater and Surface Water

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

$$I_w = \frac{(C_w)(IR_w)(EF)(ED)}{(BW)(AT)} \quad \text{Eq. 3.14}$$

where:

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

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

IR_w = drinking water ingestion rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

4.0 TOXICITY ASSESSMENT

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

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

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

4.1 Evaluation of Carcinogenicity

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

In defining the potential carcinogenicity of a chemical to humans, EPA first evaluates the sufficiency of evidence of carcinogenicity from available animal and human data. If there are sufficient quantitative data and adequate understanding of the carcinogenic process, a biologically based model may be developed to relate dose and response data on an agent-specific basis. Otherwise, as a default procedure, a standard model can be used to curve-fit the data. Once the data are evaluated, the chemical is assigned a weight-of-evidence classification. The EPA recognizes 6 weight-of-evidence group classifications for carcinogenicity, which are as follows:

- Group A – Human Carcinogenic: human data are sufficient to identify the chemical as a human carcinogen.
- Group B1 – Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.
- Group B2 – Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association.
- Group C – Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.
- Group D – Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate.
- Group E – Evidence of Non-Carcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer.

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

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

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

Cancer toxicity values and sources are provided in Table 4-1.

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 7 years, or at least 10 percent of expected lifespan; subchronic exposure is defined as 2 weeks to 7 years.

The EPA Integrated Risk information System (IRIS) expresses the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m³. 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 m³ of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the RfC (mg/m³) by 20 m³/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 are provided in the Table 4-1.

4.3 Dermal Toxicity Values

Dermal RfDs and SFs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is

multiplied by the gastrointestinal absorption factor (GAF), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the GAF. The oral SF is divided, rather than multiplied, by the GAF because the SF is expressed as a reciprocal dose.

4.4 Target Organ Toxicity

As a matter of science policy, EPA assumes dose and effect to be additive for noncarcinogenic effects (EPA, 1989a). This assumption provides the justification for adding the HQs or hazard indices (HIs) 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 are provided in the toxicity profiles.

4.5 Sources of Toxicity Information Used in the Risk Assessment

Toxicity values were selected for use in this 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, 2005) 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, 1997b) 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 was used in the BHHRA.

5.0 RISK CHARACTERIZATION

Risk characterization is the combination of the results of the exposure assessment and toxicity assessment to yield a quantitative expression of risk. Quantitative estimates are developed for individual chemicals, exposure pathways and exposure media for each receptor. The risk characterization is used to guide risk management decisions.

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

Risk characterization is limited to those site-related chemicals selected as COPCs, i.e., present at concentrations that exceed RBSCs (Section 2.1.3).

Up to this point, the term “risk” has been used generically to mean the potential for the occurrence of adverse effects, either cancer or noncancer, to arise from exposure to chemicals. However, at this point in the discussion, it is helpful to define terms more precisely. Therefore, in this section of the document, “risk” is used to describe the likelihood or probability of the occurrence of cancer. The potential for the occurrence of noncancer effects is referred to as noncancer hazard.

5.1 Cancer Risk

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

$$ILCR = (CDI)(SF) \quad \text{Eq. 5.1}$$

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 1 E-2. In these cases, cancer risk may be estimated by the one-hit model (EPA, 1989a):

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

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 (organs of the body) of action. Cancer risk arising from exposure to a given chemical in a given medium by multiple pathways is estimated from the following equation:

$$ILCR_p = ILCR_{chem1} + ILCR_{chem2} + \dots ILCR_i \quad \text{Eq. 5.3}$$

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 chemicals and across media is summed in the same manner. For risk management purposes, OEPA considers a total ILCR of 1E-6 to be a point of departure below which cancer risks are considered to be insignificant. ILCR estimates between 1E-6 and 1E-4 are considered to fall within the risk management range. ILCR estimates above 1E-4 are considered to be unacceptable. The OEPA (2004b) policy is consistent with the EPA (1990) policy of risk management.

5.2 Noncancer Hazards

The noncancer hazards associated with 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):

$$HQ = I/RfD \quad \text{Eq. 5.4}$$

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).

Chemical noncancer hazards are evaluated using chronic RfD values. This approach is different from the probabilistic approach used to evaluate cancer risks. 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. An HQ of unity (1) indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects.

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

$$HI = HQ_1 + HQ_2 + HQ_i \quad \text{Eq. 5.5}$$

where:

HI = hazard index (unitless, calculated)

HQ_i = hazard quotient for the i^{th} chemical, or for the i^{th} 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.

HQ or HI values below or equal to the threshold value of 1 are interpreted to mean that adverse noncancer effects are unlikely. HQ or HI values greater than 1 are interpreted to mean that there is a likelihood of adverse noncancer effects.

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 (Section 4.2). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ as follows:

$$Total HI_a = HI_{p1-a} + HI_{p2-a} + \dots HI_{pi-a} \quad \text{Eq. 5.6}$$

where:

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

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

Toxicity values are not available for the evaluation of lead. Risk assessment of lead generally consists of estimating blood lead levels in children associated with exposure to the environmental media at the site in question, and comparing the estimate with the threshold level of 10 µg/dL. Two common exposure scenarios are routinely evaluated. The first is residential, which involves direct exposure of a young child. The EPA (1994b) integrated exposure-uptake biokinetic (IEUBK) blood lead model for young children is used to predict blood lead levels for children hypothetically exposed at the site. The IEUBK is a self-contained DOS-based computer program. Average lead concentrations in the various media are input in the model; default

values provided by the IEUBK are used when site-specific data are not available. Arithmetic mean values, rather than conservative estimates of average, are used because the IEUBK contains a statistical module that addresses individual variation in exposure and physiological parameters. The output is a probability density histogram of predicted blood lead levels. The risk assessment is considered to "pass" if the IEUBK predicts that not more than 5 percent of young children exposed in this manner would experience a mean blood lead level above the 10.4 µg/dL threshold.

An alternative risk assessment for lead in soil for residential site use may consist of comparing the average concentration with the RBRL of 400 mg/kg. The risk assessment is considered to pass if the average concentration of lead in soil does not exceed 400 mg/kg. Development of the RBRL of 400 mg/kg is described in the next section.

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

An alternative risk assessment for lead in soil for industrial site use may consist of comparing the average concentration with the RBRL of 750 mg/kg. The risk assessment is considered to pass if the average concentration of lead in soil does not exceed 750 mg/kg. Development of the RBRL of 750 mg/kg is described in the following section.

5.3 Risk-Based Remediation Level Development

RBRLs are derived to provide support for risk management decisions. They are developed only for the COCs in media that are associated with unacceptable risk that may potentially warrant corrective action. RBRLs are site-specific risk-based concentrations that reflect the exposure and toxicity assumptions applied in the baseline RA. Consequently, RBRLs are source medium-, receptor-, and chemical-specific. The development of RBRLs involves a balance of cancer risk and noncancer hazard estimates. The development of RBRLs is an iterative process with on-going discussion between OEPA and the USACE.

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

- The concentration of the COC exceeds its medium-specific ARAR, provided one is available.

- The COPC contributes significantly to cancer risk or hazard as described below.

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

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

$$RBRL_{coc} = \frac{ST_{coc} TR}{ILCR_{coc}} \quad \text{Eq. 5.7}$$

where:

$RBRL_{coc}$ = risk-based remediation level 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.

RBRLs for noncancer COCs are estimated as follows (EPA, 2000):

$$RBRL_{coc} = \frac{ST_{coc} THI}{HI_{coc}} \quad \text{Eq. 5.8}$$

where:

$RBRL_{coc}$ = risk-based remediation level 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 5.7 or 5.8; the RBRL units are the same as the concentration units of the EPC. RBRLs are not final remedial concentrations. RBRLs are to be used by risk managers as approximate 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 would be developed before a feasibility study were initiated.

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

EPA (2004b) provides a PRG of 750 mg/kg for lead in soil for industrial sites, based on the recommendations of the TRW for lead. The PRG is appropriately considered a screening value for lead for industrial site use.

Plausible receptor scenarios for industrial site use include the groundskeeper, the indoor worker and the construction worker. Theoretically, the EPA (1996b) adult blood lead model could be used to develop RBRLs for lead in soil for these exposure scenarios. However, central tendency (CT) or mid-range exposure variable values, including estimates for incidental soil ingestion rate, are not available for these receptors. Therefore, any attempt to refine the screening level or develop a site-specific RBRL would introduce an inordinate amount of uncertainty. Largely for this reason, the EPA (2004b) PRG of 750 mg/kg for lead in industrial soil is adopted as the RBRL for the groundskeeper, indoor worker, and construction worker for this BHHRA.

5.4 Risk Characterization Results and Discussion

ILCR and HQ estimates for each receptor, medium and COPC, including sums across exposure routes for each COPC, are compiled in tables in Appendix B.

Considerable uncertainty is associated with ILCR, HQ and HI estimates; therefore, EPA (1989a) recommends that they be rounded to one significant figure for presentation in an RA. For example, an HI of 1.49E+0 is rounded to 1 and interpreted to mean that the HI does not exceed the threshold level of 1 and that occurrence of adverse noncancer effects is unlikely. An HI of 1.49E+1, for example, is rounded to 15.

COCs are defined as the chemicals that contribute significantly to an ILCR exceeding 1E-4 or an HI exceeding 1. For this discussion, an individual chemical is considered to contribute significantly to the cancer risk estimate if its ILCR summed across all exposure routes exceeds 1E-6. Similarly, an individual chemical is considered to contribute significantly to the noncancer hazard if its HI summed across all exposure routes exceeding 0.1.

When total HI summed across chemicals and/or media exceeds the threshold limit of 1, consideration is given to possible benefit of segregating HI values by target organ, as suggested by EPA (1989a). Target organ specific HIs were not developed for this BHHRA.

Total HI and ILCR estimates for each receptor and each source medium for Acid Area 2 are summarized in Table 5-1 and discussed below; detailed results are provided in Appendix B. The uncertainties associated with the HI and ILCR estimates are discussed in Section 6.0.

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. The total HI estimate for the groundskeeper receptor equals 1. The total ILCR estimate for the groundskeeper receptor was $5.0E-5$. The HI equals the threshold for noncancer effects. There were no COCs for the HI. The COCs for the ILCR were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil. Total HI estimates for the adult hunter, and adult and child venison consumer receptors were below the threshold limit of 1. The total ILCR estimate for the adult hunter was $6E-6$. The COCs were benzo(a)pyrene and PCB-1254 in surface soil. Total ILCR estimates for the adult and child venison consumer receptors were below $1E-6$, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. The total HI estimate summed across all media for the construction worker receptor was 10 (Table 5-1). The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and arsenic, iron, thallium, and PCB-1254 in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was $1E-5$. ILCR sums for surface water and sediment were below $1E-6$. ILCR summed for surface and subsurface soil was $1E-5$. The COCs for the ILCR were PCB-1254 and benzo(a)pyrene in surface soil and benzo(a)pyrene in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. Total HI estimates for the indoor worker for groundwater and surface soil were 2 and 0.4, respectively (Table 5-1). The COCs for the groundwater HI were arsenic, iron, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was $5E-5$. The ILCR for groundwater and surface soil were $7E-4$ and $2E-5$, respectively. The COCs for the ILCR were 1,1,2-trichloroethane, arsenic and benzene in groundwater, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil. Vapor intrusion into buildings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 7 and 31, respectively (Table 5-1). HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 7 and 31 for the adult and child, respectively. The groundwater COCs for the HI were aluminum, arsenic, barium, iron, manganese, thallium, vanadium, cyanide, benzene, bromomethane, and nitrobenzene for the adult, and aluminum, arsenic, barium, chromium, iron, manganese, thallium, vanadium, cyanide, 1,1,2-trichloroethane, 2-methylnaphthalene, benzene, bromomethane, nitrobenzene, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, aluminum, arsenic, iron, thallium, and PCB-1254 for the child. The subsurface soil COCs were aluminum, arsenic, iron, manganese,

thallium, and PCB-1254 for the child. There were no HI COCs for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were both $3E-4$. ILCR sums for surface water and sediment were $5E-6$ and $7E-6$ for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil for adult and child residential receptors were both $3E-4$. The groundwater COCs for the ILCR were 1,1,2-trichloroethane, arsenic, bis(2-ethylhexyl)phthalate, and benzene for the adult and 1,1,2-trichloroethane, arsenic, and benzene for the child. The surface soil COCs were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the child. The subsurface soil COCs were arsenic, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene for the adult and child. Vapor intrusion into dwellings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

RBRLs for total soil for cancer risk and noncancer effects for all receptors are compiled in Appendix C. The RBRLs should be considered as average concentrations, rather than not-to-exceed concentrations, for the COCs.

Figures 5-1 through 5-3 show the distribution of COCs (based on the adult and child residential exposure scenarios) exceeding the EPC and background concentrations for surface soil, sediment, and bedrock groundwater.

6.0 UNCERTAINTY ANALYSIS

This section evaluates the uncertainties inherent in the RA process. Uncertainty is a factor in each step of the data evaluation and exposure and toxicity assessments presented in the preceding sections. Uncertainties associated with early stages of the RA become magnified when they are concatenated with other uncertainties in the latter stages. It is not possible to eliminate all uncertainty, and sometimes not even to reduce it; however, a recognition of the uncertainties is fundamental to the understanding and reasonable use of the RA results.

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements such as instrument uncertainty (accuracy and precision) associated with contaminant concentrations. The results of the RA incorporate the accumulated variances of the individual measured values. A different kind of uncertainty stems from data gaps, i.e., additional information needed to complete the database for the assessment. Often the data gap is significant, such as imprecision regarding the number of days that a hunter might visit the site or the absence of information on the effects of human exposure to a chemical (EPA, 1992c).

EPA (1992c) guidance urges risk assessors to address or provide descriptions of individual risk to include the "high end" portions and "central tendency" of the risk distribution. One way of fulfilling this preference, if either cancer or noncancer risk exceeds generally acceptable limits (cancer risk greater than $1 \text{ E-}4$ or target organ-specific HI greater than 1) is to re-calculate the ILCRs or HIs using CT values for as many intake model variables as possible. In contrast to the RME evaluation, which prevails in RAs and uses upper-end values for intake or contact rates, exposure frequency and exposure duration, the CT evaluation uses average or midrange values for these variables (EPA, 1991a). The intent is to present a quantified risk/hazard estimate more typical for the receptor of interest.

Another method of quantifying uncertainty, called Monte Carlo simulation, provides a more graphic illustration of the uncertainty associated with a risk/hazard estimate, because it presents the risk as a range with probability densities. To be meaningful, however, Monte Carlo simulation requires that the nature of the distributions of the variables that drive the risk assessment be well characterized. However, well characterized distributions are available for few exposure or toxicological variables, in which case the Monte Carlo simulation provides an incomplete or potentially misleading illustration of the magnitude or the distribution of the uncertainty.

Because of the limitations of the CT and Monte Carlo procedures, the uncertainty analysis consists of a qualitative discussion of the sources of uncertainty and their impact on the estimated risk results and their interpretation, as described below.

Sampling and Analytical Limitations. It is not possible to completely characterize the nature and extent of contamination on any site. Uncertainties arise from limits on the number of locations that can be sampled. The sampling protocol used at Acid Area 2, however, was designed to optimize efficiency of the sampling effort and reduce uncertainty by focusing on areas around former process buildings, storage structures, and potential transfer piping. Furthermore, the sampling appears to be sufficient to show that the contamination is largely limited to the soil, with the exception of PCB-1260 in two sediment samples at Acid Area 2.

Specifically, the data show that surface water is not a medium of concern. There appears to be little uncertainty regarding the media affected by chemical releases at Acid Area 2.

Two sediment samples (AA2-SWSD-19 and AA2-SWSD-20) at Acid Area 2 had elevated concentrations of PCB-1260 at 15,000 and 18,000 ug/kg, respectively, approximately 5 times higher than the next highest detection. The sample locations are upgradient (AA2-SWSD-19) and downgradient (AA2-SWSD-20) of the former process building 706. No explanation is immediately apparent for the high concentrations of PCB-1260.

The sampling and analytical data are sufficient to identify PCB-1254 as the major contaminant in soil. Metals and PAHs were also identified. PCB-1254 was consistently detected in samples collected from 0.5 to 1.5 ft bgs, but not in samples collected from 0 to 1 ft bgs. Analyses were not performed for pesticides and herbicides, or for dioxins/dibenzofurans. Pesticides and herbicides may have been used to control insects and discourage overgrowth of weeds. These classes of compounds, however, are commonly identified in agricultural and former agricultural areas, and lack of analysis for these chemicals is not considered to impart significant uncertainty to the assessment. Dioxins/dibenzofurans are commonly associated with incineration, but their formation generally requires a source of chlorine such as chlorinated solvents. There is no record or other reason to believe that chlorinated organics were present when the former buildings were demolished and burned; therefore, lack of analysis for the dioxins/dibenzofurans is not viewed as a significant source of uncertainty.

The major contaminants in deep groundwater are metals, benzene, and bromomethane. Detection of metals in groundwater appears to be associated with sediment entrained in the samples. Specifically, samples with elevated turbidity had higher metals detections, while concentrations of metals in samples with low turbidity levels and filtered samples had low concentrations or were nondetect. Benzene may also be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBO. Bromomethane may be an artifact of the analytical process caused by laboratory equipment (off-gasing of o-rings), but could not be eliminated during data validation. This compound is also naturally occurring in the environment, and was only detected sporadically in groundwater (one of 14 deep groundwater samples) at Acid Area 2.

Selection and Quantification of Chemicals of Potential Concern. Uncertainty associated with the processes used to identify COPCs and estimate EPCs arises from the following:

1. Identifying background chemicals. Metals are judged to be present at concentrations comparable to background if the MDC does not exceed the BSC, or if statistical testing demonstrates that the site data and background data are drawn from the same population. Statistical testing of site data versus background was not performed for this RA. All inorganic constituents detected in environmental media were carried through the risk assessment to provide a conservative estimate of potential risks associated with exposure to site media. The MDCs for arsenic and iron in surface soil and aluminum, arsenic, iron, and manganese in subsurface soil were lower than their respective background criteria. The MDC of aluminum exceeded its background criterion, which was based on the maximum concentration detected in background samples. The EPC for aluminum was well below its background criterion. Detected concentrations of thallium in surface and subsurface soil exceeded its background criterion. Concentrations of lead detected in surface and subsurface soil, and sediment were 150-, 14-, and 30-times greater than background. There

was no background criterion for thallium in deep groundwater. Some organic chemicals, such as PAHs, may be considered to be anthropogenic background. PAHs were identified in soil and sediment at Acid Area 2, possibly as a result of asphalt contained in roofing material and in roads and parking areas, or associated with the rail line traversing the site. There are no site-specific background data for the PAHs, and several were selected as COCs. PAH concentrations at Acid Area 2 all fall within global background levels for urban areas compiled by the Agency for Toxic Substances and Disease Registry (ATSDR) (1997). Given the rationale for their presence, PAHs may be considered site-related compounds in soil at Acid Area 2. The PAH benzo(a)pyrene contributes approximately 40 percent of the adult residential risk at Acid Area 2. However, the total risk is within the cancer risk range of 1E-6 to 1E-4.

2. Estimated EPCs are uncertain. For statistical purposes, if a constituent was positively identified at a site and had at least a single positive hit, all the samples with nondetects were assumed to have a value equal to half the reporting limit and were included in the data set. These procedures may introduce a conservative bias into the risk assessment. Computed UCL_{95} values are only estimates of the actual upper confidence limits associated with each data set. Examples of factors affecting the uncertainty of these estimates include the number of samples, proportion of nondetects, conformance with an assumed mathematical distribution, imprecision of laboratory data, elevated detection limits (from dilutions, matrix interference, etc.), and statistical methodology. The confidence of computed UCLs for this project have been qualitatively evaluated and identified as high, moderate, low and indeterminate. For indeterminate data sets, the MDC was used for the UCL. Uncertainties associated with the statistical determination of EPCs for the COCs in each medium are:

- Groundwater

- 1,1,2-trichloroethane: Indeterminate confidence – 93% nondetects
- 2-methylnaphthalene: Indeterminate confidence – elevated detection limits for nondetects
- Aluminum (total): Moderate confidence – 43% nondetects
- Arsenic (total): Indeterminate confidence – elevated detection limits for nondetects, 73% nondetects
- Barium (total): High confidence – no nondetects, good fit to normal distribution
- Benzene: High confidence – no nondetects, good fit to normal distribution
- bis(2-ethylhexyl)phthalate: Indeterminate confidence – elevated detection limits for nondetects, 67% nondetects
- Bromomethane: Indeterminate confidence – elevated detection limits for nondetects, 93% nondetects
- Chromium (total): Low confidence – 60% nondetect
- Cyanide: Indeterminate confidence – elevated detection limits for nondetects, 86% nondetects
- Iron (total): Moderate confidence – marginal fit to lognormal distribution, non-parametric methods do not provide adequate coverage for 95 percent confidence level with only 14 samples
- Manganese (total): Moderate confidence – marginal fit to lognormal distribution, non-parametric methods do not provide adequate coverage for 95 percent confidence level with only 15 samples
- Nitrobenzene: Indeterminate confidence – elevated detection limits for nondetects, 90% nondetects

- Thallium (total): Indeterminate confidence – elevated detection limits for nondetects, 73% nondetect
- Vanadium (total): Indeterminate confidence – elevated detection limits for nondetects, 93% nondetect
- Xylenes (total): High confidence – no nondetects, good fit to gamma distribution
- Surface Soil
 - Aluminum: High confidence – no nondetects, good fit to gamma distribution
 - Arsenic: High confidence – no nondetects, good fit to gamma distribution
 - Benzo(a)anthracene: Moderate confidence – non-parametric, 50% nondetects
 - Benzo(a)pyrene: Indeterminate confidence – elevated detection limits for nondetects, 50% nondetects
 - Benzo(b)fluoranthene: Indeterminate confidence – 54% nondetects
 - Benzo(k)fluoranthene: Moderate confidence – non-parametric, 50% nondetects
 - Dibenz(a,h)anthracene: Indeterminate confidence – elevated detect limits for nondetects, 68% nondetects
 - Indeno(1,2,3-cd)pyrene: Moderate confidence – non-parametric, 54% nondetects
 - Iron: High confidence – no nondetects, good fit to gamma distribution
 - Lead: High confidence – no nondetects
 - PCB-1254: Indeterminate confidence – elevated detection limits for nondetects, 61% nondetects
 - PCB-1260: Moderate confidence – non-parametric
 - Thallium: Indeterminate confidence – elevated detection limit for nondetects, 57% nondetects
- Subsurface Soil
 - Aluminum: High confidence – no nondetects, good fit to normal distribution
 - Arsenic: High confidence – good fit to gamma distribution
 - Benzo(a)anthracene: Indeterminate – 91% nondetects
 - Benzo(a)pyrene: Indeterminate – elevated detection limits for nondetects, 91% nondetects
 - Benzo(b)fluoranthene: Indeterminate confidence – 91% nondetects
 - Dibenz(a,h)anthracene: Indeterminate – elevated detection limits for nondetects, 64% nondetect
 - Indeno(1,2,3-cd)pyrene: Indeterminate confidence – 91% nondetects
 - Iron: High confidence – no nondetects, good fit to gamma distribution
 - Manganese: High confidence – no nondetects, good fit to gamma distribution
 - PCB-1254: Indeterminate confidence – elevated detection limits for nondetects, 80% nondetect
 - PCB-1260: Indeterminate confidence – 60% nondetect
 - Thallium: Indeterminate confidence – elevated detection limits for nondetects, 60% nondetect
- Sediment
 - Arsenic: High confidence – no nondetects, good fit to normal distribution
 - Benzo(a)pyrene: Indeterminate confidence – elevated detection limits for nondetects

- Lead: Moderate confidence – parametric UCL is approximately twice the non-parametric UCL
 - PCB-1254: Indeterminate confidence – 96% nondetects
 - PCB-1260: High confidence
 - Thallium: Indeterminate confidence – elevated detection limits for nondetects, 87% nondetect
3. A limited number of samples may not completely characterize the site because they provide less information about the population from which they are drawn than do larger sample sets. Accordingly, small sets tend to have a greater variability, which results in the calculation of wide confidence intervals on the mean concentration and high EPCs. In some cases, the UCL₉₅ was greater than the maximum value; thus, the maximum value was chosen as the EPC. High confidence limits may introduce a conservative bias into the risk assessment.
 4. Laboratory analytical techniques have a degree of uncertainty associated with them. These uncertainties are documented by using data qualifiers to reflect the degree of certainty of measurement. For example, some data were estimated (e.g., J-qualified), while other data were rejected (i.e., R-qualified). The direction of bias is unclear.
 5. Per EPA (1992a) guidance, the UCL₉₅ was used for the EPC. Therefore, the exposure assessment is likely to underestimate the EPCs in 5 percent of the cases and overestimate exposures in 95 percent of cases, imparting an overall conservative bias to the risk assessment.

Selection of Hypothetical Receptors and Potential Exposure Pathways. The exposure scenarios chosen for evaluation address plausible receptors for the current and projected future site uses previously described. Although the specific uses to which the sites may be put are not entirely certain, the general categories (industrial, recreational, residential) are comprehensive and fairly standard. The receptor scenarios selected for evaluation include the most intensely exposed for each general site-use category; therefore, uncertainty regarding the specific uses has no meaningful effect on interpretation of the RA. For example, the groundskeeper represents the upper bound on exposure for any industrial application. The indoor worker represents the upper bound on any worker indoor exposure, particularly relevant for VOCs that may gain entrance to a building from subsurface soil. The construction worker represents the upper bound on short-term exposure to soil, regardless of the nature of a construction project. The hunter represents a plausible scenario for recreational site use and indirect (food-chain) exposure. Finally, the on-site resident represents the upper bound for residential site use. The resident is generally considered to represent the upper bound for any standard site use.

Another source of uncertainty in the receptor scenarios is the decision not to quantify intake or uptake from certain exposure routes. For example, inhalation of VOCs in outdoor air that volatilized from subsurface soil by the groundskeeper, indoor worker and hunter is not quantified. It is assumed that overlying soil would attenuate emissions and that the large volume of outdoor air and natural air currents would dilute concentrations in the breathing zone to toxicologically insignificant levels. This assumption is based on considerable experience with volatilization models, and is consistent with the assumption applied by EPA (2004c) in developing PRGs for soil. VOCs were generally not detected in surface or subsurface soil at Acid Area 2. Where VOCs were detected, their concentrations were below the Region 9 PRGs and none were selected as COPCs, further reducing concern that a potentially significant exposure pathway was not evaluated.

As another example, the groundskeeper and hunter were not evaluated for exposure to surface water or sediment, even though these receptors spend most of their time outdoors. Since contact with surface water would not be part of their normal activities, it is assumed that any exposure would be sporadic and would not readily lend itself to quantification. Also, such exposures should be viewed as repeated acute rather than chronic, which does not fit the EPA (1989a) paradigm or the toxicity values developed for an RA. Finally, exposure to surface water was evaluated for the construction worker and on-site resident, who are expected to be more regularly exposed. Therefore, the decision not to evaluate surface water exposure for the groundskeeper and hunter is not seen as a significant source of uncertainty affecting the results or interpretation of the RA.

The indoor worker was not evaluated for inhalation of airborne dust or VOCs from surface soil or for dermal contact with surface soil because these exposure routes are expected to be less significant than incidental ingestion which is quantified. The decision not to quantify inhalation and dermal exposure imparts a non-conservative bias to the RA. However, inhalation and dermal contact were quantified for the groundskeeper, who would be more intensely exposed by these routes. Risk estimates for the groundskeeper from inhalation exposure were negligible. Similarly, as stated above, VOCs were generally not detected in surface or subsurface soil at Acid Area 2. Where VOCs were detected, their concentrations were below the Region 9 PRGs and none were selected as COPCs, further reducing the possibility that a potentially significant exposure pathway was not evaluated. Therefore, it is assumed that inhalation exposure would be negligible for the indoor worker, as well, and that the decision not to quantify this route had no meaningful effect on the outcome of the RA or its interpretation.

Other plausible receptors include office workers, delivery personnel, and resident farmers. These receptors would be less intensively exposed to soil than the groundskeeper; therefore, their exposures were not evaluated. Much of the land around PBOW is used for agriculture, and it is possible that areas of PBOW could be farmed in the future. However, experience has shown that risk from ingestion of home-grown grains, fruits, meat, poultry, eggs, or milk is generally insignificant compared with direct exposure pathways, except for dioxin/furan compounds; therefore, indirect food-chain exposures are not evaluated. Additionally, the increased exposure to soil and ingestion of beef are adequately represented by the evaluations of groundskeeper and ingestion of venison scenarios, respectively.

The uncertainty associated with dermal exposure is not as clear. Dermal risk estimates for the groundskeeper were at the low end of the cancer risk range of $1E-6$ to $1E-4$ at Acid Area 2. It is expected that the intensity of dermal exposure to soil would be much less for an indoor worker than an outdoor worker; however, dermal exposure parameters were not developed for the indoor worker to test this assumption. Therefore, the decision not to evaluate dermal exposure represents a source of uncertainty that has not been quantified. The construction worker and on-site resident were not evaluated for inhalation of VOCs from surface water or incidental ingestion of surface water, because these exposure routes are expected to be less significant than dermal exposure, which is quantified.

The decision not to quantify incidental ingestion of surface water imparts a non-conservative bias to the RA; however, VOCs were not detected in surface water samples from Acid Area 2. The uncertainty associated with incidental ingestion is not as clear. It is expected that the potential for incidental ingestion would be very low in a wading scenario, and far less significant than dermal uptake; however, exposure parameters for incidental ingestion were not developed

to test this assumption. Therefore, the decision not to evaluate incidental ingestion represents a source of uncertainty that has not been quantified.

The hunter was not evaluated for inhalation of dust from surface soil because this receptor would be expected to spend most of his time on vegetated soil, and because inhalation exposure would be expected to be far less than incidental ingestion of soil, which was quantified. However, inhalation is quantified for the groundskeeper, who would be more intensely exposed. Estimated risk for the groundskeeper from inhalation exposure was negligible. Therefore, it was assumed that inhalation exposure would be negligible for the hunter as well and that the decision not to quantify this route had no meaningful effect on the outcome of the RA or its interpretation.

Quantification of Intakes. Ingestion rates, inhalation rates, EDs, and EFs were based on upper-bound values (EPA, 1989a, 1991a), even though it is likely that serial multiplication of conservative variable values leads to gross overestimation of COPC intakes (Cogliano, 1997).

Toxicity Assessment. Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) evaluations of a toxicity assessment. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination (EPA, 1986). Positive animal cancer test data suggest that humans also contain tissue(s) that may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of noncancer effects, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans (EPA, 1989b).

There are many sources of uncertainty in the dose-response evaluation for cancer (i.e., computation of an SF or unit risk) and noncancer effects (i.e., computation of an RfD). First, there is uncertainty regarding interspecies (animal-to-human) extrapolation which, in the absence of quantitative pharmacokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Second, there is uncertainty regarding intraspecies or individual variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal, but the human population of concern may reflect wide heterogeneity including unusual sensitivity to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals sufficiently healthy to attend work regularly and those not unusually sensitive to the COPC are likely to be occupationally exposed. Third, uncertainty arises from expansion from short-term to lifetime exposure such as the construction worker and child on-site resident. Additional uncertainty arises from the potential for children to be more sensitive than adults. Finally, the quality of the key study from which the quantitative estimate is derived and the database contributes to uncertainty. For cancer studies, the uncertainty associated with some quality factors (e.g., study group size) is expressed within the 95 percent upper-bound of the SF. For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD to reflect poor quality of the key study or gaps in the database.

Another source of uncertainty regarding quantitative risk estimation for carcinogenicity is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in most quantitative estimates of human cancer risk from animal data (PAHs, PCBs), is based on a non-threshold assumption of carcinogenesis. An impressive body of evidence, however,

suggests that epigenetic carcinogens as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Gold, et al., 1992); therefore, the use of the linearized multistage model is ultraconservative for chemicals that exhibit a threshold for carcinogenicity.

A further source of uncertainty for noncancer effects arises from use of an effect level in the estimation of an RfD or RfC, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises from estimating RfD values for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less-than-chronic study. Uncertainty also arises from the presence of chemicals (e.g., lead) for which there are no EPA-approved toxicity values, and for which quantitative risk characterization is not possible. However, the adult blood-lead model and the IEUBK are supported by a considerable body of empirical data, and are considered to be among the best validated of the various models used in risk assessment. In summary, the EPA methodology for both cancer and noncancer toxicity evaluation is intentionally designed to be protective. However, the extent to which toxicity values may overestimate toxic potency is not clear, and it is possible that the toxicity values for some compounds may not be adequately protective.

Risk Characterization. Risk characterization is the process of quantifying the risk of cancer due to exposure to carcinogens, as well as quantitatively evaluating hazards potentially posed by exposure to noncarcinogenic toxicants. Cancer risk is assumed to be additive for all carcinogens. Noncancer risk is assumed to be additive for chemicals with similar sites of toxicological action. In the event that any combination of these chemicals results in synergistic effects, risk might be underestimated. Conversely, the assumption of additivity would overestimate risk if a combination of these chemicals acted antagonistically or had no combined toxic effect at all.

7.0 SUMMARY AND CONCLUSIONS

This section briefly summarizes the RA protocol and results and interprets the results, in light of the uncertainty associated with their estimation, to draw realistic conclusions regarding risk to human health.

PBOW is currently classified for industrial use, but future residential use was considered in the risk assessment to support evaluation of all plausible receptor scenarios. Groundskeeper, construction worker and hunter scenarios were evaluated under the current site-use assumptions. Groundskeeper, construction worker, indoor worker, hunter (including a child venison consumer) and on-site residential scenarios were evaluated as plausible future exposure scenarios. The groundskeeper was evaluated for exposure to surface soil. The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. The adult hunter was evaluated for exposure to surface soil by direct contact and indirectly by ingestion of venison (deer graze vegetation growing on contaminated soil). The indoor worker was evaluated for exposure to surface and subsurface soil, and groundwater. The on-site resident was evaluated as the upper bound on exposure to surface and subsurface soil, groundwater, surface water and sediment.

7.1 Sampling and Analysis

Surface and subsurface soil samples were taken from the areas around each of the former process buildings where contamination was thought to have been possible. Surface water and sediment samples were taken from the drainage ditches that border the site. Groundwater samples were collected from monitoring wells at the site.

The analytical results revealed that the soil contains metals, PCBs, and PAHs at concentrations exceeding the Region 9 PRGs; consequently, they were selected as COPCs. PAHs possibly result from asphalt contained in roofing material and in roads and parking areas, or associated with the rail line traversing the site. Elevated concentrations of lead were also detected in two surface soil samples.

Contaminants detected in deep groundwater were metals, VOCs, and SVOCs. Detection of metals in groundwater appears to be associated with sediment entrained in the samples. Specifically, samples with elevated turbidity had higher metals concentrations while samples with low turbidity levels and filtered samples had low concentrations or were nondetects. Certain VOCs may be associated with background due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW. Other VOCs and SVOCs may be artifacts of the analytical process at the laboratory, but they could not be eliminated during data validation.

Two sediment samples (AA2-SWSD-19 and AA2-SWSD-20) at Acid Area 2 had elevated concentrations of PCB-1260 at 15,000 and 18,000 ug/kg, respectively. The sample locations are upgradient (AA2-SWSD-19) and downgradient (AA2-SWSD-20) of the former process building 706. Levels of PCBs in downgradient sediment were approximately 3 orders of magnitude lower, suggesting that off-site contaminant migration is minimal.

Metals, bis(2-ethylhexyl)phthalate, and trichloroethene were selected as COPCs in surface water. Bis(2-ethylhexyl)phthalate concentrations were either nondetect or "JB" flagged indicating

contamination in blank samples. Trichloroethene, which is not a risk driver, was only detected in one sample, suggesting possible cross contamination in the laboratory.

7.2 Risk Assessment Results

The groundskeeper, hunter, and child venison consumer were evaluated for exposure only to surface soil. The total HI estimate for the groundskeeper receptor equaled 1. The total ILCR estimate for the groundskeeper receptor was $5.0E-5$. The HI equaled the threshold for noncancer effects. There were no COCs for the HI; the COCs for the ILCR were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil. Total HI estimates for the adult hunter and the adult and child venison consumer receptors were below the threshold limit of 1. The total ILCR estimate for the adult hunter was $6E-6$. The COCs were benzo(a)pyrene and PCB-1254 in surface soil. Total ILCR estimates for the adult and child venison consumer receptors were below $1E-6$, defined as the point of departure for significant contribution to cancer risk.

The construction worker was evaluated for exposure to surface and subsurface soil, surface water and sediment. The total HI estimate summed across all media for the construction worker receptor was 10 (Table 5-1). The COCs for the HI were arsenic, iron, thallium and PCB-1254 in surface soil and arsenic, iron, thallium, and PCB-1254 in subsurface soil. The total ILCR estimate summed across all media for the construction worker receptor was $1E-5$. ILCR sums for surface water and sediment were below $1E-6$. ILCR summed for surface and subsurface soil was $1E-5$. The COCs for the ILCR were PCB-1254 and benzo(a)pyrene in surface soil and benzo(a)pyrene in subsurface soil.

The indoor worker was evaluated for exposure to surface soil and groundwater. Total HI estimates for the indoor worker for groundwater and surface soil were 2 and 0.4, respectively (Table 5-1). The COCs for the groundwater HI were arsenic, iron, and thallium. The total ILCR estimate summed across all media for the indoor worker receptor was $5E-5$. The ILCRs for groundwater and surface soil were $7E-4$ and $2E-5$, respectively. The COCs for the ILCR were 1,1,2-trichloroethane, arsenic and benzene in groundwater, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in surface soil. Vapor intrusion into buildings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

The adult and child residential receptors were evaluated for exposure to surface and subsurface soil, groundwater, surface water and sediment. Total HI estimates summed across all media for the adult and child residential receptors were 7 and 31, respectively (Table 5-1). HI sums for surface water and sediment were below 1. HI sums for groundwater and surface and subsurface soil were 7 and 31 for the adult and child, respectively. The groundwater COCs for the HI were aluminum, arsenic, barium, iron, manganese, thallium, vanadium, cyanide, benzene, bromomethane, and nitrobenzene for the adult, and aluminum, arsenic, barium, chromium, iron, manganese, thallium, vanadium, cyanide, 1,1,2-trichloroethane, 2-methylnaphthalene, benzene, bromomethane, nitrobenzene, and total xylenes for the child. The surface soil COCs were PCB-1254 for the adult, and aluminum, arsenic, iron, thallium, and PCB-1254 for the child. The subsurface soil COCs were aluminum, arsenic, iron, manganese, thallium, and PCB-1254 for the child. There were no HI COCs for adult exposures to subsurface soil.

The total ILCR estimates summed across all media for the adult and child residential receptors were both $3E-4$. ILCR sums for surface water and sediment were $5E-6$ and $7E-6$ for the adult and child, respectively. ILCR sums for groundwater and surface and subsurface soil for adult and child residential receptors were both $3E-4$. The groundwater COCs for the ILCR were 1,1,2-trichloroethane, arsenic, bis(2-ethylhexyl)phthalate, and benzene for the adult and 1,1,2-trichloroethane, arsenic, and benzene for the child. The surface soil COCs were arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the adult, and arsenic, PCB-1254, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene for the child. The subsurface soil COCs were arsenic, PCB-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene for both the adult and child. Vapor intrusion into dwellings from subsurface soil was not evaluated, as there were no VOCs detected in the subsurface soil.

7.3 Conclusions

Based on analytical results, metals, PAHs, and PCBs appear to be widespread but generally at low concentrations in environmental media at Acid Area 2, with isolated areas of elevated PAH or PCB contamination. HIs for contamination in soil are less than one for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site, suggesting that adverse effects from exposure are unlikely. Cancer risk for a groundskeeper or hunter, including an adult or child who consumes venison from deer harvested on site are within or below the cancer risk range of $1E-6$ to $1E-4$.

HIs for the indoor workers were below 1. HIs exceeded 1 for the construction worker, and adult and child residential receptors for exposure to surface soil. The primary contributor to the HIs was PCB-1254. Cancer risk estimates were within the cancer risk range of $1E-6$ to $1E-4$ for the construction worker and indoor worker, and just slightly above $1E-4$ for the adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for construction workers and adult and child residential receptors exceeded 1 for exposure to subsurface soil. The primary contributor to the HIs was thallium. Cancer risk estimates were within the cancer risk range of $1E-6$ to $1E-4$ for the construction worker and the adult and child residential receptors. The primary contributor to the ILCRs was benzo(a)pyrene.

HIs for the indoor workers and adult and child residential receptors exceeded 1 for exposure to groundwater. The primary contributor to the HIs was thallium. Cancer risk estimates were within the cancer risk range of $1E-6$ to $1E-4$ for the indoor worker, and just slightly above $1E-4$ for the adult and child residential receptors. The primary contributor to the ILCRs was arsenic.

Cancer risk and noncancer hazard estimates for exposure to surface water were below $1E-6$ and 1, respectively, for any receptor evaluated. Cancer risk estimates were within the cancer risk range of $1E-6$ to $1E-4$ for the construction worker and adult and child residential receptors for exposures to sediment.

Accounting for natural background concentrations of metals and the isolated detections of elevated concentrations of PCBs and lead, potential risks from exposure to contaminants detected in site environmental media appear to be limited.

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Legend

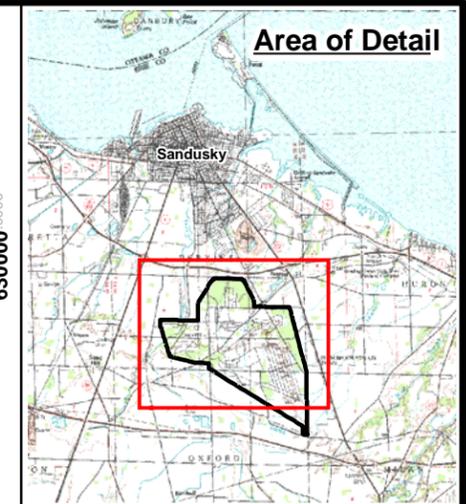
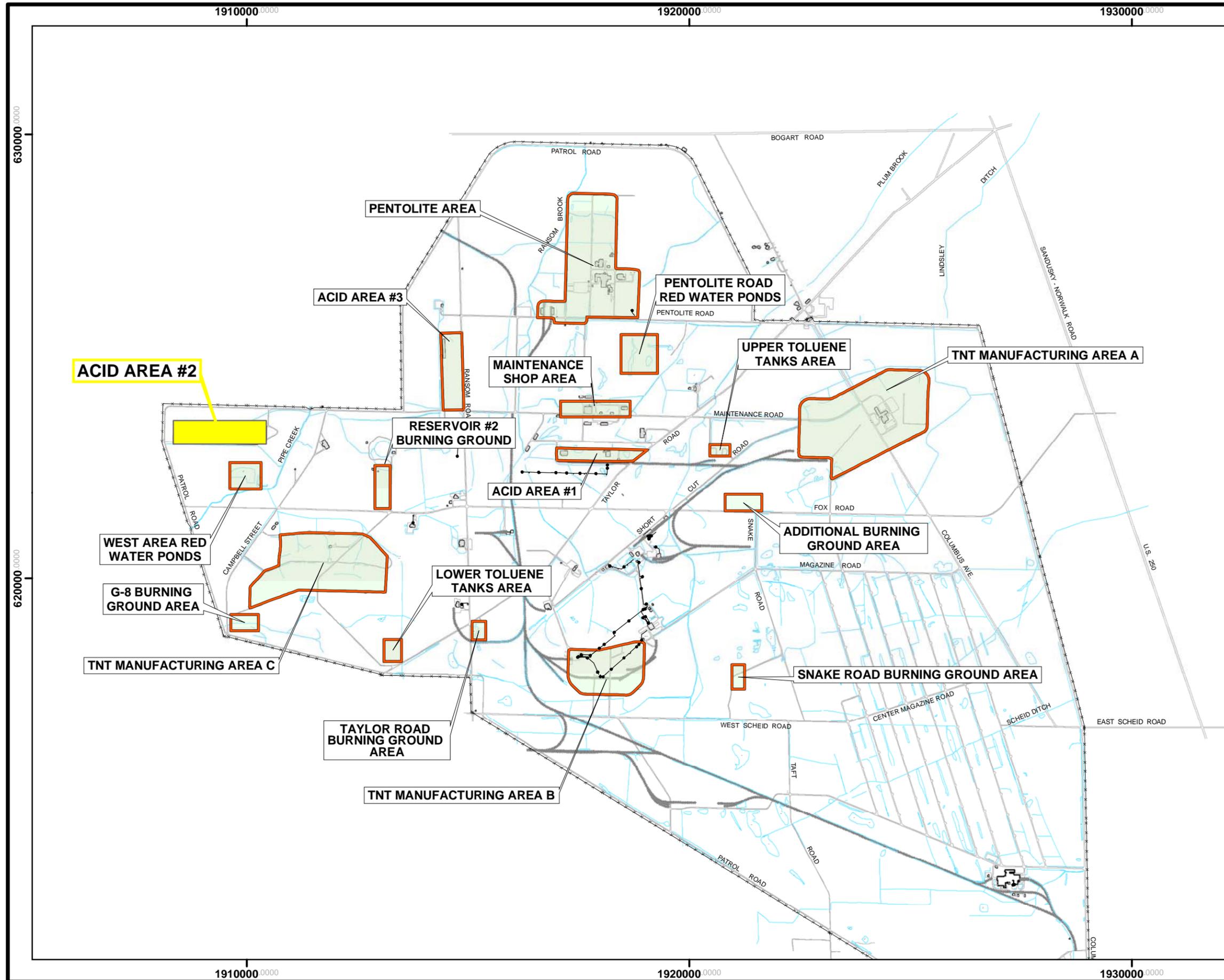


Plum Brook Ordnance Works Boundary



Location Map,
Plum Brook Ordnance Works
Sandusky, Ohio

Plumbrook Ordnance Works
Sandusky, Ohio



Legend

-  Area of Concern
-  Creek, Ditch, Conveyance



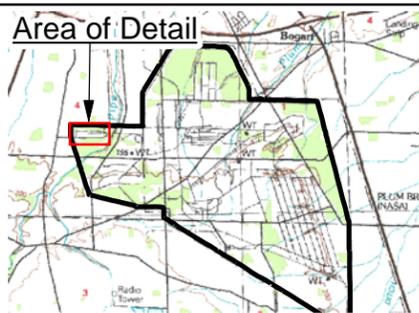
Sources
Data mapped to Ohio State Plane North NAD83, map grid units in feet.



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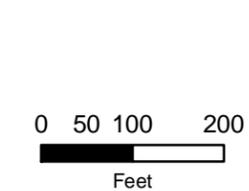
Location Map, Acid Area 2

Plum Brook Ordnance Works
Sandusky, Ohio



- Legend**
- Storage Tank Areas from Engineering Drawings
 - ~ Creek, Ditch, Conveyance
 - Buildings
 - Railway

- 1998 SI Soil Borings
- 2004 Soil Borings (1 surface sample and 2 subsurface samples)
- 2004 Soil Borings (1 surface sample and 1 subsurface sample)
- + Monitoring Wells
- ⊗ Piezometers
- Surface Water Sediment Sampling Locations



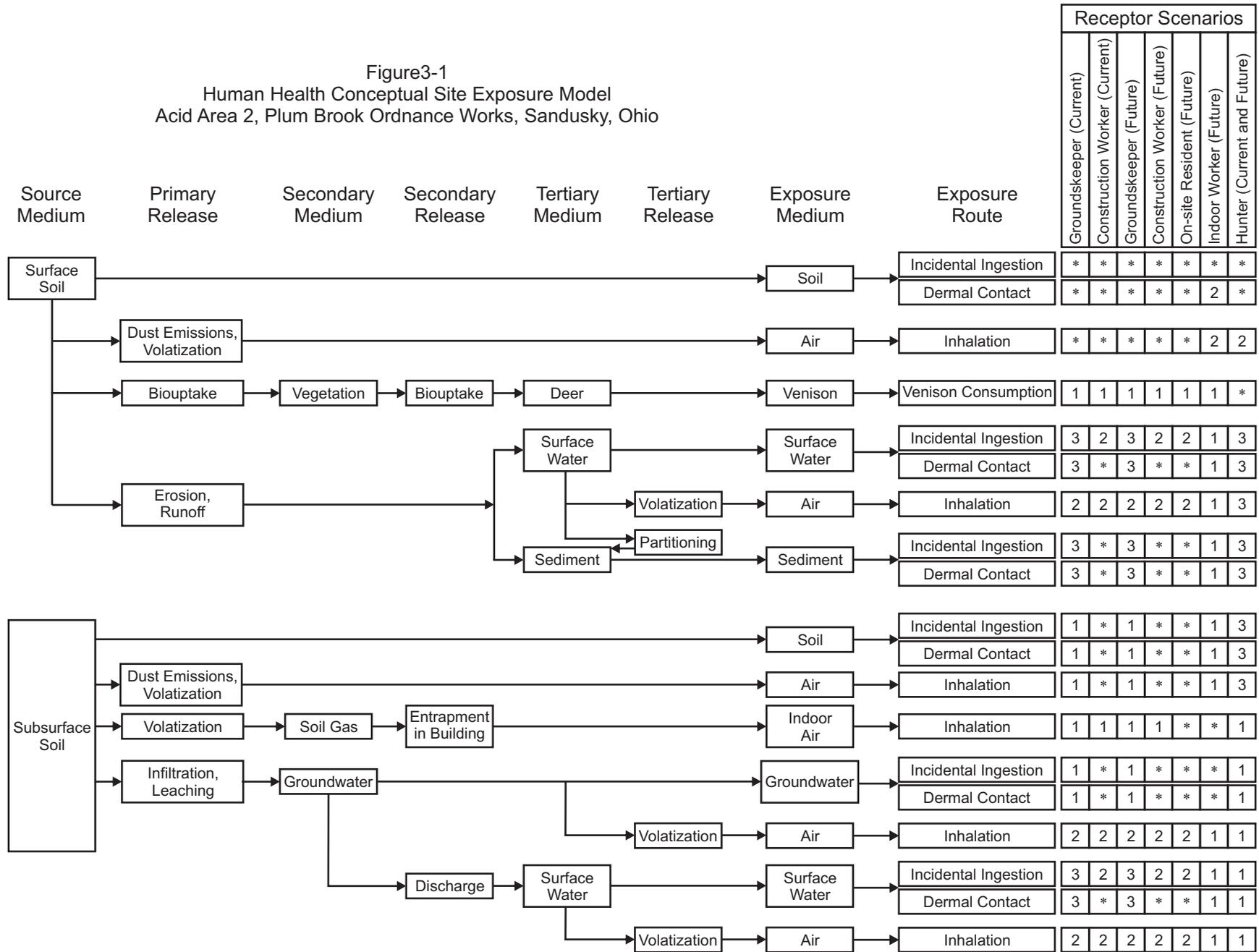
Sampling Locations — Acid Area 2
Plum Brook Ordnance Works
Sandusky, Ohio

Notes: Aerial Photography from 2005.
Data mapped to Ohio State Plane North NAD83, map units are feet.

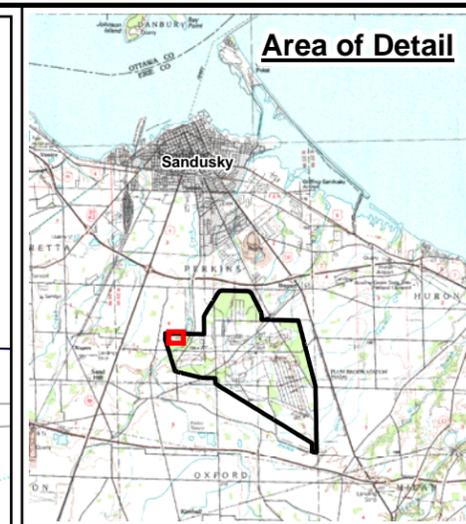
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Figure 2-1

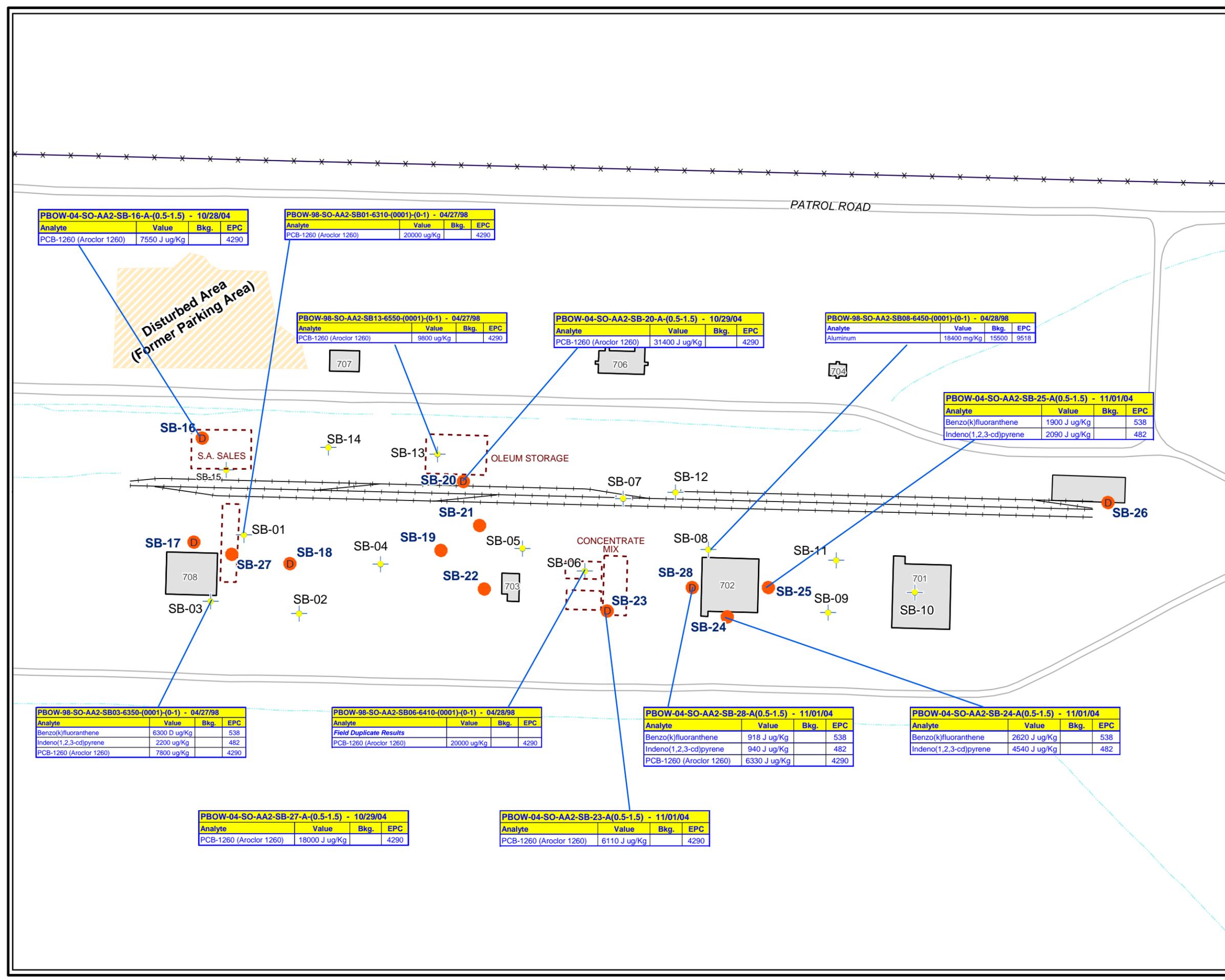
Figure3-1
Human Health Conceptual Site Exposure Model
Acid Area 2, Plum Brook Ordnance Works, Sandusky, Ohio



* = 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 is 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.



Area of Detail



Legend

- 1998 SI Soil Borings
 - 2004 Soil Borings to 10 ft bgs
 - 2004 Soil Borings to 5 ft bgs
- Note:
 bgs = below ground surface
 Bkg. = Background Sample
 PRG = Preliminary Remediation Goal
- Storage Tank Areas from Engineering Drawings
 - Creek, Ditch, Conveyance
 - Buildings
 - Railway



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



Distribution of COCs Exceeding Background and EPC in Surface Soil — Acid Area 2
 Plum Brook Ordnance Works
 Sandusky, Ohio

PBOW-04-SO-AA2-SB-16-A(0.5-1.5) - 10/28/04

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	7550 J ug/Kg		4290

PBOW-98-SO-AA2-SB01-6310-(0001)-(0-1) - 04/27/98

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	20000 ug/Kg		4290

PBOW-98-SO-AA2-SB13-6550-(0001)-(0-1) - 04/27/98

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	9800 ug/Kg		4290

PBOW-04-SO-AA2-SB-20-A(0.5-1.5) - 10/29/04

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	31400 J ug/Kg		4290

PBOW-98-SO-AA2-SB08-6450-(0001)-(0-1) - 04/28/98

Analyte	Value	Bkg.	EPC
Aluminum	18400 mg/Kg	15500	9518

PBOW-04-SO-AA2-SB-25-A(0.5-1.5) - 11/01/04

Analyte	Value	Bkg.	EPC
Benzo(k)fluoranthene	1900 J ug/Kg		538
Indeno(1,2,3-cd)pyrene	2090 J ug/Kg		482

PBOW-98-SO-AA2-SB03-6350-(0001)-(0-1) - 04/27/98

Analyte	Value	Bkg.	EPC
Benzo(k)fluoranthene	6300 D ug/Kg		538
Indeno(1,2,3-cd)pyrene	2200 ug/Kg		482
PCB-1260 (Aroclor 1260)	7800 ug/Kg		4290

PBOW-98-SO-AA2-SB06-6410-(0001)-(0-1) - 04/28/98

Analyte	Value	Bkg.	EPC
Field Duplicate Results			
PCB-1260 (Aroclor 1260)	20000 ug/Kg		4290

PBOW-04-SO-AA2-SB-28-A(0.5-1.5) - 11/01/04

Analyte	Value	Bkg.	EPC
Benzo(k)fluoranthene	918 J ug/Kg		538
Indeno(1,2,3-cd)pyrene	940 J ug/Kg		482
PCB-1260 (Aroclor 1260)	6330 J ug/Kg		4290

PBOW-04-SO-AA2-SB-24-A(0.5-1.5) - 11/01/04

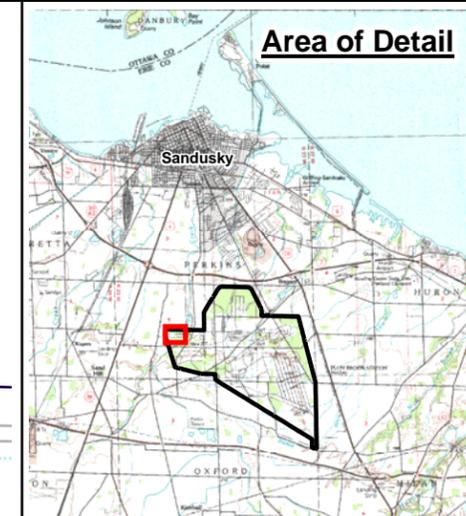
Analyte	Value	Bkg.	EPC
Benzo(k)fluoranthene	2620 J ug/Kg		538
Indeno(1,2,3-cd)pyrene	4540 J ug/Kg		482

PBOW-04-SO-AA2-SB-27-A(0.5-1.5) - 10/29/04

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	18000 J ug/Kg		4290

PBOW-04-SO-AA2-SB-23-A(0.5-1.5) - 11/01/04

Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	6110 J ug/Kg		4290



Area of Detail

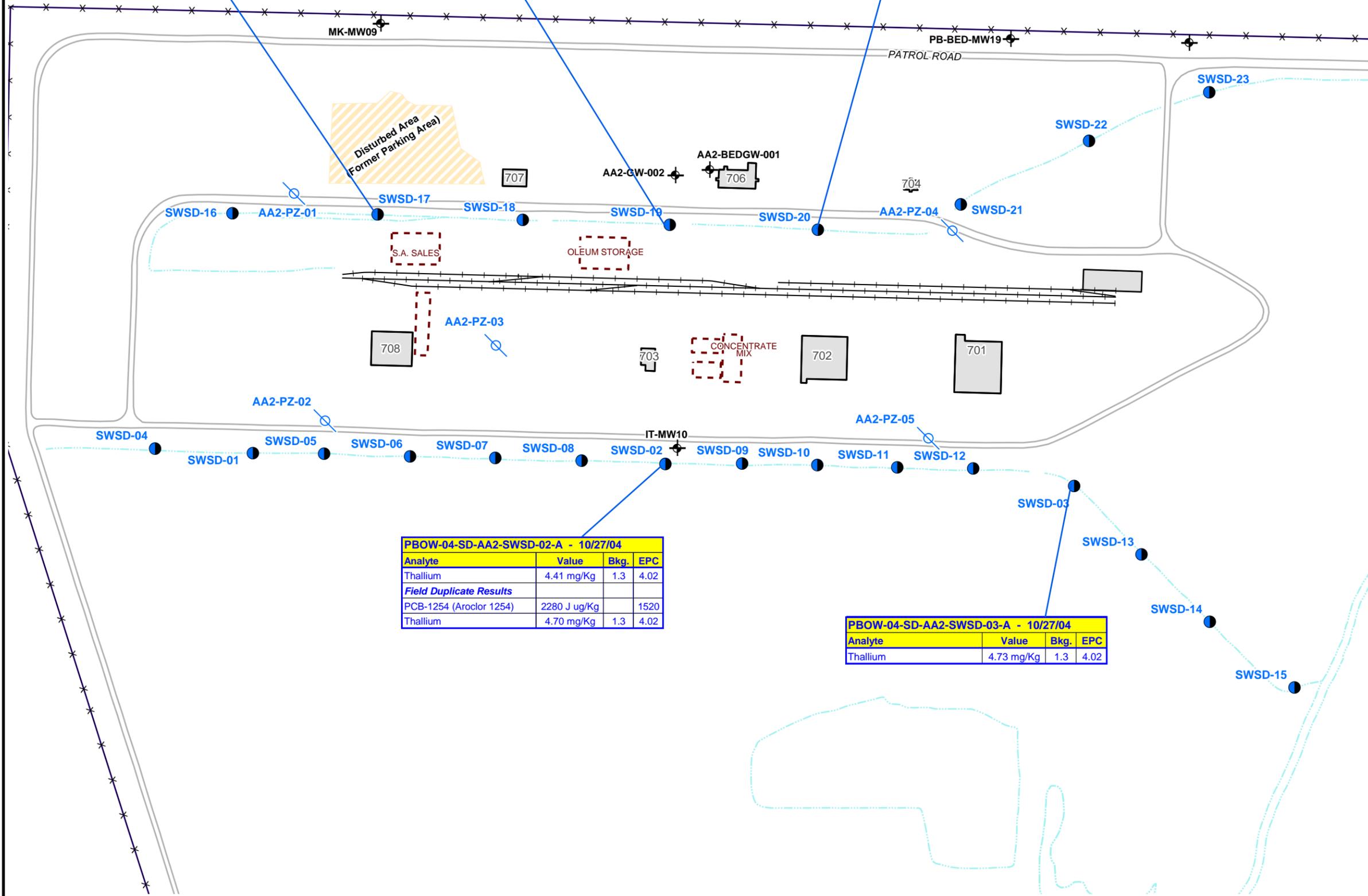
PBOW-06-SD-AA2-SD17-A - 06/11/06			
Analyte	Value	Bkg.	EPC
Lead	1460 J mg/Kg	48.6	776

PBOW-06-SD-AA2-SD19-A - 06/11/06			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	15000 ug/Kg		5780

PBOW-06-SD-AA2-SD20-A - 06/11/06			
Analyte	Value	Bkg.	EPC
PCB-1260 (Aroclor 1260)	18000 ug/Kg		5780

PBOW-04-SD-AA2-SWSD-02-A - 10/27/04			
Analyte	Value	Bkg.	EPC
Thallium	4.41 mg/Kg	1.3	4.02
<i>Field Duplicate Results</i>			
PCB-1254 (Aroclor 1254)	2280 J ug/Kg		1520
Thallium	4.70 mg/Kg	1.3	4.02

PBOW-04-SD-AA2-SWSD-03-A - 10/27/04			
Analyte	Value	Bkg.	EPC
Thallium	4.73 mg/Kg	1.3	4.02

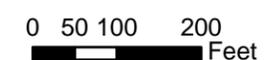


Legend

- Sediment Sampling Locations
- ⊕ Monitoring Wells
- ⊖ Piezometers

Note:
 bgs = below ground surface
 Bkg. = Background Sample
 PRG = Preliminary Remediation Goal

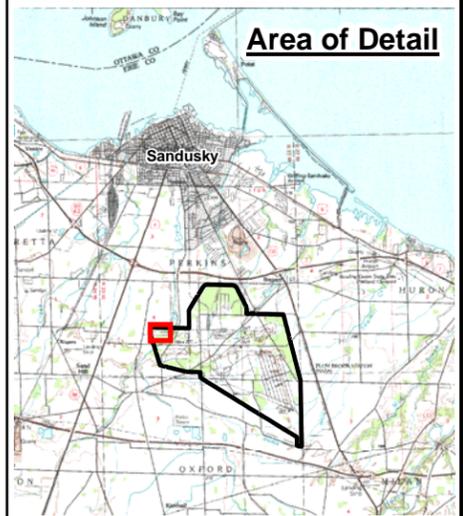
- Storage Tank Areas from Engineering Drawings
- ~ Creek, Ditch, Conveyance
- Buildings
- Railway



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



Distribution of COCs Exceeding Background and EPC in Sediment — Acid Area 2
 Plum Brook Ordnance Works
 Sandusky, Ohio



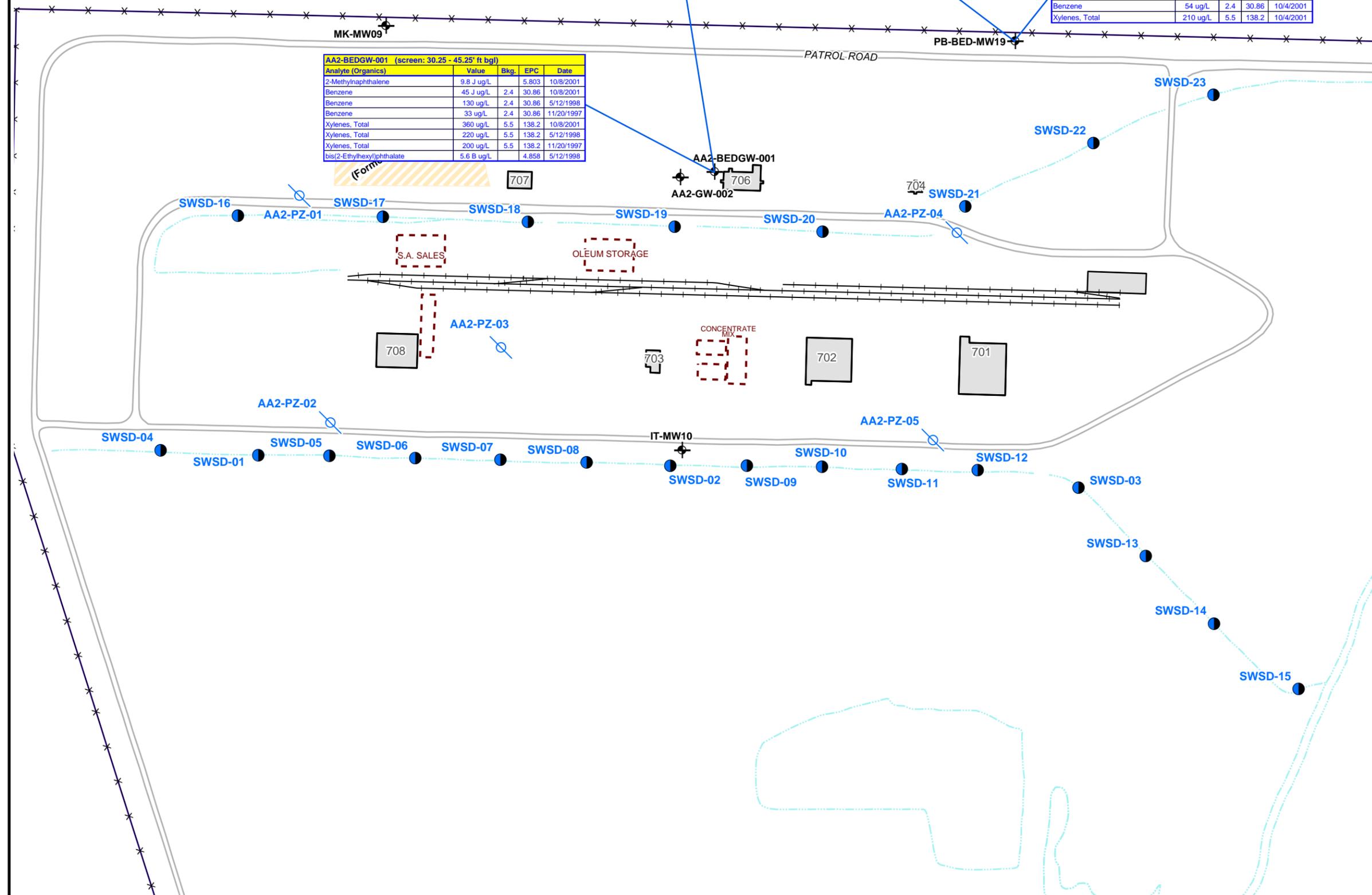
Area of Detail

AA2-BEDGW-001 (screen: 30.25 - 45.25' ft bgl)				
Analyte (Metals)	Value	Bkg.	EPC	Date
Aluminum (total)	10200 ug/L	309	8100	5/12/1998
Arsenic (total)	7.95 J ug/L	7.4	7.206	1/27/2005
Arsenic (total)	9.1 J ug/L	7.4	7.206	10/8/2001
Arsenic (total)	34.2 ug/L	7.4	7.206	5/12/1998
Chromium (total)	307 ug/L		6.204	5/12/1998
Iron (total)	51600 ug/L	1550	19059	5/12/1998
Manganese (total)	1030 ug/L	636	446.1	10/8/2001
Manganese (total)	5130 ug/L	636	446.1	5/12/1998
Vanadium (total)	108 ug/L		19.03	5/12/1998

PB-BED-MW19 (screen: 26.2 - 51.2' ft bgl)				
Analyte (Metals)	Value	Bkg.	EPC	Date
Chromium (total)	10 ug/L		6.204	11/14/1997
Chromium (total)	13.8 ug/L		6.204	10/17/1996
Cyanide	0.109 J mg/L		0.08679	1/24/2005
Field Duplicate Results				
Chromium (total)	10.7 ug/L		6.204	10/17/1996

PB-BED-MW19 (screen: 26.2 - 51.2' ft bgl)				
Analyte (Organics)	Value	Bkg.	EPC	Date
2-Methylnaphthalene	10 ug/L		5.803	4/4/2002
2-Methylnaphthalene	12 ug/L		5.803	10/4/2001
Benzene	42 J ug/L	2.4	30.86	4/4/2002
Benzene	46 ug/L	2.4	30.86	10/4/2001
Bromomethane	7.9 J ug/L		5.832	10/4/2001
Xylenes, Total	170 ug/L	5.5	138.2	4/4/2002
Xylenes, Total	180 ug/L	5.5	138.2	10/4/2001
bis(2-Ethylhexyl)phthalate	9.7 J ug/L		4.858	4/4/2002
bis(2-Ethylhexyl)phthalate	24 B ug/L		4.858	5/16/1998
bis(2-Ethylhexyl)phthalate	5.8 J ug/L		4.858	11/14/1997
Field Duplicate Results				
2-Methylnaphthalene	12 ug/L		5.803	10/4/2001
Benzene	54 ug/L	2.4	30.86	10/4/2001
Xylenes, Total	210 ug/L	5.5	138.2	10/4/2001

AA2-BEDGW-001 (screen: 30.25 - 45.25' ft bgl)				
Analyte (Organics)	Value	Bkg.	EPC	Date
2-Methylnaphthalene	9.8 J ug/L		5.803	10/8/2001
Benzene	45 J ug/L	2.4	30.86	10/8/2001
Benzene	130 ug/L	2.4	30.86	5/12/1998
Benzene	33 ug/L	2.4	30.86	11/20/1997
Xylenes, Total	360 ug/L	5.5	138.2	10/8/2001
Xylenes, Total	220 ug/L	5.5	138.2	5/12/1998
Xylenes, Total	200 ug/L	5.5	138.2	11/20/1997
bis(2-Ethylhexyl)phthalate	5.6 B ug/L		4.858	5/12/1998



Legend

- Surface Water or Sediment Sampling Locations
- ⊕ Monitoring Wells
- ⊗ Piezometers

Note:
 bgs = below ground surface
 Bkg. = Background Sample
 PRG = Preliminary Remediation Goal

- Storage Tank Areas from Engineering Drawings
- Creek, Ditch, Conveyance
- Buildings
- Railway



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



Distribution of COCs Exceeding Background and EPC in Bedrock Groundwater — Acid Area 2
 Plum Brook Ordnance Works
 Sandusky, Ohio

Table 2-1 Summary Statistics and Identification of COPCs for Constituents Detected in Environmental Media at Acid Area 2 Plum Brook Ordnance Works, Sandusky, Ohio.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Toxicity Screening Level ¹	COPC
	Surface Soil											
HE	2,4-Dinitrotoluene	mg/Kg	7	0.0546 - 0.410	0.044	5.8	0.189	Poisson	5.8		12.22	
HE	2,6-Dinitrotoluene	mg/Kg	2	0.0595 - 0.410	0.833	0.833	0.093	Poisson	0.833		6.11	
HE	3-Nitrotoluene	mg/Kg	7	0.1340 - 0.25	0.157	0.157	0.083	Poisson	0.157		73.35	
HE	Nitrobenzene	mg/Kg	2	0.0499 - 0.410	0.158	0.158	0.079	Poisson	0.158		1.96	
MET	Aluminum	mg/Kg	100		4290	18400	8658	ProUCL: Approximate Gamma	9518	15500	7614.20	Yes
MET	Antimony	mg/Kg	36	0.5559 - 7.50	0.717	2.07	1.18	Non Parametric - Indeterminate	1.45	9.3	3.13	
MET	Arsenic	mg/Kg	100		3.38	19.3	6.73	ProUCL: Approximate Gamma	7.62	36.5	0.39	Yes
MET	Barium	mg/Kg	100		18.7	188	64	Lognormal	66.8	826	537.49	
MET	Beryllium	mg/Kg	57	0.580 - 0.620	0.0842	0.86	0.379	Normal - ROS	0.432	1	15.44	
MET	Cadmium	mg/Kg	54	0.570 - 0.620	0.134	1.3	0.459	Non Parametric - Indeterminate	0.889		3.70	
MET	Calcium	mg/Kg	100		10400	12300	12300	Non Parametric	18800	52900	NA	
MET	Chromium	mg/Kg	100		8.39	25.1	14.7	Normal	16.1	29	30.10	
MET	Cobalt	mg/Kg	96	6.10 - 6.10	3.02	11.9	7.74	Normal	8.45	116	902.89	
MET	Copper	mg/Kg	100		3.66	70.4	18.5	Lognormal	18.9	56.2	312.86	
MET	Iron	mg/Kg	100		10700	36100	18664	ProUCL: Approximate Gamma	20300	234000	2346.32	Yes
MET	Lead	mg/Kg	100		3.82	7410	316	ProUCL: 99% Chebyshev (Mean, Sd)	2936	48.6	40.00	Yes
MET	Magnesium	mg/Kg	100		901	9770	3170	Lognormal	3260	10400	NA	
MET	Manganese	mg/Kg	100		90.7	1010	316	ProUCL: Approximate Gamma	375	3506	176.24	Yes
MET	Mercury	mg/Kg	61	0.038 - 0.041	0.0152	0.429	0.0679	Non Parametric - Indeterminate	0.276	0.1	2.35	
MET	Nickel	mg/Kg	100		7.35	25.9	16.9	Normal	18.5	55.1	156.43	
MET	Potassium	mg/Kg	89	586 - 618.	274	1850	862	Normal - ROS	979	3390	NA	
MET	Selenium	mg/Kg	32	0.610 - 6.00	0.59	1.87	0.719	Non Parametric - Indeterminate	0.96	2	39.11	
MET	Silver	mg/Kg	18	0.0801 - 1.20	0.0833	0.389	0.175	Non Parametric - Kaplan-Meier	0.389	11.1	39.11	
MET	Sodium	mg/Kg	46	573 - 622.	32	101	52.3	Non Parametric - Kaplan-Meier	52.5		NA	
MET	Thallium	mg/Kg	43	1.1 - 12.	2.07	5.24	2.25	Non Parametric - Indeterminate	5.24	1.3	0.52	Yes
MET	Vanadium	mg/Kg	100		17.3	35.3	22.9	ProUCL: Approximate Gamma	24.2	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		19.7	372	98.9	Non Parametric	121	322	2346.32	
PCB	PCB-1254	ug/Kg	39	18.1 - 7300.	16.7	16000	1995	Non Parametric - Indeterminate	16000		221.86	Yes
PCB	PCB-1260	ug/Kg	75	5.07 - 41.	45	31400	4274	Non Parametric	4290		221.86	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
SVO	2-Methylnaphthalene	ug/Kg	21	26.0 - 410.	60	646	114	Non Parametric - Indeterminate	646		5591.61	
SVO	3,3-Dichlorobenzidine	ug/Kg	5	666. - 2000.	140	140	140	Poisson	140		1080.85	
SVO	Acenaphthene	ug/Kg	14	11.5 - 410.	112	805	177	Non Parametric - Indeterminate	805		368170.57	
SVO	Acenaphthylene	ug/Kg	32	39.2 - 410.	60.3	265	114	Non Parametric - Indeterminate	265		NA	
SVO	Anthracene	ug/Kg	36	28.5 - 410.	45	2070	274	Non Parametric - Indeterminate	2070		2189612.06	
SVO	Benzaldehyde	ug/Kg	100		95.9	95.9	95.9	One Sample	95.9		611080.97	
SVO	Benzo(a)anthracene	ug/Kg	50	20.6 - 410	45	8500	700	Non Parametric	8500		621.46	Yes
SVO	Benzo(a)pyrene	ug/Kg	50	27.9 - 410	45	7300	621	Non Parametric - Indeterminate	7300		62.15	Yes
SVO	Benzo(b)fluoranthene	ug/Kg	46	26.6 - 410	71	9700	688	Non Parametric - Indeterminate	9700		621.46	Yes
SVO	Benzo(g,h,i)perylene	ug/Kg	46	25.3 - 410.	41	1900	303	Non Parametric - Indeterminate	1900		NA	
SVO	Benzo(k)fluoranthene	ug/Kg	50	30.2 - 410	53	6300	536	Non Parametric	6300		6214.57	Yes
SVO	Biphenyl (Diphenyl)	ug/Kg	100		72.1	72.1	72.1	One Sample	72.1		301444.94	
SVO	bis(2-Ethylhexyl)phthalate	ug/Kg	18	329. - 410.	39	55	46.2	Non Parametric - Indeterminate	55		34741.47	
SVO	Carbazole	ug/Kg	18	43.3 - 410.	89.3	1500	265	Non Parametric - Indeterminate	1500		24319.03	
SVO	Chrysene	ug/Kg	50	16.3 - 410.	52	8300	735	Non Parametric - Indeterminate	8300		62145.67	
SVO	Dibenz(a,h)anthracene	ug/Kg	32	21.2 - 410	53	1280	222	Non Parametric - Indeterminate	1280		62.15	Yes
SVO	Dibenzofuran	ug/Kg	7	242. - 410.	190	518	183	Poisson	518		14526.31	
SVO	Di-n-butylphthalate	ug/Kg	14	380. - 467.	615	9230	948	Non Parametric - Indeterminate	9230		611080.97	
SVO	Fluoranthene	ug/Kg	54	17.7 - 410.	66.7	17000	1450	Non Parametric - Indeterminate	17000		229361.02	
SVO	Fluorene	ug/Kg	14	9.65 - 410.	149	1000	240	Non Parametric - Indeterminate	1000		274710.66	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	46	26.6 - 410	38	4540	479	Non Parametric	482		621.46	Yes
SVO	Naphthalene	ug/Kg	14	9.45 - 410.	66.2	326	152	Non Parametric - Indeterminate	326		5591.61	
SVO	Phenanthrene	ug/Kg	39	19.9 - 410.	47	7100	735	Non Parametric - Indeterminate	7100		NA	
SVO	Pyrene	ug/Kg	50	15.3 - 410.	58	15000	1010	Non Parametric - Kaplan-Meier	1013		231595.11	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	32	1.17 - 240	4.39	20.9	8.49	Non Parametric - Indeterminate	8.78		2231119.78	
VOC	4-Methyl-2-pentanone (Methyl isobutyl ketone)	ug/Kg	4	0.963 - 240	4.83	4.83	123	Poisson	4.83		528088.58	
VOC	Acetone	ug/Kg	36	1.63 - 25.0	13	8600	510	Non Parametric - Indeterminate	8600		1412657.06	
VOC	Benzene	ug/Kg	18	0.884 - 60.0	2.02	6.52	2.58	Non Parametric - Kaplan-Meier	2.99		643.15	
VOC	Carbon Disulfide	ug/Kg	25	1.46 - 60.0	5.13	29.1	7.39	Non Parametric - Indeterminate	29.1		35534.04	
VOC	Cyclohexane	ug/Kg	62	1.68 - 2.04	2.06	11.6	4.2	Normal	5.99		140000.00	
VOC	Ethylbenzene	ug/Kg	18	0.673 - 60.0	1.05	2.9	1.72	Non Parametric - Kaplan-Meier	2.09		395000.00	
VOC	Methyldichlorane	ug/Kg	62	0.785 - 0.95	2.15	12	5.35	Lognormal - ROS	6.07		259105.52	
VOC	Methylene Chloride	ug/Kg	14	0.960 - 29.0	2.2	29	2.65	Non Parametric - Kaplan-Meier	4.14		9106.99	
VOC	Toluene	ug/Kg	21	0.793 - 60.0	1.8	13.6	3.72	Non Parametric - Kaplan-Meier	5.69		520000.00	
VOC	Xylenes, Total	ug/Kg	25	1.13 - 60.0	1.94	7.8	3.29	Non Parametric - Kaplan-Meier	4.79		27063.05	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	btg	Region 9 Residential PRG	COPC
Subsurface Soil												
MET	Aluminum	mg/Kg	100		3720	14200	10347	ProJCL: Normal	10939	15500	7614.20	Yes
MET	Antimony	mg/Kg	29	0.595 - 7.70	0.753	1.67	1.23	Non Parametric - Indeterminate	1.5	9.3	3.13	
MET	Arsenic	mg/Kg	97	0.641	0.808	16.5	8.11	ProJCL: Approximate Gamma	9.14	36.5	0.39	Yes
MET	Barium	mg/Kg	100		22.7	111	66.2	Non Parametric	68.6	826	537.49	
MET	Beryllium	mg/Kg	74	0.600 - 0.640	0.179	0.8	0.476	Normal - ROS	0.488	1	15.44	
MET	Cadmium	mg/Kg	60	0.610 - 0.640	0.23	0.782	0.397	Non Parametric - Indeterminate	0.583		3.70	
MET	Calcium	mg/Kg	100	0.0000 - 0.0000	3330	63000		NOT normal	63000		NA	
MET	Chromium	mg/Kg	100		6.82	31	17.2	ProJCL: Normal	17.8	29	30.10	Yes
MET	Cobalt	mg/Kg	100		4.58	17.3	10.4	Normal	11.2	116	902.89	
MET	Copper	mg/Kg	100		13.9	31.3	21.5	Normal	22.7	56.2	312.86	
MET	Iron	mg/Kg	100		14100	41800	23826	ProJCL: Approximate Gamma	24500	234000	2346.32	Yes
MET	Lead	mg/Kg	100		7.9	113	15.6	ProJCL: 95% Chebyshev (Mean, Std)	31.4	48.6	40.00	Yes
MET	Magnesium	mg/Kg	100	0.0000 - 0.0000	2290	22000		NOT normal	22000		NA	
MET	Manganese	mg/Kg	100		138	1270	431	ProJCL: Approximate Gamma	505	3506	176.24	Yes
MET	Mercury	mg/Kg	43	0.0046 - 0.0420	0.0087	0.274	0.0275	Non Parametric - Kaplan-Meier	0.254	0.1	2.35	
MET	Nickel	mg/Kg	100		12.4	39.2	25.2	Normal	26.7	55.1	156.43	
MET	Potassium	mg/Kg	100		664	2890	1650	Normal	1820	3390	NA	
MET	Selenium	mg/Kg	6	0.600 - 6.35	1.12	1.5	1.14	Poisson	1.5	2	39.11	
MET	Silver	mg/Kg	31	0.0756 - 1.30	0.101	0.359	0.229	Non Parametric - Kaplan-Meier	0.359	11.1	39.11	
MET	Sodium	mg/Kg	57	596.0000 - 644.0000	37.8	172		?NOT normal	172		NA	
MET	Thallium	mg/Kg	40	0.911 - 1.30	1.27	18.2	2.33	Non Parametric - Indeterminate	18.2	1.3	0.52	Yes
MET	Vanadium	mg/Kg	100		12.9	34.7	26	ProJCL: Normal	27.2	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		35.9	304	77.9	Non Parametric	88.8	322	2346.32	
PCB	PCB-1254	ug/Kg	20	17.0 - 945	30	333	62.7	Non Parametric - Indeterminate	333		221.86	Yes
PCB	PCB-1260	ug/Kg	40	5.02 - 5.60	13.4	2560	184	Non Parametric - Indeterminate	2560		221.86	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
SVO	2-Methylnaphthalene	ug/Kg	6	25.7000 - 420.0000	65.7	89.9		Poisson	89.9		5591.61	
SVO	Acenaphthene	ug/Kg	3	11.3000 - 420.0000	323	323		Poisson	323		368170.57	
SVO	Acenaphthylene	ug/Kg	3	35.9000 - 420.0000	597	597		Poisson	597		NA	
SVO	Anthracene	ug/Kg	9	26.2000 - 420.0000	57	1980		Poisson	1980		2189612.06	
SVO	Benzo(a)anthracene	ug/Kg	9	18.9 - 420	110	3400	197	Poisson	3400		621.46	Yes
SVO	Benzo(b)fluoranthene	ug/Kg	9	25.6 - 420	110	3050	187	Poisson	3050		62.15	Yes
SVO	Benzo(k)fluoranthene	ug/Kg	9	24.4 - 420	95	2410	167	Poisson	2410		621.46	Yes
SVO	Benzo(g,h,i)perylene	ug/Kg	9	23.2 - 420	37	1990	210	Poisson	1990		NA	
SVO	Benzo(a)pyrene	ug/Kg	9	27.7000 - 420.0000	120	2360		Poisson	2360		6214.57	
SVO	Benzyl butyl phthalate	ug/Kg	3	127.0000 - 420.0000	385	385		Poisson	385		1222061.94	
SVO	bis(2-Ethylhexyl)phthalate	ug/Kg	17	325.0000 - 420.0000	41	428		NON PARAMETRIC	428		34741.47	
SVO	Carbazole	ug/Kg	6	42.7000 - 420.0000	87.3	540		Poisson	540		24319.03	
SVO	Chrysene	ug/Kg	9	15.0000 - 420.0000	120	3480		Poisson	3480		62145.67	
SVO	Dibenz(a,h)anthracene	ug/Kg	6	19.5 - 420	148	1280	134	Poisson	1280		62.15	Yes
SVO	Di-n-butylphthalate	ug/Kg	6	390. - 511.	47	916	71.8	Poisson	916		611030.97	
SVO	Fluoranthene	ug/Kg	9	16.2000 - 420.0000	210	9020		Poisson	9020		229361.02	
SVO	Fluorene	ug/Kg	6	9.5300 - 420.0000	69.6	469		Poisson	469		274710.66	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	9	24.4 - 420	45	4220	222	Poisson	4220		621.46	Yes
SVO	Naphthalene	ug/Kg	3	9.32 - 420	103	103	93.4	Poisson	103		5591.61	
SVO	Phenanthrene	ug/Kg	9	18.2 - 420	71	4300	205	Poisson	4300		NA	
SVO	Pyrene	ug/Kg	9	14.1000 - 420.0000	170	4510		Poisson	4510		231595.11	
VOC	Acetone	ug/Kg	26	1.50 - 25.0	18	5000	395	Non Parametric - Indeterminate	5000		1412657.06	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	3	1.0300 - 250.0000	4.08	4.08		Poisson	4.08		2231119.78	
VOC	Benzene	ug/Kg	37	0.7880 - 63.0000	1.6	6.89		NON PARAMETRIC	6.89		643.15	
VOC	Carbon Disulfide	ug/Kg	3	1.2900 - 63.0000	11.6	11.6		Poisson	11.6		35534.04	
VOC	Cyclohexane	ug/Kg	70	1.4900 - 1.8700	1.87	24.5		?NOT normal	24.5		140000.00	
VOC	Ethylbenzene	ug/Kg	29	0.6000 - 63.0000	0.878	3.27		NON PARAMETRIC	3.27		395000.00	
VOC	Methylcyclohexane	ug/Kg	70	0.6940 - 0.8710	2.78	20.6		?NOT normal	20.6		259105.52	
VOC	Methylene Chloride	ug/Kg	11	0.8870 - 12.0000	2.3	20		NON PARAMETRIC	20		9106.99	
VOC	Toluene	ug/Kg	46	0.7070 - 63.0000	1.4	15.7		NON PARAMETRIC	15.7		520000.00	
VOC	Xylenes, Total	ug/Kg	43	1.0100 - 63.0000	1.39	10.4		NON PARAMETRIC	10.4		27063.05	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
Bedrock Groundwater												
GC2	Cyanide	mg/L	15	0.0030 - 0.010	0.016	0.109	0.0115	NON PARAMETRIC	8.68E-02		73.00	
GC2	Nitrogen, Nitrate (as N)	mg/L	21	0.0002 - 0.234	0.0001	10					1000.00	
GC2	Sulfate (as SO4)	mg/L	100	0.0000 - 0.0000	1.4	70					NA	
HE	1,3,5-Trinitrobenzene	ug/L	13	0.0480 - 0.2000	0.16	0.8					109.50	
HE	1,3-Dinitrobenzene	ug/L	13	0.0400 - 0.2000	0.22	0.81	6.6E-05	Lognormal	9.74107E-05		0.36	Yes
HE	2,4,6-Trinitrotoluene	ug/L	6	0.0770 - 0.6400	1.6	1.6					2.24	
HE	2,4-Dinitrotoluene	ug/L	6	0.0700 - 10.0000	0.3	2.5					7.30	
HE	2,6-Dinitrotoluene	ug/L	6	0.0730 - 10.0000	0.2	1.2					3.65	
HE	2-Nitrotoluene	ug/L	6	0.0770 - 0.3100	1.2	1.2	8.4E-05	Normal	9.89478E-05		0.05	Yes
HE	3-Nitrotoluene	ug/L	25	0.1300 - 0.3680	0.14	8.1					12.17	
HE	Nitrobenzene	ug/L	10	0.0490 - 10.0000	0.32	0.5	0.00078	Lognormal	0.001912636		0.34	Yes
HE	RDX	ug/L	13	0.0670 - 0.5000	0.14	0.17					0.61	
HE	Tetryl	ug/L	7	0.0600 - 0.2050	0.088	0.088					36.50	
MET	Aluminum (total)	ug/L	57	45.4000 - 200.0000	56.2	10200	952.37	NON PARAMETRIC	8100.43		3649.87	Yes
MET	Aluminum_FILT	ug/L	50	45.4000 - 200.0000	42.6	378	4.12	NON PARAMETRIC	7.206		NA	
MET	Arsenic (total)	ug/L	27	2.5000 - 10.0000	6.6	34.2					0.04	Yes
MET	Arsenic_FILT	ug/L	23	2.5000 - 10.0000	3.7	9					NA	
MET	Barium (total)	ug/L	100	0.0000 - 0.0000	220	2130	1029.28	NORMAL	1334.11		255.50	Yes
MET	Barium_FILT	ug/L	100	0.0000 - 0.0000	212	1940					NA	
MET	Calcium (total)	ug/L	100	0.0000 - 0.0000	81800	1970000					NA	
MET	Calcium_FILT	ug/L	100	0.0000 - 0.0000	59300	2200000					NA	
MET	Chromium (total)	ug/L	40	0.2860 - 10.0000	1.2	307	3.291	Gamma	6.2		10.95	Yes
MET	Cobalt (total)	ug/L	29	0.8980 - 50.0000	1.21	63.3					73.00	
MET	Cobalt_FILT	ug/L	17	0.8980 - 50.0000	1.27	3.4					NA	
MET	Copper (total)	ug/L	47	1.9000 - 25.0000	3.6	99					146.00	
MET	Iron (total)	ug/L	71	22.9000 - 45.8000	80.1	51600	4848.78	Gamma	19058.81		1094.99	Yes
MET	Iron_FILT	ug/L	33	22.9000 - 100.0000	106	1300					NA	
MET	Lead (total)	ug/L	20	1.5000 - 3.0000	6.5	38.6	18.53	NON PARAMETRIC	4.24		0.00	Yes
MET	Magnesium (total)	ug/L	100	0.0000 - 0.0000	41900	132000					NA	
MET	Magnesium_FILT	ug/L	100	0.0000 - 0.0000	44000	107000					NA	
MET	Manganese (total)	ug/L	80	1.6000 - 40.0000	2.2	5130	148.3	Gamma	446.08		87.60	Yes
MET	Manganese_FILT	ug/L	85	15.0000 - 40.0000	2.2	995					NA	
MET	Nickel (total)	ug/L	40	0.7450 - 40.0000	3.5	238	9.09	Lognormal	16.42		73.00	Yes
MET	Nickel_FILT	ug/L	23	0.7450 - 40.0000	4.3	7.9					NA	
MET	Potassium (total)	ug/L	100	0.0000 - 0.0000	25400	49500					NA	
MET	Potassium_FILT	ug/L	100	0.0000 - 0.0000	24800	46200					NA	
MET	Sodium (total)	ug/L	100	0.0000 - 0.0000	74300	162000					NA	
MET	Sodium_FILT	ug/L	100	0.0000 - 0.0000	75400	147000					NA	
MET	Thallium (total)	ug/L	27	3.0000 - 14.1000	0.6	5.3	4	NON PARAMETRIC	6.23		0.24	Yes
MET	Thallium_FILT	ug/L	8	0.5000 - 14.1000	4.4	4.4					NA	
MET	Vanadium (total)	ug/L	7	1.8000 - 50.0000	108	108	4.58	NON PARAMETRIC	19.03		3.65	Yes
MET	Zinc (total)	ug/L	87	1.4600 - 5.0000	6.2	144					1094.99	
MET	Zinc_FILT	ug/L	62	1.4600 - 20.0000	3.1	66.2					NA	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
SVO	2,4-Dimethylphenol	ug/L	27	0.5900 - 10.0000	1.3	8.6					73.00	
SVO	2-Methylnaphthalene	ug/L	80	1.0000 - 10.0000	1.3	12	3.81	Gamma	5.8		0.62	Yes
SVO	2-Methylphenol (o-Cresol)	ug/L	7	0.8000 - 10.0000	1.6	1.6					182.50	
SVO	4-Methylphenol (p-Cresol)	ug/L	7	0.8500 - 10.0000	1.6	1.6					18.25	
SVO	bis(2-Ethylhexyl)phthalate	ug/L	33	0.8000 - 10.0000	2	24	2.97	Gamma	4.85		4.80	Yes
SVO	Naphthalene	ug/L	67	1.0000 - 10.0000	1.09	12	3.73	NORMAL	5		0.62	Yes
SVO	Phenanthrene	ug/L	13	0.6840 - 10.0000	0.74	0.82					NA	
SVO	Phenol	ug/L	27	0.8200 - 10.0000	1.2	74					1094.99	
VOC	1,1,2-Trichloroethane	ug/L	7	0.1390 - 25.0000	0.33	0.33	2.98	Gamma	6.23		0.20	Yes
VOC	2-Butanone (Methyl ethyl ketone)	ug/L	14	0.8150 - 120.0000	18	18					696.82	
VOC	Acetone	ug/L	55	1.7300 - 250.0000	41	220					547.50	
VOC	Benzene	ug/L	100	0.0000 - 0.0000	0.439	130	16.39	Gamma	30.86		0.35	Yes
VOC	Bromomethane	ug/L	7	0.1010 - 50.0000	7.9	7.9	2.86	Gamma	5.83		0.87	Yes
VOC	Carbon Disulfide	ug/L	67	0.3000 - 10.0000	0.203	26					104.29	
VOC	Chlorobenzene	ug/L	13	0.1150 - 24.0000	2.2	21	2.34	Gamma	5		10.61	Yes
VOC	Chloromethane	ug/L	13	0.1420 - 50.0000	10	30	3.77	Gamma	9.73		15.82	Yes
VOC	Cyclohexane	ug/L	100	0.0000 - 0.0000	7.8	55					1034.17	
VOC	Ethylbenzene	ug/L	100	0.0000 - 0.0000	1.2	64					133.99	
VOC	Isopropylbenzene (Cumene)	ug/L	100	0.0000 - 0.0000	0.54	1.3					65.82	
VOC	Methylcyclohexane	ug/L	100	0.0000 - 0.0000	4	30.3					521.72	
VOC	Methylene Chloride	ug/L	53	0.1280 - 5.0000	2.3	100	4.03	Gamma	8.92		4.28	Yes
VOC	Toluene	ug/L	93	25.0000 - 25.0000	0.192	32					72.34	
VOC	Xylenes, Total	ug/L	100	0.0000 - 0.0000	10	360	79.5	Gamma	138		20.57	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
Shallow Groundwater												
GC2	Nitrogen, Nitrate (as N)	mg/L	80	0.0149 - 0.025	0.067	3.98	0.586				1000.00	
GC2	Sulfate (as SO4)	mg/L	100	0.0000 - 0.0000	18.8	308					NA	
MET	Aluminum (total)	ug/L	64	45.4000 - 200.0000	122	11500		?NOT normal	11500		3649.87	Yes
MET	Arsenic (total)	ug/L	9	3.0000 - 10.0000	36.8	36.8		Poisson	36.8		0.04	Yes
MET	Barium (total)	ug/L	73	200.0000 - 200.0000	22.6	372		?NOT normal	372		255.50	Yes
MET	Barium_FILT	ug/L	43	200.0000 - 200.0000	25.2	48.4					NA	
MET	Beryllium (total)	ug/L	9	0.1090 - 5.0000	0.156	0.156					7.30	
MET	Calcium (total)	ug/L	100	0.0000 - 0.0000	53900	185000					NA	
MET	Calcium_FILT	ug/L	100	0.0000 - 0.0000	74700	188000		NON PARAMETRIC			NA	
MET	Chromium (total)	ug/L	18	0.2360 - 10.0000	0.77	39.8			39.8		10.95	Yes
MET	Cobalt (total)	ug/L	27	3.0000 - 50.0000	1.17	1.82					73.00	
MET	Cobalt_FILT	ug/L	14	0.8980 - 50.0000	1.29	1.29					NA	
MET	Copper (total)	ug/L	18	2.5500 - 25.0000	3.1	30.8					146.00	
MET	Copper_FILT	ug/L	29	2.5500 - 25.0000	4.09	50.7					NA	
MET	Iron (total)	ug/L	73	22.9000 - 100.0000	36.6	41000		?NOT normal	41000		1094.99	Yes
MET	Iron_FILT	ug/L	29	22.9000 - 100.0000	29.8	329		NON PARAMETRIC			NA	Yes
MET	Lead (total)	ug/L	36	1.5000 - 3.0000	2	33.6			33.6		0.00	Yes
MET	Magnesium (total)	ug/L	100	0.0000 - 0.0000	13700	83700					NA	
MET	Magnesium_FILT	ug/L	100	0.0000 - 0.0000	20400	86300					NA	
MET	Manganese (total)	ug/L	45	0.4190 - 149.0000	6.6	1670		NON PARAMETRIC			87.60	Yes
MET	Manganese_FILT	ug/L	57	0.4190 - 15.0000	0.7	1630			1670		NA	
MET	Mercury (total)	ug/L	9	0.0584 - 0.2000	0.091	0.091					1.09	
MET	Nickel (total)	ug/L	18	0.7450 - 40.0000	4.15	4.5					73.00	
MET	Potassium (total)	ug/L	64	500.0000 - 5000.0000	277	5550					NA	
MET	Potassium_FILT	ug/L	29	175.0000 - 5000.0000	719	2110					NA	
MET	Sodium (total)	ug/L	91	5000.0000 - 5000.0000	2750	48200					NA	
MET	Sodium_FILT	ug/L	100	0.0000 - 0.0000	3140	50200					NA	
MET	Vanadium (total)	ug/L	9	2.1400 - 50.0000	54.4	54.4		Poisson	54.4		3.65	Yes
MET	Zinc (total)	ug/L	55	1.4600 - 20.0000	10.6	92.6					1094.99	
MET	Zinc_FILT	ug/L	14	1.4600 - 20.0000	20.4	20.4					NA	
SVO	bis(2-Ethylhexyl)phthalate	ug/L	18	1.00 - 12.0	1.2	5.1	2.18	Non Parametric - Indeterminate	5.1		4.80	Yes
VOC	Benzene	ug/L	9	0.104 - 5.00	0.117	0.117					0.35	
VOC	Carbon Disulfide	ug/L	9	0.118 - 5.00	0.17	0.17					104.29	
VOC	Cyclohexane	ug/L	17	0.0999 - 0.3000	14.8	14.8					1034.17	
VOC	Ethylbenzene	ug/L	9	0.1640 - 5.0000	0.68	0.68					133.99	
VOC	Isopropylbenzene (Cumene)	ug/L	17	0.1010 - 0.2000	0.325	0.325					65.82	
VOC	Methylcyclohexane	ug/L	17	0.1070 - 0.2000	10.2	10.2					521.72	
VOC	Methylene Chloride	ug/L	27	0.128 - 5.00	0.3	0.55	0.397				4.28	
VOC	Toluene	ug/L	9	0.1190 - 5.0000	0.13	0.13					72.34	
VOC	Xylenes, Total	ug/L	18	0.2000 - 5.0000	0.13	11.9					20.57	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
Surface Water											
MET	Aluminum	ug/L	57	100	109	7670	Non Parametric - Kaplan-Meier	634		3649.87	Yes
MET	Arsenic	ug/L	4	3	3.2	3.2	Poisson	3.2		0.04	
MET	Barium	ug/L	100		32.4	60.3	Non Parametric	36.6		255.50	
MET	Calcium	ug/L	100		47800	263000	Non Parametric	125000		NA	
MET	Chromium	ug/L	4	2.00 - 2.00	8.2	8.2	Poisson	8.2		10.95	
MET	Copper	ug/L	9	4.00 - 4.00	7.3	7.4	Poisson	7.4		146.00	
MET	Iron	ug/L	96	30	56.2	8250	Non Parametric - Kaplan-Meier	989		1094.99	Yes
MET	Lead	ug/L	13	1.5	2.9	26.3	Non Parametric	3.9		0.00	Yes
MET	Magnesium	ug/L	100		12400	28900	Non Parametric	22600		NA	
MET	Manganese	ug/L	100		3.3	227	ProCL: Approximate Gamma	59.5		87.60	Yes
MET	Nickel	ug/L	4	3.00 - 3.00	9	9	Poisson	9		73.00	
MET	Potassium	ug/L	100		1100	4880	Non Parametric	2280		NA	
MET	Sodium	ug/L	100		2440	5810	Normal	4200		NA	
MET	Vanadium	ug/L	4	3	15.4	15.4	Poisson	15.4		3.65	
MET	Zinc	ug/L	22	5.00 - 5.00	5.3	36.7	Non Parametric - Kaplan-Meier	9.13		1094.99	
SVO	bis(2-Ethylhexyl)phthalate	ug/L	70	1.0 - 1.4	1.7	5	Non Parametric	2.55		4.80	Yes
SVO	Naphthalene	ug/L	52	0.520 - 1.10	0.026	0.044	Non Parametric - Indeterminate	0.044		0.62	
VOC	Trichloroethene	ug/L	4	0.20 - 0.28	0.3	0.3	Poisson	0.3		0.03	

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
GC2	Cyanide	mg/Kg	60	0.17 - 0.21	0.2	0.74	0.352	Lognormal - ROS	0.378		122.21	
HE	1,3,5-Trinitrobenzene	mg/Kg	13	0.0306 - 0.100	0.14	0.14		NON PARAMETRIC	0.14		183.31	
HE	1,3-Dinitrobenzene	mg/Kg	4	0.0297 - 0.100	0.0552	0.0552	0.055	Poisson	0.0552		0.61	
HE	2,4,6-Trinitrotoluene	mg/Kg	13	0.0411 - 0.100	0.094	0.77	0.146	Non Parametric - Indeterminate	0.77		16.21	
HE	2,4-Dinitrotoluene	mg/Kg	17	0.0681 - 0.210	0.148	0.72	0.255	Non Parametric - Indeterminate	0.72		12.22	
HE	2-Nitrotoluene	mg/Kg	4	0.103 - 0.197	0.13	0.13	0.13	Poisson	0.13		0.88	
HE	4-Nitrotoluene	mg/Kg	4	0.074 - 0.102	0.096	0.096		Poisson	0.096		11.93	
HE	HMX	mg/Kg	13	0.0276 - 0.100	0.16	0.53	0.211	Non Parametric - Indeterminate	0.53		305.52	
HE	RDX	mg/Kg	4	0.0354 - 0.100	0.1	0.1	0.1	Poisson	0.1		4.42	
HE	Tetryl	mg/Kg	4	0.074 - 0.100	0.134	0.134		Poisson	0.134		61.10	
MET	Aluminum	mg/Kg	100		2490	18000	9523	ProUCL: Normal	10755		7614.20	Yes
MET	Antimony	mg/Kg	9	0.79 - 4.30	0.847	1.07	0.959	Poisson	1.07	9.3	3.13	
MET	Arsenic	mg/Kg	100		2.64	13	6.42	ProUCL: Normal	7.55	36.5	0.39	Yes
MET	Barium	mg/Kg	100		39.7	111	70.1	Normal	76.4	826	537.49	
MET	Beryllium	mg/Kg	96	0.2800 - 0.2800	0.28	1.1		NORMAL	1.1		15.44	
MET	Cadmium	mg/Kg	57	0.2600 - 0.3700	0.33	0.98		?NOT normal	0.98		3.70	
MET	Calcium	mg/Kg	100		1780	31200	8540	Lognormal	8850	52300	NA	
MET	Chromium	mg/Kg	100		3.5	30.4	15.5	ProUCL: Normal	17.5	29	30.10	Yes
MET	Cobalt	mg/Kg	96	1.40 - 1.40	4.1	13.1	7.24	Normal	8.12	116	902.89	
MET	Copper	mg/Kg	100		5.9	53.5	21.7	Lognormal	23.2	56.2	312.86	
MET	Iron	mg/Kg	100		5810	31800	19144	ProUCL: Normal	21585	234000	2346.32	Yes
MET	Lead	mg/Kg	100		19.6	1460	140	ProUCL: 99% Chebyshev (Mean, Sd)	776	48.6	40.00	Yes
MET	Magnesium	mg/Kg	100		486	8550	3170	Non Parametric	3600	10400	NA	
MET	Manganese	mg/Kg	100		58.6	406	172	ProUCL: Normal	203	3506	176.24	Yes
MET	Mercury	mg/Kg	100		0.049	1.1	0.17	Non Parametric - Kaplan-Meier	0.23	0.1	2.35	
MET	Nickel	mg/Kg	100		2.8	44.2	20.6	Normal	23.4	55.1	156.43	
MET	Potassium	mg/Kg	100		573	1790	1130	Normal	1790	3390	NA	
MET	Selenium	mg/Kg	43	0.7800 - 1.3900	1	3.72		NON PARAMETRIC	3.72		39.11	
MET	Silver	mg/Kg	13	0.116 - 0.430	0.177	0.32	0.232	Non Parametric - Kaplan-Meier	0.32	11.1	39.11	
MET	Sodium	mg/Kg	13	260.0000 - 427.0000	50.4	59		NON PARAMETRIC	59		NA	
MET	Thallium	mg/Kg	13	0.32 - 0.53	4.02	4.73	0.75	Non Parametric - Indeterminate	4.73		0.52	Yes
MET	Vanadium	mg/Kg	100		5.7	32.2	21.7	ProUCL: Normal	24.1	40.9	7.82	Yes
MET	Zinc	mg/Kg	100		8.6	244	84.3	Non Parametric - Kaplan-Meier	90.2	322	2346.32	
PCB	PCB-1254	ug/Kg	4	5.40 - 46.4	1520	1520	71.5	Poisson	1520		221.86	
PCB	PCB-1260	ug/Kg	96	26.9	39	18000	1520	ProUCL: 95% Chebyshev (MVUE)	5780		221.86	Yes

Table 2-1 Continued.

type	Analyte	units	Percent Detects	Range of Detection Limits	Minimum Detected Concentration	Maximum Detected Concentration	mean	Recommend Distribution	EPC	bkg	Region 9 Residential PRG	COPC
SVO	2-Methylnaphthalene	ug/Kg	9	31.4 - 82.0	29	54	41.5	Poisson	54		5591.61	
SVO	2-Methylphenol (o-Cresol)	ug/Kg	4	130 - 282	362	362	96.3	Poisson	362		305515.49	
SVO	3-Methylphenol	ug/Kg	5	130,0000 - 210,0000	150	150		Poisson	150		305515.49	
SVO	4-Methylphenol (p-Cresol)	ug/Kg	9	100 - 210	150	212	181	Poisson	212		30551.55	
SVO	Acenaphthene	ug/Kg	4	13.8 - 82.0	39	39	29.2	Poisson	39		368170.57	
SVO	Acenaphthylene	ug/Kg	48	53.0 - 82.0	48	251	98.8	Non Parametric - Indeterminate	251		NA	
SVO	Acetophenone	ug/Kg	100		95.8	156	131	Normal	156		NA	
SVO	Anthracene	ug/Kg	43	36.40 - 82.0	42	430	123	Non Parametric - Indeterminate	430		2189612.06	
SVO	Benzaldehyde	ug/Kg	100		212	329	275	Normal	329		611030.97	
SVO	Benzo(a)anthracene	ug/Kg	83	59 - 82	56	2300	302	Non Parametric - Kaplan-Meier	327		621.46	Yes
SVO	Benzo(a)pyrene	ug/Kg	61	58 - 82	96	2900	354	Non Parametric - Indeterminate	2900		62.15	Yes
SVO	Benzo(b)fluoranthene	ug/Kg	74	59 - 82	67	2900	378	Non Parametric - Indeterminate	2900		621.46	Yes
SVO	Benzo(g,h,i)perylene	ug/Kg	43	31.2 - 82.0	38	1100	193	Non Parametric - Indeterminate	1100		NA	
SVO	Benzo(k)fluoranthene	ug/Kg	74	59.0 - 82.0	57	2200	351	Non Parametric - Indeterminate	2200		6214.57	
SVO	Benzoic acid	ug/Kg	100		180	1850	676	Lognormal	784		100000000.00	
SVO	Chrysene	ug/Kg	83	59.0 - 82.0	55	2600	366	Non Parametric - Indeterminate	2600		62145.67	
SVO	Dibenz(a,h)anthracene	ug/Kg	9	23.8 - 82	100	320	45.3	Poisson	320		62.15	Yes
SVO	Di-n-butylphthalate	ug/Kg	4	130,0000 - 535,0000	584	584		Poisson	584		611030.97	
SVO	Fluoranthene	ug/Kg	91	59.0 - 66.0	43	3900	520	Non Parametric - Indeterminate	3900		229361.02	
SVO	Fluorene	ug/Kg	4	11.6 - 82.0	120	120	120	Poisson	120		274710.66	
SVO	Indeno(1,2,3-cd)pyrene	ug/Kg	48	35.9 - 82	44	1400	163	Non Parametric	242		621.46	Yes
SVO	N-Nitroso-di-n-propylamine	ug/Kg	9	104 - 210	166	272	90.2	Poisson	272		69.48	Yes
SVO	Phenanthrene	ug/Kg	61	25.3 - 82.0	45	1800	225	Non Parametric - Indeterminate	1800		NA	
SVO	Phenol	ug/Kg	4	130 - 210	535	535	535	Poisson	535		1833092.91	
SVO	Pyrene	ug/Kg	91	59.0 - 66.0	41	4200	490	Non Parametric - Indeterminate	4200		231595.11	
VOC	2-Butanone (Methyl ethyl ketone)	ug/Kg	78	1.6000 - 2.2000	2.7	22.5		2NORMAL	22.5		2231119.78	
VOC	4-Methyl-2-pentanone (Methyl isobutyl ketone)	ug/Kg	13	0.6500 - 1.3000	1.71	13.5		NON PARAMETRIC	13.5		528088.58	
VOC	Acetone	ug/Kg	96	2.04 - 2.04	7.7	336	83.5	Non Parametric - Indeterminate	336		1412857.06	
VOC	Benzene	ug/Kg	22	0.5300 - 1.8100	1.6	2.8		NON PARAMETRIC	2.8		643.15	
VOC	Carbon Disulfide	ug/Kg	9	1.40 - 2.95	2.1	2.8	1.12	Poisson	2.8		35534.04	
VOC	Cyclohexane	ug/Kg	35	0.6100 - 3.4100	0.86	8.8		NON PARAMETRIC	8.8		140000.00	
VOC	Ethylbenzene	ug/Kg	9	0.8400 - 1.7000	1.4	2.11		Poisson	2.11		395000.00	
VOC	Methyl Acetate	ug/Kg	4	1.8000 - 7.2100	290	290		Poisson	290		2208674.40	
VOC	Methylcyclohexane	ug/Kg	22	0.3400 - 1.5900	5.2	9.8		NON PARAMETRIC	9.8		259105.52	
VOC	Toluene	ug/Kg	26	0.9800 - 1.9000	2.3	8.5		NON PARAMETRIC	8.5		520000.00	
VOC	Xylenes, Total	ug/Kg	4	0.7800 - 2.3100	5.09	5.09		Poisson	5.09		27063.05	

1 Toxicity screening levels are obtained from the EPA Region 9 PRG tables for residential exposures and tap water and are concentrations equal to either an incremental lifetime cancer risk (ILCR) of 1E-6 or a noncancer hazard quotient (HQ) of 0.1.
 mg/Kg microgram/kilogram
 ug/Kg microgram/kilogram
 mg/L milligram/Liter
 ug/L microgram/Liter
 BKG Background Concentration
 UCL Upper Confidence Limit - Calculated based on the recommended distribution.
 EPC Exposure Point Concentration - Lesser of the UCL or the maximum detected concentration.
 PRG Preliminary Remediation Goal - PRGs based on noncancer effects were multiplied by 0.1.
 COPC Contaminant of Potential Concern
 nc noncancer
 ca cancer

**Table 3-1
Receptor/Exposure Scenarios
Acid Area 2
Plum Brook Ordnance Works, Sandusky, Ohio**

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

Table 3-1 (continued)

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

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

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

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

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

Table 3-2 (Continued)

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

Table 3-2 (Continued)

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

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

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

c Assumed; see text.

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

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

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

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

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

Table 3-3
Variables Used to Estimate Potential Chemical Intake
and Contact Rates from Groundwater
Acid Area 2, 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 (F _{I_{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 (F _{I_{gw}}), unitless	1 ^e	1 ^e
Body surface area exposed to water (S _{a_{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.

cm² - Square centimeter.

csv - Chemical-specific value.

kg - Kilogram.

L - Liters.

m³ - 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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Table 4-1. Toxicity Values Used in the BHHRA.

Analyte	Reference Doses			Cancer Slope Factors		
	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation
1,1,2-Trichloroethane	4.00E-03	4.00E-03	4.00E-03	5.70E-02	5.70E-02	5.60E-02
1,3-Dinitrobenzene	1.00E-04	1.00E-04	1.00E-04	--	--	--
2-Methylnaphthalene	2.00E-02	2.00E-02	8.57E-04	--	--	--
2-Nitrotoluene	1.00E-02	1.00E-02	--	2.30E-01	2.30E-01	--
Aluminum	1.00E+00	1.00E+00	1.43E-03	--	--	--
Arsenic	3.00E-04	3.00E-04	--	1.50E+00	1.50E+00	1.51E+01
Barium	2.00E-01	2.00E-01	2.00E-01	--	--	--
Benzene	4.00E-03	4.00E-03	8.57E-03	5.50E-02	5.50E-02	2.70E-02
Benz[a]anthracene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Benzo[a]pyrene	--	--	--	7.30E+00	7.30E+00	3.10E+00
Benzo[b]fluoranthene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Benzo[k]fluoranthene	--	--	--	7.30E-02	7.30E-02	3.10E-02
Bis(2-ethylhexyl)phthalate	2.00E-02	2.00E-02	2.00E-02	1.40E-02	1.40E-02	1.40E-02
Bromomethane	1.40E-03	1.40E-03	1.43E-03	--	--	--
Chlorobenzene	2.00E-02	2.00E-02	1.43E-02	--	--	--
Chloromethane	--	--	2.57E-02	--	--	6.30E-03
Chromium	3.00E-03	3.00E-03	2.85E-05	--	--	2.94E+02
Cyanide	2.00E-02	2.00E-02	--	--	--	--
Dibenz[ah]anthracene	--	--	--	7.30E+00	7.30E+00	3.10E+00
Indeno[1,2,3-cd]pyrene	--	--	--	7.30E-01	7.30E-01	3.10E-01
Iron	7.00E-01	7.00E-01	--	--	--	--
Lead	--	--	--	--	--	--
Manganese	4.67E-02	4.67E-02	1.40E-05	--	--	--
Methylene chloride	6.00E-02	6.00E-02	8.57E-01	7.50E-03	7.50E-03	1.65E-03
Naphthalene	2.00E-02	2.00E-02	8.57E-04	--	--	--
Nickel	2.00E-02	2.00E-02	--	--	--	--
Nitrobenzene	5.00E-04	5.00E-04	5.71E-04	--	--	--
N-Nitroso di-n-propylamine	--	--	--	7.00E+00	7.00E+00	7.00E+00
PCB-1254	2.00E-05	2.00E-05	2.00E-05	2.00E+00	2.00E+00	2.00E+00
PCB-1260	--	--	--	2.00E+00	2.00E+00	2.00E+00
Tetrachloroethene (PCE)	1.00E-02	1.00E-02	1.14E-01	5.40E-01	5.40E-01	2.07E-02
Thallium	7.00E-05	7.00E-05	--	--	--	--
Trichloroethylene (TCE)	3.00E-04	3.00E-04	1.14E-02	4.00E-01	4.00E-01	4.00E-01
Vanadium	5.00E-03	5.00E-03	--	--	--	--
Xylenes, total	2.00E-01	2.00E-01	2.86E-02	--	--	--

-- = Toxicity value not available

**Table 5-1. Summary of Noncancer Hazards and Cancer Risk Estimates
from Potential Exposures at Acid Area 2,
Plum Brook Ordnance Works, Sandusky, OH**

Groundskeeper Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	9.E-01	4.E-05
Dermal Contact	1.E-01	6.E-06
Inhalation	2.E-03	3.E-09
Total	1.E+00	5.E-05

Construction Worker Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E+00	5.E-06
Dermal Contact	2.E+00	2.E-06
Inhalation	3.E-03	1.E-10
Total	7.E+00	7.E-06

Adult Hunter Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E-02	3.E-06
Dermal Contact	6.E-02	3.E-06
Inhalation	NA	NA
Total	1.E-01	6.E-06

Construction Worker Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E+00	2.E-06
Dermal Contact	6.E-02	8.E-07
Inhalation	NA	NA
Total	2.E+00	3.E-06

Adult Hunter Risks From Ingestion of Venison		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	6.E-04	9.E-09
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	6.E-04	9.E-09

Construction Worker Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	4.E-03	8.E-09
Inhalation	NA	NA
Total	4.E-03	8.E-09

Child Risks From Ingestion of Venison		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E-03	3.E-09
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	1.E-03	3.E-09

Construction Worker Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	6.E-01	4.E-07
Dermal Contact	3.E-02	1.E-07
Inhalation	NA	NA
Total	7.E-01	5.E-07

Indoor Worker Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E+00	5.E-05
Dermal Contact	2.E-02	8.E-07
Inhalation	NA	NA
Total	2.E+00	5.E-05

Indoor Worker Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E-01	2.E-05
Dermal Contact	NA	NA
Inhalation	NA	NA
Total	5.E-01	2.E-05

Table 5-1. Continued

Adult Residential Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	5.E+00	1.E-04
Dermal Contact	7.E-02	3.E-06
Inhalation	2.E-01	3.E-06
Total	6.E+00	1.E-04

Child Residential Risks From Exposure to Groundwater		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+01	7.E-05
Dermal Contact	1.E-01	1.E-06
Inhalation	4.E-01	2.E-06
Total	1.E+01	7.E-05

Adult Residential Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	2.E-02	5.E-05
Dermal Contact	1.E+00	6.E-05
Inhalation	2.E-03	4.E-09
Total	1.E+00	1.E-04

Child Residential Risks From Exposure to Surface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	1.E+01	1.E-04
Dermal Contact	2.E+00	3.E-05
Inhalation	5.E-03	2.E-09
Total	1.E+01	2.E-04

Adult Residential Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	9.E-03	2.E-05
Dermal Contact	4.E-02	2.E-05
Inhalation	NA	NA
Total	5.E-02	5.E-05

Child Residential Risks From Exposure to Subsurface Soil		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	4.E+00	6.E-05
Dermal Contact	7.E-02	1.E-05
Inhalation	NA	NA
Total	4.E+00	7.E-05

Adult Recreational Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	1.E-03	1.E-07
Inhalation	NA	NA
Total	1.E-03	1.E-07

Child Recreational Risks From Exposure to Surface Water		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	NA	NA
Dermal Contact	2.E-03	5.E-08
Inhalation	NA	NA
Total	2.E-03	5.E-08

Adult Recreational Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	3.E-02	3.E-06
Dermal Contact	1.E-02	2.E-06
Inhalation	NA	NA
Total	5.E-02	5.E-06

Child Recreational Risks From Exposure to Sediment		
Exposure Route	Hazard Quotient	Excess Cancer Risk
Ingestion	3.E-01	6.E-06
Dermal Contact	3.E-02	1.E-06
Inhalation	NA	NA
Total	3.E-01	7.E-06

APPENDIX A
DERMAL ABSORBED DOSE CALCULATIONS

**Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 2 Groundwater.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

concentration (mg/L)/1000 cm³:

Input site specific concentrations in Column marked "Conc"

Area exposed (cm²):

Event time (hr/event):

Exposure frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSGI

IR: Ingestion rate of drinking water

ABSGI: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp predicted	Kp measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/Chemicals	Derm/Assess	Chem/Assess	Total Dose	B	tau (hr)	L_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc	
17 Benzene	71432	78.1	2.13	5.9E-04	1.5E-02	3.7E-01	3.7E-01	3.7E-01	10%	N	N	0%	0.1	0.29	0.70	1.0	3.09E-05	1.5E-02	3.1E-07	2.9E-05	-3.2E+00	5.71E-07	5.71E-07	
** 26 Bromomethane	74839	95.0	1.19	1.1E-04	2.8E-03	7.0E-02	7.0E-02	7.0E-02	2%	N	N	0%	0.0	0.36	0.87	1.0	5.93E-06	2.8E-03	1.2E-08	1.2E-08	1.2E-06	-3.3E+00	4.59E-07	4.59E-07
40 Chlorobenzene	108907	112.6	2.84	1.1E-03	2.8E-02	7.1E-01	7.1E-01	7.1E-01	24%	Y	Y	0%	0.1	0.46	1.09	1.0	5.00E-06	2.8E-02	1.2E-07	1.2E-07	1.1E-05	-3.4E+00	3.66E-04	3.66E-04
** 46 Chloromethane	74873	50.5	0.91	1.3E-04	3.3E-03	8.3E-02	8.3E-02	8.3E-02	2%	N	Y	0%	0.0	0.20	0.49	1.0	9.73E-06	3.3E-03	1.8E-08	1.8E-08	1.7E-06	-3.1E+00	8.16E-04	8.16E-04
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	6.6E-01	101%	Y	Y	1%	0.2	16.64	39.93	0.8	4.86E-06	2.5E-02	4.9E-07	4.9E-07	4.6E-05	-5.0E+00	1.00E-08	1.00E-08
92 2-Nitrotoluene	88722	137.1	2.45	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	11%	Y	Y	0%	0.1	0.63	1.50	1.0	9.83E-08	1.1E-02	1.1E-09	1.1E-09	1.0E-07	-3.8E+00	2.66E-04	2.66E-04
** 139 Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03	8.8E-02	8.8E-02	8.8E-02	2%	N	Y	0%	0.0	0.32	0.76	1.0	9.92E-06	3.5E-03	2.2E-08	2.2E-08	2.1E-06	-3.9E+00	5.23E-07	5.23E-07
143 2-Methylnaphthalene	91576	142.2	3.90	9.7E-02	9.7E-02	1.2E+00	1.2E+00	1.2E+00	98%	Y	Y	0%	0.4	0.67	1.60	1.0	5.90E-06	9.7E-02	5.7E-07	5.7E-07	5.4E-05	-3.8E+00	2.49E-04	2.49E-04
143 Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02	1.2E+00	1.2E+00	1.2E+00	43%	Y	Y	0%	0.2	0.56	1.34	1.0	5.00E-06	4.7E-02	2.2E-07	2.2E-07	2.0E-05	-3.8E+00	2.99E-04	2.99E-04
197 Nitrobenzene	98950	120.0	1.84	5.6E-03	5.6E-03	1.8E-03	1.8E-03	1.8E-03	2%	N	N	0%	0.0	0.50	1.20	1.0	9.74E-06	5.6E-03	9.3E-09	9.3E-09	8.7E-07	-3.9E+00	2.99E-04	2.99E-04
** 196 1,1,2-Trichlorobenzene	79005	168.1	1.62	2.6E-04	6.4E-03	1.6E-01	1.6E-01	1.6E-01	6%	N	N	0%	0.0	0.83	2.24	1.0	8.74E-06	1.8E-03	2.1E-10	2.1E-10	2.0E-08	-3.7E+00	1.78E-04	1.78E-04
** 196 1,1,2-Trichloroethane	79005	133.4	2.05	6.4E-03	6.4E-03	1.6E-01	1.6E-01	1.6E-01	6%	N	N	0%	0.0	0.60	1.43	1.0	6.23E-06	6.4E-03	3.8E-08	3.8E-08	3.6E-06	-3.8E+00	2.79E-04	2.79E-04
208 Xylenes, total	1330207	106.2	3.15	4.9E-02	4.9E-02	1.4E+00	1.4E+00	1.4E+00	39%	Y	Y	0%	0.2	0.42	1.01	1.0	1.38E-04	4.9E-02	5.4E-06	5.4E-06	5.1E-04	-3.4E+00	3.97E-04	3.97E-04

**Noncarcin Dermal/Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 2 Groundwater.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L): 10000 cm3/3

Input site specific concentrations in Column marked "Conc"

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

lsc =

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR =

ABSIG =

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp predicted	Kp measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Chemicals Drink	Chem Assess	Derm/ Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/fsc)	Dsc/fsc	Desc
** 17 Benzene	71432	78.1	2.13	5.9E-04	1.5E-02	3.7E-01	3.7E-01	3.7E-01	10%	N	0%	0.1	0.29	0.70	1.0	3.09E-05	1.5E-02	3.1E-07	8.4E-05	-3.2E+00	5.71E-04	5.71E-07
** 26 Bromomethane	74839	95.0	1.19	1.1E-04	2.8E-03	7.0E-02	7.0E-02	7.0E-02	2%	N	0%	0.0	0.36	0.87	1.0	5.83E-06	2.8E-03	1.2E-08	3.4E-06	-3.3E+00	4.59E-04	4.59E-07
** 40 Chlorobenzene	108907	112.6	2.84	1.1E-03	2.8E-02	7.1E-01	7.1E-01	7.1E-01	24%	Y	0%	0.1	0.46	1.09	1.0	5.00E-06	2.8E-02	1.2E-07	3.2E-05	-3.4E+00	3.66E-04	3.66E-07
** 4c Chloromethane	74873	50.5	0.91	1.3E-04	3.3E-03	8.3E-02	8.3E-02	8.3E-02	2%	N	0%	0.0	0.20	0.49	1.0	9.73E-06	3.3E-03	1.8E-08	4.9E-06	-3.1E+00	8.16E-04	8.16E-07
** 58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	6.6E-01	101%	Y	1%	0.2	16.64	39.93	0.8	4.86E-06	2.5E-02	4.9E-07	1.3E-04	-5.0E+00	1.00E-05	1.00E-08
** 92 2-Nitrotoluene	88722	137.1	2.45	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	11%	Y	0%	0.1	0.63	1.50	1.0	9.83E-08	1.1E-02	1.1E-09	3.0E-07	-3.2E+00	2.66E-04	2.66E-07
** 139 Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03	8.8E-02	8.8E-02	8.8E-02	2%	N	0%	0.0	0.32	0.76	1.0	8.92E-06	3.5E-03	2.2E-08	6.0E-06	-3.2E+00	5.23E-04	5.23E-07
** 143 2-Methylnaphthalene	91576	142.2	3.90	1.2E+00	9.7E-02	1.2E+00	1.2E+00	1.2E+00	98%	Y	1%	0.4	0.67	1.20	1.0	5.80E-06	9.7E-02	5.7E-07	1.8E-04	-3.2E+00	2.49E-04	2.49E-07
** 197 Nitrobenzene	91203	128.2	3.30	1.8E-03	4.7E-02	4.7E-02	4.7E-02	4.7E-02	43%	Y	0%	0.2	0.59	1.34	1.0	5.00E-06	4.7E-02	2.9E-07	5.9E-05	-3.4E+00	2.89E-04	2.89E-07
** 196 1,1,2-Trichlorobenzene	98650	168.1	1.84	5.6E-03	1.8E-03	1.8E-03	1.8E-03	1.8E-03	5%	N	0%	0.0	0.93	2.24	1.0	9.74E-08	1.8E-03	2.1E-10	5.8E-08	-3.7E+00	3.32E-04	3.32E-07
** 197 1,1,2-Trichloroethane	79005	133.4	1.52	2.6E-04	6.4E-03	1.6E-01	1.6E-01	1.6E-01	6%	N	0%	0.0	0.60	1.43	1.0	6.23E-06	6.4E-03	3.8E-08	1.0E-05	-3.6E+00	2.79E-04	2.79E-07
** 209 Xylenes, total	1330207	106.2	3.15	4.9E-02	4.9E-02	4.9E-02	4.9E-02	4.9E-02	39%	Y	0%	0.2	0.42	1.01	1.0	1.38E-04	4.9E-02	5.4E-06	1.5E-03	-3.4E+00	3.97E-04	3.97E-07

**Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 2 Groundwater.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 2.00E+04 cm2
 t_event = 2.00E-01 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 3.50E+02 days/yr
 ED = 2.40E+01 years
 BW = 7.00E+01 kg
 AT = 2.56E+04 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

$$\text{Dermal (mg/day)} = \text{DA_event} * A * \text{EV}$$

$$\text{Drinking (mg/day)} = \text{Conc} * \text{IR} * \text{ABSIG}$$

$$\text{IR} = \text{Ingestion rate of drinking water}$$

$$\text{IR} = 2.00\text{E}+03 \text{ (cm}^3\text{/day} = \text{L/day} * 1000 \text{ cm}^3\text{/L)}$$

$$\text{ABSIG} = \text{Absorption fraction in GI tract}$$

$$\text{Chemical specific}$$

$$\text{Condition for screening: "Y" when Dermal is 10\% of Drinking}$$

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

$$\text{Total dose (mg/day)} = Q * T_event * \text{EV}$$

$$Q: \text{ Shower flow rate (5-15 gal/min; here using 5 gal/Q} = 1.14\text{E}+06 \text{ (cm}^3\text{/hr} = \text{gal/min} * 3.785 \text{ gal/l} * 60 \text{ min/hr} * 1000 \text{ cm}^3\text{/L)}$$

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to be assessed	Derm/Total Dose
Aluminum (total)	1.0E-03	default	8.10E-03	1.6E-06	1.5E-04	15%	N	0.00%
Arsenic (total)	1.0E-03	default	7.21E-06	1.4E-09	1.4E-07	95%	N	0.00%
Barium (total)	1.0E-03	default	1.33E-03	2.7E-07	2.5E-05	7%	N	0.00%
Chromium (total)	1.0E-03	experimental	6.20E-06	1.2E-09	1.2E-07	1.3%	Y	15.38%
Cyanide	1.0E-03	default	8.68E-05	1.7E-08	1.6E-06	47%	N	0.00%
Iron (total)	1.0E-03	default	1.91E-02	3.8E-06	3.6E-04	6%	N	0.00%
Manganese (total)	1.0E-03	default	4.46E-04	8.9E-08	8.4E-06	6%	N	0.00%
Nickel (total)	2.0E-04	experimental	1.64E-05	6.6E-10	6.2E-08	4%	N	1.00%
Thallium (total)	1.0E-03	default	6.24E-06	1.2E-09	1.2E-07	100%	N	0.00%
Vanadium (total)	1.0E-03	default	1.90E-05	3.8E-09	3.6E-07	2.6%	N	7.69%

**Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 2 Groundwater.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 2.00E+04 cm2
 t_event = 2.00E-01 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 3.50E+02 days/yr
 ED = 2.40E+01 years
 BW = 7.00E+01 kg
 AT = 8.76E+03 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed	Total Dose
Aluminum (total)	1.0E-03	default	8.10E-03	1.6E-06	4.4E-04	15%	1.33%	N
Arsenic (total)	1.0E-03	default	7.21E-06	1.4E-09	3.9E-07	95%	0.21%	N
Barium (total)	1.0E-03	default	1.33E-03	2.7E-07	7.3E-05	7%	2.86%	N
Chromium (total)	1.0E-03	experimental	6.20E-06	1.2E-09	3.4E-07	1.3%	15.38%	Y
Cyanide	1.0E-03	default	8.68E-05	1.7E-08	4.8E-06	47%	0.43%	N
Iron (total)	1.0E-03	default	1.91E-02	3.8E-06	1.0E-03	6%	3.33%	N
Manganese (total)	1.0E-03	default	4.46E-04	8.9E-08	2.4E-05	6%	3.33%	N
Nickel (total)	2.0E-04	experimental	1.64E-05	6.6E-10	1.8E-07	4%	1.00%	N
Thallium (total)	1.0E-03	default	6.24E-06	1.2E-09	3.4E-07	100%	0.20%	N
Vanadium (total)	1.0E-03	default	1.90E-05	3.8E-09	1.0E-06	2.6%	7.69%	N

**Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L=1/1000 cm3):

Input site specific concentrations in Column marked "Conc"

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

Conc = 1E-03 mg/cm3 (default value for purpose of illustration)

SA = 5450 cm2

L_event = 3.00 hr/event (35 minutes/event)

EV = 1 event/day

EF = 52 days/yr

ED = 24 years

BW = 70.0 kg

AT = 25550 days

isc = 1.00E-03 cm

IR = 2000 (cm3/day = L/day * 1000 cm3/L)

ABSGI = 1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water

ABSGI: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/Chemicals Assess Total Dose	B	tau (hr)	L_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/isc)	Dsc/isc	Dsc
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	106% Y	0%	0.2	16.64	39.93	0.8	2.55E-06	2.5E-02	9.9E-07	3.8E-06	-5.0E+00	1.00E-05	1.00E-08

**Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L/1000 cm3):

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

lsc = 1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*) outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

Conc = 1E-03 mg/cm3 (default value for purpose of illustration)

SA = 5450 cm2

L_event = 3.00 hr/event (35 minutes/event)

EV = 1 event/day

EF = 52 days/yr

ED = 24 years

BW = 70 kg

AT = 8760 days

IR = 2000 (cm3/day = L/day * 1000 cm3/L)

ABSIG = 1.0 (assumed 100% GI absorption)

Q = 1135500.0 (cm3/hr = gal/min * 3.785 gal) * 60 min/hr * 1000 cm3/hr)

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/Chem Assess	Derm/Chem Assess Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/sec)	Dsc/lsc	Dsc	
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.8E-01	6.8E-01	100%	Y	0%	0.2	16.64	39.93	0.8	2.55E-06	2.5E-02	9.9E-07	1.1E-05	-5.0E+00	1.00E-05	1.00E-08

**Cancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)

SA= 5450 cm2

t_event = 3 hr/event (35 minutes/event)

EV = 1 event/day

EF = 52 days/yr

ED = 24 years

BW = 70 kg

AT = 25550 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to be assessed	Total Dose
Aluminum	1.0E-03	default	6.34E-04	1.9E-06	7.23E-06	15%	5.45%	N
Arsenic	1.0E-03	default	3.20E-06	9.6E-09	3.65E-08	95%	0.86%	N
Iron	1.0E-03	default	9.89E-04	3.0E-06	1.13E-05	6%	13.63%	Y
Manganese	1.0E-03	default	5.95E-05	1.8E-07	6.79E-07	6%	13.63%	Y
Vanadium	1.0E-03	default	1.54E-05	4.6E-08	1.76E-07	2.6%	31.44%	Y

**Noncancer Dermal Absorbed Dose Calculations
for Adult Residential Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)

SA= 5.45E+03 cm2

t_event = 3.00E+00 hr/event (35 minutes/event)

EV = 1.00E+00 event/day

EF = 5.20E+01 days/yr

ED = 2.40E+01 years

BW = 7.00E+01 kg

AT = 8.76E+03 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to be assessed	Chemicals to be assessed	Derm/ Total Dose
Aluminum	1.0E-03	default	6.34E-04	1.9E-06	2.1E-05	15%	Y	N	0.00%
Arsenic	1.0E-03	default	3.20E-06	9.6E-09	1.1E-07	95%	Y	N	0.00%
Iron	1.0E-03	default	9.89E-04	3.0E-06	3.3E-05	6%	Y	Y	0.00%
Manganese	1.0E-03	default	5.95E-05	1.8E-07	2.0E-06	6%	Y	Y	0.00%
Vanadium	1.0E-03	default	1.54E-05	4.6E-08	5.1E-07	2.6%	Y	Y	0.00%

**Cancer Dermal Absorbed Dose Calculations
for Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 2 Groundwater.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L/L/1000 cm3):

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for noncarcinogenic effects, ED = 30 years (used in this spreadsheet)

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) (determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp predicted	Kp (cm/hr) measured	95% UCI	Kp Special Chemicals (*) or (**)	Derm/ Chemicals Drink	Chem Assess Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/isc)	Dsofsc	Desc
17 Benzene	71432	78.1	2.13	5.9E-04	1.5E-02	3.7E-01	3.7E-01	0.1	0.29	0.1	0.29	0.70	1.0	3.08E-05	1.5E-02	4.0E-07	1.4E-05	-3.2E+00	5.71E-04	5.71E-07	
** 28 Bromomethane	74839	95.0	1.19	1.1E-04	2.8E-03	7.0E-02	7.0E-02	**	1%	N	0%	0.36	0.87	5.83E-06	2.8E-03	1.6E-08	5.7E-07	-3.3E+00	4.59E-04	4.59E-07	
40 Chlorobenzene	108907	112.6	2.84	1.1E-03	2.8E-02	7.1E-01	7.1E-01	10%	Y	0%	0.1	0.46	1.09	5.00E-06	2.8E-02	1.5E-07	5.5E-06	-3.4E+00	3.66E-04	3.66E-07	
** 46 Chloromethane	74873	50.5	0.81	1.3E-04	3.3E-03	8.3E-02	8.3E-02	**	1%	N	0%	0.20	0.49	9.73E-06	3.3E-03	2.3E-08	8.3E-07	-3.1E+00	8.16E-04	8.16E-07	
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.8E-01	6.8E-01	43%	Y	0%	0.2	16.64	39.93	0.8	4.86E-06	2.5E-02	6.3E-07	2.3E-05	-5.0E+00	1.00E-08	
92 2-Nitrotoluene	88722	137.1	2.45	1.1E-02	1.1E-02	1.1E-02	1.1E-02	5%	N	0%	0.1	0.63	1.50	1.0	9.83E-08	1.1E-02	1.4E-09	5.1E-08	-3.6E+00	2.68E-07	
** 139 Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03	8.8E-02	8.8E-02	**	1%	N	0%	0.32	0.76	1.0	8.92E-06	3.5E-03	2.8E-08	1.0E-06	-3.3E+00	5.23E-04	
143 2-Methylnaphthalene	91576	142.2	3.90	9.7E-02	9.7E-02	1.2E+00	1.2E+00	42%	Y	0%	0.4	0.67	1.60	1.0	5.80E-06	9.7E-02	7.4E-07	2.7E-06	-3.6E+00	2.49E-04	
143 Naphthalene	91203	128.0	3.30	4.7E-02	4.7E-02	1.2E+00	1.2E+00	18%	Y	0%	0.2	0.56	1.34	1.0	5.00E-06	4.7E-02	1.9E-07	1.0E-05	-3.5E+00	2.89E-04	
197 Nitrobenzene	98953	120.0	1.84	5.8E-03	5.8E-03	1.2E+00	1.2E+00	2%	N	0%	0.0	0.50	1.20	1.0	1.91E-06	5.8E-03	2.9E-08	4.3E-07	-3.5E+00	3.32E-04	
197 1,3-Dinitrobenzene	99650	168.1	1.52	1.8E-03	1.8E-03	1.8E-03	1.8E-03	1%	N	0%	0.0	0.89	2.24	1.0	9.74E-08	1.8E-03	2.7E-10	9.8E-09	-3.7E+00	1.78E-04	
** 198 1,1,2-Trichloroethane	79005	133.4	2.05	2.6E-04	6.4E-03	1.6E-01	1.6E-01	**	3%	N	0%	0.60	1.43	1.0	6.23E-06	6.4E-03	4.8E-08	1.8E-06	-3.6E+00	2.79E-04	
209 Xylenes, total	1330207	106.2	3.15	4.9E-02	4.9E-02	1.4E+00	1.4E+00	17%	Y	0%	0.2	0.42	1.01	1.0	1.38E-04	4.9E-02	7.0E-06	2.5E-04	-3.4E+00	3.97E-04	

**Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 2 Groundwater.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-I18

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L): 1/1000 cm3/3

input site specific concentrations in Column marked "Conc"

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

lsc = 1.00E-03 cm

Conc = 1E-03 mg/cm3 (default value for purpose of illustration)

SA = 6600 cm2

L_event = 0.33 hr/event (35 minutes/event)

EV = 1 event/day

EF = 350 days/yr

ED = 6 years

BW = 15.0 kg

AT = 2190 days

IR = 2000 (cm3/day = L/day * 1000 cm3/L)

ABSGI = 1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water

ABSGI: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

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(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

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Note:

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

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Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp predicted	Kp measured	95% UCI	Special Chemicals Drink (*) or (**)	Derm/ Assess Total Dose	B	tau (hr)	L_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Del/sc)	Dso/sc	Desc
** 17 Benzene	71432	78.1	2.13	5.9E-04	1.5E-02	3.7E-01	3.7E-01	4% N	0%	0.1	0.29	0.70	1.0	3.09E-05	1.5E-02	4.0E-07	1.7E-04	-3.2E+00	5.71E-04	5.71E-07
** 21 Bromomethane	74839	95.0	1.19	1.1E-04	2.8E-03	7.0E-02 **	7.0E-02 **	1% N	0%	0.0	0.36	0.87	1.0	5.83E-06	2.8E-03	1.6E-08	6.7E-06	-3.3E+00	4.59E-04	4.59E-07
** 40 Chlorobenzene	108907	112.6	2.84	1.1E-03	2.8E-02	7.1E-01	7.1E-01	10% Y	0%	0.1	0.46	1.09	1.0	5.00E-06	2.8E-02	1.5E-07	6.4E-05	-3.4E+00	3.66E-04	3.66E-07
** 41 Chloromethane	74873	50.5	0.91	1.3E-04	3.3E-03	8.3E-02 **	8.3E-02 **	1% N	0%	0.0	0.20	0.49	1.0	9.73E-06	3.3E-03	2.3E-08	9.7E-06	-3.1E+00	8.16E-04	8.16E-07
** 58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	43% Y	0%	0.2	16.64	39.93	0.8	4.86E-06	2.5E-02	6.3E-07	2.7E-04	-5.0E+00	1.00E-05	1.00E-08
** 92 2-Nitrotoluene	88722	137.1	2.45	1.1E-02	1.1E-02	1.1E-02	1.1E-02	5% N	0%	0.1	0.63	1.50	1.0	9.83E-08	1.1E-02	1.4E-09	5.9E-07	-3.6E+00	2.66E-04	2.66E-07
** 139 Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03	8.8E-02 **	8.8E-02 **	1% N	0%	0.0	0.32	0.76	1.0	8.92E-06	3.5E-03	2.8E-08	1.2E-05	-3.3E+00	5.23E-04	5.23E-07
143 2-Methylnaphthalene	91576	142.2	3.90	1.2E+00	9.7E-02	1.2E+00	1.2E+00	42% Y	0%	0.4	0.67	1.60	1.0	5.80E-06	9.7E-02	7.4E-07	3.1E-04	-3.8E+00	2.49E-04	2.49E-07
143 Naphthalene	91203	126.2	3.30	1.8E-03	4.7E-02	1.2E+00	1.2E+00	18% Y	0%	0.2	0.56	1.20	1.0	5.00E-06	4.7E-02	2.8E-07	1.2E-04	-3.5E+00	2.99E-04	2.99E-07
197 Nitrobenzene	98953	120.0	1.84	5.6E-03	5.6E-03	1.8E-03	1.8E-03	2% N	0%	0.0	0.50	1.20	1.0	1.91E-06	5.6E-03	1.2E-08	5.1E-06	-3.5E+00	3.32E-04	3.32E-07
** 197 1,3-Dinitrobenzene	98650	166.1	1.52	1.8E-03	1.8E-03	1.8E-03	1.8E-03	1% N	0%	0.0	0.93	2.24	1.0	6.23E-06	1.8E-03	2.7E-10	1.2E-07	-3.7E+00	1.78E-04	1.78E-07
** 198 1,1,2-Trichloroethane	79005	133.4	2.05	2.6E-04	6.4E-03	1.6E-01 **	1.6E-01 **	3% N	0%	0.0	0.60	1.43	1.0	6.23E-06	6.4E-03	4.9E-08	2.1E-05	-3.6E+00	2.79E-04	2.79E-07
209 Xylenes, total	1330207	106.2	3.15	4.9E-02	4.9E-02	4.9E-02	4.9E-02	17% Y	0%	0.2	0.42	1.01	1.0	1.38E-04	4.9E-02	7.0E-06	3.0E-03	-3.4E+00	3.97E-04	3.97E-07

**Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 2 Groundwater.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 6.60E+03 cm2
 t_event = 3.33E-01 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 3.50E+02 days/yr
 ED = 6.00E+00 years
 BW = 1.50E+01 kg
 AT = 2.56E+04 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

$$\text{Dermal (mg/day)} = \text{DA_event} * \text{A} * \text{EV}$$

$$\text{Drinking (mg/day)} = \text{Conc} * \text{IR} * \text{ABSIG}$$

$$\text{IR: Ingestion rate of drinking water} \quad \text{IR} = 2.00\text{E}+03 \text{ (cm}^3\text{/day} = \text{L/day} * 1000 \text{ cm}^3\text{/L)}$$

$$\text{ABSIG: Absorption fraction in GI tract} \quad \text{Chemical specific}$$

$$\text{Condition for screening: "Y" when Dermal is 10% of Drinking}$$

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

$$\text{Total dose (mg/day)} = \text{Q} * \text{T_event} * \text{EV}$$

$$\text{Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q} = 1.14\text{E}+06 \text{ (cm}^3\text{/hr} = \text{gal/min} * 3.785 \text{ gal/l} * 60 \text{ min/hr} * 1000 \text{ cm}^3\text{/hr)}$$

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed	Total Dose
Aluminum (total)	1.0E-03	default	8.10E-03	2.7E-06	9.8E-05	15%	N	0.00%
Arsenic (total)	1.0E-03	default	7.21E-06	2.4E-09	8.7E-08	95%	N	0.00%
Barium (total)	1.0E-03	default	1.33E-03	4.4E-07	1.6E-05	7%	N	0.00%
Chromium (total)	1.0E-03	experimental	6.20E-06	2.1E-09	7.5E-08	1.3%	N	0.00%
Cyanide	1.0E-03	default	8.68E-05	2.9E-08	1.0E-06	47%	N	0.00%
Iron (total)	1.0E-03	default	1.91E-02	6.3E-06	2.3E-04	6%	N	0.00%
Manganese (total)	1.0E-03	default	4.46E-04	1.5E-07	5.4E-06	6%	N	0.00%
Nickel (total)	2.0E-04	experimental	1.64E-05	1.1E-09	4.0E-08	4%	N	0.00%
Thallium (total)	1.0E-03	default	6.24E-06	2.1E-09	7.5E-08	100%	N	0.00%
Vanadium (total)	1.0E-03	default	1.90E-05	6.3E-09	2.3E-07	2.6%	N	0.00%

**Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 2 Groundwater.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 6.60E+03 cm2
 t_event = 3.33E-01 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 3.50E+02 days/yr
 ED = 6.00E+00 years
 BW = 1.50E+01 kg
 AT = 2.19E+03 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed	Total Dose
Aluminum (total)	1.0E-03	default	8.10E-03	2.7E-06	1.1E-03	15%	N	0.73%
Arsenic (total)	1.0E-03	default	7.21E-06	2.4E-09	1.0E-06	95%	N	0.12%
Barium (total)	1.0E-03	default	1.33E-03	4.4E-07	1.9E-04	7%	N	1.57%
Chromium (total)	1.0E-03	experimental	6.20E-06	2.1E-09	8.7E-07	1.3%	N	8.45%
Cyanide	1.0E-03	default	8.68E-05	2.9E-08	1.2E-05	47%	N	0.23%
Iron (total)	1.0E-03	default	1.91E-02	6.3E-06	2.7E-03	6%	N	1.83%
Manganese (total)	1.0E-03	default	4.46E-04	1.5E-07	6.3E-05	6%	N	1.83%
Nickel (total)	2.0E-04	experimental	1.64E-05	1.1E-09	4.6E-07	4%	N	0.55%
Thallium (total)	1.0E-03	default	6.24E-06	2.1E-09	8.8E-07	100%	N	0.11%
Vanadium (total)	1.0E-03	default	1.90E-05	6.3E-09	2.7E-06	2.6%	N	4.23%

**Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells I8-118

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L, 10^3 cm³):

Input site specific concentrations in Column marked "Conc"

Area exposed (cm²):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 μ m):

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL

CAS No.

MWT

logKow

95% LCI

Kp (cm/hr) predicted

Kp (cm/hr) measured

95% UCI

Kp

Special Chemicals Drink Assess Total Dose (*) or (**)

Chem Derms Assess Total Dose

B

tau (hr)

L_star (hr)

FA

Conc (mg/cm³)

Kp used in DA_event (mg/cm²-evt)

DA_event (mg/kg-day)

DAD

log(Ds/lsc)

Dsc/lsc

Dsc

58 bis(2-Ethylhexyl)phthalate

117817

391.0

5.11

9.4E-04

2.5E-02

6.6E-01

41% Y

0%

0.2

16.64

39.83

0.8

2.55E-06

2.5E-02

9.9E-07

1.7E-06

-5.0E+00

1.00E-05

1.00E-08

**Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposure to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-118

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L=1/1000 cm3):

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

lsc =

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSGI

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Chemicals Drink	Chem Derm/ Assess Total Dose	B	tau (hr)	L_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	41% Y	0%	0%	0.2	16.64	39.93	0.8	2.56E-06	2.5E-02	9.9E-07	2.0E-05	-5.0E+00	1.00E-05	1.00E-08

**Cancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm³ (default value for purpose of illustration)
 SA= 2.10E+03 cm²
 T_{event} = 3.00E+00 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 5.20E+01 days/yr
 ED = 6.00E+00 years
 BW = 1.50E+01 kg
 AT = 2.56E+04 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_{event} * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water
 ABSIG: Absorption fraction in GI tract
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_{event} * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm³/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm³/hr)

Refer to Appendix A for equations to evaluate DA_{event} and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm ³)	DA _{event} (mg/cm ² -event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to be assessed	Total Dose
Aluminum	1.0E-03 default	default	6.34E-04	1.9E-06	3.3E-06	15%	N	0.00%
Arsenic	1.0E-03 default	default	3.20E-06	9.6E-09	1.6E-08	95%	N	0.00%
Iron	1.0E-03 default	default	9.89E-04	3.0E-06	5.1E-06	6%	N	0.00%
Manganese	1.0E-03 default	default	5.95E-05	1.8E-07	3.1E-07	6%	N	0.00%
Vanadium	1.0E-03 default	default	1.54E-05	4.6E-08	7.9E-08	2.6%	Y	12.12%

**Noncancer Dermal Absorbed Dose Calculations
for Child Residential Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)

SA= 2.10E+03 cm2

t_event = 3.00E+00 hr/event (35 minutes/event)

EV = 1.00E+00 event/day

EF = 5.20E+01 days/yr

ED = 6.00E+00 years

BW = 1.50E+01 kg

AT = 2.19E+03 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
ABSIG: Absorption fraction in GI tract Chemical specific
Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to be assessed	Total Dose
Aluminum	1.0E-03	default	6.34E-04	1.9E-06	3.8E-05	15%	N	0.00%
Arsenic	1.0E-03	default	3.20E-06	9.6E-09	1.9E-07	95%	N	0.00%
Iron	1.0E-03	default	9.89E-04	3.0E-06	5.9E-05	6%	N	0.00%
Manganese	1.0E-03	default	5.95E-05	1.8E-07	3.6E-06	6%	N	0.00%
Vanadium	1.0E-03	default	1.54E-05	4.6E-08	9.2E-07	2.6%	Y	0.00%

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for carcinogenic effects of chemicals in water through showering

Concentration (mg/L) / 1000 cm³ = 1 mg/L (1 pi = 1 ug/cm³ = 1000 ppb)

Area exposed (cm²): 3300 cm²

Event time (hr/event): 1.00 hr/event (35 minutes/event)

Event frequency (events/day): 1 event/day

Exposure frequency (days/year): 250 days/yr

Exposure duration (years): 25 years

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg): 70.0 kg

Averaging time (days): 25550 days

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um): 1.00E-03 cm

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR = 2000 cm³/day = L/day * 1000 cm³/L

ABSIG = 1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MW	logKow	95% LCI Kp (cm/hr)	predicted Kp (cm/hr)	measured Kp (cm/hr)	95% UCI Kp (cm/hr)	Special Chemicals (*) or (**)	Derm/Chem Assess	Derm/Drink Assess	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm ³)	Kp used in DA_event	DA_event (mg/cm ² -ev)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
17 Benzene	71432	78.1	2.13	5.9E-04	1.8E-02	3.7E-01	3.7E-01	4% N	N	4%	0.1	0.29	0.70	1.0	3.09E-05	1.5E-02	7.2E-07	8.3E-06	-3.2E+00	5.71E-04	5.71E-07
** 2-Bromomethane	74839	95.0	1.19	1.1E-04	2.8E-03	7.0E-02 **	7.0E-02 **	1% N	N	1%	0.0	0.36	0.87	1.0	5.83E-06	2.8E-03	2.9E-08	3.3E-07	-3.3E+00	4.59E-04	4.59E-07
40 Chlorobenzene	108907	112.6	2.84	1.1E-03	2.8E-02	7.1E-01	7.1E-01	9% N	N	9%	0.1	0.46	1.09	1.0	5.00E-06	2.8E-02	2.6E-07	3.0E-06	-3.4E+00	3.66E-04	3.66E-07
** 4-Chloromethane	74873	50.5	0.91	1.3E-04	3.3E-03	8.3E-02 **	8.3E-02 **	1% N	N	1%	0.0	0.20	0.49	1.0	9.73E-06	3.3E-03	4.5E-08	5.2E-07	-3.1E+00	8.16E-04	8.16E-07
58 Bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.6E-02	6.6E-01	6.6E-01	37% Y	Y	37%	0.2	16.64	39.93	0.8	4.86E-06	2.6E-02	1.1E-06	1.3E-05	-5.0E+00	1.00E-05	1.00E-08
82 2-Nitrotoluene	88722	137.1	2.45	1.1E-04	1.1E-02	1.1E-02	1.1E-02	4% N	N	4%	0.1	0.63	1.50	1.0	9.83E-08	1.1E-02	2.4E-09	2.8E-08	-3.6E+00	2.66E-04	2.66E-07
** 139 Methylene chloride	75092	84.9	1.25	1.4E-04	3.5E-03	8.8E-02 **	8.8E-02 **	1% N	N	1%	0.0	0.32	0.76	1.0	8.92E-06	3.5E-03	5.2E-08	5.9E-07	-3.3E+00	5.23E-04	5.23E-07
143 2-Methylnaphthalene	91276	142.2	3.30	1.8E-03	9.7E-02	1.2E+00	1.2E+00	38% Y	Y	38%	0.4	0.67	1.60	1.0	5.80E-06	9.7E-02	1.3E-08	1.5E-05	-3.6E+00	2.49E-04	2.49E-07
143 Naphthalene	91203	128.2	3.30	1.8E-03	4.7E-02	1.2E+00	1.2E+00	16% Y	Y	16%	0.0	0.50	1.20	1.0	5.00E-06	4.7E-02	4.9E-07	5.6E-06	-3.5E+00	2.89E-04	2.89E-07
197 Nitrobenzene	98953	120.0	1.84	1.8E-03	5.6E-03	1.8E-03	1.8E-03	2% N	N	2%	0.0	0.80	2.24	1.0	1.91E-06	1.8E-03	2.1E-08	2.4E-07	-3.9E+00	3.32E-04	3.32E-07
** 197 1,3-Dinitrobenzene	99650	168.1	1.52	2.6E-04	6.4E-03	1.6E-01 **	1.6E-01 **	2% N	N	2%	0.0	0.93	2.43	1.0	6.23E-06	6.4E-03	4.8E-10	9.8E-07	-3.7E+00	1.78E-04	1.78E-07
** 196 1,1,2-Trichloroethane	79005	133.4	2.05	2.6E-04	6.4E-03	1.4E-01 **	1.4E-01 **	1% N	N	1%	0.0	0.80	1.43	1.0	6.23E-06	6.4E-03	8.6E-08	9.8E-07	-3.6E+00	2.79E-04	2.79E-07
209 Xylenes, total	1330207	106.2	3.15	2.6E-04	4.9E-02	1.4E-01 **	1.4E-01 **	15% Y	Y	15%	0.2	0.42	1.01	1.0	1.38E-04	4.9E-02	1.2E-05	1.4E-04	-3.4E+00	3.97E-04	3.97E-07

Cancer Dermal Absorbed Dose Calculations for Indoor Worker Exposures to Organics in Acid Area 2 Groundwater.

Conc = 1E-03 mg/cm³ (default value for purpose of illustration)

SA = 3300 cm²

t_event = 1.00 hr/event (35 minutes/event)

EV = 1 event/day

EF = 250 days/yr

ED = 25 years

BW = 70.0 kg

AT = 25550 days

IR = 2000 cm³/day = L/day * 1000 cm³/L

ABSIG = 1.0 (assumed 100% GI absorption)

lsc = 1.00E-03 cm

IR = 2000 cm³/day = L/day * 1000 cm³/L

ABSIG = 1.0 (assumed 100% GI absorption)

Q = 1135500.0 cm³/hr = gal/min * 3.785 gal/l * 1000 cm³/hr

**Noncancer Dermal Absorbed Dose Calculations
for Indoor Worker Exposures to Inorganics in Acid Area 2 Groundwater.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 3.30E+03 cm2
 t_event = 1.00E+00 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 2.50E+02 days/yr
 ED = 2.50E+01 years
 BW = 7.00E+01 kg
 AT = 9.13E+03 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/r Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed	Total Dose
Aluminum (total)	1.0E-03	default	8.10E-03	8.1E-06	2.6E-04	15%	N	1.10%
Arsenic (total)	1.0E-03	default	7.21E-06	7.2E-09	2.3E-07	95%	N	0.17%
Barium (total)	1.0E-03	default	1.33E-03	1.3E-06	4.3E-05	7%	N	2.36%
Chromium (total)	1.0E-03	experimental	6.20E-06	6.2E-09	2.0E-07	1.3%	Y	12.69%
Cyanide	1.0E-03	default	8.68E-05	8.7E-08	2.8E-06	47%	N	0.35%
Iron (total)	1.0E-03	default	1.91E-02	1.9E-05	6.2E-04	6%	N	2.75%
Manganese (total)	1.0E-03	default	4.46E-04	4.5E-07	1.4E-05	6%	N	2.75%
Nickel (total)	2.0E-04	experimental	1.64E-05	3.3E-09	1.1E-07	4%	N	0.83%
Thallium (total)	1.0E-03	default	6.24E-06	6.2E-09	2.0E-07	100%	N	0.17%
Vanadium (total)	1.0E-03	default	1.90E-05	1.9E-08	6.1E-07	2.6%	N	6.35%

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01) **Cancer Dermal Absorbed Dose Calculations**
for Indoor Worker Exposures to Inorganics in Acid Area 2 Groundwater.

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 3.30E+03 cm2
 t_event = 1.00E+00 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 2.50E+02 days/yr
 ED = 2.50E+01 years
 BW = 7.00E+01 kg
 AT = 2.56E+04 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E-03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr *1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed Total Dose
Aluminum (total)	1.0E-03 default	default	8.10E-03	8.1E-06	9.3E-05	15%	1.10% N
Arsenic (total)	1.0E-03 default	default	7.21E-06	7.2E-09	8.3E-08	95%	0.17% N
Barium (total)	1.0E-03 default	default	1.33E-03	1.3E-06	1.5E-05	7%	2.36% N
Chromium (total)	1.0E-03 experimental	experimental	6.20E-06	6.2E-09	7.2E-08	1.3%	12.69% Y
Cyanide	1.0E-03 default	default	8.68E-05	8.7E-08	1.0E-06	47%	0.35% N
Iron (total)	1.0E-03 default	default	1.91E-02	1.9E-05	2.2E-04	6%	2.75% N
Manganese (total)	1.0E-03 default	default	4.46E-04	4.5E-07	5.1E-06	6%	2.75% N
Nickel (total)	2.0E-04 experimental	experimental	1.64E-05	3.3E-09	3.8E-08	4%	0.83% N
Thallium (total)	1.0E-03 default	default	6.24E-06	6.2E-09	7.2E-08	100%	0.17% N
Vanadium (total)	1.0E-03 default	default	1.90E-05	1.9E-08	2.2E-07	2.6%	6.35% N

**Cancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L/1000 cm3):

Input site specific concentrations in Column marked "Conc"

Area exposed (cm2):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

lsc =

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV

Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*) outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MUEB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp (cm/hr) predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Chemicals Drink	Chem Assess Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm3)	Kp used in DA_event	DA_event (mg/cm2-ev)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	6.6E-01	70% Y	0%	0%	0.2	16.64	39.93	0.8	2.56E-06	2.5E-02	1.1E-06	2.5E-07	-5.0E+00	1.00E-05	1.00E-08

**Noncancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Organics in Acid Area 2 Surface Water.**

FOR ORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Organic Chemicals from Aqueous Media (latest version 04/01)

Enter the Following Exposure Conditions: for site specific conditions, change values in Cells B8-B18

The default exposure conditions used in this spreadsheet assume exposure duration for

carcinogenic effects of chemicals in water through showering

Concentration (mg/L/1000 cm³):

Area exposed (cm²):

Event time (hr/event):

Event frequency (events/day):

Exposure frequency (days/year):

Exposure duration (years):

for carcinogenic effects, ED = 30 years (used in this spreadsheet)

for noncarcinogenic effects, ED = 9 years

Body weight (kg):

Averaging time (days):

for carcinogenic effects, AT=70 years (25,550 days)

for noncarcinogenic effects, AT=ED (in days)

Skin thickness (assumed to be 10 um):

Conc = 1E-03 mg/cm³ (default value for purpose of illustration)

SA = 3100 cm²

L_event = 4.00 hr/event (35 minutes/event)

EF = 1.0 event/day

ED = 250.0 days/yr

0.5 years

BW = 70.0 kg

AT = 183 days

lsc = 1.00E-03 cm

IR = 2000 (cm³/day = L/day * 1000 cm³/L)

ABSGI = 1.0 (assumed 100% GI absorption)

IR: Ingestion rate of drinking water

ABSIG: Absorption fraction in GI tract

Refer to Appendix A for equations to evaluate DA_event and DAD

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/min)

(*): outside of the Effective Prediction Domain (EPD) determined by the Flynn's measured Kp data

as evaluated using MLAB (Civilized Software, Bethesda, MD)

95% LCI and UCI are evaluated using STATA

(**): halogenated chemicals.

Note:

CHEMICAL	CAS No.	MWT	logKow	Kp 95% LCI	Kp predicted	Kp (cm/hr) measured	Kp 95% UCI	Special Chemicals (*) or (**)	Derm/ Chemicals Drink	Chem Derm/ Assess Total Dose	B	tau (hr)	t_star (hr)	FA	Conc (mg/cm ³)	Kp used in DA_event	DA_event (mg/cm ² -evt)	DAD (mg/kg-day)	log(Ds/lsc)	Dsc/lsc	Dsc
58 bis(2-Ethylhexyl)phthalate	117817	391.0	5.11	9.4E-04	2.5E-02	6.6E-01	70% Y	0%	70% Y	0%	0.2	16.64	39.93	0.8	2.55E-06	2.5E-02	1.1E-06	3.5E-05	-5.0E+00	1.00E-05	1.00E-08

**Cancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 3.10E+03 cm2
 T_event = 4.00E+00 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 2.50E+02 days/yr
 ED = 5.00E-01 years
 BW = 7.00E+01 kg
 AT = 2.56E+04 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water
 ABSIG: Absorption fraction in GI tract
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/ Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSIG (chemical specific)	Screening Chemicals to Dermal be assessed	Total Dose
Aluminum	1.0E-03 default	default	6.34E-04	2.5E-06	5.5E-07	15%	4.13%	N
Arsenic	1.0E-03 default	default	3.20E-06	1.3E-08	2.8E-09	95%	0.65%	N
Iron	1.0E-03 default	default	9.89E-04	4.0E-06	8.6E-07	6%	10.33%	Y
Manganese	1.0E-03 default	default	5.95E-05	2.4E-07	5.2E-08	6%	10.33%	Y
Vanadium	1.0E-03 default	default	1.54E-05	6.2E-08	1.3E-08	2.6%	23.85%	Y

**Noncancer Dermal Absorbed Dose Calculations
for Construction Worker Exposures to Inorganics in Acid Area 2 Surface Water.**

FOR INORGANIC CHEMICALS IN WATER (latest version 04/01)

Worksheet to Calculate Dermal Absorption of Inorganic Chemicals from Aqueous Media

Enter the Following Exposure Conditions: for site specific conditions, change values for A through AT (Given are default values from Table 8-6)

Conc = 1.00E-03 mg/cm3 (default value for purpose of illustration)
 SA= 3.10E+03 cm2
 L_event = 4.00E+00 hr/event (35 minutes/event)
 EV = 1.00E+00 event/day
 EF = 2.50E+02 days/yr
 ED = 5.00E-01 years
 BW = 7.00E+01 kg
 AT = 1.83E+02 days

Default conditions for screening purposes:

Compare Dermal to Drinking: Adults showering for 35 minutes/day, compared to drinking 2L water/day

Dermal (mg/day) = DA_event * A * EV
 Drinking (mg/day) = Conc * IR * ABSIG

IR: Ingestion rate of drinking water IR = 2.00E+03 (cm3/day = L/day * 1000 cm3/L)
 ABSIG: Absorption fraction in GI tract Chemical specific
 Condition for screening: "Y" when Dermal is 10% of Drinking

Compare Dermal to Total dose exposed during adult showering assuming 5 gal/min of water flow rate

Total dose (mg/day) = Q * T_event * EV

Q: Shower flow rate (5-15 gal/min; here using 5 gal/Q = 1.14E+06 (cm3/hr = gal/min * 3.785 gal/l * 60 min/hr * 1000 cm3/hr)

Refer to Appendix A for equations to evaluate DA_event and DAD

CHEMICAL	Kp (cm/hr)	Source of Kp (exp or default)	Conc (mg/cm3)	DA_event (mg/cm2-event)	DAD (mg/kg-day)	ABSGI (chemical specific)	Screening Chemicals to Dermal be assessed Total Dose
Aluminum	1.0E-03 default	default	6.34E-04	2.5E-06	7.7E-05	15%	4.13% N
Arsenic	1.0E-03 default	default	3.20E-06	1.3E-08	3.9E-07	95%	0.65% N
Iron	1.0E-03 default	default	9.89E-04	4.0E-06	1.2E-04	6%	10.33% Y
Manganese	1.0E-03 default	default	5.95E-05	2.4E-07	7.2E-06	6%	10.33% Y
Vanadium	1.0E-03 default	default	1.54E-05	6.2E-08	1.9E-06	2.6%	23.85% Y

APPENDIX B
RISK CALCULATIONS

Table B-1. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	9.31E-03	9.31E-03	3.33E-03	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	7.46E-06	2.49E-02	2.66E-06	1.50E+00	3.99E-06	
Iron	2.03E+04	7.00E-01	1.99E-02	2.84E-02	7.09E-03	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	2.87E-03	NA	1.03E-03	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	3.67E-04	7.86E-03	1.31E-04	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	5.13E-06	7.32E-02	1.83E-06	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	2.37E-05	4.74E-03	8.46E-06	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	1.57E-05	7.83E-01	5.59E-06	No toxicity value	NA	
PCB-1260	4.29E+00	No toxicity value	4.20E-06	NA	1.50E-06	2.00E+00	1.12E-05	
Benzo(a)anthracene	8.50E+00	No toxicity value	8.32E-06	NA	2.97E-06	2.00E+00	3.00E-06	
Benzo(a)pyrene	7.30E+00	No toxicity value	7.14E-06	NA	2.55E-06	7.30E-01	2.17E-06	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	9.49E-06	NA	3.39E-06	7.30E+00	1.86E-05	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	5.26E-07	NA	1.88E-07	7.30E-01	2.47E-06	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.25E-06	NA	4.47E-07	7.30E-02	1.37E-08	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	4.72E-07	NA	1.68E-07	7.30E+00	3.27E-06	
						7.30E-01	1.23E-07	
Hazard Index				9.31E-01				
Total Cancer Risk					4.48E-05			

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-2. Risks and Hazards from Dermal contact with Surface Soil at Acid Area 2 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	ND	NA	ND	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	2.27E-07	7.58E-04	8.12E-08	1.50E+00	1.22E-07	
Iron	2.03E+04	7.00E-01	ND	NA	ND	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	ND	NA	ND	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	ND	NA	ND	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	ND	NA	ND	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	ND	NA	ND	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	2.23E-06	1.11E-01	7.96E-07	2.00E+00	1.59E-06	
PCB-1260	4.29E+00	No toxicity value	5.98E-07	NA	2.13E-07	2.00E+00	4.27E-07	
Benzo(a)anthracene	8.50E+00	No toxicity value	1.10E-06	NA	3.93E-07	7.30E-01	2.87E-07	
Benzo(a)pyrene	7.30E+00	No toxicity value	9.44E-07	NA	3.37E-07	7.30E+00	2.46E-06	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	1.25E-06	NA	4.48E-07	7.30E-01	3.27E-07	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	6.96E-08	NA	2.49E-08	7.30E-02	1.81E-09	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.66E-07	NA	5.91E-08	7.30E+00	4.32E-07	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	6.24E-08	NA	2.23E-08	7.30E-01	1.63E-08	
Hazard Index				1.12E-01				
Total Cancer Risk							5.67E-06	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-3. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 2 for Groundskeeper Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.43E-03	4.35E-07	3.05E-04	1.55E-07	No toxicity value	NA	
Arsenic	7.62E+00	No toxicity value	3.48E-10	NA	1.24E-10	1.51E+01	1.87E-09	
Iron	2.03E+04	No toxicity value	9.28E-07	NA	3.31E-07	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	1.34E-07	NA	4.79E-08	No toxicity value	NA	
Manganese	3.75E+02	1.40E-05	1.71E-08	1.22E-03	6.12E-09	No toxicity value	NA	
Thallium	5.24E+00	No toxicity value	2.40E-10	NA	8.56E-11	No toxicity value	NA	
Vanadium	2.42E+01	No toxicity value	1.11E-09	NA	3.95E-10	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	7.32E-10	3.66E-05	2.61E-10	No toxicity value	NA	
PCB-1260	4.29E+00	No toxicity value	1.96E-10	NA	7.01E-11	2.00E+00	5.23E-10	
Benzo(a)anthracene	8.50E+00	No toxicity value	3.89E-10	NA	1.39E-10	2.00E+00	1.40E-10	
Benzo(a)pyrene	7.30E+00	No toxicity value	3.34E-10	NA	1.19E-10	3.10E-01	4.30E-11	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	4.44E-10	NA	1.58E-10	3.10E+00	3.70E-10	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	2.46E-11	NA	8.79E-12	3.10E-01	4.91E-11	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	5.85E-11	NA	2.09E-11	3.10E-02	2.72E-13	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	2.20E-11	NA	7.87E-12	3.10E+00	6.48E-11	
Hazard Index				1.57E-03				2.44E-12
Total Cancer Risk								3.06E-09

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-4. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Adult Hunter Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	9.52E+03	1.00E+00	5.22E-04	5.22E-04	2.24E-04	No toxicity value	NA		
Arsenic	7.62E+00	3.00E-04	4.18E-07	1.39E-03	1.79E-07	1.50E+00	2.68E-07		
Iron	2.03E+04	7.00E-01	1.11E-03	1.59E-03	4.77E-04	No toxicity value	NA		
Lead	2.94E+03	No toxicity value	1.61E-04	NA	6.89E-05	No toxicity value	NA		
Manganese	3.75E+02	4.67E-02	2.05E-05	4.40E-04	8.81E-06	No toxicity value	NA		
Thallium	5.24E+00	7.00E-05	2.87E-07	4.10E-03	1.23E-07	No toxicity value	NA		
Vanadium	2.42E+01	5.00E-03	1.33E-06	2.65E-04	5.68E-07	No toxicity value	NA		
PCB-1254	1.60E+01	2.00E-05	8.77E-07	4.38E-02	3.76E-07	No toxicity value	NA		
PCB-1260	4.29E+00	No toxicity value	2.35E-07	NA	1.01E-07	2.00E+00	7.51E-07		
Benzo(a)anthracene	8.50E+00	No toxicity value	4.66E-07	NA	2.00E-07	2.00E+00	2.01E-07		
Benzo(a)pyrene	7.30E+00	No toxicity value	4.00E-07	NA	1.71E-07	7.30E-01	1.46E-07		
Benzo(b)fluoranthene	9.70E+00	No toxicity value	5.32E-07	NA	2.28E-07	7.30E+00	1.25E-06		
Benzo(k)fluoranthene	5.38E-01	No toxicity value	2.95E-08	NA	1.26E-08	7.30E-01	1.66E-07		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	7.01E-08	NA	3.01E-08	7.30E-02	9.22E-10		
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	2.64E-08	NA	1.13E-08	7.30E+00	2.19E-07		
Hazard Index				5.21E-02			8.26E-09		
Total Cancer Risk							3.01E-06		

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-5. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 2 for Adult Hunter Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	9.52E+03	1.00E+00	ND	NA	ND	No toxicity value	NA		
Arsenic	7.62E+00	3.00E-04	1.13E-07	3.76E-04	4.83E-08	1.50E+00	7.25E-08		
Iron	2.03E+04	7.00E-01	ND	NA	ND	No toxicity value	NA		
Lead	2.94E+03	No toxicity value	ND	NA	ND	No toxicity value	NA		
Manganese	3.75E+02	4.67E-02	ND	NA	ND	No toxicity value	NA		
Thallium	5.24E+00	7.00E-05	ND	NA	ND	No toxicity value	NA		
Vanadium	2.42E+01	5.00E-03	ND	NA	ND	No toxicity value	NA		
PCB-1254	1.60E+01	2.00E-05	1.10E-06	5.52E-02	4.73E-07	2.00E+00	9.47E-07		
PCB-1260	4.29E+00	No toxicity value	2.96E-07	NA	1.27E-07	2.00E+00	2.54E-07		
Benzo(a)anthracene	8.50E+00	No toxicity value	5.45E-07	NA	2.34E-07	7.30E-01	1.70E-07		
Benzo(a)pyrene	7.30E+00	No toxicity value	4.68E-07	NA	2.01E-07	7.30E+00	1.46E-06		
Benzo(b)fluoranthene	9.70E+00	No toxicity value	6.22E-07	NA	2.67E-07	7.30E-01	1.95E-07		
Benzo(k)fluoranthene	5.38E-01	No toxicity value	3.45E-08	NA	1.48E-08	7.30E-02	1.08E-09		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	8.21E-08	NA	3.52E-08	7.30E+00	2.57E-07		
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	3.09E-08	NA	1.32E-08	7.30E-01	9.67E-09		
Hazard Index				5.56E-02					
Total Cancer Risk							3.37E-06		

RfD = reference dose

RME = reasonable maximum exposure

SF = slope factor

kg = kilogram

mg = milligram

Table B-6. Risks and Hazards from Ingestion of Venison Harvested from Acid Area 2 for Adult Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Venison (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	1.86E-04	1.00E+00	3.32E-08	3.32E-08	1.42E-08	No toxicity value	NA		
Arsenic	2.65E-07	3.00E-04	4.72E-11	1.57E-07	2.02E-11	1.50E+00	3.04E-11		
Iron	7.06E-02	7.00E-01	1.26E-05	1.80E-05	5.39E-06	No toxicity value	NA		
Lead	2.30E-06	No toxicity value	4.09E-10	NA	1.75E-10	No toxicity value	NA		
Manganese	5.22E-07	4.67E-02	9.30E-11	1.99E-09	3.98E-11	No toxicity value	NA		
Thallium	7.29E-05	7.00E-05	1.30E-08	1.86E-04	5.57E-09	No toxicity value	NA		
Vanadium	1.32E-06	5.00E-03	2.34E-10	4.69E-08	1.00E-10	No toxicity value	NA		
PCB-1254	4.44E-05	2.00E-05	7.91E-09	3.96E-04	3.39E-09	No toxicity value	NA		
PCB-1260	3.37E-06	No toxicity value	6.00E-10	NA	2.57E-10	2.00E+00	6.78E-09		
Benzo(a)anthracene	1.40E-06	No toxicity value	2.49E-10	NA	1.07E-10	2.00E+00	5.15E-10		
Benzo(a)pyrene	1.46E-06	No toxicity value	2.60E-10	NA	1.11E-10	7.30E-01	7.79E-11		
Benzo(b)fluoranthene	2.40E-06	No toxicity value	4.27E-10	NA	1.83E-10	7.30E+00	8.14E-10		
Benzo(k)fluoranthene	1.73E-07	No toxicity value	3.08E-11	NA	1.32E-11	7.30E-01	1.34E-10		
Dibenz(a,h)anthracene	1.23E-06	No toxicity value	2.19E-10	NA	9.39E-11	7.30E-02	9.63E-13		
Indeno(1,2,3-cd)pyrene	9.86E-08	No toxicity value	1.76E-11	NA	7.53E-12	7.30E+00	6.86E-10		
Hazard Index				5.99E-04					
Total Cancer Risk								9.05E-09	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-7. Risks and Hazards from Ingestion of Venison Harvested from Acid Area 2 for Child Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Venison (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	1.86E-04	1.00E+00	5.96E-08	5.96E-08	5.10E-09	No toxicity value	NA		
Arsenic	2.65E-07	3.00E-04	8.48E-11	2.83E-07	7.27E-12	1.50E+00	1.09E-11		
Iron	7.06E-02	7.00E-01	2.26E-05	3.23E-05	1.94E-06	No toxicity value	NA		
Lead	2.30E-06	No toxicity value	7.35E-10	NA	6.30E-11	No toxicity value	NA		
Manganese	5.22E-07	4.67E-02	1.67E-10	3.58E-09	1.43E-11	No toxicity value	NA		
Thallium	7.29E-05	7.00E-05	2.33E-08	3.33E-04	2.00E-09	No toxicity value	NA		
Vanadium	1.32E-06	5.00E-03	4.21E-10	8.41E-08	3.61E-11	No toxicity value	NA		
PCB-1254	4.44E-05	2.00E-05	1.42E-08	7.10E-04	1.22E-09	No toxicity value	NA		
PCB-1260	3.37E-06	No toxicity value	1.08E-09	NA	9.24E-11	2.00E+00	2.44E-09		
Benzo(a)anthracene	1.40E-06	No toxicity value	4.47E-10	NA	3.83E-11	2.00E+00	1.85E-10		
Benzo(a)pyrene	1.46E-06	No toxicity value	4.67E-10	NA	4.00E-11	7.30E-01	2.80E-11		
Benzo(b)fluoranthene	2.40E-06	No toxicity value	7.67E-10	NA	6.58E-11	7.30E+00	2.92E-10		
Benzo(k)fluoranthene	1.73E-07	No toxicity value	5.52E-11	NA	4.74E-12	7.30E-01	4.80E-11		
Dibenz(a,h)anthracene	1.23E-06	No toxicity value	3.93E-10	NA	3.37E-11	7.30E-02	3.46E-13		
Indeno(1,2,3-cd)pyrene	9.86E-08	No toxicity value	3.15E-11	NA	2.70E-12	7.30E+00	2.46E-10		
Hazard Index							1.08E-03		
Total Cancer Risk								3.25E-09	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-8. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	5.40E-02	5.40E-02	3.86E-04	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	4.32E-05	1.44E-01	3.09E-07	1.50E+00	4.63E-07	
Iron	2.03E+04	7.00E-01	1.15E-01	1.65E-01	8.23E-04	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	1.67E-02	NA	1.19E-04	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	2.13E-03	4.56E-02	1.52E-05	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	2.97E-05	4.25E-01	2.12E-07	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	1.37E-04	2.75E-02	9.81E-07	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	9.08E-05	4.54E+00	6.49E-07	2.00E+00	1.30E-06	
PCB-1260	4.29E+00	No toxicity value	2.43E-05	NA	1.74E-07	2.00E+00	3.48E-07	
Benzo(a)anthracene	8.50E+00	No toxicity value	4.82E-05	NA	3.45E-07	7.30E-01	2.52E-07	
Benzo(a)pyrene	7.30E+00	No toxicity value	4.14E-05	NA	2.96E-07	7.30E+00	2.16E-06	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	5.50E-05	NA	3.93E-07	7.30E-01	2.87E-07	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	3.03E-06	NA	2.18E-08	7.30E-02	1.59E-09	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	7.26E-06	NA	5.19E-08	7.30E+00	3.79E-07	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	2.74E-06	NA	1.95E-08	7.30E-01	1.43E-08	
Hazard Index				5.40E+00				
Total Cancer Risk							5.20E-06	

kg = kilogram

mg = milligram

RfD = reference dose

RME = reasonable maximum exposure

SF = slope factor

Table B-9. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	ND	NA	ND	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	4.04E-06	1.35E-02	2.89E-08	1.50E+00	4.33E-08	
Iron	2.03E+04	7.00E-01	ND	NA	ND	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	ND	NA	ND	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	ND	NA	ND	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	ND	NA	ND	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	ND	NA	ND	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	3.96E-05	1.98E+00	2.83E-07	2.00E+00	5.66E-07	
PCB-1260	4.29E+00	No toxicity value	1.06E-05	NA	7.59E-08	2.00E+00	1.52E-07	
Benzo(a)anthracene	8.50E+00	No toxicity value	1.95E-05	NA	1.40E-07	7.30E-01	1.02E-07	
Benzo(a)pyrene	7.30E+00	No toxicity value	1.68E-05	NA	1.20E-07	7.30E+00	8.75E-07	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	2.23E-05	NA	1.59E-07	7.30E-01	1.16E-07	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	1.24E-06	NA	8.84E-09	7.30E-02	6.45E-10	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	2.94E-06	NA	2.10E-08	7.30E+00	1.53E-07	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	1.11E-06	NA	7.92E-09	7.30E-01	5.78E-09	
Hazard Index				1.99E+00				
Total Cancer Risk							2.01E-06	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-10. Risks and Hazards from inhalation of Surface Soil at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.43E-03	8.70E-07	6.09E-04	6.22E-09	No toxicity value	NA	
Arsenic	7.62E+00	No toxicity value	6.97E-10	NA	4.98E-12	1.51E+01	7.49E-11	
Iron	2.03E+04	No toxicity value	1.86E-06	NA	1.33E-08	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	2.68E-07	NA	1.92E-09	No toxicity value	NA	
Manganese	3.75E+02	1.40E-05	3.43E-08	2.45E-03	2.45E-10	No toxicity value	NA	
Thallium	5.24E+00	No toxicity value	4.79E-10	NA	3.42E-12	No toxicity value	NA	
Vanadium	2.42E+01	No toxicity value	2.21E-09	NA	1.58E-11	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	1.46E-09	7.32E-05	1.05E-11	No toxicity value	NA	
PCB-1260	4.29E+00	No toxicity value	3.92E-10	NA	2.80E-12	2.00E+00	2.09E-11	
Benzo(a)anthracene	8.50E+00	No toxicity value	7.77E-10	NA	5.55E-12	2.00E+00	5.60E-12	
Benzo(a)pyrene	7.30E+00	No toxicity value	6.68E-10	NA	4.77E-12	3.10E-01	1.72E-12	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	8.87E-10	NA	6.34E-12	3.10E+00	1.48E-11	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	4.92E-11	NA	3.51E-13	3.10E-01	1.96E-12	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.17E-10	NA	8.36E-13	3.10E-02	1.09E-14	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	4.41E-11	NA	3.15E-13	3.10E+00	2.59E-12	
Hazard Index				3.13E-03			9.76E-14	
Total Cancer Risk							1.23E-10	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-11. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)				Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME			
Aluminum	1.09E+04	1.00E+00	6.21E-02	6.21E-02	4.43E-04	No toxicity value	NA			
Arsenic	9.14E+00	3.00E-04	5.19E-05	1.73E-01	3.71E-07	1.50E+00	5.56E-07			
Chromium	1.78E+01	3.00E-03	1.01E-04	3.37E-02	7.22E-07	No toxicity value	NA			
Iron	2.45E+04	7.00E-01	1.39E-01	1.99E-01	9.93E-04	No toxicity value	NA			
Lead	3.14E+01	No toxicity value	1.78E-04	NA	1.27E-06	No toxicity value	NA			
Manganese	5.05E+02	4.67E-02	2.87E-03	6.14E-02	2.05E-05	No toxicity value	NA			
Thallium	1.82E+01	7.00E-05	1.03E-04	1.48E+00	7.38E-07	No toxicity value	NA			
Vanadium	2.72E+01	5.00E-03	1.54E-04	3.09E-02	1.10E-06	No toxicity value	NA			
PCB-1254	3.33E-01	2.00E-05	1.89E-06	9.45E-02	1.35E-08	No toxicity value	NA			
PCB-1260	2.56E+00	No toxicity value	1.45E-05	NA	1.04E-07	2.00E+00	2.70E-08			
Benzo(a)anthracene	3.40E+00	No toxicity value	1.93E-05	NA	1.38E-07	2.00E+00	2.08E-07			
Benzo(a)pyrene	3.05E+00	No toxicity value	1.73E-05	NA	1.24E-07	7.30E-01	1.01E-07			
Benzo(b)fluoranthene	2.41E+00	No toxicity value	1.37E-05	NA	9.77E-08	7.30E+00	9.03E-07			
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	7.26E-06	NA	5.19E-08	7.30E-01	7.13E-08			
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	2.39E-05	NA	1.71E-07	7.30E+00	3.79E-07			
Hazard Index				2.13E+00				2.37E-06		
Total Cancer Risk								2.37E-06		

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-12. Risks and Hazards from Dermal contact with Subsurface Soil at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	1.09E+04	1.00E+00	ND	NA	ND	No toxicity value	NA		
Arsenic	9.14E+00	3.00E-04	4.85E-06	1.62E-02	3.46E-08	1.50E+00	5.20E-08		
Chromium	1.78E+01	3.00E-03	ND	NA	ND	No toxicity value	NA		
Iron	2.45E+04	7.00E-01	ND	NA	ND	No toxicity value	NA		
Lead	3.14E+01	No toxicity value	ND	NA	ND	No toxicity value	NA		
Manganese	5.05E+02	4.67E-02	ND	NA	ND	No toxicity value	NA		
Thallium	1.82E+01	7.00E-05	ND	NA	ND	No toxicity value	NA		
Vanadium	2.72E+01	5.00E-03	ND	NA	ND	No toxicity value	NA		
PCB-1254	3.33E-01	2.00E-05	8.25E-07	4.12E-02	5.89E-09	2.00E+00	1.18E-08		
PCB-1260	2.56E+00	No toxicity value	6.34E-06	NA	4.53E-08	2.00E+00	9.06E-08		
Benzo(a)anthracene	3.40E+00	No toxicity value	7.82E-06	NA	5.59E-08	7.30E-01	4.08E-08		
Benzo(a)pyrene	3.05E+00	No toxicity value	7.01E-06	NA	5.01E-08	7.30E+00	3.66E-07		
Benzo(b)fluoranthene	2.41E+00	No toxicity value	5.54E-06	NA	3.96E-08	7.30E-01	2.89E-08		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	2.94E-06	NA	2.10E-08	7.30E+00	1.53E-07		
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	9.71E-06	NA	6.93E-08	7.30E-01	5.06E-08		
Hazard Index				5.74E-02					
Total Cancer Risk					7.94E-07				

RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

kg = kilogram
mg = milligram

Table B-13. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration In Surface Water (mg/L)		Noncarcinogenic Effects:				Carcinogenic Effects:	
	RME		Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	6.34E-01		1.00E+00	7.67E-05	7.67E-05	5.49E-07	No toxicity value	NA
Arsenic	3.20E-03		3.00E-04	3.87E-07	1.29E-03	2.77E-09	1.50E+00	4.16E-09
Iron	9.89E-01		7.00E-01	1.20E-04	1.71E-04	8.57E-07	No toxicity value	NA
Lead	3.90E-03		No toxicity value	NA	NA	NA	No toxicity value	NA
Manganese	5.95E-02		4.67E-02	7.20E-06	1.54E-04	5.16E-08	No toxicity value	NA
Vanadium	1.54E-02		5.00E-03	1.86E-06	3.73E-04	1.33E-08	No toxicity value	NA
bis(2-Ethylhexyl)phthalate	2.55E-03		2.00E-02	3.47E-05	1.73E-03	2.48E-07	1.40E-02	3.48E-09
			#N/A		NA		#N/A	NA
Hazard Index					3.80E-03			
Total Cancer Risk								7.64E-09

RME = reasonable maximum exposure

RfD = reference dose

Sf = slope factor

Table B-14. Risks and Hazards from Ingestion of Sediment at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	1.08E+04	1.00E+00	3.05E-02	3.05E-02	7.50E-05	No toxicity value	NA	
Arsenic	7.55E+00	3.00E-04	2.14E-05	7.14E-02	5.26E-08	1.50E+00	7.90E-08	
Chromium	1.75E+01	3.00E-03	4.97E-05	1.66E-02	1.22E-07	No toxicity value	NA	
Iron	2.16E+04	7.00E-01	6.12E-02	8.75E-02	1.50E-04	No toxicity value	NA	
Lead	7.76E+02	No toxicity value	2.20E-03	NA	5.41E-06	No toxicity value	NA	
Manganese	2.03E+02	4.67E-02	5.76E-04	1.23E-02	1.42E-06	No toxicity value	NA	
Thallium	4.73E+00	7.00E-05	1.34E-05	1.92E-01	3.30E-08	No toxicity value	NA	
Vanadium	2.41E+01	5.00E-03	6.84E-05	1.37E-02	1.68E-07	No toxicity value	NA	
PCB-1254	1.52E+00	2.00E-05	4.31E-06	2.16E-01	1.06E-08	2.00E+00	2.12E-08	
PCB-1260	5.78E+00	No toxicity value	1.64E-05	NA	4.03E-08	2.00E+00	8.06E-08	
Benzo(a)anthracene	3.27E-01	No toxicity value	9.28E-07	NA	2.28E-09	7.30E-01	1.66E-09	
Benzo(a)pyrene	2.90E+00	No toxicity value	8.23E-06	NA	2.02E-08	7.30E+00	1.48E-07	
Benzo(b)fluoranthene	2.90E+00	No toxicity value	8.23E-06	NA	2.02E-08	7.30E-01	1.48E-08	
Dibenz(a,h)anthracene	3.20E-01	No toxicity value	9.08E-07	NA	2.23E-09	7.30E+00	1.63E-08	
Indeno(1,2,3-cd)pyrene	2.42E-01	No toxicity value	6.87E-07	NA	1.69E-09	7.30E-01	1.23E-09	
N-Nitroso-dl-n-propylamine	2.72E-01	No toxicity value	7.72E-07	NA	1.90E-09	7.00E+00	1.33E-08	
Hazard Index				6.39E-01				
Total Cancer Risk							3.76E-07	

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure

SF = slope factor

Table B-15. Risks and Hazards from Dermal Contact with Sediment at Acid Area 2 for Construction Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Noncarcinogenic Effects:				Carcinogenic Effects:	
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.08E+04	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.55E+00	3.00E-04	5.67E-07	1.89E-03	4.05E-09	1.50E+00	6.08E-09
Chromium	1.75E+01	3.00E-03	ND	NA	ND	No toxicity value	NA
Iron	2.16E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	7.76E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	2.03E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	4.73E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.41E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	1.52E+00	2.00E-05	5.33E-07	2.66E-02	3.81E-09	2.00E+00	7.61E-09
PCB-1260	5.78E+00	No toxicity value	2.03E-06	NA	1.45E-08	2.00E+00	2.89E-08
Benzo(a)anthracene	3.27E-01	No toxicity value	1.06E-07	NA	7.60E-10	7.30E-01	5.55E-10
Benzo(b)fluoranthene	2.90E+00	No toxicity value	9.44E-07	NA	6.74E-09	7.30E+00	4.92E-08
Dibenz(a,h)anthracene	2.90E+00	No toxicity value	9.44E-07	NA	6.74E-09	7.30E-01	4.92E-09
Indeno(1,2,3-cd)pyrene	3.20E-01	No toxicity value	1.04E-07	NA	7.44E-10	7.30E+00	5.43E-09
N-Nitroso-di-n-propylamine	2.42E-01	No toxicity value	7.88E-08	NA	5.63E-10	7.30E-01	4.11E-10
2.72E-01	No toxicity value	ND	ND	NA	ND	7.00E+00	NA
Hazard Index				2.85E-02			
Total Cancer Risk							1.03E-07

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure

SF = slope factor

Table B-16. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 2 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L)				Noncarcinogenic Effects:				Carcinogenic Effects:	
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day)		Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Cancer Lifetime Risk (Intake x sf) RME	Carcinogenic Effects:	
			RME	RME					Excess Lifetime Cancer Risk (Intake x sf) RME	
1,1,2-Trichloroethane	6.23E-03	4.00E-03	6.10E-05	1.53E-02	2.18E-05	5.70E-02	1.24E-06			
1,3-Dinitrobenzene	9.74E-05	1.00E-04	9.53E-07	9.53E-03	3.40E-07	No toxicity value	NA			
2-Methylnaphthalene	5.80E-03	2.00E-02	5.68E-05	2.84E-03	2.03E-05	No toxicity value	NA			
2-Nitrotoluene	9.83E-05	1.00E-02	9.62E-07	9.62E-05	3.44E-07	2.30E-01	7.90E-08			
Aluminum (total)	8.10E+00	1.00E+00	7.93E-02	7.93E-02	2.83E-02	No toxicity value	NA			
Arsenic (total)	7.21E-03	3.00E-04	7.05E-05	2.35E-01	2.52E-05	1.50E+00	3.78E-05			
Barium (total)	1.33E+00	2.00E-01	1.31E-02	6.53E-02	4.66E-03	No toxicity value	NA			
Benzene	3.09E-02	4.00E-03	3.02E-04	7.55E-02	1.08E-04	5.50E-02	5.93E-06			
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	4.75E-05	2.38E-03	1.70E-05	1.40E-02	2.38E-07			
Bromomethane	5.83E-03	1.40E-03	5.71E-05	4.08E-02	2.04E-05	No toxicity value	NA			
Chlorobenzene	5.00E-03	2.00E-02	4.89E-05	2.45E-03	1.75E-05	No toxicity value	NA			
Chloromethane	9.73E-03	No toxicity value	9.52E-05	NA	3.40E-05	No toxicity value	NA			
Chromium (total)	6.20E-03	3.00E-03	6.07E-05	2.02E-02	2.17E-05	No toxicity value	NA			
Cyanide	8.68E-02	2.00E-02	8.49E-04	4.25E-02	3.03E-04	No toxicity value	NA			
Iron (total)	1.91E+01	7.00E-01	1.86E-01	2.66E-01	6.66E-02	No toxicity value	NA			
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA			
Manganese (total)	4.46E-01	4.67E-02	4.36E-03	9.35E-02	1.56E-03	No toxicity value	NA			
Methylene Chloride	8.92E-03	6.00E-02	8.72E-05	1.45E-03	3.12E-05	No toxicity value	2.34E-07			
Naphthalene	5.00E-03	2.00E-02	4.89E-05	2.45E-03	1.75E-05	No toxicity value	NA			
Nickel (total)	1.64E-02	2.00E-02	1.61E-04	8.04E-03	5.74E-05	No toxicity value	NA			
Nitrobenzene	1.91E-03	5.00E-04	1.87E-05	3.74E-02	6.68E-06	No toxicity value	NA			
Thallium (total)	6.24E-03	7.00E-05	6.10E-05	8.72E-01	2.18E-05	No toxicity value	NA			
Vanadium (total)	1.90E-02	5.00E-03	1.86E-04	3.72E-02	6.65E-05	No toxicity value	NA			
Xylenes, total	1.38E-01	2.00E-01	1.35E-03	6.76E-03	4.83E-04	No toxicity value	NA			
Hazard Index					1.92E+00					
Total Cancer Risk								4.55E-05		

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-17. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 2 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Dermal Absorbed Dose RME	Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
1,1,2-Trichloroethane	6.23E-03	4.00E-03	2.77E-06	6.92E-04	9.88E-07	5.70E-02	5.63E-08	
1,3-Dinitrobenzene	9.74E-05	1.00E-04	1.53E-08	1.53E-04	5.48E-09	No toxicity value	NA	
2-Methylnaphthalene	5.80E-03	2.00E-02	4.13E-05	2.06E-03	1.47E-05	No toxicity value	NA	
2-Nitrotoluene	9.83E-05	1.00E-02	7.86E-08	7.86E-06	2.81E-08	2.30E-01	6.45E-09	
Aluminum (total)	8.10E+00	1.00E+00	2.62E-04	2.62E-04	9.34E-05	No toxicity value	NA	
Arsenic (total)	7.21E-03	3.00E-04	2.33E-07	7.76E-04	8.31E-08	1.50E+00	1.25E-07	
Barium (total)	1.33E+00	2.00E-01	4.31E-05	2.15E-04	1.54E-05	No toxicity value	NA	
Benzene	3.09E-02	4.00E-03	2.32E-05	5.80E-03	8.28E-06	5.50E-02	4.55E-07	
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	3.53E-05	1.76E-03	1.26E-05	1.40E-02	1.76E-07	
Bromomethane	5.83E-03	1.40E-03	9.20E-07	6.57E-04	3.29E-07	No toxicity value	NA	
Chlorobenzene	5.00E-03	2.00E-02	8.50E-06	4.25E-04	3.04E-06	No toxicity value	NA	
Chloromethane	9.73E-03	No toxicity value	1.45E-06	NA	5.17E-07	No toxicity value	NA	
Chromium (total)	6.20E-03	3.00E-03	2.00E-07	6.68E-05	7.15E-08	No toxicity value	NA	
Cyanide	8.68E-02	2.00E-02	2.80E-06	1.40E-04	1.00E-06	No toxicity value	NA	
Iron (total)	1.91E+01	7.00E-01	6.15E-04	8.79E-04	2.20E-04	No toxicity value	NA	
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA	
Manganese (total)	4.46E-01	4.67E-02	1.44E-05	3.09E-04	5.14E-06	No toxicity value	NA	
Methylene Chloride	8.92E-03	6.00E-02	1.67E-06	2.78E-05	5.95E-07	No toxicity value	4.46E-09	
Naphthalene	5.00E-03	2.00E-02	1.55E-05	7.77E-04	5.55E-06	No toxicity value	NA	
Nickel (total)	1.64E-02	2.00E-02	1.06E-07	5.30E-06	3.79E-08	No toxicity value	NA	
Nitrobenzene	1.91E-03	5.00E-04	6.71E-07	1.34E-03	2.40E-07	No toxicity value	NA	
Thallium (total)	6.24E-03	7.00E-05	2.01E-07	2.88E-03	7.19E-08	No toxicity value	NA	
Vanadium (total)	1.90E-02	5.00E-03	6.14E-07	1.23E-04	2.19E-07	No toxicity value	NA	
Xylenes, total	1.38E-01	2.00E-01	3.93E-04	1.97E-03	1.40E-04	No toxicity value	NA	
Hazard Index				2.13E-02				
Total Cancer Risk					8.24E-07			

RME = reasonable maximum exposure

RfD = reference dose

Sf = slope factor

Table B-18. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Indoor Worker Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Noncarcinogenic Effects:			Carcinogenic Effects:		
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	9.52E+03	1.00E+00	4.66E-03	4.66E-03	1.66E-03	No toxicity value	NA
Arsenic	7.62E+00	3.00E-04	3.73E-06	1.24E-02	1.33E-06	1.50E+00	2.00E-06
Iron	2.03E+04	7.00E-01	9.93E-03	1.42E-02	3.55E-03	No toxicity value	NA
Lead	2.94E+03	No toxicity value	1.44E-03	NA	5.13E-04	No toxicity value	NA
Manganese	3.75E+02	4.67E-02	1.83E-04	3.93E-03	6.55E-05	No toxicity value	NA
Thallium	5.24E+00	7.00E-05	2.56E-06	3.66E-02	9.16E-07	No toxicity value	NA
Vanadium	2.42E+01	5.00E-03	1.18E-05	2.37E-03	4.23E-06	No toxicity value	NA
PCB-1254	1.60E+01	2.00E-05	7.83E-06	3.91E-01	2.80E-06	No toxicity value	NA
PCB-1260	4.29E+00	No toxicity value	2.10E-06	NA	7.50E-07	2.00E+00	5.59E-06
Benzo(a)anthracene	8.50E+00	No toxicity value	4.16E-06	NA	1.49E-06	2.00E+00	1.50E-06
Benzo(a)pyrene	7.30E+00	No toxicity value	3.57E-06	NA	1.28E-06	7.30E-01	1.08E-06
Benzo(b)fluoranthene	9.70E+00	No toxicity value	4.75E-06	NA	1.69E-06	7.30E+00	9.31E-06
Benzo(k)fluoranthene	5.38E-01	No toxicity value	2.63E-07	NA	9.40E-08	7.30E-02	1.24E-06
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	6.26E-07	NA	2.24E-07	7.30E+00	6.86E-09
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	2.36E-07	NA	8.42E-08	7.30E-01	1.63E-06
Hazard Index				4.66E-01			6.15E-08
Total Cancer Risk							2.24E-05

kg = kilogram

mg = milligram

RfD = reference dose

RME = reasonable maximum exposure

SF = slope factor

Table B-19. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Noncarcinogenic				Carcinogenic		
	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Effects:		Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME			
1,1,2-Trichloroethane	6.23E-03	4.00E-03	1.71E-04	4.27E-02	5.86E-05	3.34E-06	
1,3-Dinitrobenzene	9.74E-05	1.00E-04	2.67E-06	2.67E-02	9.15E-07	NA	
2-Methylnaphthalene	5.80E-03	2.00E-02	1.59E-04	7.95E-03	5.45E-05	NA	
2-Nitrotoluene	9.83E-05	1.00E-02	2.69E-06	2.69E-04	9.24E-07	2.12E-07	
Aluminum (total)	8.10E+00	1.00E+00	2.22E-01	2.22E-01	7.61E-02	NA	
Arsenic (total)	7.21E-03	3.00E-04	1.97E-04	6.58E-01	6.77E-05	1.02E-04	
Barium (total)	1.33E+00	2.00E-01	3.66E-02	1.83E-01	1.25E-02	NA	
Benzene	3.09E-02	4.00E-03	8.46E-04	2.11E-01	2.90E-04	1.59E-05	
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	1.33E-04	6.65E-03	4.56E-05	6.39E-07	
Bromomethane	5.83E-03	1.40E-03	1.60E-04	1.14E-01	5.48E-05	NA	
Chlorobenzene	5.00E-03	2.00E-02	1.37E-04	6.85E-03	4.70E-05	NA	
Chloromethane	9.73E-03	No toxicity value	2.67E-04	NA	9.14E-05	NA	
Chromium (total)	6.20E-03	3.00E-03	1.70E-04	5.67E-02	5.83E-05	NA	
Cyanide	8.68E-02	2.00E-02	2.38E-03	1.19E-01	8.15E-04	NA	
Iron (total)	1.91E+01	7.00E-01	5.22E-01	7.46E-01	1.79E-01	NA	
Lead (total)	4.24E-03	No toxicity value	NA	NA	No toxicity value	NA	
Manganese (total)	4.46E-01	4.67E-02	1.22E-02	2.62E-01	4.19E-03	NA	
Methylene Chloride	8.92E-03	6.00E-02	2.44E-04	4.07E-03	8.38E-05	6.28E-07	
Naphthalene	5.00E-03	2.00E-02	1.37E-04	6.85E-03	4.70E-05	NA	
Nickel (total)	1.64E-02	2.00E-02	4.50E-04	2.23E-02	1.54E-04	NA	
Nitrobenzene	1.91E-03	5.00E-04	5.24E-05	1.05E-01	1.80E-05	NA	
Thallium (total)	6.24E-03	7.00E-05	1.71E-04	2.44E+00	5.86E-05	NA	
Vanadium (total)	1.90E-02	5.00E-03	5.21E-04	1.04E-01	1.79E-04	NA	
Xylenes, total	1.38E-01	2.00E-01	3.78E-03	1.89E-02	1.30E-03	NA	
Hazard Index						5.37E+00	
Total Cancer Risk							1.22E-04

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-20. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L)		Reference Dose 1/(mg/kg-day)		Dermal Absorbed Dose RME		Hazard Quotient (Intake/RfD) RME		Dermal Absorbed Dose RME		Cancer Slope Factor (mg/kg-day) ⁻¹		Carcinogenic Effects: Excess Lifetime Cancer Risk (Intake x sf) RME	
	RME		Dose		Dose	RME	Quotient	RME	Dose	RME	Slope Factor			
1,1,2-Trichloroethane	6.23E-03		4.00E-03		1.05E-05		2.62E-03		3.60E-06		5.70E-02		2.05E-07	
1,3-Dinitrobenzene	9.74E-05		1.00E-04		5.82E-08		5.82E-04		2.00E-08		No toxicity value		NA	
2-Methylnaphthalene	5.80E-03		2.00E-02		1.57E-04		7.83E-03		5.37E-05		No toxicity value		NA	
2-Nitrotoluene	9.83E-05		1.00E-02		2.98E-07		2.98E-05		1.02E-07		2.30E-01		2.35E-08	
Aluminum (total)	8.10E+00		1.00E+00		4.44E-04		4.44E-04		1.52E-04		No toxicity value		NA	
Arsenic (total)	7.21E-03		3.00E-04		3.95E-07		1.32E-03		1.35E-07		1.50E+00		2.03E-07	
Barium (total)	1.33E+00		2.00E-01		7.31E-05		3.66E-04		2.51E-05		No toxicity value		NA	
Benzene	3.09E-02		4.00E-03		8.40E-05		2.10E-02		2.88E-05		5.50E-02		1.58E-06	
bis(2-Ethylhexyl)phthalate	4.86E-03		2.00E-02		1.34E-04		6.69E-03		4.59E-05		1.40E-02		6.42E-07	
Bromomethane	5.83E-03		1.40E-03		3.37E-06		2.41E-03		1.16E-06		No toxicity value		NA	
Chlorobenzene	5.00E-03		2.00E-02		3.23E-05		1.61E-03		1.11E-05		No toxicity value		NA	
Chloromethane	9.73E-03		No toxicity value		4.89E-06		NA		1.68E-06		No toxicity value		NA	
Chromium (total)	6.20E-03		3.00E-03		3.40E-07		1.13E-04		1.17E-07		No toxicity value		NA	
Cyanide	8.68E-02		2.00E-02		4.76E-06		2.38E-04		1.63E-06		No toxicity value		NA	
Iron (total)	1.91E+01		7.00E-01		1.04E-03		1.49E-03		3.58E-04		No toxicity value		NA	
Lead (total)	4.24E-03		No toxicity value		NA		NA		NA		No toxicity value		NA	
Manganese (total)	4.46E-01		4.67E-02		2.44E-05		5.24E-04		8.38E-06		No toxicity value		NA	
Methylene Chloride	8.92E-03		6.00E-02		6.04E-06		1.01E-04		2.07E-06		No toxicity value		1.55E-08	
Naphthalene	5.00E-03		2.00E-02		5.90E-05		2.95E-03		2.02E-05		No toxicity value		NA	
Nickel (total)	1.64E-02		2.00E-02		1.80E-07		9.00E-06		6.17E-08		No toxicity value		NA	
Nitrobenzene	1.91E-03		5.00E-04		2.55E-06		5.09E-03		8.73E-07		No toxicity value		NA	
Thallium (total)	6.24E-03		7.00E-05		3.42E-07		4.88E-03		1.17E-07		No toxicity value		NA	
Vanadium (total)	1.90E-02		5.00E-03		1.04E-06		2.09E-04		3.58E-07		No toxicity value		NA	
Xylenes, total	1.38E-01		2.00E-01		1.49E-03		7.46E-03		5.12E-04		No toxicity value		NA	
Hazard Index												6.80E-02		
Total Cancer Risk													2.67E-06	

RME = reasonable maximum exposure

RfD = reference dose

Sf = slope factor

Table B-21. Risks and Hazards from Inhalation of Volatiles from Bedrock Groundwater at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
1,1,2-Trichloroethane	6.23E-03	4.00E-03	3.56E-05	8.89E-03	1.22E-05	5.60E-02	6.83E-07	
1,3-Dinitrobenzene	9.74E-05	1.00E-04	5.56E-07	5.56E-03	1.91E-07	No toxicity value	NA	
2-Methylnaphthalene	5.80E-03	8.57E-04	3.31E-05	3.86E-02	1.14E-05	No toxicity value	NA	
2-Nitrotoluene	9.83E-05	No toxicity value	5.61E-07	NA	1.92E-07	No toxicity value	NA	
Aluminum (total)	8.10E+00	1.43E-03	4.62E-02	NA	1.58E-02	No toxicity value	NA	
Arsenic (total)	7.21E-03	No toxicity value	4.11E-05	NA	1.41E-05	1.51E+01	NA	
Barium (total)	1.33E+00	2.00E-01	7.61E-03	NA	2.61E-03	No toxicity value	NA	
Benzene	3.09E-02	8.57E-03	1.76E-04	2.05E-02	6.04E-05	2.70E-02	1.63E-06	
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	2.77E-05	1.39E-03	9.50E-06	1.40E-02	1.33E-07	
Bromomethane	5.83E-03	1.43E-03	3.33E-05	2.33E-02	1.14E-05	No toxicity value	NA	
Chlorobenzene	5.00E-03	1.43E-02	2.85E-05	2.00E-03	9.78E-06	No toxicity value	NA	
Chloromethane	9.73E-03	2.57E-02	5.55E-05	2.16E-03	1.90E-05	6.30E-03	1.20E-07	
Chromium (total)	6.20E-03	2.85E-05	3.54E-05	NA	1.21E-05	2.94E+02	NA	
Cyanide	8.68E-02	No toxicity value	4.95E-04	NA	1.70E-04	No toxicity value	NA	
Iron (total)	1.91E+01	No toxicity value	1.09E-01	NA	3.73E-02	No toxicity value	NA	
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA	
Manganese (total)	4.46E-01	1.40E-05	2.55E-03	NA	8.73E-04	No toxicity value	NA	
Methylene Chloride	8.92E-03	8.57E-01	5.09E-05	5.93E-05	1.74E-05	1.65E-03	2.87E-08	
Naphthalene	5.00E-03	8.57E-04	2.85E-05	3.33E-02	9.79E-06	No toxicity value	NA	
Nickel (total)	1.64E-02	No toxicity value	9.37E-05	NA	3.21E-05	No toxicity value	NA	
Nitrobenzene	1.91E-03	5.71E-04	1.09E-05	1.91E-02	3.74E-06	No toxicity value	NA	
Thallium (total)	6.24E-03	No toxicity value	3.56E-05	NA	1.22E-05	No toxicity value	NA	
Vanadium (total)	1.90E-02	No toxicity value	1.09E-04	NA	3.72E-05	No toxicity value	NA	
Xylenes, total	1.38E-01	2.86E-02	7.88E-04	2.76E-02	2.70E-04	No toxicity value	NA	

Hazard Index

1.83E-01

Total Cancer Risk

2.59E-06

RME = reasonable maximum exposure

Sf = slope factor

RfD = reference dose

Table B-22. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	9.52E+03	1.00E+00	2.35E-04	2.35E-04	4.02E-03	No toxicity value	NA		
Arsenic	7.62E+00	3.00E-04	1.88E-07	6.26E-04	3.22E-06	1.50E+00	4.83E-06		
Iron	2.03E+04	7.00E-01	5.01E-04	7.15E-04	8.58E-03	No toxicity value	NA		
Lead	2.94E+03	No toxicity value	7.24E-05	NA	1.24E-03	No toxicity value	NA		
Manganese	3.75E+02	4.67E-02	9.25E-06	1.98E-04	1.59E-04	No toxicity value	NA		
Thallium	5.24E+00	7.00E-05	1.29E-07	1.85E-03	2.21E-06	No toxicity value	NA		
Vanadium	2.42E+01	5.00E-03	5.97E-07	1.19E-04	1.02E-05	No toxicity value	NA		
PCB-1254	1.60E+01	2.00E-05	3.95E-07	1.97E-02	6.76E-06	No toxicity value	NA		
PCB-1260	4.29E+00	No toxicity value	1.06E-07	NA	1.81E-06	2.00E+00	1.35E-05		
Benzo(a)anthracene	8.50E+00	No toxicity value	2.10E-07	NA	3.59E-06	2.00E+00	3.63E-06		
Benzo(a)pyrene	7.30E+00	No toxicity value	1.80E-07	NA	3.09E-06	7.30E-01	2.62E-06		
Benzo(b)fluoranthene	9.70E+00	No toxicity value	2.39E-07	NA	4.10E-06	7.30E+00	2.25E-05		
Benzo(k)fluoranthene	5.38E-01	No toxicity value	1.33E-08	NA	2.27E-07	7.30E-01	2.99E-06		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	3.16E-08	NA	5.41E-07	7.30E-02	1.66E-08		
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	1.19E-08	NA	2.04E-07	7.30E+00	3.95E-06		
Hazard Index							2.35E-02		
Total Cancer Risk								5.42E-05	

RfD = reference dose

RME = reasonable maximum exposure

SF = slope factor

kg = kilogram

mg = milligram

Table B-23. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	9.52E+03	1.00E+00	ND	NA	ND	No toxicity value	NA		
Arsenic	7.62E+00	3.00E-04	2.56E-06	8.55E-03	8.79E-07	1.50E+00	1.32E-06		
Iron	2.03E+04	7.00E-01	ND	NA	ND	No toxicity value	NA		
Lead	2.94E+03	No toxicity value	ND	NA	ND	No toxicity value	NA		
Manganese	3.75E+02	4.67E-02	ND	NA	ND	No toxicity value	NA		
Thallium	5.24E+00	7.00E-05	ND	NA	ND	No toxicity value	NA		
Vanadium	2.42E+01	5.00E-03	ND	NA	ND	No toxicity value	NA		
PCB-1254	1.60E+01	2.00E-05	2.51E-05	1.26E+00	8.62E-06	2.00E+00	1.72E-05		
PCB-1260	4.29E+00	No toxicity value	6.74E-06	NA	2.31E-06	2.00E+00	4.62E-06		
Benzo(a)anthracene	8.50E+00	No toxicity value	1.24E-05	NA	4.25E-06	7.30E-01	3.10E-06		
Benzo(a)pyrene	7.30E+00	No toxicity value	1.06E-05	NA	3.65E-06	7.30E+00	2.66E-05		
Benzo(b)fluoranthene	9.70E+00	No toxicity value	1.41E-05	NA	4.85E-06	7.30E-01	3.54E-06		
Benzo(k)fluoranthene	5.38E-01	No toxicity value	7.85E-07	NA	2.69E-07	7.30E-02	1.96E-08		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.87E-06	NA	6.40E-07	7.30E+00	4.67E-06		
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	7.03E-07	NA	2.41E-07	7.30E-01	1.76E-07		
Hazard Index				1.27E+00					
Total Cancer Risk							6.13E-05		

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-24. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.43E-03	5.48E-07	3.84E-04	1.88E-07	No toxicity value	NA	
Arsenic	7.62E+00	No toxicity value	4.39E-10	NA	1.51E-10	1.51E+01	2.27E-09	
Iron	2.03E+04	No toxicity value	1.17E-06	NA	4.01E-07	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	1.69E-07	NA	5.80E-08	No toxicity value	NA	
Manganese	3.75E+02	1.40E-05	2.16E-08	1.54E-03	7.41E-09	No toxicity value	NA	
Thallium	5.24E+00	No toxicity value	3.02E-10	NA	1.04E-10	No toxicity value	NA	
Vanadium	2.42E+01	No toxicity value	1.39E-09	NA	4.78E-10	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	9.22E-10	4.61E-05	3.16E-10	No toxicity value	6.32E-10	
PCB-1260	4.29E+00	No toxicity value	2.47E-10	NA	8.47E-11	2.00E+00	1.69E-10	
Benzo(a)anthracene	8.50E+00	No toxicity value	4.90E-10	NA	1.68E-10	3.10E-01	5.20E-11	
Benzo(a)pyrene	7.30E+00	No toxicity value	4.21E-10	NA	1.44E-10	3.10E+00	4.47E-10	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	5.59E-10	NA	1.92E-10	3.10E-01	5.94E-11	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	3.10E-11	NA	1.06E-11	3.10E-02	3.29E-13	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	7.37E-11	NA	2.53E-11	3.10E+00	7.84E-11	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	2.78E-11	NA	9.52E-12	3.10E-01	2.95E-12	
Hazard Index				1.97E-03				
Total Cancer Risk				3.71E-09				

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-25. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	1.09E+04	1.00E+00	2.70E-04	2.70E-04	4.62E-03	No toxicity value	NA		
Arsenic	9.14E+00	3.00E-04	2.25E-07	7.51E-04	3.86E-06	1.50E+00	5.80E-06		
Chromium	1.78E+01	3.00E-03	4.39E-07	1.46E-04	7.52E-06	No toxicity value	NA		
Iron	2.45E+04	7.00E-01	6.04E-04	8.63E-04	1.04E-02	No toxicity value	NA		
Lead	3.14E+01	No toxicity value	7.74E-07	NA	1.33E-05	No toxicity value	NA		
Manganese	5.05E+02	4.67E-02	1.25E-05	2.67E-04	2.13E-04	No toxicity value	NA		
Thallium	1.82E+01	7.00E-05	4.49E-07	6.41E-03	7.69E-06	No toxicity value	NA		
Vanadium	2.72E+01	5.00E-03	6.71E-07	1.34E-04	1.15E-05	No toxicity value	NA		
PCB-1254	3.33E-01	2.00E-05	8.21E-09	4.11E-04	1.41E-07	No toxicity value	NA		
PCB-1260	2.56E+00	No toxicity value	6.31E-08	NA	1.08E-06	2.00E+00	2.82E-07		
Benzo(a)anthracene	3.40E+00	No toxicity value	8.38E-08	NA	1.44E-06	2.00E+00	2.16E-06		
Benzo(a)pyrene	3.05E+00	No toxicity value	7.52E-08	NA	1.29E-06	7.30E-01	1.05E-06		
Benzo(b)fluoranthene	2.41E+00	No toxicity value	5.94E-08	NA	1.02E-06	7.30E+00	9.41E-06		
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	3.16E-08	NA	5.41E-07	7.30E-01	7.44E-07		
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	1.04E-07	NA	1.78E-06	7.30E+00	3.95E-06		
Hazard Index	9.25E-03								
Total Cancer Risk								2.47E-05	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-26. Risks and Hazards from Dermal Contact with Subsurface Soil at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Noncarcinogenic Effects:				Carcinogenic Effects:	
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.09E+04	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	9.14E+00	3.00E-04	3.08E-06	1.03E-02	1.05E-06	1.50E+00	1.58E-06
Chromium	1.78E+01	3.00E-03	ND	NA	ND	No toxicity value	NA
Iron	2.45E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	3.14E+01	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	5.05E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	1.82E+01	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.72E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	3.33E-01	2.00E-05	5.23E-07	2.62E-02	1.79E-07	2.00E+00	3.59E-07
PCB-1260	2.56E+00	No toxicity value	4.02E-06	NA	1.38E-06	2.00E+00	2.76E-06
Benzo(a)anthracene	3.40E+00	No toxicity value	4.96E-06	NA	1.70E-06	7.30E-01	1.24E-06
Benzo(a)pyrene	3.05E+00	No toxicity value	4.45E-06	NA	1.53E-06	7.30E+00	1.11E-05
Benzo(b)fluoranthene	2.41E+00	No toxicity value	3.51E-06	NA	1.21E-06	7.30E-01	8.80E-07
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.87E-06	NA	6.40E-07	7.30E+00	4.67E-06
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	6.15E-06	NA	2.11E-06	7.30E-01	1.54E-06
Hazard Index				3.64E-02			
Total Cancer Risk							2.42E-05

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-27. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Water (mg/L) RME	Noncarcinogenic Effects:				Carcinogenic Effects:	
		Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	6.34E-01	1.00E+00	2.11E-05	2.11E-05	7.23E-06	No toxicity value	NA
Arsenic	3.20E-03	3.00E-04	1.06E-07	3.55E-04	3.65E-08	1.50E+00	5.48E-08
Iron	9.89E-01	7.00E-01	3.29E-05	4.70E-05	1.13E-05	No toxicity value	NA
Lead	3.90E-03	No toxicity value	NA	NA	NA	No toxicity value	NA
Manganese	5.95E-02	4.67E-02	1.98E-06	4.24E-05	6.79E-07	No toxicity value	NA
Vanadium	1.54E-02	5.00E-03	5.12E-07	1.02E-04	1.76E-07	No toxicity value	NA
bis(2-Ethylhexyl)phthalate	2.56E-03	2.00E-02	1.10E-05	5.51E-04	3.78E-06	1.40E-02	5.29E-08
		#N/A	#N/A	NA	#N/A	#N/A	NA
Hazard Index			1.12E-03				
Total Cancer Risk							1.08E-07

RME - Reasonable Maximum Exposure
RfD - Reference Dose
SF - Slope factor

Table B-28. Risks and Hazards from Ingestion of Sediment at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
Aluminum	1.08E+04	1.00E+00	1.47E-03	1.47E-03	5.05E-04	No toxicity value	NA		
Arsenic	7.55E+00	3.00E-04	1.08E-06	3.45E-03	3.55E-07	1.50E+00	5.32E-07		
Chromium	1.75E+01	3.00E-03	2.40E-06	7.99E-04	8.22E-07	No toxicity value	NA		
Iron	2.16E+04	7.00E-01	2.96E-03	4.22E-03	1.01E-03	No toxicity value	NA		
Lead	7.76E+02	No toxicity value	1.06E-04	NA	3.64E-05	No toxicity value	NA		
Manganese	2.09E+02	4.67E-02	2.78E-05	5.96E-04	9.53E-06	No toxicity value	NA		
Thallium	4.79E+00	7.00E-05	6.48E-07	9.26E-03	2.22E-07	No toxicity value	NA		
Vanadium	2.41E+01	5.00E-03	3.30E-06	6.60E-04	1.13E-06	No toxicity value	NA		
PCB-1254	1.52E+00	2.00E-05	2.08E-07	1.04E-02	7.14E-08	2.00E+00	1.43E-07		
PCB-1260	5.78E+00	No toxicity value	7.92E-07	NA	2.71E-07	2.00E+00	5.43E-07		
Benzo(a)anthracene	3.27E-01	No toxicity value	4.48E-08	NA	1.54E-08	7.30E-01	1.12E-08		
Benzo(a)pyrene	2.90E+00	No toxicity value	3.97E-07	NA	1.36E-07	7.30E+00	9.94E-07		
Benzo(b)fluoranthene	2.90E+00	No toxicity value	3.97E-07	NA	1.36E-07	7.30E-01	9.94E-08		
Dibenz(a,h)anthracene	3.20E-01	No toxicity value	4.38E-08	NA	1.50E-08	7.30E+00	1.10E-07		
Indeno(1,2,3-cd)pyrene	2.42E-01	No toxicity value	3.32E-08	NA	1.14E-08	7.30E-01	8.30E-09		
N-Nitroso-di-n-propylamine	2.72E-01	No toxicity value	3.79E-08	NA	1.28E-08	7.00E+00	8.94E-08		
Hazard Index				3.09E-02					
Total Cancer Risk							2.53E-06		

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-29. Risks and Hazards from Dermal Contact with Sediment at Acid Area 2 for Adult Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Sediment (mg/kg) RME	Noncarcinogenic			Carcinogenic		
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.08E+04	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.55E+00	3.00E-04	2.82E-07	9.41E-04	9.68E-08	1.50E+00	1.45E-07
Chromium	1.75E+01	3.00E-03	ND	NA	ND	No toxicity value	NA
Iron	2.16E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	7.76E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	2.03E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	4.73E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.41E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	1.52E+00	2.00E-05	2.65E-07	1.33E-02	9.10E-08	2.00E+00	1.82E-07
PCB-1260	5.78E+00	No toxicity value	1.01E-06	NA	3.46E-07	2.00E+00	6.92E-07
Benzo(a)anthracene	3.27E-01	No toxicity value	5.30E-08	NA	1.82E-08	7.30E-01	1.33E-08
Benzo(a)pyrene	2.90E+00	No toxicity value	4.70E-07	NA	1.61E-07	7.30E+00	1.18E-06
Benzo(b)fluoranthene	2.90E+00	No toxicity value	4.70E-07	NA	1.61E-07	7.30E-01	1.18E-07
Dibenz(a,h)anthracene	3.20E-01	No toxicity value	5.19E-08	NA	1.78E-08	7.30E+00	1.30E-07
Indeno(1,2,3-cd)pyrene	2.42E-01	No toxicity value	3.92E-08	NA	1.34E-08	7.30E-01	9.82E-09
N-Nitroso-di-n-propylamine	2.72E-01	No toxicity value	ND	NA	ND	7.00E+00	NA
Hazard Index				1.42E-02			
Total Cancer Risk							2.47E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure

SF = slope factor

Table B-30. Risks and Hazards from Ingestion of Bedrock Groundwater at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L)			Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME		
1,1,2-Trichloroethane	6.23E-03	4.00E-03	3.99E-04	9.96E-02	3.42E-05	5.70E-02	1.95E-06		
1,3-Dinitrobenzene	9.74E-05	1.00E-04	6.23E-06	6.23E-02	5.34E-07	No toxicity value	NA		
2-Methylnaphthalene	5.80E-03	2.00E-02	3.71E-04	1.85E-02	3.18E-05	No toxicity value	NA		
2-Nitrotoluene	9.83E-05	1.00E-02	6.29E-06	6.29E-04	5.39E-07	2.30E-01	1.24E-07		
Aluminum (total)	8.10E+00	1.00E+00	5.18E-01	5.18E-01	4.44E-02	No toxicity value	NA		
Arsenic (total)	7.21E-03	3.00E-04	4.61E-04	1.54E+00	3.95E-05	1.50E+00	5.92E-05		
Barium (total)	1.33E+00	2.00E-01	8.53E-02	4.26E-01	7.31E-03	No toxicity value	NA		
Benzene	3.09E-02	4.00E-03	1.97E-03	4.93E-01	1.69E-04	5.50E-02	9.30E-06		
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	3.11E-04	1.55E-02	2.66E-05	1.40E-02	3.73E-07		
Bromomethane	5.83E-03	1.40E-03	3.73E-04	2.66E-01	3.20E-05	No toxicity value	NA		
Chlorobenzene	5.00E-03	2.00E-02	3.20E-04	1.60E-02	2.74E-05	No toxicity value	NA		
Chloromethane	9.73E-03	No toxicity value	6.22E-04	NA	5.33E-05	No toxicity value	NA		
Chromium (total)	6.20E-03	3.00E-03	3.97E-04	1.32E-01	3.40E-05	No toxicity value	NA		
Cyanide	8.68E-02	2.00E-02	5.55E-03	2.77E-01	4.76E-04	No toxicity value	NA		
Iron (total)	1.91E+01	7.00E-01	1.22E+00	1.74E+00	1.04E-01	No toxicity value	NA		
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA		
Manganese (total)	4.46E-01	4.67E-02	2.85E-02	6.11E-01	2.44E-03	No toxicity value	NA		
Methylene Chloride	8.92E-03	6.00E-02	5.70E-04	9.50E-03	4.89E-05	7.50E-03	3.66E-07		
Naphthalene	5.00E-03	2.00E-02	3.20E-04	1.60E-02	2.74E-05	No toxicity value	NA		
Nickel (total)	1.64E-02	2.00E-02	1.05E-03	5.25E-02	9.00E-05	No toxicity value	NA		
Nitrobenzene	1.91E-03	5.00E-04	1.22E-04	2.45E-01	1.05E-05	No toxicity value	NA		
Thallium (total)	6.24E-03	7.00E-05	3.99E-04	5.70E+00	3.42E-05	No toxicity value	NA		
Vanadium (total)	1.90E-02	5.00E-03	1.22E-03	2.43E-01	1.04E-04	No toxicity value	NA		
Xylenes, total	1.38E-01	2.00E-01	8.83E-03	4.42E-02	7.57E-04	No toxicity value	NA		
Hazard Index				1.25E+01					
Total Cancer Risk					7.13E-05				

RME = reasonable maximum exposure
Sf = slope factor
RfD = reference dose

Table B-31. Risks and Hazards from Dermal Contact with Bedrock Groundwater at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L) RME	Noncarcinogenic Effects:				Carcinogenic Effects:	
		Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
1,1,2-Trichloroethane	6.23E-03	4.00E-03	2.09E-05	5.21E-03	1.79E-06	5.70E-02	1.02E-07
1,3-Dinitrobenzene	9.74E-05	1.00E-04	1.16E-07	1.16E-03	9.92E-09	No toxicity value	NA
2-Methylnaphthalene	5.80E-03	2.00E-02	3.11E-04	1.56E-02	2.67E-05	No toxicity value	NA
2-Nitrotoluene	9.83E-05	1.00E-02	5.92E-07	5.92E-05	5.08E-08	2.30E-01	1.17E-08
Aluminum (total)	8.10E+00	1.00E+00	1.14E-03	1.14E-03	9.76E-05	No toxicity value	NA
Arsenic (total)	7.21E-03	3.00E-04	1.01E-06	3.37E-03	8.68E-08	1.50E+00	1.30E-07
Barium (total)	1.33E+00	2.00E-01	1.87E-04	9.37E-04	1.61E-05	No toxicity value	NA
Benzene	3.09E-02	4.00E-03	1.67E-04	4.17E-02	1.43E-05	5.50E-02	7.86E-07
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	2.66E-04	1.33E-02	2.28E-05	1.40E-02	3.19E-07
Bromomethane	5.83E-03	1.40E-03	6.71E-06	4.79E-03	5.75E-07	No toxicity value	NA
Chlorobenzene	5.00E-03	2.00E-02	6.41E-05	3.20E-03	5.49E-06	No toxicity value	NA
Chloromethane	9.73E-03	No toxicity value	9.72E-06	NA	8.33E-07	No toxicity value	NA
Chromium (total)	6.20E-03	3.00E-03	8.72E-07	2.91E-04	7.47E-08	No toxicity value	NA
Cyanide	8.68E-02	2.00E-02	1.22E-05	6.10E-04	1.05E-06	No toxicity value	NA
Iron (total)	1.91E+01	7.00E-01	2.68E-03	3.83E-03	2.30E-04	No toxicity value	NA
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA
Manganese (total)	4.46E-01	4.67E-02	6.27E-05	1.34E-03	5.37E-06	No toxicity value	NA
Methylene Chloride	8.92E-03	6.00E-02	1.20E-05	2.00E-04	1.03E-06	No toxicity value	7.71E-09
Naphthalene	5.00E-03	2.00E-02	1.17E-04	5.86E-03	1.00E-05	No toxicity value	NA
Nickel (total)	1.64E-02	2.00E-02	4.62E-07	2.31E-05	3.96E-08	No toxicity value	NA
Nitrobenzene	1.91E-03	5.00E-04	5.06E-06	1.01E-02	4.34E-07	No toxicity value	NA
Thallium (total)	6.24E-03	7.00E-05	8.76E-07	1.25E-02	7.51E-08	No toxicity value	NA
Vanadium (total)	1.90E-02	5.00E-03	2.67E-06	5.35E-04	2.29E-07	No toxicity value	NA
Xylenes, total	1.38E-01	2.00E-01	2.97E-03	1.48E-02	2.54E-04	No toxicity value	NA
Hazard Index				1.41E-01			
Total Cancer Risk					1.36E-06		

RME = reasonable maximum exposure
RfD = reference dose
Sf = slope factor

Table B-32. Risks and Hazards from Inhalation of Volatiles from Bedrock Groundwater at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Groundwater (mg/L)				Noncarcinogenic Effects:				Carcinogenic Effects:	
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day)	RME	Hazard Quotient (Intake/RfD)	Intake Values (mg/kg-day)	RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf)	RME
1,1,2-Trichloroethane	6.23E-03	4.00E-03	8.29E-05	2.07E-02	7.11E-06	5.60E-02	3.98E-07			
1,3-Dinitrobenzene	9.74E-05	1.00E-04	1.30E-06	1.30E-02	1.11E-07	No toxicity value	NA			
2-Methylnaphthalene	5.80E-03	8.57E-04	7.72E-05	9.00E-02	6.61E-06	No toxicity value	NA			
2-Nitrotoluene	9.83E-05	No toxicity value	1.31E-06	NA	1.12E-07	No toxicity value	NA			
Aluminum (total)	8.10E+00	1.43E-03	1.08E-01	NA	9.23E-03	No toxicity value	NA			
Arsenic (total)	7.21E-03	No toxicity value	9.58E-05	NA	8.21E-06	1.51E+01	NA			
Barium (total)	1.33E+00	2.00E-01	1.77E-02	NA	1.52E-03	No toxicity value	NA			
Benzene	3.09E-02	8.57E-03	4.10E-04	4.79E-02	3.52E-05	2.70E-02	9.50E-07			
bis(2-Ethylhexyl)phthalate	4.86E-03	2.00E-02	6.46E-05	3.23E-03	5.54E-06	1.40E-02	7.75E-08			
Bromomethane	5.83E-03	1.43E-03	7.75E-05	5.43E-02	6.65E-06	No toxicity value	NA			
Chlorobenzene	5.00E-03	1.43E-02	6.65E-05	4.65E-03	5.70E-06	No toxicity value	NA			
Chloromethane	9.73E-03	2.57E-02	1.29E-04	5.03E-03	1.11E-05	6.30E-03	6.99E-08			
Chromium (total)	6.20E-03	2.85E-05	8.25E-05	NA	7.07E-06	2.94E+02	NA			
Cyanide	8.68E-02	No toxicity value	1.15E-03	NA	9.89E-05	No toxicity value	NA			
Iron (total)	1.91E+01	No toxicity value	2.53E-01	NA	2.17E-02	No toxicity value	NA			
Lead (total)	4.24E-03	No toxicity value	NA	NA	NA	No toxicity value	NA			
Manganese (total)	4.46E-01	1.40E-05	5.93E-03	NA	5.08E-04	No toxicity value	NA			
Methylene Chloride	8.92E-03	8.57E-01	1.19E-04	1.38E-04	1.02E-05	1.65E-03	1.67E-08			
Naphthalene	5.00E-03	8.57E-04	6.65E-05	7.76E-02	5.70E-06	No toxicity value	NA			
Nickel (total)	1.64E-02	No toxicity value	2.18E-04	NA	1.87E-05	No toxicity value	NA			
Nitrobenzene	1.91E-03	5.71E-04	2.54E-05	4.45E-02	2.18E-06	No toxicity value	NA			
Thallium (total)	6.24E-03	No toxicity value	8.29E-05	NA	7.11E-06	No toxicity value	NA			
Vanadium (total)	1.90E-02	No toxicity value	2.53E-04	NA	2.17E-05	No toxicity value	NA			
Xylenes, total	1.38E-01	2.86E-02	1.84E-03	6.43E-02	1.57E-04	No toxicity value	NA			
Hazard Index				4.25E-01						
Total Cancer Risk										1.51E-06

RME = reasonable maximum exposure

Sf = slope factor

RfD = reference dose

Table B-33. Risks and Hazards from Ingestion of Surface Soil at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/L) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	1.10E-01	1.10E-01	9.39E-03	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	8.77E-05	2.92E-01	7.52E-06	1.50E+00	1.13E-05	
Iron	2.03E+04	7.00E-01	2.34E-01	3.34E-01	2.00E-02	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	3.38E-02	NA	2.90E-03	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	4.32E-03	9.25E-02	3.70E-04	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	6.03E-05	8.61E-01	5.17E-06	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	2.78E-04	5.57E-02	2.39E-05	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	1.84E-04	9.21E+00	1.58E-05	2.00E+00	3.16E-05	
PCB-1260	4.29E+00	No toxicity value	4.94E-05	NA	4.23E-06	2.00E+00	8.46E-06	
Benzo(a)anthracene	8.50E+00	No toxicity value	9.78E-05	NA	8.38E-06	7.30E-01	6.12E-06	
Benzo(a)pyrene	7.30E+00	No toxicity value	8.40E-05	NA	7.20E-06	7.30E+00	5.26E-05	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	1.12E-04	NA	9.57E-06	7.30E-01	6.98E-06	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	6.19E-06	NA	5.31E-07	7.30E-02	3.87E-08	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.47E-05	NA	1.26E-06	7.30E+00	9.22E-06	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	5.55E-06	NA	4.75E-07	7.30E-01	3.47E-07	
Hazard Index				1.10E+01				
Total Cancer Risk							1.27E-04	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-34. Risks and Hazards from Dermal Contact with Surface Soil at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:		
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME	
Aluminum	9.52E+03	1.00E+00	ND	NA	ND	No toxicity value	NA	
Arsenic	7.62E+00	3.00E-04	4.60E-06	1.53E-02	3.95E-07	1.50E+00	5.92E-07	
Iron	2.03E+04	7.00E-01	ND	NA	ND	No toxicity value	NA	
Lead	2.94E+03	No toxicity value	ND	NA	ND	No toxicity value	NA	
Manganese	3.75E+02	4.67E-02	ND	NA	ND	No toxicity value	NA	
Thallium	5.24E+00	7.00E-05	ND	NA	ND	No toxicity value	NA	
Vanadium	2.42E+01	5.00E-03	ND	NA	ND	No toxicity value	NA	
PCB-1254	1.60E+01	2.00E-05	4.51E-05	2.26E+00	3.87E-06	2.00E+00	7.73E-06	
PCB-1260	4.29E+00	No toxicity value	1.21E-05	NA	1.04E-06	2.00E+00	2.07E-06	
Benzo(a)anthracene	8.50E+00	No toxicity value	2.23E-05	NA	1.91E-06	7.30E-01	1.39E-06	
Benzo(a)pyrene	7.30E+00	No toxicity value	1.91E-05	NA	1.64E-06	7.30E+00	1.20E-05	
Benzo(b)fluoranthene	9.70E+00	No toxicity value	2.54E-05	NA	2.18E-06	7.30E-01	1.59E-06	
Benzo(k)fluoranthene	5.38E-01	No toxicity value	1.41E-06	NA	1.21E-07	7.30E-02	8.81E-09	
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	3.35E-06	NA	2.87E-07	7.30E+00	2.10E-06	
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	1.26E-06	NA	1.08E-07	7.30E-01	7.90E-08	
Hazard Index				2.27E+00				
Total Cancer Risk							2.75E-05	

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-35. Risks and Hazards from Inhalation of Particulates from Surface Soil at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg) RME	Reference Dose 1/(mg/kg-day)	Noncarcinogenic Effects:			Carcinogenic Effects:	
			Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	9.52E+03	1.43E-03	1.28E-06	8.96E-04	1.10E-07	No toxicity value	NA
Arsenic	7.62E+00	No toxicity value	1.02E-09	NA	8.78E-11	1.51E+01	1.32E-09
Iron	2.03E+04	No toxicity value	2.73E-06	NA	2.34E-07	No toxicity value	NA
Lead	2.94E+03	No toxicity value	3.95E-07	NA	3.38E-08	No toxicity value	NA
Manganese	3.75E+02	1.40E-05	5.04E-08	3.60E-03	4.32E-09	No toxicity value	NA
Thallium	5.24E+00	No toxicity value	7.04E-10	NA	6.04E-11	No toxicity value	NA
Vanadium	2.42E+01	No toxicity value	3.25E-09	NA	2.79E-10	No toxicity value	NA
PCB-1254	1.60E+01	2.00E-05	2.15E-09	1.08E-04	1.84E-10	No toxicity value	NA
PCB-1260	4.29E+00	No toxicity value	5.77E-10	NA	4.94E-11	2.00E+00	3.69E-10
Benzo(a)anthracene	8.50E+00	No toxicity value	1.14E-09	NA	9.79E-11	2.00E+00	9.89E-11
Benzo(a)pyrene	7.30E+00	No toxicity value	9.81E-10	NA	8.41E-11	3.10E-01	3.04E-11
Benzo(b)fluoranthene	9.70E+00	No toxicity value	1.30E-09	NA	1.12E-10	3.10E+00	2.61E-10
Benzo(k)fluoranthene	5.38E-01	No toxicity value	7.23E-11	NA	6.20E-12	3.10E-01	3.46E-11
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.72E-10	NA	1.47E-11	3.10E-02	1.92E-13
Indeno(1,2,3-cd)pyrene	4.82E-01	No toxicity value	6.48E-11	NA	5.55E-12	3.10E+00	4.57E-11
Hazard Index				4.60E-03			
Total Cancer Risk							2.16E-09

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-36. Risks and Hazards from Ingestion of Subsurface Soil at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)				Noncarcinogenic Effects:			Carcinogenic Effects:		
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME			
Aluminum	1.09E+04	1.00E+00	1.26E-01	1.26E-01	1.08E-02	No toxicity value	NA			
Arsenic	9.14E+00	3.00E-04	1.05E-04	3.51E-01	9.01E-06	1.50E+00	1.35E-05			
Chromium	1.78E+01	3.00E-03	2.05E-04	6.83E-02	1.76E-05	No toxicity value	NA			
Iron	2.45E+04	7.00E-01	2.82E-01	4.03E-01	2.42E-02	No toxicity value	NA			
Lead	3.14E+01	No toxicity value	3.61E-04	NA	3.10E-05	No toxicity value	NA			
Manganese	5.05E+02	4.67E-02	5.81E-03	1.25E-01	4.98E-04	No toxicity value	NA			
Thallium	1.82E+01	7.00E-05	2.09E-04	2.99E+00	1.80E-05	No toxicity value	NA			
Vanadium	2.72E+01	5.00E-03	3.13E-04	6.26E-02	2.68E-05	No toxicity value	NA			
PCB-1254	3.33E-01	2.00E-05	3.83E-06	1.92E-01	3.28E-07	2.00E+00	6.57E-07			
PCB-1260	2.56E+00	No toxicity value	2.95E-05	NA	2.52E-06	2.00E+00	5.05E-06			
Benzo(a)anthracene	3.40E+00	No toxicity value	3.91E-05	NA	3.35E-06	7.30E-01	2.45E-06			
Benzo(a)pyrene	3.05E+00	No toxicity value	3.51E-05	NA	3.01E-06	7.30E+00	2.20E-05			
Benzo(b)fluoranthene	2.41E+00	No toxicity value	2.77E-05	NA	2.38E-06	7.30E-01	1.74E-06			
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	1.47E-05	NA	1.26E-06	7.30E+00	9.22E-06			
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	4.86E-05	NA	4.16E-06	7.30E-01	3.04E-06			
Hazard Index				4.32E+00						
Total Cancer Risk					5.76E-05					

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-37. Risks and Hazards from Dermal Contact with Subsurface Soil at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Surface Soil (mg/kg)				Noncarcinogenic Effects:				Carcinogenic Effects:	
	RME	Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME			
Aluminum	1.09E+04	1.00E+00	ND	NA	ND	No toxicity value	NA			
Arsenic	9.14E+00	3.00E-04	5.52E-06	1.84E-02	4.73E-07	1.50E+00	7.10E-07			
Chromium	1.78E+01	3.00E-03	ND	NA	ND	No toxicity value	NA			
Iron	2.45E+04	7.00E-01	ND	NA	ND	No toxicity value	NA			
Lead	3.14E+01	No toxicity value	ND	NA	ND	No toxicity value	NA			
Manganese	5.05E+02	4.67E-02	ND	NA	ND	No toxicity value	NA			
Thallium	1.82E+01	7.00E-05	ND	NA	ND	No toxicity value	NA			
Vanadium	2.72E+01	5.00E-03	ND	NA	ND	No toxicity value	NA			
PCB-1254	3.33E-01	2.00E-05	9.39E-07	4.69E-02	8.03E-08	2.00E+00	1.61E-07			
PCB-1260	2.56E+00	No toxicity value	7.22E-06	NA	6.19E-07	2.00E+00	1.24E-06			
Benzo(a)anthracene	3.40E+00	No toxicity value	8.90E-06	NA	7.63E-07	7.30E-01	5.57E-07			
Benzo(a)pyrene	3.05E+00	No toxicity value	7.98E-06	NA	6.84E-07	7.30E+00	5.00E-06			
Benzo(b)fluoranthene	2.41E+00	No toxicity value	6.31E-06	NA	5.41E-07	7.30E-01	3.95E-07			
Dibenz(a,h)anthracene	1.28E+00	No toxicity value	3.35E-06	NA	2.87E-07	7.30E+00	2.10E-06			
Indeno(1,2,3-cd)pyrene	4.22E+00	No toxicity value	1.10E-05	NA	9.47E-07	7.30E-01	6.91E-07			
Hazard Index				6.53E-02						
Total Cancer Risk							1.08E-05			

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

Table B-38. Risks and Hazards from Dermal Contact with Surface Water at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration In Surface Water (mg/L) RME	Noncarcinogenic						Carcinogenic	
		Reference Dose 1/(mg/kg-day)	Dermal Absorbed Dose RME	Hazard Quotient (Intake/RfD) RME	Dermal Absorbed Dose RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x Sf) RME	Effects:	
								Effects: Hazard Quotient (Intake/RfD) RME	Effects: Excess Lifetime Cancer Risk (Intake x Sf) RME
Aluminum	6.34E-01	1.00E+00	3.79E-05	3.79E-05	3.25E-06	No toxicity value	NA	NA	
Arsenic	3.20E-03	3.00E-04	1.91E-07	6.38E-04	1.64E-08	1.50E+00	2.46E-08	2.46E-08	
Iron	9.89E-01	7.00E-01	5.92E-05	8.45E-05	5.07E-06	No toxicity value	NA	NA	
Lead	3.90E-03	No toxicity value	NA	NA	NA	No toxicity value	NA	NA	
Manganese	5.95E-02	4.67E-02	3.56E-06	7.63E-05	3.05E-07	No toxicity value	NA	NA	
Vanadium	1.54E-02	5.00E-03	9.21E-07	1.84E-04	7.90E-08	No toxicity value	NA	NA	
bis(2-Ethylhexyl)phthalate	2.55E-03	2.00E-02	1.98E-05	9.90E-04	1.70E-06	1.40E-02	2.38E-08	2.38E-08	
		#N/A	#N/A	NA	#N/A	#N/A	NA	NA	
Hazard Index				2.01E-03					
Total Cancer Risk								4.84E-08	

RME - Reasonable Maximum Exposure

RfD - Reference Dose

Sf - Slope factor

Table B-39. Risks and Hazards from Ingestion of Sediment at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration in Fish (mg/kg) RME	Noncarcinogenic Effects:				Carcinogenic Effects:	
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.08E+04	1.00E+00	1.38E-02	1.38E-02	1.18E-03	No toxicity value	NA
Arsenic	7.55E+00	3.00E-04	9.65E-06	3.22E-02	8.27E-07	1.50E+00	1.24E-06
Chromium	1.75E+01	3.00E-03	2.24E-05	7.46E-03	1.92E-06	No toxicity value	NA
Iron	2.16E+04	7.00E-01	2.76E-02	3.94E-02	2.37E-03	No toxicity value	NA
Lead	7.76E+02	No toxicity value	9.92E-04	NA	8.50E-05	No toxicity value	NA
Manganese	2.03E+02	4.67E-02	2.60E-04	5.56E-03	2.22E-05	No toxicity value	NA
Thallium	4.79E+00	7.00E-05	6.05E-06	8.64E-02	5.18E-07	No toxicity value	NA
Vanadium	2.41E+01	5.00E-03	3.08E-05	6.16E-03	2.64E-06	No toxicity value	NA
PCB-1254	1.52E+00	2.00E-05	1.94E-06	9.72E-02	1.67E-07	2.00E+00	3.33E-07
PCB-1260	5.78E+00	No toxicity value	7.99E-06	NA	6.33E-07	2.00E+00	1.27E-06
Benzo(a)anthracene	3.27E-01	No toxicity value	4.18E-07	NA	3.58E-08	7.30E-01	2.62E-08
Benzo(a)pyrene	2.90E+00	No toxicity value	3.71E-06	NA	3.18E-07	7.30E+00	2.32E-06
Benzo(b)fluoranthene	2.90E+00	No toxicity value	3.71E-06	NA	3.18E-07	7.30E-01	2.32E-07
Dibenz(a,h)anthracene	3.20E-01	No toxicity value	4.09E-07	NA	3.51E-08	7.30E+00	2.56E-07
Indeno(1,2,3-cd)pyrene	2.42E-01	No toxicity value	3.09E-07	NA	2.65E-08	7.30E-01	1.94E-08
N-Nitroso-di-n-propylamine	2.72E-01	No toxicity value	3.48E-07	NA	2.98E-08	7.00E+00	2.09E-07
Hazard Index				2.88E-01			
Total Cancer Risk							5.90E-06

kg = kilogram
mg = milligram

RfD = reference dose
RME = reasonable maximum exposure

SF = slope factor

Table B-40. Risks and Hazards from Dermal Contact with Sediment at Acid Area 2 for Child Residential Receptors at Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Exposure Point Concentration (mg/kg) RME	Noncarcinogenic Effects:			Carcinogenic Effects:		
		Reference Dose 1/(mg/kg-day)	Intake Values (mg/kg-day) RME	Hazard Quotient (Intake/RfD) RME	Intake Values (mg/kg-day) RME	Cancer Slope Factor (mg/kg-day) ⁻¹	Excess Lifetime Cancer Risk (Intake x sf) RME
Aluminum	1.08E+04	1.00E+00	ND	NA	ND	No toxicity value	NA
Arsenic	7.55E+00	3.00E-04	5.07E-07	1.69E-03	4.34E-08	1.50E+00	6.52E-08
Chromium	1.75E+01	3.00E-03	ND	NA	ND	No toxicity value	NA
Iron	2.16E+04	7.00E-01	ND	NA	ND	No toxicity value	NA
Lead	7.76E+02	No toxicity value	ND	NA	ND	No toxicity value	NA
Manganese	2.03E+02	4.67E-02	ND	NA	ND	No toxicity value	NA
Thallium	4.73E+00	7.00E-05	ND	NA	ND	No toxicity value	NA
Vanadium	2.41E+01	5.00E-03	ND	NA	ND	No toxicity value	NA
PCB-1254	1.52E+00	2.00E-05	4.76E-07	2.38E-02	4.08E-08	2.00E+00	8.16E-08
PCB-1260	5.78E+00	No toxicity value	1.81E-06	NA	1.55E-07	2.00E+00	3.10E-07
Benzo(a)anthracene	3.27E-01	No toxicity value	9.51E-08	NA	8.15E-09	7.30E-01	5.95E-09
Benzo(a)pyrene	2.90E+00	No toxicity value	8.44E-07	NA	7.23E-08	7.30E+00	5.28E-07
Benzo(b)fluoranthene	2.90E+00	No toxicity value	8.44E-07	NA	7.23E-08	7.30E-01	5.28E-08
Dibenz(a,h)anthracene	3.20E-01	No toxicity value	9.31E-08	NA	7.98E-09	7.30E+00	5.82E-08
Indeno(1,2,3-cd)pyrene	2.42E-01	No toxicity value	7.04E-08	NA	6.03E-09	7.30E-01	4.40E-09
N-Nitroso-di-n-propylamine	2.72E-01	No toxicity value	ND	NA	ND	7.00E+00	NA
Hazard Index				2.55E-02			
Total Cancer Risk							1.11E-06

kg = kilogram
mg = milligram
RfD = reference dose
RME = reasonable maximum exposure
SF = slope factor

APPENDIX C
RISK-BASED REMEDIATION LEVELS

Risk-Based Remediation Criteria for Groundskeeper Exposures to Surface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	3.E+01	2.E+00	3.E+02	2.E+01
PCB-1254	mg/Kg	2.E+00	1.E+00	2.E+01	1.E+01
PCB-1260	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)anthracene	mg/Kg	NA	3.E+00	NA	3.E+01
Benzo(a)pyrene	mg/Kg	NA	3.E-01	NA	3.E+00
Benzo(b)fluoranthene	mg/Kg	NA	3.E+00	NA	3.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	3.E-01	NA	3.E+00

Risk-Based Remediation Criteria for Adult Hunter Exposures to Surface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
PCB-1254	mg/Kg	2.E+01	9.E+00	2.E+02	9.E+01
Benzo(a)pyrene	mg/Kg	NA	3.E+00	NA	3.E+01

Risk-Based Remediation Criteria for Indoor Worker Exposures to Bedrock Groundwater at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
1,1,2-Trichloroethane	mg/L	4.E-02	5.E-03	4.E-01	5.E-02
Arsenic (total)	mg/L	3.E-03	2.E-04	3.E-02	2.E-03
Benzene	mg/L	4.E-02	5.E-03	4.E-01	5.E-02
Iron (total)	mg/L	7.E+00	NA	7.E+01	NA
Thallium (total)	mg/L	7.E-04	NA	7.E-03	NA

Risk-Based Remediation Criteria for Indoor Worker Exposures to Surface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	6.E+01	4.E+00	6.E+02	4.E+01
PCB-1254	mg/Kg	4.E+00	3.E+00	4.E+01	3.E+01
PCB-1260	mg/Kg	NA	3.E+00	NA	3.E+01
Benzo(a)anthracene	mg/Kg	NA	8.E+00	NA	8.E+01
Benzo(a)pyrene	mg/Kg	NA	8.E-01	NA	8.E+00
Benzo(b)fluoranthene	mg/Kg	NA	8.E+00	NA	8.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	8.E-01	NA	8.E+00

Risk-Based Remediation Criteria for Construction Worker Exposures to Surface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	5.E+00	2.E+01	5.E+01	2.E+02
Iron	mg/Kg	1.E+04	NA	1.E+05	NA
Thallium	mg/Kg	1.E+00	NA	1.E+01	NA
PCB-1254	mg/Kg	2.E-01	9.E+00	2.E+00	9.E+01
Benzo(a)pyrene	mg/Kg	NA	2.E+00	NA	2.E+01

Risk-Based Remediation Criteria for Construction Worker Exposures to Subsurface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	5.E+00	2.E+01	5.E+01	2.E+02
Iron	mg/Kg	1.E+04	NA	1.E+05	NA
Thallium	mg/Kg	1.E+00	NA	1.E+01	NA
PCB-1254	mg/Kg	2.E-01	9.E+00	2.E+00	9.E+01
Benzo(a)pyrene	mg/Kg	NA	2.E+00	NA	2.E+01

Risk-Based Remediation Criteria for Construction Worker Exposures to Sediment at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Thallium	mg/Kg	2.E+00	NA	2.E+01	NA
PCB-1254	mg/Kg	6.E-01	5.E+01	6.E+00	5.E+02

Risk-Based Remediation Criteria for Adult Residential Exposures to Bedrock Groundwater at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
1,1,2-Trichloroethane	mg/L	1.E-02	1.E-03	1.E-01	1.E-02
Aluminum (total)	mg/L	4.E+00	NA	4.E+01	NA
Arsenic (total)	mg/L	1.E-03	7.E-05	1.E-02	7.E-04
Barium (total)	mg/L	7.E-01	NA	7.E+00	NA
Benzene	mg/L	1.E-02	2.E-03	1.E-01	2.E-02
bis(2-Ethylhexyl)phthalate	mg/L	3.E-02	3.E-03	3.E-01	3.E-02
Bromomethane	mg/L	4.E-03	NA	4.E-02	NA
Cyanide	mg/L	7.E-02	NA	7.E-01	NA
Iron (total)	mg/L	3.E+00	NA	3.E+01	NA
Manganese (total)	mg/L	2.E-01	NA	2.E+00	NA
Nitrobenzene	mg/L	1.E-03	NA	1.E-02	NA
Thallium (total)	mg/L	3.E-04	NA	3.E-03	NA
Vanadium (total)	mg/L	2.E-02	NA	2.E-01	NA

Risk-Based Remediation Criteria for Adult Residential Exposures to Surface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	8.E+01	1.E+00	8.E+02	1.E+01
PCB-1254	mg/Kg	1.E+00	5.E-01	1.E+01	5.E+00
PCB-1260	mg/Kg	NA	5.E-01	NA	5.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Benzo(b)fluoranthene	mg/Kg	NA	1.E+00	NA	1.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00

Risk-Based Remediation Criteria for Adult Residential Exposures to Subsurface Soil at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	8.E+01	1.E+00	8.E+02	1.E+01
PCB-1260	mg/Kg	NA	5.E-01	NA	5.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Benzo(b)fluoranthene	mg/Kg	NA	1.E+00	NA	1.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00
Indeno(1,2,3-cd)pyrene	mg/Kg	NA	1.E+00	NA	1.E+01

Risk-Based Remediation Criteria for Adult Residential Exposures to Sediment at Acid Area 2,					
Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
PCB-1260	mg/Kg	NA	5.E+00	NA	5.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E+00	NA	1.E+01

**Risk-Based Remediation Criteria for Child Residential Exposures to Bedrock
Groundwater at Acid Area 2,**

Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
1,1,2-Trichloroethane	mg/L	5.E-03	3.E-03	5.E-02	3.E-02
2-Methylnaphthalene	mg/L	5.E-03	NA	5.E-02	NA
Aluminum (total)	mg/L	2.E+00	NA	2.E+01	NA
Arsenic (total)	mg/L	5.E-04	1.E-04	5.E-03	1.E-03
Barium (total)	mg/L	3.E-01	NA	3.E+00	NA
Benzene	mg/L	5.E-03	3.E-03	5.E-02	3.E-02
Bromomethane	mg/L	2.E-03	NA	2.E-02	NA
Chromium (total)	mg/L	5.E-03	NA	5.E-02	NA
Cyanide	mg/L	3.E-02	NA	3.E-01	NA
Iron (total)	mg/L	1.E+00	NA	1.E+01	NA
Manganese (total)	mg/L	7.E-02	NA	7.E-01	NA
Nitrobenzene	mg/L	6.E-04	NA	6.E-03	NA
Thallium (total)	mg/L	1.E-04	NA	1.E-03	NA
Vanadium (total)	mg/L	8.E-03	NA	8.E-02	NA
Xylenes, total	mg/L	1.E-01	NA	1.E+00	NA

**Risk-Based Remediation Criteria for Child Residential Exposures to Surface
Soil at Acid Area 2,**

Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Aluminum	mg/Kg	9.E+03	NA	9.E+04	NA
Arsenic	mg/Kg	2.E+00	6.E-01	2.E+01	6.E+00
Iron	mg/Kg	6.E+03	NA	6.E+04	NA
Thallium	mg/Kg	6.E-01	NA	6.E+00	NA
PCB-1254	mg/Kg	1.E-01	4.E-01	1.E+00	4.E+00
PCB-1260	mg/Kg	NA	4.E-01	NA	4.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Benzo(b)fluoranthene	mg/Kg	NA	1.E+00	NA	1.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00

**Risk-Based Remediation Criteria for Child Residential Exposures to
Subsurface Soil at Acid Area 2,**

Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Aluminum	mg/Kg	9.E+03	NA	9.E+04	NA
Arsenic	mg/Kg	2.E+00	6.E-01	2.E+01	6.E+00
Iron	mg/Kg	6.E+03	NA	6.E+04	NA
Manganese	mg/Kg	4.E+02	NA	4.E+03	NA
Thallium	mg/Kg	6.E-01	NA	6.E+00	NA
PCB-1254	mg/Kg	1.E-01	4.E-01	1.E+00	4.E+00
PCB-1260	mg/Kg	NA	4.E-01	NA	4.E+00
Benzo(a)anthracene	mg/Kg	NA	1.E+00	NA	1.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E-01	NA	1.E+00
Benzo(b)fluoranthene	mg/Kg	NA	1.E+00	NA	1.E+01
Dibenz(a,h)anthracene	mg/Kg	NA	1.E-01	NA	1.E+00
Indeno(1,2,3-cd)pyrene	mg/Kg	NA	1.E+00	NA	1.E+01

**Risk-Based Remediation Criteria for Child Residential Exposures to Sediment
at Acid Area 2,**

Analyte	Units	THI = 0.1	TILCR 10 ⁻⁶	THI = 1.0	TILCR 10 ⁻⁵
Arsenic	mg/Kg	2.E+01	6.E+00	2.E+02	6.E+01
PCB-1254	mg/Kg	1.E+00	4.E+00	1.E+01	4.E+01
PCB-1260	mg/Kg	NA	4.E+00	NA	4.E+01
Benzo(a)pyrene	mg/Kg	NA	1.E+00	NA	1.E+01

APPENDIX D
TOXICOLOGICAL PROFILES FOR CHEMICALS OF CONCERN

TOXICOLOGICAL PROFILES FOR THE CHEMICALS OF CONCERN

INTRODUCTION

Toxicological profiles are presented for each chemical of concern. The doubly hyphenated number in parentheses following the chemical name is its unique Chemical Abstract Service (CAS) registration number. The CAS number may be located in the profile title, or, in the case of multiple isomers or members of a chemical class, in the introductory text or the table that provides the physical properties.

Toxicological profiles contain brief descriptions of the nature of the potential adverse effects associated with the chemical. It is important to note that a discussion of adverse effects without a discussion of dose is incomplete and potentially misleading, because virtually any chemical may be toxic at some dose, and many chemicals (e.g., nutritionally required minerals, vitamins, amino acids, etc.) enhance human health at some low dose. An ever growing and compelling body of evidence suggests that many environmental contaminants also enhance health at low doses (Hart and Frame, 1996).

When sufficient data are available, the EPA Integrated Risk Information System (IRIS) presents the EPA's verified chronic toxicity values for noncancer effects, and for cancer risk (EPA, 2001). The toxicity values for noncancer effects include a reference dose (RfD) expressed in milligrams per kilogram per day (mg/kg-day) for chronic oral exposure, and a reference concentration (RfC), in milligrams per cubic meter (mg/m³), for chronic inhalation exposure. The inhalation RfC in units of mg/m³ may be converted to an equivalent inhalation RfD by assuming continuous chronic exposure of humans with a body weight of 70 kg and an inhalation rate of 20 m³/day. In other words, the RfC expressed as mg/m³ is multiplied by the inhalation rate of 20 m³/day, and the result is divided by the body weight of 70 kg to yield an inhalation RfD expressed as mg/kg-day.

RfDs and RfCs are usually derived from empirical benchmark doses (BMD) or concentrations called no-observed-effect levels (NOEL) or no-observed-adverse-effect levels (NOAEL) from animal toxicity or human epidemiology studies. If the data do not permit identifying a NOEL or NOAEL, a lowest-observed-adverse-effect level (LOAEL) or lowest-effect level (LEL) may be used. A frank-effect level (FEL), e.g., mortality, shortened life span or serious physiologic, neurologic or behavioral disturbances, is generally considered an inappropriate benchmark from which to develop an RfD or RfC. Some RfD and RfC derivations employ a BMD that is a statistically estimated dose for humans at which some low proportion of the population may experience some minimally adverse effect. A BMD at which 10 percent of the population may be expected to respond is expressed as BMD₁₀. The RfD or RfC is derived by dividing the benchmark level (e.g., NOAEL or BMD₁₀) by a series of uncertainty and modifying factors, which collectively are designated the uncertainty factor (UF).

For cancer effects, IRIS presents a verified EPA cancer weight-of-evidence group classification that reflects qualitatively the likelihood that the chemical is carcinogenic to humans. IRIS also presents a slope factor (SF) for oral exposure, expressed as the risk per mg/kg-day ingested dose, and a unit risk factor (URF) for inhalation exposure, expressed as the risk per microgram per cubic meter (µg/m³) in ambient air. These quantitative estimates are generally provided for chemicals in EPA weight-of-evidence Groups A and B and C, if the data are adequate. The SF or URF is usually estimated as an upper bound on the slope of the dose- or concentration response curve from animal

toxicity or human epidemiology studies. The inhalation URF in units of risk per $\mu\text{g}/\text{m}^3$ may be converted to an equivalent inhalation SF in units of risk per $\text{mg}/\text{kg}\text{-day}$ by assuming continuous lifetime exposure of humans with a body weight to 70 kg and an inhalation rate of $20 \text{ m}^3/\text{day}$. In other words, the URF expressed as risk per $\mu\text{g}/\text{m}^3$ is divided by the inhalation rate of $20 \text{ m}^3/\text{day}$, and multiplied by the assumed body weight of 70 kg and a conversion factor of $1000 \mu\text{g}/\text{mg}$.

Toxicity values are not estimated for acute toxicity and acute exposure is not evaluated in the risk assessment. Nonetheless, the levels associated with acute lethality and data regarding the effects of acute exposure to levels higher than ordinarily observed in chronic environmental exposure provide additional perspective regarding the toxicity of the chemical. Therefore, information regarding acute toxicity, when available, is included in the profiles. Lethality data for laboratory animals are generally expressed as the oral dose associated with lethality of 50 percent of an exposed population (LD_{50}) or the concentration in air associated with lethality of 50 percent of an exposed population (LC_{50}). Occasionally the dose associated with lethality in a low percentage of an exposed population (LD_{LO}) is presented.

The toxicity profiles also provide documentation for physical constants that are important for chemical transport modeling, such as molecular weight (MW) in grams per mole (g/mole), the log of the octanol/water partition coefficient ($\log K_{ow}$), Henry's law constant (H) in atmosphere-cubic meter/mole ($\text{atm}\text{-m}^3/\text{mole}$), the soil/water partition coefficient (K_d) in liters per kilogram (L/kg) for metals, the log of the soil/organic carbon partition coefficient ($\log K_{oc}$ (unitless) for organic chemicals, diffusivity in air (D_a) in square centimeters per second (cm^2/s), diffusivity in water (D_w) in cm^2/s , vapor pressure (VP) in atmospheres (atm), and solubility in water (S) in milligrams per liter (mg/L). In addition, organic chemicals are designated as volatile organic compounds (VOC) or semivolatile organic compounds (SVOC) based on their propensity to volatilize from environmental media. Chemicals designated as VOCs generally have a MW less than 200 g/mole and H greater than $1 \text{ E-}5 \text{ atm}\text{-m}^3/\text{mole}$ (EPA, 1991).

The physical constants generally are taken from the most reliable source (i.e., the source that provides the highest level of documentation). Values for interrelated properties are usually taken from the same source (e.g., H is often estimated from VP and S; therefore, the same source is generally used for all three property values). When one source provides several values for a given property, professional judgment is used to select the most appropriate. Obvious outliers may be dropped from consideration. The average or the midpoint of a range of values may be selected. K_d values for metals and K_{oc} values for ionizing organic compound are based on a default pH of 6.8 (EPA, 1996) if the data are available. VP, S and H values are limited to those provided for normal ambient temperatures (0 to 30°C), but the temperatures reported in the original sources are not presented in the toxicity profile, nor is any attempt made to extrapolate K, VP or S to any default temperature.

When values for H were not located, they were calculated as follows, provided the requisite information was available (EPA, 1998):

$$H = \frac{VP \cdot MW}{S} \quad \text{Eq. 1}$$

where :

H = Henry's law constant ($\text{atm}\text{-m}^3/\text{mole}$, calculated)

VP = vapor pressure (atm)
MW = molecular weight (g/mole)
S = solubility in water (mg/L).

When values for D_a were not located, they were calculated as follows (EPA, 1998):

$$D_s = \frac{1.9}{MW^{2/3}} \quad \text{Eq. 2}$$

where:

D_a = diffusivity in air (cm²/s, calculated)
MW = molecular weight (g/mole) .

When values for D_w were not located, they were calculated as follows (EPA, 1998):

$$D_w = \frac{22E - 5}{MW^{2/3}} \quad \text{Eq. 3}$$

where :

D_w = diffusivity in water (cm²/s, calculated)
MW = molecular weight (g/mole).

When values for K_{oc} were not located, they were calculated as follows for phthalates and polyaromatic aromatic hydrocarbons (PAH) provided $\log K_{ow}$, was available (EPA, 1998):

$$\log K_{oc} = 0.97 \log K_{ow} - 0.094 \quad \text{Eq. 4}$$

where:

K_{oc} = soil/organic carbon partition coefficient (unitless, calculated)
 K_{ow} = octanol/water partition coefficient (unitless).

K_{oc} , for other organic chemicals was calculated as follows provided $\log K_{ow}$ was available (EPA, 1998):

$$\log K_{oc} = 0.18 \log K_{ow} + 0.151 \quad \text{Eq. 5}$$

where:

K_{oc} = soil/organic carbon partition coefficient (unitless, calculated)
 K_{ow} = octanol/water partition coefficient (unitless).

The toxicity profiles also present the predominant sources of release to the environment as well as a qualitative description of the fate of the chemical in air, surface water and sediment, and soil. No attempt is made to present quantitative data because environmental fate is usually highly dependent on climatic conditions and the characteristics of the medium to which the chemical is released, which may differ from location to location and change from time to time. The source and fate information may provide perspective regarding the likelihood that the chemical's presence is related to site activities, that the chemical will migrate across media, or that the chemical will persist at toxicologically significant levels.

Biotransfer factors are provided for chemicals for which food-chain pathways may be significant, which includes many inorganic chemicals and those organic chemicals that are highly lipophilic and persist in the environment. High lipophilicity is indicated by a log

K_{ow} greater than 3 (Lyman et al., 1990). Lipophilicity enhances partitioning to biomedica and passage across biological membranes. Persistence in the environment is evidence that the chemical might resist biotransformation and, therefore, remain in edible tissues at toxicologically significant concentrations. VOCs tend to be mobile and labile (i.e., subject to rapid and extensive biotransformation and excretion), and generally do not participate significantly in food-chain pathways. Therefore, biotransfer factors are not estimated for VOCs. Some of the SVOCs, however, are highly lipophilic. They may persist or yield metabolites that are significant toxicants in their own right. For example, the organochlorine pesticide DDT is metabolized by mammals to DDE, which is similar in carcinogenic potency to the parent compound. Biotransfer factors are generally estimated for SVOCs that have $\log K_{ow}$ values greater than 3.

The biotransfer factors of interest are soil-to-plant biotransfer factors (B_p) and cattle ingestion-to-beef factors (B_b). Separate soil-to-plant biotransfer factors are available for the reproductive parts of plants (e.g., fruits, seeds) and the vegetative parts of plants (e.g., stems, leaves) for inorganic and some organic chemicals. Soil-to-plant factors for the reproductive parts of plants are designated B_{pr} ; soil-to-plant factors for the vegetative parts of plants are designated B_{pv} .

Soil-to-plant biotransfer factors (B_p) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on $\log K_{ow}$:

$$\log B_p = 1.588 - 0.578 \log K_{ow} \quad \text{Eq. 6}$$

where:

B_p = soil-to-plant biotransfer factor (unitless, calculated)

K_{ow} = octanol/water partition coefficient (unitless).

Separate biotransfer factors are not estimated for the reproductive parts of plants (B_{pr}) and the vegetative parts of plants (B_{pv}).

Cattle ingestion-to-beef factors (B_b) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on $\log K.W$:

$$\log B_p = 7.6 + \log K_{ow} \quad \text{Eq. 7}$$

where:

B_b = cattle ingestion-to-beef biotransfer factor (days/kg, calculated)

K_{ow} = octanol/water partition coefficient (unitless).

This risk assessment followed EPA's *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)* (EPA 2004a). Therefore, oral RfDs and slope factors were used without modification. Additionally, only those constituents identified in the guidance as having sufficient data for dermal uptake from soil were evaluated for soil and sediment. Dermal absorbed doses for surface water and sediment were calculated using the spreadsheet model developed by EPA that accompanies the guidance.

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INORGANIC CHEMICALS

ARSENIC (7440-38-2)

Arsenic is a natural metalloid that occurs in both inorganic and organic forms (ATSDR, 1998). Inorganic arsenic is more toxic than organic forms. Major uses in the U.S. include its incorporation into wood preservatives and other agricultural chemicals. Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm-m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
74.92 (element)	NA	NA	2.9e+1 ^a	NA	NA	Note 1 ^b	Note 2 ^b

NA = not applicable
 Note 1 : Variable : inorganic arsenic compounds are not likely to volatilize ; some organic arsenic compounds are low-boiling liquids or gases at normal temperatures .
 Note 2 : Variable: inorganic arsenic compounds range from practically insoluble to freely miscible in water; most organic arsenic compounds are not readily soluble, most arsenic acid compounds are soluble to freely miscible.
 a U.S . Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
 b Agency for Toxic Substances and Disease Registry, (ATSDR), 1998, Update Toxicological Profile for Arsenic, U.S. Public Health Service, Atlanta, Georgia, April.

The major source of arsenic release to the environment is from copper, zinc and lead smelting operations (HSDB, 2001). Releases also occur from several other industries that use arsenic. Most (approximately 80 percent) anthropogenic releases are initially to soil (ATSDR, 1998).

Arsenic occurs in the air as a combination of trivalent and pentavalent forms almost entirely adsorbed to small particles that permit dispersion over long distances (ATSDR, 1998). Residence time in the atmosphere averages approximately nine days. Removal is largely by wet and dry deposition. Arsenic in surface water can undergo a variety of transformations and exist in several soluble forms. Sorption to sediment is often an important removal process, but biotransformation in sediment may return soluble forms to the water. Arsenic in soil generally exists as insoluble forms sorbed to clay or organic matter or complexed with calcium or iron. Mobility is low and leaching is not generally significant, except that increasing soil pH can dramatically increase mobility.

Biotransfer factors for arsenic are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
20 ^a	6.0E-3 ^b	4.0E-2 ^b	2.0E-3 ^b

a U .S. Environmental Protection Agency (EPA), 1998, Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume Two, Peer Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, EPA530-D-98-001 B, July.
 b Baes, C.F., R.D. Sharp, A.L . Sjoreen, R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September.

Data regarding the dermal uptake of arsenic were not located. The default ABS of 0 .01 for metals (OEPA, 1998) is used herein.

Inorganic arsenic may be an essential nutrient, exerting beneficial effects on growth, health and feed conversion efficiency (Underwood, 1977). A lethal dose of arsenic trioxide in humans is 70-180 mg (=50-140 mg arsenic (Ishinishi et al., 1986)). Acute oral exposure of humans to high doses of arsenic produces liver swelling, skin lesions, disturbed heart function and neurological effects. The only noncancer effects in humans clearly attributable to chronic oral exposure to arsenic are dermal hyperpigmentation and keratosis, as revealed by studies of several hundred Chinese exposed to naturally occurring arsenic in well water (EPA, 2001). Similar effects were observed in persons exposed to high levels of arsenic in water in Utah and the northern part of Mexico . EPA (2001) verified an RfD of $3E-4$ mg/kg-day for chronic oral exposure, based on a NOAEL of $8E-4$ mg/kg-day for hyperpigmentation and kertatosis of the skin from the Chinese data. An uncertainty factor of 3 was applied. An increased incidence of Blackfoot disease was also observed, which may not be related to arsenic alone. Goyer (1991) describes black-foot disease as a peripheral vascular disorder manifested as acrocyanosis and Raynaud's disease, which may progress to gangrene. Confidence in the RfD is medium. EPA (2001) notes that the skin is the more sensitive target organ. Nonetheless, in keeping with EPA (1989) guidance regarding selection of target organ, both the skin and peripheral vascular system are selected as target organs for prolonged oral exposure to arsenic.

Occupational (predominantly inhalation) exposure is also associated with neurological deficits, anemia, and vascular effects (Ishinishi et al., 1986), but concomitant exposure to other chemicals cannot be ruled out. The data are not sufficient for estimation of an inhalation RfC. Inorganic arsenic is clearly a carcinogen in humans. Inhalation exposure is associated with increased risk of lung cancer in persons employed as smelter workers, in arsenical pesticide applicators, and in a population residing near a pesticide manufacturing plant (EPA, 2001). Oral exposure to high levels in well water is associated with increased risk of skin cancer. Extensive animal testing with various forms of arsenic given by many routes of exposure to several species, however, has not demonstrated the carcinogenicity of arsenic. EPA (2001) classified inorganic arsenic in cancer weight-of-evidence Group A (human carcinogen), and recommended an oral SF of $1.5E+0$ per mg/kg-day, based on the incidence of skin cancer in the Chinese study. EPA (2001) noted that the uncertainties associated with the oral unit risk are considerably less than those for most carcinogens, so that the unit risk might be reduced an order of magnitude. An inhalation URF of $4E-3$ per pg/m³, equivalent to an inhalation SF of $1.5E+1$ per mg/kg-day, was derived for inorganic arsenic from the incidence of lung cancer in occupationally exposed men.

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LEAD (7439-92-1)

Lead is a naturally occurring metal used in the manufacture of batteries, ammunition, and other metal products (ATSDR, 1997). Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm-m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
207.2 (element)	NA	NA	ND	NA	NA	ND	9.9E-3 ^a

NA = not applicable, ND = do data

a Value for lead chloride as a typical lead salt (Agency for Toxic Substances and Disease Registry, [ATSDR], 1997, Update Toxicological Profile for Lead, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, August.)

Lead may enter the environment during mining, ore processing, smelting, refining, use, recycling or disposal (ATSDR, 1997; HSDB, 2001). Emission from automobile exhaust was at one time the largest source of atmospheric lead. Natural sources are minor compared with anthropogenic sources. Generally the form of lead that enters the atmosphere is not known. However, metallic lead may be released from smelting and refining plants. Lead in air exists attached to small particles that may travel great distances before removal by wet or dry deposition. Lead deposited on or released to soil generally remains in the top 2 to 5 cm where it remains relatively immobile, although a small percentage may be present in soluble forms that are subject to leaching. Acid conditions increase the potential for leaching. Lead released to surface water tends to form salts that are only sparingly soluble. Deposition in bed sediment is the primary removal mechanism, although biomethylation may mobilize lead and return it to the water column. Soil and sediment act as sinks for anthropogenic releases of lead.

Lead in fish is localized in the mucus on the epidermis, the dermis, and scales so that the edible portions generally do not pose a hazard to human health (HSDB, 2001). Therefore, the BCF listed below probably overstates the danger to humans. Lead does not biomagnify through the aquatic or terrestrial food chains (ATSDR, 1997). Biotransfer factors for lead are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
49 ^a	9.0E-3 ^b	4.5E-2 ^b	3.0E-4 ^b

a U.S. Environmental Protection Agency (EPA), 1986, Superfund Public Health Evaluation Manual, Office of Emergency and Remedial Response, Washington, DC, OSWER Directive 9285-4-1, EPA/540/1-86/060, PB87-183125, October.

b Baes, C.F., R.D. Sharp, A.L. Sjoreen, R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September.

The noncancer toxicity of lead to humans has been well characterized through decades of medical observation and scientific research (EPA, 2001). The principal effects of acute oral exposure are gastrointestinal colic with diffuse paroxysmal abdominal pain (probably due to vagal irritation), anemia, and, in severe cases, acute encephalopathy, particularly in children (Tsuchiya, 1986). The primary effects of long-term exposure are neurological and hematological. Limited occupational data indicate that long-term exposure to lead may induce kidney damage. The principal target organs of lead toxicity are the nervous system and the erythrocyte. Some of the effects on the blood, particularly changes in levels of certain blood enzymes, and subtle neurobehavioral changes in children, appear to occur at levels so low as to be considered non-threshold

effects. In part for this reason the EPA (1990, 2001) considered inappropriate the derivation of an RfD for chronic oral exposure.

The Integrated Exposure, Uptake Biokinetic Model (IEUBK) Version 0.99D (EPA, 1994a) is generally used to evaluate lead in children, the most sensitive receptor under a residential exposure scenario. The IEUBK model integrates lead uptake from inhalation, drinking water, diet, soil and dust ingestion, and ingestion of incidental sources such as chips of lead-based paint, and estimates blood lead concentrations over the first seven years of a child's life. Generally, it is considered that childhood blood lead levels below 10 µg/dL reflect minimal likelihood of adverse effects from exposure to lead. Since it is plausible that children could be present under most residential site-use scenarios, it is appropriate to use the IEUBK to establish target levels for lead in soil for residential use. EPA (1994b) used the IEUBK to estimate a lead concentration of 400 mg/kg in bare soil to which children might be regularly exposed as the level below which further evaluation and exposure-reduction action is not necessary.

The IEUBK, however, does not address lead concentrations in media to which adults may be exposed in a non-residential site-use scenario. EPA (1996) adopted a model similar to the IEUBK to estimate blood lead concentrations in adult women in an occupational exposure scenario. The pregnant woman is assumed to be the member of the adult population most sensitive to exposure to lead because of the potential for developmental effects on the fetus. The EPA (1996) adult blood lead model estimates a lead concentration in soil of approximately 750 mg/kg (EPA, 2001) as the level below which the 95' percentile fetal blood lead concentration would not exceed 10 µg/dL.

EPA (2001) classified lead in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate evidence in humans and sufficient animal evidence. The human data consist of several epidemiologic occupational studies that yield confusing results. All the studies lacked quantitative exposure data and failed to control for smoking and concomitant exposure to other possibly carcinogenic metals. Rat and mouse bioassays showed statistically significant increases in renal tumors following dietary and subcutaneous exposure to several soluble lead salts. Various lead compounds were observed to induce chromosomal alterations in vivo and in vitro, sister chromatid exchange in exposed workers and cell transformation in Syrian hamster embryo cells, to enhance simian adenovirus induction, and to alter molecular processes that regulate gene expression. EPA (2001) declined to estimate risk for oral exposure to lead because many factors (e.g., age, general health, nutritional status, existing body burden and duration of exposure) influence the bioavailability of ingested lead, introducing a great deal of uncertainty into any estimate of risk.

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MANGANESE (7439-96-5)

Manganese is a naturally occurring metal used in the manufacture of steel, and in other metallurgical processes, batteries, and various manganese-containing chemicals including matches, glass and porcelain, fireworks, varnishes, ceramics and fungicides (ATSDR, 1997; Keen and Leach, 1988). Relevant physical properties are compiled below:

MW (g/mole) (element)	log K _{ow} (unitless)	H (atm-m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
54.94	NA	NA	ND	NA	NA	ND	Note 1 ^a

NA = not applicable, ND = do data

Note 1: Metallic manganese decomposes in the presence of water. Manganous chloride as a typical manganese salt: 7.23E+5.

a Agency for Toxic Substances and Disease Registry, (ATSDR), 1997, Update Toxicological Profile for Manganese, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, September.

Anthropogenic sources of atmospheric manganese include metal processing, disposal of manganese-containing materials, resuspension of manganese-containing soil dust, fly ash emissions from incinerators, and the combustion of gasoline containing manganese anti-knock ingredients (ATSDR, 1997; HSDB, 2001). Manganese may be released to water by discharge from industrial facilities or in leachate from landfills and soil. Landfill disposal of manganese-containing wastes is the predominant source of manganese release to soil.

Manganese exists in the air bound to particles; dry deposition is the primary removal mechanism, although wet deposition may also be significant (ATSDR, 1997). Manganese in fly ash exists as chlorides and oxides that are relatively soluble and mobile in the environment.

Manganese in water exists as any number of sparingly soluble salts that attach to suspended sediment (ATSDR, 1977). Sedimentation is the primary removal process. Soluble forms also exist, depending on pH of the water, and may be released from sediment. The extent of absorption to constituents of soil is highly variable. Low concentrations may occur in an irreversibly "fixed" form to clay, but higher concentrations often manifest considerable mobility.

Biotransfer factors for manganese are compiled below:

BCF (L/kg)	Bpr (unitless)	BPV (Unitless)	Bb (days/kg)
See Below	5.0E-2 ^a	2.5E-1 ^a	4.0E-4 ^a

a Baes, C.F., R.D. Sharp, A.L. Sjoreen, R.W. Shor, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Health and Safety Division, Oak Ridge National Laboratory, ORNL-5786, September.

Manganese in aquatic systems tends to bioaccumulate more strongly in plants and lower trophic levels, and less strongly in edible fish. ATSDR (1997) reports BCFs of 10,000 to 20,000 L/kg for marine and freshwater plants, 2500 to 6300 L/kg for phytoplankton, 300 to 5500 L/kg for marine algae, 800 to 830 L/kg for intertidal mussels, and 100 to 600 L/kg reported for fin fish. The midpoint of the BCF range for intertidal mussels of 815 L/kg is used herein for shellfish. The midpoint of the BCF range for fin fish of 350 L/kg is used herein for fin fish.

Keen and Leach (1988) and ATSDR (1997) reviewed the empirical data and reported that approximately three to five percent of dietary manganese is absorbed, regardless of the amount present in the diet. EPA (2001) selected five percent as a rough approximation of the extent of GI absorption. This value (0.05) is selected as the GAF for manganese.

The ABS of 0.01 is an OEPA (1998) default for metals for which empirical data are lacking.

Manganese is nutritionally required in humans for normal growth and health (EPA, 2001). Humans exposed to approximately 0.8 mg manganese/kg-day in drinking water (28 mg/L) exhibited lethargy, increased muscle tonus, tremor and mental disturbances. The elderly appeared to be more sensitive than children. Oral treatment of laboratory rodents induces biochemical changes in the brain, but rodents do not exhibit the neurological signs exhibited by humans. Occupational exposures to high concentrations in air induce a generally typical spectrum of neurological effects, and increased incidence of pneumonia (ACGIH, 1991).

EPA (2001) derived an oral RfD for manganese of $1.4E-1$ mg/kg-day from a NOAEL of $1.4E-1$ mg/kg-day for neurologic effects from human dietary studies and an uncertainty factor of 1. Confidence in the RfD is medium. The oral RfD of $1.4E-1$ mg/kg-day will be used for dietary items other than drinking water. EPA (2001) recommends that a modifying factor of 3 should be used to adjust the RfD for use when oral exposure involves drinking water and non-dietary ingestion. The oral RfD resulting from application of the modifying factor, $4.7E-2$ mg/kg-day, will be used for drinking water and incidental ingestion of non-dietary items, and will serve as the basis for developing the dermal RfD. The CNS is the target organ for chronic oral exposure to manganese. EPA (2001) presents a verified chronic inhalation RfC of $5E-5$ mg/m³ (equivalent to an inhalation RfD of $1.4E-5$ mg/kg-day) based on a LOAEL for neurological effects in occupationally exposed humans and an uncertainty factor of 1000. Confidence in the RfC is medium. The CNS is the target organ for inhalation exposure to manganese.

EPA (2001) classified manganese in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans). Quantitative cancer risk estimates are not derived for Group D chemicals.

References for Manganese

Agency for Toxic Substances and Disease Registry, (ATSDR), 1992, Toxicological Profile for Acetone, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, ACGIH, Cincinnati, OH, pp. 10-11.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011B, January.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System(IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

Benzene (71-43-2)

Benzene is a naturally occurring VOC, present in low levels in many plants and animals, as well as a synthetic compound derived from petroleum (ATSDR, 1995). Benzene is widely used as a solvent and in the manufacturing of other organic compounds such as styrene, phenol, detergents, pesticides, explosives, polychlorinated biphenyls, flavors, perfumes, paints and coatings, nylon intermediates and photographic chemicals, among others. It is also used in food processing and leather tanning and occurs a component of gasoline. Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm-m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
78.1	2.13 ^a	5.56E-3 ^b	1.77 ^b	8.8E-2 ^b	9.8E-6 ^b	1.25E-1 ^c	1.75E+3 ^b

a U.S . Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01113, January.
b U.S . Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.
c U. S. Environmental Protection Agency (EPA), 1994, Technical Background Document for Soil Screening Guidance, Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, Publication No. 9355.4-17, EPA540/R-94/106, PB95-963532, November.

Benzene will enter the atmosphere primarily from fugitive emissions and exhaust connected with its use in gasoline (ATSDR, 1995 ; HSDB, 2001) . Other important sources are emissions associated with its production and use as a solvent, as an industrial intermediate in the production of materials mentioned above, and coke oven blast furnaces and coke by-product recovery plants. In addition, there are discharges into water from industrial effluents and losses during spills. Sources of release to soil include land disposal of benzene-containing wastes, industrial discharge and leaks from underground storage tanks.

Benzene released to the atmosphere will exist almost exclusively in the vapor phase (ATSDR, 1995; HSDB, 2001). It is not subject to direct photolysis but it will react with photochemically produced hydroxyl radicals with a half-life of approximately 13 days. The reaction time in polluted atmospheres which contain nitrogen oxides or sulfur dioxide is accelerated with the half-life being reported as 4-6 hours. Products of photooxidation include phenol, nitrophenols, nitrobenzene, formic acid, and peroxyacetyl nitrate. Benzene is fairly soluble in water and is removed from the atmosphere in rain.

Benzene released to soil will be subject to rapid volatilization near the surface; that which does not evaporate will be highly to very highly mobile in the soil and may leach to groundwater (ATSDR, 1995; HSDB, 2001). Benzene may be subject to biodegradation under aerobic conditions. Microbial transformation proceeds through formation of cis-dihydrodiols to catechols, which lead to fission of the aromatic ring.

Benzene may be subject to photooxidation and biodegradation in shallow, aerobic groundwaters, but probably not significantly under deeper or anaerobic conditions (ATSDR, 1995; HSDB, 12001). Benzene released to surface water will be subject to rapid volatilization. It is not expected to sorb to sediment or to hydrolyze significantly. It may be subject to biodegradation, but this is unlikely to be a significant fate process in sediment.

Benzene is not expected to participate significantly in food-chain pathways (HSDB, 2001); therefore, biotransfer factors are not provided.

The OEPA (1998) default ABS of 0.1 for organic chemicals is adopted for this evaluation.

Short-term exposure to benzene induces central nervous system (CNS) effects such as drowsiness, dizziness and headaches; long-term exposure may induce anemia (ATSDR, 1995). Oral dosing in animals induces hematopoietic and immune effects. EPA (1996) derived a provisional RfD for chronic oral exposure of $3E-3$ mg/kg-day, based on a LOAEL of 8 mg/kg-day in a 28-day drinking water study in mice. The LOAEL was associated with minor hematologic effects (erythrocytopenia, leucopenia, lymphocytopenia), all associated with decreased cell counts, and increased response in several tests of immunologic activity. Depressed immunologic activity was observed at higher dose levels. An uncertainty factor of 3000 was applied to derive the provisional RfD from the LOAEL. Confidence in the RfD is medium. The hematopoietic mechanism and the immune system are the target organs for chronic oral exposure to benzene.

A provisional chronic inhalation RfC of $6E-3$ mg/m³ for benzene was based on a LOAEL of 32 mg/m³ for depressed hematopoiesis in a study in which mice were exposed intermittently for up to 178 days (EPA, 1994). The exposure concentration was adjusted to an equivalent human continuous exposure concentration of 5.7 mg/m³. Application of an uncertainty factor of 1000 to the LOAEL of 5.7 mg/m³ yields the RfC of $6E-3$. The RfC is equivalent to an RfD of $1.7E-3$ mg/kg-day. Confidence in the inhalation RfC is low. The hematopoietic mechanism and the immune system are the target organs for chronic inhalation exposure to benzene.

Benzene is classified as an EPA cancer weight-of-evidence Group A chemical (known human carcinogen) based on epidemiologic studies and case studies that provide clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia, and that also provide supportive evidence for chronic nonlymphocytic leukemia and chronic lymphocytic leukemia (EPA, 2001). Other neoplastic conditions that are associated with an increased risk in humans are hematologic neoplasms, blood disorders such as preleukemia and aplastic anemia, Hodgkin's lymphoma, and myelodysplastic syndrome. Experimental animal data add to the weight of evidence that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (hematopoietic, oral and nasal, liver, forestomach, preputial gland, lung, ovary, and mammary gland).

A verified URF for inhalation exposure of $2.2E-6$ to $7.8E-6$ per $\mu\text{g}/\text{m}^3$ was based on the incidence of leukemia in humans exposed to benzene while employed in the Pliofilm industry (EPA, 2001). A low-dose linearity model utilizing maximum likelihood estimates was used to estimate the URF. The range reflects differences in the exposure assumptions estimated from the study. EPA (2001) concluded that neither any specific URF value nor either end of the range is more defensible than the other. Therefore, the upper end of the range, $7.8E-6$ per $4\text{g}/\text{m}^3$, is conservatively selected for this evaluation. The URF of $7.8E-6$ per $\sim\text{Lg}/\text{m}^3$ is equivalent to an inhalation SF of $2.7E-2$ per mg/kg/day.

The occupational data that serve as the basis for the inhalation URF also serve as the basis for a verified oral SF for benzene (EPA, 2001). The inhalation URF range was mathematically converted to an equivalent oral SF range by applying standard inhalation rate and body weight assumptions, and by adjusting for route-specific differences in absorption. EPA (2001) assumed that GI absorption is 100 percent and that respiratory tract uptake is 50 percent. The oral SF range so derived is $1.5E-2$ to $5.5E-2$ per mg/kg-

day. The upper end of the range, 5.5E-2 per mg/kg-day, is selected as the oral SF for this evaluation.

References for Benzene

Agency for Toxic Substances and Disease Registry, (ATSDR), 1995, Update Toxicological Profile for Benzene, Draft for Public Comment, U.S . Public Health Service, Atlanta, Georgia, August.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Jones, T.D. and BA Owen, 1989, Health Risks from Mixtures of Radionuclides and Chemicals in Drinking Water, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22 .

U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. Environmental Protection Agency (EPA), 1994, Risk Assessment Issue Paper for: Derivation of a Provisional Chronic Inhalation RfC for Benzene (CASRN 71-43-2), National Center for Environmental Assessment, Cincinnati, OH, March 23.

U.S. Environmental Protection Agency (EPA), 1996, Risk Assessment Issue Paper for: Derivation of a Provisional Oral RfD for Benzene (CASRN 71-43-2), National Center for Environmental Assessment, Cincinnati, OH, July 2.

U.S. Environmental Protection Agency (EPA), 2001, Integrated Risk Information System (IRIS), National Center for Environmental Assessment, Cincinnati, OH, on line.

NITROTOLUENES

The nitrotoluenes consist of three isomers: o-nitrotoluene (2-nitrotoluene), m-nitrotoluene (3-nitrotoluene) and p-nitrotoluene (4-nitrotoluene) (Lewis, 1997). All behave in the environment as VOCs. The nitrotoluenes, especially the o- and p-isomers, are used as intermediates in the synthesis of other organic chemicals, particularly toluidine, tolidine, fuchsine and other synthetic dyes, explosives, petrochemicals, pesticides, pharmaceuticals, rubber and agricultural chemicals, dyes and pigments (HSDB, 2001). Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm- m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
o-nitrotoluene (88-72-2)							
137.13	2.3 ^a	5.56E-5 ^a	2.44 ^a	7.14E-2 ^b	8.0E-6 ^c	1.32E-4 ^c	6.52E+2 ^a
m-nitrotoluene (99-08-1)							
137.13	2.45 ^a	7.5E-5 ^a	2.16 ^a	7.14E-2 ^b	8.0E-6 ^c	2.72E-4 ^c	4.98E+2 ^c
p-nitrotoluene (99-99-0)							
137.13	2.37 ^a	5.0E-5 ^a	2.49 ^a	7.14E-2 ^b	8.1E-6 ^c	1.22E-4 ^c	4.22E+2 ^c
a Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line. b Calculated as described in Introduction to the Toxicity Profiles. c Montgomery, J .H., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York, pp. 790-795 .							

The major sources of release of nitrotoluenes to the environment appear to be production and use facilities and plants which produce these compounds as by-products (HSDB, 2001). These include manufacturers of dinitrotoluene, trinitrotoluene, intermediates for rubber and agricultural chemicals, and various azo and sulfur dye intermediates. Nitrotoluenes may also enter the environment from the disposal of waste products which contain these compounds.

Nitrotoluenes released to soil are expected to be resistant to oxidation and chemical hydrolysis (HSDB, 2001). The nitrotoluenes are reported to biodegrade under anaerobic conditions to form toluidine; one study under aerobic conditions in a mixed culture of soil microorganisms resulted in persistence exceeding 64 days. The nitrotoluenes are expected to be moderately to highly mobile in soil and volatilize slowly from dry soil surfaces.

Nitrotoluenes released to water are expected to be susceptible to photolysis, volatilization and aerobic biodegradation, provided suitable acclimation has been achieved (HSDB, 2001). Oxidation, chemical hydrolysis, adsorption to suspended solids and sediments and bioaccumulation in aquatic organisms are not expected to be significant fate processes. Insufficient data were available to indicate the significance of anaerobic biodegradation as a possible removal mechanism. Nitrotoluenes released to the atmosphere are expected to exist entirely in the vapor phase (HSDB, 2001). The dominant removal mechanism is expected to be reaction with photochemically generated hydroxyl radicals (estimated half-life 8 hours) and direct photolysis. Photoproducts include 2-methyl-6-nitrophenol and 2-methyl-4-nitrophenol (o-isomer), 3-methyl-4-nitrophenol, 3-methyl-2-nitrophenol and 3-methyl-6-nitrophenol (m-isomer) and 2-methyl-6-nitrophenol (p-isomer).

The nitrotoluenes are not expected to bioconcentrate or bioaccumulate significantly (HSDB, 2001); therefore, biotransfer factors are not estimated.

Data regarding the dermal uptake of the nitrotoluenes from soil were not located in the available literature; the OEPA (1998) default ABS of 0.1 for organic chemicals is selected for this evaluation.

Data regarding the acute toxicity of oral exposure to the nitrotoluenes were not located. A 13-week dietary study with the three nitrotoluene isomers in rats and mice indicated that effects were most notable with o-nitrotoluene (ACGIH, 1991). Effects included biochemical evidence of altered liver function, and splenic and renal lesions. EPA (1997) derived a provisional RfD of 1×10^{-2} mg/kg-day for chronic oral exposure to all three nitrotoluene isomers from data for o-nitrotoluene. In the key study, rats were treated by gavage for 6 months. The LOAEL was 200 mg/kg-day associated with lesions in the spleen. An uncertainty factor of 10,000 was applied to the LOAEL. The derivation of the provisional RfD is unclear, because dividing the LOAEL of 200 mg/kg-day by an uncertainty factor of 10,000 would be expected to yield an RfD of 2×10^{-2} mg/kg-day, not 1×10^{-2} mg/kg-day as reported by EPA (1997). The liver, spleen and kidney are considered to be the target organs for chronic oral exposure to the nitrotoluenes.

Data regarding the toxicity of inhalation exposure to the nitrotoluenes were not located in the available literature. The data are inadequate for developing an inhalation RfC.

Data regarding the potential carcinogenicity of the nitrotoluenes were not located in the available literature. The nitrotoluenes are not assigned to a cancer weight-of-evidence group and URFs and SFs are not available.

References for Nitrotoluenes

Agency for Toxic Substances and Disease Registry, (ATSDR), 1990, Toxicological Profile for Nitrobenzene, U.S. Department of Health and Human Services, Atlanta, GA.

Agency for Toxic Substances and Disease Registry, (ATSDR), 1997, Update Toxicological Profile for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, GA, September.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, ACGIH, Cincinnati, OH, pp. 1131-1133.

Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

Lewis, R.J., Sr., 1997, Hawley's Condensed Chemical Dictionary, Thirteenth Edition, John Wiley & Sons, Inc., New York, pp. 800-801.

Ohio Environmental Protection Agency (OEPA), 1998, U.S. NASA Plum Brook, Erie County, Ohio LD#: 322-0552, Risk Assessment Work Plans, letter from R.E. Nabors, Site Coordinator, to L.S. Ingram, Department of the Army, June 22.

Environmental Protection Agency (EPA), 1992a, Health Advisory for 2,4- and 2,6-Dinitrotoluene (DNT), Health and Ecological Criteria Division, Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1992b, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01 1 B, January.

U.S. Environmental Protection Agency (EPA), 1997, Health Effects Assessment Summary Tables, FY1997 Update, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

POLYAROMATIC HYDROCARBONS (PAHs)

The PAHs COCs are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. All are SVOCs. PAHs are the products of incomplete combustion of fossil fuels or other organic matter, hence include both natural and anthropogenic sources (ATSDR, 1993a). Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm- m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
benzo(a)anthracene (56-55-3)							
228.29	5.66 ^a	1.6E-6 ^a	5.30 ^a	5.10E-2 ^d	9.0E-6 ^d	2.9E-11 ^c	1 ^a
Benzo(a)pyrene (50-32-8)							
252.3	6.16 ^e	4.9E-7 ^a	6.74 ^a	4.30E-2 ^d	9.0E-6 ^d	7.4E-12 ^a	3.8E+3 ^a
Benzo(b)fluoranthene (99-99-0)							
252.3	6.12 ^e	1.22-5 ^a	5.74 ^a	2.26E-2 ^d	5.56E-6 ^d	1.3E-9 ^a	1 ^a
Benzo(k)fluoranthene (207-08-9)							
252.3	6.06 ^a	3.87-5 ^a	5.74 ^a	2.26E-2 ^d	5.56E-6 ^d	6.6E-10 ^a	1 ^a
Dibenz(a,h)anthracene (53-70-3)							
278.35	6.84 ^e	7.3-8 ^a	6.52 ^a	2.02E-2 ^d	5.18E-6 ^d	8.2E-12 ^a	5E-7 ^a
Indeno(1,2,3-cd)pyrene (193-39-5)							
276.3	6.58 ^e	6.95-8 ^a	6.20 ^a	1.90E-2 ^d	5.66E-6 ^d	1.3E-12 ^a	6.23E-2 ^a
<p>a Agency for Toxic Substances and Disease Registry (ATSDR), 1993a, Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, Georgia, October.</p> <p>b Montgomery, J.H ., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York.</p> <p>c Calculated as described in Introduction to the Toxicity Profiles. 'U.S. Environmental Protection Agency (EPA), 1996,</p> <p>d Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.</p> <p>e U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/01113, January.</p> <p>f U .S. Environmental Protection Agency (EPA), 1994, Technical Background Document for Soil Screening Guidance, Review Draft, Office of Solid Waste and Emergency Response, Washington, DC, Publication No . 9355 .4-17, EPA540/R-94/106, PB95-963532, November. 9</p> <p>g Agency for Toxic Substances and Disease Registry, (ATSDR), 1993b, Update Toxicological Profile for Naphthalene, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, October.</p>							

The PAHs are ubiquitous products of incomplete combustion; natural sources include volcanoes and forest fires (ATSDR, 1993a, b; HSDB, 2001). There is some evidence for biosynthesis by plants, bacteria and algae. Some of the PAHs occur naturally in fossil fuels. Anthropogenic releases to the environment, primarily to the atmosphere, greatly outweigh the natural sources and include any processes that involve incomplete combustion of fossil fuels and organic matter, including wood-burning for home heat (the predominant source), cigarette smoke, internal combustion engine exhaust, and fuel oil emissions. Other sources include various crude oils, fresh and used motor oils,

gasolines, charcoal-broiled foods, processed foods, various oils, margarine, butter and fats, fruits, vegetables, and cereals, roasted coffee and tea. Naphthalene is released during its manufacture and processes that involve its use (e.g., vaporization from moth balls).

PAHs exist in the atmosphere as both gases and particulates, the proportion depending on the vapor pressure of the individual chemical (ATSDR, 1993a, b; HSDB, 2001). They may travel short or long distances before removal from the air. Wet and dry deposition accounts for removal of the particulates. Vapor forms are subject to chemical oxidation processes in the air.

The predominant sources of PAHs in surface water are deposition from the atmosphere, industrial and sewage effluent and oil spills (ATSDR, 1993x, b). Runoff and erosion can also contribute PAHs to surface water bodies. Depending on solubility and vapor pressure, volatilization is a significant fate process for some of the PAHs in surface water. Adsorption to sediment is another significant removal process. Low molecular weight PAHs (acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene) are subject to chemical degradation and biodegradation. Naphthalene is relatively water soluble and may remain largely in solution. PAHs in sediment may biodegrade or accumulate in living organisms.

Deposition from the atmosphere is the principal source of PAHs in soil (ATSDR, 1993a, b). Other sources include industrial activities, disposal of sewage sludge, and leaching from coal storage sites. Most PAHs sorb to soil constituents because of their low solubility and high affinity for organic matter. Volatilization is an important removal process for the low molecular weight compounds. Some of the low molecular weight compounds, particularly naphthalene, may leach fairly rapidly to groundwater.

The propensity for the PAHs to participate in food-chain pathways is chemical specific, depending largely on the tendency for biodegradation or biotransformation (ATSDR, 1993a, b; HSDB, 2001). Biotransfer factors for the PAHs are compiled below:

BCF (L/kg)	$B_{pr}^{a,b}$ (unitless)	$B_{pv}^{a,b}$ (unitless)	B_b (days/kg)
benzo(a)anthracene (56-55-3)			
350 ^e	2.07E-2	2.07E-2	1.15E-2
Benzo(a)pyrene (50-32-8)			
480 ^c	1.07E-2	1.07E-2	3.63E-2
Benzo(b)fluoranthene (99-99-0)			
2800 ^d	1.12E-2	1.12E-2	3.31E-2
Benzo(k)fluoranthene (207-08-9)			
17,100 ^a	6.78E-3	6.78E-3	2.88E-2
Dibenz(a,h)anthracene (53-70-3)			
10 ^e	5.33E-2	5.33E-2	2.24E-3
Indeno(1,2,3-cd)pyrene (193-39-5)			
12,800 ^a	6.09E-3	6.09E-3	9.55E-2

a Calculated as described in Introduction to the Toxicity Profiles.

b The methodology for estimating biotransfer of organic chemicals to plants does not differentiate vegetative and reproductive portions.

c Empirical data in Bluegill Sunfish (*Lepomis macrochirus*) from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

d Estimated value from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

e Empirical data in golden ide fish (*Leuciscus idus melanotus*) from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

f Empirical data in clams from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

f Empirical data in guppies (*Poecilia reticulata*), from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line.

f Empirical data in fathead minnows, from Hazardous Substance Data Bank (HSDB), 2001, National Library of Medicine, on line .

The BCF for indeno(1,2,3-cd)pyrene may be overestimated because the PAHs are generally readily metabolized by vertebrates, reducing the potential for bioconcentration (ATSDR, 1993a; HSDB, 2001). The BCF for benzo(b)fluoranthene is probably overestimated for fin fish because fin fish biotransform and eliminate PAHs much more readily than invertebrates.

Toxicokinetic studies of several PAHs summarized by ATSDR (1993a) provide limited quantitative information regarding the extent of GI absorption. Qualitatively, these studies indicate that absorption is incomplete. A study of benzo(a)pyrene in rats suggested that GI absorption ranges from 38 to 58 percent. The GAF of 0.5 (Jones and Owen, 1989), near the midpoint of the range from the rat study, is selected for benzo(a)pyrene and the other PAHs for which quantitative data are not available. GI absorption of dibenzo(a,h)anthracene is described as high; a GAF of 0.8 is assumed for this compound.

Empirical data with pure compound dissolved or suspended in vehicles suggest that dermal uptake of benzo(a)pyrene is extensive (ATSDR, 1993x), but data regarding absorption from soil were not located. Lacking suitable empirical data for dermal uptake from soil, the OEPA (1998) Region IV default ABS of 0.1 for organic chemicals is chosen for the PAHs.

The PAHs are generally divided into two EPA cancer weight-of-evidence groups: Group D - not classifiable as to carcinogenicity to humans, and Group B2 - probable human carcinogens. No Group D PAHs were retained as COCs.

Cancer SFs and URFs are available for the Group B2 compounds but noncancer RfDs or RfCs are not. Therefore, evaluation and RGO development for these compounds are limited to cancer risk. These compounds have the morphologic requirements for carcinogenicity; therefore, it has been thought that cancer risk is the driver, and that noncancer effects are relatively insignificant, although empirical data were lacking.

Recent data, however, support this assumption. De Jong et al. (1999) reported a study in which male rats were treated by gavage with benzo(a)pyrene 5 days per week for 35 days at dose rates of 0 (control), 3, 10, 30 or 90 mg/kg. Significantly reduced rate of body weight gain and altered organ weights were observed in the 90 mg/kg group. Forestomach lesions were found in the 30 and 90 mg/kg group. Decreased thymus weights and hematological evidence of erythrocyte toxicity were observed in a dose-related manner in rats treated with 10 mg/kg and above. Subtle alterations in measures of immune function were also observed in these groups, establishing 10 mg/kg as the LOAEL and 3 mg/kg as the NOAEL for this study. The 3 mg/kg dose is equivalent to an adjusted NOAEL of 2.1 mg/kg-day. Application of an uncertainty factor of 1000 (factor of 10 to expand from subchronic to chronic exposure, and factors of 10 each to provide additional protection for intra- and interspecies variation) allows development of a preliminary oral RfD of 2E-3 mg/kg-day. Uncertainty surrounding the preliminary oral RfD is very high because the data base for benzo(a)pyrene is essentially limited to one study and several toxicological endpoints (e.g., developmental, reproductive, neurological) were not investigated .

Benzo(a)pyrene is the most extensively studied member of the class, inducing tumors in tissues at the point of contact of virtually all laboratory species tested by all routes of exposure. Although epidemiology studies suggested that complex mixtures that contain PAHs (coal tar, soots, coke oven emissions, cigarette smoke) are carcinogenic to humans, the carcinogenicity cannot be attributed to PAHs alone because of the presence of other potentially carcinogenic substances in these mixtures (ATSDR, 1993a). In addition, recent investigations showed that the PAH fraction of roofing tar, cigarette smoke and coke oven emissions accounted for only 0.1-8% of the total mutagenic activity in *Salmonella* of the unfractionated complex mixture (Lewtas, 1988). Aromatic amines, nitrogen heterocyclic compounds, highly oxygenated quinones, diones, and nitrooxygenated compounds, none of which would be expected to arise from in vivo metabolism of PAHs, probably accounts for the majority of the mutagenicity of coke oven emissions and cigarette smoke. Furthermore, coal tar, which contains a mixture of many PAHs, has a long history of use in the clinical treatment of a variety of skin disorders in humans (ATSDR, 1993a).

Because of the lack of human cancer data, assignment of individual PAHs to EPA cancer weight-of-evidence groups is based largely on the results of animal studies with large doses of purified compound (EPA, 2001). Frequently, unnatural routes of exposure, including implants of the test chemical in beeswax and trioctanoin in the lungs of female rats, intratracheal instillation, and subcutaneous or intraperitoneal injection, were used.

EPA (2001) verified a SF for oral exposure to benzo(a)pyrene of 7.3×10^0 per mg/kg-day, based on several dietary studies in mice and rats. Recent reevaluations of the carcinogenicity and mutagenicity of the Group B2 PAHs suggest that there are large differences between individual PAHs in cancer potency (Krewski et al., 1989). Based on the available cancer and mutagenicity data, and assuming that there is a constant relative potency between different carcinogens across different bioassay systems and that the PAHs under consideration have similar dose-response curves, EPA (1993b) adopted relative potency values for several PAHs.

Although the EPA has not verified SFs for Group B2 PAHs other than benzo(a)pyrene, the SFs above represent reasonable estimates based on the data available. The relative potency approach employed here meets criteria considered to be desirable for this type of analysis (Lewtas, 1988). For example, the chemicals compared have similar chemical structures and would be expected to have similar toxicokinetic fate in mammalian systems. In addition, the available data suggest that the Group B2 PAHs have a similar mechanism of action, inducing frameshift mutations in *Salmonella* and tumor initiation in the mouse skin painting assay. Similar noncancer effects (minor changes in the blood, liver, kidneys) of the Group D PAHs support the hypothesis of a common mechanism of toxicity. Finally, the same endpoints of toxicity, i.e., potency in various cancer assays, and related data, were used to derive the relative potency values (Krewski et al., 1989). The oral SF for benzo(a)pyrene of 7.3×10^0 per mg/kg-day, and the SFs presented above for the other Group B2 PAHs are adopted for the purposes of this evaluation.

An EPA (1994) evaluation of the inhalation cancer data suggests adoption of an inhalation SF for benzo(a)pyrene of 3.1×10^0 per mg/kg-day, based on the incidence of upper respiratory and digestive tract tumors in hamsters. Applying the relative potency estimates presented above yield the inhalation SFs for the other Group B2 PAHs presented above.

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POLYCHLORINATED BIPHENYLS (PCBs)

The PCBs are a class of SVOCs including 209 possible individual congeners, each consisting of a biphenyl structure and 1 to 10 chlorine atoms (ATSDR, 1995). The PCBs manufactured and used in the U.S. are called Aroclors. The Aroclors are mixtures of several PCB congeners and related compounds. Aroclors were used as dielectric and heat exchange agents in several open and closed systems, but since the middle 1970s, use has been restricted largely to electrical transformers and capacitors.

Analysis of PCBs in environmental media frequently involves "fingerprinting" the mixture, and reporting the result as the Aroclor(s) that most closely reflect the fingerprint(s) (ATSDR, 1995). Recently, however, more attention has been paid to analyzing and reporting individual congeners, because of the possibility that certain congeners may be dioxin-like in their mechanism of toxicity. The Aroclors most commonly identified in environmental media include Aroclor-1016, -1221, -1232, -1242, -1248, -1254, -1260, -1262, and -1268. Relevant physical properties are compiled below:

MW (g/mole)	log K _{ow} (unitless)	H (atm- m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
Aroclor-1254 (11097-69-1)							
328 ^{a,b}	6.5 ^b	2.0E-3 ^b	5.00 ^c	3.99E-2 ^d	5.6E-6 ^c	1.01E-7 ^b	3.5E-2 ^b
Aroclor-1260 (11096-82-5)							
375.7 ^{a,b}	6.8 ^b	4.6E-3 ^b	6.42 ^c	3.65E-2 ^d	5.3E-6 ^c	5.33E-8 ^a	4.1E-2 ^b
<p>a Average molecular mass for the proportions of individual congeners in the commercial product.</p> <p>b Agency for Toxic Substances and Disease Registry (ATSDR), 1995, Update Toxicological Profile for Polychlorinated Biphenyls, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, Georgia, August.</p> <p>c Montgomery, J.H., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, New York.</p> <p>d Calculated as described in Introduction to the Toxicity Profiles.</p>							

Former PCB releases occurred as a result of their manufacture, use, disposal, and leakage from damaged PCB-containing equipment (ATSDR, 1995). Currently the major source of PCB release to the environment is recycling of PCBs previously introduced into the environment, which involves volatilization from ground surfaces (water, soil) into the atmosphere with subsequent removal from the atmosphere via wet/dry deposition, followed by volatilization (HSDB, 2001). PCBs are also currently released to the environment from landfills containing PCB waste materials and products, incineration of municipal refuse and sewage sludge, and improper (or illegal) disposal of PCB materials, such as waste transformer fluid, to open areas. Major sources to air include emissions from the overhaul, repair or reuse of PCB-containing items, and the recycling of previously released PCBs described above (ATSDR, 1995; HSDB, 2001). The vapor pressures of the PCBs indicate that they would exist primarily in the vapor phase in the atmosphere; monitoring data have shown that between 87 and 100% of the PCBs in air are in the vapor-phase. Vapor pressure of the PCBs generally decreases with an increase in the extent of chlorination; therefore, the more highly chlorinated PCBs are more likely to be associated with the particulate-adsorption-phase in air than are the lesser chlorinated PCBs. Physical removal of PCBs in the atmosphere is accomplished by wet and dry deposition; dry deposition occurs only for PCBs in the particulate phase.

Major sources to soil include leaks or discharges from PCB-containing items and deposition from the atmosphere (ATSDR, 1995). PCBs sorb tightly to constituents of soil with adsorption generally increasing with the degree of chlorination. Although the lesser chlorinated biphenyls may exhibit low mobility in soil, PCBs will generally not leach significantly in most aqueous soil systems. In the presence of organic solvents, PCBs may leach quite rapidly through soil. Vapor loss of PCBs from soil surfaces appears to be an important loss mechanism with the rate of volatilization decreasing with increasing chlorination. Although the volatilization rate may be low, the total loss by volatilization over time may be significant because of the persistence and stability of PCBs. In general, the persistence of PCBs increases with an increase in the degree of chlorination (HSDB, 2001). Mono-, di- and trichlorinated biphenyls (Aroclors-1221 and -1232) biodegrade relatively rapidly, tetrachlorinated biphenyls (Aroclors-1016 and -1242) biodegrade slowly, and higher chlorinated biphenyls (Aroclors-1248, 1-254 and -1260) are resistant to biodegradation. The position of chlorination in the isomeric classes also determines the extent of biodegradation. Although biodegradation of higher chlorinated congeners may occur very slowly on an environmental basis, no other degradation mechanisms have been shown to be important in soil systems; therefore, biodegradation may be the ultimate degradation process in soil.

Former sources of PCBs to surface water include waste streams and discharges from waste water treatment plants (ATSDR, 1995). Currently, direct deposition, runoff and erosion probably predominate. Removal from water involves sorption to particles and sedimentation, as well as volatilization.

The PCBs are among the compounds that bioaccumulate in food chain pathways and are of special concern for biomagnification from sediment in benthic fish. Biotransfer factors for the PCBs are compiled below:

BCF (L/kg)	$B_{pr}^{a,b}$ (unitless)	$B_{pv}^{a,b}$ (unitless)	B_b^a (days/kg)
Aroclor-1254 (11097-69-1)			
See below	6.78E-3	6.78E-3	7.94E-2
Aroclor-1260 (11096-82-5)			
See below	4.55E-3	4.55E-3	1.58E-1
a Calculated as described in Introduction to the Toxicity Profiles.			
b The methodology for estimating biotransfer of organic chemicals to plants does not differentiate vegetative and reproductive portions .			

The acute oral toxicity of the PCBs is low to moderate, as indicated by LD₅₀ values in laboratory animals ranging from 750 mg/kg (mink) to 4250 mg/kg (rats) (ATSDR, 1995). Mink appear to be unusually sensitive. Death appears to be due to respiratory depression and dehydration from diarrhea

The best known incident involving oral exposure by humans is the "Yusho" incident in Japan, in which persistent chloracne, gastrointestinal irritation and central nervous symptoms followed ingestion of cooking oil contaminated with PCBs (Gaffey, 1983). Further investigation, however, revealed that concentrations of polychlorinated dibenzofurans (PCDF) and polychlorinated quaterphenyls in the cooking oil were similar to those of PCBs, which confounds interpretation of the reported observations and symptoms.

Prolonged oral exposure of laboratory animals leads to liver damage, signs of chloracne, immunological effects, and neurological impairment, particularly of the young. A verified oral RfD for Aroclor-1254 of 2E-5 mg/kg-day for chronic oral exposure is based on a

LOAEL of $5E-3$ mg/kg-day associated with chloracne and related signs and immunological effects in monkeys treated with the test material in gelatin capsules for over five years (EPA, 2001). An uncertainty factor of 300 was applied. Confidence in the RfD is medium. The immune system and skin are considered the target organs for prolonged oral exposure to Aroclor-1254.

Occupational exposure to PCBs, which involved both inhalation and dermal exposure, was associated with upper respiratory tract and ocular irritation, loss of appetite, liver enlargement and increased serum concentrations of liver enzymes, skin irritation, rashes and chloracne, and, in heavily exposed female workers, decreased birth weight of their infants (ATSDR, 1995). Concurrent exposure to PCB contaminants, such as PCDFs, confounds the interpretation of the occupational exposure studies. Rats, mice, rabbits and guinea pigs intermittently exposed to Aroclor-1254 vapors exhibit moderate liver degeneration, decreased body weight gain and slight renal tubular degeneration; however, the accuracy of the reported exposure concentration is in doubt. Neither verified nor provisional chronic inhalation RfC values are available.

EPA (2001) classified PCBs in cancer weight-of-evidence Group B2 (probable human carcinogen) based on adequate evidence for liver tumors in laboratory animals and inadequate data in humans. EPA (2001) established a tiered approach for estimating the cancer potency of exposure to the PCBs. For the high risk tier, A SF of $2.0E+0$ per mg/kg-day is verified as an upper-bound for exposure to PCBs via ingestion in the food chain, ingestion of soil or sediment, inhalation of dust or aerosol, or dermal contact with soil or sediment if an absorption factor is applied. In addition, the SF of $2.0E+0$ per mg/kg-day is used for any congeners considered to be persistent or acting in a dioxin-like manner, and for any early life exposures. The high risk tier SF for central tendency (CT) analyses is $1.0E+0$ per mg/kg-day. EPA (2001) verified an upperbound SF of $4.0E-1$ per mg/kg-day for the low risk tier, which includes ingestion of watersoluble congeners, inhalation of evaporated congeners, and dermal exposure if no absorption factor is applied. A SF of $3E-1$ per mg/kg-day is recommended for the low risk CT evaluation. The SF of $2.0E+0$ per mg/kg-day is used for all exposure scenarios and exposure routes in this evaluation because analytical data that demonstrate the absence of dioxin-like or persistent congeners are not available, and the exposure of children or youths is plausible.

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XYLENES, TOTAL

The xylenes (1330-20-7), also known as dimethylbenzenes, are synthetic VOCs derived from coal tar, coal gas, and petroleum distillation (ATSDR, 1993; HSDB, 2001). Natural sources include petroleum, forest fires and volatiles from plants.

Xylenes are used in the manufacture of other organic compounds, dyes, insecticides and pharmaceuticals, and as solvents (ATSDR, 1993; HSDB, 2001). They are components of aviation gasoline, asphalt and naphtha, and automobile exhaust. Technical xylene consists of approximately 44 percent m-xylene (1,3-dimethylbenzene [108-38-3]), 20 percent o-xylene (1,2-dimethylbenzene [95-47-6]), 20 percent p-xylene (1,4-dimethylbenzene [106-42-3]), and 15 percent ethylbenzene. Laboratory analyses of environmental media often report values for total xylenes (1330-20-7), mixed xylenes or m- and p-xylene. The xylene isomers have similar physical property values and are toxicologically similar; therefore, the relevant physical properties for m-xylene, presented below, may be applied to the mixed xylenes, total xylene or any of the three isomers:

MW (g/mole)	log K _{ow} (unitless)	H (atm- m ³ /mole)	Kd (L/kg)	Da (cm ² /s)	Dw (cm ² /s)	VP (atm)	S (mg/L)
106.2	3.20 ^a	7.34E-3 ^b	2.61 ^b	7.00E-2 ^b	7.8E-6 ^b	1.06E-2 ^c	1.61E+2 ^b

a U.S. Environmental Protection Agency (EPA), 1992, Dermal Exposure Assessment: Principles and Applications, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91 /011 B, January. '

b U.S. Environmental Protection Agency (EPA), 1996, Soil Screening Guidance: Users Guide, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9355 .4-23, April.

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Naturally occurring sources of xylenes are petroleum, forest fires and volatiles from plants (ATSDR, 1993; HSDB, 2001). The production and use of xylenes in petroleum products and as chemical solvents and intermediates may result in their release to the environment through various waste streams. Outgassing from landfills and automobile exhaust are other significant sources. Spills, leaking underground storage tanks, and leaching from landfills may release xylenes to soil and groundwater.

Xylenes will exist solely in the vapor phase in the ambient atmosphere, where they are subject to degradation by reaction with photochemically-produced hydroxyl radicals as the only significant removal process (ATSDR, 1993; HSDB, 2001). The atmospheric lifetime of xylenes is about 1 to 2 days. Products of photooxidation include a wide variety of ring hydroxylation and ring cleavage products.

Volatilization is expected to be the major removal mechanism for xylenes released to surface soil, but, depending on the size and rate of release, the majority of the release may infiltrate to subsurface soil (ATSDR, 1993). Photooxidation may degrade a significant part of the small amount that remains at the surface. Biodegradation is probably the only significant subsurface removal mechanism, but it is expected to be slow. A wide range of experimental K_d values have been reported in soil samples with differing pH and organic carbon content (HSDB, 2001), suggesting a wide range in the extent to which the xylenes adsorb to soil particles. Generally, however, xylene is fairly mobile and may readily leach to groundwater.

Volatilization is probably the most significant removal mechanism for xylenes in surface water (ATSDR, 1993). Biodegradation may occur in surface water, groundwater and

landfill leachate, although quite slowly. Oxidative reactions are expected to be insignificant. Xylenes are expected to adsorb somewhat to suspended solids and sediment in water (HSDB, 2001).

Xylenes are not expected to participate significantly in food-chain pathways (ATSDR, 1993; HSDB, 2001); therefore, biotransfer factors are not provided.

Oral LD50 values for xylenes include 3.5 to 8.6 g/kg in rats and 1.6 to 5.6 g/kg in mice (HSDB, 2001), suggesting that the acute toxicity is low, but that mice may be slightly more sensitive than rats to the acute effects of ingested xylenes. Prolonged oral exposure of animals to xylenes is associated with CNS signs and increased mortality without histopathological alterations in the internal organs (EPA, 2001). EPA (2001) presents a verified chronic oral RfD for total xylenes of 2E+0 mg/kg-day based on a NOAEL for hyperactivity and decreased body weight and increased mortality in male rats in chronic gavage studies with mixed xylenes. An uncertainty factor of 100 was used. Confidence in the chronic oral RfD is medium. EPA (1997) presents provisional RfDs for o-xylene and m-xylene of 2E+0 mg/kg-day based on the same study. The CNS is considered the target organ for prolonged oral exposure to the xylenes. The oral RfD of 2E+0 mg/kg-day is applied to total or mixed xylenes, and to each of the xylene isomers.

Occupational exposure to xylenes induces CNS effects and GI disturbances (ACGIH, 1991). Other effects attributed to occupational exposure to xylene (blood dyscrasias, and heart, liver and kidney damage) may arise from concurrent exposure to other chemicals. The data are not sufficient for derivation of an inhalation RfC. The CNS is the principal target organ for inhalation exposure to the xylenes.

Xylene is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) (EPA, 2001). There are no reported human cancer data, and gavage studies in rat and mice of both sexes did not result in significant increases in tumor incidence.

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APPENDIX E
**PROUCL CALCULATIONS FOR EXPOSURE-POINT
CONCENTRATIONS**

Data File AA2 Surface Soil

Variable: Aluminum

Raw Statistics

Number of Valid Samples	28
Number of Unique Samples	25
Minimum	4230
Maximum	18400
Mean	8607.143
Median	8055
Standard Deviation	2780.245
Variance	7729762
Coefficient of Variation	0.323016
Skewness	1.559397

Gamma Statistics

k hat	11.30068
k star (bias corrected)	10.1137
Theta hat	761.6485
Theta star	851.0381
nu hat	632.8378
nu star	566.3671
Approx. Chi Square Value (.05)	512.1566
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	508.9775

Log-transformed Statistics

Minimum of log data	8.349957
Maximum of log data	9.820106
Mean of log data	9.015451
Standard Deviation of log data	0.301481
Variance of log data	0.090891

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.889298
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	9502.079
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Gamma Distribution Test

A-D Test Statistic	0.369402
A-D 5% Critical Value	0.745186
K-S Test Statistic	0.111053
K-S 5% Critical Value	0.16519

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	9518.188
Adjusted Gamma UCL	9577.638

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.974723
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	9563.162
95% Chebyshev (MVUE) UCL	10767.12
97.5% Chebyshev (MVUE) UCL	11705.98
99% Chebyshev (MVUE) UCL	13550.21

95% Non-parametric UCLs

CLT UCL	9471.377
Adj-CLT UCL (Adjusted for skewness)	9636.825
Mod-t UCL (Adjusted for skewness)	9527.886
Jackknife UCL	9502.079
Standard Bootstrap UCL	9457.96
Bootstrap-t UCL	9742.203
Hall's Bootstrap UCL	10012.73
Percentile Bootstrap UCL	9471.071
BCA Bootstrap UCL	9708.929
95% Chebyshev (Mean, Sd) UCL	10897.38
97.5% Chebyshev (Mean, Sd) UCL	11888.37
99% Chebyshev (Mean, Sd) UCL	13834.98

Data File AA2 Surface Soil

Variable: Arsenic

Raw Statistics

Number of Valid Samples	28
Number of Unique Samples	27
Minimum	3.38
Maximum	19.3
Mean	6.684286
Median	6.15
Standard Deviation	3.103828
Variance	9.633751
Coefficient of Variation	0.464347
Skewness	2.627571

Gamma Statistics

k hat	6.732111
k star (bias corrected)	6.034623
Theta hat	0.992896
Theta star	1.107656
nu hat	376.9982
nu star	337.9389
Approx.Chi Square Value (.05)	296.3349
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	293.9309

Log-transformed Statistics

Minimum of log data	1.217876
Maximum of log data	2.960105
Mean of log data	1.823654
Standard Deviation of log data	0.377577
Variance of log data	0.142564

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.766224
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	7.683381
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Gamma Distribution Test

A-D Test Statistic	0.507705
A-D 5% Critical Value	0.747404
K-S Test Statistic	0.112777
K-S 5% Critical Value	0.165648

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	7.622728
Adjusted Gamma UCL	7.685071

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.953171
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	7.612009
95% Chebyshev (MVUE) UCL	8.749428
97.5% Chebyshev (MVUE) UCL	9.664718
99% Chebyshev (MVUE) UCL	11.46263

95% Non-parametric UCLs

CLT UCL	7.649105
Adj-CLT UCL (Adjusted for skewness)	7.96033
Mod-t UCL (Adjusted for skewness)	7.731926
Jackknife UCL	7.683381
Standard Bootstrap UCL	7.60828
Bootstrap-t UCL	8.302954
Hall's Bootstrap UCL	12.39801
Percentile Bootstrap UCL	7.694286
BCA Bootstrap UCL	8.021071
95% Chebyshev (Mean, Sd) UCL	9.241078
97.5% Chebyshev (Mean, Sd) UCL	10.3474
99% Chebyshev (Mean, Sd) UCL	12.52057

Data File AA2 Surface Soil

Variable: Iron

Raw Statistics

Number of Valid Samples	28
Number of Unique Samples	27
Minimum	10700
Maximum	36100
Mean	18612.5
Median	17775
Standard Deviation	5155.573
Variance	26579931
Coefficient of Variation	0.276995
Skewness	1.37967

Gamma Statistics

k hat	15.06387
k star (bias corrected)	13.47369
Theta hat	1235.573
Theta star	1381.396
nu hat	843.5765
nu star	754.5266
Approx. Chi Square Value (.05)	691.7737
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	688.0693

Log-transformed Statistics

Minimum of log data	9.277999
Maximum of log data	10.49405
Mean of log data	9.79803
Standard Deviation of log data	0.260322
Variance of log data	0.067768

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.912644
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	20272.03
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Gamma Distribution Test

A-D Test Statistic	0.238444
A-D 5% Critical Value	0.744915
K-S Test Statistic	0.072046
K-S 5% Critical Value	0.16519

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	20300.9
Adjusted Gamma UCL	20410.19

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.981185
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	20357.35
95% Chebyshev (MVUE) UCL	22631.52
97.5% Chebyshev (MVUE) UCL	24377.98
99% Chebyshev (MVUE) UCL	27808.56

95% Non-parametric UCLs

CLT UCL	20215.1
Adj-CLT UCL (Adjusted for skewness)	20486.54
Mod-t UCL (Adjusted for skewness)	20314.37
Jackknife UCL	20272.03
Standard Bootstrap UCL	20168.81
Bootstrap-t UCL	20367.54
Hall's Bootstrap UCL	21172.88
Percentile Bootstrap UCL	20282.14
BCA Bootstrap UCL	20594.64
95% Chebyshev (Mean, Sd) UCL	22859.43
97.5% Chebyshev (Mean, Sd) UCL	24697.07
99% Chebyshev (Mean, Sd) UCL	28306.78

Data File AA2 Surface Soil

Variable: Lead

Raw Statistics		Normal Distribution Test	
Number of Valid Samples	28	Shapiro-Wilk Test Statistic	0.22945
Number of Unique Samples	27	Shapiro-Wilk 5% Critical Value	0.924
Minimum	3.82	Data not normal at 5% significance level	
Maximum	7410	95% UCL (Assuming Normal Distribution)	
Mean	316.528	Student's-t UCL	765.0069
Median	17.45	Gamma Distribution Test	
Standard Deviation	1393.262	A-D Test Statistic	4.700881
Variance	1941180	A-D 5% Critical Value	0.858732
Coefficient of Variation	4.401703	K-S Test Statistic	0.320871
Skewness	5.255013	K-S 5% Critical Value	0.179898
Gamma Statistics		Data do not follow gamma distribution at 5% significance level	
k hat	0.289554	95% UCLs (Assuming Gamma Distribution)	
k star (bias corrected)	0.28234	Approximate Gamma UCL	639.3421
Theta hat	1093.156	Adjusted Gamma UCL	668.9771
Theta star	1121.087	Lognormal Distribution Test	
nu hat	16.21504	Shapiro-Wilk Test Statistic	0.866215
nu star	15.81105	Shapiro-Wilk 5% Critical Value	0.924
Approx. Chi Square Value (.05)	7.827798	Data not lognormal at 5% significance level	
Adjusted Level of Significance	0.0404	95% UCLs (Assuming Lognormal Distribution)	
Adjusted Chi Square Value	7.481035	95% H-UCL	311.446
Log-transformed Statistics		95% Chebyshev (MVUE) UCL	268.236
Minimum of log data	1.34025	97.5% Chebyshev (MVUE) UCL	341.5278
Maximum of log data	8.910586	99% Chebyshev (MVUE) UCL	485.4954
Mean of log data	3.362136	95% Non-parametric UCLs	
Standard Deviation of log data	1.631127	CLT UCL	749.621
Variance of log data	2.660577	Adj-CLT UCL (Adjusted for skewness)	1029.023
RECOMMENDATION		Mod-t UCL (Adjusted for skewness)	808.5879
Data are Non-parametric (0.05)		Jackknife UCL	765.0069
Use 99% Chebyshev (Mean, Sd) UCL		Standard Bootstrap UCL	726.0918
		Bootstrap-t UCL	10020.32
		Hall's Bootstrap UCL	4356.24
		Percentile Bootstrap UCL	836.3875
		BCA Bootstrap UCL	1125.799
		95% Chebyshev (Mean, Sd) UCL	1464.234
		97.5% Chebyshev (Mean, Sd) UCL	1960.847
		99% Chebyshev (Mean, Sd) UCL	2936.348

Data File AA2 Surface Soil

Variable: Manganese

Raw Statistics

Number of Valid Samples	28
Number of Unique Samples	28
Minimum	90.7
Maximum	1010
Mean	316.0071
Median	279.5
Standard Deviation	182.9606
Variance	33474.57
Coefficient of Variation	0.578976
Skewness	2.228951

Gamma Statistics

k hat	3.998231
k star (bias corrected)	3.593659
Theta hat	79.03674
Theta star	87.93466
nu hat	223.9009
nu star	201.2449
Approx.Chi Square Value (.05)	169.4147
Adjusted Level of Significance	0.0404
Adjusted Chi Square Value	167.6114

Log-transformed Statistics

Minimum of log data	4.507557
Maximum of log data	6.917706
Mean of log data	5.625528
Standard Deviation of log data	0.514364
Variance of log data	0.264571

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.809237
Shapiro-Wilk 5% Critical Value	0.924
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	374.9005
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Gamma Distribution Test

A-D Test Statistic	0.454853
A-D 5% Critical Value	0.749707
K-S Test Statistic	0.137932
K-S 5% Critical Value	0.166101

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	375.3796
Adjusted Gamma UCL	379.4183

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.973506
Shapiro-Wilk 5% Critical Value	0.924
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	384.3824
95% Chebyshev (MVUE) UCL	454.4922
97.5% Chebyshev (MVUE) UCL	514.8558
99% Chebyshev (MVUE) UCL	633.4285

95% Non-parametric UCLs

CLT UCL	372.8801
Adj-CLT UCL (Adjusted for skewness)	388.4426
Mod-t UCL (Adjusted for skewness)	377.328
Jackknife UCL	374.9005
Standard Bootstrap UCL	370.6192
Bootstrap-t UCL	397.085
Hall's Bootstrap UCL	460.241
Percentile Bootstrap UCL	375.3214
BCA Bootstrap UCL	400.1143
95% Chebyshev (Mean, Sd) UCL	466.7217
97.5% Chebyshev (Mean, Sd) UCL	531.936
99% Chebyshev (Mean, Sd) UCL	660.037

Data File AA2 Surface Soil

Variable: Vanadium

Raw Statistics		Normal Distribution Test	
Number of Valid Samples	28	Shapiro-Wilk Test Statistic	0.898928
Number of Unique Samples	25	Shapiro-Wilk 5% Critical Value	0.924
Minimum	17.3	Data not normal at 5% significance level	
Maximum	35.3	95% UCL (Assuming Normal Distribution)	
Mean	22.72321	Student's-t UCL	24.18157
Median	21.2	Gamma Distribution Test	
Standard Deviation	4.530585	A-D Test Statistic	0.592137
Variance	20.5262	A-D 5% Critical Value	0.74415
Coefficient of Variation	0.199381	K-S Test Statistic	0.13855
Skewness	1.147932	K-S 5% Critical Value	0.165103
Gamma Statistics		Data follow gamma distribution at 5% significance level	
k hat	28.72924	95% UCLs (Assuming Gamma Distribution)	
k star (bias corrected)	25.67492	Approximate Gamma UCL	24.18801
Theta hat	0.790944	Adjusted Gamma UCL	24.2815
Theta star	0.885036	Lognormal Distribution Test	
nu hat	1608.837	Shapiro-Wilk Test Statistic	0.939506
nu star	1437.795	Shapiro-Wilk 5% Critical Value	0.924
Approx. Chi Square Value (.05)	1350.724	Data are lognormal at 5% significance level	
Adjusted Level of Significance	0.0404	95% UCLs (Assuming Lognormal Distribution)	
Adjusted Chi Square Value	1345.524	95% H-UCL	24.19153
Log-transformed Statistics		95% Chebyshev (MVUE) UCL	26.22224
Minimum of log data	2.850707	97.5% Chebyshev (MVUE) UCL	27.74317
Maximum of log data	3.563883	99% Chebyshev (MVUE) UCL	30.73075
Mean of log data	3.105882	95% Non-parametric UCLs	
Standard Deviation of log data	0.186734	CLT UCL	24.13154
Variance of log data	0.03487	Adj-CLT UCL (Adjusted for skewness)	24.33001
RECOMMENDATION		Mod-t UCL (Adjusted for skewness)	24.21253
Data follow gamma distribution (0.05)		Jackknife UCL	24.18157
Use Approximate Gamma UCL		Standard Bootstrap UCL	24.08904
		Bootstrap-t UCL	24.50784
		Hall's Bootstrap UCL	24.58708
		Percentile Bootstrap UCL	24.1375
		BCA Bootstrap UCL	24.43214
		95% Chebyshev (Mean, Sd) UCL	26.4553
		97.5% Chebyshev (Mean, Sd) UCL	28.07018
		99% Chebyshev (Mean, Sd) UCL	31.2423

Data File AA2 Subsurface Soil

Variable: Aluminum

Raw Statistics

Number of Valid Samples	35
Number of Unique Samples	26
Minimum	3720
Maximum	10347
Mean	10422
Median	10400
Standard Deviation	2071
Variance	3415410
Coefficient of Variation	0.177325
Skewness	0.77

Gamma Statistics

k hat	32.30732
k star (bias corrected)	29.09881
Theta hat	322.5894
Theta star	358.159
nu hat	1938.439
nu star	1745.929
Approx. Chi Square Value (.05)	1649.861
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	1644.497

Log-transformed Statistics

Minimum of log data	8.776476
Maximum of log data	9.560997
Mean of log data	9.236118
Standard Deviation of log data	0.180971
Variance of log data	0.03275

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.976448
Shapiro-Wilk 5% Critical Value	0.927
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	10939
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Gamma Distribution Test

A-D Test Statistic	0.258687
A-D 5% Critical Value	0.744246
K-S Test Statistic	0.088688
K-S 5% Critical Value	0.159623

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	11028.85
Adjusted Gamma UCL	11064.82

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.975792
Shapiro-Wilk 5% Critical Value	0.927
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	11057.2
95% Chebyshev (MVUE) UCL	11935.27
97.5% Chebyshev (MVUE) UCL	12588.86
99% Chebyshev (MVUE) UCL	13872.73

95% Non-parametric UCLs

CLT UCL	10976.99
Adj-CLT UCL (Adjusted for skewness)	10986.04
Mod-t UCL (Adjusted for skewness)	10996.72
Jackknife UCL	10995.31
Standard Bootstrap UCL	10606
Bootstrap-t UCL	10989.19
Hall's Bootstrap UCL	11019.05
Percentile Bootstrap UCL	11,100
BCA Bootstrap UCL	10926.67
95% Chebyshev (Mean, Sd) UCL	11892.75
97.5% Chebyshev (Mean, Sd) UCL	12529.14
99% Chebyshev (Mean, Sd) UCL	13779.21

Data File AA2 Subsurface Soil

Variable: Arsenic

Raw Statistics		Normal Distribution Test	
Number of Valid Samples	35	Shapiro-Wilk Test Statistic	0.96649
Number of Unique Samples	29	Shapiro-Wilk 5% Critical Value	0.927
Minimum	0.808	Data are normal at 5% significance level	
Maximum	165	95% UCL (Assuming Normal Distribution)	
Mean	8.11	Student's-t UCL	9.24
Median	7.69	Gamma Distribution Test	
Standard Deviation	3.96	A-D Test Statistic	1.160312
Variance	12.33044	A-D 5% Critical Value	0.751286
Coefficient of Variation	0.436256	K-S Test Statistic	0.176244
Skewness	0.354468	K-S 5% Critical Value	0.160963
Gamma Statistics		Data do not follow gamma distribution at 5% significance level	
k hat	3.397175	95% UCLs (Assuming Gamma Distribution)	
k star (bias corrected)	3.07968	Approximate Gamma UCL	9.637209
Theta hat	2.369356	Adjusted Gamma UCL	9.738319
Theta star	2.613621	Lognormal Distribution Test	
nu hat	203.8305	Shapiro-Wilk Test Statistic	0.725337
nu star	184.7808	Shapiro-Wilk 5% Critical Value	0.927
Approx. Chi Square Value (.05)	154.3312	Data not lognormal at 5% significance level	
Adjusted Level of Significance	0.041	95% UCLs (Assuming Lognormal Distribution)	
Adjusted Chi Square Value	152.7288	95% H-UCL	11.87647
Log-transformed Statistics		95% Chebyshev (MVUE) UCL	14.33616
Minimum of log data	-1.137873	97.5% Chebyshev (MVUE) UCL	16.71392
Maximum of log data	2.80336	99% Chebyshev (MVUE) UCL	21.38456
Mean of log data	1.931221	95% Non-parametric UCLs	
Standard Deviation of log data	0.719424	CLT UCL	9.103639
Variance of log data	0.51757	Adj-CLT UCL (Adjusted for skewness)	9.147972
RECOMMENDATION		Mod-t UCL (Adjusted for skewness)	9.145349
Data are normal (0.05)		Jackknife UCL	9.138434
Use Student's-t UCL		Standard Bootstrap UCL	8.93
		Bootstrap-t UCL	9.243347
		Hall's Bootstrap UCL	9.322383
		Percentile Bootstrap UCL	9.5
		BCA Bootstrap UCL	9.084833
		95% Chebyshev (Mean, Sd) UCL	10.84363
		97.5% Chebyshev (Mean, Sd) UCL	12.05281
		99% Chebyshev (Mean, Sd) UCL	14.42802

Data File AA2 Subsurface Soil

Variable: Chromium

Raw Statistics

Number of Valid Samples	35
Number of Unique Samples	28
Minimum	6.82
Maximum	31
Mean	17.2
Median	16.825
Standard Deviation	2.495693
Variance	6.228485
Coefficient of Variation	0.146469
Skewness	0.76

Gamma Statistics

k hat	46.28059
k star (bias corrected)	41.67476
Theta hat	0.368167
Theta star	0.408857
nu hat	2776.836
nu star	2500.485
Approx.Chi Square Value (.05)	2385.289
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	2378.828

Log-transformed Statistics

Minimum of log data	2.451005
Maximum of log data	3.063391
Mean of log data	2.824662
Standard Deviation of log data	0.151683
Variance of log data	0.023008

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.97128
Shapiro-Wilk 5% Critical Value	0.927
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	18.3

Gamma Distribution Test

A-D Test Statistic	0.346189
A-D 5% Critical Value	0.744162
K-S Test Statistic	0.133621
K-S 5% Critical Value	0.159557

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	17.86189
Adjusted Gamma UCL	17.91041

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.960727
Shapiro-Wilk 5% Critical Value	0.927
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	17.89836
95% Chebyshev (MVUE) UCL	19.10986
97.5% Chebyshev (MVUE) UCL	20.0039
99% Chebyshev (MVUE) UCL	21.76008

95% Non-parametric UCLs

CLT UCL	17.78848
Adj-CLT UCL (Adjusted for skewness)	17.76916
Mod-t UCL (Adjusted for skewness)	17.81019
Jackknife UCL	17.81321
Standard Bootstrap UCL	17.7
Bootstrap-t UCL	17.79976
Hall's Bootstrap UCL	17.7579
Percentile Bootstrap UCL	18.8
BCA Bootstrap UCL	17.79367
95% Chebyshev (Mean, Sd) UCL	19.02513
97.5% Chebyshev (Mean, Sd) UCL	19.88453
99% Chebyshev (Mean, Sd) UCL	21.57265

Data File AA2 Subsurface Soil

Variable: Iron

Raw Statistics

Number of Valid Samples	35
Number of Unique Samples	28
Minimum	14,100
Maximum	41800
Mean	23826
Median	23500
Standard Deviation	3686.604
Variance	13591049
Coefficient of Variation	0.157828
Skewness	1.104666

Gamma Statistics

k hat	44.68748
k star (bias corrected)	40.24095
Theta hat	522.7042
Theta star	580.4618
nu hat	2681.249
nu star	2414.457
Approx.Chi Square Value (.05)	2301.28
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	2294.934

Log-transformed Statistics

Minimum of log data	9.746834
Maximum of log data	10.42969
Mean of log data	10.04748
Standard Deviation of log data	0.150227
Variance of log data	0.022568

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.926236
Shapiro-Wilk 5% Critical Value	0.927
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	24501.98
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Gamma Distribution Test

A-D Test Statistic	0.446249
A-D 5% Critical Value	0.744172
K-S Test Statistic	0.112961
K-S 5% Critical Value	0.159565

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	24507.1
Adjusted Gamma UCL	24574.86

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.96719
Shapiro-Wilk 5% Critical Value	0.927
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	24713
95% Chebyshev (MVUE) UCL	26154.11
97.5% Chebyshev (MVUE) UCL	27367.14
99% Chebyshev (MVUE) UCL	29749.9

95% Non-parametric UCLs

CLT UCL	24465.45
Adj-CLT UCL (Adjusted for skewness)	24610.5
Mod-t UCL (Adjusted for skewness)	24524.6
Jackknife UCL	24501.98
Standard Bootstrap UCL	24462
Bootstrap-t UCL	24717.52
Hall's Bootstrap UCL	24747.52
Percentile Bootstrap UCL	24300
BCA Bootstrap UCL	24545
95% Chebyshev (Mean, Sd) UCL	26292.22
97.5% Chebyshev (Mean, Sd) UCL	27561.71
99% Chebyshev (Mean, Sd) UCL	30055.38

Data File AA2 Subsurface Soil

Variable: Lead

Raw Statistics

Number of Valid Samples	30
Number of Unique Samples	28
Minimum	7.9
Maximum	113
Mean	16.112
Median	11.75
Standard Deviation	19.22976
Variance	369.7835
Coefficient of Variation	1.193505
Skewness	4.782166

Gamma Statistics

k hat	2.45004
k star (bias corrected)	2.227259
Theta hat	6.576218
Theta star	7.234005
nu hat	147.0024
nu star	133.6355
Approx.Chi Square Value (.05)	107.9237
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	106.5925

Log-transformed Statistics

Minimum of log data	2.066863
Maximum of log data	4.727388
Mean of log data	2.561819
Standard Deviation of log data	0.510417
Variance of log data	0.260526

RECOMMENDATION

Data are Non-parametric (0.05)

Use 95% Chebyshev (Mean, Sd) UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.356718
Shapiro-Wilk 5% Critical Value	0.927
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	22.07739
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Gamma Distribution Test

A-D Test Statistic	5.244079
A-D 5% Critical Value	0.755761
K-S Test Statistic	0.374329
K-S 5% Critical Value	0.161694

Data do not follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	19.95053
Adjusted Gamma UCL	20.19969

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.633358
Shapiro-Wilk 5% Critical Value	0.927
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	17.74632
95% Chebyshev (MVUE) UCL	20.93144
97.5% Chebyshev (MVUE) UCL	23.6317
99% Chebyshev (MVUE) UCL	28.93583

95% Non-parametric UCLs

CLT UCL	21.88685
Adj-CLT UCL (Adjusted for skewness)	25.1622
Mod-t UCL (Adjusted for skewness)	22.58828
Jackknife UCL	22.07739
Standard Bootstrap UCL	21.98128
Bootstrap-t UCL	49.41336
Hall's Bootstrap UCL	42.72187
Percentile Bootstrap UCL	22.6205
BCA Bootstrap UCL	27.99383
95% Chebyshev (Mean, Sd) UCL	31.41547
97.5% Chebyshev (Mean, Sd) UCL	38.0373
99% Chebyshev (Mean, Sd) UCL	51.04459

Data File AA2 Subsurface Soil

Variable: Manganese

Raw Statistics

Number of Valid Samples	30
Number of Unique Samples	30
Minimum	138
Maximum	1270
Mean	437.0833
Median	398.25
Standard Deviation	219.8819
Variance	48348.04
Coefficient of Variation	0.503066
Skewness	2.166498

Gamma Statistics

k hat	5.177905
k star (bias corrected)	4.682337
Theta hat	84.41316
Theta star	93.34726
nu hat	310.6743
nu star	280.9402
Approx.Chi Square Value (.05)	243.1126
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	241.0876

Log-transformed Statistics

Minimum of log data	4.927254
Maximum of log data	7.146772
Mean of log data	5.980463
Standard Deviation of log data	0.449444
Variance of log data	0.202

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.808827
Shapiro-Wilk 5% Critical Value	0.927
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	505.2944
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Gamma Distribution Test

A-D Test Statistic	0.745943
A-D 5% Critical Value	0.746454
K-S Test Statistic	0.160319
K-S 5% Critical Value	0.160298

Data follow approximate gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	505.0923
Adjusted Gamma UCL	509.3346

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.94892
Shapiro-Wilk 5% Critical Value	0.927

Data are lognormal at 5% significance level

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	512.703
95% Chebyshev (MVUE) UCL	597.6454
97.5% Chebyshev (MVUE) UCL	667.5614
99% Chebyshev (MVUE) UCL	804.8979

95% Non-parametric UCLs

CLT UCL	503.1156
Adj-CLT UCL (Adjusted for skewness)	520.0826
Mod-t UCL (Adjusted for skewness)	507.9409
Jackknife UCL	505.2944
Standard Bootstrap UCL	500.8076
Bootstrap-t UCL	539.3951
Hall's Bootstrap UCL	574.8735
Percentile Bootstrap UCL	506.8833
BCA Bootstrap UCL	530.1833
95% Chebyshev (Mean, Sd) UCL	612.0703
97.5% Chebyshev (Mean, Sd) UCL	687.7872
99% Chebyshev (Mean, Sd) UCL	836.5186

Data File AA2 Subsurface Soil

Variable: Vanadium

Raw Statistics

Number of Valid Samples	35
Number of Unique Samples	30
Minimum	12.9
Maximum	34.7
Mean	26.05167
Median	26.3
Standard Deviation	3.616378
Variance	13.07819
Coefficient of Variation	0.138816
Skewness	0.674146

Gamma Statistics

k hat	55.6819
k star (bias corrected)	50.13593
Theta hat	0.467866
Theta star	0.519621
nu hat	3340.914
nu star	3008.156
Approx.Chi Square Value (.05)	2881.693
Adjusted Level of Significance	0.041
Adjusted Chi Square Value	2874.586

Log-transformed Statistics

Minimum of log data	3.020425
Maximum of log data	3.54674
Mean of log data	3.251075
Standard Deviation of log data	0.135588
Variance of log data	0.018384

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.940191
Shapiro-Wilk 5% Critical Value	0.927
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	27.17353
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Gamma Distribution Test

A-D Test Statistic	0.46237
A-D 5% Critical Value	0.744251
K-S Test Statistic	0.133263
K-S 5% Critical Value	0.159546

Data follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	27.19494
Adjusted Gamma UCL	27.26218

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.959156
Shapiro-Wilk 5% Critical Value	0.927
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	27.2075
95% Chebyshev (MVUE) UCL	28.8688
97.5% Chebyshev (MVUE) UCL	30.08917
99% Chebyshev (MVUE) UCL	32.48635

95% Non-parametric UCLs

CLT UCL	27.13769
Adj-CLT UCL (Adjusted for skewness)	27.22453
Mod-t UCL (Adjusted for skewness)	27.18707
Jackknife UCL	27.17353
Standard Bootstrap UCL	26.4
Bootstrap-t UCL	27.20325
Hall's Bootstrap UCL	27.27392
Percentile Bootstrap UCL	26.9
BCA Bootstrap UCL	27.20333
95% Chebyshev (Mean, Sd) UCL	28.92966
97.5% Chebyshev (Mean, Sd) UCL	30.17497
99% Chebyshev (Mean, Sd) UCL	32.62114

Data File AA2 Sediment

Variable: Aluminum

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	23
Minimum	2490
Maximum	16000
Mean	9555.87
Median	9220
Standard Deviation	3349.322
Variance	11217956
Coefficient of Variation	0.350499
Skewness	-0.031207

Gamma Statistics

k hat	6.862973
k star (bias corrected)	5.996788
Theta hat	1392.381
Theta star	1593.498
nu hat	315.6967
nu star	275.8522
Approx. Chi Square Value (.05)	238.3796
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	235.8585

Log-transformed Statistics

Minimum of log data	7.820038
Maximum of log data	9.680344
Mean of log data	9.090291
Standard Deviation of log data	0.429749
Variance of log data	0.184685

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.973146
Shapiro-Wilk 5% Critical Value	0.914
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	10755.09
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Gamma Distribution Test

A-D Test Statistic	0.532166
A-D 5% Critical Value	0.745623
K-S Test Statistic	0.163623
K-S 5% Critical Value	0.181883

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	11058.03
Adjusted Gamma UCL	11176.23

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.885032
Shapiro-Wilk 5% Critical Value	0.914
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	11595.72
95% Chebyshev (MVUE) UCL	13579.74
97.5% Chebyshev (MVUE) UCL	15265.16
99% Chebyshev (MVUE) UCL	18575.84

95% Non-parametric UCLs

CLT UCL	10704.61
Adj-CLT UCL (Adjusted for skewness)	10699.75
Mod-t UCL (Adjusted for skewness)	10754.33
Jackknife UCL	10755.09
Standard Bootstrap UCL	10711.26
Bootstrap-t UCL	10679.48
Hall's Bootstrap UCL	10789.65
Percentile Bootstrap UCL	10645.65
BCA Bootstrap UCL	10715.22
95% Chebyshev (Mean, Sd) UCL	12600.05
97.5% Chebyshev (Mean, Sd) UCL	13917.26
99% Chebyshev (Mean, Sd) UCL	16504.68

Data File AA2 Sediment

Variable: Arsenic

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	23
Minimum	2.64
Maximum	13
Mean	6.467391
Median	5.6
Standard Deviation	3.01622
Variance	9.097584
Coefficient of Variation	0.466374
Skewness	0.703393

Gamma Statistics

k hat	4.989698
k star (bias corrected)	4.367853
Theta hat	1.296149
Theta star	1.48068
nu hat	229.5261
nu star	200.9212
Approx. Chi Square Value (.05)	169.1176
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	167.0052

Log-transformed Statistics

Minimum of log data	0.924259
Maximum of log data	2.564949
Mean of log data	1.763232
Standard Deviation of log data	0.468287
Variance of log data	0.219292

RECOMMENDATION
Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.922004
Shapiro-Wilk 5% Critical Value	0.914
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	7.47
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Gamma Distribution Test

A-D Test Statistic	0.349209
A-D 5% Critical Value	0.746536
K-S Test Statistic	0.129051
K-S 5% Critical Value	0.182083

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	7.683624
Adjusted Gamma UCL	7.780814

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.968256
Shapiro-Wilk 5% Critical Value	0.914
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	7.905302
95% Chebyshev (MVUE) UCL	9.324443
97.5% Chebyshev (MVUE) UCL	10.55821
99% Chebyshev (MVUE) UCL	12.98172

95% Non-parametric UCLs

CLT UCL	7.501881
Adj-CLT UCL (Adjusted for skewness)	7.600444
Mod-t UCL (Adjusted for skewness)	7.562721
Jackknife UCL	7.547347
Standard Bootstrap UCL	7.1
Bootstrap-t UCL	7.654742
Hall's Bootstrap UCL	7.528691
Percentile Bootstrap UCL	7.498261
BCA Bootstrap UCL	8.5
95% Chebyshev (Mean, Sd) UCL	9.208813
97.5% Chebyshev (Mean, Sd) UCL	10.39503
99% Chebyshev (Mean, Sd) UCL	12.72512

Data File AA2 Sediment

Variable: Chromium

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	23
Minimum	3.5
Maximum	30.4
Mean	15.54565
Median	15.95
Standard Deviation	5.546885
Variance	30.76793
Coefficient of Variation	0.356813
Skewness	0.388177

Gamma Statistics

k hat	6.804765
k star (bias corrected)	5.946172
Theta hat	2.284524
Theta star	2.614396
nu hat	313.0192
nu star	273.5239
Approx. Chi Square Value (.05)	236.2149
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	233.7056

Log-transformed Statistics

Minimum of log data	1.252763
Maximum of log data	3.414443
Mean of log data	2.668507
Standard Deviation of log data	0.434276
Variance of log data	0.188596

RECOMMENDATION
Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.964498
Shapiro-Wilk 5% Critical Value	0.914
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	17.53171
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Gamma Distribution Test

A-D Test Statistic	0.572263
A-D 5% Critical Value	0.745651
K-S Test Statistic	0.131981
K-S 5% Critical Value	0.181889

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	18.00102
Adjusted Gamma UCL	18.19429

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.87714
Shapiro-Wilk 5% Critical Value	0.914
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	18.93001
95% Chebyshev (MVUE) UCL	22.1889
97.5% Chebyshev (MVUE) UCL	24.96459
99% Chebyshev (MVUE) UCL	30.4169

95% Non-parametric UCLs

CLT UCL	17.4481
Adj-CLT UCL (Adjusted for skewness)	17.54813
Mod-t UCL (Adjusted for skewness)	17.54731
Jackknife UCL	17.53171
Standard Bootstrap UCL	17.36493
Bootstrap-t UCL	17.73818
Hall's Bootstrap UCL	17.91419
Percentile Bootstrap UCL	17.31957
BCA Bootstrap UCL	17.54348
95% Chebyshev (Mean, Sd) UCL	20.58718
97.5% Chebyshev (Mean, Sd) UCL	22.76865
99% Chebyshev (Mean, Sd) UCL	27.05373

Data File AA2 Sediment

Variable: Iron

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	22
Minimum	5810
Maximum	31800
Mean	19402.61
Median	18400
Standard Deviation	6094.634
Variance	37144566
Coefficient of Variation	0.314114
Skewness	0.239903

Gamma Statistics

k hat	9.296878
k star (bias corrected)	8.113227
Theta hat	2087.003
Theta star	2391.479
nu hat	427.6564
nu star	373.2085
Approx. Chi Square Value (.05)	329.4264
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	326.4503

Log-transformed Statistics

Minimum of log data	8.667336
Maximum of log data	10.36722
Mean of log data	9.818418
Standard Deviation of log data	0.360067
Variance of log data	0.129649

RECOMMENDATION
Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.958107
Shapiro-Wilk 5% Critical Value	0.914
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	21584.79
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Gamma Distribution Test

A-D Test Statistic	0.455299
A-D 5% Critical Value	0.744465
K-S Test Statistic	0.138459
K-S 5% Critical Value	0.181625

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	21981.29
Adjusted Gamma UCL	22181.68

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.896472
Shapiro-Wilk 5% Critical Value	0.914

Data not lognormal at 5% significance level

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	22617.58
95% Chebyshev (MVUE) UCL	26071.27
97.5% Chebyshev (MVUE) UCL	28896.97
99% Chebyshev (MVUE) UCL	34447.51

95% Non-parametric UCLs

CLT UCL	21492.92
Adj-CLT UCL (Adjusted for skewness)	21560.85
Mod-t UCL (Adjusted for skewness)	21595.38
Jackknife UCL	21584.79
Standard Bootstrap UCL	21429.42
Bootstrap-t UCL	21676.01
Hall's Bootstrap UCL	21650.64
Percentile Bootstrap UCL	21443.48
BCA Bootstrap UCL	21617.39
95% Chebyshev (Mean, Sd) UCL	24941.98
97.5% Chebyshev (Mean, Sd) UCL	27338.87
99% Chebyshev (Mean, Sd) UCL	32047.1

Data File AA2 Sediment

Variable: Lead

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	23
Minimum	19.6
Maximum	1460
Mean	140.1413
Median	46.8
Standard Deviation	306.4801
Variance	93930.06
Coefficient of Variation	2.186936
Skewness	4.048956

Gamma Statistics

k hat	0.739407
k star (bias corrected)	0.671948
Theta hat	189.5319
Theta star	208.5596
nu hat	34.01274
nu star	30.90962
Approx. Chi Square Value (.05)	19.20731
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	18.53868

Log-transformed Statistics

Minimum of log data	2.97553
Maximum of log data	7.286192
Mean of log data	4.13147
Standard Deviation of log data	1.035325
Variance of log data	1.071898

RECOMMENDATION

Data are Non-parametric (0.05)

Use 99% Chebyshev (Mean, Sd) UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.40155
Shapiro-Wilk 5% Critical Value	0.914
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	249.8763
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Gamma Distribution Test

A-D Test Statistic	2.697904
A-D 5% Critical Value	0.783206
K-S Test Statistic	0.2546
K-S 5% Critical Value	0.188768

Data do not follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	225.5243
Adjusted Gamma UCL	233.6582

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.846219
Shapiro-Wilk 5% Critical Value	0.914
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	188.1995
95% Chebyshev (MVUE) UCL	212.9904
97.5% Chebyshev (MVUE) UCL	260.629
99% Chebyshev (MVUE) UCL	354.2058

95% Non-parametric UCLs

CLT UCL	245.2565
Adj-CLT UCL (Adjusted for skewness)	302.9064
Mod-t UCL (Adjusted for skewness)	258.8685
Jackknife UCL	249.8763
Standard Bootstrap UCL	244.4815
Bootstrap-t UCL	823.7988
Hall's Bootstrap UCL	683.4292
Percentile Bootstrap UCL	255.5087
BCA Bootstrap UCL	333.4152
95% Chebyshev (Mean, Sd) UCL	418.699
97.5% Chebyshev (Mean, Sd) UCL	539.2312
99% Chebyshev (Mean, Sd) UCL	775.9932

Data File AA2 Sediment

Variable: Manganese

Raw Statistics		Normal Distribution Test	
Number of Valid Samples	23	Shapiro-Wilk Test Statistic	0.821638
Number of Unique Samples	22	Shapiro-Wilk 5% Critical Value	0.914
Minimum	58.6	Data not normal at 5% significance level	
Maximum	406	95% UCL (Assuming Normal Distribution)	
Mean	172.1783	Student's-t UCL	202.8787
Median	151	Gamma Distribution Test	
Standard Deviation	85.74369	A-D Test Statistic	0.894627
Variance	7351.981	A-D 5% Critical Value	0.746401
Coefficient of Variation	0.497994	K-S Test Statistic	0.20472
Skewness	1.554482	K-S 5% Critical Value	0.182056
Gamma Statistics		Data do not follow gamma distribution at 5% significance level	
k hat	5.229908	95% UCLs (Assuming Gamma Distribution)	
k star (bias corrected)	4.576731	Approximate Gamma UCL	203.706
Theta hat	32.92186	Adjusted Gamma UCL	206.2193
Theta star	37.62036	Lognormal Distribution Test	
nu hat	240.5757	Shapiro-Wilk Test Statistic	0.941847
nu star	210.5296	Shapiro-Wilk 5% Critical Value	0.914
Approx. Chi Square Value (.05)	177.9458	Data are lognormal at 5% significance level	
Adjusted Level of Significance	0.0389	95% UCLs (Assuming Lognormal Distribution)	
Adjusted Chi Square Value	175.7771	95% H-UCL	206.1759
Log-transformed Statistics		95% Chebyshev (MVUE) UCL	242.0062
Minimum of log data	4.070735	97.5% Chebyshev (MVUE) UCL	272.6522
Maximum of log data	6.006353	99% Chebyshev (MVUE) UCL	332.8503
Mean of log data	5.049891	95% Non-parametric UCLs	
Standard Deviation of log data	0.441424	CLT UCL	201.5863
Variance of log data	0.194855	Adj-CLT UCL (Adjusted for skewness)	207.7784
RECOMMENDATION		Mod-t UCL (Adjusted for skewness)	203.8446
Data are lognormal (0.05)		Jackknife UCL	202.8787
Use Student's-t UCL		Standard Bootstrap UCL	201.1923
Use Modified-t UCL		Bootstrap-t UCL	213.6992
Use H-UCL		Hall's Bootstrap UCL	207.3562
		Percentile Bootstrap UCL	203.9783
		BCA Bootstrap UCL	205.8522
		95% Chebyshev (Mean, Sd) UCL	250.1101
		97.5% Chebyshev (Mean, Sd) UCL	283.8313
		99% Chebyshev (Mean, Sd) UCL	350.07

Data File AA2 Sediment

Variable: Vanadium

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	21
Minimum	5.7
Maximum	32.2
Mean	21.74348
Median	22.4
Standard Deviation	6.485023
Variance	42.05552
Coefficient of Variation	0.298251
Skewness	-0.482166

Gamma Statistics

k hat	8.876334
k star (bias corrected)	7.747537
Theta hat	2.449601
Theta star	2.806502
nu hat	408.3114
nu star	356.3867
Approx. Chi Square Value (.05)	313.63
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	310.7278

Log-transformed Statistics

Minimum of log data	1.740466
Maximum of log data	3.471966
Mean of log data	3.021928
Standard Deviation of log data	0.382107
Variance of log data	0.146006

RECOMMENDATION
Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.965574
Shapiro-Wilk 5% Critical Value	0.914
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	24.06544
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Gamma Distribution Test

A-D Test Statistic	0.667219
A-D 5% Critical Value	0.744665
K-S Test Statistic	0.151976
K-S 5% Critical Value	0.181669

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	24.70773
Adjusted Gamma UCL	24.9385

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.842304
Shapiro-Wilk 5% Critical Value	0.914
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	25.74497
95% Chebyshev (MVUE) UCL	29.83709
97.5% Chebyshev (MVUE) UCL	33.22332
99% Chebyshev (MVUE) UCL	39.87492

95% Non-parametric UCLs

CLT UCL	23.96768
Adj-CLT UCL (Adjusted for skewness)	23.82242
Mod-t UCL (Adjusted for skewness)	24.04278
Jackknife UCL	24.06544
Standard Bootstrap UCL	23.97192
Bootstrap-t UCL	23.92876
Hall's Bootstrap UCL	23.86472
Percentile Bootstrap UCL	23.85435
BCA Bootstrap UCL	23.77826
95% Chebyshev (Mean, Sd) UCL	27.63767
97.5% Chebyshev (Mean, Sd) UCL	30.18809
99% Chebyshev (Mean, Sd) UCL	35.19791

Data File AA2 Sediment

Variable: PCB-1260

Raw Statistics

Number of Valid Samples	23
Number of Unique Samples	23
Minimum	0.01345
Maximum	18
Mean	2.054933
Median	0.26
Standard Deviation	4.670143
Variance	21.81024
Coefficient of Variation	2.27265
Skewness	2.990636

Gamma Statistics

k hat	0.376362
k star (bias corrected)	0.356257
Theta hat	5.459986
Theta star	5.768118
nu hat	17.31266
nu star	16.38782
Approx.Chi Square Value (.05)	8.235198
Adjusted Level of Significance	0.0389
Adjusted Chi Square Value	7.817633

Log-transformed Statistics

Minimum of log data	-4.308776
Maximum of log data	2.890372
Mean of log data	-1.04547
Standard Deviation of log data	1.910329
Variance of log data	3.649357

RECOMMENDATION

Data are lognormal (0.05)

Use 95% Chebyshev (MVUE) UCL

Normal Distribution Test

Shapiro-Wilk Test Statistic	0.47337
Shapiro-Wilk 5% Critical Value	0.914
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)

Student's-t UCL	3.727074
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Gamma Distribution Test

A-D Test Statistic	1.528819
A-D 5% Critical Value	0.83212
K-S Test Statistic	0.199581
K-S 5% Critical Value	0.194959

Data do not follow gamma distribution at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	4.089261
Adjusted Gamma UCL	4.307682

Lognormal Distribution Test

Shapiro-Wilk Test Statistic	0.956349
Shapiro-Wilk 5% Critical Value	0.914
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	10.78364
95% Chebyshev (MVUE) UCL	5.780462
97.5% Chebyshev (MVUE) UCL	7.499986
99% Chebyshev (MVUE) UCL	10.87766

95% Non-parametric UCLs

CLT UCL	3.656678
Adj-CLT UCL (Adjusted for skewness)	4.305531
Mod-t UCL (Adjusted for skewness)	3.828282
Jackknife UCL	3.727074
Standard Bootstrap UCL	3.676379
Bootstrap-t UCL	9.892498
Hall's Bootstrap UCL	11.50859
Percentile Bootstrap UCL	3.810087
BCA Bootstrap UCL	4.384193
95% Chebyshev (Mean, Sd) UCL	6.299594
97.5% Chebyshev (Mean, Sd) UCL	8.136263
99% Chebyshev (Mean, Sd) UCL	11.74404

Data File AA2 Surface Water

Variable: Manganese

Raw Statistics		Normal Distribution Test	
Number of Valid Samples	24	Shapiro-Wilk Test Statistic	0.674154
Number of Unique Samples	24	Shapiro-Wilk 5% Critical Value	0.916
Minimum	0.0033	Data not normal at 5% significance level	
Maximum	0.227	95% UCL (Assuming Normal Distribution)	
Mean	0.043123	Student's-t UCL	0.058917
Median	0.0322	Gamma Distribution Test	
Standard Deviation	0.045147	A-D Test Statistic	0.332792
Variance	0.002038	A-D 5% Critical Value	0.762553
Coefficient of Variation	1.046942	K-S Test Statistic	0.090263
Skewness	3.140141	K-S 5% Critical Value	0.18136
Gamma Statistics		Data follow gamma distribution at 5% significance level	
k hat	1.450881	95% UCLs (Assuming Gamma Distribution)	
k star (bias corrected)	1.297299	Approximate Gamma UCL	0.059519
Theta hat	0.029722	Adjusted Gamma UCL	0.060906
Theta star	0.033241	Lognormal Distribution Test	
nu hat	69.6423	Shapiro-Wilk Test Statistic	0.974355
nu star	62.27034	Shapiro-Wilk 5% Critical Value	0.916
Approx.Chi Square Value (.05)	45.11615	Data are lognormal at 5% significance level	
Adjusted Level of Significance	0.0392	95% UCLs (Assuming Lognormal Distribution)	
Adjusted Chi Square Value	44.08906	95% H-UCL	0.072053
Log-transformed Statistics		95% Chebyshev (MVUE) UCL	0.084569
Minimum of log data	-5.713833	97.5% Chebyshev (MVUE) UCL	0.102107
Maximum of log data	-1.482805	99% Chebyshev (MVUE) UCL	0.136556
Mean of log data	-3.526327	95% Non-parametric UCLs	
Standard Deviation of log data	0.925102	CLT UCL	0.058281
Variance of log data	0.855814	Adj-CLT UCL (Adjusted for skewness)	0.064593
RECOMMENDATION		Mod-t UCL (Adjusted for skewness)	0.059902
Data follow gamma distribution (0.05)		Jackknife UCL	0.058917
Use Approximate Gamma UCL		Standard Bootstrap UCL	0.058181
		Bootstrap-t UCL	0.072556
		Hall's Bootstrap UCL	0.124699
		Percentile Bootstrap UCL	0.05921
		BCA Bootstrap UCL	0.064519
		95% Chebyshev (Mean, Sd) UCL	0.083293
		97.5% Chebyshev (Mean, Sd) UCL	0.100675
		99% Chebyshev (Mean, Sd) UCL	0.134817

APPENDIX F

**RESPONSES TO COMMENTS ON THE DRAFT BASELINE HUMAN
HEALTH RISK ASSESSMENT**

Interoffice Memorandum

To: Paul Jayko, Site Coordinator, DERR-NWDO
From: John Weaver through Tim Fishbaugh, Manager, DDAGW-NWDO
Date: October 23, 2007
Facility: NASA Plum Brook Ordnance Works, Erie County, RR 322-0552.
Subject: Draft Baseline Human Health Risk Assessment Acid Area 2, document dated September 2007.

INTRODUCTION

The NASA Plum Brook Station (NPBS) is a formerly used defense site and is being investigated by the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program. The USACE Nashville, TN district contracted Jacobs Engineering Group, Inc. (Jacobs) to prepare a baseline human health risk assessment for Acid Area 2. The ERA was prepared as an element of a remedial investigation (RI) completed at Acid Area 2 during a period of time from approximately November 2004 to April 2005. For reference, Acid Area 2 was formerly used to produce materials for the manufacture of trinitrotoluene (TNT) including sulfuric and nitric acid. Constituents of concern (COCs) detected in soil samples include semivolatile organic compounds, polynuclear aromatic hydrocarbons, and PCBs.

NPBS/Jacobs submitted a Draft Baseline Human Health Risk Assessment Acid Area 2 to Ohio EPA on September 27, 2007. The Division of Emergency and Remedial Response (DERR) has requested that the Division of Drinking and Ground Waters (DDAGW) review the aforementioned risk assessment to determine its adequacy and completeness in support of the RI at Acid Area 2.

COMMENTS

- Ohio EPA requests that USACE Nashville, TN district (USACE) and/or Jacobs Engineering Group, Inc. (Jacobs) provide a technical/regulatory reference for the equation to calculate risk-based remediation levels ($RBRL_{COC}$); equation 5.7 (Eq. 5.7) on page 5-5 of the September 2007 Draft Baseline Human Health Risk Assessment Acid Area 2 (HHRA).**

Ohio EPA is unclear as to how the equation for $RBRL_{COC}$ is developed using the variables of ST_{COC} (source term concentration, TR (target risk level of 1×10^{-6}), and $ILCR_{COC}$ (incremental lifetime cancer risk [$CDI \times SF$]).

Response: The basis of the equation is that risks and remediation levels are proportional; as the concentration of a chemical rises, the risk will rise proportionally. Therefore, for a calculated level of risk ($ILCR_{COC}$) at a known concentration (ST_{COC}), the remediation level may be calculated for any specified risk level (TR; such as 1×10^{-6}).

The equation in the document has been referenced in the document USEPA. 2000. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment Bulletins. EPA Region 4, originally published November 1995, Website version last updated May 2000: <http://www.epa.gov/region4/waste/ots/healthbul.htm>.

2. **The HHRA should have included an appendix containing ProUCL calculations for all constituents of concern (COCs) for each media type for cross-referencing purposes.**

The exposure point concentration (EPC) column found on Table 2.1 of the HHRA is represented by the lesser of the ProUCL value or the maximum detected concentration of the COC in a particular media. The maximum detected concentration of each COC is provided but not the derivation of the ProUCL value.

Response: ProUCL Version 3 was only used to calculate EPCs for data sets containing fewer than 15 percent nondetects. This is consistent with the documentation for ProUCL Version 3 which indicates that it is not suited for data sets with greater than 15 percent nondetects. The data sets calculated using ProUCL for Acid Areas 2 and 3 were all metal constituents. The ProUCL output has been added as an Appendix to the document.

As detailed in Section 2.2 of the BHHRA, statistical computations for data sets with greater than 15 percent nondetects were made using a FoxPro based statistical package developed by Jacobs. This software package was developed based on EPA and other statistical guidance and documentation. The operations performed by the software include: 1) Data distribution evaluations using Shapiro-Wilk and Shapiro-Francia methods, 2) Data distribution evaluations using box-plots and probability plots, 3) Outlier evaluation using ASTM E178-75, 4) Summary statistics computed using classical methods as described section 4-7 of the USEPA QA/G-9 publication and in Richard Gilbert's textbook "Statistical Methods for Environmental Pollution Monitoring", and 5) Calculations of UCLs as described in Gilbert, using Kaplan-Meier, using simple bootstrap with replacement, and by MLE (maximum likelihood estimation).

3. **Ohio EPA is unclear as to what USACE/Jacobs intend to do with the human health risk assessment conclusions found in Section 7.3 of the HHRA.**

Response: The results will be used to determine the need for additional investigation or any remediation at the site.

ec: Archie Lunsey, DERR-NWDO
Paul Jayko, DHWM-NWDO
pc: Jeff Patzke, DDAGW-CO
ID: 5000007254



inter-office communication

To:	Paul Jayko, NWDO-DERR	Date: 26 November 2007
From:	Janusz Z. Byczkowski, DERR, CO	
Subject:	Draft Baseline Human Health Risk Assessment, Acid Area 2, Former Plum Brook Ordnance Works Sandusky, Ohio, April 2007. Site: US NASA PLUM BROOK, TAYLOR & COLUMBUS Rds., SANDUSKY, OH 44870; ERIE Cnt.; OHID# 322-0552.	

The following memo is about the document ***"Draft Baseline Human Health Risk Assessment, Acid Area 2", Former Plum Brook Ordnance Works Sandusky, Ohio***, dated September, 2007.

Please note the new format for comments, requested for all FUDS sites (by NEDO).

If you have any questions or need further technical support, please call me at: 614-644-3070 or e-mail at jbyczkowski@epa.state.oh.us.

DOCUMENT TITLE: *Draft Baseline Human Health Risk Assessment, Acid Area 2*

SITE: US NASA PLUM BROOK, TAYLOR &
COLUMBUS Rds., SANDUSKY, OH 44870;
ERIE Cnt.; OHID# 322-0552.

DOCUMENT/DATE: Draft /September 2007

**Ohio EPA – Division of Emergency and Remedial Response
COMMENTS**

REVIEWER: Dr. Janusz Z. Byczkowski, DERR, CO; Tel: 614-644-3070; e-mail: jbyczkowski@epa.state.oh.us.

Review/DATE: 11/26/2007

1. S 1.4, P 1-3, L# 36

Comment:

General Remark:

This Document should be revised to include some of the current Ohio EPA – Division of Emergency and Remedial Response (OEPA-DERR) remedial investigation/feasibility study (RI/FS) programmatic guidelines.

If you have any questions or need further technical support, please give me a call at: 614-644-3070 or e-mail at jbyczkowski@epa.state.oh.us.

For example, this Document states:

"...*This BHHRA was prepared based on [...] Ohio Environmental Protection Agency guidance...*"

However, the one and only OEPA guidance listed on the next page 1-4 and in the Reference section on page 8-2: OEPA (1993) "*Closure Plan Review Guidance for RCRA Facilities*," is already obsolete.

Recommendation: I suggest a **revision** of the Document:

- (i) to include OEPA-DERR - RI/FS programmatic recommendations available on-line at: <http://www.epa.state.oh.us/derr/rules/guidance.html>, and
- (ii) to follow the suggestions and resolve the specific issues listed below.

Response: The document has been revised to include an expanded list of OEPA-DERR Guidance documents. The obsolete guidance document cited in the comment has been removed from the list of references.

2. S 5.4, P 5-7, L# 36

Comment:

Specific Issues:

This Document states:

"...*Total ILCR estimates for the adult and child venison consumer receptors were below the risk management range...*" This statement is repeated in Section 7.2 (P. 7-2, L# 14) and the expression "*risk management range*" appears in numerous places (e.g., in S. 7.3 on P. 7-3).

Essentially, the description of baseline human health risk should be kept separate from risk management decisions, e.g., from setting "*risk management range*" or "*unacceptable risk*" levels (see: NRC, 1983). Risk management statements, are premature at a Baseline Risk

Assessment phase of the project. However, they may be discussed later, during the Feasibility Study (FS).

In this document, the results of quantitative baseline risk assessment should be objectively communicated as numerical values. They may be interpreted regarding their significance, health protection, and compared to the regulatory goals (e.g., OEPA, 2004, cumulative excess lifetime carcinogenic risk goal of 1E-5).

References:

NRC (1983) Commission on Life Sciences. "Risk Assessment in the Federal Government: Managing the Process". On line: <http://books.nap.edu/books/0309033497/html/index.html> .

OEPA (2004) Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight. On line: <http://www.epa.state.oh.us/derr/rules/riskgoal.pdf>.

Recommendation: Please search this document for phrases containing "*management*", remove them (except those correctly explaining that values in BHHRA "*are derived to support risk management decisions*") and also remove all statements and other phrases suggesting that risk management decisions are being made at the baseline risk assessment phase of the RI.

Response: The use of the term "risk management range" is not used to indicate any risk management decision. Its use is consistent with EPA guidance such as *Role of the Baseline Risk Assessment*, which indicates that EPA seeks to "manage" risks within the range of 10⁻⁴ to 10⁻⁶ ELCR, also referred to as a "target risk range," and OEPA's Technical Decision Compendium *Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for DERR Remedial Response and Office of Federal Facility Oversight*, which states that "the NCP defines an acceptable upper excess lifetime cancer risk as generally between 10⁻⁶ and 10⁻⁴". The text has been revised to eliminate references to "risk management" and any statements indicating that risk management decision are being made at the risk assessment phase.

3. Table 2-1

Comment: The column head states: "*Region 9 Residential PRG...*", while actually listing **1/10** of the residential PRG values for non-carcinogenic chemicals in soil. For chemicals in water: there are listed PRG values for **tap water** (100% or 1/10 for carcinogenic or non-carcinogenic chemicals, respectively), rather than "*Residential*" values.

Since values in this column are being used as screening levels, based on toxicity values derived from U.S. EPA Region 9 PRGs for residential soil and tap water, they should be labeled appropriately (there are no "*Residential PRGs*" for water).

Reference:

OEPA – DERR (2004) Use of U.S. EPA Region 9 PRGs as screening Values in Human Health Risk Assessments. Technical Decision Compendium, 28 April 2004. On-line:

<http://www.epa.state.oh.us/derr/rules/screening.pdf>

(U.S. EPA Region 9 PRGs may be found at

<http://www.epa.gov/region09/waste/sfund/prg/index.htm>)

Recommendation: Please change the column heading to "**Toxicity Screen Level**", mark it with an asterisk and explain in a footnote to the table the origin (PRGs for Residential soil and Tap

water) and the method of derivation (100% for carcinogenic chemicals and 1/10 for non-carcinogenic chemicals). Refer to OEPA – DERR (2004) guidelines.

Response: The term “tap water” in the Region 9 PRG Tables denotes a residential use of groundwater. The column heading has been changed to “Toxicity Screening Level” and a footnote has been added.

4. Table 2-1

Comment: In the rows for "*Surface Water*", *Arsenic* is not flagged as a COPC, despite the max. detected concentration of 3.2 ug/L, almost two orders of magnitude higher than screening level of 0.04 ug/L.

According to U.S. EPA (1989): "*...infrequently detected chemicals with concentrations that greatly exceeded reference concentrations should not be eliminated...*"

Even though frequency of its detection is low (4%), As cannot be screened out of risk assessment, given the information provided in the Table 2-1.

Reference:

U.S. EPA (1989) Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), Interim Final, EPA/540/1-89/002, December 1989. On-line: <http://www.epa.gov/oswer/riskassessment/ragsa/index.htm>

Recommendation: Please flag **Arsenic** in Surface Water as "**COPC**".

Response: Quantitative analysis of this constituent, while appropriate based on the guidance, is not warranted because arsenic was detected in only one surface water sample at the site and its presence in the surface water sample is likely to be associated with particulates in the sample. In addition, the PRGs are based on the use of groundwater as a drinking water source and their application to surface water likely overestimates potential risk.

5. Table 2-1

Comment: In the rows for "*Sediment*", *PCB-1254* is not flagged as a COPC, despite the max. detected concentration of 1,520 ug/kg, almost seven times higher than screening level of 222 ug/kg.

According to U.S. EPA (1989): "*...infrequently detected chemicals with concentrations that greatly exceeded reference concentrations should not be eliminated...*"

Even though frequency of its detection is low (4%), PCB-1254 cannot be screened out from risk assessment, given the information provided in the Table 2-1 (see the comment #4 above for reference).

Recommendation: Please flag **PCB-1254** in Sediment as "**COPC**".

Response: Quantitative analysis of this constituent, while appropriate based on the guidance, is not warranted because PCB-1254 was only detected in one sediment sample at the site. Additionally, the PRG was based on residential contact with soil, which likely overestimates potential risk from exposure to sediment.

6. Table 4-1

Comment: Several toxicity values listed in this table are different from those, derived according to OEPA-DERR (2004) methodology and guidance. Also, the toxicity values for TCE are different from those, listed by OEPA at <http://www.epa.state.oh.us/derr/rules/vapor.pdf>.

However, in this case the differences between values in the table and OEPA guidelines do not affect the overall risk assessment, because they do concern chemicals not selected as COCs for this Site.

Reference:

OEPA-DERR (2004) "Assessing Compounds without Formal Toxicity Values Available for Use in Human Health Risk Assessment". Ohio EPA Division of Emergency and Remedial Response, Remedial Response Program. Date: 14 April 2004 (updated August 2005). On-line: <http://www.epa.state.oh.us/derr/rules/notaxtdc.pdf>

Recommendation: No change needed.

Response: Comment noted.

Comments of Jim Beaujon Concerning Jacob's *Draft Baseline Human Health Risk Assessment, Acid Area 2, Former Plum Brook Ordnance Works*, dated September 2007

1. Table of Contents: Please revise/update the page listings, for example the first 4 are incorrect.

Response: The Table of Contents has been corrected.

2. Executive Summary: Please add an Executive Summary.

Response: An Executive Summary has been added to the document.

3. Page 1-1, Section 1.0, 2nd paragraph: Please change appropriate sentences to read- "This work is being conducted for ... (DERP)-Formerly Used Defense Sites (FUDS). Investigations at PBOW under DERP-FUDS are being managed by" ...

Response: In response to this comment and a similar comment from another reviewer, the text has been revised as follows:

"This work is being conducted for the U.S. Army Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the USACE Huntington District and technically overseen by the USACE Nashville District (CELRN)."

4. Page 1-2, Section 1.2, end of 2nd paragraph: The U.S. General Services Administration (GSA) is an independent federal agency and not a component of the Army.

Response: The text has been modified to remove reference to the Army.

5. Page 2-1, second line: Given the EPA's current naming system wouldn't it be "Region 3" rather than "Region III"?

Response: The EPA regional naming convention has been changed throughout the document in response to this comment.

6. Page 2-4, Section 2.1.5, 1st paragraph: Please edit for clarity. The first reference to "derivation of BSCs" (4th line of paragraph) appears to be for groundwater but it isn't clearly stated (e.g. "derivation of groundwater BSCs"). Then in the last sentence "Background values for soil" are mentioned, are these also BSCs?

Response: The text has been revised to clarify that are two sets of BSCs: one for groundwater and one for soil.

7. Page 2-5: Definitions for Equation 2.2 variables: The “s_y” in the equation appears to use a lower case “s” rather than the upper case as used in the definition.

Response: The “S” in the definition has been changed to lower case.

8. Page 2-8, Shallow Groundwater, end of 1st paragraph: When discussing possible lab artifacts showing up in sample analysis rather than saying “detected in monitoring well” it might be better to say something like “detected in the sample from monitoring well”.

Response: The text has been modified to read “reported in the sample...”

9. Page 2-8, Bedrock Groundwater, last sentence of section: Edit for clarity the sentence concerning 2-nitrotoluene.

Response: The text has been revised to read “was not detected during Round 1 and the Round 2 detection...”

10. Page 2-9, last sentence of 1st full paragraph: Shouldn’t the “E” in “2-Ethylhexyl” be lower case?

Response: The “E” has been changed to lower case.

11. Page 3-2, last two sentences of paragraph preceding Section 3.1.1 and page 3-3 last sentence of paragraph preceding Section 3.1.2: There seems to be a conflict between these two areas as the first indicates groundwater can plausibly be used as tap water and the second that it is unsuitable as a potable water source. Please reconcile this conflict.

Response: Although the presence of petroleum and hydrogen sulfide makes site groundwater unsuitable for use as a drinking water source at Acid Area 2, groundwater in the PBOW area is used for drinking water. Because future use of groundwater is plausible, it was retained as a potential exposure medium.

12. Page 3-7, Future On-Site Resident, last sentence of 1st paragraph: Rather than “Cancer risk were estimated” shouldn’t it be “Cancer risk was estimated”?

Response: The text has been revised to read “Lifetime cancer risk was...”

13. Page 5-3, Equation 5.6 and definitions: Shouldn’t there be a space between “Total” and “HI_a”?

Response: A space has been added between “Total” and “HI_a.”

14. Page 5-6, Section 5.4, 2nd paragraph, 4th line: “level of I” should be “level of 1”, the number one.

Response: The “I” has been changed to a “1.”

15. Tables and Figures appendix: If the tables and figures are to be presented in the same appendix then they should not be segregated within the appendix but should be presented in the order in which they are first referenced in the text. For example, Figures 1-1 and 1-2 are referenced before any tables therefore they should be presented in the appendix ahead of the tables.

Response: The figures and tables are now provided under separate tabs.

16. Tables: Please add page numbers to each table that lacks them, in the form of “Page # of # pages”. This would probably work best as a header or footer.

Response: The page numbers have been added as requested.

17. Figure 1-2: Although not critical to this document you might as well correct the following now. The area marked as Acid Area #1 is incorrect. The correct area is just south of what is marked. Also, consider narrowing the area marked for Acid Area #3. Generally the #3 area is considered to be bounded by Ransom Road on the east and the service road on the west.

Response: The figure has been modified as requested.

18. Figure 2-1: Please add a North arrow.

Response: A North arrow has been added as requested.

MCHB-TS-REH

MEMORANDUM FOR District Engineer, US Army Corps of Engineers, Nashville District (CELRN-EC-R-M/Ms. Kathy McClanahan), 110 Ninth Avenue South, Room 682, US Court House Annex, Nashville, TN 37203

SUBJECT: Draft Baseline Human Health Risk Assessment (BHHRA), Acid Area 2, Former Plum Brook Ordnance Works (PBOW), Sandusky, OH, September 2007

1. The US Army Center for Health Promotion and Preventive Medicine (USACHPPM) reviewed the subject document on behalf of the Office of The Surgeon General pursuant to AR 200-1 (Environmental Protection and Enhancement). We appreciate the opportunity to review this risk assessment. Our comments and recommendations are enclosed.
2. Our comments on this well-written assessment are seeking a few technical clarifications. We look forward to providing further technical risk assessment support on this and other PBOW projects.
3. The scientist reviewing this document and our point of contact is Mr. Larry Tannenbaum, Environmental Health Risk Assessment Program, at DSN 584-5210 or commercial (410-436-5210).

FOR THE COMMANDER:

Encl

JEFFREY S. KIRKPATRICK
Director, Health Risk Management

CF:
HQDA (DASG-PPM-NC) (wo/encl)
USACE (CENWO-HX-H) (w/encl)

COMMENTS AND RECOMMENDATIONS

1. Page 1-1, Section 1.0, L. Tannenbaum

Introduction

Comment: The Army Corps of Engineers, in this Section's second paragraph, is said to be the lead agency for environmental response actions at PBOW. Might the text mean that the U.S. Army is the lead agency in this regard?

Recommendation: Please reword the identified text, and consider clarifying the matter based on a distinction found on the Corps' website: "The Army is the executive agent for the (FUDS) program and the U.S. Army Corps of Engineers manages and directs the program's administration."

Response: In response to this comment and a similar comment from another reviewer, the text has been revised as follows:

"This work is being conducted for the U.S. Army Corp of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) – Formerly Used Defense Sites (FUDS). The Army is the executive agent for the FUDS program and the USACE manages and directs the program's administration. Investigations at PBOW under DERP-FUDS are being managed by the USACE Huntington District and technically overseen by the USACE Nashville District (CELRN)."

2. Page 1-2, Section 1.2, L. Tannenbaum

Background

Comment: At the start of the Section's third paragraph, "Acid Areas" should be "Acid Area".

Recommendation: Please make the correction.

Response: The text has been revised as requested.

3. Page 2-4, Section 2.1.5, L. Tannenbaum

Background Screening

Comment: It would make more sense to have "background screening" of contaminants of potential concern (COPC) occur before risk-based screening (i.e., what is described in Section 2.1.3).

Recommendation: Please consider rearranging the COPC screening steps to have frequency of detection followed by background comparison screening, and then risk-based screening. Please rearrange any text or sequencing of tables, and do this even if outcomes are unchanged.

Response: Background screening was placed last because it was not used to eliminate COPCs on the front end of the process; rather, the potential risk associated with COPCs detected at background concentrations is addressed in the uncertainty analysis.

4. Page 5-4, Section 5.2, L. Tannenbaum

Noncancer Hazards

Comment: The term “RBRL” does not appear to have been coined in its first usage in the page’s first full paragraph. Note that the term appears to be fully spelled out in the title of Section 5.3 (on this same page).

Recommendation: Please coin the identified term in its first usage.

Response: “RBRL” has been called out in its first usage in Section 1.5 and the acronym used thereafter.

5. Page 5-6, Section 5.4, L. Tannenbaum

Risk Characterization Results and Discussion

Comment: The page’s last paragraph presents a few complications. First, after a definition is supplied for contaminant of concern (COC), the text goes on to provide two examples of COCs, but these do not satisfy the definition. An exposure route that has a summed incremental lifetime cancer risk (ILCR) that exceeds 1E-06 is not necessarily “unacceptable” (note that 1E-04 is a cancer risk “trigger” level), and not all of the computed ILCRs in the subject document exceeded 1E-04. Similarly, a summed Hazard Index (HI; across all exposure routes) exceeding 0.1 is not necessarily “unacceptable”. There is surely no need to speak in terms of “risk drivers” (see this paragraph’s last sentence) for HIs that are less than 1.0. Second, a reference is not supplied for the definitions that are provided here. The definitions are questionable since, as a matter of course, sites are usually not remediated unless the ILCR is 1E-04 or greater, or there is a final HI in excess of 1.0 (unity).

Recommendation: Please address the issues raised in the Comment and modify the text as necessary.

Response: The definitions here and on page 5-5 have been revised to be consistent with the discussion on Page 15/16 of RAGS Part B, wherein COCs are selected for a given medium when the total ILCR or HI summed across chemicals and exposure routes is greater than 10^{-4} or 1, respectively. When either of these conditions is met, a COC is selected if it’s ILCR or HI summed across exposure routes is greater than 10^{-6} or 0.1, respectively. The sentence referencing “risk drivers” has been deleted.

6. Appendix B, L. Tannenbaum

Risk Calculations

Comment: All 40 tables of this appendix share a title that is not fully descriptive of the contents.

Recommendation: In the revised risk assessment, please have all 40 titles begin “Risk and Hazards from . . .”

Response: The table titles have been revised as requested.

MEMORANDUM

TO: LISA Humphreys, USACE PBOW Coordinator, and others
FROM: Julie Weatherington-Rice, Ph.D., RAB TAPP Coordinator
RE: Draft Baseline Human Health Risk Assessment Acid Area 2 & Acid Area 3; Draft Screening Level Ecological Risk Assessment Acid Area 2 & Acid Area 3, Jacobs Engineering Group, September, 2007 (four volumes)
DATE: November 29, 2007

Per our current contractual arrangement with US ACE which require both a technical memorandum for each report and an educational explanation to the RAB, this memorandum constitutes the technical review of the Jacobs September 2007 "Draft Baseline Human Health Risk Assessment Acid Area 2 & Acid Area 3; Draft Screening Level Ecological Risk Assessment Acid Area 2 & Acid Area 3, (four volumes)" documents. Please forward to those who need to read this technical review.

Introduction

These four documents were reviewed together. The comments for the Human Health Risk Assessments and the Ecological Risk Assessments hold for both Acid Areas 2 & 3 unless so noted. In some cases, the explanations and/or supporting information needed for further clarity for some of my technical comments are contained in the educational memorandum. Rather than repeat that supporting information here, if the reviewer needs to understand the source(s) of documentation that support the request and/or comment and/or correction, the reviewer is directed to the educational memorandum which should also be available through Lisa Humphreys if the reviewer is interested.

Review Draft Baseline Human Health Risk Assessment Acid Area 2 and Acid Area 3 Specific Comments

1. 1.3.2 Groundwater Use

Thank you for referencing the new Ohio Department of Natural Resources Division of Water bedrock aquifer map for projected yields of the carbonate aquifer at the site. More text is found in this section in the educational memorandum.

2. 2.3 Results of the Data Evaluation

Did anyone ever determine the source(s) of the thallium that keeps showing up at the site in surface and subsurface soils and ground water?

Response: Thallium is likely present as a background constituent. The detections of thallium in recent soil and groundwater samples is likely due to either a lowering of the detection limits for thallium or a change in the analytical methods which have lower detection limits. For example, the background data set for thallium was reported as 100 percent nondetect for thallium and the

reported concentrations were <1.1 to <6.1 mg/kg, which is a common practice for reporting nondetects. For Acid Area 2, the detection limits were reported as 1.1 to 12 mg/kg and the range of detected concentrations was reported as 2.07 to 5.24 mg/kg. Therefore, the detected concentrations are within the range of detection limits for the background data.

3. Shallow Groundwater and Bedrock Groundwater sections

Change the bedrock identification from Delaware Limestone to Columbus Limestone when referencing naturally occurring petroleum products in the carbonate formations under the PBOW site. See the October 22, 2007 Response to Comments documents from Shaw Engineering for clarification.

Response: The text has been revised as requested.

4. 3.1.1 Physical Setting Groundwater

Note: There is no local information that the Delaware Limestone has petroleum or hydrogen sulfide gas in the formation. These comments are attached to other formations in the area. The Columbus Limestone is noted to have petroleum products in the formation. The presence of hydrogen sulfide gas in the formation is more typically noted in the Raisin River underlying the Columbus Limestone and/or in the overlying Ohio Shale. Please correct the text. This information was documented in the May 31, 2007 presentation to the RAB on the Wagner Quarry by Dr. Julie Weatherington-Rice.

Response: The text has been revised as requested.

5. 3.1.3.2 Bedrock Groundwater Resident

We should be adding a risk assessment for intensive site gardening for vegetable and fruit production for the projected family who will be moving to the site and using ground water resources. While there is no "official" risk assessment for intensive cropping of the site as an annual food source of vegetables and fruit for an average family that I know of, it should be possible to create such a risk assessment from existing risk assessment components and information in the literature. The soil and subsoil exposure risk assessment to skin and breathing can be coupled with chemicals of concern uptake from the soil, subsoil, and ground water of typical vegetable plants and fruit trees and brambles. As a conservative surrogate, I would recommend using the phyto-remediation literature for heavy metals up take of the Brassicaceae family of plants (broccoli/mustard family). I would assume ingestion of at least 80 percent of all fruits and vegetables year round for the family would be a reasonable expectation.

Response: The assessment of potential risks from consumption of home grown produce is seldom performed due to the uncertainties associated with the selection of exposure parameters for ingestion rates (such as the ratio of root or leaf vegetables and fruit) and contaminant uptake factors. EPA's *Risk Assessment Guidance for Superfund* has equations and default parameters for the consumption of produce and the *Exposure Factors Handbook* has information to develop such an exposure scenario. In addition, this scenario seldom results in unacceptable risks/hazards as suggested by the results of the assessment for ingestion of venison. Concerns over contact rates are also applicable to the tending of flower beds. The contact rates for the residential and the groundskeeper scenarios are adequate to account for the variability in contact

over the course of the year. The short term increase in dermal contact and ingestion of soil during planting and harvesting are off-set by the long duration of reduced or minimal contact with soil. Additionally, there are numerous variations in how gardens may be tended ranging from nearly complete manual tending to nearly complete mechanical tending. As gardens become larger as would be needed for production of sufficient crop yield to provide for a family, the less direct contact with the soil the receptor experiences. For small scale intensive cropping, such as in raised beds, the amount of amendments necessary to maintain proper nutrients, aeration, etc. effectively reduce contaminant concentrations in the soil. Therefore, with the exception of the potential increase in contaminant uptake from ingestion of home grown produce, the residential scenario adequately addresses the potential risk from exposure to contaminants in soil. The document has been revised to include a discussion relative to the exclusion of this potential exposure scenario.

For an explanation as to why this risk behavior should be added to the analyses, see the section "*Human Activities for Which There are no Developed Risk Assessments*" in the educational memorandum to the RAB. In addition, there is supporting text in the educational memorandum in this section that will help to clarify this request.

6. 3.1.3.3 Surface Soil Future on-Site Resident

See comment above about site intensive gardening.

Response: Please see the response to Comment #5.

7. 3.1.3.4 Subsurface Soil Future On-Site Resident

See comment above about site intensive gardening.

Response: Please see the response to Comment #5.

8. 3.2.2 Concentrations in Household Air from Groundwater Use

The number used in model assumption 3) "the daily groundwater use is 720 L/day" for a family of four is not a typical water use for that size of a family in Ohio. A more realistic figure would be approximately 400 gallons per day or approximately 1515 liters per day. For supporting documentation, see section "*Some of the Pitfalls of a Standardized Risk Assessment*" in the educational memorandum to the RAB.

Response: The number used in the baseline human health risk assessment is a default value from EPA.

9. 7.3 Conclusions

This comment number was used in the educational memorandum.