CB&I
312 Directors Drive
Knoxville, TN 37923
Tel: +1 865 690 3211
Fax: +1 865 690 3626
StevenT.Downey@CBI.com

April 10, 2013

U.S. Army Engineer District, Nashville
ATTN: CELRN-EC-E (Ms. Paula Coleman)
110 Ninth Avenue South, Room 682
U.S. Court House Annex
Nashville, Tennessee 37203

Subject: ***Submittal of the Final Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment for Waste Water Treatment Plant No. 3 Former Plum Brook Ordnance Works, Sandusky, Ohio Contract No. W912QR-08-D-0013: Shaw Project Number 132457***

Dear Ms. Coleman:

In accordance with the requirements of Delivery Order No. DX02 of Contract No. W912QR-08-D-0013 to Shaw Environmental & Infrastructure, Inc., a CB&I company, we are pleased to submit the Final Baseline Human Health Risk Assessment and the Final Screening Level Ecological Risk Assessment for Waste Water Treatment Plant No. 3 at the Former Plum Brook Ordnance Works (PBOW) located in Sandusky, Ohio. Responses to comments received on the draft risk assessment reports have been incorporated into the final reports and are attached to these documents.

Enclosed for your records are four copies of this report. Copies have also been sent to those on the distribution list as indicated.

Should you have any questions of require additional information regarding this submittal, please do not hesitate to contact me at (865) 694-7496.

Sincerely,

Steven. T. Downey, PE, PMP
Project Manager

Please Reply To: Steven T. Downey
Phone: 865 694 7496
E-Mail Address: StevenT.Downey@CBI.com

200-1e
G05OH001817_03.11_0506_a

Control Copy Distribution List

Name	Control Copy
U.S. Army Engineer District, Nashville ATTN: CELRN-EC-E (Ms. Paula Coleman) 110 Ninth Avenue South, Room 682 Annex Nashville, TN 37203	1-4
U.S. Army Engineer District, Huntington ATTN: CELRH-PM-PP-P (Mr. Rick Meadows) 502 Eighth Street Huntington, West Virginia 25701-2070	5-7 (CD provided)
Mr. Paul Jayko Site Coordinator Division of Emergency and Remedial Response (DERR) Ohio Environmental Protection Agency 347 North Dunbridge Road Bowling Green, Ohio 43402-0466	8, 9
Mr. Janusz Z. Byczkowski Division of Emergency and Remedial Response (DERR) Lazarus Government Center 50 W. Town Street, Suite 700 Columbus, OH 43216-1049	10
Mr. Robert Lallier Environmental Coordinator NASA - Plum Brook Station 6100 Columbus Avenue Sandusky, Ohio 44870	11
U.S. Army Corps of Engineers (**electronic only**) HTRW Center of Expertise ATTN: CEHNC-CX-EG (Vern StJohn) 1616 Capitol Avenue Omaha, Nebraska 68144-3869	(CD provided)
Mr. John Blakeman (**electronic only**) PBOW RAB Co-chairman 2412 Scheid Road Huron, Ohio 44839	(CD provided)
Mr. Jeffrey G. Leach US Army Public Health Command ATTN: MCHB-IP-REH, BLDG E1675 Aberdeen Proving Grounds, MD 21010-5403	12

DISCIPLINE SIGN-OFF REVIEW

Shaw Environmental & Infrastructure, Inc.

Client Name: U.S. Army Engineer District, Nashville; CELRN-EC-E

Project Description: Baseline Human Health Risk Assessment for Waste Water Treatment Plant No. 3
Former Plum Brook Ordnance Works, Sandusky, Ohio

Contract No. W912QR-08-D-0013 Delivery Order No. DX02

Project No. 132457 Task/Phase Number: 11000000

Document Type		Identify specific section or segment covered by this checkprint	Document Origin
☐	Technical / Cost Proposal		X Originator Developed
☐	RFP		☐ Edited Standard
☐	Contract / Subcontract		☐ Client Furnished
☐	Work Plans		
☐	Report		**Document Status**
X	Risk Assessment / Evaluation	Baseline Human Health Risk Assessment	☐ Preliminary
☐	Specifications & Plans		☐ Internal Draft
☐	Design Calculations		☐ Draft
☐	Tables		☐ Draft Final
☐	Drawings / Figures		X Final
☐	Other:		☐ Other:

	Required Person	Signature	Date
Originator	Tom Siard		4-9-13
Editor	Donald Groseclose		4-9-13
Technical Review	Michael Gunderson		4-9-13
Technical Review	Jon Lindberg		4-9-13
Quality Assurance Mgr	Ken Martinez		04-09-13
Project Manager	Steven Downey		4-9-13

NOTICE: By signature above, parties certify that the subject document has been prepared by and/or reviewed by them (as appropriate), that all review comments have been resolved, and that the document is ready for submittal.

Final
Baseline Human Health Risk Assessment
Waste Water Treatment Plant No. 3

Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

U.S. Army Corps of Engineers
P.O. Box 1070
Nashville, Tennessee 37202-1070

Prepared by:

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)
312 Directors Drive
Knoxville, Tennessee 37923

FUDS Project No. G05OH001817
Shaw Project Number 132457

April 2013

Table of Contents

Page

List of Appendices iv
List of Tables v
List of Figures vi
List of Acronyms vii
Executive Summary ES-1
1.0 Introduction 1-1
1.1 Facility Location and Description 1-1
1.2 Facility History and Background 1-1
1.3 WWTP3 Description and History 1-3
1.4 Groundwater Use and Site Use 1-4
1.5 Protocol for the Baseline Human Health Risk Assessment 1-5
1.6 Report Organization 1-6
2.0 Data Evaluation 2-1
2.1 Data Sources 2-1
2.2 Organization of the Analytical Data 2-1
2.3 Evaluation of Data Quality 2-2
2.4 Identification of Chemicals of Potential Concern 2-3
2.4.1 Risk-Based Screening 2-3
2.4.2 Frequency of Detection 2-6
2.4.3 Comparison to Background 2-6
2.4.3.1 Background Screening of Inorganics 2-7
2.4.3.2 Statistical Data Set Testing of Inorganics 2-8
2.4.3.3 Treatment of Organic Compounds 2-9
2.5 Data Evaluation Summary 2-9
3.0 Exposure Assessment 3-1
3.1 Conceptual Site Exposure Model 3-1
3.1.1 Physical Setting 3-2
3.1.1.1 Climate/Meteorology 3-3
3.1.1.2 Geology 3-3
3.1.1.3 Soils 3-4
3.1.1.4 Hydrology 3-5

Table of Contents *(Continued)*

Page

3.1.1.5 Surface Water 3-6
3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways 3-6
3.1.3 Receptors and Exposure Pathways 3-7
3.1.3.1 Current Groundskeeper 3-8
3.1.3.2 Future Groundskeeper 3-9
3.1.3.3 Future Indoor Worker 3-10
3.1.3.4 Current/Future Construction Worker 3-11
3.1.3.5 Future On-Site Resident 3-13
3.1.3.6 Future Hunter 3-17
3.1.3.7 Future Hunter's Child 3-18
3.1.3.8 Other Receptors Not Considered 3-18
3.2 Quantification of Exposure-Point Concentrations 3-19
3.2.1 Soil, Groundwater, Surface Water, and Sediment Concentrations 3-19
3.2.2 Exposure-Point Concentrations in Air 3-21
3.2.2.1 COPC Concentrations from Dust 3-21
3.2.2.2 Concentrations in Household Air from Groundwater Use 3-23
3.2.2.3 Concentrations of VOCs in Groundwater: Resident Dermal Uptake 3-23
3.2.2.4 Exposure-Point Concentrations of COPCs in Venison 3-24
3.3 Quantification of Chemical Intake 3-26
3.3.1 Inhalation of COPCs in Air 3-26
3.3.2 Incidental Ingestion of COPCs in Soil or Sediment 3-27
3.3.3 Incidental Ingestion of COPCs in Water 3-27
3.3.4 Dermal Contact with COPCs in Soil, Sediment, or Water 3-28
3.3.5 Consumption of Venison 3-31
4.0 Toxicity Evaluation 4-1
4.1 Evaluation of Carcinogenicity 4-1
4.2 Evaluation of Noncarcinogenic Effects 4-2
4.3 Dermal Toxicity Values 4-4
4.4 Target Organ Toxicity 4-4
4.5 Sources of Toxicity Information Used in the Risk Assessment 4-5

Table of Contents *(Continued)*

Page

5.0 Risk Characterization 5-1
5.1 Cancer Risk 5-1
5.2 Noncancer Effects of Chemicals 5-3
5.3 Risk Characterization Results 5-4
5.3.1 Current Groundkeeper 5-5
5.3.2 Future Groundskeeper 5-6
5.3.3 Future Indoor Worker 5-9
5.3.4 Current/Future Construction Worker 5-11
5.3.5 Future Resident 5-11
5.3.6 Future Adult Hunter 5-15
5.3.7 Future Hunter's Child 5-15
5.4 Re-Evaluation of Cancer Risks Associated with PAHs 5-15
6.0 Uncertainty Analysis 6-1
6.1 Types of Uncertainty 6-1
6.2 Sources of Uncertainty 6-2
6.2.1 Sample Selection 6-2
6.2.2 Laboratory Analysis 6-2
6.2.3 Exposure-Point Concentration Estimates 6-2
6.2.4 Land-Use Assumptions/Receptor Selection 6-3
6.2.5 Groundwater Use 6-3
6.2.6 Exposure Assumption Values 6-4
6.2.7 Groundwater-to-Air Household Model 6-4
6.2.8 Toxicity Assessment 6-4
6.2.9 Risk Characterization 6-6
6.2.10 Evaluation of Selected COPCs for Site Relatedness 6-6
7.0 Summary and Conclusions 7-1
7.1 Summary 7-1
7.2 Conclusions 7-3
8.0 References 8-1

List of Appendices

Appendix A – Data Summary of Chemicals Detected in Overburden Groundwater Piezometers

Appendix B – ProUCL Output for Upper Confidence Limits on the Mean

Appendix C – Toxicological Profiles

Appendix D – Risk Characterization Spreadsheets

Appendix E – Analytical Data Sets Used in the BHHRA

Appendix F – Evaluation of Cancer Risks Excluding the Samples with the Three Highest PAH Concentrations

Appendix G – Wilcoxon Rank Sum Test Statistical Output

List of Tables

Table	*Title*	*Follows Tab*
2-1	Summary of Samples Evaluated in the Baseline Human Health Risk Assessment	
2-2	Background Screening Concentrations of Inorganics in Soil	
2-3	Background Screening Concentrations of Inorganics in Groundwater	
2-4	Statistical Summary and Selection of Chemicals of Potential Concern in Surface Soil	
2-5	Statistical Summary and Selection of Chemicals of Potential Concern in Subsurface Soil	
2-6	Statistical Summary and Selection of Chemicals of Potential Concern in Total Soil	
2-7	Statistical Summary and Selection of Chemicals of Potential Concern Detected in Bedrock Groundwater	
2-8	Statistical Summary and Selection of Chemicals of Potential Concern in Overburden Monitoring Well Groundwater	
2-9	Statistical Summary and Selection of Chemicals of Potential Concern in Sediment	
2-10	Statistical Summary and Selection of Chemicals of Potential Concern in Surface Water	
3-1	Receptor/Exposure Scenarios	
3-2	Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors	
3-3	Physical Properties of Site-Related Chemicals	
4-1	Summary of Toxicity Assessment	
5-1	Summary of Risk for All Receptors	
5-2	Summary of Risk for Receptors Excluding Exposure to Groundwater	
5-3	Cancer Risks for Current Groundskeeper and Future Resident Based on Re-Evaluation of Soil	

List of Figures

Figure	*Title*	*Follows Tab*
1-1	PBOW Vicinity Map	
1-2	Site Location Map	
1-3	Sample Locations at Waste Water Treatment Plant No. 3	
3-1	Human Health Conceptual Site Exposure Model	
5-1	Identification of NASA K-Site Control Building Removal Area at Waste Water Treatment Plant No. 3	

List of Acronyms

ABS	dermal absorption factor
AF	soil-to-skin adherence factor
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSC	background screening concentration
BTEX	benzene, toluene, ethylbenzene, and xylenes
CDI	chronic daily intake
cm/hr	centimeters per hour
cm^2	square centimeter
COPC	chemical of potential concern
CSEM	conceptual site exposure model
°F	degrees Fahrenheit
DA	dose absorbed per unit body surface area per day
D&M	Dames and Moore, Inc.
DERP	Defense Environmental Restoration Program
DM	dry matter
DNT	dinitrotoluene
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
ET	exposure time
FI	fractional term
FUDS	Formerly Used Defense Sites
GAF	gastrointestinal absorption factor
gpm	gallons per minute
g	gram
g/kg-day	grams per kilogram of body weight per day
g/m^3	grams per cubic meter
GSA	General Services Administration
HHEM	human health evaluation manual
HI	hazard index
HQ	hazard quotient
ICI	International Consultants Incorporated
IEUBK	Integrated Exposure Uptake Biokinetic

List of Acronyms *(Continued)*

ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IT	IT Corporation
kg	kilogram
kg/day	kilograms per day
K_p	permeability coefficient
L/cm^3	liters per cubic centimeter
L/day	liters per day
LMS	linearized multistage
LSI	limited site investigation
m^3	cubic meter
m^3/day	cubic meters per day
m^3/hr	cubic meters per hour
m^3/kg	cubic meters per kilogram
m/second	meters per second
MDC	maximum detected concentration
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
mg/cm^2	milligrams per square centimeter
mg/cm^2-day	milligrams per square centimeter per day
mg/m^3	milligrams per cubic meter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NTU	nephelometric turbidity unit
OEPA	Ohio Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PEF	particulate emission factor
ppm	parts per million
PRG	preliminary remediation goal

List of Acronyms *(Continued)*

RBSC	risk-based screening concentration
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RSL	regional screening level
SF	cancer slope factor
Shaw	Shaw Environmental, Inc.
TNT	trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTC	TNT Area C
UCL	95th percent upper confidence limit on the arithmetic mean
UF	uncertainty factor
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
WRS	Wilcoxon Rank Sum
WWTP1	Waste Water Treatment Plant No. 1
WWTP2	Waste Water Treatment Plant No. 2
WWTP3	Waste Water Treatment Plant No. 3

Executive Summary

A baseline human health risk assessment (BHHRA) was conducted to evaluate risks associated with exposure to soil, groundwater, surface water and sediment at Waste Water Treatment No. 3 (WWTP3) at the Plum Brook Ordnance Works (PBOW), Sandusky, Ohio. The approach used in the BHHRA is consistent with methodologies described in the U.S. Environmental Protection Agency's primary risk assessment guidance documents, the site-specific work plan, and discussions and agreements between the Ohio Environmental Protection Agency, the U.S. Army Corps of Engineers Nashville and Huntington Districts, and Shaw Environmental, Inc.

Site History/Description. The PBOW facility was constructed on property comprising 9,009 acres in early 1941 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), 2,4-dinitroluene, and pentolite. Production of explosives at PBOW began in December 1941 and continued until 1945. It is estimated that more than 1 billion pounds of nitroaromatic explosives were manufactured during the 4-year operating period. After plant operations ceased, the manufacturing process lines were decontaminated by the Army in late 1945. After the property was certified as decontaminated, 3,230 acres of the property were initially transferred to the Ordnance Department, then to the War Assets Administration. In 1949, PBOW was transferred to the General Services Administration. The Department of the Army reacquired the 3,230 acres in 1954 and performed cleanup efforts from the mid-1950s until 1963.

Accountability and custody for the entire portion of the former PBOW property that had been under the accountability and custody of the Department of the Army were transferred to the National Aeronautics and Space Administration (NASA) on March 15, 1963. NASA performed further decontamination efforts during 1964. NASA has operated and maintained the former PBOW property since 1963, and the facility is currently the NASA Glenn Research Center, Plum Brook Station. NASA operates the property as a space research facility in support of their John Glenn Research Center at Lewis Field, Cleveland, Ohio. Most of the aerospace testing facilities built in the 1960s at the site are currently on standby or inactive status.

WWTP3 is located in the west-central portion of the PBOW facility. During PBOW manufacturing operations 1941 to 1944, WWTP3 received TNT manufacturing wastes from the TNT manufacturing area settling basins via waste water sewer lines for treatment. Chemical contamination that may have resulted from operations at WWTP3 are expected to be primarily nitroaromatics, volatile organic compounds, semivolatile organic compounds, and metals.

The neutral storage tank of WWTP3 was converted by NASA into the K-Site control building and associated patio area. The K-Site itself was operated in the former Power House 3 Building, which is approximately 300 feet to the southeast of WWTP3. Operations at the K-Site Test Facility officially ceased in 2007. The K-Site control building was demolished by NASA in October 2012. Contaminated soils identified during the performance of this BHHRA were removed by NASA and disposed of in October 2012,

Approach. The BHHRA evaluated exposure to chemicals in bedrock groundwater, overburden groundwater, surface soil, subsurface soil, surface water, and sediment for cancer risks and noncancer hazards. Only validated analytical data were used in the BHHRA. Validated analytical data are from samples collected during 2008 and 2009, as reported in the site characterization report, and those collected in 1999 and reported in the limited site investigation report.

A screening for chemicals of potential concern (COPC) was used to focus the evaluation on those chemicals most likely to present a risk to potentially exposed individuals. This screening included a risk-based screening and, for inorganics in soil and bedrock groundwater, a background screening. This background screening protocol, which is based on PBOW Project Delivery Team agreement, differs somewhat from the current Ohio Environmental Protection Agency guidance. Use of this method for the screening of background ensures consistency between all of the PBOW project sites.

Each COPC in each medium was evaluated for exposure via the relevant exposure pathways and the resultant risk and hazards were estimated. One or more COPCs were found in each WWTP3 environmental medium. The receptors listed below were evaluated for exposure to the COPCs and their associated hazards and risks. The media evaluated for each receptor are shown in parentheses.

- Current groundskeeper (surface soil)
- Future groundskeeper (combined surface and subsurface soil [referred to as "total soil"], bedrock groundwater, and overburden groundwater)
- Indoor worker (surface soil, subsurface soil [air pathway only], bedrock groundwater, and overburden groundwater)
- Current/future Construction worker (total soil, surface water, and sediment)
- On-site future hypothetical resident (total soil, surface water, sediment, bedrock groundwater, and overburden groundwater)

- Future hunter (surface soil)
- Future hunter's child (surface soil [venison pathway only]).

Note that there is currently no groundskeeper at WWTP3, but the current groundskeeper is included because current land use does not prohibit the presence of a groundskeeper or other on-site workers. On-site worker activity is limited to mowing. Even though hunting is not currently permitted at WWTP3, hunting is permitted in other areas within PBOW; therefore, future use of WWTP3 for hunting is evaluated in this BHHRA. No construction is planned for WWTP3, but a construction worker is assumed to be potentially exposed under current or future land use. The future hypothetical groundskeeper, indoor worker, and resident are evaluated for future land use; these three receptors are also evaluated assuming groundwater use as potable water, although local groundwater sources are of low quality and limited quantity and unsuitable as drinking water resources. Overburden groundwater and bedrock groundwater are evaluated for each receptor separately.

Results/Conclusions. Risks were characterized for each COPC identified in each medium for the relevant receptors. Noncancer hazards were evaluated against a target hazard index (HI) criterion of 1 and the PBOW Project Delivery Team target incremental lifetime cancer risk (ILCR) goal of 1E-5 (i.e., 1 additional incidence of cancer per 100,000 individuals exposed). Cancer risk results are also compared to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) acceptable cancer risk range of 1E-6 to 1E-4 (i.e., a rate of 1 additional incidence of cancer per 1,000,000 to 1 in 10,000 individuals exposed), which is referred to herein as the "NCP risk management range." A target cancer risk goal of 1E-5 is used by the Ohio Environmental Protection Agency and was selected by the PBOW Project Delivery Team as a basis to consider remedial action. Use of this 1E-5 goal represents a departure from the Army's practice of consistently using a cancer risk exceeding a value of 1E-4 (the upper end of the NCP risk management range) to trigger remedial action considerations.

The overall HI and ILCR values are summarized in the following bullets; exceedances of the PBOW cancer risk goal (ILCR>1E-5) are shown as bold and exceedances of the noncancer hazard criterion (HI>1) or the NCP risk management range (1E-6 to 1E-4) are shown as bold italics:

- Current groundskeeper: **ILCR = 5E-5** (re-evaluated as 7E-6); HI = 0.07

- Future groundskeeper – all pathways, including bedrock groundwater use: ***ILCR = 4E-4; HI = 4***
- Future groundskeeper – all pathways, including overburden groundwater use: **ILCR = 9E-5**; HI = 1
- Future groundskeeper – all pathways, excluding groundwater use: ILCR = 1E-5; HI = 0.05
- Future indoor worker – all pathways, including bedrock groundwater use: ***ILCR = 4E-4; HI = 3***
- Future indoor worker – all pathways, including overburden groundwater use: **ILCR = 8E-5**; HI = 1
- Future indoor worker – all pathways, excluding groundwater use: ILCR = 1E-5; HI = 0.02
- Current/future construction worker: ILCR = 1E-6; HI = 0.9
- Resident – all pathways, including bedrock groundwater use: ***ILCR = 2E-3***; ***child HI = 25***; ***adult HI = 10***
- Future hypothetical resident – all pathways, including overburden groundwater use: ***ILCR = 3E-4***; ***child HI = 7***; ***adult HI = 3***
- Future hypothetical resident – all pathways, excluding groundwater use: **ILCR = 5E-5** (re-evaluated as 1E-5)*;* child HI = 0.7; adult HI = 0.1
- Future hunter: ILCR = 3E-6; HI = 0.004
- Future hunter's child: ILCR = 2E-10; HI = 0.00004.

The ILCRs of the WWTP3 future groundskeeper, indoor worker, and resident that are hypothetically assumed to use bedrock groundwater, as tap water exceeds the NCP risk management range as well as the PBOW target cancer risk goal. The ILCR for each of these three receptors assumed to use overburden groundwater as tap water exceeds the PBOW risk goal, but only the ILCR associated with the hypothetical future resident exceeds the NCP risk management range. The HI values of these receptors, if assumed to use either the bedrock or overburden groundwater as a potable source, also exceed the target criterion of 1, indicating that adverse human health risks cannot be regarded as unlikely to occur under these hypothetical scenarios.

Cancer risks for the current groundskeeper and hypothetical future resident, assuming no use of site groundwater, exceed the PBOW cancer risk goal but are within the NCP risk management

range. The ILCR values of the current groundkeeper scenario (5E-5) and the future hypothetical resident (5E-5) associated with exposure to surface soil and total soil, respectively, are due nearly exclusively to polycyclic aromatic hydrocarbons (PAH) in soil. The source of the PAHs is possibly cinders observed in several WWTP3 soil borings from a depth of just below the surface to approximately 3.5 feet below the surface. Based on analytical samples collected to date and a review of the boring log descriptions, the cinders appear to be more widely occurring than the elevated levels of PAHs. Although the cinders likely contribute to the PAH concentrations, it appears that sources other than the cinders are responsible for PAHs in surface and near-surface soils, especially at the locations with the highest concentrations. These include two surface soil samples from immediately adjacent to a patio that adjoined the former NASA K-Site control building (former neutralization tank) and a surface soil sample located immediately east of the current access road. NASA demolished the K-Site control building in October 2012 and removed the associated soil with elevated PAH concentrations in the immediate vicinity of this building. Therefore, the risks associated with these samples may be excluded from this BHHRA. The sample collected along the access road represents anthropogenic background associated with the asphalt road materials and vehicle emissions. If these three samples (road sample and K-Site samples) are excluded from the PAH database for WWTP3, the resulting hypothetical current groundskeeper ILCR is 7E-6 and the future hypothetical resident ILCR is 1E-5.

For all other receptors evaluated for WWTP3 under current or future land use, cancer risks and noncancer hazards are within or less than the NCP risk management range, are less than or equal to the target HI goal, and are less than the PBOW cancer risk goal, indicating that cancer risks are at acceptable levels and adverse noncancer effects are unlikely to occur under these potential current and future scenarios. These scenarios include the future groundskeeper, indoor worker, and future hypothetical resident not assumed to use bedrock or overburden groundwater and the scenarios for the current construction worker, future hunter, and hunter's child. Note that even though the current full-time groundskeeper is used to represent a maximum exposure under current potential land use (i.e., NASA control), groundskeeping activities at WWTP3 appear to be limited to mowing.

The cancer risks and noncancer hazards associated with bedrock groundwater are mostly attributable to natural petroleum-related compounds, cyanide, and arsenic. The cancer risks associated with overburden groundwater are mostly due to arsenic, which does not appear to be associated with former site activities. Use of either the overburden or bedrock groundwater is regarded as implausible because of insufficient yield. Additionally, the naturally poor quality of the bedrock groundwater and associated hydrogen sulfide off-gassing make it unsuitable as a

potable source. The readily available municipal water supply obviates the need for use of groundwater as a potential source of tap water in the general vicinity of PBOW.

1.0 Introduction

This baseline human health risk assessment (BHHRA) evaluates potential human health risks associated with exposure to soil, groundwater, surface water, and sediment associated with Waste Water Treatment Plant No. 3 (WWTP3) at the former Plum Brook Ordnance Works (PBOW), Sandusky, Erie County, Ohio. This work is being conducted for the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP)-Formerly Used Defense Sites (FUDS), managed by the USACE Huntington District, and technically overseen by the USACE Nashville District. This BHHRA is consistent with U.S. Environmental Protection Agency (EPA) guidance and with the procedures established in the BHHRA for TNT Area A (TNTA) and TNT Area C (TNTC) soil (IT Corporation [IT], 2001a), the BHHRA for groundwater at PBOW (Shaw Environmental, Inc. [Shaw], 2006) and, most specifically, the WWTP3 BHHRA work plan (Shaw, 2009).

In this BHHRA, the term "facility" refers to the entire former PBOW property, and the term "site" refers to areas within PBOW under investigation, in this case WWTP3.

1.1 Facility Location and 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 areas surrounding PBOW are mostly agricultural and residential. 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. Hunting is allowed by permit on portions of PBOW during the annual deer hunting season.

1.2 Facility History and Background

The PBOW facility was constructed on property comprising 9,009 acres in early 1941 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), 2,4-dinitroluene (DNT), and pentolite (International Consultants Incorporated [ICI], 1995). Production of explosives at PBOW began in December 1941 and continued until 1945. It is estimated that more than 1 billion pounds of nitroaromatic explosives were manufactured during the 4-year operating period. The three explosive manufacturing areas were designated TNTA, TNT Area B (TNTB), and TNTC.

Twelve process lines were used in the manufacture of TNT: four lines at TNTA, three lines at TNTB, and five lines at TNTC.

After plant operations ceased, the manufacturing process lines were decontaminated by the Army in late 1945. During decontamination, all structures, equipment, and manufacturing debris were either removed and salvaged or removed and burned. After the property was certified as decontaminated, 3,230 acres of the property were initially transferred to the Ordnance Department, then to the War Assets Administration. In 1949, PBOW was transferred to the General Services Administration (GSA). This transfer did not include the Plum Brook Depot area, which consists of 2,800 acres. The Department of the Army reacquired the 3,230 acres in 1954. In 1955, the Army completed further decontamination of the manufacturing process lines. This effort included removal of contaminated surface and subsurface soil around the building and wooden and ceramic waste disposal lines containing TNT. Thousands of pounds of TNT were discovered in catch basins; this TNT was removed and burned at the burning grounds. The Army continued cleanup efforts until 1963.

Two property use agreements were entered into by the Army and the National Advisory Committee of Aeronautics, the predecessor of the National Aeronautics and Space Administration (NASA), in 1956 and 1958, respectively. Accountability and custody for the entire portion of the former PBOW property (6,030 acres) that had been under the accountability and custody of the Department of the Army were transferred to NASA on March 15, 1963. NASA performed further decontamination efforts during 1964. The NASA decontamination process included removing contaminated surface soil above the drain tiles, flumes, etc.; destruction of all buildings by fire; then removal of all soil, debris, sumps, and above-grade portions of concrete foundations. Portions of the concrete foundations located below grade were left buried, and some that had been previously slightly above grade were covered with fill material. All materials, including the soil in those areas, were flashed; the area was then rough-graded. The decontamination process was also to have included the burning of excavated nitroaromatic-filled flumes (Dames & Moore, Inc. [D&M], 1997a).

NASA has operated and maintained the former PBOW property since 1963, and the facility is currently the NASA Glenn Research Center, Plum Brook Station. NASA operates the property as a space research facility in support of the John H. Glenn Research Center at Lewis Field, Cleveland, Ohio. Most of the aerospace testing facilities built in the 1960s at the site are currently on standby or inactive status. On April 18, 1978, NASA declared approximately 2,152 acres of PBOW as excess. This excess included former buffer areas that had not been used by the Army and thus were not subject to decontamination efforts. The Perkins Township Board of

Education acquired 46 acres of the excess acreage and uses this area as a bus transportation area. The GSA retains ownership of the remaining excess acreage and currently has a use agreement with the Ohio National Guard for 604 acres of this land. The details of land transactions are listed in the site management plan (ICI, 1995).

1.3 WWTP3 Description and History

The former WWTP3 is located in the western-central portion of PBOW, approximately 650 feet southwest of the intersection of Maintenance Road and Ransom Road and 450 feet southeast of the patrol road. The area represented by WWTP3 environmental samples occupies approximately 3 acres of land (Figure 1-2). During PBOW manufacturing operations from 1941 to 1944, WWTP3 acted as an overflow treatment plant for Waste Water Treatment Plant No. 1 (WWTP1) and Waste Water Treatment Plant No. 2 (WWTP2) and was connected to those facilities by a 6-inch steel sewer line (ICI, 1995). WWTP1 received wastes from TNTA and TNTB, while WWTP2 received waste from TNTC. The purpose of the treatment plants was to reduce the volume of waste water discharged from each of the manufacturing areas prior to incineration or disposal in the red water ponds. The waste water that was transferred and received from the TNT manufacturing areas consisted of spent sulfuric acid and nitric acids and red water from the TNT purification process. Chemicals in the waste streams included sodium salts of sulfite, sulfate, nitrite, nitrate, sulfonates of unwanted TNT isomers, trinitrobenzoic acid, trinitrobenzaldehyde, trinitrobenzyl alcohol, nitrotoluenes, and dinitrotoluenes (D&M, 1996).

WWTP3 consisted of a neutral storage tank, an equalization tank, a condensate storage tank, an evaporator building, an incinerator, and a thick liquid storage tank. The waste water treatment plants received waste water from the TNT manufacturing settling basins via the sewer lines. This waste water was neutralized through a chemical depuration process. The liquid was discharged to open ditches or ponds surrounding the facilities or thickened by evaporation. The thickened liquid was then incinerated. The incinerators were located to the north of the storage tanks at WWTP3. Ash from the WWTP3 incinerator was disposed of in nearby Ash Pit 3. D&M (1997b) conducted a review of records and found that a bermed, square depression north of WWTP3 and south of Maintenance Road was thought to have possibly been used as an ash settling basin. A depression was found during 1995 field reconnaissance, but no berms were present (D&M, 1997b). This depression was sampled in 1999 as part of the limited site investigation (LSI) (USACE, 2000). This area, represented by LSI samples SSW309 and SSW310, has since been paved as part of the parking area shown on Figure 1-3.

The neutralization storage tank of WWTP3 was converted by NASA into the K-Site control building and an associated patio. The K-Site itself was operated in the former Power House 3

Building (USACE, 2000), which is approximately 300 feet to the southeast of WWTP3. Operations at the K-Site Test Facility officially ceased in 2007. The K-Site control building and associated patio were demolished and removed by NASA in October 2012. Contaminated soils identified during the performance of this BHHRA were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012).

1.4 Groundwater Use and Site Use

Two groundwater aquifer systems are utilized for drinking water in the region: a carbonate aquifer to the west and a shale aquifer to the east (Shaw, 2005). PBOW is located within the transition of the two systems. Upwards of 170 private drinking water wells permitted by the Erie County Health Department are located within 4 miles of PBOW. Groundwater is not used on the PBOW facility. Permits are not required for agricultural wells. The Erie County Health Department does not permit using surface water as private drinking water. A shallow discontinuous and variably saturated groundwater system exists within the unconsolidated material atop the bedrock under much of the site.

Current use of the PBOW facility is classified as industrial for the purpose of identifying plausible human receptors and exposure pathways for evaluation in the BHHRA. D&M (1997a) describes potential future uses of all or portions of the facility as follows:

- Industrial use (NASA activities and programs) may continue.
- Portions of the site may be used for recreation by hunters and fishermen.
- Portions of the site may be sold to state or local government or private individuals (no land-use restrictions were mentioned).
- Parts of the facility may be used in the future for residential or agricultural purposes.
- Parts of the facility may be used for training by the National Guard.
- Construction activities may be performed during development of any of the sites.

In summary, future site uses of WWTP3 are considered to be industrial or residential for the purpose of developing receptor and exposure scenarios. The only current NASA activity at WWTP3 is regular mowing. However, PBOW is under NASA control, and the potential for NASA activities at WWTP3 exists. Even though hunting is not currently permitted at WWTP3, hunting is permitted in other areas within PBOW; therefore, future use of WWTP3 for hunting is evaluated in this BHHRA. It is conservatively assumed for purposes of this BHHRA that

groundwater may be developed as a source of potable water in the future. Refer to Section 3.1.3 for a discussion of receptors and exposure scenarios.

1.5 Protocol for the Baseline Human Health Risk Assessment

The BHHRA was performed consistent with the WWTP1 BHHRA work plan (Shaw, 2009). The WWTP3 BHHRA work plan was developed consistent with previous PBOW BHHRAs and is based on EPA, USACE, and Ohio Environmental Protection Agency (OEPA) guidance, including, but not limited to, the following:

- OEPA, 2009a***, Use of U.S. EPA's Regional Screening Levels as Screening Values in Human Health Risk Assessments***, Technical Decision Compendium, Division of Emergency and Remedial Response, August.

- OEPA, 2009b***, Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for the DERR Remedial Response Program***, Technical Decision Compendium, Division of Emergency and Remedial Response, August.

- USACE, 1999, ***Risk Assessment Handbook, Volume I: Human Health Evaluation***, Engineer Manual EM 200-1-4.

- 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.

- 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.

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

- EPA, 1997a, ***Exposure Factors Handbook***, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002Fa, August.

- EPA, 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

- 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.

- EPA, 2010a, ***ProUCL Version 4.1 Technical Guide***, Draft, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, EPA/600/R-07/041, May.

- EPA, 2010b, ***ProUCL Version 4.1 User Guide***, Draft, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, EPA/600/R-07/038, May.

- EPA, 2011, ***ProUCL Version 4.1***, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, February, on line at http://www.epa.gov/esd/tsc/form.htm.

1.6 Report Organization

The remainder of this document is organized as follows:

- ***Chapter 2.0, Data Evaluation.*** Identifies data sources, evaluates data quality, identifies chemicals of potential concern (COPC), and provides a background screening and evaluation protocol. It is noted that the background screening protocol differs from the current OEPA (2009c) guidance, as explained in Section 2.4.3.

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

- ***Chapter 4.0, Toxicity Evaluation.*** 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.

- ***Chapter 5.0, Risk Characterization.*** Combines the output of the exposure assessment and toxicity assessment to quantify the risk to each receptor at each site. Risks associated with exposure to all appropriate media for each site are evaluated.

- ***Chapter 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 pertinent to WWTP3 and those most likely to have the greatest effect on risk estimates.

- ***Chapter 7.0, Summary and Conclusions.*** Provides a brief summary of the BHHRA, including quantitative results, uncertainties, and pertinent site information. Summary and discussion is focused on those results and issues that are most directly relevant to the risk assessment conclusions for WWTP3 that are likely to directly affect site management decisions.

- ***Chapter 8.0, References.*** Presents the references used in the preparation of this document.

2.0 Data Evaluation

Data evaluation consists of a description of the appropriate data sources for each environmental medium sampled for each site, a discussion of data quality, a description of the methodology used for identification of the COPCs, and a summary of the COPCs for each WWTP3 environmental medium.

2.1 Data Sources

All soil, groundwater, sediment, and surface water samples from which the validated analytical data used in the BHHRA were derived are presented in Table 2-1. These data include surface soil, subsurface soil, surface water, sediment, overburden groundwater, and bedrock groundwater monitoring well samples. The sample summary table identifies each sample used in the BHHRA and the associated analytical suite. Samples included those collected as part of the LSI for WWTP3 (USACE, 2000) and the remedial investigation (RI) samples (Shaw, 2011). All WWTP3 sampling locations are shown on Figure 1-3.

2.2 Organization of the Analytical Data

Prior to initiation of BHHRA calculations, a database of chemicals present in site samples was compiled for each environmental medium. This database includes all chemicals detected as described in the RI report (Shaw, 2011) and the LSI report (USACE, 2000). The surface soil and subsurface soil are considered separate media. Surface and subsurface soil data are typically combined to assess exposures under the construction worker, future groundskeeper, and hypothetical future residential site-use scenarios, which would likely occur after surface and subsurface soil had been excavated and/or mixed. Combined surface and subsurface soil data are termed “total soil” in the BHHRA. However, it is understood that a reference to the evaluation of exposure to total soil is actually an evaluation of exposure to both surface soil and subsurface soil. The total soil COPC list is created by combining the list of COPCs identified in surface and subsurface soil. If a chemical is either a surface soil COPC or a subsurface soil COPC (or both), then that chemical is a total soil COPC. The EPCs for total soil are typically generated from the combined data sets.

Generally, surface soil is defined as samples collected from within the interval of 0 to 1 foot below ground surface (bgs), and subsurface soil is defined as samples collected from depths greater than 1 foot bgs per the RI work plan (Shaw, 2008a). The LSI (USACE, 2000) historical surface soil samples were collected from a depth of 0.5 to 1 foot bgs.

2.3 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 third-party data evaluation. Some of the more common qualifiers and their meanings are as follows (EPA, 1989a):

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

J - Value is estimated, usually below the reporting 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 reporting limit. However, the reporting 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 - The concentration in the sample is not sufficiently higher than the concentration in the blank, using the 5-times, 10-times rule, which states that a chemical is considered a nondetect unless its concentration exceeds 5 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 are treated in the BHHRA as detected concentrations; "R" data and "B" qualified chemical data are not used. "U" qualified data (nondetects) are treated in the BHHRA as nondetections. The use of data with other, less common qualifiers is evaluated on a case-by-case basis. Generally, data for which the identity of the chemical is unclear are not used in the BHHRA. If confidence is reasonably high that the chemical is present but the actual concentration is somewhat in question, the data generally are used in the BHHRA.

Some chemicals may be analyzed under two different analytical programs. For example, the DNT isomers are analyzed by EPA Method 8330 for nitroaromatics as well as EPA Method 8270C for semivolatile organic compounds. Risks associated with the reported values from both

analyses are considered in the risk characterization (Chapter 5.0) and discussed as appropriate in the uncertainty analysis (Chapter 6.0), together with potential issues such as the relative sensitivities (i.e., differences in respective reporting limits) of the methods.

2.4 Identification of Chemicals of Potential Concern

A screening process is used to identify COPCs, which are the detected chemical analytes carried through the full risk assessment process. The objectives of COPC screening are to focus the risk assessment on those chemicals that may contribute significantly to overall risk and to remove from quantification those chemicals whose contribution is clearly inconsequential. COPC screening includes a risk-based screen which also considers status as a human nutrient (Section 2.4.1), a frequency-of-detection evaluation (Section 2.4.2), and a background screen (Section 2.4.3).

2.4.1 Risk-Based Screening

In the risk-based screen, the maximum detected concentration (MDC) of a chemical in a given medium is compared to the appropriate risk-based screening concentration (RBSC) for that chemical and medium. This is performed for each chemical in each medium. The units of the MDC and RBSC are the same for each chemical in a given medium. In groundwater, for example, both the MDC and RBSC have units of micrograms per liter (µg/L) in water.

If the MDC of a chemical is less than or equal to its RBSC, then the chemical is not considered further in the BHHRA for this medium because it is very unlikely that chemical concentrations at or below the RBSC would contribute substantially to risk. An analyte may be identified as a COPC if its MDC exceeds its RBSC. As indicated in Section 2.4, actual status as a COPC also depends on a chemical's frequency of detection (Section 2.4.2), concentration with respect to background (Section 2.4.3), and potential status as a nutrient. Groundwater RBSCs used in the BHHRA are derived from the EPA (2012a) regional screening level (RSL) table "tap water" values, and RBSCs for soil are derived from "residential soil" RSL values. This is a change in the source of the RBSCs for PBOW BHHRA work plans begun prior to March 2009 based on discussion between USACE and OEPA (2009d), and this change is consistent with recent OEPA (2009a) guidelines. Previously, the groundwater and soil RBSCs were derived from the corresponding EPA (2004b) Region 9 preliminary remediation goals (PRG). The soil RBSCs are applied to both surface and subsurface soil.

RSL 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 the BHHRA, the noncancer

values listed in the RSL tables are multiplied by a factor of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals (OEPA, 2009a; EPA, 2012a). This results in RBSC values associated with an HQ of 0.1. For cancer risk, the RSL values based on an ILCR of 1E-6 were used directly as RBSCs in the BHHRA. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) identifies acceptable exposure levels that are generally associated with concentration levels that represent an excess upper bound lifetime cancer risk to an individual of 1E-6 to 1E-4 (EPA, 1990). This range is hereinafter referred to as the "NCP risk management range." Cancer risks associated with RSL values represent the lower end of this range. OEPA recognizes an overall cancer risk of 1E-5, which represents the logarithmic midpoint of the EPA risk management range, as a remedial goal (OEPA, 2009b). The RBSC for a chemical that elicits both cancer and noncancer health effects is selected based on either a cancer risk of 1E-6 or an HQ of 0.1, whichever associated concentration is lower.

Risks associated with exposure to sediment and surface water in the drainage ditch west of the former WWTP3 facility are also evaluated in the BHHRA (Figure 1-3). This ditch had little water: sample WTP3-SW02 had to be moved approximately 21 feet north to a small area of pooled water, and a small sump had to be dug within the ditch to sample WTP3-SW03.

Although RSLs have not been developed specifically for sediment and surface water, RBSCs can be derived from the RSLs based on site conditions at PBOW and the types of exposure to these media that may reasonably be anticipated. The routes by which receptors may be exposed to sediment (i.e., incidental ingestion or dermal contact) are similar to those by which receptors may be exposed to soil. However, sediment contact is expected to be appreciably less intense than soil contact, due to the lower duration and frequency of contact with sediment as compared with soil. Similarly, surface water exposure is expected to be much less intense than exposure to groundwater, as surface water from WWTP3 is not regarded as a plausible source of drinking water, partly because the Erie County Health Department does not permit using surface water as private drinking water and also because the drainage ditch does not contain nearly enough water for drinking water use. Consequently, the exposure frequency is expected to be much lower for surface water, and the incidental ingestion of surface water would be much lower than the assumed intentional ingestion and use of groundwater from the tap. For these reasons, OEPA (1999) stated that unadjusted tap water PRG values (i.e., HQ = 1; ILCR = 1E-6) should be used for screening PBOW surface water. This screening protocol was adopted specifically because it was agreed that the magnitude of exposure associated with PBOW surface water exposure would be far less than that associated with household tap water. In other words, it was agreed that analytes with a maximum concentration at the PRG level would not contribute appreciably to overall risks and hazards for PBOW sites based on the exposure pathways of the surface water

exposure scenarios for PBOW. The same agreement was reached for screening sediment against unadjusted residential soil PRGs. This protocol has been updated to base sediment and surface water RBSCs on RSLs rather than PRGs, just as soil and groundwater RBSCs are currently based on RSLs. Even though the sediment and surface water RBSCs are an order of magnitude higher for noncarcinogens than the respective soil and groundwater RBSCs, these sediment and surface water RBSCs are regarded as protective of sediment and surface water receptors for screening because of the lower exposure rate to these media. Note that this previously made PBOW Team agreement for screening surface water and sediment (OEPA, 1999), which considered site-specific conditions, takes precedence over current OEPA (2009b) guidance, which simply states that adjusted RSLs (i.e., RBSCs) for soil may be used to screen contaminants in sediment and those for groundwater may be used to screen surface water. The surface water RBSCs also meet the outside-of-the-mixing-zone average non-drinking water concentrations for the Lake Erie Basin.

The screening of lead in soil and groundwater is a special case. The EPA (2012b) Office of Water treatment technique action level of 15 µg/L for lead is listed in the RSL table, and the RSL user's guide recommends this level for use as an RSL. Lead exposure and risk is evaluated separately from other chemicals using the EPA (2004c) Integrated Exposure Uptake Biokinetic (IEUBK) model. The selection of the action level as the drinking water RSL is based partly on IEUBK model. Section 5.2 of the RSL user's guide states that if the average tap water concentration exceeds 15 µg/L and the average soil concentration exceeds 250 milligrams per kilogram (mg/kg), then more than the IEUBK target (EPA, 2004c) of 5 percent of the population of exposed children would exceed 10 micrograms per deciliter of lead in blood. Because the Office of Drinking Water action level of 15 µg/L can be used to conservatively screen for a potential average concentration of 15 µg/L, this concentration is used as the RBSC. However, it is possible that the residential soil RSL of 400 mg/kg, which is selected as the soil RBSC, may not be protective of an average soil concentration of 250 mg/kg within a given data set. Therefore, the following conditions were placed on the screening of lead: 1) If either the soil RBSC or groundwater RBSC is exceeded, then the IEUBK blood-lead model is run using both average soil and groundwater concentrations, and 2) if the average soil concentration exceeds 250 mg/kg, then the IEUBK model is run, even if neither RBSC is exceeded, using average concentrations of lead in both soil and groundwater. Note that for WWTP3 total soil, the MDC for lead (134 mg/kg) is less than both the RBSC (400 mg/kg) and the criterion for average concentration (250 mg/kg). Likewise, the lead MDC in WWTP3 bedrock groundwater (3.65 µg/L) is less than the RBSC (15 µg/L), and lead was not detected in overburden groundwater. Therefore, the IEUBK model was not run for WWTP3 soil and groundwater.

There are no RSLs for sulfate in tap water, but the drinking water outside-of-the-mixing-zone average value of 250 milligrams per liter (mg/L) for the Lake Erie Basin is used as the RBSC. This value is the same as the secondary drinking water regulation of 250 mg/L (EPA, 2012b). Secondary drinking water regulations are nonpromulgated values, based on aesthetic characteristics, which are used as guidelines for public water systems. A health-based advisory level of 500 mg/L also exists for sulfate (EPA, 2012b).

The evaluation of 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, chloride, iodine, magnesium, phosphorous, potassium, and sodium are generally considered innocuous at levels found in environmental media. No RSLs are listed for these nutrients. Should any of these chemicals be identified as site related, an exposure analysis is performed whereby a daily dose of chemical from ingestion of the medium in question is calculated. The dose is compared with levels known or expected to be safe or toxic, and/or with recommended daily allowances, depending on the availability of data.

2.4.2 Frequency of Detection

When confidence is high that a given chemical is present, the data generally are used in the BHHRA. For most chemicals, their detection is presumptive evidence of their presence. As suggested by EPA (1989a), chemicals that are reported infrequently may be artifacts in the data that do not reflect the actual presence of the chemical in question. For the BHHRA, chemicals that are reported only at low concentrations in less than 5 percent of the samples from a given medium are excluded from further consideration, unless the presence of a given chemical is expected based on historical information about the site. Chemicals detected infrequently at high concentrations may identify the existence of contaminant plumes or limited “hot spots” and are retained as COPCs.

2.4.3 Comparison to Background

A number of the chemicals detected in PBOW environmental media may have MDCs that exceed RBSCs but are part of normal background concentrations. Such chemicals may include inorganics and polycyclic aromatic hydrocarbons (PAH), a class of organic compounds which form from natural or anthropogenic combustion of organic matter, including fossil fuels, and are generally ubiquitous in the environment. Airborne PAHs associated with non-U.S. Department of Defense (DoD) sources may be deposited on soil and leach to groundwater. Benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds, as well as PAHs, may also be associated with background concentrations due to the presence of natural petroleum-derived compounds present in the vicinity of PBOW (Section 3.1.1).

Site concentrations of inorganic chemicals in site environmental media may be compared to those of PBOW background using a two-step approach: 1) background screening and 2) statistical data set testing. This second step (Section 2.4.3.2) is initiated only in cases where the concentration used for background screening is exceeded (Section 2.4.3.1) and is performed after the risk characterization (Chapter 5.0). The results of the statistical data testing are discussed in the uncertainty analysis (Chapter 6.0). No suitable background data set exists for overburden groundwater, so no background screening or statistical comparisons to background concentrations can be made for overburden groundwater samples. Similarly, no background screening or statistical evaluation can be performed for surface water or sediment analytical data, as these media lack PBOW background data sets.

Inorganics and organics are treated similarly from a quantitative perspective. However, all organics not eliminated on the basis of RBSC exceedance (Section 2.4.1) or infrequent detection (Section 2.4.2) are carried through the risk calculation process (exposure assessment, toxicity assessment, and risk characterization). As presented in Section 2.4.3.3, organic compounds are quantitatively eliminated as background related only through the uncertainty analysis if applicable.

2.4.3.1 Background Screening of Inorganics

Background screening is applied to each inorganic whose MDC in soil or limestone bedrock groundwater exceeds the RBSC and that cannot be characterized as an infrequently detected analyte. In background screening, the MDC is compared to the PBOW chemical-specific background screening concentration (BSC). The background data set and derivation of soil BSCs for all PBOW soil investigations are described in IT (1998) (Table 2-2), and the background data set and derivation of BSCs for PBOW bedrock groundwater are described in the 2004 groundwater report (Shaw, 2005) (Table 2-3). It is noted that the method agreed upon for the development of BSCs, as recorded in the May 10, 2000 PBOW Team meeting minutes, differs from that shown in current OEPA (2009c) guidance. This PBOW Team agreement, which has been used for all PBOW risk assessments to date, takes precedence over the subsequent OEPA (2009c) guidance. Use of this method for the development of BSCs and as part of the COPC screening process ensures consistency between all of the PBOW FUDS project sites. Summary tables of the background data sets for soil and groundwater are provided as Tables 2-2 and 2-3, respectively. The background soil samples were collected from near the property boundary, away from any potential source areas, and the background groundwater wells were installed in off-site areas upgradient of PBOW sources. Briefly, BSCs were calculated for use at PBOW based on concentrations found in these background soil and bedrock monitoring well samples. Each BSC

is either the MDC or the calculated 95th percent upper tolerance limit of the background data set, whichever value is lower (IT, 1998; Shaw, 2005). The background monitoring well samples were collected using low-flow samples and were unfiltered.

The background screening consists of comparing the MDC of the site data set to the BSC. The chemical may be regarded as a COPC if its MDC exceeds the BSC for that chemical or if no BSC can be determined due to a lack of detections in the background data set. COPCs are fully evaluated in the exposure assessment, toxicity assessment, and risk characterization. An inorganic analyte is not regarded as a COPC if its MDC is equal to or less than the BSC.

2.4.3.2 Statistical Data Set Testing of Inorganics

Statistical testing is performed to compare data sets of site inorganics data against the appropriate PBOW background data sets. As described in Section 2.4.3.1, the background data set for groundwater is presented in the 2004 groundwater report (Shaw, 2005), and the background data set for soil is presented in the site investigation for the acid areas (IT, 1998). As mentioned previously, background data sets do not exist for overburden groundwater, surface water, or sediment; therefore, a statistical background evaluation for COPCs in these media cannot be performed. The method for statistical comparison of the site data sets to the background data sets, described in Appendix M of Shaw (2005), is the Wilcoxon Rank Sum (WRS) statistical test (also known as the Mann-Whitney U test). WRS testing is performed for inorganics having MDCs that exceed the respective BSCs and are identified as COPCs based on RBSC comparison (Section 2.4.1) and frequency of detection (Section 2.4.2). All COPCs are carried through the risk characterization process; thus, statistical testing results are not used to screen out any chemicals.

Site data sets are interpreted as being significantly different from PBOW background if the associated p-level is less than 0.05. WRS statistical output and box-and-whisker plots of the various inorganic COPC data sets are appended to the BHHRA for each inorganic data set evaluated against the appropriate site background data set; the WRS results are discussed as part of the uncertainties. Analytes shown by the WRS results to exceed background (or for which the WRS testing was not run) are assumed to be site related, unless a qualitative chemical-specific explanation is presented in the uncertainties analysis as to why the analyte should not be regarded as site related. The WRS is not run if the COPC was not detected in the PBOW background data set. Data sets for which the WRS results do not suggest site relatedness (i.e., site data and background data are not statistically different) are still evaluated for risks and hazards in the risk characterization (Chapter 5.0).

2.4.3.3 Treatment of Organic Compounds

As mentioned in Section 2.4.3, certain organic compounds (e.g., BTEX and PAHs) in site media may be attributable to background conditions. However, no organic compounds are summarily screened out. Instead, all detected organic compounds are carried through the risk assessment process (i.e., exposure assessment, toxicity assessment, risk characterization) unless screened out on the basis of comparison to RBSCs (Section 2.4.1) or characterized as infrequently detected (Section 2.4.2). Background contributions of organics are discussed in the uncertainties analysis, as applicable.

2.5 Data Evaluation Summary

Data summary tables are provided for the following WWTP3 media: surface soil (Table 2-4), subsurface soil (Table 2-5), total soil (Table 2-6), bedrock groundwater (Table 2-7), overburden groundwater (wells) (Table 2-8), sediment (Table 2-9), and surface water (Table 2-10). These tables provide the following information for each detected chemical in each environmental medium:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of reporting limits
- Arithmetic mean of site concentrations
- Appropriate BSC
- Appropriate RBSC
- Selection/exclusion of chemical as a COPC
- 95th percent upper confidence limit on the arithmetic mean (UCL) (for COPCs only)
- EPC (for COPCs only).

The estimation of the UCL values for COPCs is discussed in Section 3.2.1. For duplicate samples, the associated values are averaged in the data summary, if both samples are detects or if both are nondetects; if only one of the duplicates is a detect, then this detected value is used in the data summary.

An analogous summary table for the overburden groundwater piezometer samples is included as Appendix A. Note that these direct-push groundwater samples are collected for nature-and-extent purposes to determine groundwater flow direction and the placement of monitoring wells. These data are not sufficiently representative of groundwater conditions for use in risk assessment. Therefore, they are not used to identify COPCs and are not quantitatively evaluated in the BHHRA. This piezometer groundwater summary table is appended only to provide ancillary information.

The COPCs for each of the WWTP3 media are identified as follows:

- ***Surface Soil*** – Aroclor 1016, Aroclor 1254, Aroclor 1260, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene

- ***Subsurface Soil*** – benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-c,d)pyrene

- ***Total Soil*** – Aroclor 1016, Aroclor 1254, Aroclor 1260, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

- ***Bedrock Groundwater*** – arsenic, manganese, vanadium, 2-methylnaphthalene, naphthalene, benzene, ethylbenzene, xylenes, and cyanide

- ***Overburden Groundwater*** – arsenic, barium, chromium, cobalt, iron, manganese, 1,3-dinitrobenzene, 2,4-DNT, and cyanide

- ***Sediment*** – arsenic, chromium, manganese, thallium, benzo(a)pyrene, and benzo(b)fluoranthene

- ***Surface Water*** – arsenic, chromium, cobalt, iron, and manganese.

As discussed in Section 2.2, the total soil COPCs include all surface soil and subsurface soil COPCs.

3.0 Exposure Assessment

Exposure is the contact of 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). An exposure assessment includes the following steps:

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

The BHHRA characterizes potential exposures to COPCs in WWTP3 environmental media as portrayed by the CSEM in Section 3.1. Note that these environmental media include soil, surface water, sediment, and groundwater.

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, graphically depicted on Figure 3-1, includes the receptors appropriate to all plausible site-use scenarios and the potential exposure pathways. This presentation of all possible pathways by which a potential receptor may be exposed, including all sources, release and transport pathways, and exposure routes, facilitates consistent and comprehensive evaluation of risk to human health and helps to ensure that potential pathways are not overlooked. The elements of a CSEM include the following:

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

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

The receptors and pathways on Figure 3-1 reflect scenarios developed from information regarding site background and history, topography, climate, and demographics as presented by

D&M (1997a) and the sitewide groundwater investigation (IT, 1997). On Figure 3-1, asterisks identify exposure pathways that are complete and addressed in this BHHRA. Justification for exclusion of other pathways is provided in the Figure 3-1 footnotes, and the exclusion of other potential receptors is discussed in Section 3.1.3.8. No current or future exposure by off-site residents is evaluated. Most of the off-site residents are serviced by municipal water from surface water sources. Although there are numerous private groundwater wells in the vicinity, including eight within 1 mile of the facility boundary, none of these is used as a potable source. Based on the investigations of other PBOW sites (e.g., Shaw [2008b]), natural hydrocarbons and hydrogen sulfide are known to be present within the bedrock limestone, and shale formation groundwater generally provides low yields and is of low quality; however, the groundwater underlying WWTP3 is not summarily excluded for consideration as a tap water source based on natural water quality parameters or general assumptions concerning yield. Therefore, given the presence of numerous off-site wells and the assumption of unrestricted future land use on site, the development of groundwater for hypothetical future on-site residential (or on-site worker) use as tap water is initially regarded as plausible for purposes of this BHHRA. Groundwater quality and potential use is discussed further in the risk characterization (Chapter 5.0) and uncertainty analysis (Chapter 6.0). It is important to note that the site-specific risk assessment, including the evaluation of future land uses and groundwater use, was performed to satisfy administrative requirements, including those described by FUDS regulations (USACE, 2004).

3.1.1 Physical Setting

The topography of WWTP3 is essentially flat with a slight sloping to the west in the vicinity of the ditch which runs south to north. Most of the present ground surface at WWTP3 is interpreted as being very near the 1940s ground surface. Little to no fill material is believed to be present. In several of the borings, black cinders and gravel were found within 1 foot of the surface. The former neutral waste storage tank had been used by NASA as the K-Site control building until recently. This structure had an associated patio within the footprint of the former neutralization tank, and a gas grill was observed on the patio. This K-Site control building and associated patio were demolished and removed by NASA in October 2012. The other former WWTP3 structures were previously burned and demolished. Most of WWTP3 is regularly mowed and is composed of various grasses and herbs. The areas not mowed are mostly composed of shrub thickets, with the areas adjacent to the ditch represent the areas of densest (and least disturbed) vegetation cover.

The following subsections further describe the physical setting of WWTP3, including the climate and meteorology of the Sandusky region (Section 3.1.1.1) and the geology (Section 3.1.1.2), soil (3.1.1.3), hydrology (Section 3.1.1.4), and surface water characteristics (Section 3.1.1.5) of the area and of WWTP3 in particular. A general description of WWTP3 is provided in Section 1.3.

3.1.1.1 Climate/Meteorology

The climate in the Sandusky area is continental and strongly affected by Lake Erie. July is generally the warmest month (average high and low temperatures of 82 and 65 degrees Fahrenheit [°F], respectively), and January is generally the coldest (average high and low temperatures of 32 and 19°F, respectively) (The Weather Channel, 2004). On average, the first freezing day (low of 32°F or less) occurs in late October (average of three per month), and the last freezing day falls in early May (average of one per month) (National Oceanic and Atmospheric Administration, 1990). The average annual precipitation for Sandusky is 34.5 inches per year, with a monthly average of more than 3 inches per month falling in April through September and less than 3 inches in each of the other seven months (The Weather Channel, 2004). Precipitation is fairly evenly distributed throughout the year, with the fewest precipitation days (0.01 inch or greater) per month (10) occurring during July, August, September, and October, and the most (15) occurring in December and January (City-Data.com, 2004). The mean annual wind speed is 10.3 miles per hour (City-Data.com, 2004), with winds predominantly from the southwest (Science Applications International Corporation, 1991). Sandusky area winters are cloudy, with 33 percent sunshine during November through February, as compared with to 65 percent sunshine during the summer months (City-Data.com, 2004).

3.1.1.2 Geology

Three formations, all of Devonian Age, outcrop across PBOW; each was encountered in the upper 100 feet of bedrock (Shaw, 2005). The Delaware Limestone is the lowermost formation screened by site wells. It is characterized as a hard, dense, finely crystalline limestone and dolomite. The unit is typically buff colored and usually is described as fossiliferous. In the vicinity of PBOW, quarries mine limestone from the Delaware. Traces of natural petroleum-derived hydrocarbons and hydrogen sulfide are common in area quarries (Shaw, 2005).

At WWTP3, petroleum was observed at depth in the rock cores of all three bedrock monitoring wells, including WTP-BEDGW-001 (40.4 to 42.9, 47.6, 51.0, and 53.1 feet bgs), WTP-BEDGW-002 (40.5 to 43.4 and 47.8 feet bgs), and WTP3-BEDGW-003 (40.2 to 44.2, 47.3, and 52.9 feet bgs) (Shaw, 2011). Well WTP3-BEDGW-002 also exhibited high levels of hydrogen sulfide (above 200 parts per million [ppm]), which indicates that bedrock groundwater in the vicinity of WWTP3 is of naturally poor quality. Overlying the Delaware Limestone is the Olentangy Shale. Two members of the Olentangy Shale have been characterized at the site: the Plum Brook Shale and the overlying Prout Limestone. The Plum Brook Shale is interpreted to consist of approximately 35 feet of bluish-gray, soft, fossiliferous shale containing thin layers of dark, hard, fossiliferous limestone. The Prout Limestone has been described as a 15-foot-thick

unit which occasionally outcrops in a 1,000- to 2,000-foot-wide, northeast-striking band across the middle portion of PBOW. It is described as a dark-gray to blue, very hard, siliceous, fossiliferous limestone or dolomitic mudstone. The uppermost formation at the site is the Ohio Shale. Only one member of the Ohio Shale, the Huron Shale, is present in the PBOW area. This unit has been described as black, thinly bedded, with abundant carbonaceous matter. Some large pyrite/carbonate concretions are also present in the Huron Shale, some as large as 6 feet in diameter (D&M, 1997a). Based on drilling logs, the total thickness of shale in the WWTP3 area averages approximately 1.3 feet.

3.1.1.3 Soils

The overburden in Erie County and the soil at WWTP3 is predominantly glacial till, glacial outwash, or glacial lacustrine (lake) deposits. In the vicinity of PBOW, the soil has been interpreted to be lacustrine. In many areas, the overburden also consists of highly weathered bedrock. The thickness of the overburden ranges from less than 1 foot to more than 25 feet. Overburden is thickest on the northern portion of the PBOW facility in the vicinity of the Reactor Facility Area, where it has filled in a bedrock low (Shaw, 2005). In the WWTP3 area, the overburden thickness is approximately 26 feet thick, based on boring logs (Shaw, 2011).

The native soil at PBOW and the soil at WWTP3 is predominantly derived from glacial till, glacial outwash, or glacial lacustrine (lake) deposits. Below the 1940 fill material at WWTP3, the soil generally consists of a stiff, dark brown to dark gray, mottled silt to a depth of approximately 7 feet, then changes to a homogenous, dark gray, highly plastic silt or clay. Rock fragments (shale) were typically found in split-spoon samples during monitoring well borehole drilling prior to refusal. Interpreted boring log information from piezometer and monitoring well drilling shows the thickness of the 1940 disturbed soil ranges from the existing ground surface (SB-06) to a maximum depth of 4 feet bgs (WTP3-BEDGW-003).

At many PBOW sites, following closure and removal of the manufacturing structures, tanks, and equipment, a local fill sand was brought to the areas to cover the remaining concrete building foundations and demolition scars and to provide a natural landscape appearance. This does not appear to be the case at WWTP3. A review of the boring logs reveals that little to no fill material is believed to be present. In several of the borings, black cinders and gravel were found within 1 foot of the surface and down to a depth of approximately 3.5 feet. The origin of the cinders and gravel in the surface and near-surface soil is not known, but their presence may be associated with the historic access road from the north and parking area formerly associated with WWTP3. Further discussion of these cinders in context of potential human health risks is provided in Section 5.3.1.

3.1.1.4 Hydrology

The two main water-bearing zones at PBOW are located in the overburden/shale unit and the limestone bedrock and are thus called the overburden/shale and bedrock water-bearing zones. The overburden and shale groundwater units show similar water levels in these two units, suggesting substantial vertical communication. Therefore, these two geologic units are combined for purposes of PBOW groundwater evaluation. Data collected during the more recent investigations (Shaw, 2005; IT, 1997, 1999, 2001b) indicate that groundwater in the overburden is in discontinuous pockets during dry time periods. The shallow overburden generally has low yields over most of PBOW due to the high percentage of silt and clay. In contrast, the limestone bedrock water-bearing zone is saturated year round. During periods of low precipitation, only limited migration of contaminants would occur in the overburden due to less infiltration.

Regional groundwater flow in both the overburden/shale and the limestone bedrock is to the north-northeast towards Lake Erie, although local flow may vary due to local topography. The general flow direction in the overburden water-bearing zone is to the north in the immediate vicinity of WWTP3. A hydrogeological study by the U.S. Geological Survey (1992) conducted in the glacial deposits of Sandusky in 1990 reported a horizontal hydraulic conductivity of 0.046 feet per day and a vertical hydraulic conductivity of 1.2 feet per day.

Water in the limestone typically occurs in joints and along bedding planes or in solutionally enlarged openings. The conceptual model interprets that bedrock groundwater flow in the Delaware Limestone water-bearing zone is influenced by the frequency, orientation, density, and connectivity of the bedrock fractures. These fractures result in localized groundwater flow direction to the southeast in the vicinity of WWTP3.

At PBOW, the bedrock groundwater has been subdivided into three zones based on location and yield. Zone 1 occurs in the north and northwestern portion of PBOW. It has been characterized as yielding from 100 to 500 gallons per minute (gpm) from karstic limestone approximately 100 feet below grade. Zone 2 is in the northern portion of PBOW and has yields of 15 gpm or less from limestone approximately 300 feet below grade. Zone 3 is located in the eastern and southern portion of the site in predominantly shale bedrock. In addition to being found in the shale, groundwater is located in thin sand and gravel horizons interbedded with silt and clay deposits. Most Zone 3 wells are poor yielding, many of them providing less than 3 gpm (D&M, 1997a). WWTP3 appears to be within Zone 2.

Overburden groundwater at WWTP3 was encountered at depths ranging from 3.4 feet bgs (SB-06) to 10.5 feet bgs (SB-02/PZ-03) in December 2008 (wet season) during soil boring drilling/piezometer installation. During monitoring well installation conducted in March and April 2009 (wet season), overburden/shale groundwater was encountered at depths of 9.7 feet bgs (WTP3-MW03) to 10.3 feet bgs (WTP3-BEDGW-001). Groundwater flow within the overburden is toward the northeast and northwest.

Three bedrock wells were installed at WWTP3 during the RI. Bedrock groundwater was encountered in fractures at depths of 36 feet (WTP1-BEDGW-003) to 37.1 feet (WTP-BEWGW-002) during bedrock monitoring well installation in March 2009. Bedrock groundwater flow underlying WWTP3 is in a southeast direction toward a bedrock groundwater trough (Shaw, 2011).

3.1.1.5 Surface Water

WWTP3 surface water drains toward a small ditch west of the former WWTP3 facility. Portions of this ditch have contained a few inches of water during numerous site visits, but it has not been observed to contain flowing water. During precipitation events, this ditch apparently flows toward the north and eventually to Pipe Creek.

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways

Contaminant sources, release mechanisms, and migration pathways are summarized on Figure 3-1. Briefly, TNT is made by nitrating toluene in a three-step process that uses nitric and sulfuric acids (D&M, 1997a). WWTP3 received waste water via sewer lines from the TNTA and TNTB manufacturing operations waste water settling basins. This waste water was either treated and evaporated (thickened to reduce mass), or discharged to open waste water ponds. If treated, the thickened liquid was incinerated, and the ash from this incineration was disposed of in Ash Pit 3. Contamination resulted from the inadvertent release of TNT, its precursors, contaminants and residues, and acids or sellite (sodium sulfite made from soda ash and sulfur) from the process lines or drying areas. Releases occurred to the surface soil and subsurface soil from vertical migration. 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 or groundwater. It is possible that surface water and sediment at the drainage ditches may have been impacted by contaminants originating from WWTP3 through surface drainage.

3.1.3 Receptors and Exposure Pathways

Receptors selected to represent the upper bound on exposure from all plausibly exposed groups of people associated with WWTP3 as well as the pathways by which they may be exposed to chemicals are summarized on Figure 3-1 and in Table 3-1. The exposure variable values used in the contaminant intake models are compiled in Table 3-2. The receptors evaluated in the BHHRA are listed below. Note that the current (Section 3.1.3.1) and future (Section 3.1.3.2) groundskeeper scenarios include different environmental media and are, thus, listed separately. Receptors such as the construction worker, hunter, and hunter's child may be viable under current or future land use. However, the evaluation for these receptors is exactly the same under current and hypothetical future land use.

- Current groundskeeper
- Future groundskeeper
- Indoor worker (future)
- Construction worker (current/future)
- On-site resident (future)
- Hunter (future)
- Hunter's child (future).

Most BHHRAs 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 upper 90 to 95th percentile on exposure. In keeping with EPA (1989a; 1991a) guidance, variables chosen for a baseline RME scenario for ingestion rate, exposure frequency, and exposure duration are generally upper bounds. Other variables, such as body weight and exposed skin surface area, are generally central or average values. In the case of contact rates consisting of multiple components, e.g., dermal contact with soil or water, which consists of a dermal absorption factor (ABS) and soil-to-skin adherence factor (AF) for soil, and permeability coefficient (K_p) and exposure time (ET) for water, only one variable, ABS or K_p, needs to be an upper bound. The conservativeness built into the individual variables ensures that the entire estimate for contact rate is sufficiently conservative.

The averaging time for noncancer evaluation is computed as the product of the exposure duration (years) multiplied by 365 days per year. The resultant noncancer averaging time is used to estimate an average daily dose over the entire exposure period (EPA, 1989a). For cancer evaluation, the averaging time is computed as the product of 70 years, the assumed human lifetime, times 365 days/year. This cancer-based averaging time is used to estimate an average daily dose prorated over a lifetime, regardless of the frequency or duration of exposure. The methodology used in deriving the averaging time for cancer risks assumes that the risk from

short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is generally consistent with the EPA (2005) policy of carcinogen evaluation, although it introduces considerable uncertainty into the BHHRA cancer risk estimates.

A fractional term (FI) is introduced into the chemical intake equations to account for scenarios in which exposure to a potentially contaminated medium associated with the site is less than total daily exposure to that medium. For example, if the site of interest is small or has unusual dimensions so that a groundskeeper would be unlikely to spend all (or nearly all) of his working time at the site, an FI value of less than 1 might be applied to the soil ingestion and dermal intake equations. An FI may also be split between two comparable media. For example, if a future hypothetical resident is exposed to both soil and sediment, FI values are introduced that apportion exposure between the two media such that the FI value for the two analogous media does not exceed a value of 1 (Section 3.1.3.5).

Receptors and the associated exposure pathways are presented in the following subsections. Please note that some of the pathways considered for the receptors (e.g., surface water exposure; volatile organic compounds [VOC] in soil) could not be quantitatively evaluated because pertinent chemicals associated with these pathways were not identified as COPCs.

3.1.3.1 Current Groundskeeper

The groundskeeper scenario is designed to evaluate the upper bound for long-term site worker exposure to surface soil in the current site-use scenario and total soil in the future site-use scenario. It is noted that groundskeeping is currently limited to mowing, but current land use does not prohibit a site worker from performing full-time groundskeeping and/or other activities at the site.

Exposure to surface soil is evaluated for a (potential) current groundskeeper. Total soil is typically evaluated under the future groundskeeper use scenario because hypothetical future construction may include considerable excavation of subsurface soil. This soil may be spread on the surface and regraded such that some of the soil currently in the subsurface (i.e., 1 to 10 feet bgs) will be spread as surface soil (0 to 1 foot bgs). Groundwater use is also evaluated for the groundskeeper in the future site-use scenario, as discussed in Section 3.1, in which groundwater could theoretically be developed as a source of drinking water. It is assumed that any contact with surface water or sediment associated with WWTP3 by this receptor would be infrequent and sporadic, because such contact would not be a part of the groundskeeper's regular duties or activities. Therefore, exposure to these media is not quantified.

Direct soil exposure pathways include incidental ingestion and dermal contact. Inhalation of dust raised by lawnmowers or other equipment is also evaluated because relatively high dust concentrations may be produced within the groundskeeper's breathing zone, with little opportunity for dilution by the large volume of ambient air.

Shaw's experience has been that surface soil that is contaminated with VOCs and that has been in place for extended periods is not a significant source of airborne VOCs, because infiltration and dissipation over time reduces residues at the surface (i.e., the first few centimeters) from which volatilization would occur. However, as noted previously, the data set for surface soil may include samples taken from up to 1 foot bgs, which would include the soil zone deeper than the top few centimeters, where dissipation has not reduced VOC concentrations. In other words, the surface soil data set might indicate the presence of VOCs, although volatilization to the air is unlikely to be significant. Therefore, a surface soil-to-air volatilization model is not used in addition to the activity-based dust emissions model to estimate airborne concentrations of VOCs. Instead, the airborne concentrations estimated by the dust emissions model are assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust emissions model treats the VOCs as if they were located at the surface. It is assumed that VOC emissions from subsurface soil (i.e., at depths greater than 1 foot bgs) would be attenuated by the overlying soil so that concentrations in ambient air would not be toxicologically significant.

The groundskeeper is assumed to be a 70-kilogram (kg) adult who works 8 hours per day, approximately 5 days per week year-round on site for a total of 250 days/year for 25 years (EPA, 2004a). The respiratory rate for the groundskeeper is assumed to be 20 cubic meters (m^3) per 8-hour workday or 2.5 cubic meters per hour (m^3/hr) (EPA, 1991a), and the soil incidental ingestion rate is assumed to be 100 milligrams per day (mg/day) (EPA, 2002). The groundskeeper is assumed to be exposed dermally to soil. An exposed skin surface area of 3,300 square centimeters (cm^2) and a soil AF of 0.2 milligrams per square centimeter (mg/cm^2) are assumed (EPA, 2004a).

3.1.3.2 Future Groundskeeper

A future groundskeeper would be exposed to soil via the same exposure pathways as the current groundskeeper described in Section 3.1.3.1. However, the future groundskeeper scenario assumes that construction has taken place and that some of the soil currently in the subsurface has been brought to the surface during earthmoving activities. Therefore, the future groundskeeper is assumed to be exposed to a combination of surface and subsurface soil (total soil) rather than surface soil alone.

In addition, a hypothetical future groundskeeper is assumed to be exposed to groundwater, which could theoretically be developed as a source of drinking water in the future. His drinking water ingestion rate is assumed to be 1 liter per day (L/day) (EPA, 1991a). He may also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it is assumed that the head, forearms, and hands, approximately 3,300 cm^2 of his body (EPA, 2004a), would be exposed intermittently for up to 1 hour/day. Because exposure is assumed to be intermittent rather than continuous, organic chemical uptake across the dermis would not reach steady state, which guides the selection of the EPA (2004a) model used to quantify this pathway (Section 3.3).

3.1.3.3 Future Indoor Worker

This hypothetical future receptor scenario was used to evaluate exposure to indoor airborne VOCs entrapped in a building. VOCs released from subsurface soil may enter a building through joints or cracks in the foundation or slab. The indoor worker is also potentially exposed to surface soil via incidental ingestion. Exposure to COPCs in surface soil via dermal contact and inhalation of airborne dust and VOCs from surface soil, although plausible, is expected to be less significant than incidental ingestion, because this receptor spends his work time indoors. Therefore, dermal contact and inhalation of dust and airborne VOCs from surface soil are not quantified separately from ingestion exposure (EPA, 2002). Under a future use scenario for this receptor, construction of a building would be necessary. This would require excavation and regrading of soil. Normally, when construction is involved (e.g., for the future groundskeeper or future hypothetical resident), total soil rather than surface soil would be evaluated for ingestion exposure. However, the chief purpose for this receptor is to evaluate exposure via vapor intrusion of contaminants from subsurface soil into indoor air. Thus, the evaluation of direct contact with subsurface soil as a component of total soil would equate to “double counting” of COPCs in subsurface soil. Also, the groundskeeper reflects a worst-case exposure for a long-term worker with respect to direct contact with both surface soil and total soil. Therefore, direct contact with surface soil for the indoor worker is included to reflect a more complete exposure scenario, but direct contact with subsurface soil is most effectively addressed from an RME perspective by the groundskeeper.

The indoor worker is 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, 2002). His incidental soil ingestion rate is assumed to be 50 mg/day (EPA, 2002), and his inhalation rate is assumed to be 20 m^3/8-hour workday (EPA, 1991a).

A future indoor worker is assumed to be exposed to groundwater, which could theoretically be developed as a source of drinking water (Section 3.1). His drinking water ingestion rate is assumed to be 1 L/day (EPA, 1991a). Some indoor worker positions may require relatively frequent dermal contact with groundwater as well, e.g., a food preparer/cafeteria worker who would wash his hands, produce, equipment, etc. For this evaluation, it is assumed that the head, forearms, and hands, approximately 3,300 cm^2 of his body (EPA, 2004a), would be exposed intermittently for up to 1 hour per day. Because exposure is assumed to be intermittent rather than continuous, organic chemical uptake across the dermis would not reach steady state, which guides the selection of the EPA (2004a) model used to quantify this pathway (Section 3.3.4).

3.1.3.4 Current/Future Construction Worker

The construction worker scenario is used to evaluate short-term exposure to surface and subsurface soil (total soil) in either the current or future land-use scenario. Construction projects are expected to be infrequent. It is assumed that the construction worker participates in only one construction project on the site. Note that no construction projects are anticipated for WWTP3, but WWTP3 is currently under NASA control and a construction project may be possible under current land use. 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. Exposure to groundwater by the construction worker is also possible; however, if on-site groundwater were developed as a tap water source, other potential future groundwater receptors such as the groundskeeper would have longer and/or more frequent groundwater exposure. Therefore, groundwater exposure is not evaluated for the construction worker.

The construction worker may also be exposed to surface water and sediment associated with WWTP3 during projects such as installation of underground utilities or rerouting of surface flow. Sediment and especially surface water are relatively scarce at WWTP3, and exposure associated with these media for the WWTP3 construction worker would be correspondingly minimal to negligible. However, for the sake of consistency and in accordance with the work plan (Shaw, 2009), the construction worker exposure to surface water and sediment is being evaluated with the same protocol used for other PBOW sites. It is understood that WWTP3-specific issues associated with these media may lead to the risk characterization results being revisited, if appropriate, in the uncertainty analysis. Dermal contact is the most significant pathway for exposure to surface water. Incidental ingestion of surface water is also possible but is not expected to be nearly as significant as dermal contact. Inhalation of VOCs from surface water is also possible, but the large volume of outdoor air and natural air currents are expected to dilute airborne concentrations so that this pathway is expected to be less significant than dermal

contact, which is quantified. For these reasons, incidental ingestion and inhalation of VOCs from surface water are not quantified separately from dermal contact. Dermal contact and incidental ingestion may be important pathways for exposure to sediment, and both are evaluated.

The construction worker is assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week. This represents an annual exposure frequency rate of about 250 days per year, which is the same as described for the groundskeeper (Section 3.1.3.1) and indoor worker (Section 3.1.3.3). Construction projects involving soil exposure are assumed to last 6 months. The respiratory rate for the construction worker is assumed to be 20 m^3/8-hour workday (2.5 m^3/hr) (EPA, 1991a). A soil ingestion rate of 330 mg/day is assumed for the construction worker (EPA, 2002). A dermal soil AF for the construction worker of 0.3 mg/cm^2 and an exposed body surface area of 3,300 cm^2 are assumed, which represent the head, hands, and forearms (EPA, 2002; 2004a).

The construction worker may be exposed to surface water and sediment during the 6-month construction period. The construction worker dermal exposure parameters for sediment are assumed to be exactly the same as those for soil. Dermal exposure to surface water is assumed to occur for up to 4 hours per day, or one-half the normal work day. It is assumed the exposure to surface water is intermittent during this period. An exposed body surface area of 3,300 cm^2, the same as for sediment and soil, is assumed for exposure of the construction worker to surface water. It is expected that the construction worker would wear appropriate footgear and leg protection to minimize surface water and sediment exposure to the legs.

As mentioned previously, the exposure assumptions used in the evaluation of surface water and sediment exposure and included in the work plan (Shaw, 2009) are selected to be consistent with other PBOW sites. Therefore, these assumptions (e.g., body surface area available for exposure) are particularly conservative for WWTP3, where the presence of sediment and especially surface water, and the corresponding exposure, are minimal. As stated previously, this exposure assessment protocol was used for WWTP3 surface water and sediment evaluation with the understanding that the risk characterization results that are based on the exposure assumptions can be revisited in the uncertainty analysis.

The construction worker scenario provides for several different kinds of construction projects, such as upland excavation and building projects (exposure primarily to soil), as well as stream rerouting (exposure primarily to surface water and sediment). It is unlikely, however, that a single construction worker would participate in all these activities during a given project. Therefore, the evaluation described above is probably overly conservative and may represent

some double counting. For example, it is unlikely that the construction worker would be simultaneously ingesting soil, sediment, and surface water. Similarly, the air in his breathing zone is not likely to contain the reasonable maximum concentrations of COPCs estimated for soil while he is exposed to surface water. The potential for double counting is not expected to contribute significantly to total risk estimates summed across chemicals, pathways, and media. Should construction worker risk estimates exceed acceptable limits, risk and hazard estimates may be performed using refined exposure assumptions based on the physical characteristics of the site. For example, an upland excavation and building project may be assumed for one or more areas of the site, and a stream rerouting project may be assumed for another. Effectively, the risks and hazards associated with surface water/sediment exposure and soil exposure could be separated. This approach would more precisely reflect plausible exposure scenarios, reduce the likelihood of double counting, and more accurately identify risk-driving media and chemicals. These refined estimates would be presented in the uncertainty analysis.

3.1.3.5 Future On-Site Resident

The hypothetical future on-site residential scenario is used to evaluate the upper bound for long-term exposure to site soil, surface water, sediment, and groundwater under the future land-use scenario. Residential land use is plausible because property surrounding the PBOW facility includes rural residential use. This type of land use is also consistent with assumed future land use of other PBOW sites such as TNTA and TNTC (IT, 2001a).

The future hypothetical on-site residential scenario is evaluated assuming a 30-year residential exposure scenario, considering exposure to a resident as a young child (6-year duration, ages 1 through 6 years) through the adult portion of life spent at this residence (24-year duration) (EPA, 1991a). Noncancer hazard estimates are derived separately for the child and adult life stages. Cancer risk is estimated as the sum of the risks calculated for the adult (24 years) and the child (6 years) (EPA, 2002; 2012c).

The future hypothetical resident is assumed to be exposed directly to total soil, because residential development would involve excavation and regrading, which would mix surface and subsurface soil. Relevant pathways for total soil exposure include incidental ingestion, dermal contact, and inhalation of dust and VOCs. Evaluation of VOCs from total soil is addressed during evaluation of airborne dust, as described for the groundskeeper. For evaluating inhalation of airborne dust, it is assumed that 80 percent of the soil surface is covered with pavement or vegetation. Inhalation of VOCs released from subsurface soil entrapped in indoor air is also evaluated. The future hypothetical resident is also assumed to be exposed to VOCs that have been released from subsurface soil through cracks in the building foundation to indoor air. It is

noted that because some of the subsurface soil is expected to be brought to the surface in the future, using only subsurface soil data will conservatively result in some double counting of exposure to any VOC COPCs that may be present in the subsurface soil. This can be addressed in the uncertainty analysis in cases where the subsurface soil-to-indoor air pathway significantly affects risk and hazard estimates. This pathway did not contribute significantly to risk at WWTP3, as no VOCs were identified as COPCs in subsurface soil.

It is assumed that, under future residential land use, the overburden and limestone bedrock water units will be developed as sources of potable water (Section 3.1). The future hypothetical resident is assumed to use groundwater underlying the site as the sole source of household tap water. Exposure to COPCs in groundwater would occur via ingestion, dermal contact during bathing/washing, and inhalation of VOCs released to the air during household use of tap water associated with multiple household uses.

The future hypothetical resident could have access to the WWTP3 drainage ditches and be exposed to associated contaminants in surface water and sediment. Sediment and especially surface water are relatively scarce at WWTP3, and exposure associated with these media for the WWTP3 future hypothetical resident would be correspondingly minimal to negligible. However, for the sake of consistency and in accordance with the work plan (Shaw, 2009), the resident exposure to surface water and sediment is being evaluated with the same protocol used for other PBOW sites, with the understanding that WWTP3-specific issues may lead to the risk characterization results being revisited if appropriate in the uncertainty analysis. Plausible exposure pathways include dermal contact with surface water and incidental ingestion and dermal contact with sediment. Incidental ingestion of surface water in a wading scenario is considered less significant than dermal contact and is not quantified separately from dermal contact. Inhalation of VOC emissions from surface water is also possible, but the large volume of outdoor air and natural air currents are expected to dilute airborne concentration so that this pathway is expected to be less significant than dermal contact, which is quantified. For these reasons, the inhalation of VOC emissions from surface water is not quantified separately from dermal contact.

The future hypothetical adult resident is assumed to be a 70-kg person with an incidental soil ingestion rate of 100 mg/day and an inhalation rate of 20 cubic meters per day (m^3/day) or 0.83 m^3/hr (EPA, 1991a). A body surface area of 5,700 cm^2, representing the hands, forearms, head, and lower legs, is assumed to be available for dermal exposure to soil (EPA, 2004a). A soil AF of 0.07 mg/cm^2 is used as the default RME value for the adult resident (EPA, 2004a). The adult

future hypothetical resident is assumed to be exposed for 350 days/year for 24 years (EPA, 1991a; 2002).

The hypothetical future child resident is assumed to be a 1- through 6-year-old child with an average body weight of 15 kg, a soil ingestion rate of 200 mg/day, and an average inhalation rate of 10 m^3/day or 0.417 m^3/hr (EPA, 2004d). An average body surface area of 2,800 cm^2 throughout the 6-year childhood exposure period, representing the head, hands, forearms, lower legs, and feet, is assumed for dermal contact with soil (EPA, 2004a). A soil AF of 0.2 mg/cm^2 is used as the default RME value for the child resident (EPA, 2004a). The hypothetical future child resident is assumed to be exposed for 350 days/year for 6 years (EPA, 1991a; 2002).

It is assumed that the future hypothetical resident would visit the WWTP3 drainage ditch for 8 hours/day, 2 days/week during the warmer half of the year. This resident is assumed to wade for 3 hours/day on 52 days of the year. Mechanisms of exposure to soil and sediment are likely to be similar. Therefore, the incidental soil ingestion rate of 100 mg/day, the surface area of 5,700 cm^2, and the AF of 0.07 mg/cm^2 are also applied to sediment exposure in the adult. Similarly, the resident child soil ingestion rate of 200 mg/day, skin surface area of 2,800 cm^2, and soil AF of 0.2 mg/cm^2 are applied to sediment exposure for this receptor. The WWTP3 drainage ditch generally contains only a few inches of water, and this water is pooled only in isolated areas. It is assumed that an adult body surface area of 7,000 cm^2 is available for exposure to surface water. This represents the same body parts to which soil and sediment would be exposed (i.e., hands, forearms, head, and lower legs) plus the feet (EPA, 1997a; 2004a). The body surface area of 2,800 cm^2, representing the hands, forearms, head, lower legs, and feet, used for soil and sediment exposure in the young child are also used for surface water exposure for this receptor.

As mentioned above, the exposure assumptions used in the evaluation of surface water and sediment exposure and included in the work plan are selected to be consistent with other PBOW sites. Therefore, these assumptions (e.g., body surface area available for exposure) are particularly conservative for WWTP3, where the presence of sediment and especially surface water are minimal. As stated previously, this exposure assessment protocol was used for WWTP3 surface water and sediment evaluation with the understanding that the risk characterization results that are based on the exposure assumptions can be revisited in the uncertainty analysis.

EPA (1989a) permits the development of an FI to reflect the proportion of total daily exposure that a receptor obtains from a potentially contaminated medium (Section 3.1.3). For this receptor, the FI is used to apportion the resident's time of exposure between site soil and sediment. It is

assumed that the future hypothetical resident spends 16 hours/day awake and potentially exposed to soil or sediment. As previously noted, 350 days/year are available for contact with soil; 52 of those days are also available for contact with sediment. It is assumed that contact with soil and sediment does not occur simultaneously; i.e., on those days when the resident spends time at the streams, 8 hours would be spent in contact with soil and 8 hours would be spent in contact with sediment. Therefore, the fraction of exposure to soil is 16 hours/16 hours = 1 on the 298 days without time spent at the streams, and the fraction of exposure to soil is estimated as 8 hours/16 hours = 0.5 on the 52 days with some time spent at the streams. A weighted fraction of 0.93 (rounded to 0.9) is estimated for exposure to soil over the entire 350 days/year exposure frequency. A weighted fraction of 0.07 (rounded to 0.1) is estimated for exposure to sediment over the entire 350 days/year exposure frequency.

A future hypothetical adolescent resident may be the most likely individual to have regular exposure to sediment and surface water associated with WWTP3. It is not expected that adults would regularly visit the WWTP3 drainage ditches, as these areas do not support game fish and would seemingly not provide any attraction. It is unlikely that a young child (i.e., ages 1 through 6) would frequent these areas for substantial portions of time, because such young children (especially at the lower end of this age range) would require continued adult supervision. However, as described above, it is conservatively assumed that the resident will be regularly exposed to surface water and sediment for 30 years, 6 years assumed as a young child and 24 years assumed as an adult. For cancer effects, the 30-year exposure to surface water and sediment represented by both the young child and adult are combined. This approach is more conservative than evaluating an adolescent and is also consistent with BHHRAs performed for PBOW sites in the past.

With respect to groundwater exposure, it is assumed that a future hypothetical adult resident ingests 2 L/day of tap water (EPA, 1991a) and that the young child drinks 1 L/day (EPA, 2012c). The total body surface areas of the adult and of the young child resident are assumed to be exposed to tap water while bathing/showering. The total surface area for an adult is assumed to be 20,000 cm^2 and the total surface area for the young child is assumed to be 6,600 cm^2 (EPA, 1997a). Both the child and adult future hypothetical residents are assumed to be dermally exposed to COPCs in groundwater while bathing/showering. The child is assumed to bathe for 20 minutes per day (0.33 hour/day) (EPA, 1997a), and the adult is assumed to shower for 12 minutes per day (0.2 hour/day) (EPA, 1997a). Inhalation rates of 0.833 m^3/hr for the adult (EPA, 1991a) and 0.416 m^3/hr for the child (EPA, 2004d) are used. Because EPA (1997a) lists a 90th percentile for time spent in a residence as over 23 hours per day, it is conservatively assumed that the future hypothetical resident spends 24 hours per day in the house.

3.1.3.6 Future Hunter

This scenario is created to evaluate the potential for contaminants in soil to affect food chain pathways. WWTP3 provides habitat for deer and other wildlife. Even though hunting is not currently permitted at WWTP3, deer hunting is permitted in other areas within PBOW; therefore, future use of WWTP3 for hunting is evaluated in this BHHRA.

Many kinds of game animals may be hunted and consumed (e.g., squirrel, pheasant and other upland birds, turkey, deer); however, the deer is the species most likely to contribute meaningfully to the diet. Therefore, this evaluation is limited to a deer hunter. Potential exposure pathways include incidental surface soil ingestion, dermal contact with surface soil, and ingestion of venison from deer that browse plants growing on contaminated surface soil, all of which are evaluated quantitatively. Inhalation of airborne dust from wind currents is a potentially complete exposure pathway; however, vegetation reduces dust emissions to insignificant levels (EPA, 1996), and it is assumed that the deer hunter would spend virtually all of his time on vegetated rather than bare soil. Therefore, it is assumed that inhalation exposure would contribute much less than incidental ingestion, and the inhalation exposure pathway is not quantified separately from ingestion.

Inhalation exposure to airborne VOCs from subsurface soil and surface water is not evaluated for the reasons previously explained for other receptors. Also, ingestion and dermal exposure to surface water and sediment are expected to be negligible for this receptor, as contact with these media would generally be avoided during hunting activities.

The deer hunter is assumed to be a 70-kg adult who harvests deer and consumes venison over a 30-year period. It is assumed that he spends 14 days per year hunting on PBOW. His incidental soil ingestion rate is assumed to be 100 mg/day (EPA, 1991a). Hunting at PBOW occurs in the fall and winter. Given the temperate climate of northern Ohio during hunting season, a hunter would dress appropriately, with typically only the hands and head exposed, at most. The default industrial RME exposed skin surface area of 3,300 cm^2, which represents the hands, forearms, and head (EPA, 2004a), is conservatively assumed for the hunter. The default industrial RME soil AF of 0.2 mg/cm^2 (EPA, 2004a) is also assumed.

Data regarding the rate of venison ingestion were not located; therefore, a hypothetical scenario is adapted from the assumptions applied to a similar site in West Virginia (IT, 2000) and subsequently applied to TNTA and TNTC (IT, 2001a). A highly conservative but plausible scenario consists of a hunter who kills one deer from the WWTP3 property each year. It is assumed that the hunter eats 10 pounds (4.5 kg) of venison per year (Sharp, 1995). This

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

3.1.3.7 Future Hunter's Child

It is likely that a successful hunter, described in Section 3.1.3.6, would share his venison with the rest of the family, which may include small children. Small children, however, would be unlikely to accompany the hunter afield. Therefore, the direct exposure pathways evaluated for the hunter (i.e., incidental ingestion and dermal contact with soil) are not evaluated for the small child.

Data regarding the rate of venison ingestion by small children were not located. However, if it is assumed that venison may replace beef in the diet, the differences in beef consumption between adults and children can be used to estimate a venison ingestion rate for children. EPA (1997a) provides per capita beef intake data for <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-plus-year-old adults ranging from 0.568 to 0.83 g/kg-day (time-weighted average of 0.727 g/kg-day). From these data, it can be estimated that the rate of beef consumption for small children, expressed on a body weight basis, is approximately 1.8 times that of an adult. Therefore, a venison ingestion rate of 0.335 g/kg-day is estimated for a young child from the venison ingestion rate of 0.186 g/kg-day for the adult. Assuming that the child is 1 through 6 years old with an average body weight of 15 kg (EPA, 1991a; 2002), the child's venison ingestion rate may be expressed as 0.005 kg/day.

3.1.3.8 Other Receptors Not Considered

Another plausible receptor group is delivery personnel. These receptors, however, would be less intensively exposed to soil than the groundskeeper; therefore, their exposures are not evaluated. WWTP3 could become part of the area used for National Guard training activities. National Guard trainees, however, may be less exposed to any of the potentially contaminated media than the receptors identified above. Because they would likely not represent an upper bound for nonresidential exposure, these receptors are not evaluated. The WWTP3 drainage ditch does not support game fish. Therefore, fish ingestion as an indirect pathway for exposure to surface water and sediment is not evaluated. Also, as discussed in Section 3.1, off-site use of groundwater is not evaluated because nearby residents use municipal water from surface water sources as a potable source, and potential on-site users would be exposed to higher concentrations of contaminants in groundwater.

3.2 Quantification of Exposure-Point Concentrations

The EPC is an estimate of the concentration of a COPC in a given medium to which a receptor may be exposed over the duration of the exposure. An EPC may be based on chemical concentrations in media that have been directly measured using laboratory analysis, or it may be derived based on environmental medium-to-medium transport modeling. The EPCs of COPCs in soil, groundwater, surface water, and sediment are derived based on measured analytical data. Note that the EPC for dermal exposure to VOCs in groundwater is based on one-half the EPC derived from the measured concentrations in groundwater (Sections 3.2.1 and 3.2.2.3). This value is used because it is assumed that 50 percent of the groundwater VOC concentration is volatilized during normal household use (Section 3.2.2.2). Concentrations of COPCs in air and venison are not measured (and in some cases cannot reasonably be measured) but are based on models that use the EPCs of COPCs in the appropriate directly measured media (i.e., soil and groundwater) as input values.

Section 3.2.1 describes the approaches used to derive EPCs for direct exposure to soil, groundwater, surface water, and sediment based on analytical measurements from samples of these media. Models to derive EPCs for the air are described in Sections 3.2.2.1 and 3.2.2.2, and the model used to derive venison EPCs is described in Section 3.2.2.4.

3.2.1 Soil, Groundwater, Surface Water, and Sediment Concentrations

Exposure to an environmental medium is generally assumed to be random, and the EPC should be the arithmetic average encountered over the duration of exposure (EPA, 1989a). Therefore, the population mean concentration, if known, would be the ideal value selected as the EPC. The sample mean is an obvious estimate of the population mean. However, uncertainties exist as to how well the sample mean represents the population mean. Therefore, EPA (1989a) has recommended the inclusion of a UCL for RME evaluation as a conservative estimate of the true mean exposure concentration.

The EPA (2011; 2010a,b) ProUCL (Version 4.1) software was used to estimate UCLs for the data sets of all environmental media represented by at least five samples. If the data set consists of fewer than five data points, the MDC was selected as the EPC. Analytical data from field duplicates are averaged with originals to yield one result for use in the statistical manipulations (Section 2.5). One-half the reporting limit is used as the ProUCL input concentration for nondetects. Nondetect sample results with aberrantly high detection limits due to matrix interferences or other sample-specific causes are included in the initial ProUCL calculations. This is a conservative approach, as EPA (1989a) recommends that nondetect results with aberrantly high detection limits be removed from the data set so that calculation of the UCL is

not unduly skewed by a nondetect. Because the latest version of ProUCL (EPA, 2011) includes mathematical manipulations under the default "with NDs" mode that are more robust than previous versions, single elevated detection limits are less likely to skew the UCL estimates than in the past. If it is observed during the risk characterization that an elevated nondetect value skews a UCL estimate such that this value substantially affects the result of the risk estimate, the ProUCL model is rerun without the elevated nondetect value and the risks are recalculated. If this recalculation is performed on a data set, data eliminated for the recalculation are identified in the risk characterization and discussed in the uncertainty analysis. The re-evaluation of elevated nondetects was not performed in the WWTP3 BHHRA.

ProUCL generates a variety of UCL estimates for each data set. The ProUCL output for each COPC is included in Appendix B. Generally, the results of one or two (sometimes more) of the UCL estimates are recommended. This recommendation is based on a variety of factors, including the distribution (i.e., normal, lognormal, gamma, or not discernable) that provides the best fit, number of nondetects, size of the data set, and skewness. If the recommended value(s) under the default mode equals or exceeds the MDC, ProUCL is rerun using the full data set mode, under the assumption that the COPC is present in nondetects at one-half the reporting limit. Occasionally, ProUCL recommends the 97.5 or 99 percent upper confidence limit on the arithmetic mean estimated by the Chebyshev method. In these cases, the UCL estimated by the Chebyshev method (95th percent) is selected as the EPC because this is more consistent with the intent of the RME paradigm as defined by EPA (1989a; 1991a).

The UCL generated by the ProUCL protocol described in the preceding paragraphs or the MDC, whichever is smaller, is selected as the EPC and is understood to represent a conservative estimate of average for use in the risk assessment or in various transport models used to estimate EPCs. Note that EPA (1989a) guidance states that an estimate of average rather than the MDC should be used to represent the EPC under chronic exposure and that use of the maximum is typically not reasonable. Therefore, data sets which use the MDC as the EPC are generally biased high. Unusually high detected values are included in the calculation of the UCL concentration. Inclusion of these high values increases the statistical variability and the overall conservativeness of the risk estimate.

ProUCL is a software tool that provides estimates of the UCL using a variety of mathematical approaches. As mentioned, its output includes one or more recommendations. Depending on the data set, some of the estimates generated by the various calculation methods included in ProUCL may vary by an order of magnitude. ProUCL and the decision tree on which its recommendations are based have been developed using multitudes of simulated data sets with a variety of

distributions and other characteristics. There are uncertainties as to how well this decision tree derives a recommended UCL for a given data set. This uncertainty tends to increase with variability and skewness and where a large number of the samples are nondetects. For example, with respect to distribution testing, ProUCL bases the determination of distribution type only on the detected samples. The true concentrations of the nondetected values are unknown, and this lack of information can affect the distribution determination and consequently affect the ProUCL recommendation. The general uncertainties associated with the EPC values and the use of ProUCL are discussed in the uncertainty analysis (Chapter 6.0). Specific uncertainties associated with the EPC values of specific data sets may be discussed in the uncertainty analysis as appropriate.

3.2.2 Exposure-Point Concentrations in Air

The models shown in the following subsections for estimating COPC concentrations in air include only those relevant and used specifically for WWTP3 COPCs and media.

3.2.2.1 COPC Concentrations from Dust

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

$$C_a = (D)(C_s)(CF_1) \qquad \text{Eq. 3.1}$$

where:

- C_a = contaminant concentration in air (milligrams per cubic meter [mg/m^3], calculated)
- D = dust loading factor (grams [g] of soil/m^3 of air)
- C_s = contaminant concentration in soil (mg/kg)
- CF_1 = conversion factor (1E-3 kg per g).

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

Airborne concentrations of VOCs estimated by the dust loading model are 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 is more likely to be exposed to dust arising from wind erosion than from dust-raising activities on the site. EPA (1996) derived a model for estimating a dust particulate emission factor (PEF) based on an "unlimited reservoir" model and the assumption that the source area is square:

Eq. 3.2

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

where:

PEF	=	particulate emission factor (cubic meters per kilogram [m^3/kg], calculated)
Q/C	=	inverse of the mean concentration at center of square source (55.99 grams per square meter-second per kg/m^3, site-specific value from Table 3 in EPA [1996] [Zone 7, Cleveland, 5-acre site])
3600	=	seconds/hour
V	=	fraction of surface covered with vegetation (0.8, unitless, assumed)
U_m	=	mean annual wind speed (default, 4.60 meters per second [m/second] equals mean annual wind speed of 10.3 miles per hour [see Section 3.1.1])
U_t	=	equivalent threshold value of wind speed at 7 meters (default, 11.32 m/second)
F(x)	=	function dependent on U_m/U_t (default, 0.194).

The concentration of a COPC in air is calculated as follows:

Eq. 3.3

$$C_a = \frac{C_s}{PEF}$$

where:

C_a	=	contaminant concentration in air (mg/m^3, calculated)
C_s	=	contaminant concentration in soil (mg/kg)
PEF	=	particulate emission factor (m^3/kg).

Airborne concentrations of VOCs estimated by the wind erosion model are 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.

3.2.2.2 Concentrations in Household Air from Groundwater Use

The inhalation of VOCs released from groundwater, which is assumed to be used as tap water, is evaluated for the on-site residential scenario. Chemicals that have a Henry's Law value exceeding 1E-5 atmospheres/m^3-mole and a molecular weight less than 200 g/mole are considered to be VOCs and are subject to evaluation via this pathway; Henry's Law values and molecular weights are presented in Table 3-3. Other groundwater contaminants are considered 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 EPA (1991b) Human Health Evaluation Manual (HHEM) was used to evaluate the tap water-to-air pathway. This model was selected based on correspondence between OEPA (2004) and 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:

Eq. 3.4

$$C_a = C_{gw} \times K_{wa} \times 1{,}000 \, {}^{L}\!/_{m^3}$$

where:

C_a = modeled concentration in air (mg/m^3)
C_{gw} = groundwater EPC (mg/L)
K_{wa} = tap water-to-air volatilization constant (0.0005 [unitless]: [EPA, 1991b])

Implicit in the HHEM Part B application of this model are the following assumptions: 1) A family of four uses the groundwater as the sole source of household tap water, 2) the volume of the house is 150 m^3, 3) the daily groundwater use is 720 L/day, 4) 50 percent of VOCs in tap water volatilize to household air, and 5) the air exchange rate of the house is 0.25 volumes per hour (EPA, 1991b).

3.2.2.3 Concentrations of VOCs in Groundwater: Resident Dermal Uptake

Volatilization of VOCs from household water reduces the remaining concentration available for dermal contact. As mentioned in Section 3.2.2.2, 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:

Eq. 3.5

$$C_d = C_{gw} \times (1 - F_v)$$

where:

C_d = concentration of VOC in household water available for dermal exposure (mg/L, calculated)
C_{gw} = concentration of VOC in groundwater (mg/L)
F_v = fraction of VOCs volatilized to air, (0.5 unitless).

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

3.2.2.4 Exposure-Point Concentrations of COPCs in Venison

The hunter is assumed to harvest and consume game and share it with family members, including small children. The game is assumed to be venison, because the white-tailed deer is the species hunted most widely and most likely to provide a regular contribution to the diet. Data to reliably estimate contaminant concentrations in venison do not exist, but the following simplifying assumptions permit estimates sufficient for a BHHRA.

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

- Deer are expected to browse a much larger area than that encompassed in WWTP3; therefore, the fraction of total browse consumed from WWTP3 is expected to be relatively small.

- Indirect food chain pathways may be significant for some metals and for those semivolatile organic compounds that persist in the environment and have the tendency to bioaccumulate. VOCs are generally mobile in the environment and labile 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_r. This fraction reflects the areal portion of the site compared to a deer's home range area. These assumptions are captured in the following equation:

Eq. 3.6

$$B_v = 0.20(B_b)(FI_r)$$

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_r	=	areal portion of site compared to a deer's home range (0.03, unitless, see below)
B_b	=	biotransfer factor for beef.

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

The WWTP3 area is relatively small in comparison to the home range of a white-tailed deer. The total acreage of the WWTP3 study area is approximately 3 acres. The home range of the white-tailed deer is between 150 and 1,280 acres (Sample and Suter, 1994). Even if the low end of this range (150 acres) is assumed for deer in northern Ohio, the area represented by WWTP3 is approximately 2 percent of this land area. Although the use of FI_r equal to 0.02 or lower is justified, an FI_r value of 0.03 is used in the BHHRA to be consistent with other small sites evaluated at PBOW.

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

Eq. 3.7

$$C_p = (CF)(C_s)(B_p)$$

where:

C_p	=	concentration of contaminant in (plant) forage DM (mg/kg, calculated)
CF	=	conversion factor to adjust for soil containing 20 percent moisture (1.25, unitless).
C_s	=	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 are taken from the toxicity profiles in Appendix C. B_p values for the vegetative parts of plants, rather than the reproductive parts of plants, are selected, as possible, because deer browse year-round, and the vegetative parts are more available for the greater part of the year.

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

Eq. 3.8

$$C_v = (Q_p)(C_p)(B_v)$$

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 Intake

This section describes the models used to quantify doses or intakes of the COPCs by the exposure pathways identified above. Models were taken or modified from EPA (1989a) unless otherwise indicated.

3.3.1 Inhalation of COPCs in Air

The inhaled dose of a COPC in air (for the groundskeeper, construction worker, and on-site resident: inhalation of dust and VOCs in ambient air from surface or total soil; for the construction worker: inhalation of VOCs in ambient air from subsurface soil; for the indoor worker and on-site resident: inhalation of VOCs in indoor air from subsurface soil) is estimated as follows:

Eq. 3.9

$$I_a = \frac{(C_a)(FI_a)(IR_a)(EF)(ED)}{(BW)(AT)}$$

where:

I_a = inhaled dose of COPC (milligrams per kilograms per day [mg/kg-day], calculated)
C_a = concentration of COPC in air (mg/m^3)
FI_a = fraction of exposure attributed to site media (unitless)
IR_a = inhalation rate (m^3/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 or Sediment

The ingested dose of a COPC in soil (groundskeeper, construction worker, resident, indoor worker, hunter) or sediment (construction worker, resident) is estimated from the following equation:

Eq. 3.10

$$I = \frac{(C)(FI)(IR)(EF)(ED)(CF)}{(BW)(AT)}$$

where:

I = I_s for soil, I_{sd} for sediment, = ingested dose of COPC (mg/kg-day, calculated)
C = C_s for soil; C_{sd} for sediment; = concentration of COPC (mg/kg)
FI = FI_s for soil; FI_{sd} for sediment; = fraction of exposure attributed to site medium (unitless)
IR = IR_s for soil; IR_{sd} for sediment; = ingestion rate of medium (mg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
CF = conversion factor (1E-6 kg/mg)
BW = body weight (kg)
AT = averaging time (days).

3.3.3 Incidental Ingestion of COPCs in Water

The ingested dose of a COPC in groundwater (future groundskeeper, resident) is estimated from the following equation:

$$I_w = \frac{(C_w)(IR_w)(FI_w)(EF_w)(ED_w)}{(BW)(AT)} \qquad \text{Eq. 3.11}$$

where:

I_w = ingested dose of COPC in water (mg/kg-day, calculated)
C_w = concentration of COPC in water (mg/L)
IR_w = water ingestion rate (L/day)
FI_w = fraction of exposure attributed to site water (unitless)
EF_w = fraction of exposure attributed to site water exposure frequency (days/year)
ED_w = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

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

Unlike the methodologies for estimating inhaled or ingested doses of a COPC, 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 following equation (EPA, 2004a):

Eq. 3.12

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)}$$

where:

DAD = average dermally absorbed dose of COPC (mg/kg-day, calculated)
DA = dose absorbed per unit body surface area per day (milligrams per square centimeter per day [mg/cm^2-day])
SA = SA_s for soil, SA_{sd} for sediment, S_{gw} for groundwater, SA_{sw} for surface water, = surface area of the skin exposed (cm^2)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

Dose absorbed per unit body surface area per day (DA) is calculated differently for dermal uptake from soil/sediment and from water. Dermal uptake of constituents from soil (groundskeeper, construction worker, on-site resident, or hunter) or sediment (construction worker or on-site resident) assumes that absorption is a function of the fraction of a dermally applied dose that is absorbed. DA is calculated from the following equation (EPA, 2004a):

Eq. 3.13

$$DA = (C_s)(FI_s)(CF)(AF)(ABS)$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C = C_s for soil, C_{sd} for sediment, = concentration of COPC in medium (mg/kg)
FI = FI_s for soil, FI_{sd} for sediment, = fraction of exposure attributed to site medium (unitless)
CF = conversion factor (1E-6 kg/mg)
AF = AF_s for soil, AF_{sd} for sediment, = soil- or sediment-to-skin adherence factor (mg/cm^2-day)
ABS = absorption fraction (unitless, chemical-specific).

ABS values are provided in the toxicity profiles for each COPC (Appendix C).

Quantification of dermal uptake of constituents from groundwater (future groundskeeper or resident) or surface water (construction worker or resident) depends on a K_p, which describes the rate of movement of a constituent from water across the dermal barrier to the systemic circulation (EPA, 2004a). The equation for dermal uptake of chemicals from water is the same as the equation for dermal uptake of chemicals from soil (Eq. 3.12). DA is calculated differently for inorganic and organic chemicals in water. For inorganic chemicals, DA is calculated from the following equation:

Eq. 3.14

$$DA = (C_w)(FI)(K_p)(ET_w)(CF)$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C_w = concentration of COPC in water (mg/L)
K_p = permeability coefficient (centimeters per hour [cm/hr])
ET_w = time of exposure (hours/day)
CF = conversion factor (1E-3 liters per cubic centimeter [L/cm^3]).

K_p for organic chemicals varies by several orders of magnitude and is highly dependent on lipophilicity, expressed as a function of the octanol/water partition coefficient (EPA, 2004a). Because the stratum corneum (the outer skin layer) is rich in lipid content, it may act as a sink, initially reducing the transport of chemical to the systemic circulation. With continued exposure and the attainment of steady-state conditions, the rate of dermal uptake increases. Therefore, different equations are used to estimate DA, depending on whether the ET is less than or greater than the estimated time to reach steady state. Non-steady-state exposures occur either when the ET is relatively brief (e.g., showering, for most chemicals) or when intermittent exposure occurs throughout the day (e.g., wading exposure to surface water or washing of hands). For exposure scenarios under which steady state is not reached for a given organic chemical (τ> ET, see below), the following equation is used to calculate DA (EPA, 2004a):

Eq. 3.15

$$DA = 2(FA)(K_p)(C_w)(CF)\sqrt{\left(\frac{6\tau(ET_w)}{\pi}\right)}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C_w = C_{sw} for surface water, C_{gw} for groundwater, = concentration of COPC in water (mg/L)
FA = fraction absorbed from the water (unitless)

K_p = permeability coefficient (cm/hr)
CF = conversion factor (1E-3 L/cm^3)
τ = time for concentration of contaminant in stratum corneum to reach steady state per event (hours)
ET_w = time of contact (hour(s)/day).

In cases where steady state is reached (τ<ET), such as where the duration of a bath exceeds the time to reach steady state for a given organic compound, the following equation is used to calculate DA (EPA, 2004a):

Eq. 3.16

$$DA = (FA)(K_p)(C_w)(CF)\left[\frac{ET_w}{1+B} + 2\tau\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C_w = concentration of COPC in water (mg/L)
FA = fraction absorbed from the water (unitless)
K_p = permeability coefficient (cm/hr)
CF = conversion factor (1E-3 L/cm^3)
τ = time for concentration of contaminant in stratum corneum to reach steady state per event (hours)
ET_w = time of contact (hour[s]/day)
B = Ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (unitless).

Assuming one exposure event/day allows expressing ET as hour(s)/day, which preserves the dimensional integrity of the equation.

When available, values for K_p and τ are taken from EPA (2004a). For organics that have no K_p values listed, the values are calculated using the following equation (EPA, 2004a):

Eq. 3.17

$$\text{Log}(K_p) = -2.80 + 0.66(\log K_{ow}) - 0.0056(MW)$$

where:

K_p = permeability coefficient (cm/hr, calculated)
log K_{ow} = log of the octanol/water partition coefficient (unitless)
MW = molecular weight.

Where values for τ are not available, they were calculated using the following equation (EPA, 2004a):

Eq. 3.18

$$\tau = 0.105 \times 10^{(0.0056 \times MW)}$$

where:

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

Values of K_p and τ used in the BHHRA are summarized in Table 3-3 and documented in Appendix C.

3.3.5 Consumption of Venison

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

Eq. 3.19

$$I_v = \frac{(C_v)(IR_v)(EF)(ED)}{(BW)(AT)}$$

where:

I_v = ingested dose of COPC in venison (mg/kg-day, calculated)
Cv = concentration of COPC in venison (mg/kg)
IRv = venison ingestion rate (kg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

4.0 Toxicity Evaluation

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 sections.

4.1 Evaluation of Carcinogenicity

A few chemicals are known, and many more are suspected, to be human carcinogens. The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (EPA, 2005). The qualitative aspect is a weight-of-evidence evaluation of the likelihood that a chemical might induce cancer in humans. EPA (2005) recognizes five weight-of-evidence group classifications for carcinogenicity. Formerly, EPA (1986) used a letter-based system to describe the weight of evidence for carcinogenicity. Reference to this former system is included because many of the carcinogenicity assessments listed on the Integrated Risk Information System (IRIS) use the former letter-based system (EPA, 2012d). The five EPA weight-of-evidence classifications are as follows:

- ***Carcinogenic to Humans*** (corresponds to the former Group A - Human Carcinogen)
- ***Likely to be Carcinogenic to Humans*** (includes both the former Group B1 and Group B2 - Probable Human Carcinogens)
- ***Suggestive Evidence of Carcinogenic Potential*** (corresponds to the former Group C - Possible Human Carcinogen)
- ***Inadequate Information to Assess Carcinogenic Potential*** (corresponds to the former Group D - Not Classifiable as to Human Carcinogenicity)
- ***Not Likely to be Carcinogenic to Humans*** (corresponds to the former Group E - Evidence of Noncarcinogenicity to Humans).

The toxicity value for carcinogenicity, called a cancer slope factor (SF), is an estimate of potency. SFs are developed only for chemicals in the first three groups and only if the data are sufficient. The SFs are statistically derived from the dose-response curve from the best human or animal study or studies of the chemical. Human data are often considered to be more reliable than animal data because there is no need to extrapolate the results obtained in one species to another. Because human studies typically have limitations (e.g., uncertainties regarding exposure concentrations, durations, lack of experimental control, small sample sizes, and representativeness of the exposed population), most SFs are derived from animal data. Uncertainties associated with animal studies are further mentioned in the uncertainties analysis.

The SF is expressed as risk per mg/kg-day, shown mathematically as $(mg/kg\text{-}day)^{-1}$. To be appropriately conservative, the SF is usually the 95 percent upper bound on the slope of the dose-response curve extrapolated from high (experimental) doses to the low-dose range expected in environmental exposure scenarios. EPA (2005) assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk, however miniscule it may be.

The oral SF is usually derived directly from the experimental dose data, because oral dose is usually expressed as mg/kg-day. When the test chemical was administered in the diet or drinking water, oral dose first must be estimated from data for the concentration of the test chemical in the food or water, food or water intake data, and body weight data.

IRIS (EPA, 2012d) expresses inhalation cancer potency as a unit risk based on concentration, or risk per microgram of chemical per m^3 of ambient air, shown mathematically as (micrograms per cubic meter $[\mu g/m^3])^{-1}$. Because cancer risk characterization requires an SF expressed as risk per mg/kg-day, the unit risk must be converted to the mathematical equivalent of an inhalation cancer SF, or risk per unit dose as $(mg/kg\text{-}day)^{-1}$. Because the inhalation unit risk is based on continuous lifetime exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the unit risk (per $\mu g/m^3$) by 70 kg and by 1,000 micrograms per kilogram and dividing the result by 20 m^3 per day.

4.2 Evaluation of Noncarcinogenic Effects

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

- Qualitative identification of the adverse effect(s) associated with the chemical; these 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, with uncertainty of an order of magnitude or greater, at which adverse effects are not expected to occur. Mathematically, it is estimated as the ratio of the threshold dose to the UF. For purposes of risk assessment, chronic exposure is typically defined as equal to or greater than 7 years, i.e., at least 10 percent of expected life span; subchronic exposure is typically defined as 2 weeks to 7 years. However, professional judgment may be used where exposure durations approach 10 percent of the expected life span. Also, exposure during a critical stage of development, such as a portion of early childhood, may be treated as chronic even if the anticipated exposure duration is considerably less than 10 percent of the expected life span.

IRIS (EPA, 2012d) expresses the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m^3. Because noncancer hazard characterization requires a reference value expressed as mg/kg-day, the RfC must be converted to an inhalation RfD. Because the inhalation RfC is based on continuous exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion consists of multiplying the RfC (mg/m^3) by 20 m^3/day and dividing the result by 70 kg.

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

- If the UF applied in the derivation of the chronic RfD (or RfC) 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 (or RfC) 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 would be 10 times larger than the chronic RfD).

Only chronic RfDs and RfCs are used in the risk characterization of this BHHRA.

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 doses 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 HQ or hazard index (HI) values 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, because 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 all 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.

4.5 Sources of Toxicity Information Used in the Risk Assessment

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

- ***Tier 1*** values: IRIS (EPA, 2012d) database.
- ***Tier 2*** values: These are 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: These are 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 (2012) Office of Environmental Health Hazard Assessment Toxicity Criteria Database.

The Environmental Council of States-DoD (2007) has issued a toxicity value hierarchy that basically supports the EPA (2003) hierarchy presented previously but places higher emphasis on the necessity for external peer review.

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

- Oral absorption efficiency data compiled by the National Center for Environmental Assessment for the Superfund Health Risk Technical Support Center of EPA, as listed in EPA (2004a).
- 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 in deriving dermal toxicity values from oral toxicity values. Some of the GAF values are also listed on the RSL table (EPA, 2012a). 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.

Individual COPC-specific toxicity profiles, including sources of the toxicity and GAF values, are included in Appendix C for all of the COPCs evaluated in the BHHRA. Summary toxicity information sufficient to support the risk calculations, including toxicity values, GAFs, and target organs, are provided in Table 4-1.

5.0 Risk Characterization

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

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

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

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):

Eq. 5.1

$$ILCR = (CDI)(SF)$$

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 chronic daily intake (CDI) term in Equation 5.1 is equivalent to the "I" or "DAD" terms (intake or dose) in Equations 3.9 through 3.12 and 3.19 when these equations are evaluated for cancer intakes.

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

Eq. 5.2

$$ILCR = 1 - e^{[-(CDI)(SF)]}$$

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 negative of the risk calculated using Equation 5.1.

Because none of the COPCs had an ILCR greater than 1E-2 using Equation 5.1, it was not necessary to use Equation 5.2 for any of the WWTP3 COPCs. As a matter of policy, EPA (1986) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemicals' mechanisms of toxicity or sites of action (organs of the body). Cancer risk arising from exposure to multiple chemicals in a given exposure medium and pathway is estimated from the following equation (EPA, 1989a):

Eq. 5.3

$$ILCR_p = ILCR_{(chem1)} + ILCR_{(chem2)} + \cdots ILCR_{(chem\,i)}$$

where:

$ILCR_p$ = total pathway risk of cancer incidence, calculated
$ILCR_{(chem\ i)}$ = individual chemical cancer risk for the pathway.

The sum of the ILCRs summed across pathways is the total ILCR as shown in the following equation:

Eq. 5.4

$$Total\ ILCR = ILCR_{(p\,1)} + ILCR_{(p\,2)} + \cdots ILCR_{(p\,i)}$$

where:

Total ILCR = total incremental lifetime cancer risk across all pathways
$ILCR_{pi}$ = incremental lifetime cancer risks associate with pathway "*i*."

The total ILCR represents all additional cancer risks posed to a given receptor by contact with contaminants in site environmental media.

Total ILCRs in the range of 1E-6 to 1E-4 are regarded as acceptable (EPA, 1990); as mentioned in Section 2.4.1, this range is referred to as the "NCP risk management range." Risks less than this range are regarded as negligible. A target cancer risk goal of 1E-5 is used by OEPA and was selected by the PBOW Project Delivery Team as a basis to consider remedial action. Use of this 1E-5 goal represents a departure from the Army's practice of generally using a cancer risk exceeding a value of 1E-4 (the upper end of the NCP risk management range) to trigger remedial action considerations. Total ILCR values are rounded to one significant figure, consistent with EPA (1989a) guidance.

5.2 Noncancer Effects of Chemicals

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

Eq. 5.5

$$HQ = I \ / \ RfD$$

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).

The I term in Equation 5.5 is equivalent to the "I" or "DAD" terms (intake or dose) in Equations 3.9 through 3.12 and 3.19 when these equations are evaluated for noncancer intakes.

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 only that the estimated intake is 100 times lower than the RfD. An HQ of unity 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 the following equation:

Eq. 5.6

$$HI = HQ_1 + HQ_2 + \ldots HQ_i$$

where:

HI = hazard index (unitless, calculated)
HQ_i = hazard quotient for the ith chemical, or for the ith pathway.

A total HI is calculated as the sum of all HI values, including all media and all COPCs, for a given receptor. Calculating a total HI as the sum of HQ values is based on the assumption that the potential for noncancer effects is additive. EPA (1989a), however, acknowledges that the assumption of additivity is probably appropriate only for chemicals that induce adverse effects by the same mechanism (Section 4.4). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ.

A total target organ HI is calculated by summing the HI values (associated by target organ[s]), across exposure pathways as follows:

Eq. 5.7

$$Total\ Target\ Organ\ HI_a = HI_{p1-a} + HI_{p2-a} + \ldots HI_{pi-a}$$

where:

Total target organ HI_a = total hazard index for target organ "*a*" (unitless, calculated)
HI_{pi-a} = hazard index for target organ "*a*" via pathway "*i*."

HI values of 1 or less indicate that adverse noncancer health effects associated with that target organ of any individual under the exposure assumptions for that receptor are unlikely. If the total target organ HI exceeds a value of 1, then adverse noncancer health effects concerning that target organ and receptor cannot be regarded as unlikely. Total HI values (including those specific to target organs) are rounded to one significant figure or to the nearest whole number if greater than 1, consistent with EPA (1989a) guidance.

5.3 Risk Characterization Results

Cancer and noncancer risk characterization results were evaluated for each receptor and each environmental medium, using the methods described in Sections 5.1 and 5.2. The following sections describe the risk characterization results for each receptor associated with WWTP3. Risk summary tables are shown for each receptor as referenced. The detailed quantitative

evaluation tables that include the exposure equations presented in Chapter 3.0, and the risk characterization equations presented in Chapter 5.0 are provided in Appendix D. Analytical results used as input for the BHHRA are included as Appendix E.

Based on the risk characterization results presented in this section, a further evaluation of risks was performed with respect to the origin of the PAHs in soil. As described in Sections 5.3.1 and 5.3.5, the origin of PAHs in soil samples with the highest concentrations are likely unrelated to former DoD activities. Therefore, a re-evaluation of the risks associated with soil was performed (Section 5.4) that exclude three samples in which PAHs appear to be unrelated to DoD activities. Two of these samples were collected from immediately adjacent to the former neutralization tank that had been used by NASA as the K-Site control building and associated patio. This building and patio were demolished and removed by NASA in October 2012 (NASA, 2012). A third soil sample collected immediately adjacent to a former access road was also deleted as part of this re-evaluation of risks because it is regarded as anthropogenic background that originated from the asphalt and vehicle traffic.

5.3.1 Current Groundkeeper

The ILCR for the current groundskeeper (Table 5-1) exposed to surface soil both through direct contact and via inhalation of suspended particulates is estimated as 5E-5. This is within the 1E-6 to 1E-4 NCP risk management range but exceeds the PBOW cancer risk goal of 1E-5. Approximately 98 percent of this ILCR value is associated with exposure to PAHs in surface soil, and 67 percent of the total ILCR (3.3E-5) is associated with benzo(a)pyrene.

PAHs were not part of the TNT manufacturing waste stream; thus, their origin at WWTP3 is unclear. The sample collection logs indicate that the surface soil samples with elevated PAH concentrations contain both cinders and gravel. It is possible that both the cinders and gravel originate from materials used for the former WWTP3 access road and parking area. However, it is also possible that the PAHs originate from the burning of the former WWTP3 buildings. However, PAHs were not detected in the surface soil samples from boring SB-03, the only boring in which burnt wood was observed (and cinders were also observed in this boring); it is noted that low levels of PAHs were detected in the subsurface sample collected from SB-03 at 3 to 5 feet bgs. Thus, it is questionable that the PAHs observed at WWTP3 are associated primarily with burning of the buildings, or else it would seem that boring SB-03 should exhibit rather high concentrations of PAHs. Cinders have not been reported in the boring logs or sample collection logs of soil samples from other PBOW sites, including those at TNTC which had elevated concentrations of PAHs in soil (IT, 2001b). In summary, although the presence of cinders is associated with two of the surface soil samples with the highest PAH concentrations (SB-01 and

SB-02) and likely contributes to the PAH concentrations of these and other surface soil samples in which cinders have been observed (SB-6 and SB-07), it is unknown whether the cinders are the primary source of elevated PAHs in WWTP3 surface soil or are related to the burning of WWTP3 buildings.

Likely non-DoD-related sources exist for the three soil samples with benzo(a)pyrene concentrations exceeding 2 mg/kg, all of which are surface soil samples. Two of these samples were collected immediately adjacent to the former neutralization tank, which has been used by NASA as the K-Site control building and associated patio. The surface soil sample from SB-01 (10.0 mg/kg benzo[a]pyrene) was collected just south of the control building patio, and the surface soil from SB-02 (2.41 mg/kg benzo[a]pyrene) was collected just south of the control building patio (Figure 1-3). During a May 2011 site visit, a gas grill was located on the small patio outside the building, within approximately 20 feet of boring SB-02. This grill was also observed during a 2009 reconnaissance. It is possible that the grill may be a source of PAHs at the SB-01 and SB-02 locations, although no evidence was observed that the grill was cleaned immediately near either of these sampling locations. Another possible source for the PAHs at SB-01 is a utility pole immediately adjacent to this sampling location; PAHs associated with the preservative treatment used on the pole may over time have made their way to the soil. The K-Site control building and associated patio were demolished and removed by NASA in October 2012. Contaminated soils (Figure 5-1) identified during the performance of this BHHRA were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012).

The third sample with elevated PAH concentrations is LSI sample SSW303, located immediately east of the current road (Figure 1-3), which had a benzo(a)pyrene concentration of 4.2 mg/kg. It is likely that asphalt and possibly vehicle traffic represent sources of PAHs at this sample location. PAHs were present in other samples, but at lower concentrations. Please refer to Section 5.4 for further evaluation of cancer risks associated with soils, excluding these non-DoD sources.

The total HI for the current groundskeeper (Table 5-1) is 0.07. This is less than the target HI value of 1, indicating that noncancer health effects are unlikely to occur.

5.3.2 Future Groundskeeper

The exposure assumptions for the future groundskeeper differ from those of the current groundskeeper (Section 5.3.1) in that the future groundskeeper is assumed to be exposed to total soil rather than surface soil, and the future groundkeeper is also assumed to be exposed to

groundwater via direct contact (ingestion and dermal exposure). The risk characterization was run separately for bedrock groundwater exposure and overburden (well) groundwater exposure.

Bedrock Groundwater Use. The total ILCR for the future groundskeeper, assuming hypothetical bedrock groundwater use, is 4E-4 (Table 5-1). This value exceeds both the NCP risk management range and the PBOW target cancer risk goal of 1E-5. Approximately 96 percent of this ILCR is associated with arsenic (4.0E-4) in groundwater. Benzene (2.1E-6) in bedrock groundwater also contributed to the ILCR, but its contribution was over two others of magnitude less than that of arsenic in groundwater.

Arsenic was detected in each of the three bedrock groundwater samples collected in May 2009 but was not detected in any of the three bedrock groundwater samples collected in November 2009. Because of insufficient water yield, none of these six groundwater samples could be collected using the low-flow method, and all except for the November 2009 sample from WTP3-BEDGW-003 were collected by bailer. The bailer method tends to resuspend sediments, resulting in elevated inorganics concentrations. With the exception of the November 2009 sample from WTP3-BEDGW-002 (11.6 nephelometric turbidity units [NTU]), the bailed samples yielded rather high turbidities, ranging from 36 to 217 NTUs (Shaw, 2011).

Benzene is a petroleum constituent that is known to be naturally occurring in the limestone groundwater at PBOW (Shaw, 2006). As described in Section 3.1.1.2, petroleum hydrocarbon staining was observed at depth during the drilling of all three WWTP3 wells, One of these wells, WWTP3-BEDGW-002, also exhibited high levels of hydrogen sulfide (above 200 ppm). These observations provide evidence that petroleum hydrocarbons and elevated levels of hydrogen sulfide are naturally occurring in this area of PBOW.

The low yield for WWTP3, as well as the presence of naturally occurring petroleum, indicates that potable use by a site worker is not a plausible exposure pathway. In addition, the arsenic present in the WWTP3 bedrock groundwater appears to be unrelated to PBOW activities based on the following observations:

- Arsenic was detected within background concentrations in the overlying WWTP3 soil samples. The MDC (20.8 mg/kg) and mean concentration (7.32 mg/kg) of arsenic in total soil are both less than those of PBOW background data set (36.5 and 10.1 mg/kg, respectively).

- Arsenic is not a component of any waste stream related to TNT manufacturing.

The ILCR for the future groundskeeper without the contributions of groundwater is 1E-5 (Table 5-2), which is within the NCP cancer risk management range and equals the 1E-5 PBOW cancer risk goal.

The total HI for the future groundskeeper (Table 5-1) is 4. This exceeds the target HI value of 1, which would seem to indicate that noncancer health effects cannot be regarded as unlikely to occur. Virtually all this HI is associated with the hypothetical use of bedrock groundwater, which alone represents an HI of 4 (3.5 prior to rounding). As discussed previously for cancer risk to the future groundskeeper, WWTP3 groundwater is not present in sufficient quantity for use. Also, note that approximately 70 percent of this HI value is associated with arsenic (HQ=2.5) in groundwater. As stated previously, arsenic does not appear to be associated with former PBOW operations and was only detected in the May 2009 groundwater samples.

As discussed previously for cancer effects, arsenic soil concentrations were within background levels.

If the contributions of groundwater pathways are appropriately excluded for this receptor based on low water yield and in recognition that the majority of the noncancer hazards are associated with naturally occurring constituents, the resulting HI for this receptor is 0.05 (Table 5-2). This is less than the target HI criterion of 1, indicating that this receptor is unlikely to encounter adverse noncancer health effects.

Overburden Groundwater Use. The total ILCR for the future groundskeeper, assuming hypothetical use of overburden groundwater, is 9E-5 (Table 5-1). This value is within the NCP risk management range but exceeds the PBOW target cancer risk goal of 1E-5. Approximately 82 percent of this value is associated with exposure to arsenic (ILCR=7.0E-5) in groundwater.

Arsenic was detected in three of the six overburden groundwater samples. Each of the six overburden well samples had to be collected by bailer because of insufficient water yield for low-flow sampling. The MDC (15.8 µg/L) was detected in the November 2009 sample from WTP3-MW01, and this sample also had the highest turbidity among the overburden monitoring well samples (36.5 NTUs). The filtered November 2009 sample from this well had a lower arsenic concentration (5.9 µg/L), which was within the range of PBOW bedrock background groundwater. Arsenic was not detected in the May 2009 sample from this well and had a much lower turbidity (3.2 NTUs). Arsenic was also detected in both samples from WTP3-MW02 at a concentration of 10.4 µg/L. The agitation associated with sampling by bailer suspends sediments

in the water sample , resulting in elevated concentrations of inorganics in water samples that are unrepresentative of actual groundwater concentrations under undisturbed conditions.

As mentioned in the discussion of bedrock groundwater, the MDC and mean concentrations of arsenic in soil are less than those of the PBOW background soil data set. Based on the lack of elevated arsenic concentrations in overlying soil and the knowledge that arsenic is not a component of any known waste stream, the presence of arsenic in overburden groundwater does not appear to be related to any former site operations.

Because the WWTP3 overburden monitoring wells could not be sampled using the low-flow method, the WWTP3 overburden water-bearing unit is thus interpreted as having insufficient production for use as tap water. Also, use of the bailer method may result in a nonrepresentative groundwater sample with inorganics concentrations that are biased high. Therefore, inclusion of the groundwater use pathway exaggerates exposure of this receptor to WWTP3 contamination.

If groundwater use is appropriately excluded for this receptor in recognition that virtually all of the cancer risks are associated with naturally occurring constituents, then the resulting ILCR is 1E-5 (Table 5-2). This is within the NCP risk management range and equals the PBOW cancer risk goal.

The total HI for the future groundskeeper, assuming hypothetical use of overburden groundwater, is 1 (Table 5-1). This equals the target HI criterion of 1, indicating that noncancer health effects are regarded as unlikely to occur under this scenario. If groundwater exposure pathways are appropriately excluded for this receptor because of low groundwater yield and because the majority of noncancer hazards are associated with naturally occurring constituents as described previously, the HI (0.05) is even lower (Table 5-2).

5.3.3 Future Indoor Worker

The exposure assumptions for the future indoor worker include direct contact with surface soil, inhalation of volatiles from subsurface soil, and direct exposure with groundwater via direct contact (ingestion and dermal exposure). The risk characterization was run separately for bedrock groundwater exposure and overburden (well) groundwater exposure.

Bedrock Groundwater Use. The total ILCR for the future indoor worker, assuming hypothetical bedrock groundwater use, is 4E-4 (Table 5-1). This value exceeds both the NCP risk management range and the PBOW target cancer risk goal of 1E-5. Approximately 96 percent of this ILCR is associated with arsenic (4.0E-4) in groundwater. Benzene (2.1E-6) in bedrock

groundwater also contributed to the ILCR, but its contribution was over two orders of magnitude less than that of arsenic in groundwater. As discussed in Section 5.3.2, the presence of elevated arsenic detections in WWTP3 bedrock groundwater does not appear to be related to former site activities. Benzene is associated with naturally occurring petroleum hydrocarbons, and the bedrock groundwater underlying WWTP3 would not yield sufficient volume for tap water use.

The ILCR for the future indoor worker is 1E-5 if the contribution of bedrock groundwater is appropriately excluded because of low yield and in recognition that virtually all of the noncancer hazards are associated with naturally occurring constituents (Table 5-2). This value is less than the NCP risk management range and equals the PBOW 1E-5 cancer risk goal.

The total HI for the future indoor worker (Table 5-1) is 3 (3.49, prior to rounding). This exceeds the target HI value of 1, which would seem to indicate that noncancer health effects cannot be regarded as unlikely to occur. Virtually all of this HI is associated with the hypothetical use of bedrock groundwater, nearly all of which is associated with arsenic (HQ=3.47. prior to rounding). If the contributions of hypothetical bedrock groundwater are excluded because of low yield and naturally poor quality as described in Section 5.3.2, the resulting HI for the indoor worker is 0.02 (Table 5-2). This is far less than the target criterion of 1 and suggests that adverse noncancer health effects are unlikely.

Overburden Groundwater Use. The total ILCR for the future indoor worker, assuming hypothetical use of overburden groundwater, is 8E-5 (Table 5-1). This value is within the NCP risk management range but exceeds the PBOW target cancer risk goal of 1E-5. Approximately 85 percent of this value is associated with exposure to overburden groundwater, and approximately 84 percent of this value is associated with exposure to arsenic (ILCR=7.0E-5) in groundwater. As described in Section 5.3.2, arsenic does not appear to be associated with former PBOW operations. Further, Section 5.3.2 describes that the volume of water in the overburden unit underlying WWTP3 would not provide enough yield for tap water use.

If the contributions of hypothetical groundwater exposure pathways are excluded because of low yield and because virtually all groundwater cancer risks are associated with naturally occurring background chemicals, the resulting ILCR for this receptor is 1E-5. This value is within the NCP risk management range and equals the PBOW cancer risk goal.

The total HI for the indoor worker is 1, assuming hypothetical use of overburden groundwater (Table 5-1). This equals the target HI criterion of 1, indicating that noncancer health effects are regarded as unlikely to occur under this scenario. If groundwater exposure pathways are

appropriately excluded for this receptor because of low groundwater yield as described previously, the HI (0.02) is even lower.

5.3.4 Current/Future Construction Worker

The construction worker is assumed to be exposed to total soil through direct contact and via inhalation of suspended particulates, and to sediment and surface water via direct contact. The ILCR for the WWTP3 construction worker (Table 5-1) is estimated as 1E-6. This represents the lower end of the 1E-6 to 1E-4 NCP risk management range and is less than the PBOW cancer risk goal of 1E-5.

The total HI for the construction worker (Table 5-1) is 0.9. This is less than the target HI value of 1. Therefore, noncancer health effects are regarded as unlikely to occur.

5.3.5 Future Hypothetical Resident

The exposure assumptions for the future hypothetical resident include direct contact with total soil, inhalation of particulates from total soil, inhalation of volatiles from subsurface soil, direct exposure to sediment and surface water (ingestion and dermal exposure), and direct exposure with groundwater via direct contact (ingestion and dermal exposure). The risk characterization was run separately for bedrock groundwater exposure and overburden (well) groundwater exposure. The ILCR was calculated assuming exposure during a combined 30-year child/adult exposure duration, whereas separate noncancer HI values were calculated for the young child and adult life stages (Section 3.1.3.5). The results of each are described below.

Bedrock Groundwater Use. The total ILCR for the future hypothetical resident, assuming bedrock groundwater exposure, is 2E-3 (Table 5-1). This value exceeds both the NCP risk management range and the PBOW target cancer risk goal. Approximately 97 percent of this ILCR is associated with arsenic (1.7E-3), benzene (3.0E-5), and naphthalene (1.8E-5) in groundwater. As discussed in Section 5.3.2, the presence of elevated arsenic in WWTP3 bedrock groundwater appears to be unrelated to former site activities; benzene is a petroleum constituent that is known to be naturally occurring in the limestone groundwater at PBOW (Shaw, 2006), and during well installation, petroleum hydrocarbon staining was observed at depth in all three WWTP3 wells. Naphthalene is also a naturally occurring constituent in petroleum. Evidence that the naphthalene found in WWTP3 bedrock groundwater is not related to PBOW activities includes the following observations: 1) Naphthalene and other petroleum-related compounds were not detected in the overlying overburden groundwater, and 2) naphthalene was not identified as a soil COPC. Additionally, as discussed in Section 5.3.2, bedrock groundwater underlying WWTP3 does not provide adequate yield for tap water use.

If the bedrock groundwater use is appropriately excluded because of low yield and in recognition that virtually all cancer risks are related to naturally occurring constituents, the ILCR for the future hypothetical resident is 5E-5 (Table 5-2). This value is within the NCP risk management range but exceeds the PBOW 1E-5 cancer risk goal.

Approximately 95 percent of this value (4.9E-5) is associated with PAHs in total soil, which includes both surface and subsurface soil. The five highest concentrations and most of the detections were found in surface soil. As discussed in Section 5.3.1, the origin of the PAHs at WWTP3 is unclear, as PAHs were not part of the TNT manufacturing waste stream. The sample collection logs indicate that the surface and near-surface soil samples with elevated PAH concentrations contain both cinders and gravel. It is possible that both the cinders and gravel originate from materials used for the former WWTP3 access road and parking area. It is also possible that the PAHs originate from the burning of the former buildings. However, PAHs were not detected in the surface soil samples from boring SB-03, the only boring in which burnt wood was observed (cinders were also observed in this boring); it is noted that low levels of PAHs were detected in the subsurface sample collected from SB-03 at 3 to 5 feet bgs. Thus, it is questionable that the PAHs observed at WWTP3 are associated primarily with burning of the buildings or else the surface soil sample from boring SB-03 (and possibly the SB-03 3 to 5 feet bgs sample) would be expected to exhibit rather high concentrations of PAHs. Cinders have not been reported in the boring logs or sample collection logs of soil samples from other PBOW sites, including those at TNTC with elevated PAHs (IT, 2001b). In summary, it is unknown whether the cinders are associated with the burning of former WWTP3 buildings or if they are the primary source of elevated PAHs in WWTP3 surface soil.

The K-Site control building and associated patio were demolished and removed by NASA in October 2012. Contaminated soils identified during the performance of this BHHRA were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012). The former K-Site control building area includes the samples with the highest and third highest PAH concentrations. Therefore, risks associated with soil were re-evaluated for this receptor excluding these two samples, which are in the area of NASA responsibility that has been excluded from the DERP-FUDS project, as well as a third sample that was collected immediately adjacent to a former access road. The results of this evaluation are presented in Section 5.4.

The total HI for the future hypothetical child resident, assuming bedrock groundwater exposure, is 25 (Table 5-1). This exceeds the target HI value of 1, indicating that noncancer health effects

cannot be regarded as unlikely to occur. Virtually all of this HI is associated with exposure to bedrock groundwater, and approximately 95 percent of the groundwater HI value is associated with arsenic (HQ=16.4), naphthalene (HQ=0.7), benzene (HQ=0.6), and xylenes (HQ=0.3). Arsenic, benzene, and naphthalene are discussed above, with respect to cancer risks, as unrelated to former site operations. Xylenes are a component of naturally occurring petroleum, similar to benzene and naphthalene. Xylenes appear to be unrelated to former PBOW activities based on the observations that xylenes were not detected in the overlying overburden unit or in WWTP3 soil. In addition, the cyanide concentrations in groundwater result in an HQ of 4.5 for this receptor. Cyanide is not known to be part of the TNT manufacturing waste stream, so its presence is not likely to be site related. Regardless of its source, the cyanide MDC in bedrock groundwater is substantially less than the maximum contaminant level of 200 µg/L (EPA, 2012a).

As discussed in Section 5.3.2, bedrock groundwater underlying WWTP3 does not provide adequate yield for potable use, and the large majority of the bedrock groundwater HI is associated with non-site-related chemicals in groundwater. Therefore, if the contribution of bedrock groundwater is appropriately excluded, the resultant HI for the future hypothetical child resident is 0.7 (Table 5-2). This is less than the target HI, indicating that adverse noncancer health effects are unlikely to result from exposure by the future hypothetical child resident receptor to WWTP3 total soil, sediment, and surface water.

The total HI for the future hypothetical adult resident, assuming bedrock groundwater exposure, is 10 (Table 5-1). This exceeds the target HI value of 1, indicating that noncancer health effects cannot be regarded as unlikely to occur. Similar to the future hypothetical child resident discussed previously, virtually all of this HI is associated with exposure to bedrock groundwater, and over 75 percent of the groundwater HI value is associated with arsenic (HQ=7.0) and petroleum-related benzene (HQ=0.2), naphthalene (HQ=0.3), and xylenes (HQ=0.1). Additionally, cyanide in groundwater contributes an HQ of 2.0, which exceeds the target value of 1. These four compounds are discussed for the future hypothetical child resident above as unrelated to former site activities. Also, as discussed in Section 5.3.2, bedrock groundwater underlying WWTP3 provides insufficient yield to be considered as a source of residential tap water. Therefore, the contribution of bedrock groundwater may be appropriately excluded.

If the contributions of groundwater are excluded, the resultant HI for the hypothetical future adult resident is 0.1 (Table 5-2). This is less than the target HI, indicating that adverse noncancer health effects are unlikely to result from exposure by the hypothetical future adult resident receptor to WWTP3 total soil, sediment, and surface water.

Overburden Groundwater Use. The total ILCR for the future hypothetical resident, assuming overburden groundwater exposure, is 3E-4 (Table 5-1). This value exceeds both the NCP risk management range and the PBOW target cancer risk goal. Approximately 86 percent of this value is associated with exposure to overburden groundwater, virtually all of which is associated with exposure to arsenic (ILCR=2.9E-4) in groundwater. As described in Section 5.3.2, arsenic does not appear to be associated with former PBOW operations. Further, Section 5.3.2 describes that the volume of water in the overburden unit underlying WWTP3 would not provide enough yield for tap water use.

If the contributions of hypothetical groundwater exposure pathways are appropriately excluded, the resulting ILCR for this receptor is 5E-5. This value is within the NCP risk management range but exceeds the PBOW cancer risk goal. Approximately 95 percent of this ILCR value is associated with exposure to total soil, and approximately 90 percent of the total ILCR value is associated with PAHs in soil. As described previously under the "Bedrock Groundwater Use," heading for this receptor, the source of these PAHs is uncertain but may be related to cinders, which possibly were part of the former road base.

The total HI for the future hypothetical child resident, assuming overburden groundwater exposure, is 7 (Table 5-1). This exceeds the target HI value of 1, which would seem to indicate that noncancer health effects cannot be regarded as unlikely to occur. Approximately 91 percent of this HI is associated with exposure to overburden groundwater, and approximately 60 percent of the total HI is associated with arsenic in groundwater (HQ=2.9). As described in Section 5.3.2, arsenic concentrations in overburden groundwater do not appear to be related to former PBOW activities. Also, cyanide (HQ=2.0) accounted for approximately 30 percent of the groundwater HI for this receptor. Cyanide is not known to be part of the TNT manufacturing waste stream, so its presence is not likely to be site related. Regardless of its source, the cyanide (23 µg/L) MDC in overburden groundwater is an order of magnitude less than the maximum contaminant level of 200 µg/L (EPA, 2012a).

If the groundwater pathway is appropriately excluded based on chemicals responsible for the majority of the risk being unrelated to former DoD activities and insufficient groundwater yield, then the total HI for the future hypothetical child resident exposed to WWTP3 total soil, sediment, and surface water is 0.7 (Table 5-2). This value is less than the target HI criterion of 1, indicating that adverse noncancer health effects are unlikely.

The total HI for the future hypothetical adult resident, assuming overburden groundwater exposure, is 3 (Table 5-1). This exceeds the target HI value of 1, which indicates that noncancer health effects are not regarded as unlikely to occur. As discussed above for the future hypothetical child resident, most of the contribution to this HI is associated with arsenic and cyanide in overburden groundwater, which appear to be unrelated to former PBOW activities. Further, overburden groundwater would not provide adequate yield for tap water use. Thus, the contribution of the groundwater exposure may be appropriately excluded to evaluate for potential DoD-related hazards. The resultant total HI for the future hypothetical adult resident exposed to WWTP3 total soil, sediment, and surface water is 0.1 (Table 5-2), which is less than the target HI criterion of 1.

5.3.6 Future Adult Hunter

The ILCR for the adult hunter (Table 5-1) exposed to surface soil both through direct contact and via the ingestion of venison is estimated as 3E-6. This is within the 1E-6 to 1E-4 NCP risk management range and is less than the PBOW cancer risk goal of 1E-5.

The total HI for the adult hunter is (Table 5-1) is 0.004. This is far less than the target HI value of 1, indicating that noncancer health effects are unlikely to occur.

5.3.7 Future Hunter's Child

The ILCR for the hunter's child (Table 5-1) exposed to surface soil via the ingestion of venison from deer which grazed on site is estimated as 2E-10. This is less than both the 1E-6 to 1E-4 NCP risk management range and the PBOW cancer risk goal of 1E-5.

The total HI for the hunter's child (Table 5-1) is estimated at 0.00004. This value is far less than the target HI criterion of 1 and indicates that noncancer health effects are unlikely to occur.

5.4 Re-Evaluation of Cancer Risks Associated with PAHs

Cancer risks associated with exposure to soil were found to exceed the PBOW cancer risk goal for the current groundskeeper (surface soil ILCR=5E-5) and for the future hypothetical resident (total soil ILCR=5E-5), as described in Sections 5.3.1 and 5.3.5, respectively. As discussed in these sections, virtually all of the cancer risks associated with soils for these receptors result from the contributions of PAHs, the highest concentrations of which are likely unrelated to former DoD activities. Therefore, a re-evaluation of the risks associated with soil were performed for the current groundkeeper and the future hypothetical resident that excludes three samples with elevated PAH concentrations in which PAHs appear to be unrelated to DoD activities.

Two of these samples were collected from the former neutralization tank that has been used by NASA as the K-Site control building and associated patio. The K-Site control building and associated patio were demolished and removed by NASA in October 2012. Contaminated soils identified during the performance of this BHHRA were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012). A third soil sample collected immediately adjacent to a former access road was also deleted as part of this re-evaluation of risks because it is regarded as anthropogenic background that originated from the asphalt and vehicle traffic.

The re-evaluated ILCRs for the current groundkeeper and future hypothetical resident based on exclusion of these three high-PAH surface soil samples are shown in Table 5-3. Similar to Table 5-2, the values in Table 5-3 assume no exposure to WWTP3 groundwater. The re-evaluated ILCR for the current groundskeeper is 7E-6, which is less than the PBOW cancer risk goal. All of this value is associated with exposure to surface soil. The re-evaluated ILCR for the future hypothetical resident equals the PBOW cancer risk goal of 1E-5; the re-evaluated ILCR for total soil alone is also 1E-5, as exposure to sediment and surface water contribute relatively little to the overall ILCR.

COPC summary tables, cancer risk calculation tables, and ProUCL input/output based on the exclusion of these three samples are provided in Appendix F. The amended ILCR results for all applicable receptors are provided in Appendix F as ancillary information, but because the ILCR values of these other receptors meet the PBOW ILCR risk goal without excluding the three highest PAH concentrations as presented in Section 5.3, the re-evaluation results of these other receptors are not discussed.

6.0 Uncertainty Analysis

The primary objective of the BHHRA is to characterize and quantify potential human health risks. However, these risks are estimated using incomplete and imperfect information that introduces uncertainties at various stages of the risk assessment process. Uncertainties associated with earlier stages of the risk assessment become magnified when they are linked with other uncertainties in the latter stages. Reliance on a simplified numerical presentation of dose rate and risk without consideration of uncertainties, limitations, and assumptions inherent in their derivation can be misleading. For example, the calculated ILCR for a given scenario "A" may be 1E-5 (meets the PBOW risk goal) and that of scenario "B" may be 5E-5 (exceeds the PBOW risk goal). However, if the uncertainties associated with scenario "B," for instance, span orders of magnitude and the ILCR is regarded as biased high, it is not unlikely that scenario "A" actually presents a higher risk of developing cancer.

The chief goal of this analysis is to evaluate uncertainties and present them in context of their potential impact on the interpretation of the risk assessment results and the types of environmental management decisions that may be based on these results. The uncertainty analysis does not exhaustively describe all potential uncertainties but presents those that have the largest implications for the interpretation of the risk assessment results. This analysis also summarizes the types and, as applicable, the magnitude of the uncertainties at each stage of the risk assessment. Although the discussion in the following sections includes generic uncertainties that are common to the state of human health risk assessment practice overall (e.g., additivity of health effects in the risk characterization), the uncertainty analysis focuses on the sets of uncertainties that are specific to WWTP3.

6.1 Types of Uncertainty

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

6.2 Sources of Uncertainty

The discussion in the following subsections provides an overview of uncertainty, with a focus on those sources that are most likely to affect interpretation of the risk assessment results.

6.2.1 Sample Selection

Soil samples were collected from within the former WWTP3, where TNT manufacturing process waste water was treated. The monitoring well locations were selected from within WWTP3. The surface water and sediment samples were collected from appropriate locations within the WWTP3 area, along the adjacent drainage ditch. The sample locations, described further in the final site characterization report (Shaw, 2011) appear to be representative of the site, and no information suggests that they have introduced an identifiable bias.

6.2.2 Laboratory Analysis

State-of-the-practice SW-846 laboratory methods were used for analysis of the RI samples (Shaw, 2011). Site investigation samples, also used in this BHHRA, were collected in 1999 (USACE, 2000). No laboratory analytical data quality issues were identified that affected the BHHRA results.

6.2.3 Exposure-Point Concentration Estimates

Uncertainty is introduced in the statistical approach used to calculate the EPCs. As stated in the HHEM (EPA, 1989a), the average concentration of the site should be used as the concentration term. Generally, a UCL is used to account for the uncertainty of using a sample data set to estimate the true population mean concentration for the site. ProUCL Version 4.1 software (EPA, 2011) was used to calculate the EPCs for those media with five or more samples. However, as is readily observed by reviewing the ProUCL output (Appendix B), the calculation of the UCL can vary with statistical methodology. It is unclear whether the UCL value of a specific EPC would result in an underestimate or overestimate of the true population mean. However, the general use of a UCL on all the data sets as a single estimator of average concentration, even given the uncertainty as to whether a given method provides full distribution coverage at 95 percent confidence, would result in general overestimation of the population mean and associated risks. Therefore, as intended by the guidance (EPA, 1989a), the practice of using the UCL as the EPC (note that the MDC is used as the EPC if the UCL exceeds the MDC) introduces bias that tends to overestimate the population mean and the resultant risk values.

Sediment and surface water data sets have fewer than five samples. Thus, the MDC was used as the EPC for these data sets. Use of the MDC likely introduces a high bias to the risk values.

6.2.4 Land-Use Assumptions/Receptor Selection

The current groundskeeper is intended to represent an on-site worker under the current land use as NASA-controlled property. Because there is currently no identified NASA activity other than mowing at WWTP3, the use of this receptor likely overestimates risks and hazards to a current site worker. The assumed future use of the hunter and the hunter's child are reasonable, as other areas within PBOW may currently be legally hunted by permit.

Unrestricted land use, including residential use, is a reasonable assumption for the future WWTP3, given the residential use of property adjacent to the PBOW facility. The assumption that either the overburden or bedrock groundwater will be used as a potable water source in the future is regarded as implausible for reasons described in Section 6.2.5.

6.2.5 Groundwater Use

The use of WWTP3 bedrock groundwater is regarded as unlikely because it contains natural petroleum and hydrogen sulfide, which can be commonly observed in area quarries (Shaw, 2005). Petroleum was observed at depth in the rock cores of all three monitoring wells (Shaw, 2011). One of these WWTP3 wells, WWTP3-BEDGW-002, also exhibited high levels of hydrogen sulfide (above 200 ppm), which supports the assumption that bedrock groundwater in the general vicinity of WWTP3 is of naturally poor quality. Additionally, none of the three WWTP3 bedrock wells could be sampled using low-flow sampling methodology. The lack of sufficient groundwater to perform low-flow sampling indicates insufficient yield for tap water use, because potable wells need to provide a flow rate that is orders of magnitude greater than that needed for low-flow sampling.

The WWTP3 overburden groundwater has been found to be of low yield, and the overburden groundwater is regionally and seasonally discontinuous throughout much of PBOW (Shaw, 2006). Based on the results of the three WWTP3 overburden wells (Shaw, 2011), this discontinuity also appears to be true of WWTP3, as none of the three WWTP3 overburden groundwater monitoring wells could be sampled using low-flow sampling but had to be collected by bailer. The lack of sufficient groundwater indicates insufficient yield for tap water use.

In summary, use of the bedrock groundwater and overburden groundwater as a potable source at WWTP3 is regarded as implausible for the following reasons: 1) Both bedrock and overburden groundwater yield water volumes that are clearly insufficient; 2) bedrock groundwater has naturally occurring petroleum and hydrogen sulfide constituents that make the water unsuitable for potable or industrial use (Section 6.2.10), regardless of yield; 3) this poor bedrock quality is

associated with the presence of hydrogen sulfide off-gassing, a concern with respect to nuisance odors and potential health issues; 4) no residential wells in the area have been identified as potable; and 5) municipal water is available in the area.

6.2.6 Exposure Assumption Values

The exposure assumption values used in the exposure assessment (Table 3-1) are selected to represent either an upper bound (e.g., 95th percentile) or mid-range value, depending on the particular parameter. Mathematically combining these terms in exposure equations is generally thought to result in decidedly conservative exposure estimations (Cogliano, 1997; Burmaster and Harris, 1993). In general, this conservativeness is associated with the state of risk assessment practice, which attempts to focus on the upper end of exposure possibilities rather than more realistic levels of exposure, and not on assumptions made specifically for WWTP3.

6.2.7 Groundwater-to-Air Household Model

The groundwater-to-air household model (EPA, 1991b) used to evaluate the volatile organic COPCs identified in WWTP3 bedrock groundwater has considerable associated uncertainties. Some parameters that affect the model include the air exchange rate of the house (which can vary with the season), level of groundwater usage, and size of the house. EPA (1991b) states that the model assumes a four-member household that uses 720 L/day of water, a home with a volume of 150 m^3, and 0.25 household air exchanges per hour. The *Exposure Factors Handbook* (EPA, 1997a) lists the following information for the average four-person home: household use of 892 L/day (4 × 223 L/day), a volume of 431 m^3, and an air exchange rate of 0.63 volumes per hour. If the values from the *Exposure Factors Handbook* were used instead of the default values from EPA (1991b), the resultant estimated household air concentrations would be less than those estimated in the BHHRA by a factor of nearly 5. In summary, the selection of the groundwater-to-air model parameter values used by EPA (1991b) may contribute a conservative bias to the resultant risk estimates of VOCs in WWTP3 bedrock groundwater.

6.2.8 Toxicity Assessment

Uncertainties associated with the toxicity assessment include those regarding development of the health effects criteria values, the classification of potential carcinogenicity, the extrapolation of exposure route-specific toxicity values to other routes of exposure, and the extrapolation of toxic effects observed in animal studies to potential adverse effects in humans. A general summary of these uncertainties is provided in the following paragraphs.

The development of health effects criteria for noncancer effects involves considerable professional judgment. An uncertainty factor of up to 10 may be applied to a toxicologically

identified benchmark dose or concentration to address the unknown regarding each of the following (EPA, 1989b): lowest-observed-adverse-effects level to no-observed-adverse-effects level, subchronic-to-chronic extrapolation, route-to-route extrapolation, and species-to-species extrapolation. A "modifying factor" of 10 or less is likewise applied in the development of RfDs and RfCs, using professional judgment. This modifying factor is intended to address gaps in the database and steepness of the dose-response curve. In practice, the overall UF, derived by multiplying the individual uncertainty factors by the modifying factor, associated with RfD and RfC values may span up to four orders of magnitude.

The EPA weight-of-evidence classification system for carcinogens is used to examine and classify chemical agents with respect to their carcinogenic potential. Most EPA potential carcinogens are classified based on animal data, without sufficient human data to support a causal association (i.e., former Group B2 [Section 4.1]). Also, the linearized multistage (LMS) mathematical model was used to extrapolate values from relatively high-dose rodent studies to relatively low-dose human exposures in the development of SFs for these compounds. This application of the LMS model is the subject of much controversy. Thus, the LMS approach used to develop SFs, combined with other assumptions, tends to overestimate potential risks.

Human data are often considered to be more reliable than animal data because there is no need to extrapolate the results obtained in one species to another. Because of limitations in most human studies (e.g., uncertainties regarding exposure concentrations, durations, lack of experimental control, small sample sizes, and representativeness of the exposed population), have one or more of the following limitations:

- The duration of exposure is usually considerably less than lifetime.
- The concentration or dose of chemical to which the humans were exposed can be approximated only crudely, usually from historical data.
- Concurrent exposure to other chemicals frequently confounds interpretation.
- Data regarding other factors (tobacco, alcohol, illicit or medicinal drug use, nutritional factors and dietary habits, heredity) are usually insufficient to eliminate or quantify confounding effects on the results.
- Most epidemiologic studies are occupational investigations of workers, which may not accurately reflect the range of sensitivities of the general population.
- Most epidemiologic studies lack the statistical power (i.e., sample size) to detect a low, but chemical-related increased incidence of tumors.

Most potency estimates are derived from animal data, which present different limitations:

- It is necessary to extrapolate from results in animals to predict results in humans, usually by estimating an equivalent human dose from the animal dose.
- The range of sensitivities arising from genotypic and phenotypic diversity in the human population is not reflected in the animal models ordinarily used in cancer studies.
- Usually, very high doses of chemical are used, which may alter normal biology, creating a physiologically artificial state and introducing substantial uncertainty regarding the extrapolation to the low-dose range expected with environmental exposure.
- Individual studies vary in quality (e.g., duration of exposure, group size, scope of evaluation, adequacy of control groups, appropriateness of dose range, absence of concurrent disease, sufficient long-term survival to detect tumors with long induction or latency periods).

Overall, the toxicity values, assuming similar effects between humans and test species, tend to result in overestimates of noncancer hazards or cancer risks. However, it is possible that a given chemical can elicit a toxic response in humans that is not observed in the laboratory species studied or that humans may be more sensitive to a given chemical. In this instance, it is possible for the use of the toxicity values to result in underestimates of risks/hazards.

6.2.9 Risk Characterization

It is assumed that the effects of simultaneous exposures to multiple carcinogens at a site are additive. Likewise, it is assumed that noncancer effects of contaminants are additive if they have a similar mechanism of toxicity. In risk assessment practice, it is assumed that the effects of chemicals that affect the same target organ are additive unless chemical-specific information would dictate otherwise. However, chemicals in combination may act additively, synergistically, or antagonistically or may not influence one another at all. Therefore, depending on the interactive effects (if any), the risk characterization approach to multiple contaminants may lead to either underestimates or overestimates of potential risk/hazard.

6.2.10 Evaluation of Selected COPCs for Site Relatedness

As described in Section 2.4.3, a comparison of naturally occurring metals is performed in two steps. The first is a comparison to BSCs; a chemical whose MDC does not exceed the BSC is assumed to be related to background and thus eliminated from further evaluation. The second step is performed for selected metals and organic compounds during the risk characterization

step, after exposure calculations are performed which include the potential background-related contributions as part of the overall ILCR and HI results.

For inorganics in soil or bedrock groundwater, the risk characterization background evaluation step typically may include a statistical comparison of the site data set to the background data set using the WRS statistical test as appropriate (Section 2.4.3.2). Note that no suitable background data sets exist for overburden groundwater, sediment, or surface water. Also note that no inorganics were identified as WWTP3 total soil (or surface soil) COPCs. For organic COPCs, such as those related to petroleum hydrocarbons in bedrock groundwater, a qualitative evaluation of site relatedness may be performed.

Bedrock Groundwater. Arsenic is the main risk driver in bedrock groundwater with respect to both cancer risk and noncancer hazard. A WRS statistical test was run for both arsenic and manganese, the other COPC in bedrock groundwater. As expected based on the rather elevated concentrations, arsenic ($p=0.015$) failed the WRS test at a p criterion of $p<0.05$, indicating that arsenic concentrations in WWTP3 bedrock groundwater are significantly greater than those in the PBOW background groundwater data set. The WRS results of manganese ($p= 0.71$) passed the WRS test, indicating that concentrations of manganese in WWTP3 bedrock groundwater do not differ significantly from those of the background data set. It is noted that the bedrock groundwater data sets ($n=6$) are rather small; thus, the results of the WRS test have greater uncertainty than would a larger data set. The WRS results and box-and-whisker plot for each WRS test are included in Appendix G.

Although arsenic concentrations in WWTP3 bedrock groundwater appear to be elevated with respect to background concentrations and arsenic failed the WRS background comparison as described in the preceding paragraph, a qualitative evaluation was performed for site relatedness of arsenic in WWTP3 bedrock groundwater. Please note that each of the samples comprising the PBOW background bedrock groundwater data set were collected using low-flow methodology. This includes complete purging prior to sampling. Although an attempt was made to purge each of the WWTP3 wells, the removal of water resulted in hydrogen sulfide off-gassing due to the decreased head pressure associated with removal of water. Also, none of these samples could be collected using the low-flow method. Both the off-gassing and the sample collection method likely contributed to the generally high turbidity observed in these samples; also, the agitation of the water associated with off-gassing and sampling using the bailer method (used for all but one of the six samples) may facilitate dissolution of inorganics present in suspended materials.

Arsenic was detected in each of the three bedrock groundwater samples collected in May 2009 but was not detected in any of the three bedrock groundwater samples collected in November 2009. These results indicate that arsenic is not consistently present in groundwater at detectable levels (method detection limit of each sample was 3.6 µg/L). Because of insufficient water yield, none of these six groundwater sample could be collected using the low-flow method, and all except for the November 2009 sample collected from WTP3-BEDGW-003 were collected by bailer. The bailer method tends to resuspend sediments, resulting in elevated inorganics concentrations. With the exception of the November 2009 sample from WTP3-BEDGW-002 (11.6 NTUs), the bailed samples yielded rather high turbidities, ranging from 36 to 217 NTUs, as did the only sample which could be collected with a pump (from WTP3-BEDGW-003 in November 2009), which had a turbidity of 190 NTUs. Also, arsenic is not a component of any waste stream related to TNT manufacturing, and it was not identified as a COPC in soil. In summary, arsenic detected in WWTP3 bedrock groundwater does not appear to be related to former site activities based on the following reasons and observations:

- Arsenic was detected only in the well samples collected in May 2009 but was not detected in any of the subsequent samples collected in November 2009. It may be that the presence of arsenic in May 2009 was an artifact of sampling methods and/or differing site groundwater conditions (unrelated to site impact). If WWTP3 were a source of arsenic to the groundwater, it is expected that arsenic would be detected at comparable concentrations during both sampling events.

- Arsenic was detected within background concentrations in the overlying WWTP3 soil samples. The MDC (20.8 mg/kg) and mean concentration (7.32 mg/kg) of arsenic in total soil are both less than those of PBOW background data set (36.5 and 10.1 mg/kg, respectively).

- Arsenic is not a component of any waste stream related to TNT manufacturing.

As mentioned, a qualitative evaluation of organic COPCs may be performed to evaluate site relatedness of these compounds. Benzene is a petroleum constituent that is known to be naturally occurring in the limestone groundwater at PBOW (Shaw, 2006). As described in Section 3.1.1.2, petroleum hydrocarbon staining was observed at depth during the drilling of all three WWTP3 wells. One of these wells, WWTP3-BEDGW-002, also exhibited high levels of hydrogen sulfide (above 200 ppm). These observations provide evidence that petroleum hydrocarbons and elevated levels of hydrogen sulfide are naturally occurring in this area of PBOW.

Overburden Groundwater. Similar to risks associated with bedrock groundwater, arsenic was also the primary risk driver in overburden groundwater. As mentioned previously, there is

no suitable background data set for the overburden groundwater. Therefore, a qualitative evaluation for site relatedness was performed for arsenic in overburden groundwater.

The MDC (15.8 µg/L) for arsenic in overburden groundwater was detected in the relatively turbid (36.5 NTUs) May 2009 sample from well WTP3-MW01; the turbidities of all other overburden groundwater samples were less than 7 NTUs. Also, the May 2009 filtered sample from WTP3-MW01 yielded a reported arsenic concentration of only 5.9 µg/L, and arsenic was not detected in the November 2009 sample from this well. The lower arsenic concentration in the filtered sample indicates that the arsenic is predominantly associated with suspended solids measured as turbidity. The only other overburden well in which arsenic was detected was WTP3-MW02, in which it was reported at 10.4 µg/L during both sampling events. Please note that none of the WWTP3 overburden wells could be purged due to inadequate water production and that all six samples had to be collected by bailer for this same reason. The concentration detected in WTP3-MW02 is comparable to the bedrock PBOW BSC (7.4 µg/L). Although the BSC is not specific to overburden groundwater, this value is used to observe that the maximum concentration of arsenic detected in unpurged WWTP3 overburden wells sampled by bailer does not appreciably differ from a local background data set that was collected from a properly purged well using low-flow methodology. In summary, arsenic detected in WWTP3 bedrock groundwater does not appear to be related to former site activities based on the following reasons and observations:

- The MDC of arsenic in overburden groundwater appears to be associated with turbidity. The remaining detected concentrations are comparable to those of bedrock background levels.

- Arsenic was detected within background concentrations in the overlying WWTP3 soil samples. The MDC (20.8 mg/kg) and mean concentration (7.32 mg/kg) of arsenic in total soil are both less than those of PBOW background data set (36.5 and 10.1 mg/kg, respectively).

- Arsenic is not a component of any waste stream related to TNT manufacturing.

Soils. Potential cancer risk levels exceeding the PBOW risk goal were associated with exposure to soils for the future hypothetical resident assumed to be exposed to total soil and for the full-time groundskeeper assumed to be exposed to surface soil. (Please note that even though this groundskeeper has been referred to as “current” exposure, to reflect current undisturbed soil conditions, there is currently no full-time groundskeeper at WWTP3.) These soil risks are almost completely associated with PAHs. As noted in Section 3.1.1.3, black cinders and gravel were found within 1 foot of the surface and down to a depth of approximately 3.5 feet in several of the

borings. The origin of the cinders and gravel in the surface and near-surface soil is not known, but their presence may be associated with the historic access road from the north and parking area formerly associated with WWTP3. It is also possible that the PAHs originate from the burning of the former WWTP3 buildings. However, PAHs were not detected in the surface soil samples from boring SB-03, the only boring in which burnt wood was observed (and cinders were also observed in this boring). Thus, it is questionable that the PAHs observed at WWTP3 are associated primarily with burning of the buildings or else it would seem that boring SB-03 should exhibit rather high concentrations of PAHs. Cinders have not been reported in the boring logs or sample collection logs of soil samples from other PBOW sites, including those at TNTC with elevated with elevated PAHs (IT, 2001b). In summary, although the presence of cinders is associated with the surface soil samples with the highest PAH concentrations, it is unknown whether the cinders are directly associated with the source of elevated PAHs in WWTP3 surface soil or are related to the burning of WWTP3 buildings.

As described in Section 5.3.1, likely non-DoD-related sources have been identified for each of the three samples with benzo(a)pyrene concentrations exceeding 2 mg/kg. The surface soil samples from SB-01 (2.41 mg/kg) and SB-02 (10.0 mg/kg) were collected immediately adjacent to a patio that had adjoined the former NASA K-Site control building (former neutralization tank). During site visits in May 2011 and in 2009, a gas grill was observed on the small patio outside the building, within approximately 20 feet of boring SB-02. It is possible that the grill may have been a source of PAHs at SB-01 and SB-02. The benzo(a)pyrene concentration of 2.41 mg/kg at surface soil sample at SB-01 is located immediately adjacent to a utility pole; it is likely that the PAHs associated with this location originated largely from the preservative treatment used for this pole. Regardless of the sources, it appears that the PAHs in surface soil samples SB-01 and SB-02 were very limited in extent. LSI sample SSW303, collected immediately east of the current road, had a benzo(a)pyrene concentration of 4.2 mg/kg. It is likely that asphalt and possibly vehicle traffic represent the main sources of PAHs at this location; these sources are regarded as anthropogenic background. The K-Site control building and associated patio were demolished and removed by NASA in October 2012. Contaminated soils identified during the performance of this BHHRA were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012).

If the PAH results from RI surface soil samples from SB-01 and SB-02 (adjacent to the former NASA K-Site control building patio) and the LSI surface soil sample SSW303 (adjacent to the access road) are excluded from the respective data sets, then the resulting ILCR of the current groundskeeper (7E-6) is less than the PBOW 1E-5 cancer risk goal, and the ILCR of the future hypothetical resident (1E-5) equals the PBOW cancer risk goal (Table 5-3).

In summary, PAHs were detected in several soil samples located at or near the surface. The highest concentrations were found in two RI samples collected immediately adjacent to the former NASA K-Site control building (former neutralization tank) where the soils have since been removed, and from an LSI sample collected from immediately east of the access road (Figure 1-3). If the results of these three samples are excluded, the PBOW cancer risk goal is met for all receptors.

7.0 Summary and Conclusions

7.1 Summary

The BHHRA was conducted to evaluate cancer risk and noncancer hazards associated with WWTP3 surface soil, subsurface soil, surface water, sediment, bedrock groundwater, and overburden groundwater. A risk-based screening approach was used to identify COPCs and focus the risk assessment on those chemicals detected at WWTP3 that may contribute appreciably to risk or hazard. The sampled media were screened against the respective RBSCs, and inorganics in bedrock groundwater and soil were also screened against BSCs. COPCs for the various media were identified based on this screening. Exposure and risk/hazard associated with the COPCs were evaluated using the following receptors (media evaluated in parentheses):

- Current groundskeeper (surface soil)
- Future groundskeeper (total soil and groundwater)
- Future indoor worker (surface soil, subsurface soil [vapor inhalation pathway only], and groundwater)
- Current/future construction worker (total soil, surface water, and sediment)
- Future hypothetical resident (total soil, surface water, sediment, overburden groundwater, and bedrock groundwater)
- Future adult hunter (surface soil, including venison pathway)
- Future hunter's child (surface soil [venison pathway only]).

Each receptor scenario that includes groundwater was run separately for overburden groundwater and bedrock groundwater. Because groundwater yield was found to be insufficient for potable use in the overburden and bedrock units underlying WWTP3, and the WWTP3 bedrock groundwater was observed to be of naturally poor quality due to the presence of petroleum and hydrogen sulfide, the receptors evaluated for potable groundwater use were also evaluated assuming no groundwater use. The future hypothetical resident was evaluated for noncancer hazards separately for the young child (ages 1 through 6 years) and adult life stages.

The overall HI and ILCR values are summarized in the following bullets; exceedances of PBOW cancer risk goal (ILCR>1E-5) are shown as bolded and exceedances of the noncancer hazard criterion (HI>1) or the NCP risk management range (1E-6 to 1E-4) are shown as bold italics:

- Current groundskeeper: **ILCR = 5E-5** (re-evaluated as 7E-6); HI = 0.07
- Future groundskeeper – all pathways, including bedrock groundwater use: ***ILCR = 4E-4; HI = 4***
- Future groundskeeper – all pathways, including overburden groundwater use: **ILCR = 9E-5**; HI = 1
- Future groundskeeper –all pathways, excluding groundwater use: ILCR = 1E-5; HI = 0.05
- Indoor worker – all pathways, including bedrock groundwater use: ***ILCR = 4E-4; HI = 3***
- Indoor worker – all pathways, including overburden groundwater use: **ILCR = 8E-5**; HI = 1
- Future indoor worker – all pathways, excluding groundwater use: ILCR = 1E-5; HI = 0.02
- Construction worker: ILCR = 1E-6; HI = 0.9
- Future hypothetical resident – all pathways, including bedrock groundwater use: ***ILCR = 2E-3***; ***child HI = 25***; ***adult HI = 10***

  Future hypothetical resident – all pathways, including overburden groundwater use: ***ILCR = 3E-4***; ***child HI = 7***; ***adult HI = 3***
- Future hypothetical resident – all pathways, excluding groundwater use: **ILCR = 5E-5** (re-evaluated as 1E-5)*;* child HI = 0.7; adult HI = 0.1
- Hunter: ILCR = 3E-6; HI = 0.004
- Hunter's child: ILCR = 2E-10; HI = 0.00004.

As indicated above, the current groundkeeper and future hypothetical residential receptor scenarios yield ILCR values that exceed the PBOW cancer risk goal but not the NCP risk management range, even if groundwater exposure is excluded. However, as described in Section 6.2.10, two of the samples with the highest PAH concentrations were collected immediately adjacent to the former NASA K-Site control building patio (former neutralization tank) in an area from which soil has been removed and the third represents anthropogenic background concentrations associated with the access road. If these three samples are excluded from the surface soil and total soil data sets as described in Section 6.2.10, the resulting EPC values are much lower and result in an ILCR value for the groundskeeper (7E-6) that is less than the PBOW 1E-5 cancer risk goal and an ILCR value for the future hypothetical resident that equals the PBOW cancer risk goal. Note that the two samples collected from adjacent to the K-Site patio

were excluded in this uncertainty exercise because, regardless of their source, it appears that their areal extent may be very limited and not representative of WWTP3 soil as a whole.

7.2 Conclusions

It is important to note that the site-specific risk assessment, including the evaluation of future land uses and groundwater use, was performed to satisfy administrative requirements, including those described by FUDS regulations (USACE, 2004).

The ILCR for the current groundskeeper (5E-5) exceeds the PBOW cancer risk goal (ILCR$\geq$1E-5) but is well within the NCP risk management range. Note that groundskeeping or other site worker activities appear to be limited to regular mowing. Because workers are only occasionally present on site, the current groundskeeper scenario, which assumes a full-time, 25-year employee who works exclusively at WWTP3 for 250 days per year, appears to greatly overestimate the exposure levels of any current on-site worker or other current receptor. Risks to any individual currently working at the site would likely be well below the 1E-5 goal. The ILCR for the current construction worker is less than the PBOW cancer risk goal and represents the low end of the NCP risk management range. Also, the HI values for the two current exposure scenarios (current groundskeeper and construction worker) each meet the noncancer hazard criterion (HI$\leq$1), indicating that noncancer hazards are unlikely for any on-site worker under current conditions. Note that no construction is currently planned at WWTP3.

Each of the potential future exposure scenarios that does not assume potable use of groundwater also meets the PBOW hazard criterion. Of the potential future exposure scenarios that exclude groundwater use, only the ILCR of the future hypothetical resident exceeds the PBOW cancer risk criterion; this ILCR does not exceed the NCP risk management range.

The cancer risks associated with each of the future receptors evaluated under the assumption of bedrock groundwater use as a hypothetical source of tap water (i.e., future groundskeeper, future indoor worker, or future hypothetical resident) exceed the NCP risk management range and PBOW cancer risk goal. Each of these receptors assuming bedrock groundwater use also exceeds the target noncancer HI criterion of 1. The ILCR for each of these under the assumption of overburden groundwater use also exceeds the PBOW cancer risk goal, but only the future hypothetical resident exceeds the NCP risk management range. Of all the receptors that are assumed to use overburden groundwater, only the future hypothetical child resident and adult resident exceed the HI criterion.

The cancer risks associated with bedrock groundwater are nearly entirely attributable to natural petroleum hydrocarbon-related BTEX compounds and arsenic, which also does not appear to be related to former site activities. The noncancer hazards associated with overburden groundwater are mostly due to arsenic, which does not appear to be associated with former site activities. Use of either the overburden or bedrock groundwater is regarded as implausible because of insufficient water yield. Additionally, the naturally poor quality of the bedrock groundwater and associated hydrogen sulfide off-gassing make it unsuitable as a potable source. The readily available municipal water supply obviates the need for use of groundwater as a potential source of tap water in the general vicinity of PBOW.

The ILCR values of the current groundkeeper scenario (5E-5) and the future hypothetical resident (5E-5) associated with exposure to surface soil and total soil, respectively, are due to PAHs in soil. The source of the PAHs is possibly cinders observed in several WWTP3 soil borings from a depth of just below the surface to approximately 3.5 feet bgs. Based on analytical samples collected to date and a review of the boring log descriptions, the cinders appear to be more widely occurring than the elevated levels of PAHs. Although the cinders likely contribute to the PAH concentrations, it appears that sources other than the cinders are responsible for PAHs in surface and near-surface soils, especially at the locations with the highest concentrations. These include the surface soil samples from SB-01 and SB-02 (located immediately adjacent to the patio adjoining the former NASA K-Site control building [former neutralization tank]) and surface soil sample SSW303 which is located immediately east of the current access road as is attributable to anthropogenic background (e.g., asphalt materials and vehicle emissions). Please note the K-Site control building and associated patio were demolished and removed by NASA in October 2012. These PAH-contaminated soils were removed by NASA and disposed of at the Erie County Landfill as nonhazardous waste in October 2012 (NASA, 2012).

If these three samples are excluded from the PAH database for WWTP3, the resulting re-evaluated hypothetical current groundskeeper ILCR is 7E-6 and the future hypothetical resident ILCR is 1E-5 (Section 5.4). Both of these re-evaluated ILCR values meet the PBOW cancer risk goal and are within the NCP risk management range.

8.0 References

Burmaster, D.E., and R.H. Harris, 1993, "The Magnitude of Compounding Conservatisms in Superfund Risk Assessment," ***Risk Analysis, 13(2): 131-134.***

California Environmental Protection Agency, 2012, ***Toxicity Criteria Database***, Office of Environmental Health Hazard Assessment, Sacramento, California, http://www.oehha.ca.gov/risk/ChemicalDB/index.asp.

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

Cogliano, V.J., 1997, "Plausible Upper Bounds: Are Their Sums Plausible?" ***Risk Analysis***, 17(1): 77-84.

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

Dames and Moore, Inc. (D&M), 1997b, ***Draft Records Review Report, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio***, April.

Dames and Moore, Inc. (D&M), 1996, ***Red Water Ponds Focused Remedial Investigation, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio***, May.

Environmental Council of States-U.S. Department of Defense (DoD), 2007, ***Identification and Selection of Toxicity Values/Criteria for CERCLA and Hazardous Waste Site Risk Assessments in the Absence of IRIS Values,*** ECO-DOD Sustainability Work Group, Emerging Contaminants Task Group, Risk Assessment Provisional Values Subgroup Issue Paper, April.

International Consultants Incorporated (ICI), 1995, ***Site Management Plan, Plum Brook Ordnance Works, Sandusky, Ohio, Part B, Areas of Concern***, September.

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

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

IT Corporation (IT), 2000, ***Draft Baseline Human Health Risk Assessment Work Plan for the Former TNT Manufacturing Area, West Virginia Ordnance Works, Mason Count, West Virginia***, January.

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

IT Corporation (IT), 1998, ***Site Investigation of the Acid Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio***, August.

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

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

National Aeronautics and Space Administration (NASA), 2012, *PBOW: Removal of PAH Contaminated Soil at K-Site Building,* email correspondence from R. Lallier (Environmental Manager, NASA Plum Brook Station) to R. Meadows (Project Manager, U.S. Army Corps of Engineers, Huntington District), March 4.

National Oceanic and Atmospheric Administration, 1990, ***Comparative Climatic Data for the United States through 1989***, National Climatic Data Center, Asheville, North Carolina.

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

Ohio Environmental Protection Agency (OEPA), 2009a***, Use of U.S. EPA's Regional Screening Levels as Screening Values in Human Health Risk Assessments***, Technical Decision Compendium, Division of Emergency and Remedial Response, August.

Ohio Environmental Protection Agency (OEPA), 2009b***, Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for the DERR Remedial Response Program***, Technical Decision Compendium, Division of Emergency and Remedial Response, August.

Ohio Environmental Protection Agency (OEPA), 2009c***, Use of Background for Remedial Response Sites***, Technical Decision Compendium, Division of Environmental Response and Revitalization, August 21.

Ohio Environmental Protection Agency (OEPA), 2009d, Email Correspondence from B. Buthker, OEPA Risk Assessor, to L. Long, USACE Risk Assessor, March 18.

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

Ohio Environmental Protection Agency (OEPA), 1999, email correspondence between Lawrence Sirinek (OEPA Risk Assessor) and Paul Goetchius (Shaw Risk Assessor), March 5.

Sample, B.E. and Suter II, G.W., 1994, ***Estimating Exposure of Terrestrial Wildlife Contaminants***, Environmental Sciences Division, Oak Ridge National Laboratory, ES/ER/TM-125.

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

Science Applications International Corporation, 1991, ***Plum Brook Station Preliminary Assessment,*** June.

Sharp, G., 1995, Personal Communication: Telephone conversation between P. Goetchius, IT Corp. and Gary Sharp, Wildlife Biologist, West Virginia Division of Natural Resources, Point Pleasant, West Virginia, 17 February.

Shaw Environmental, Inc. (Shaw), 2011, ***Waste Water Treatment Plant 3, Site Characterization Report, Final, Plum Brook Ordnance Works, Sandusky, Ohio***, August.

Shaw Environmental, Inc. (Shaw), 2009, ***Baseline Human Health Risk Assessment and Screening Level Ecological Risk Assessment Work Plans for Waste Water Treatment Plants 1 and 3 and Ash Pits 1and 3, Final, Plum Brook Ordnance Works, Sandusky, Ohio***, August.

Shaw Environmental, Inc. (Shaw), 2008a, ***Final Phase 1 Remedial Investigation, Site-Specific Sampling and Analysis Plan and Site-Specific Safety and Health Plan, Waste Water Treatment Plants 1 and 3 and Ash Pits 1 and 3,*** *Plum Brook Ordnance Works, Sandusky, Ohio,* November.

Shaw Environmental, Inc. (Shaw), 2008b, ***Feasibility Study for Groundwater, TNT and Red Water Pond Areas, Final,*** *Former Plum Brook Ordnance Works, Sandusky, Ohio*, December.

Shaw Environmental, Inc. (Shaw), 2006, ***Baseline Human Health Risk Assessment of Groundwater, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

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

The Weather Channel, 2004, on-line data search for weather averages and records for Sandusky, Ohio, performed November 11, 2004, http://www.weather.com.

U.S. Army Corps of Engineers (USACE), 2004, ***Formerly Used Defense Sites (FUDS) Program Policy***, Washington, D.C., ER-200-3-1, May.

U.S. Army Corps of Engineers (USACE), 2000, ***Limited Site Investigation for the Former Plum Brook Ordnance Works, Waste Water Treatment Plants No. 1 and 3, Final Report***, July.

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

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

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

U.S. Environmental Protection Agency (EPA), 2012a, ***Regional Screening Level Table***, April, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

U.S. Environmental Protection Agency (EPA), 2012b, ***2012 Edition of the Drinking Water Standards and Health Advisories***, Office of Water, April, EPA 822-S-12-001.

U.S. Environmental Protection Agency (EPA), 2012c, ***Regional Screening Level Table, User's Guide,*** May, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

U.S. Environmental Protection Agency (EPA), 2012d, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

U.S. Environmental Protection Agency (EPA), 2011, ***ProUCL Version 4.1.01***, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, February, on line at http://www.epa.gov/esd/tsc/form.htm.

U.S. Environmental Protection Agency (EPA), 2010a, ***ProUCL Version 4.1 Technical Guide***, Draft, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, EPA/600/R-07/041, May.

U.S. Environmental Protection Agency (EPA), 2010b, ***ProUCL Version 4.1 User Guide***, Draft, Office of Research and Development, Technology Support Center Characterization and Monitoring Branch, Las Vegas, Nevada, EPA/600/R-07/038, May.

U.S. Environmental Protection Agency (EPA), 2005, ***Guidelines for Carcinogen Risk Assessment***, Risk Assessment Forum, Washington, D.C., March, EPA/630/P-03/001B.

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

U.S. Environmental Protection Agency (EPA), 2004b, ***Region 9 Preliminary Remediation Goals (PRG) Table***, San Francisco, California, October.

U.S. Environmental Protection Agency (EPA), 2004c, ***User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows 32-bit Version,*** Lead and IEUBK Technical Review Workgroup, Washington, D.C., May http://www.epa.gov/superfund/health/contaminants/lead/products.htm.

U.S. Environmental Protection Agency (EPA), 2004d, ***User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table***, Region 9, San Francisco, California, October, <http://www.epa.gov/region9/superfund /prg/files/04usersguide.pdf>.

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

U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

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

U.S. Environmental Protection Agency (EPA), 1997b, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, NTIS No. PB97-921199.

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

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

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

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

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

U.S. Environmental Protection Agency (EPA), 1990, “National Oil and Hazardous Substances Pollution Contingency Plan,” ***Federal Register*** 55(46): 8666-8865.

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

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

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

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

TABLES

Table 2-1

Summary of Samples Evaluated in the Baseline Human Health Risk Assessment
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

Location	Sample Number	Sample Type	Sample Date	Depth (ft bgs)	Analyses
Soil					
PBOW99-SSW301	PBOW99SSW301	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW302	PBOW99SSW302	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals, PCB, SVOC, VOC
PBOW99-SSW303	PBOW99SSW303	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals, PCB, SVOC, VOC
PBOW99-SSW304	PBOW99SSW304	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW305	PBOW99SSW305	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW306	PBOW99SSW306	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW307	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW308	FD	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW309	PBOW99SSW309	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW310	PBOW99SSW310	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
WWTP3-SB03	WW0041	REG	10-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB05	WW0048	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB06	WW0051	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB07	WW0054	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0060	REG	11-Dec-08	0.2 - 1.6	Explosives, Metals, PCB, SVOC
WWTP3-SB02	WW0038	REG	10-Dec-08	0.5 - 1.5	Explosives, Metals, PCB, SVOC
WWTP3-SB01	WW0034	REG	10-Dec-08	0.7 - 1.7	Explosives, Gen Chem, Metals, PCB, SVOC
WWTP3-SB06	WW0052	REG	11-Dec-08	3 - 3.7	Explosives, Metals, PCB, SVOC
WWTP3-SB03	WW0042	REG	10-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB03	WW0043	FD	10-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB05	WW0049	REG	11-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB07	WW0055	REG	11-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0061	REG	11-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0063	FD	11-Dec-08	3 - 5	Explosives, Metals, PCB, SVOC
WWTP3-SB02	WW0039	REG	10-Dec-08	5 - 5.5	Explosives, Metals, PCB, SVOC
WWTP3-SB01	WW0035	REG	10-Dec-08	5 - 5.7	Explosives, Metals, PCB, SVOC
WWTP3-SB01	WW0036	REG	10-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB01	WW0037	FD	10-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB02	WW0040	REG	10-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB03	WW0044	REG	10-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB05	WW0050	REG	11-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB06	WW0053	REG	11-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB07	WW0056	REG	11-Dec-08	8 - 10	Explosives, Metals, SVOC
WWTP3-SB09	WW0062	REG	11-Dec-08	8 - 10	Explosives, Metals, SVOC

Table 2-1

Summary of Samples Evaluated in the Baseline Human Health Risk Assessment
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

Location	Sample Number	Sample Type	Sample Date	Depth (ft bgs)	Analyses
Groundwater - Bedrock					
WTP3-BEDGW-001	WW3024	REG	22-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-001	WW3035	REG	13-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-002	WW3025	REG	23-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-002	WW3036	REG	13-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-003	WW3026	REG	22-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-003	WW3027	FD	22-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-BEDGW-003	WW3037	REG	12-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
Groundwater - Overburden					
WTP3-MW01	WW3021	REG	19-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-MW01	WW3032	REG	11-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-MW02	WW3022	REG	21-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-MW02	WW3033	REG	12-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-MW03	WW3023	REG	21-May-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
WTP3-MW03	WW3034	REG	12-Nov-09	NA	Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC, VOC
Sediment					
PBOW99-SDW301	PBOW99SDW301	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals, SVOC
PBOW99-SDW302	PBOW99SDW302	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals, SVOC
WWTP3-SD01	WW1004	REG	23-May-09	0 - 0.5	Gen Chem, PCB
WWTP3-SD01	WW1005	FD	23-May-09	0 - 0.5	Gen Chem, PCB
WWTP3-SD02	WW1007	REG	23-May-09	0 0.5	Gen Chem, PCB
WWTP3-SD03	WW1008	REG	23-May-09	0 0.5	Explosives, Gen Chem, Metals, PCB, SVOC
Surface Water					
WWTP3-SW01	WW2004	REG	23-May-09	NA	Explosives, Field Tests, Metals, SVOC
WWTP3-SW02	WW2005	REG	23-May-09	NA	Explosives, Field Tests, Metals, SVOC
WWTP3-SW03	WW2006	REG	23-May-09	NA	Explosives, Metals, SVOC
WWTP3-SW03	WW2007	FD	23-May-09	NA	Explosives, Field Tests, Metals, SVOC

ft bgs - Feet below ground surface.
f & uf - Metals analysis performed on filtered and unfiltered samples, respectively.
FD - Field duplicate; averaged with the regular sample at the same location to create one result.
Gen Chem - General chemistry.
PCB - Polychlorinated biphenyl.
REG - Regular sample.
SVOC - Semivolatile organic compound.
VOC - Volatile organic compound.

Table 2-2

Background Screening Concentrations of Inorganics in Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical Name (mg/kg)	Frequency of Detection	Range of Detected Concentrations	Range of Reporting Limits [a]	Statistical Distribution	Arithmetic Mean	95% UTL [b]	Background Screening Concentration [c]
Aluminum	12 / 12	3520 - 15500	22.6 - 26.5	L	8.43E+03	2.69E+04	15500
Antimony	9 / 25	5.9 - 9.3	5.4 - 8.0	NP	4.68E+00	NA	9.30
Arsenic	23 / 26	2.1 - 36.5	1.1 - 24.7	L	1.08E+01	7.10E+01	36.5
Barium	9 / 12	35.6 - 826	22.6 - 26.5	L	1.16E+02	1.30E+03	826
Beryllium	6 / 25	0.57 - 1	0.57 - 1.2	L	5.65E-01	1.17E+00	1.00
Cadmium	0 / 25	NA	0.57 1.2	L	4.49E-01	NA	NA
Calcium	12 / 12	735 - 52300	566 - 663	L	1.13E+04	2.18E+05	52300
Chromium	25 / 26	4.4 - 29	1.1 - 12.3	NP	1.34E+01	NA	29.0
Cobalt	9 / 12	9.6 - 116	5.7 - 61.7	L	2.26E+01	2.48E+02	116
Copper	23 / 26	2.3 - 56.2	2.2 - 3.3	L	1.70E+01	1.47E+02	56.2
Iron	12 / 12	5880 - 234000	11.3 - 123	L	4.01E+04	3.58E+05	234000
Lead	26 / 26	1.9 - 48.6	0.34 - 7.4	L	1.28E+01	5.13E+01	48.6
Magnesium	12 / 12	629 - 10400	566 - 663	L	3.26E+03	3.08E+04	10400
Manganese	26 / 26	21 - 13300	1.7 - 18.5	L	7.29E+02	3.51E+03	3506
Mercury	2 / 26	0.085 - 0.085	0.037 - 0.3	L	9.06E-02	5.60E-01	0.085
Nickel	26 / 26	5.4 - 55.1	4.5 - 5.3	L	2.28E+01	7.79E+01	55.1
Potassium	11 / 12	579 - 3390	566 - 663	L	1.24E+03	6.08E+03	3390
Selenium	5 / 25	0.61 - 2	0.57 - 4.9	NP	1.55E+00	NA	2.00
Silver	2 / 26	1.1 - 11.1	1.1 - 1.3	NP	1.00E+00	NA	11.1
Sodium	0 / 12	NA	566 - 663	L	3.03E+02	NA	NA
Thallium	2 / 25	1.2 - 1.3	1.1 - 6.1	NP	1.91E+00	NA	1.30
Vanadium	11 / 12	9 - 40.9	5.7 - 61.7	L	2.48E+01	8.31E+01	40.9
Zinc	26 / 26	6.6 - 655	0.57 - 12.3	L	7.30E+01	3.22E+02	322

L - Lognormal; mg/kg - milligrams per kilogram; NP - nonparametric; NA - not applicable; not available.

[a] A single background sample had to be diluted such that the reporting limits of this sample (BCG-SB01, 6990) were elevated 10 or 20 times higher than they would have been if not diluted. This affects the maximum reporting limit shown for arsenic, chromium, cobalt, iron, lead, manganese, and vanadium. Reporting limits for these analytes in all other samples were much lower, approximately by an order of magnitude or more in each case.

[b] 95% UTL - 95% upper tolerance limit calculated as described in IT Corporation (IT), 1998, *Site Investigation of Acid Areas* , Plum Brook Ordnance Works, Sandusky, Ohio, August.

[c] The maximum detected concentration is used as the background screening criterion for nonparametric data sets; for normal or lognormal data sets, the 95% UTL or the maximum detected concentration, whichever is less, is used. This approach was agreed upon for all future Plum Brook Ordnance Works (PBOW) risk assessments by the PBOW Project Delivery Team (PDT) during the May 10, 2000 PDT meeting.

Note: Detection limits from sample 6990 were deleted when calculating results for antimony, beryllium, cadmium, selenium, and thallium. The detection limits were elevated by dilution factors which greatly exceed any detected concentration and would bias results unrealistically high.

Source: IT, 2001, *TNT Areas A and C Remedial Investigation, Volume 2 Baseline Human Health Risk Assessment* , Final, Former Plum Brook Ordnance Works, Sandusky, Ohio,November, and reports referenced therein, including IT (1998).

Table 2-3

Background Screening Concentrations of Inorganics in Groundwater Waste Water Treatment Plant No. 3 Former Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of Values, µg/L: Detected Concentrations Minimum	Detected Concentrations Maximum	Reporting Limits Minimum	Reporting Limits Maximum	Mean µg/L	Standard Deviation	UTL [a] µg/L	BSC [b] µg/L
Metals - Unfiltered										
Aluminum	11 / 13	85	3.15E+01	3.09E+02	2.00E+02	2.00E+02	1.05E+02	6.98E+01	4.17E+02	309
Arsenic	4 / 26	15	3.30E+00	7.40E+00	1.00E+01	1.00E+01	4.99E+00	6.56E-01	7.92E+00	7.4
Barium	28 / 28	100	2.58E+01	1.18E+04	2.00E+02	2.00E+03	1.73E+03	3.77E+03	1.86E+04	11800
Calcium	28 / 28	100	1.74E+04	3.16E+05	5.00E+03	5.00E+03	1.38E+05	8.31E+04	5.09E+05	316000
Cobalt	6 / 27	22	1.00E+00	1.21E+01	5.00E+01	5.00E+01	2.05E+01	8.75E+00	5.96E+01	12.1
Copper	2 / 28	7	3.30E+00	1.98E+01	2.50E+01	2.50E+01	1.24E+01	2.26E+00	2.25E+01	19.8
Iron	24 / 27	89	3.82E+01	1.55E+03	1.00E+02	1.00E+02	4.15E+02	4.87E+02	2.59E+03	1550
Magnesium	28 / 28	100	7.28E+03	2.17E+05	5.00E+03	5.00E+03	7.17E+04	5.85E+04	3.33E+05	217000
Manganese	28 / 28	100	3.60E+00	6.88E+02	1.50E+01	1.50E+01	8.12E+01	1.24E+02	6.36E+02	636
Nickel	4 / 27	15	4.80E+00	8.60E+00	4.00E+01	4.00E+01	1.81E+01	4.67E+00	3.90E+01	8.6
Potassium	28 / 28	100	2.53E+03	1.16E+05	5.00E+03	5.00E+04	2.70E+04	3.06E+04	1.64E+05	116000
Sodium	28 / 28	100	1.33E+04	1.39E+06	5.00E+03	5.00E+04	3.55E+05	4.36E+05	2.30E+06	1390000
Zinc	14 / 19	74	8.30E-01	5.07E+02	2.00E+01	2.00E+01	5.55E+01	1.23E+02	6.06E+02	507

[a] The UTL (upper tolerance limit) is calculated as described in Shaw (2005).

[b] The BSC (background screening criterion) is the calculated UTL or the maximum detected concentration, whichever is less.

µg/L - Micrograms per liter.

BTEX - Benzene, toluene, ethylbenzene, and xylenes.

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

Table 2-4

Statistical Summary and Selection of Chemicals of Potential Concern in Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Inorganics															
Aluminum	16 / 16	100	3.11E+03		9.47E+03		1.70E+00	2.40E+01	7.11E+03	1.55E+04	7700		N (b)		---
Antimony	6 / 16	38	2.75E-01	J	4.13E-01	J	4.24E-01	7.20E+00	2.05E+00	9.30E+00	3.1		N (b)		---
Arsenic	16 / 16	100	3.90E+00		2.08E+01		8.49E-01	1.20E+00	7.48E+00	3.65E+01	0.39		N (b)		---
Barium	16 / 16	100	2.97E+01		7.47E+01		1.74E-01	2.40E+01	5.31E+01	8.26E+02	1500		N (b)		---
Beryllium	9 / 16	56	5.90E-01		8.44E+00		1.70E-01	6.00E-01	2.74E+00	1.00E+00	16		N (a)		---
Cadmium	5 / 16	31	2.24E-01	J	3.64E-01	J	4.24E-01	6.00E-01	2.73E-01	NA	7		N (a)		---
Calcium	16 / 16	100	3.29E+03		6.07E+04		4.24E+00	6.00E+02	1.97E+04	5.23E+04	Nutrient		N (c)		---
Chromium	16 / 16	100	6.90E+00		1.49E+01		4.24E-01	1.20E+00	1.17E+01	2.90E+01	0.29		N (b)		---
Cobalt	14 / 16	88	3.97E+00	J	9.78E+00		1.70E-01	6.00E+00	6.16E+00	1.16E+02	2.3		N (b)		---
Copper	16 / 16	100	7.10E+00		2.45E+01		4.24E-01	3.00E+00	1.54E+01	5.62E+01	310		N (b)		---
Iron	16 / 16	100	1.02E+04	J	2.90E+04		1.70E+00	1.20E+01	1.62E+04	2.34E+05	5500		N (b)		---
Lead	16 / 16	100	9.60E+00		1.34E+02	J	3.10E-01	5.00E-01	3.11E+01	4.86E+01	400		N (a)		---
Magnesium	16 / 16	100	2.01E+03		8.75E+03	J	1.74E+00	6.00E+02	5.08E+03	1.04E+04	Nutrient		N (c)		---
Manganese	16 / 16	100	1.70E+02		6.06E+02		1.74E-01	1.80E+00	3.27E+02	3.51E+03	180		N (b)		---
Mercury	14 / 16	88	2.00E-02	J	5.97E-01		2.06E-02	4.00E-02	9.50E-02	8.50E-02	2.3		N (a)		---
Nickel	16 / 16	100	8.40E+00		2.41E+01		2.55E-01	4.80E+00	1.56E+01	5.51E+01	150		N (b)		---
Potassium	15 / 16	94	3.63E+02		9.36E+02		2.12E+01	6.00E+02	6.17E+02	3.39E+03	Nutrient		N (c)		---
Selenium	12 / 16	75	4.83E-01	J	1.10E+00		5.20E-01	1.00E+00	6.66E-01	2.00E+00	39		N (b)		---
Sodium	7 / 16	44	2.50E+01		6.46E+01		8.49E+00	6.00E+02	1.80E+02	NA	Nutrient		N (c)		---
Thallium	7 / 16	44	2.21E-01	J	1.10E+00		4.24E-01	1.20E+00	5.59E-01	1.30E+00	0.078		N (b)		---
Vanadium	16 / 16	100	1.38E+01		2.32E+01		1.70E-01	6.00E+00	1.91E+01	4.09E+01	39		N (b)		---
Zinc	16 / 16	100	3.38E+01		1.05E+02		2.10E+00	2.50E+00	5.77E+01	3.22E+02	2300		N (b)		---
Polychlorinated biphenyls (PCB)															
Aroclor 1016	2 / 9	22	1.40E-01	J	1.22E+00	J	4.02E-02	2.05E-01	2.12E-01		0.39		Y	7.64E-01	7.64E-01
Aroclor 1254	2 / 9	22	2.50E-01		1.00E+00	J	4.02E-02	2.05E-01	1.90E-01		0.11		Y	5.40E-01	5.40E-01
Aroclor 1260	2 / 9	22	1.80E-01	J	2.29E-01		4.02E-02	4.60E-01	1.22E-01		0.22		Y	2.04E-01	2.04E-01
Nitroaromatics															
Amino-2,6-dinitrotoluene, 4-	1 / 16	6	2.60E-01		2.60E-01		2.50E-01	3.11E-01	1.42E-01		15		N (a)		---
Amino-4,6-dinitrotoluene, 2-	1 / 16	6	2.28E-01	/U	2.28E-01	/U	2.50E-01	3.11E-01	1.40E-01		15		N (a)		---
Trinitrotoluene, 2,4,6-	1 / 16	6	8.80E-01		8.80E-01		2.50E-01	3.11E-01	1.81E-01		3.6		N (a)		---
Semivolatile Organic Compounds															
Acenaphthene	2 / 9	22	4.78E-01		6.43E-01	J	3.60E-01	2.00E+00	3.68E-01		340		N (a)		---
Acenaphthylene	5 / 9	56	5.41E-02	J	3.23E+00		3.60E-01	2.00E+00	6.97E-01		340	g	N (a)		---
Anthracene	5 / 9	56	5.04E-02	J	4.53E+00		3.60E-01	2.00E+00	1.06E+00		1700		N (a)		---
Benzo(a)anthracene	7 / 9	78	1.01E-01	J	1.19E+01		3.60E-01	2.00E+00	2.56E+00		0.15		Y	8.20E+00	8.20E+00
Benzo(a)pyrene	7 / 9	78	9.09E-02	J	1.00E+01		3.60E-01	2.00E+00	2.23E+00		0.015		Y	6.96E+00	6.96E+00
Benzo(b)fluoranthene	7 / 9	78	1.40E-01	J	1.39E+01		3.60E-01	2.00E+00	2.84E+00		0.15		Y	9.35E+00	9.35E+00
Benzo(ghi)perylene	6 / 9	67	1.78E-01	J	5.57E+00		3.60E-01	2.00E+00	1.35E+00		170	h	N (a)		---
Benzo(k)fluoranthene	6 / 9	67	1.27E-01	J	4.49E+00		3.60E-01	2.00E+00	1.28E+00		1.5		Y	2.21E+00	2.21E+00
Carbazole	2 / 7	29	4.32E-01		1.12E+00	J	4.00E-01	2.00E+00	4.81E-01		24	i	N (a)		---
Chrysene	7 / 9	78	9.25E-02	J	1.03E+01		3.60E-01	2.00E+00	2.29E+00		15		N (a)		---
Dibenz(a,h)anthracene	3 / 9	33	3.97E-01	J	1.46E+00	J	3.60E-01	2.00E+00	5.08E-01		0.015		Y	8.54E-01	8.54E-01

Table 2-4

Statistical Summary and Selection of Chemicals of Potential Concern in Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Dibenzofuran	2 / 9	22	4.36E-01		1.35E+00	J	3.60E-01	2.00E+00	4.42E-01		7.8		N (a)		---
Fluoranthene	7 / 9	78	1.87E-01	J	2.48E+01		3.60E-01	2.00E+00	5.06E+00		230		N (a)		---
Fluorene	3 / 9	33	5.81E-01		1.78E+00	J	3.60E-01	2.00E+00	5.52E-01		230		N (a)		---
Indeno(1,2,3-cd)pyrene	7 / 9	78	3.05E-01	J	8.10E+00		3.60E-01	2.00E+00	1.84E+00		0.15		Y	5.55E+00	5.55E+00
Methylnaphthalene, 2-	2 / 9	22	7.21E-01		1.57E+00	J	3.60E-01	2.00E+00	4.98E-01		23		N (a)		---
Naphthalene	2 / 9	22	6.77E-01		1.38E+00	J	3.60E-01	2.00E+00	4.72E-01		3.6		N (a)		---
Phenanthrene	7 / 9	78	6.77E-02	J	1.39E+01		3.60E-01	2.00E+00	2.79E+00		170	h	N (a)		---
Pyrene	7 / 9	78	1.57E-01	J	1.81E+01		3.60E-01	2.00E+00	3.93E+00		170		N (a)		---
Volatile Organic Compounds															
Methylene chloride	2 / 2	100	1.20E-02		1.30E-02		5.50E-03	6.00E-03	1.25E-02		36		N (a)		---

BSC - Background screening criterion.
COPC - Chemical of potential concern.
mg/kg - Milligrams per kilogram.
RBSC - Risk-based screening concentration.
VQ - Validation qualifier.
/ - When in the VQ column, this separates two qualifiers where the concentration is the result of a sample averaged with a field duplicate.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
U - The sample result was nondetect.

[a] IT Corporation, 2000, *TNT Area B Remedial Investigation, Volume II, Baseline Human Health Risk Assessment, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio* , August, and reports referenced therein.

[b] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) residential soil values (unless otherwise noted), and are based on a risk level of 1.0E-06 and a hazard index of 0.1.

[c] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Maximum detected concentration is less than the BSC.
(c) = Essential nutrient.

[d] Y = Chemical is chosen as a COPC.

[e] 95% UCL (Upper confidence limit) determined using ProUCL Version 4.00.05 U.S. Environmental Protection Agency (EPA), 2010, ProUCL Version 4.00.05, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.

[f] Exposure-point concentration (EPC) used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.

[g] RBSC based on acenaphthene.

[h] RBSC based on pyrene.

[i] Because no RSL is available, the RBSC is based on the PRG (EPA, 2004). Note that the slope factor used for the PRG is the most current available.

Table 2-5

Statistical Summary and Selection of Chemicals of Potential Concern in Subsurface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]
Inorganics													
Aluminum	14 / 14	100	6.65E+03		1.05E+04		1.76E+00	2.05E+00	8.20E+03	1.55E+04	7700		N (b)
Antimony	14 / 14	100	2.61E-01	J	4.36E-01	J	4.40E-01	5.12E-01	3.35E-01	9.30E+00	3.1		N (b)
Arsenic	14 / 14	100	4.35E+00		1.56E+01		8.79E-01	1.02E+00	7.14E+00	3.65E+01	0.39		N (b)
Barium	14 / 14	100	4.13E+01		1.97E+02		1.77E-01	4.10E-01	6.56E+01	8.26E+02	1500		N (b)
Beryllium	14 / 14	100	4.72E+00	J	8.08E+00		1.76E-01	2.05E-01	6.14E+00	1.00E+00	16		N (a)
Cadmium	9 / 14	64	2.38E-01	U/J	1.01E+00		4.40E-01	5.12E-01	3.19E-01	NA	7		N (a)
Calcium	14 / 14	100	3.71E+03		5.08E+04	J	4.40E+00	5.12E+00	3.17E+04	5.23E+04	Nutrient		N (c)
Chromium	14 / 14	100	9.49E+00		1.78E+01		4.40E-01	5.12E-01	1.26E+01	2.90E+01	0.29		N (b)
Cobalt	14 / 14	100	5.69E+00	J	2.21E+01		1.76E-01	2.05E-01	9.41E+00	1.16E+02	2.3		N (b)
Copper	14 / 14	100	1.29E+01		2.94E+01		4.40E-01	5.12E-01	2.29E+01	5.62E+01	310		N (b)
Iron	14 / 14	100	1.30E+04	J	2.80E+04		1.76E+00	3.58E+00	1.95E+04	2.34E+05	5500		N (b)
Lead	14 / 14	100	9.86E+00		8.29E+01	J	4.40E-01	5.12E-01	1.95E+01	4.86E+01	400		N (a)
Magnesium	14 / 14	100	3.56E+03	J/J	1.90E+04	J	1.77E+00	4.10E+00	1.17E+04	1.04E+04	Nutrient		N (c)
Manganese	14 / 14	100	2.41E+02	J	2.52E+03		1.77E-01	4.10E-01	5.89E+02	3.51E+03	180		N (b)
Mercury	14 / 14	100	1.63E-02	J	1.80E-01	J	2.08E-02	2.51E-02	3.37E-02	8.50E-02	2.3		N (a)
Nickel	14 / 14	100	1.35E+01	J	5.71E+01		2.64E-01	3.07E-01	2.48E+01	5.51E+01	150		N (a)
Potassium	14 / 14	100	3.21E+02		1.09E+03		2.20E+01	2.56E+01	7.20E+02	3.39E+03	Nutrient		N (c)
Selenium	3 / 14	21	4.65E-01	U/J	5.07E-01	J	8.79E-01	1.02E+00	4.71E-01	2.00E+00	39		N (b)
Sodium	14 / 14	100	4.89E+01		1.78E+02		8.79E+00	1.02E+01	1.07E+02	NA	Nutrient		N (c)
Thallium	9 / 14	64	2.31E-01	U/J	2.92E-01	J	4.40E-01	5.12E-01	2.51E-01	1.30E+00	0.078		N (b)
Vanadium	14 / 14	100	1.82E+01		2.85E+01		1.76E-01	2.05E-01	2.15E+01	4.09E+01	39		N (b)
Zinc	14 / 14	100	4.39E+01		7.85E+01		2.20E+00	2.56E+00	5.95E+01	3.22E+02	2300		N (b)
Polychlorinated biphenyls (PCB)													
Aroclor 1016	1 / 7	14	1.00E-01	J	1.00E-01	J	3.99E-02	2.04E-01	7.75E-02		0.39		N (a)
Aroclor 1260	1 / 7	14	6.67E-02	J	6.67E-02	J	3.99E-02	2.04E-01	6.10E-02		0.22		N (a)
Semivolatile Organic Compounds													
Acenaphthene	1 / 14	7	5.92E-02	J	5.92E-02	J	3.92E-01	4.20E-01	1.94E-01		340		N (a)
Acenaphthylene	2 / 14	14	5.77E-02	J	7.88E-02	J	3.92E-01	4.20E-01	1.85E-01		340	g	N (a)
Anthracene	3 / 14	21	6.17E-02	J	2.63E-01	J	3.92E-01	4.20E-01	1.95E-01		1700		N (a)
Benzo(a)anthracene	4 / 14	29	3.98E-02	J	3.09E-01	J	3.92E-01	4.20E-01	2.05E-01		0.15		Y
Benzo(a)pyrene	3 / 14	21	1.96E-01	J/U	3.06E-01	J	3.92E-01	4.20E-01	2.12E-01		0.015		Y
Benzo(b)fluoranthene	3 / 14	21	2.53E-01	J/U	4.09E-01		3.92E-01	4.20E-01	2.30E-01		0.15		Y
Benzo(ghi)perylene	3 / 14	21	1.20E-01	J	1.80E-01	J	3.92E-01	4.20E-01	1.94E-01		170	h	N (a)
Benzo(k)fluoranthene	1 / 14	7	1.36E-01	J	1.36E-01	J	3.92E-01	4.20E-01	1.99E-01		1.5		N (a)
Bis(2-ethylhexyl)phthalate	1 / 14	7	1.21E-01	U/J	1.21E-01	U/J	3.92E-01	4.20E-01	1.98E-01		35		N (a)
Carbazole	1 / 14	7	4.43E-02	J	4.43E-02	J	3.92E-01	4.20E-01	1.93E-01		24	i	N (a)
Chrysene	3 / 14	21	2.21E-01	J/U	2.76E-01	J	3.92E-01	4.20E-01	2.13E-01		15		N (a)
Dibenzofuran	1 / 14	7	7.80E-02	J	7.80E-02	J	3.92E-01	4.20E-01	1.95E-01		7.8		N (a)

Table 2-5

Statistical Summary and Selection of Chemicals of Potential Concern in Subsurface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]
Fluoranthene	4 / 14	29	5.05E-02	J	8.16E-01		3.92E-01	4.20E-01	2.65E-01		230		N (a)
Fluorene	1 / 14	7	1.14E-01	J	1.14E-01	J	3.92E-01	4.20E-01	1.98E-01		230		N (a)
Indeno(1,2,3-cd)pyrene	3 / 14	21	2.84E-01	J/U	4.36E-01		3.92E-01	4.20E-01	2.40E-01		0.15		Y
Phenanthrene	3 / 14	21	2.75E-01	J/U	8.45E-01		3.92E-01	4.20E-01	2.62E-01		170	h	N (a)
Pyrene	4 / 14	29	4.06E-02	J	5.84E-01		3.92E-01	4.20E-01	2.37E-01		170		N (a)

BSC - Background screening criterion.
COPC - Chemical of potential concern.
mg/kg - Milligrams per kilogram.
RBSC - Risk-based screening concentration.
VQ - Validation qualifier.
/ - When in the VQ column, this separates two qualifiers where the concentration is the result of a sample averaged with a field duplicate.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
U - The sample result was nondetect.

[a] IT Corporation, 2000, *TNT Area B Remedial Investigation, Volume II, Baseline Human Health Risk Assessment, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio* , August, and reports referenced therein.
[b] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) residential soil values (unless otherwise noted), and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[c] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Maximum detected concentration is less than the BSC.
(c) = Essential nutrient.
[d] Y = Chemical is chosen as a COPC.
[e] 95% UCL (Upper confidence limit) determined using ProUCL Version 4.00.05 U.S. Environmental Protection Agency (EPA), 2010, ProUCL Version 4.00.05, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[f] Exposure-point concentration (EPC) used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.
[g] RBSC based on acenaphthene.
[h] RBSC based on pyrene.
[i] Because no RSL is available, the RBSC is based on the PRG (EPA, 2004). Note that the slope factor used for the PRG is the most current available.

Table 2-6

Statistical Summary and Selection of Chemicals of Potential Concern in Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg	COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Inorganics														
Aluminum	30 / 30	100	3.11E+03		1.05E+04		1.70E+00	2.40E+01	7.62E+03	1.55E+04	7700	N (b)		---
Antimony	20 / 30	67	2.61E-01	J	4.36E-01	J	4.24E-01	7.20E+00	1.25E+00	9.30E+00	3.1	N (b)		---
Arsenic	30 / 30	100	3.90E+00		2.08E+01		8.49E-01	1.20E+00	7.32E+00	3.65E+01	0.39	N (b)		---
Barium	30 / 30	100	2.97E+01		1.97E+02		1.74E-01	2.40E+01	5.90E+01	8.26E+02	1500	N (b)		---
Beryllium	23 / 30	77	5.90E-01		8.44E+00		1.70E-01	6.00E-01	4.33E+00	1.00E+00	16	N (a)		---
Cadmium	14 / 30	47	2.24E-01	J	1.01E+00		4.24E-01	6.00E-01	2.94E-01	NA	7	N (a)		---
Calcium	30 / 30	100	3.29E+03		6.07E+04		4.24E+00	6.00E+02	2.53E+04	5.23E+04	Nutrient	N (c)		---
Chromium	30 / 30	100	6.90E+00		1.78E+01		4.24E-01	1.20E+00	1.21E+01	2.90E+01	0.29	N (b)		---
Cobalt	28 / 30	93	3.97E+00	J	2.21E+01		1.70E-01	6.00E+00	7.67E+00	1.16E+02	2.3	N (b)		---
Copper	30 / 30	100	7.10E+00		2.94E+01		4.24E-01	3.00E+00	1.89E+01	5.62E+01	310	N (b)		---
Iron	30 / 30	100	1.02E+04	J	2.90E+04		1.70E+00	1.20E+01	1.78E+04	2.34E+05	5500	N (b)		---
Lead	30 / 30	100	9.60E+00		1.34E+02	J	3.10E-01	5.12E-01	2.57E+01	4.86E+01	400	N (a)		---
Magnesium	30 / 30	100	2.01E+03		1.90E+04	J	1.74E+00	6.00E+02	8.17E+03	1.04E+04	Nutrient	N (c)		---
Manganese	30 / 30	100	1.70E+02		2.52E+03		1.74E-01	1.80E+00	4.49E+02	3.51E+03	180	N (b)		---
Mercury	28 / 30	93	1.63E-02	J	5.97E-01		2.06E-02	4.00E-02	6.64E-02	8.50E-02	2.3	N (a)		---
Nickel	30 / 30	100	8.40E+00		5.71E+01		2.55E-01	4.80E+00	1.99E+01	5.51E+01	150	N (a)		---
Potassium	29 / 30	97	3.21E+02		1.09E+03		2.12E+01	6.00E+02	6.65E+02	3.39E+03	Nutrient	N (c)		---
Selenium	15 / 30	50	4.65E-01	U/J	1.10E+00		5.20E-01	1.02E+00	5.75E-01	2.00E+00	39	N (b)		---
Sodium	21 / 30	70	2.50E+01		1.78E+02		8.49E+00	6.00E+02	1.46E+02	NA	Nutrient	N (c)		---
Thallium	16 / 30	53	2.21E-01	J	1.10E+00		4.24E-01	1.20E+00	4.15E-01	1.30E+00	0.078	N (b)		---
Vanadium	30 / 30	100	1.38E+01		2.85E+01		1.70E-01	6.00E+00	2.02E+01	4.09E+01	39	N (b)		---
Zinc	30 / 30	100	3.38E+01		1.05E+02		2.10E+00	2.56E+00	5.85E+01	3.22E+02	2300	N (b)		---
Polychlorinated biphenyls (PCB)														
Aroclor 1016	3 / 16	19	1.00E-01	J	1.22E+00	J	3.99E-02	2.05E-01	1.53E-01		0.39	Y	3.21E-01	3.21E-01
Aroclor 1254	2 / 16	13	2.50E-01		1.00E+00	J	3.99E-02	2.05E-01	1.36E-01		0.11	Y	4.09E-01	4.09E-01
Aroclor 1260	3 / 16	19	6.67E-02	J	2.29E-01		3.99E-02	4.60E-01	9.52E-02		0.22	Y	1.30E-01	1.30E-01
Nitroaromatics														
Amino-2,6-dinitrotoluene, 4-	1 / 30	3	2.60E-01		2.60E-01		2.50E-01	3.14E-01	1.44E-01		15	N (a)		---
Amino-4,6-dinitrotoluene, 2-	1 / 30	3	2.28E-01	/U	2.28E-01	/U	2.50E-01	3.14E-01	1.43E-01		15	N (a)		---
Trinitrotoluene, 2,4,6-	1 / 30	3	8.80E-01		8.80E-01		2.50E-01	3.14E-01	1.65E-01		3.6	N (a)		---
Semivolatile Organic Compounds														
Acenaphthene	3 / 23	13	5.92E-02	J	6.43E-01	J	3.60E-01	2.00E+00	2.62E-01		340	N (a)		---
Acenaphthylene	7 / 23	30	5.41E-02	J	3.23E+00		3.60E-01	2.00E+00	3.86E-01		340 [g]	N (a)		---
Anthracene	8 / 23	35	5.04E-02	J	4.53E+00		3.60E-01	2.00E+00	5.34E-01		1700	N (a)		---
Benzo(a)anthracene	11 / 23	48	3.98E-02	J	1.19E+01		3.60E-01	2.00E+00	1.13E+00		0.15	Y	2.05E+00	2.05E+00
Benzo(a)pyrene	10 / 23	43	9.09E-02	J	1.00E+01		3.60E-01	2.00E+00	1.00E+00		0.015	Y	1.78E+00	1.78E+00
Benzo(b)fluoranthene	10 / 23	43	1.40E-01	J	1.39E+01		3.60E-01	2.00E+00	1.25E+00		0.15	Y	2.34E+00	2.34E+00
Benzo(ghi)perylene	9 / 23	39	1.20E-01	J	5.57E+00		3.60E-01	2.00E+00	6.44E-01		170 [h]	N (a)		---
Benzo(k)fluoranthene	7 / 23	30	1.27E-01	J	4.49E+00		3.60E-01	2.00E+00	6.21E-01		1.5	Y	1.13E+00	1.13E+00
Bis(2-ethylhexyl)phthalate	1 / 23	4	1.21E-01	U/J	1.21E-01	U/J	3.60E-01	2.00E+00	2.68E-01		35	N (a)		---
Carbazole	3 / 21	14	4.43E-02	J	1.12E+00	J	3.92E-01	2.00E+00	2.89E-01		24 [i]	N (a)		---
Chrysene	10 / 23	43	9.25E-02	J	1.03E+01		3.60E-01	2.00E+00	1.03E+00		15	N (a)		---
Dibenz(a,h)anthracene	3 / 23	13	3.97E-01	J	1.46E+00	J	3.60E-01	2.00E+00	3.23E-01		0.015	Y	5.62E-01	5.62E-01
Dibenzofuran	3 / 23	13	7.80E-02	J	1.35E+00	J	3.60E-01	2.00E+00	2.92E-01		7.8	N (a)		---

Table 2-6

Statistical Summary and Selection of Chemicals of Potential Concern in Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Fluoranthene	11 / 23	48	5.05E-02	J	2.48E+01		3.60E-01	2.00E+00	2.14E+00		230		N (a)		---
Fluorene	4 / 23	17	1.14E-01	J	1.78E+00	J	3.60E-01	2.00E+00	3.36E-01		230		N (a)		---
Indeno(1,2,3-cd)pyrene	10 / 23	43	2.84E-01	J/U	8.10E+00		3.60E-01	2.00E+00	8.68E-01		0.15		Y	1.53E+00	1.53E+00
Methylnaphthalene, 2-	2 / 23	9	7.21E-01		1.57E+00	J	3.60E-01	2.00E+00	3.19E-01		23		N (a)		---
Naphthalene	2 / 25	8	6.77E-01		1.38E+00	J	5.50E-03	2.00E+00	2.84E-01		3.6		N (a)		---
Phenanthrene	10 / 23	43	6.77E-02	J	1.39E+01		3.60E-01	2.00E+00	1.25E+00		170	h	N (a)		---
Pyrene	11 / 23	48	4.06E-02	J	1.81E+01		3.60E-01	2.00E+00	1.68E+00		170		N (a)		---
Volatile Organic Compounds															
Methylene chloride	2 / 2	100	1.20E-02		1.30E-02		5.50E-03	6.00E-03	1.25E-02		36		N (a)		---

BSC - Background screening criterion.
COPC - Chemical of potential concern.
mg/kg - Milligrams per kilogram.
RBSC - Risk-based screening concentration.
VQ - Validation qualifier.
/ - When in the VQ column, this separates two qualifiers where the concentration is the result of a sample averaged with a field duplicate.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
U - The sample result was nondetect.

[a] IT Corporation, 2000, *TNT Area B Remedial Investigation, Volume II, Baseline Human Health Risk Assessment, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio* , August, and reports referenced therein.
[b] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) residential soil values (unless otherwise noted), and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[c] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Maximum detected concentration is less than the BSC.
(c) = Essential nutrient.
[d] Y = Chemical is chosen as a COPC.
[e] 95% UCL (upper confidence limit) determined using ProUCL Version 4.00.05 U.S. Environmental Protection Agency (EPA), 2010, ProUCL Version 4.00.05, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[f] Exposure-point concentration (EPC) used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.
[g] RBSC based on acenaphthene.
[h] RBSC based on pyrene.
[i] Because no RSL is available, the RBSC is based on the PRG (EPA, 2004). Note that the slope factor used for the PRG is the most current available.

Table 2-7

Statistical Summary and Selection of Chemicals of Potential Concern in Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of values, µg/L: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Arithmetic Mean µg/L	BSC [a] µg/L	RBSC [b] µg/L	COPC? [c,d]	95% UCL [e] µg/L	EPC [f] µg/L
Inorganics - Unfiltered														
Aluminum	4 / 4 [g]	100	3.19E+01	JJ	1.25E+02	J	2.00E+02	2.00E+02	8.18E+01	3.09E+02	1600	N (a)		---
Arsenic	3 / 6	50	2.08E+01		1.23E+02		1.00E+01	1.00E+01	3.09E+01	7.40E+00	0.045	Y	7.68E+01	7.68E+01
Barium	6 / 6	100	2.40E+02		7.66E+02		2.00E+02	2.00E+02	4.37E+02	1.18E+04	290	N (b)		---
Calcium	6 / 6	100	8.46E+04	J	1.50E+05		1.00E+03	1.00E+03	1.15E+05	3.16E+05	Nutrient	N (c)		---
Iron	1 / 6	17	2.96E+02	J	2.96E+02	J	3.00E+02	3.00E+02	1.74E+02	1.55E+03	1100	N (a)		---
Lead	2 6	33	3.30E+00	J	3.65E+00	U/J	1.00E+01	1.00E+01	4.49E+00	NA	15 [h]	N (a)		---
Magnesium	6 / 6	100	5.71E+04		8.64E+04		5.00E+03	5.00E+03	7.25E+04	2.17E+05	Nutrient	N (c)		---
Manganese	6 / 6	100	1.35E+01	J	6.63E+02		1.50E+01	1.50E+01	1.70E+02	6.36E+02	32	Y	NA	6.63E+02
Potassium	6 / 6	100	2.48E+04		4.73E+04		1.00E+04	2.00E+04	4.03E+04	1.16E+05	Nutrient	N (c)		---
Selenium	3 / 6	50	4.20E+00	J/U	4.70E+00	J	1.00E+01	1.00E+01	4.72E+00	NA	7.8	N (a)		---
Sodium	6 / 6	100	1.07E+05		2.70E+05		5.00E+04	1.00E+05	2.18E+05	1.39E+06	Nutrient	N (c)		---
Vanadium	6 / 6	100	1.10E+00	J	1.31E+01	U/J	5.00E+01	5.00E+01	3.55E+00	NA	7.8	Y	1.19E+01	1.19E+01
Zinc	1 / 3 [g]	33	8.90E+00	J	8.90E+00	J	2.00E+01	2.00E+01	9.63E+00	5.01E+02	470	N (a)		---
Semivolatile Organic Compounds														
Methylnaphthalene, 2-	5 / 6	83	1.10E+00	J	2.80E+00	J	4.80E+00	5.00E+00	2.03E+00		2.7	Y	2.51E+00	2.51E+00
Naphthalene	4 / 6	67	1.10E+00	J	2.05E+00	J/U	4.80E+00	5.00E+00	1.83E+00		0.14	Y	1.98E+00	1.98E+00
Volatile Organic Compounds														
Benzene	6 / 6	100	2.10E+00		1.54E+01		1.00E+00	2.00E+00	6.15E+00		0.39	Y	1.03E+01	1.03E+01
Butanone, 2-	4 / 6	67	6.35E+00	/U	1.44E+01		5.00E+00	1.00E+01	8.03E+00		490	N (a)		---
Ethylbenzene	6 / 6	100	1.20E+00		4.60E+00		1.00E+00	2.00E+00	2.96E+00		1.3	Y	4.08E+00	4.08E+00
Toluene	6 / 6	100	2.70E+00		1.64E+01	J	1.00E+00	1.00E+00	1.02E+01		86	N (a)		---
Xylenes, total	6 / 6	100	7.70E+00		3.46E+01		3.00E+00	6.00E+00	2.08E+01		19	Y	2.97E+01	2.97E+01
General Chemistry														
Chloride	6 / 6	100	2.38E+04		1.63E+05		2.00E+03	2.00E+04	1.27E+05		Nutrient	N (c)		---
Cyanide, total	3 / 6	50	2.90E+01		5.30E+01		1.00E+01	1.00E+01	2.36E+01		0.93	Y	4.53E+01	4.53E+01
Nitrate-Nitrite	4 / 6	67	8.60E+01	J	8.10E+02	J	1.00E+02	4.00E+03	6.93E+02		1000 [i]	N (a)		---
Sulfate	4 / 6	67	4.20E+03	J	4.05E+04		2.00E+03	2.00E+04	1.57E+04		250,000 [j]	N (a)		---

BSC - Background screening concentration.
COPC - Chemical of potential concern.
RBSC - Risk-based screening concentration.
µg/L - Micrograms per liter.
VQ - Validation qualifier.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
/ - Indicates result is from two samples, regular and field duplicate, averaged and reflects both qualifiers.

[a] Shaw Environmental, Inc. (Shaw), 2005b, *2004 Groundwater Data Summary and Evaluation Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio* , April.
[b] Risk-based screening concentrations based on EPA Regional Screening Level Table (April 2012) tap water values and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[c] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Maximum detected concentration is less than the BSC.
(c) = Essential nutrient.

Table 2-7

Statistical Summary and Selection of Chemicals of Potential Concern in Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

[d] Y = Chemical is chosen as COPC.
[e] 95% UCL (upper confidence limit) determined using ProUCL Version 4.1 (U.S. Environmental Protection Agency (EPA), 2011, ProUCL Version 4.1, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[f] Concentration used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.
[g] Some samples were excluded from the dataset because of blank contamination.
[h] Screening criteria for lead based on the action level of 15 µg/L (EPA, 1996, *Drinking Water Regulations and Health Advisories*, Office of Water, Washington, DC, October).
[i] Because no Regional Screening Level exists for nitrate-nitrite, 0.1 X the nitrate-nitrite MCL (10 mg/L) is used for screening.
[j] US Environmental Protection Agency (EPA), 2012, 2012 *Edition of the Drinking Water Standards and Health Advisories*, Office of Water, October, April, EPA 822-S-12-001.

Table 2-8

Statistical Summary and Selection of Chemicals of Potential Concern in Overburden Monitoring Well Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of values, µg/L: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Arithmetic Mean µg/L	RBSC [a] µg/L	COPC? [b,c]	95% UCL [d] µg/L	EPC [e] µg/L
Inorganics-Unfiltered													
Aluminum	6 / 6	100	8.76E+01	J	1.19E+03		2.00E+02	2.00E+02	2.78E+02	1600	N (a)		---
Arsenic	3 / 6	50	1.04E+01		1.58E+01		1.00E+01	1.00E+01	8.60E+00	0.045	Y	1.33E+01	1.33E+01
Barium	6 / 6	100	1.62E+02	J	4.11E+02		2.00E+02	2.00E+02	2.42E+02	290	Y	3.19E+02	3.19E+02
Calcium	6 / 6	100	8.69E+04	J	1.23E+05		1.00E+03	1.00E+03	1.07E+05	Nutrient	N (b)		---
Chromium	1 / 6	17	2.90E+00	J	2.90E+00	J	1.00E+01	1.00E+01	4.65E+00	0.031	Y	NA	2.90E+00
Cobalt	2 / 6	33	1.40E+00	J	3.00E+00	J	5.00E+01	5.00E+01	1.74E+01	0.47	Y	NA	3.00E+00
Iron	3 / 6	50	5.99E+01	J	2.87E+03		3.00E+02	3.00E+02	5.85E+02	1100	Y	1.60E+03	1.60E+03
Magnesium	6 / 6	100	3.44E+04		4.45E+04		5.00E+03	5.00E+03	3.95E+04	Nutrient	N (b)		---
Manganese	6 / 6	100	3.00E+01		5.21E+02		1.50E+01	1.50E+01	3.01E+02	32	Y	4.76E+02	4.76E+02
Mercury	1 / 6	17	2.10E-01	J	2.10E-01	J	1.00E+00	1.00E+00	4.52E-01	0.43	N (a)		---
Nickel	5 / 6	83	2.30E+00	J	4.50E+00	J	4.00E+01	4.00E+01	5.93E+00	30	N (a)		---
Potassium	6 / 6	100	1.76E+03	J	4.85E+03	J	1.00E+04	2.00E+04	3.02E+03	Nutrient	N (b)		---
Selenium	3 / 6	50	3.40E+00	J	5.20E+00	J	1.00E+01	1.00E+01	4.68E+00	7.8	N (a)		---
Sodium	6 / 6	100	1.70E+04		2.80E+04		1.00E+04	1.00E+04	2.30E+04	Nutrient	N (b)		---
Vanadium	3 / 6	50	9.00E-01	J	2.50E+00	J	5.00E+01	5.00E+01	1.32E+01	7.8	N (a)		---
Zinc	1 / 4 [f]	25	1.31E+01	J	1.31E+01	J	2.00E+01	2.00E+01	1.08E+01	470	N (a)		---
Nitroaromatics													
Dinitrobenzene, 1,3-	2 / 6	33	1.30E-01	J	1.50E-01	J	1.90E-01	2.00E-01	1.11E-01	0.15	Y	1.50E-01	1.50E-01
Dinitrotoluene, 2,4-	2 / 6	33	1.60E-01	J	1.90E-01	J	1.90E-01	2.00E-01	1.23E-01	0.092	Y	1.81E-01	1.81E-01
Trinitrobenzene, 1,3,5-	2 / 6	33	1.40E-01	J	2.90E-01		1.90E-01	2.00E-01	1.36E-01	46	N (a)		---
General Chemistry													
Chloride	6 / 6	100	7.20E+03		2.06E+04		2.00E+03	2.00E+03	1.27E+04	Nutrient	N (b)		---
Cyanide, total	2 / 6	33	1.30E+01		2.30E+01		1.00E+01	1.00E+01	9.33E+00	0.93	Y	1.90E+01	1.90E+01
Nitrate-Nitrite	3 / 6	50	2.40E+02		3.50E+02		1.00E+02	2.00E+03	3.35E+02	1000 [g]	N (a)		---
Sulfate	6 / 6	100	3.73E+04	J	8.36E+04	J	2.00E+03	2.00E+03	6.27E+04	250,000 [h]	N (a)		---

µg/L - Micrograms per liter.
COPC - Chemical of potential concern.
NA - Not applicable; UCL is not calculated due to low frequency of detection and elevated reporting limits.
RBSC - Risk-based screening concentration.
VQ - Validation qualifier.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed

[a] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) tap water values and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[b] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Essential nutrient.

Table 2-8

Statistical Summary and Selection of Chemicals of Potential Concern in Overburden Monitoring Well Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

[c] Y = Chemical is chosen as COPC.
[d] 95% UCL (upper confidence limit) determined using ProUCL Version 4.00.05 (U.S. Environmental Protection Agency (EPA), 2010, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm. Calculated only for COPC
[e] Concentration used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.
[f] Some samples were excluded from the dataset because of blank contamination.
[g] Because no regional screening level exists for nitrate-nitrite, 0.1 X the nitrate-nitrite MCL (10 mg/L) is used for screening.
[h] U.S. Environmental Protection Agency (EPA), 2012, *2012 Edition of the Drinking Water Standards and Health Advisories, Office of Water, April*, EPA 822-S-12-001.

Table 2-9

Statistical Summary and Selection of Chemicals of Potential Concern in Sediment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

(Page 1 of 2)

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	RBSC [a] mg/kg	COPC? [b,c]	EPC [d] mg/kg
Inorganics												
Aluminum	3 / 3	100	8.41E+03		9.58E+03		2.10E+01	2.54E+01	9.00E+03	7.70E+04	N (a)	---
Arsenic	3 / 3	100	6.40E+00		7.20E+00		8.50E-01	1.30E+00	6.80E+00	3.90E-01	Y	7.20E+00
Barium	3 / 3	100	5.86E+01		8.25E+01		2.10E+01	2.54E+01	6.91E+01	1.50E+04	N (a)	---
Beryllium	1 / 3	33	6.40E-01		6.40E-01		5.30E-01	6.30E-01	4.20E-01	1.60E+02	N (a)	---
Cadmium	1 / 3	33	8.60E-01		8.60E-01		4.20E-01	6.30E-01	4.93E-01	7.00E+01	N (a)	---
Calcium	3 / 3	100	7.24E+03		3.30E+04		5.30E+02	6.35E+02	2.38E+04	Nutrient	N (b)	---
Chromium	3 / 3	100	1.41E+01		1.51E+01		1.10E+00	1.30E+00	1.45E+01	2.90E-01	Y	1.51E+01
Cobalt	3 / 3	100	7.10E+00		1.14E+01		5.30E+00	6.30E+00	8.90E+00	2.30E+01	N (a)	---
Copper	3 / 3	100	1.79E+01		2.64E+01		2.60E+00	3.20E+00	2.11E+01	3.10E+03	N (a)	---
Iron	3 / 3	100	1.83E+04		1.93E+04		1.10E+01	1.27E+01	1.87E+04	5.50E+04	N (a)	---
Lead	3 / 3	100	9.40E+00		1.86E+01		3.60E-01	1.10E+01	1.47E+01	4.00E+02	N (a)	---
Magnesium	3 / 3	100	3.78E+03		1.10E+04		5.30E+02	6.35E+02	8.39E+03	Nutrient	N (b)	---
Manganese	3 / 3	100	1.42E+02		1.87E+03		1.80E+00	1.60E+01	8.01E+02	1.80E+03	Y	1.87E+03
Mercury	2 / 3	67	4.70E-02		5.80E-02	J	4.00E-02	1.80E-01	4.17E-02	2.30E+01	N (a)	---
Nickel	3 / 3	100	1.91E+01		2.37E+01		4.20E+00	5.10E+00	2.11E+01	1.50E+03	N (a)	---
Potassium	2 / 2	100	8.77E+02		9.98E+02		6.05E+02	6.35E+02	9.38E+02	Nutrient	N (b)	---
Selenium	3 / 3	100	7.10E-01		2.80E+00	J	6.10E-01	1.10E+01	1.50E+00	3.90E+02	N (a)	---
Sodium	1 / 3	33	1.72E+02	J	1.72E+02	J	6.05E+02	2.20E+03	2.64E+02	Nutrient	N (b)	---
Thallium	1 / 3	33	1.20E+00		1.20E+00		1.20E+00	4.40E+00	1.35E+00	7.80E-01	Y	1.20E+00
Vanadium	3 / 3	100	2.20E+01		2.45E+01		5.30E+00	6.30E+00	2.36E+01	3.90E+02	N (a)	---
Zinc	3 / 3	100	5.26E+01		7.19E+01		2.10E+00	2.50E+00	6.32E+01	2.30E+04	N (a)	---
Semivolatile Organic Compounds												
Benzo(a)pyrene	1 / 3	33	1.20E-01	J	1.20E-01	J	3.50E-01	4.20E-01	1.77E-01	1.50E-02	Y	1.20E-01
Benzo(b)fluoranthene	1 / 3	33	1.91E-01	J	1.91E-01	J	3.50E-01	4.20E-01	2.00E-01	1.50E-01	Y	1.91E-01
Benzo(ghi)perylene	1 / 3	33	1.05E-01	J	1.05E-01	J	3.50E-01	4.20E-01	1.72E-01	1.70E+03 e	N (a)	---
Chrysene	1 / 3	33	1.03E-01	J	1.03E-01	J	3.50E-01	4.20E-01	1.71E-01	1.50E+01	N (a)	---
Fluoranthene	1 / 3	33	1.56E-01	J	1.56E-01	J	3.50E-01	4.20E-01	1.89E-01	2.30E+03	N (a)	---
Indeno(1,2,3-cd)pyrene	1 / 3	33	1.10E-01	J	1.10E-01	J	3.50E-01	4.20E-01	1.73E-01	1.50E-01	N (a)	---
Pyrene	1 / 3	33	1.38E-01	J	1.38E-01	J	3.50E-01	4.20E-01	1.83E-01	1.70E+03	N (a)	---

RBSC - Risk-based screening concentration.
COPC - Chemical of potential concern.

Table 2-9

Statistical Summary and Selection of Chemicals of Potential Concern in Sediment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

mg/kg - Milligrams per kilogram.
VQ - Validation qualifier.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.

[a] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) residential soil and are based on a risk level of 1.0E-06 and a hazard index of 1.
[b] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Essential nutrient.
[c] Y = Chemical is chosen as a COPC.
[d] Exposure-point concentration (EPC) used in risk assessment equal to maximum detected concentration.
[e] RBSC based on pyrene.

Table 2-10

Statistical Summary and Selection of Chemicals of Potential Concern in Surface Water
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of values, µg/L: Detected Conc Minimum	VQ	Detected Conc Maximum	VQ	Reporting Limits Minimum	Reporting Limits Maximum	Arithmetic Mean µg/L	RBSC [a] µg/L		COPC? [b,c]	EPC [d] µg/L
Metals													
Aluminum	3 / 3	100	1420		3590	J/J	200	200	2.22E+03	1.60E+04		N (a)	---
Arsenic	2 / 3	67	6.1	J	7.2	J/U	10	10	6.10E+00	4.50E-02		Y	7.20E+00
Barium	3 / 3	100	47	J	105	J/J	200	200	7.25E+01	2.90E+03		N (a)	---
Calcium	3 / 3	100	91200		119500		1000	1000	1.07E+05	Nutrient		N (b)	---
Chromium	3 / 3	100	2.1	J	5.65	J/J	10	10	3.42E+00	3.10E-02		Y	5.65E+00
Cobalt	3 / 3	100	1.6	J	5.95	J/J	50	50	3.22E+00	4.70E+00		Y	5.95E+00
Copper	2 / 3	67	6.9	J	8.4	J/J	25	25	9.27E+00	6.20E+02		N (a)	---
Iron	3 / 3	100	2440		11300		300	300	5.98E+03	1.10E+04		Y	1.13E+04
Lead	3 / 3	100	2.2	J	7.2		5	5	4.63E+00	1.50E+01	e	N (a)	---
Magnesium	3 / 3	100	23600		29300		5000	5000	2.57E+04	Nutrient		N (b)	---
Manganese	3 / 3	100	134		1980		15	15	9.67E+02	3.20E+02		Y	1.98E+03
Nickel	1 / 3	33	4.1	J/J	4.1	J/J	40	40	1.47E+01	3.00E+02		N (a)	---
Potassium	3 / 3	100	703	J	1465	J/J	20000	20000	9.81E+02	Nutrient		N (b)	---
Selenium	1 / 3	33	4.6	J/J	4.6	J/J	10	10	4.87E+00	7.80E+01		N (a)	---
Sodium	3 / 3	100	3850	J	4955	J/J	20000	20000	4.43E+03	Nutrient		N (b)	---
Vanadium	3 / 3	100	4.7	J	9.65	J/J	50	50	6.45E+00	7.80E+01		N (a)	---

RBSC - Risk-based screening concentration.
COPC - Chemical of potential concern.
µg/L - Micrograms per liter.
VQ - Validation qualifier.
/ - When in the VQ column, this separates two qualifiers where the concentration is the result of a sample averaged with a field duplicate.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed
U - The sample result was nondetect.

[a] Risk-based screening concentrations based on EPA Regional Screening Level Table (May 2012) tap water values are based on a risk level of 1.0E-06 and a hazard index of 1.
[b] N = Chemical is not chosen as a COPC:
(a) = Maximum detected concentration is less than the RBSC.
(b) = Essential nutrient.
[c] Y = Chemical is chosen as COPC.
[d] Exposure-point concentration (EPC) used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower. The EPC for lead is the mean.
[e] Screening criteria for lead based on the action level of 15 µg/L U.S. Environmental Protection Agency (EPA), 2012, 2012 Edition of the Drinking Water Standards and Health Advisories, Office of Water, April, EPA 822-S-12-001.

Table 3-1

Receptor/Exposure Scenarios
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Route
Groundskeeper – Current			
Surface Soil	None	Soil	Incidental Ingestion
			Dermal Contact
	Dust Emissions Based on Activity	Ambient Air	Inhalation
	Volatilization from Soil	Ambient Air	Inhalation[a]
Subsurface Soil	Not Quantified[b]		
Groundwater	Not Quantified[c]		
Surface Water	Not Quantified[b]		
Sediment	Not Quantified[b]		
Groundskeeper – Future			
Total Soil[d]	None	Soil	Incidental Ingestion
			Dermal Contact
	Dust Emissions Based on Activity	Ambient Air	Inhalation
	Volatilization from Soil	Ambient Air	Inhalation
Groundwater	None	Tap Water	Ingestion
			Dermal Contact
Surface Water	Not Quantified[b]		
Sediment	Not Quantified[b]		
Indoor Worker – Future[c]			
Surface Soil	None	Soil	Incidental Ingestion
			Dermal Contact[a]
	Dust Emissions; Volatilization	Indoor Air	Inhalation[a]
Subsurface Soil	Volatilization from Soil	Indoor Air	Inhalation
Groundwater	None	Tap Water	Ingestion
			Dermal Contact
Surface Water	Not Quantified[b]		
Sediment	Not Quantified[b]		

Table 3-1

Receptor/Exposure Scenarios
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Route
Construction Worker – Current/Future			
Total Soil	None	Soil	Incidental Ingestion
			Dermal Contact
	Dust Emissions Based on Activity	Ambient Air	Inhalation
	Volatilization from Soil	Ambient Air	Inhalation
Groundwater	Not Quantified[b]		
Surface Water	None	Surface Water	Dermal Contact
	Volatilization from Water	Ambient Air	Inhalation[a]
Sediment	None	Sediment	Incidental Ingestion
			Dermal Contact
On-Site Resident – Future			
Total Soil[d]	None	Soil	Incidental Ingestion
			Dermal Contact
	Dust Emissions Based on Wind Erosion	Ambient Air	Inhalation
	Volatilization from Soil	Ambient Air	Inhalation
Subsurface Soil	Volatilization from Soil	Indoor Air	Inhalation
Groundwater	None	Tap Water	Ingestion
			Dermal Contact
	Volatilization from Water	Indoor Air	Inhalation
Surface Water	None	Surface Water	Dermal Contact
	Volatilization from Water	Ambient Air	Inhalation[a]
Sediment	None	Sediment	Incidental Ingestion
			Dermal Contact

Table 3-1

Receptor/Exposure Scenarios
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Route
Hunter – Current/Future			
Surface Soil	None	Soil	Incidental Ingestion
			Dermal Contact
	Dust Emissions, Volatilization	Ambient Air	Inhalation[a]
	Biouptake	Venison	Venison Consumption
Subsurface Soil	Not Quantified[e]		
Surface Water	Not Quantified[b]		
Sediment	Not Quantified[b]		
Hunter's Child – Current/Future			
Surface Soil	Not Quantified[e]		
	Not Quantified[e]		
	Biouptake	Venison	Venison Consumption
Subsurface Soil	Not Quantified[e]		
Surface Water	Not Quantified[e]		
Sediment	Not Quantified[e]		

[a] Although theoretically complete, this pathway is not quantified as explained in text.

[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.

[c] Even though the mixing of surface and subsurface soil described in footnote "d" might otherwise be applicable, this receptor was selected primarily to evaluate exposure to indoor air resulting from subsurface soil contamination. Surface soil was used for direct contact exposure to avoid potential "double counting" of contaminants in subsurface soil (refer to Section 3.1.3.2 of text).

[d] Total soil represents a mixture of surface and subsurface soil. This is assumed for future scenarios where excavation and regrading is assumed to take place.

[e] There is no plausible pathway for exposure.

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter and Hunter's Child
General Variables Used in All Intake Models					
Body weight (BW), kg	70[a]	70[a]	Child: 15[a] Adult: 70[a]	70[a]	Child: 15[a] Adult: 70[a]
Averaging time, noncancer (AT), days[b]	9125	183	Child: 2190 Adult: 8760	9125	Child: 2190 Adult: 10950
Averaging time, cancer (AT), days[b]	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[d]	20[d]	Child: 10[e] Adult: 20[d]	NA	NA
Exposure frequency (EF), days/year	250[d]	250[f]	350[a]	NA	NA
Exposure duration (ED), years	25[a]	0.5[f]	Child: 6[a] Adult: 24[a]	NA	NA

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter and Hunter's Child
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: 10[e] Adult: 20[d]	20[d]	NA
Exposure frequency (EF), days/year	NA	NA	350[a]	250[a]	NA
Exposure duration (ED), years	NA	NA	Child: 6[a] Adult: 24[a]	25[a]	NA
Incidental Ingestion of Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	0.9[g]	1[c]	1[c]
Soil incidental ingestion rate (IR_{so}), mg/day	100[a]	330[a]	Child: 200[a] Adult: 100[a]	50[a]	Child: NA Adult: 100[a]
Exposure frequency (EF), days/year	250[d]	250[a]	350[a]	250[a]	14[d]
Exposure duration (ED), years	25[a]	0.5[f]	Child: 6[a] Adult: 24[a]	25[a]	30[a]
Dermal Contact with Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	1[c]	NA	1[c]
Body surface area exposed to soil (SA_{so}), cm^2	3,300[h]	3,300[h]	Child: 2,800[h] Adult: 5,700[h]	NA	Child: NA Adult: 3,300[h,i]
Soil-to-skin adherence factor (AF_{so}), mg/cm^2	0.2[h]	0.3[h]	Child: 0.2[h] Adult: 0.07[h]	NA	0.2[h,i]

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter and Hunter's Child
Dermal absorption factor (ABS), unitless	csv	csv	csv	NA	csv
Exposure frequency (EF), days/year	250[d]	250[a]	350[a]	NA	14[i]
Exposure duration (ED), years	25[a]	0.5[f]	Child: 6[a] Adult: 24[a]	NA	30[a]
Inhalation of VOCs from Groundwater					
Exposure time (ET), hours/day	NA	NA	24[j]	NA	NA
Inhalation rate (IR_a), m^3/hour	NA	NA	Child: 0.417[e] Adult: 0.833[e]	NA	NA
Exposure frequency (EF), days/year	250[d]	NA	350[a]	250[a]	NA
Drinking Water Ingestion of Groundwater					
Fraction exposed to contaminated medium (Fl_{gw}), unitless	1[c]	NA	1[c]	1[c]	NA
Drinking water ingestion rate (IR_{gw}), L/day	1[d]	NA	Child: 1[e] Adult: 2[d]	1[d]	NA
Exposure frequency (EF), days/year	250[d]	NA	350[a]	250[a]	NA
Dermal Contact with Groundwater					
Fraction exposed to contaminated medium (Fl_{gw}), unitless	1[c]	NA	1[c]	1[c]	NA
Body surface area exposed to water (SA_{gw}), cm^2	3,300[h,k]	NA	Child: 6,600[l] Adult: 20,000[l]	3,300[l]	NA

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter and Hunter's Child
Permeability coefficient (PC), cm/hour	csv	NA	csv	csv	NA
Exposure time (ET_{gw}), hours/day	1[c]	NA	Child: 0.333[l] Adult: 0.2[l]	1[c]	NA
Exposure frequency (EF), days/year	250[d]	NA	350[d]	250[a]	NA
Incidental Ingestion of Sediment					
Fraction exposed to contaminated medium (FI_{sd}), unitless	NA	1[c]	0.1[g]	NA	NA
Sediment incidental ingestion rate (IR_{sd}), mg/day	NA	330[a]	Child: 200[a] Adult: 100[a]	NA	NA
Exposure frequency (EF), days/year	NA	250[f]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[f]	Child: 6[a] Adult: 24[a]	NA	NA
Dermal Contact with Sediment					
Fraction exposed to contaminated medium (FI_{sd}), unitless	NA	1[f]	0.1[g]	NA	NA
Body surface area exposed to sediment (SA_{sd}), cm^2	NA	3,300[h]	Child: 2,800[h] Adult: 5,700[h]	NA	NA
Sediment-to-skin adherence factor (AF_{sd}), mg/cm^2	NA	0.3[h]	Child: 0.2[h] Adult: 0.07[h]	NA	NA
Dermal absorption factor (ABS), unitless	NA	csv	csv	NA	NA
Exposure frequency (EF), days/year	NA	250[f]	52[m]	NA	NA
Exposure duration (ED), years	NA	0.5[f]	Child: 6[a] Adult: 24[a]	NA	NA

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter and Hunter's Child
Dermal Contact with Surface Water					
Body surface area exposed to surface water (SA_{sw}), cm^2	NA	3,300[n]	Child: 2,800[n] Adult: 7,000[o]	NA	NA
Permeability coefficient (PC), cm/hour	NA	csv	csv	NA	NA
Exposure time (ET_{sw}), hour/day	NA	4[f]	3[m]	NA	NA
Exposure frequency (EF), days/year	NA	250[f]	52[m]	NA	NA
Exposure duration (ED), years	NA	0.5[f]	Child: 6[a] Adult: 24[a]	NA	NA
Venison Consumption					
Venison ingestion rate (IR_v), kg/day	NA	NA	NA	NA	Child: 0.005[i] Adult: 0.013[p]
Exposure frequency (EF), days/year	NA	NA	NA	NA	350[a]
Exposure duration (ED), years	NA	NA	NA	NA	Child: 6[a] Adult: 30[q]

[a] U.S. Environmental Protection Agency (EPA), 2002, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

[b] For noncancer evaluation, calculated as the product of ED (years) x 365 days/year; for cancer evaluation, calculated as the product of 70 years (assumed human lifetime) x 365 days/year. Source: U.S. Environmental Protection Agency (EPA), 1989a, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, Office of Emergency and Remedial Response, Washington, D.C., EPA/540/1-89/002.

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

[c] Default value which assumes 100 percent of exposure is to contaminated medium.
[d] 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.
[e] U.S. Environmental Protection Agency (EPA), 2004a, *User's Guide and Background Technical Document for Region 9 Preliminary Remediation Goals (PRG) Table*, Region 9, San Francisco, California, October, <http://www.epa.gov/region09/waste/sfund /prg/files/04usersguide.pdf>.
[f] Assumed; see Section 3.1.3.4 of text for explanation.
[g] It is assumed that on days when the resident is visiting the ditches and is exposed to sediment that half of the daily exposure via dermal contact and ingestion are associated with ditch sediment (sediment FI=0.5) and half of the exposure is associated with soil (soil FI=0.5). The resident is assumed to be exposed to soil 350 days/year and to sediment 52 days/year. The FI values of 0.1 for sediment and 0.9 for soil are weighted average daily values as described in Section 3.1.3.4 of the text.
[h] U.S. Environmental Protection Agency (EPA), 2004b, *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.
[i] Please see Section 3.1.3.7 of text for detailed explanation.
[j] The *Exposure Factors Handbook* (see reference h) indicates that the 90th percentile for the amount of time spent at a residence is more than 23 hours per day.
[k] Please see Section 3.1.3.2 of text for detailed explanation.
[l] U.S. Environmental Protection Agency (EPA), 1997, *Exposure Factors Handbook*, Final, National Center for Environmental Assessment, Washington, D.C., EPA/600/P-95/002Fa, August.
[m] Assumed; please see Section 3.1.3.5 of text for detailed explanation.
[n] Value for dermal soil exposure (EPA, 2004b) was selected as appropriate for exposure to this medium by this receptor; refer to Section 3.1.3.5 of text for detail.
[o] Value based on the Exposure Factors Handbook (EPA, 1997). See Section 3.1.3.5 of the text for detailed explanation.
[p] Please see Section 3.1.3.5 of the text for detailed explanation.
[q] Assumes deer are hunted for a 30-year duration.

csv – Chemical-specific value.
NA – Pathway not applicable for receptor.

Table 3-3

Physical Properties of Site-Related Chemicals[a]
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

Chemical of Potential Concern	Soil-to-forage Biotransfer Factor B_p (unitless)	Biotransfer Factor for Beef B_b (days/kg)	Biotransfer Factor for Venison B_v (unitless)	Diffusivity In Air (D_i) (cm^2/second)	Soil Organic Carbon-Water Partition Coefficient K_{oc} (cm^3/g)	log K_{ow}	Absorption Fraction ABS (unitless)	Permeability Coefficient K_p (cm/hour)	*tau* (hour)	*t** (hour)	Fraction Absorbed from Water FA (unitless)	B (unitless)	Molecular Weight (g/mole)	Henry's Law Constant (atm-m^3/mole)
Inorganics														
Arsenic	NA	NA	NA	NA	2.90E+01	NA	0.03	1.00E-03	NA	NA	NA	NA	74.92	NA
Barium	1.5E-01	1.57-4	9.0E-07	4.1E+01	1.58E+00	2.30E-01	NA	1.00E-03	NA	NA	NA	NA	137.33	NA
Chromium, Total	NA	NA	NA	NA	NA	NA	NA	1.00E-03	NA	NA	NA	NA	52	NA
Cobalt	NA	NA	NA	NA	4.50E+01	NA	NA	4.00E-04	NA	NA	NA	NA	58.93	NA
Iron	NA	NA	NA	NA	2.50E+01	NA	NA	1.00E-03	NA	NA	NA	NA	55.845	NA
Manganese	NA	NA	NA	NA	6.50E+01	NA	NA	1.00E-03	NA	NA	NA	NA	54.94	NA
Thallium	4.00E-04	4.00E-02	2.40E-04	NA	7.10E+01	NA	NA	1.00E-03	NA	NA	NA	NA	204.38	NA
Vanadium	NA	NA	NA	NA	1.55E+02	NA	NA	1.00E-03	NA	NA	NA	NA	50.94	NA
Polychlorinated biphenyls (PCB)														
Aroclor 1016	2.24E-02	1.00E-02	6.00E-05	4.69E-02	9.12E+04	5.60E+00	0.14	4.30E-01	11.3	47.9	0.5	3.2	257.9	2.90E-04
Aroclor 1254	6.78E-03	7.94E-02	4.76E-04	3.99E-02	1.00E+05	6.79E+00	0.14	4.30E-01	11.3	47.9	0.5	3.2	326.4	2.83E-04
Aroclor 1260	4.55E-03	1.58E-01	9.48E-04	3.65E-02	4.40E+05	8.27E+00	0.14	4.30E-01	11.3	47.9	0.5	3.2	395.3	3.36E-04
Nitroaromatics														
Dinitrobenzene, 1,3-	NA	NA	NA	6.24E-02	1.54E+02	1.49E+00	0.1	1.75E-03	0.917	2.20	1	0	168.11	4.90E-08
Dinitrotoluene, 2,4-	NA	NA	NA	2.03E-01	2.87E+02	1.98E+00	0.102	3.10E-03	1.12	2.69	1	0	182.1	5.40E-08
Semivolatile Organic Compounds														
Benzo(a)anthracene	NA	NA	NA	5.10E-02	3.98E+05	5.66E+00	0.13	4.70E-01	2.03	8.53	1	2.8	228.3	3.34E-06
Benzo(a)pyrene	NA	NA	NA	4.30E-02	1.02E+06	6.10E+00	0.13	7.00E-01	2.69	11.67	1	4.3	252.3	4.57E-07
Benzo(b)fluoranthene	NA	NA	NA	2.26E-02	1.23E+06	6.12E+00	0.13	7.00E-01	2.77	12.03	1	4.3	252.3	6.57E-07
Benzo(k)fluoranthene	NA	NA	NA	2.26E-02	2.01E+05	6.11E+00	0.13	2.00E+00	2.72	12.4	0.4	12	252.32	5.84E-07
Dibenz(a,h)anthracene	NA	NA	NA	2.02E-02	4.74E+05	6.75E+00	0.13	1.50E+00	3.88	17.57	0.6	9.7	278.4	1.41E-07
Indeno(1,2,3-cd)pyrene	NA	NA	NA	1.90E-02	3.47E+06	6.58E+00	0.13	1.00E+00	3.78	16.83	0.6	6.7	276.3	1.60E-06
Methylnaphthalene, 2-	NA	NA	NA	6.97E-02	3.98E+03	3.86E+00	0.13	8.94E-02	0.657	1.58	1	0.41	142.2	5.18E-04
Naphthalene	NA	NA	NA	5.90E-02	2.00E+03	3.30E+00	0.13	4.70E-02	0.56	1.34	1	0.2	128.2	4.40E-04
Volatile Organic Compounds														
Benzene	NA	NA	NA	8.80E-02	5.89E+01	2.13E+00	NA	1.50E-02	0.29	0.7	1	0.1	78.1	5.55E-03
Ethylbenzene	NA	NA	NA	7.50E-02	3.63E+02	3.15E+00	NA	4.90E-02	0.42	1.01	1	0.2	106.2	7.88E-03
Xylenes	NA	NA	NA	7.00E-02	4.07E+02	3.20E+00	NA	5.30E-02	0.42	1.01	1	0.2	106.2	5.18E-03
General Chemistry														
Cyanide, total	NA	NA	NA	NA	2.84E+00	NA	NA	0.001	NA	NA	NA	NA	26.02	1.33E-04

tau - Lag time associated with rate at which chemical crosses stratum corneum per event.
t* - Time for absorption across the stratum corneum to reach steady state; equals 2.4 times tau.
B - Ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis.
kg - Kilogram.
g - Gram.
atm-m^3 - Atmospheres per cubic meter.

[a] See Appendix C, which provides references for these values.

Table 4-1

Summary of Toxicity Assessment [a]
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

Chemical of Potential Concern	GAF	Weight of Evidence	Oral Slope Factor (mg/kg-day) $^{-1}$	Dermal Slope Factor (mg/kg-day) $^{-1}$	Weight of Evidence	Inhalation Unit Risk (µg/m^3) $^{-1}$	Inhalation Slope Factor (mg/kg-day) $^{-1}$
Inorganics							
Arsenic	1	A	1.50E+00	1.50E+00	A	4.30E-03	1.50E+01
Barium	1	D	NA	NA	D	NA	NA
Chromium, Total	0.013	D	NA	NA	A	1.20E-02	4.20E+01
Cobalt	1	ND	NA	NA	B	9.00E-03	3.20E+01
Iron	1	ND	NA	NA	ND	NA	NA
Manganese	0.04	D	NA	NA	D	NA	NA
Thallium	1	D	NA	NA	D	NA	NA
Vanadium	0.026	NA	NA	NA	NA	NA	NA
Polychlorinated biphenyls (PCB)							
Aroclor 1016	1	B2	7.00E-02	7.00E-02	B2	2.00E-05	7.00E-02
Aroclor 1254	1	B2	2.00E+00	2.00E+00	B2	5.70E-04	2.00E+00
Aroclor 1260	1	B2	2.00E+00	2.00E+00	B2	5.70E-04	2.00E+00
Nitroaromatics							
Dinitrobenzene, 1,3-	1	D	NA	NA	D	NA	NA
Dinitrotoluene, 2,4-	1	B2	6.80E-01	6.80E-01	D	NA	NA
Semivolatile Organic Compounds							
Benzo(a)anthracene	1	B2	7.30E-01	7.30E-01	B2	8.80E-05	3.10E-01
Benzo(a)pyrene	1	B2	7.30E+00	7.30E+00	B2	8.80E-04	3.10E+00
Benzo(b)fluoranthene	1	B2	7.30E-01	7.30E-01	B2	8.80E-05	3.10E-01
Benzo(k)fluoranthene	1	B2	7.30E-02	7.30E-02	B2	8.80E-05	3.10E-02
Dibenz(a,h)anthracene	1	B2	7.30E+00	7.30E+00	B2	8.80E-04	3.10E+00
Indeno(1,2,3-cd)pyrene	1	B2	7.30E-01	7.30E-01	B2	8.80E-05	3.10E-01
Methylnaphthalene, 2-	1	D	NA	NA	D	NA	NA
Naphthalene	1	C	ND	NA	C	3.40E-05	1.20E-01
Volatile Organic Compounds							
Benzene	1	A	5.50E-02	5.50E-02	A	7.80E-06	2.70E-02
Ethylbenzene	1	D	NA	NA	D	NA	NA
Xylenes	1	D	NA	NA	D	NA	NA
General Chemistry							
Cyanide, total	1	D	NA	NA	D	NA	NA

Table 4-1

Summary of Toxicity Assessment [a]
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

(Page 2 of 3)

		Oral		Dermal	Reference	Inhalation	
Chemical of Potential Concern	GAF	Reference Dose mg/kg-day	Target Organs	Reference Dose mg/kg-day	Concentration mg/m^3	Reference Dose mg/kg-day	Target Organs
Inorganics							
Arsenic	1	3.00E-04	S	3.00E-04	ND	NA	NA
Barium	0.07	2.00E-01	K	1.40E-02	5.00E-04	1.75E-03	F
Chromium, Total	0.013	2.10E-02	ND	2.70E-04	7.00E-04	2.03E-04	Lung
Cobalt	1	3.00E-04	Thyroid	3.00E-04	6.00E-06	1.70E-06	RT
Iron	1	7.00E-01	GI	NA	ND	NA	NA
Manganese	0.04	4.70E-02	CNS	1.90E-03	5.00E-05	1.40E-05	CNS
Thallium	1	1.00E-05	Hair	1.00E-05	ND	NA	NA
Vanadium	0.026	5.00E-03	Hair	1.30E-04	ND	NA	NA
Polychlorinated biphenyls (PCB)							
Aroclor 1016	1	7.00E-05	F	7.00E-05	ND	NA	NA
Aroclor 1254	1	2.00E-05	IS	2.00E-05	ND	NA	NA
Aroclor 1260	1	ND	NA	NA	ND	NA	NA
Nitroaromatics							
Dinitrobenzene, 1,3-	1	1.00E-04	E, Sp	1.00E-04	ND	NA	NA
Dinitrotoluene, 2,4-	1	2.00E-03	CNS,E,L	2.00E-03	ND	NA	NA
Semivolatile Organic Compounds							
Benzo(a)anthracene	1	ND	NA	NA	ND	NA	NA
Benzo(a)pyrene	1	ND	NA	NA	ND	NA	NA
Benzo(b)fluoranthene	1	ND	NA	NA	ND	NA	NA
Benzo(k)fluoranthene	1	ND	NA	NA	ND	NA	NA
Dibenz(a,h)anthracene	1	ND	NA	NA	ND	NA	NA
Indeno(1,2,3-cd)pyrene	1	ND	NA	NA	ND	NA	NA
Methylnaphthalene, 2-	1	4.00E-03	RT	4.00E-03	ND	NA	NA
Naphthalene	1	2.00E-02	RB/OW	2.00E-02	3.00E-03	8.60E-04	RT
Volatile Organic Compounds							
Benzene	1	4.00E-03	IS	4.00E-03	3.00E-03	8.60E-03	BC
Ethylbenzene	1	1.00E-01	L,K	1.00E-01	1.00E+00	2.90E-01	F
Xylenes	1	2.00E-01	RB/OW, Su	2.00E-01	1.00E-01	2.90E-02	CNS
General Chemistry							
Cyanide, total	1	6.00E-04	Repro	6.00E-04	8.0E-04	2.30E-04	Thyroid

Table 4-1

Summary of Toxicity Assessment [a]
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

mg/kg-day - Milligrams per kilogram - day.
$\mu g/m^3$ - Milligrams per cubic meter.
GAF - Gastrointestinal absorption factor.
NA - Not available or not applicable.
ND - No data or not determined.
NC - Noncancer value is regarded as protective of cancer effects in the Integrated Risk Information System (IRIS) evaluation (EPA, 2010).
[a] See Appendix C which provides references for these values.

Weight of Evidence (WOE) EPA Group:
A - Carcinogenic to humans.
B - Likely to be carcinogenic to humans (includes both the former B1 and B2 probable human carcinogens as classified on IRIS).
C - Suggested evidence of carcinogenic potential.
D - Inadequate evidence to assess carcinogenic potential.

Table 5-1

Summary of Risk for All Receptors
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

	Groundskeeper [a]		Construction Worker		Indoor Worker		Resident			Hunter		Hunter's Child	
	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	Adult - HI	Child - HI	ILCR	HI	ILCR	HI
Bedrock Groundwater Use													
Exposure Media													
Surface Soil	4.94E-05	0.07	NE	NE	1.32E-05	0.02	NE	NE	NE	3.30E-06	0.004	1.59E-10	0.00004
Total Soil	1.48E-05	0.05	7.31E-07	0.1	NE	NE	4.64E-05	0.05	0.4	NE	NE	NE	NE
Groundwater	4.06E-04	3.5	NE	NE	4.06E-04	3.5	1.76E-03	10	24.0	NE	NE	NE	NE
Sediment	NE	NE	3.04E-07	0.6	NE	NE	1.88E-06	0.025	0.24	NE	NE	NE	NE
Surface Water	NE	NE	9.96E-09	0.1	NE	NE	2.32E-07	0.05	0.09	NE	NE	NE	NE
Total ILCR or HI	**4.E-04**	**4**	**1.E-06**	**0.9**	**4.E-04**	**3**	**2.E-03**	**10**	**25**	**3.E-06**	**0.004**	**2.E-10**	**0.00004**
Overburden Groundwater Use													
Exposure Media													
Surface Soil	4.94E-05	0.07	NE	NE	1.32E-05	0.019	NE	NE	NE	3.30E-06	0.004	1.59E-10	0.00004
Total Soil	1.48E-05	0.05	7.31E-07	0.1	NE	NE	4.64E-05	0.05	0.4	NE	NE	NE	NE
Groundwater	7.05E-05	1.0	NE	NE	7.05E-05	1.0	3.00E-04	2.8	6.6	NE	NE	NE	NE
Sediment	NE	NE	3.04E-07	0.6	NE	NE	1.88E-06	0.025	0.24	NE	NE	NE	NE
Surface Water	NE	NE	9.96E-09	0.1	NE	NE	2.32E-07	0.05	0.09	NE	NE	NE	NE
Total ILCR or HI	**9.E-05**	**1**	**1.E-06**	**0.9**	**8.E-05**	**1**	**3.E-04**	**3**	**7**	**3.E-06**	**0.004**	**2.E-10**	**0.00004**

HI - Hazard index.
ILCR - Incremental lifetime cancer risk.
NA - No chemicals of potential concern available for exposure evaluation.
NE - Pathway not evaluated for this receptor.

Note:
[a] Total ILCR and total HI values for the groundskeeper reflect the respective totals for the future groundskeeper assumed to use either bedrock or overburden groundwater. The total ILCR and HI values for the current groundskeeper are simply those shown for soil. The rounded current groundskeeper ILCR is 5E-5 and the rounded HI is 0.07.

Table 5-2

Summary of Risk for Receptors[a] Excluding Exposure to Groundwater[b]
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

	Future Groundskeeper		Indoor Worker		Resident		
	ILCR	HI	ILCR	HI	ILCR	Adult - HI	Child - HI
Exposure Media							
Surface Soil	NE	NE	1.32E-05	0.02	NE	NE	NE
Total Soil	1.48E-05	0.05	NE	NE	4.64E-05	0.05	0.41
Sediment	NE	NE	NE	NE	1.88E-06	0.025	0.24
Surface Water	NE	NE	NE	NE	2.32E-07	0.05	0.09
Total ILCR or HI	**1.E-05**	**0.05**	**1.E-05**	**0.02**	**5.E-05**	**0.1**	**0.7**

HI - Hazard index.
ILCR - Incremental lifetime cancer risk.
NA - No chemicals of potential concern available for exposure evaluation.
NE - Pathway not evaluated for this receptor.

Notes:
[a] The above receptors are those which were evaluated for groundwater exposure as shown in Table 5-1.
[b] Groundwater use is not regarded as plausible because of low yield and naturally poor quality in the in the overburden and bedrock units.

Table 5-3

Cancer Risks for Current Groundskeeper and Future Resident Based on Re-Evaluation of Soil[a,b]
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

	Current Groundskeeper ILCR	Future Resident ILCR
Exposure Media		
Surface Soil	6.79E-06	NE
Total Soil	NE	1.05E-05
Sediment	NE	1.88E-06
Surface Water	NE	2.32E-07
Total ILCR	**7.E-06**	**1.E-05**

PAH - Polycyclic aromatic hydrocarbon.
ILCR - Incremental lifetime cancer risk.
NE - Pathway not evaluated for this receptor.

Notes:
[a] The above two receptors are those which have ILCR values exceeding the PBOW cancer risk goal of 1E-5 based on soil exposure using the full data set. Note that no groundwater exposure is assumed based on low water yield in the overburden and bedrock units and naturally poor water quality in the bedrock unit.
[b] The soil samples with the three highest PAH concentrations are excluded. The two surface soil samples (SB-01 and SB-02) located immediately beside the NASA K-Site control building are excluded because they are within the area where NASA has demolished the building and removed associated PAH-contaminated soil. A third high-PAH soil sample (SSW-303) was collected immediately east of the access road and was excluded from this evaluation because it is interpreted to represent anthropogenic background sources (i.e., petroleum constituents of the asphalt and vehicle emissions).

FIGURES

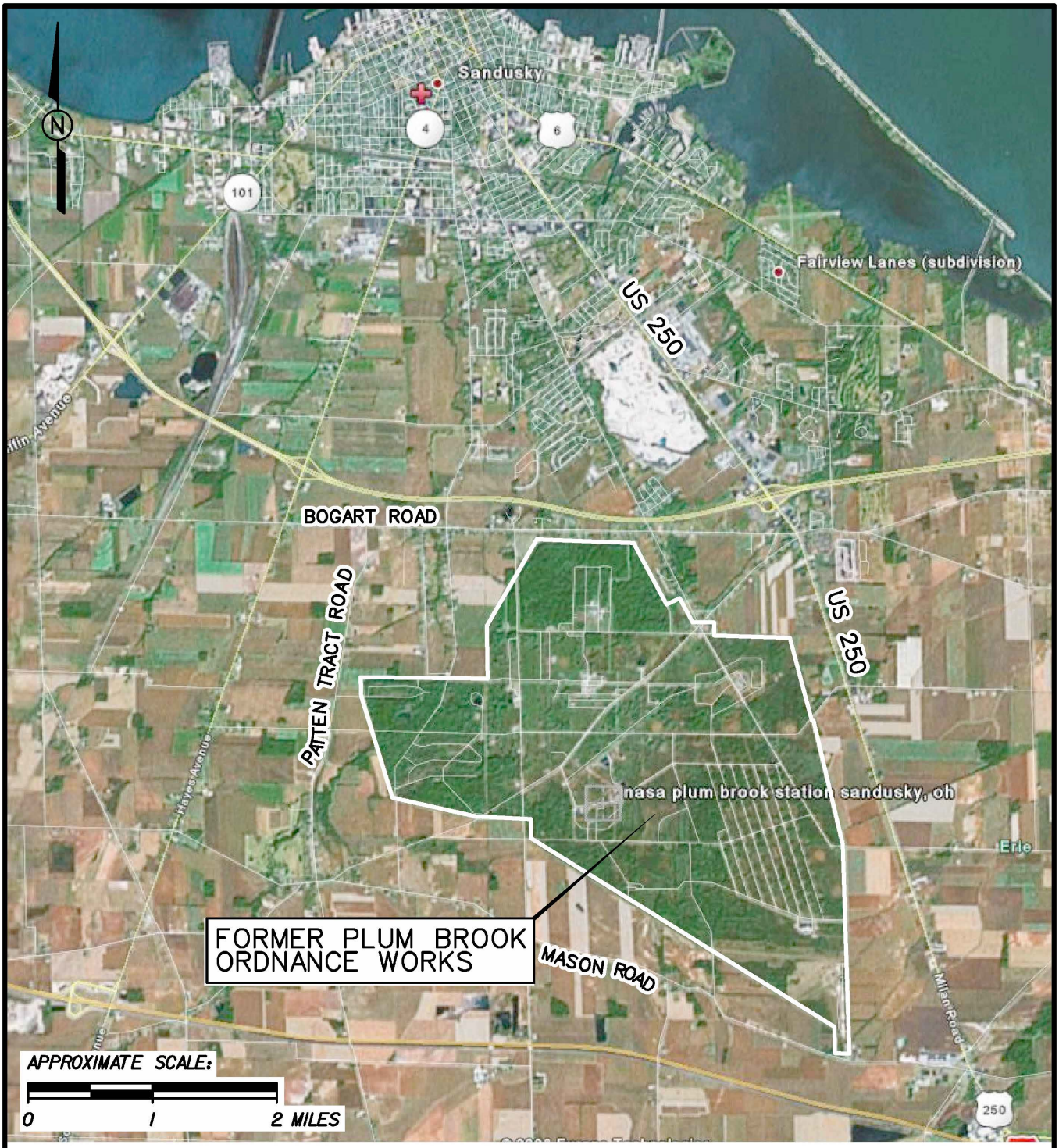


FIGURE 1-1
PBOW VICINITY MAP

WWTP3 BASELINE HUMAN HEALTH RISK ASSESSMENT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

wwtp3_blhhra_001.dgn cbentley 3/26/2013 10:08:37 AM PDF_with_Levels.plt SEI_TEXTSUB_ONLY.TBL

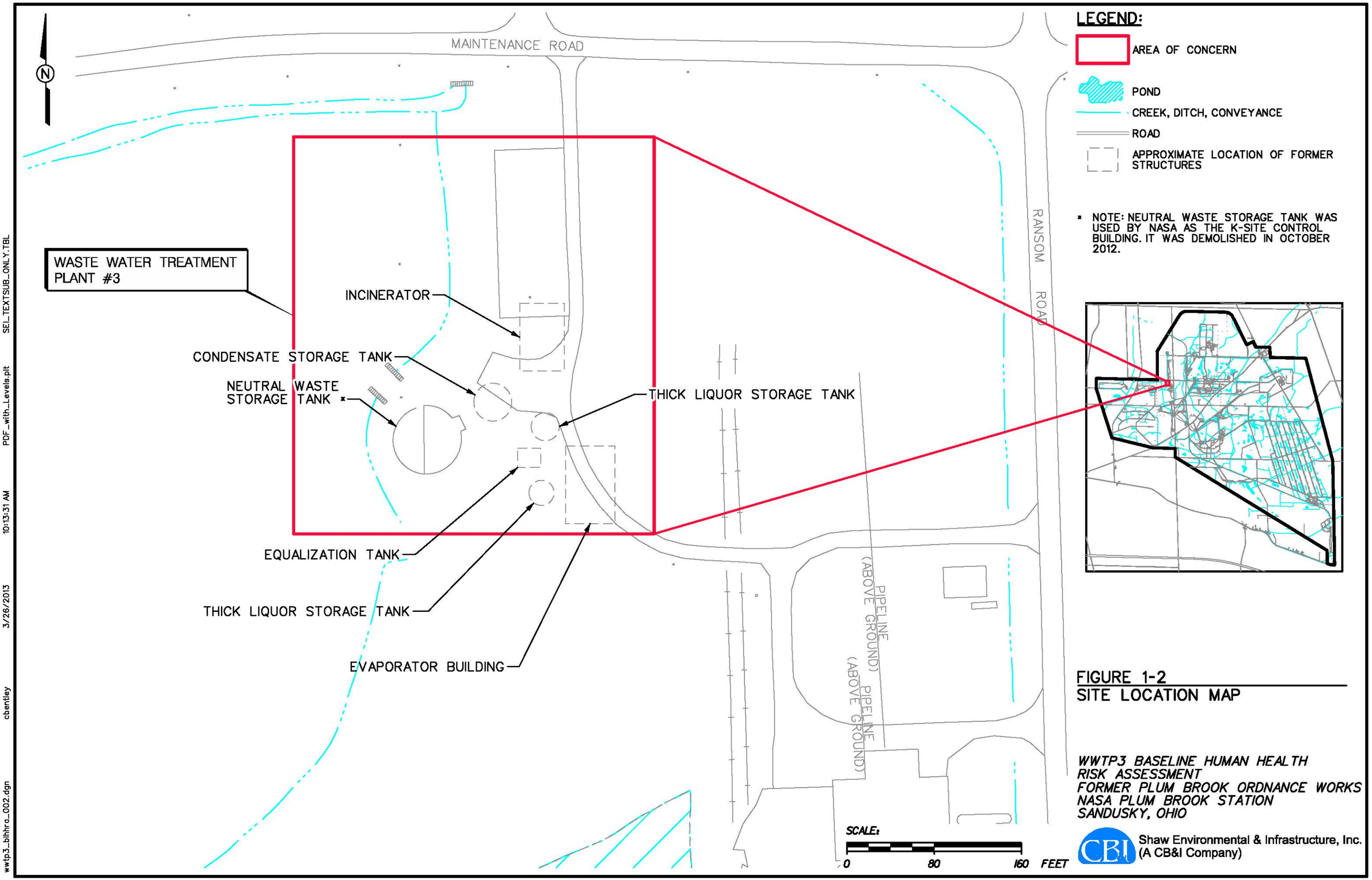
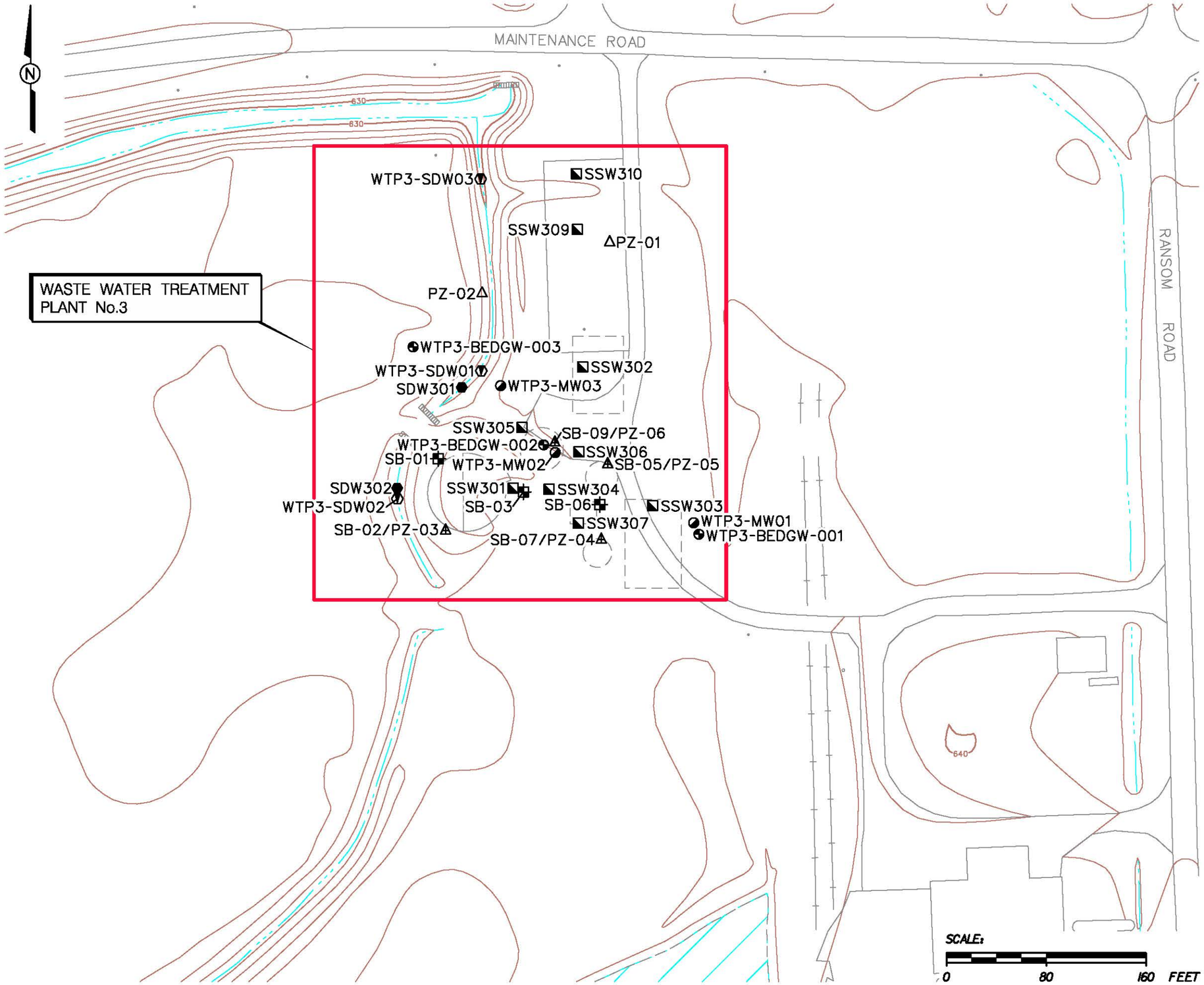


FIGURE 1-2
SITE LOCATION MAP

WWTP3 BASELINE HUMAN HEALTH RISK ASSESSMENT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

wwtp3_blhhra_002.dgn cbentley 3/26/2013 10:13:31 AM PDF_with_Levels.plt SEL_TEXTSUB_ONLY.TBL



LEGEND:

- AREA OF CONCERN
- POND
- CREEK, DITCH, CONVEYANCE
- ROAD
- 640 TOPOGRAPHIC CONTOUR (2 FT. INTERVAL)
- APPROXIMATE LOCATION OF FORMER STRUCTURES
- 1999 SURFACE SOIL SAMPLE (USACE, 2000)
- 1999 SEDIMENT SAMPLE (USACE, 2000)
- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- SURFACE WATER/SEDIMENT SAMPLE
- SOIL BORING
- SOIL BORING/PIEZOMETER
- PIEZOMETER

NOTES:

1. SAMPLES WERE COLLECTED IN 2009 AS PART OF THE REMEDIAL INVESTIGATION OR WERE COLLECTED PREVIOUSLY IN 1999 (U.S. ARMY CORPS OF ENGINEERS, 2000, FINAL REPORT, LIMITED SITE INVESTIGATION FOR THE FORMER PLUM BROOK ORDNANCE WORKS WASTE WATER TREATMENT PLANTS 1 AND 3, JULY).
2. SEDIMENT SAMPLES WERE COLLECTED FROM EACH LOCATION IN 1999 AND IN 2009. 1999 SAMPLE IDENTIFICATION IS SHOWN IN PARENTHESES.

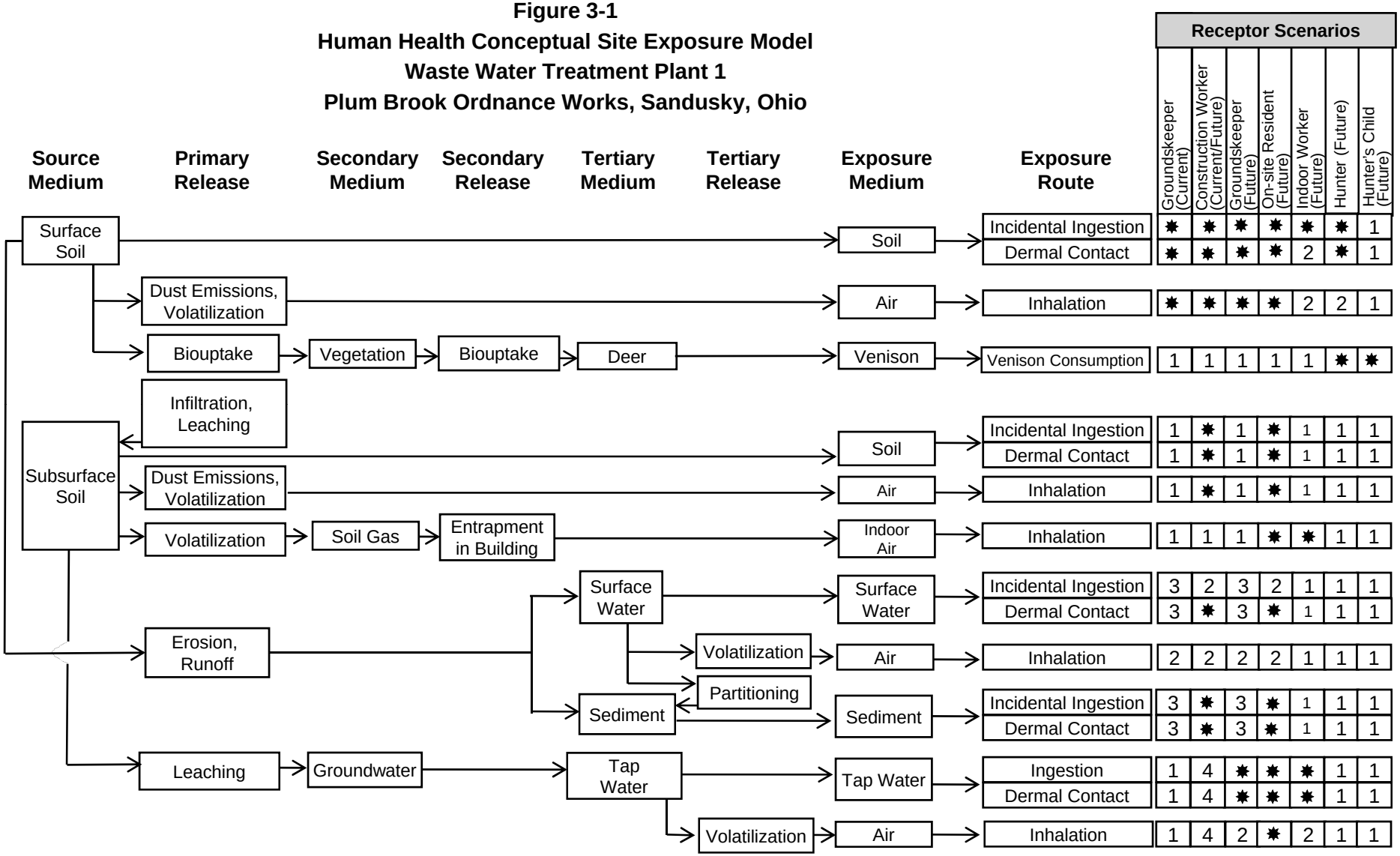
FIGURE 1-3
SAMPLE LOCATIONS AT WASTE WATER TREATMENT PLANT No.3

WWTP3 BASELINE HUMAN HEALTH RISK ASSESSMENT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

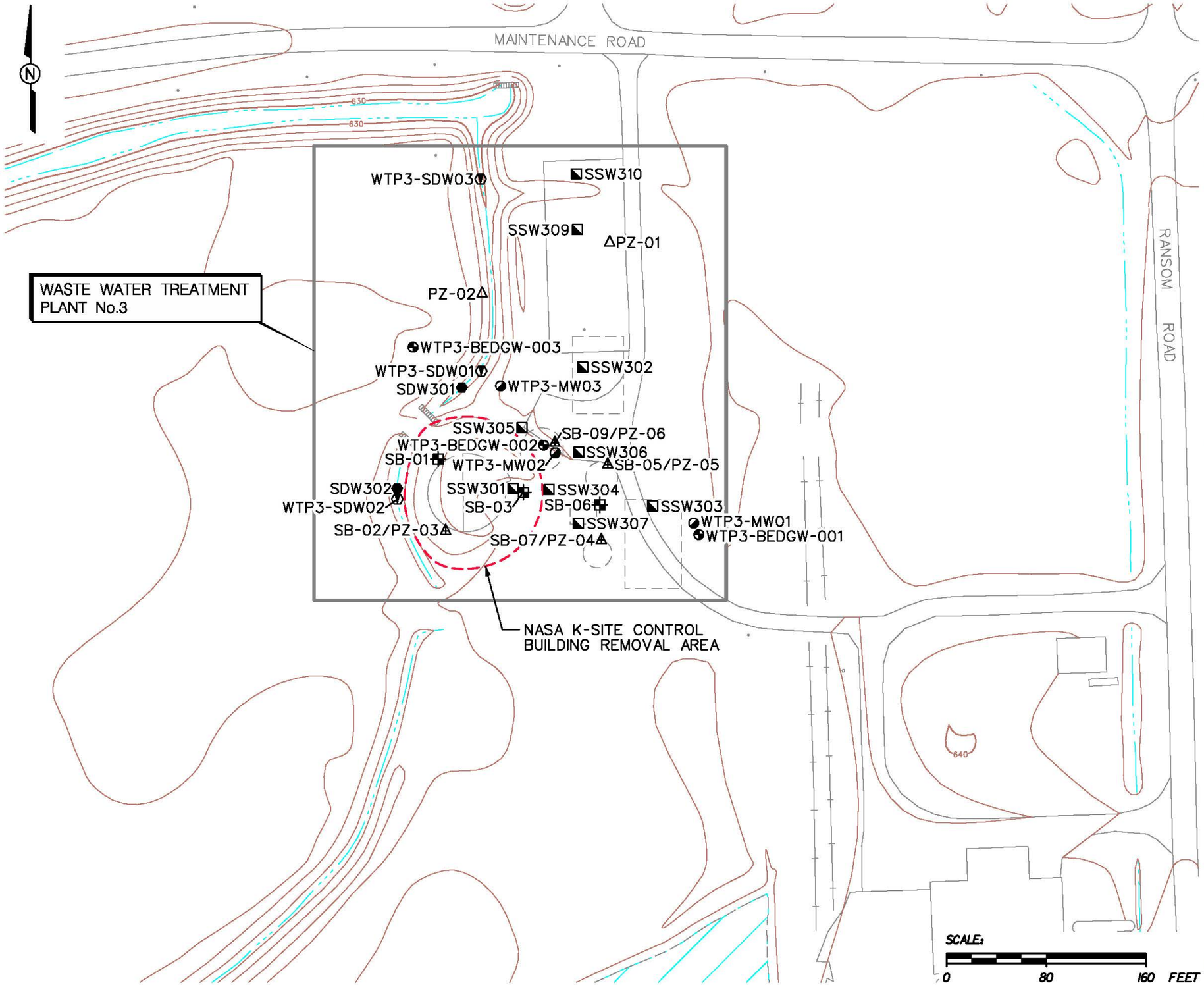
Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

wwtp3_blhhra_003.dgn cbentley 3/26/2013 10:15:05 AM PDF_with_Levels.plt SEL_TEXTSUB_ONLY.TBL

Figure 3-1
Human Health Conceptual Site Exposure Model
Waste Water Treatment Plant 1
Plum Brook Ordnance Works, Sandusky, Ohio



✸ = Complete exposure route quantified in the risk assessment.
1 = There is no plausible pathway for exposure to 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.
4 = For current use there is no plausible exposure pathway. For future use, the pathway is potentially complete, but is not quantified as explained in the text.



LEGEND:

- AREA OF CONCERN
- POND
- CREEK, DITCH, CONVEYANCE
- ROAD
- 640 TOPOGRAPHIC CONTOUR (2 FT. INTERVAL)
- APPROXIMATE LOCATION OF FORMER STRUCTURES
- 1999 SURFACE SOIL SAMPLE (USACE, 2000)
- 1999 SEDIMENT SAMPLE (USACE, 2000)
- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- SURFACE WATER/SEDIMENT SAMPLE
- SOIL BORING
- SOIL BORING/PIEZOMETER
- PIEZOMETER
- BOUNDARY OF BUILDING REMOVAL AREA

NOTE:

NASA ACCEPTED RESPONSIBILITY FOR THE REMOVAL OF THE K-SITE CONTROL BUILDING AND THE CONTAMINATED SOIL IN THE ASSOCIATED AREA. THIS AREA EXTENDED TO THE CREST OF A BERM WHICH PARTIALLY SURROUNDED THE BUILDING. THE BUILDING AND CONTAMINATED SOIL WERE REMOVED IN OCTOBER 2012.

FIGURE 5-1
IDENTIFICATION OF NASA K-SITE CONTROL BUILDING REMOVAL AREA AT WASTE WATER TREATMENT PLANT No.3

WWTP3 BASELINE HUMAN HEALTH RISK ASSESSMENT
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

Shaw Environmental & Infrastructure, Inc.
(A CB&I Company)

wwtp3_blhhra_004.dgn cbentley 3/26/2013 10:15:38 AM PDF_with_Levels.plt SEL_TEXTSUB_ONLY.TBL

APPENDIX A

DATA SUMMARY OF CHEMICALS DETECTED IN OVERBURDEN GROUNDWATER PIEZOMETERS

Table A-1

Sample Summary of Overburden Piezometer Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Location	Sample Number	Sample Purpose	Sample Date	Depth (ft)			Analyses
WWTP3-PZ01	WW3007	REG	16-Dec-08	18	-	18	Cyanide, Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC
WWTP3-PZ02	WW3008	REG	17-Dec-08	15	-	15	Cyanide, Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC
WWTP3-PZ03	WW3009	REG	17-Dec-08	21	-	21	Cyanide, Explosives, Field Tests, Gen Chem, Metals (f & uf), SVOC

Exp - Explosives
f & uf - filtered and unfiltered
Gen Chem - General Chemistry
REG - Regular sample
SVOC - Semivolatile organic compounds

Table A-2

Summary and Screening of Chemicals Detected in Groundwater Overburden Piezometer
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of values, µg/L: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Arithmetic Mean µg/L	RBSC [a] µg/L		Exceeds RBSCs? [b,c]
Inorganics - Unfiltered												
Aluminum	3 / 3	100	42200	J	599000		88.9	88.9	2.59E+05	1600		Y
Antimony	2 / 3	67	4.42	J	6.26		2.78	2.78	4.02E+00	0.6		Y
Arsenic	3 / 3	100	19		210		5.56	5.56	1.08E+02	0.045		Y
Barium	3 / 3	100	261		2460		8.89	8.89	1.15E+03	290		Y
Beryllium	3 / 3	100	19.4		170		4.44	4.44	8.57E+01	1.6		Y
Cadmium	1 / 3	33	8.22		8.22		2.78	2.78	3.67E+00	0.69		Y
Calcium	3 / 3	100	265000	J	3080000		111	556	1.34E+06	Nutrient		N
Chromium	3 / 3	100	50.4		618		11.1	11.1	2.77E+02	0.031		Y
Cobalt	3 / 3	100	22		217		4.44	4.44	1.04E+02	0.47		Y
Copper	3 / 3	100	68.2		1070		11.1	11.1	4.65E+02	62		Y
Iron	3 / 3	100	53500	J	814000		88.9	444	3.53E+05	1100		Y
Lead	3 / 3	100	33.4		467		2.78	2.78	2.16E+02	15	d	Y
Magnesium	3 / 3	100	104000		1050000		44.4	222	4.47E+05	Nutrient		N
Manganese	3 / 3	100	3460		18400		4.44	4.44	8.95E+03	32		Y
Mercury	2 / 3	67	0.126	J	0.276		0.2	0.2	1.67E-01	0.43		N
Nickel	3 / 3	100	36.5		599		6.67	6.67	2.48E+02	30		Y
Potassium	3 / 3	100	13100		174000		556	556	7.46E+04	Nutrient		N
Selenium	1 / 3	33	8.45	J	8.45	J	5.56	5.56	4.67E+00	7.8		Y
Sodium	3 / 3	100	8060		27400		222	222	2.08E+04	Nutrient		N
Thallium	2 / 3	67	5.09	J	14.1		2.78	2.78	6.86E+00	0.016	e	Y
Vanadium	3 / 3	100	95.9		1290		4.44	4.44	5.71E+02	7.8		Y
Zinc	3 / 3	100	145		2020		55.6	55.6	8.83E+02	470		Y
Inorganics - Filtered												
Arsenic	3 / 3	100	6.95	J	20		5.56	5.56	1.36E+01	0.045		Y
Barium	3 / 3	100	51.1		313		8.89	8.89	1.47E+02	290		Y
Calcium	3 / 3	100	104000		141000	J	111	111	1.18E+05	Nutrient		N
Iron	3 / 3	100	324		926		88.9	88.9	5.77E+02	1100		N
Lead	1 / 3	33	3.06	J	3.06	J	2.78	2.78	1.95E+00	15	d	N
Magnesium	3 / 3	100	32500	J	56700	J	88.9	88.9	4.36E+04	Nutrient		N
Manganese	3 / 3	100	172		2360	J	4.44	4.44	9.07E+02	88		Y
Potassium	3 / 3	100	284	J	2330		556	556	1.11E+03	Nutrient		N
Selenium	1 / 3	33	7.44	J	7.44	J	5.56	5.56	4.33E+00	7.8		N
Sodium	3 / 3	100	5400		25600		222	222	1.60E+04	Nutrient		N
General Chemistry												
Chloride	3 / 3	100	3930		5970		250	250	5.00E+03	Nutrient		N
Nitrate-Nitrite	1 / 3	33	40		40		40	40	2.67E+01	1000	f	N

Table A-2

Summary and Screening of Chemicals Detected in Groundwater Overburden Piezometer
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works, Sandusky, Ohio

Chemical	Detection Frequency	Percent hits	Range of values, µg/L: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Arithmetic Mean µg/L	RBSC [a] µg/L		Exceeds RBSCs? [b,c]
Sulfate	3 / 3	100	83100		179000		1000	2500	1.30E+05	250000	g	N

RBSC - Risk based screening concentration.
µg/L - micrograms per liter.

VQ - Validation qualifier.
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.

[a] Risk-Based Screening Concentrations based on USEPA Regional Screening Level Table (April 2012) tap water values and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[b] N = Chemical concentration does not exceed the RBSC or is an essential nutrient.
[c] Y = Chemical concentration exceeds the RBSC, or no RBSC is available.
[d] Screening criteria for lead based on the action level of 15 µg/L (U.S. Environmental Protection Agency (EPA), 2012, 2012 Edition of the Drinking Water Standards and Health Advisories, Office of Water, Washington, D.C.).
[e] RBSC for thallium based on IRIS, 2009.
[f] Because no Regional Screening Level exists for nitrate-nitrite, 0.1 X the nitrate-nitrite MCL (10 mg/L) is used for screening.
[g] Source: EPA (2012) as referenced in footnote d.

APPENDIX B

ProUCL OUTPUT FOR UPPER CONFIDENCE LIMITS ON THE MEAN

Data Input for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Aroclor 1016	Aroclor 1254	D_Aroclor 1254	Aroclor 1260	D_Aroclor 1260	Benzo(a)anthracene	D_Benzo(a)anthracene	Benzo(a)pyrene
PBOW99-SSW302	PBOW99SSW302	0.09	0.18	1	0.46	0	1.2	1	1.3
PBOW99-SSW303	PBOW99SSW303	0.0395	0.079	1	0.23	0	4.5	1	4.2
WWTP3-SB01	WW0034	0.0203	0.0406	0	0.18	1	3.25	1	2.41
WWTP3-SB02	WW0038	1.22	0.0402	0	0.0402	0	11.9	1	10
WWTP3-SB03	WW0041	0.14	0.0429	0	0.0429	0	0.425	0	0.425
WWTP3-SB05	WW0048	0.1015	0.203	0	0.229	1	0.276	1	0.289
WWTP3-SB06	WW0051	0.1025	0.205	0	0.205	0	0.607	1	0.538
WWTP3-SB07	WW0054	0.0985	0.197	0	0.197	0	0.101	1	0.0909
WWTP3-SB09	WW0060	0.099	0.198	0	0.198	0	1.99	0	1.99

Data Input for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	D_Benzo(a)pyrene	Benzo(b)fluoranthene	D_Benzo(b)fluoranthene	Benzo(k)fluoranthene	D_Benzo(k)fluoranthene	Dibenz(a,h)anthracene
PBOW99-SSW302	PBOW99SSW302	1	1.2	1	1.1	1	0.36
PBOW99-SSW303	PBOW99SSW303	1	4.3	1	3	1	0.72
WWTP3-SB01	WW0034	1	3.58	1	1.08	1	0.397
WWTP3-SB02	WW0038	1	13.9	1	4.49	1	1.46
WWTP3-SB03	WW0041	0	0.425	0	0.425	0	0.425
WWTP3-SB05	WW0048	1	0.438	1	0.127	1	0.403
WWTP3-SB06	WW0051	1	0.756	1	0.291	1	0.411
WWTP3-SB07	WW0054	1	0.14	1	0.4	0	0.4
WWTP3-SB09	WW0060	0	1.99	0	1.99	0	1.99

Data Input for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	D_Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	D_Indeno(1,2,3-cd)pyrene
PBOW99-SSW302	PBOW99SSW302	0	0.87	1
PBOW99-SSW303	PBOW99SSW303	1	2.9	1
WWTP3-SB01	WW0034	1	2.14	1
WWTP3-SB02	WW0038	1	8.1	1
WWTP3-SB03	WW0041	0	0.425	0
WWTP3-SB05	WW0048	0	0.45	1
WWTP3-SB06	WW0051	0	0.62	1
WWTP3-SB07	WW0054	0	0.305	1
WWTP3-SB09	WW0060	0	1.99	0

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

General UCL Statistics for Full Data Sets

User Selected Options

From File	UCL input ss.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Aroclor 1016 - SS

General Statistics

Number of Valid Observations 9

Number of Distinct Observations 9

Raw Statistics

Minimum	0.0203
Maximum	1.22
Mean	0.212
Median	0.099
SD	0.38
Coefficient of Variation	1.787
Skewness	2.948

Log-transformed Statistics

Minimum of Log Data	-3.897
Maximum of Log Data	0.199
Mean of log Data	-2.278
SD of log Data	1.106

Warning: There are only 9 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.477
Shapiro Wilk Critical Value	0.829

Data not Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.831
Shapiro Wilk Critical Value	0.829

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	0.448

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	0.553
95% Modified-t UCL (Johnson-1978)	0.468

Assuming Lognormal Distribution

95% H-UCL	0.736
95% Chebyshev (MVUE) UCL	0.459
97.5% Chebyshev (MVUE) UCL	0.583
99% Chebyshev (MVUE) UCL	0.826

Gamma Distribution Test

k star (bias corrected)	0.616
Theta Star	0.345
MLE of Mean	0.212
MLE of Standard Deviation	0.271
nu star	11.09
Approximate Chi Square Value (.05)	4.635
Adjusted Level of Significance	0.0231
Adjusted Chi Square Value	3.794
Anderson-Darling Test Statistic	1.365
Anderson-Darling 5% Critical Value	0.749
Kolmogorov-Smirnov Test Statistic	0.376
Kolmogorov-Smirnov 5% Critical Value	0.289

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL	0.508
95% Adjusted Gamma UCL	0.621

Data Distribution

Data appear Lognormal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL	0.42
95% Jackknife UCL	0.448
95% Standard Bootstrap UCL	0.409
95% Bootstrap-t UCL	1.978
95% Hall's Bootstrap UCL	2.112
95% Percentile Bootstrap UCL	0.458
95% BCA Bootstrap UCL	0.593
95% Chebyshev(Mean, Sd) UCL	0.764
97.5% Chebyshev(Mean, Sd) UCL	1.002
99% Chebyshev(Mean, Sd) UCL	1.471

Potential UCL to Use

Use 95% Chebyshev (Mean, Sd) UCL 0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Aroclor 1254 - SS

General Statistics

Number of Valid Data	9	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	7
		Percent Non-Detects	77.78%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.25	Minimum Detected	-1.386
Maximum Detected	1	Maximum Detected	0
Mean of Detected	0.625	Mean of Detected	-0.693
SD of Detected	0.53	SD of Detected	0.98
Minimum Non-Detect	0.0402	Minimum Non-Detect	-3.214
Maximum Non-Detect	0.205	Maximum Non-Detect	-1.585

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	7
Number treated as Detected	2
Single DL Non-Detect Percentage	77.78%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.19	Mean	-2.47
SD	0.312	SD	1.293
95% DL/2 (t) UCL	0.384	95% H-Stat (DL/2) UCL	1.174
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only
Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.333
SD	0.236
SE of Mean	0.111
95% KM (t) UCL	0.54
95% KM (z) UCL	0.516
95% KM (jackknife) UCL	0.865
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	0.818
97.5% KM (Chebyshev) UCL	1.027
99% KM (Chebyshev) UCL	1.439
Potential UCLs to Use	
95% KM (t) UCL	0.54
95% KM (% Bootstrap) UCL	N/A

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Aroclor 1260 - SS

General Statistics

Number of Valid Data	9	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	7
		Percent Non-Detects	77.78%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.18	Minimum Detected	-1.715
Maximum Detected	0.229	Maximum Detected	-1.474
Mean of Detected	0.205	Mean of Detected	-1.594
SD of Detected	0.0346	SD of Detected	0.17
Minimum Non-Detect	0.0402	Minimum Non-Detect	-3.214
Maximum Non-Detect	0.46	Maximum Non-Detect	-0.777

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	0
Single DL Non-Detect Percentage	100.00%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A

Data not Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.122
SD	0.0778
95% DL/2 (t) UCL	0.17
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A

Data not Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-2.387
SD	0.91
95% H-Stat (DL/2) UCL	0.37
Log ROS Method	
Mean in Log Scale	N/A
SD in Log Scale	N/A
Mean in Original Scale	N/A
SD in Original Scale	N/A
95% t UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.187
SD	0.0171
SE of Mean	0.00917
95% KM (t) UCL	0.204
95% KM (z) UCL	0.202
95% KM (jackknife) UCL	0.222
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	0.229
95% KM (Chebyshev) UCL	0.227
97.5% KM (Chebyshev) UCL	0.244
99% KM (Chebyshev) UCL	0.278

Potential UCLs to Use

95% KM (t) UCL	0.204
95% KM (% Bootstrap) UCL	0.229

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Benzo(a)anthracene - SS

General Statistics

Number of Valid Data	9	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	2
		Percent Non-Detects	22.22%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.101	Minimum Detected	-2.293
Maximum Detected	11.9	Maximum Detected	2.477
Mean of Detected	3.119	Mean of Detected	0.18
SD of Detected	4.207	SD of Detected	1.671
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	3
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	66.67%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.763	Shapiro Wilk Test Statistic	0.981
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	2.56	Mean	-0.0324
SD	3.814	SD	1.556
95% DL/2 (t) UCL	4.924	95% H-Stat (DL/2) UCL	40.42
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-0.175
		SD in Log Scale	1.621
		Mean in Original Scale	2.484
		SD in Original Scale	3.856
		95% t UCL	4.874
		95% Percentile Bootstrap UCL	4.696
		95% BCA Bootstrap UCL	5.908

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.461
Theta Star	6.771
nu star	6.449
A-D Test Statistic	0.204
5% A-D Critical Value	0.743
K-S Test Statistic	0.743
5% K-S Critical Value	0.325

Data appear Gamma Distributed at 5% Significance Level

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.101
Maximum	11.9
Mean	2.618
Median	1.2
SD	3.789
k star	0.513
Theta star	5.106
Nu star	9.229
AppChi2	3.466
95% Gamma Approximate UCL	6.972
95% Adjusted Gamma UCL	8.745

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	2.5
SD	3.629
SE of Mean	1.308
95% KM (t) UCL	4.931
95% KM (z) UCL	4.651
95% KM (jackknife) UCL	4.889
95% KM (bootstrap t) UCL	8.972
95% KM (BCA) UCL	4.701
95% KM (Percentile Bootstrap) UCL	4.734
95% KM (Chebyshev) UCL	8.2
97.5% KM (Chebyshev) UCL	10.67
99% KM (Chebyshev) UCL	15.51

Potential UCLs to Use

95% KM (Chebyshev) UCL	8.2

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(a)pyrene - SS

General Statistics

Number of Valid Data	9
Number of Distinct Detected Data	7
Number of Detected Data	7
Number of Non-Detect Data	2
Percent Non-Detects	22.22%

Raw Statistics

Minimum Detected	0.0909
Maximum Detected	10
Mean of Detected	2.69
SD of Detected	3.533
Minimum Non-Detect	0.425
Maximum Non-Detect	1.99

Log-transformed Statistics

Minimum Detected	-2.398
Maximum Detected	2.303
Mean of Detected	0.0886
SD of Detected	1.624
Minimum Non-Detect	-0.856
Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	6
Number treated as Detected	3
Single DL Non-Detect Percentage	66.67%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.776
5% Shapiro Wilk Critical Value	0.803

Data not Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	2.226
SD	3.201
95% DL/2 (t) UCL	4.21
Maximum Likelihood Estimate(MLE) Method	N/A

MLE yields a negative mean

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.987
5% Shapiro Wilk Critical Value	0.803

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-0.104
SD	1.508
95% H-Stat (DL/2) UCL	30.29
Log ROS Method	
Mean in Log Scale	-0.255
SD in Log Scale	1.575
Mean in Original Scale	2.147
SD in Original Scale	3.243
95% t UCL	4.158
95% Percentile Bootstrap UCL	4.047
95% BCA Bootstrap UCL	4.779

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.481
Theta Star	5.596
nu star	6.729
A-D Test Statistic	0.173
5% A-D Critical Value	0.741
K-S Test Statistic	0.741
5% K-S Critical Value	0.324

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0909
Maximum	10
Mean	2.28
Median	1.3
SD	3.176
k star	0.55
Theta star	4.145
Nu star	9.902
AppChi2	3.88
95% Gamma Approximate UCL	5.818
95% Adjusted Gamma UCL	7.22

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	2.167
SD	3.05
SE of Mean	1.1
95% KM (t) UCL	4.212
95% KM (z) UCL	3.976
95% KM (jackknife) UCL	4.177
95% KM (bootstrap t) UCL	7.716
95% KM (BCA) UCL	4.298
95% KM (Percentile Bootstrap) UCL	3.987
95% KM (Chebyshev) UCL	6.961
97.5% KM (Chebyshev) UCL	9.035
99% KM (Chebyshev) UCL	13.11

Potential UCLs to Use

95% KM (Chebyshev) UCL	6.961

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Benzo(b)fluoranthene - SS

General Statistics

Number of Valid Data	9	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	2
		Percent Non-Detects	22.22%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.14	Minimum Detected	-1.966
Maximum Detected	13.9	Maximum Detected	2.632
Mean of Detected	3.473	Mean of Detected	0.354
SD of Detected	4.87	SD of Detected	1.553
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	3
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	66.67%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.723	Shapiro Wilk Test Statistic	0.986
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	2.836	Mean	0.103
SD	4.407	SD	1.485
95% DL/2 (t) UCL	5.568	95% H-Stat (DL/2) UCL	33.72
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-0.055
		SD in Log Scale	1.601
		Mean in Original Scale	2.762
		SD in Original Scale	4.448
		95% t UCL	5.519
		95% Percentile Bootstrap UCL	5.373
		95% BCA Bootstrap UCL	6.769

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.484
Theta Star	7.173
nu star	6.779
A-D Test Statistic	0.258
5% A-D Critical Value	0.74
K-S Test Statistic	0.74
5% K-S Critical Value	0.324

Data appear Gamma Distributed at 5% Significance Level

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	1E-12
Maximum	13.9
Mean	2.869
Median	1.2
SD	4.401
k star	0.204
Theta star	14.09
Nu star	3.666
AppChi2	0.594
95% Gamma Approximate UCL	17.7
95% Adjusted Gamma UCL	27.09

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	2.777
SD	4.188
SE of Mean	1.509
95% KM (t) UCL	5.582
95% KM (z) UCL	5.258
95% KM (jackknife) UCL	5.51
95% KM (bootstrap t) UCL	10.26
95% KM (BCA) UCL	5.413
95% KM (Percentile Bootstrap) UCL	5.524
95% KM (Chebyshev) UCL	9.353
97.5% KM (Chebyshev) UCL	12.2
99% KM (Chebyshev) UCL	17.79

Potential UCLs to Use

95% KM (Chebyshev) UCL	9.353

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(k)fluoranthene - SS

General Statistics

Number of Valid Data	9
Number of Distinct Detected Data	6
Number of Detected Data	6
Number of Non-Detect Data	3
Percent Non-Detects	33.33%

Raw Statistics

Minimum Detected	0.127
Maximum Detected	4.49
Mean of Detected	1.681
SD of Detected	1.713
Minimum Non-Detect	0.4
Maximum Non-Detect	1.99

Log-transformed Statistics

Minimum Detected	-2.064
Maximum Detected	1.502
Mean of Detected	-0.0875
SD of Detected	1.357
Minimum Non-Detect	-0.916
Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	7
Number treated as Detected	2
Single DL Non-Detect Percentage	77.78%

Warning: There are only 6 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.867
5% Shapiro Wilk Critical Value	0.788

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	1.277
SD	1.501
95% DL/2 (t) UCL	2.208
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.944
5% Shapiro Wilk Critical Value	0.788

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-0.41
SD	1.262
95% H-Stat (DL/2) UCL	8.191
Log ROS Method	
Mean in Log Scale	-0.516
SD in Log Scale	1.261
Mean in Original Scale	1.209
SD in Original Scale	1.53
95% t UCL	2.157
95% Percentile Bootstrap UCL	2.118
95% BCA Bootstrap UCL	2.287

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.589
Theta Star	2.854
nu star	7.068
A-D Test Statistic	0.253
5% A-D Critical Value	0.716
K-S Test Statistic	0.716
5% K-S Critical Value	0.341

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.127
Maximum	4.49
Mean	1.422
Median	1.08
SD	1.428
k star	0.874
Theta star	1.627
Nu star	15.74
AppChi2	7.778
95% Gamma Approximate UCL	2.878
95% Adjusted Gamma UCL	3.375

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	1.223
SD	1.442
SE of Mean	0.53
95% KM (t) UCL	2.208
95% KM (z) UCL	2.095
95% KM (jackknife) UCL	2.182
95% KM (bootstrap t) UCL	3.456
95% KM (BCA) UCL	2.223
95% KM (Percentile Bootstrap) UCL	2.171
95% KM (Chebyshev) UCL	3.532
97.5% KM (Chebyshev) UCL	4.532
99% KM (Chebyshev) UCL	6.494

Potential UCLs to Use

95% KM (t) UCL	2.208
95% KM (Percentile Bootstrap) UCL	2.171

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Dibenz(a,h)anthracene

General Statistics

Number of Valid Data	9	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	6
		Percent Non-Detects	66.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.397	Minimum Detected	-0.924
Maximum Detected	1.46	Maximum Detected	0.378
Mean of Detected	0.859	Mean of Detected	-0.291
SD of Detected	0.545	SD of Detected	0.652
Minimum Non-Detect	0.36	Minimum Non-Detect	-1.022
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	0
Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.951	Shapiro Wilk Test Statistic	0.998
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.508	Mean	-0.993
SD	0.458	SD	0.809
95% DL/2 (t) UCL	0.792	95% H-Stat (DL/2) UCL	1.154
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.103
		SD in Log Scale	0.728
		Mean in Original Scale	0.439
		SD in Original Scale	0.419
		95% t UCL	0.699
		95% Percentile Bootstrap UCL	0.674
		95% BCA Bootstrap UCL	0.776

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only
Data appear Normal at 5% Significance Level

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.57
SD	0.353
SE of Mean	0.153
95% KM (t) UCL	0.854
95% KM (z) UCL	0.821
95% KM (jackknife) UCL	0.858
95% KM (bootstrap t) UCL	0.87
95% KM (BCA) UCL	1.46
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	1.236
97.5% KM (Chebyshev) UCL	1.524
99% KM (Chebyshev) UCL	2.089
Potential UCLs to Use	
95% KM (t) UCL	0.854
95% KM (Percentile Bootstrap) UCL	N/A

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Indeno(1,2,3-cd)pyrene - SS

General Statistics			
Number of Valid Data	9	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	2
		Percent Non-Detects	22.22%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.305	Minimum Detected	-1.187
Maximum Detected	8.1	Maximum Detected	2.092
Mean of Detected	2.198	Mean of Detected	0.188
SD of Detected	2.776	SD of Detected	1.165
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	3
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	66.67%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Data Output for ProUCL
Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.731
5% Shapiro Wilk Critical Value	0.803

Data not Normal at 5% Significance Level

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.951
5% Shapiro Wilk Critical Value	0.803

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	1.844
SD	2.512
95% DL/2 (t) UCL	3.401
Maximum Likelihood Estimate(MLE) Method	
Mean	0.0112
SD	4.178
95% MLE (t) UCL	2.601
95% MLE (Tiku) UCL	4.217

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-0.0266
SD	1.161
95% H-Stat (DL/2) UCL	8.387
Log ROS Method	
Mean in Log Scale	-0.111
SD in Log Scale	1.192
Mean in Original Scale	1.787
SD in Original Scale	2.539
95% t UCL	3.361
95% Percentile Bootstrap UCL	3.275
95% BCA Bootstrap UCL	3.841

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.647
Theta Star	3.395
nu star	9.064
A-D Test Statistic	0.386
5% A-D Critical Value	0.729
K-S Test Statistic	0.729
5% K-S Critical Value	0.32

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	1E-12
Maximum	8.1
Mean	1.855
Median	0.87
SD	2.52
k star	0.213
Theta star	8.712
Nu star	3.832
AppChi2	0.656
95% Gamma Approximate UCL	10.83
95% Adjusted Gamma UCL	16.4

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	1.8
SD	2.387
SE of Mean	0.86
95% KM (t) UCL	3.399
95% KM (z) UCL	3.214
95% KM (jackknife) UCL	3.359
95% KM (bootstrap t) UCL	6.468
95% KM (BCA) UCL	3.351
95% KM (Percentile Bootstrap) UCL	3.289
95% KM (Chebyshev) UCL	5.548
97.5% KM (Chebyshev) UCL	7.17
99% KM (Chebyshev) UCL	10.36

Potential UCLs to Use

95% KM (Chebyshev) UCL	5.548

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Input for ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Depth (ft)		Aroclor 1016	D_Aroclor 1016	Aroclor 1254	D_Aroclor 1254	Aroclor 1260	D_Aroclor 1260	Benzo(a)anthracene
PBOW99-SSW302	PBOW99SSW302	0	0	0.18	0	1	1	0.46	0	1.2
PBOW99-SSW303	PBOW99SSW303	0	0	0.079	0	0.25	1	0.23	0	4.5
WWTP3-SB01	WW0034	0.7	1.7	0.0406	0	0.0406	0	0.18	1	3.25
WWTP3-SB01	WW0035	5	5.7	0.0413	0	0.0413	0	0.0413	0	0.417
WWTP3-SB01	WW0037WW0036	8	10							0.402
WWTP3-SB02	WW0038	0.5	1.5	1.22	1	0.0402	0	0.0402	0	11.9
WWTP3-SB02	WW0039	5	5.5	0.1	1	0.0399	0	0.0399	0	0.309
WWTP3-SB02	WW0040	8	10							0.402
WWTP3-SB03	WW0041	0	1	0.14	1	0.0429	0	0.0429	0	0.425
WWTP3-SB03	WW0043WW0042	3	5	0.0399	0	0.0399	0	0.0399	0	0.2265
WWTP3-SB03	WW0044	8	10							0.419
WWTP3-SB05	WW0048	0	1	0.203	0	0.203	0	0.229	1	0.276
WWTP3-SB05	WW0049	3	5	0.204	0	0.204	0	0.0667	1	0.0398
WWTP3-SB05	WW0050	8	10							0.413
WWTP3-SB06	WW0051	0	1	0.205	0	0.205	0	0.205	0	0.607
WWTP3-SB06	WW0052	3	3.7	0.199	0	0.199	0	0.199	0	0.238
WWTP3-SB06	WW0053	8	10							0.416
WWTP3-SB07	WW0054	0	1	0.197	0	0.197	0	0.197	0	0.101
WWTP3-SB07	WW0055	3	5	0.201	0	0.201	0	0.201	0	0.4
WWTP3-SB07	WW0056	8	10							0.415
WWTP3-SB09	WW0060	0.2	1.6	0.198	0	0.198	0	0.198	0	1.99
WWTP3-SB09	WW0062	8	10							0.42
WWTP3-SB09	WW0063WW0061	3	5	0.1995	0	0.1995	0	0.1995	0	0.399

Data Input for ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Depth (ft)		D_Benzo(a)anthracene	Benzo(a)pyrene	D_Benzo(a)pyrene	Benzo(b)fluoranthene	D_Benzo(b)fluoranthene
PBOW99-SSW302	PBOW99SSW302	0	0	1	1.3	1	1.2	1
PBOW99-SSW303	PBOW99SSW303	0	0	1	4.2	1	4.3	1
WWTP3-SB01	WW0034	0.7	1.7	1	2.41	1	3.58	1
WWTP3-SB01	WW0035	5	5.7	0	0.417	0	0.417	0
WWTP3-SB01	WW0037WW0036	8	10	0	0.402	0	0.402	0
WWTP3-SB02	WW0038	0.5	1.5	1	10	1	13.9	1
WWTP3-SB02	WW0039	5	5.5	1	0.306	1	0.409	1
WWTP3-SB02	WW0040	8	10	0	0.402	0	0.402	0
WWTP3-SB03	WW0041	0	1	0	0.425	0	0.425	0
WWTP3-SB03	WW0043WW0042	3	5	1	0.196	1	0.253	1
WWTP3-SB03	WW0044	8	10	0	0.419	0	0.419	0
WWTP3-SB05	WW0048	0	1	1	0.289	1	0.438	1
WWTP3-SB05	WW0049	3	5	1	0.41	0	0.41	0
WWTP3-SB05	WW0050	8	10	0	0.413	0	0.413	0
WWTP3-SB06	WW0051	0	1	1	0.538	1	0.756	1
WWTP3-SB06	WW0052	3	3.7	1	0.209	1	0.3	1
WWTP3-SB06	WW0053	8	10	0	0.416	0	0.416	0
WWTP3-SB07	WW0054	0	1	1	0.0909	1	0.14	1
WWTP3-SB07	WW0055	3	5	0	0.4	0	0.4	0
WWTP3-SB07	WW0056	8	10	0	0.415	0	0.415	0
WWTP3-SB09	WW0060	0.2	1.6	0	1.99	0	1.99	0
WWTP3-SB09	WW0062	8	10	0	0.42	0	0.42	0
WWTP3-SB09	WW0063WW0061	3	5	0	0.399	0	0.399	0

Data Input for ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Depth (ft)		Benzo(k)fluoranthene	D_Benzo(k)fluoranthene	Dibenz(a,h)anthracene	D_Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene
PBOW99-SSW302	PBOW99SSW302	0	0	1.1	1	0.36	0	0.87
PBOW99-SSW303	PBOW99SSW303	0	0	3	1	0.72	1	2.9
WWTP3-SB01	WW0034	0.7	1.7	1.08	1	0.397	1	2.14
WWTP3-SB01	WW0035	5	5.7	0.417	0	0.417	0	0.417
WWTP3-SB01	WW0037WW0036	8	10	0.402	0	0.402	0	0.402
WWTP3-SB02	WW0038	0.5	1.5	4.49	1	1.46	1	8.1
WWTP3-SB02	WW0039	5	5.5	0.136	1	0.392	0	0.436
WWTP3-SB02	WW0040	8	10	0.402	0	0.402	0	0.402
WWTP3-SB03	WW0041	0	1	0.425	0	0.425	0	0.425
WWTP3-SB03	WW0043WW0042	3	5	0.4	0	0.4	0	0.284
WWTP3-SB03	WW0044	8	10	0.419	0	0.419	0	0.419
WWTP3-SB05	WW0048	0	1	0.127	1	0.403	0	0.45
WWTP3-SB05	WW0049	3	5	0.41	0	0.41	0	0.41
WWTP3-SB05	WW0050	8	10	0.413	0	0.413	0	0.413
WWTP3-SB06	WW0051	0	1	0.291	1	0.411	0	0.62
WWTP3-SB06	WW0052	3	3.7	0.4	0	0.4	0	0.388
WWTP3-SB06	WW0053	8	10	0.416	0	0.416	0	0.416
WWTP3-SB07	WW0054	0	1	0.4	0	0.4	0	0.305
WWTP3-SB07	WW0055	3	5	0.4	0	0.4	0	0.4
WWTP3-SB07	WW0056	8	10	0.415	0	0.415	0	0.415
WWTP3-SB09	WW0060	0.2	1.6	1.99	0	1.99	0	1.99
WWTP3-SB09	WW0062	8	10	0.42	0	0.42	0	0.42
WWTP3-SB09	WW0063WW0061	3	5	0.399	0	0.399	0	0.399

Data Input for ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Depth (ft)		D_Indeno(1,2,3-cd)pyrene
PBOW99-SSW302	PBOW99SSW302	0	0	1
PBOW99-SSW303	PBOW99SSW303	0	0	1
WWTP3-SB01	WW0034	0.7	1.7	1
WWTP3-SB01	WW0035	5	5.7	0
WWTP3-SB01	WW0037WW0036	8	10	0
WWTP3-SB02	WW0038	0.5	1.5	1
WWTP3-SB02	WW0039	5	5.5	1
WWTP3-SB02	WW0040	8	10	0
WWTP3-SB03	WW0041	0	1	0
WWTP3-SB03	WW0043WW0042	3	5	1
WWTP3-SB03	WW0044	8	10	0
WWTP3-SB05	WW0048	0	1	1
WWTP3-SB05	WW0049	3	5	0
WWTP3-SB05	WW0050	8	10	0
WWTP3-SB06	WW0051	0	1	1
WWTP3-SB06	WW0052	3	3.7	1
WWTP3-SB06	WW0053	8	10	0
WWTP3-SB07	WW0054	0	1	1
WWTP3-SB07	WW0055	3	5	0
WWTP3-SB07	WW0056	8	10	0
WWTP3-SB09	WW0060	0.2	1.6	0
WWTP3-SB09	WW0062	8	10	0
WWTP3-SB09	WW0063WW0061	3	5	0

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	UCL input ts.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Aroclor 1016 - TS

General Statistics

Number of Valid Data	16	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	13
		Percent Non-Detects	81.25%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.1	Minimum Detected	-2.303
Maximum Detected	1.22	Maximum Detected	0.199
Mean of Detected	0.487	Mean of Detected	-1.357
SD of Detected	0.635	SD of Detected	1.358
Minimum Non-Detect	0.0399	Minimum Non-Detect	-3.221
Maximum Non-Detect	0.205	Maximum Non-Detect	-1.585

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	15
Number treated as Detected	1
Single DL Non-Detect Percentage	93.75%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.777	Shapiro Wilk Test Statistic	0.849
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.153	Mean	-2.487
SD	0.287	SD	0.977
95% DL/2 (t) UCL	0.279	95% H-Stat (DL/2) UCL	0.263
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-3.639
		SD in Log Scale	1.289
		Mean in Original Scale	0.105
		SD in Original Scale	0.3
		95% t UCL	0.236
		95% Percentile Bootstrap UCL	0.251
		95% BCA Bootstrap UCL	0.334

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.176
SD	0.27
SE of Mean	0.0828
95% KM (t) UCL	0.321
95% KM (z) UCL	0.312
95% KM (jackknife) UCL	0.284
95% KM (bootstrap t) UCL	1.132
95% KM (BCA) UCL	1.22
95% KM (Percentile Bootstrap) UCL	1.22
95% KM (Chebyshev) UCL	0.537
97.5% KM (Chebyshev) UCL	0.693
99% KM (Chebyshev) UCL	1

Potential UCLs to Use

95% KM (t) UCL	0.321
95% KM (Percentile Bootstrap) UCL	1.22

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Aroclor 1254 - TS

General Statistics

Number of Valid Data	16	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	14
		Percent Non-Detects	87.50%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.25	Minimum Detected	-1.386
Maximum Detected	1	Maximum Detected	0
Mean of Detected	0.625	Mean of Detected	-0.693
SD of Detected	0.53	SD of Detected	0.98
Minimum Non-Detect	0.0399	Minimum Non-Detect	-3.221
Maximum Non-Detect	0.205	Maximum Non-Detect	-1.585

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	14
Number treated as Detected	2
Single DL Non-Detect Percentage	87.50%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A
Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	0.136
SD	0.238
95% DL/2 (t) UCL	0.24
Maximum Likelihood Estimate(MLE) Method	N/A
MLE method failed to converge properly	

Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	-2.696
SD	1.121
95% H-Stat (DL/2) UCL	0.292
Log ROS Method	
Mean in Log Scale	N/A
SD in Log Scale	N/A
Mean in Original Scale	N/A
SD in Original Scale	N/A
95% t UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A
Data not Gamma Distributed at 5% Significance Level	

Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only
Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.297
SD	0.182
SE of Mean	0.0642
95% KM (t) UCL	0.409
95% KM (z) UCL	0.402
95% KM (jackknife) UCL	0.799
95% KM (bootstrap t) UCL	0.297
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	1
95% KM (Chebyshev) UCL	0.577
97.5% KM (Chebyshev) UCL	0.698
99% KM (Chebyshev) UCL	0.936
Potential UCLs to Use	
95% KM (t) UCL	0.409
95% KM (% Bootstrap) UCL	1

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Aroclor 1260 - TS

General Statistics

Number of Valid Data	16	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	13
		Percent Non-Detects	81.25%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0667	Minimum Detected	-2.708
Maximum Detected	0.229	Maximum Detected	-1.474
Mean of Detected	0.159	Mean of Detected	-1.965
SD of Detected	0.0832	SD of Detected	0.654
Minimum Non-Detect	0.0399	Minimum Non-Detect	-3.221
Maximum Non-Detect	0.46	Maximum Non-Detect	-0.777

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	16
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.95	Shapiro Wilk Test Statistic	0.89
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.0952	Mean	-2.675
SD	0.0696	SD	0.906
95% DL/2 (t) UCL	0.126	95% H-Stat (DL/2) UCL	0.189
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-3.013
		SD in Log Scale	0.604
		Mean in Original Scale	0.0617
		SD in Original Scale	0.0573
		95% t UCL	0.0868
		95% Percentile Bootstrap UCL	0.0876
		95% BCA Bootstrap UCL	0.0956

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A
Data not Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only
Data appear Normal at 5% Significance Level

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.0933
SD	0.0536
SE of Mean	0.021
95% KM (t) UCL	0.13
95% KM (z) UCL	0.128
95% KM (jackknife) UCL	0.164
95% KM (bootstrap t) UCL	0.115
95% KM (BCA) UCL	0.229
95% KM (Percentile Bootstrap) UCL	0.229
95% KM (Chebyshev) UCL	0.185
97.5% KM (Chebyshev) UCL	0.225
99% KM (Chebyshev) UCL	0.303
Potential UCLs to Use	
95% KM (t) UCL	0.13
95% KM (Percentile Bootstrap) UCL	0.229

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(a)anthracene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	11
Number of Distinct Detected Data	11	Number of Non-Detect Data	12
		Percent Non-Detects	52.17%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0398	Minimum Detected	-3.224
Maximum Detected	11.9	Maximum Detected	2.477
Mean of Detected	2.059	Mean of Detected	-0.551
SD of Detected	3.576	SD of Detected	1.723
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	3
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	86.96%

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.626
5% Shapiro Wilk Critical Value	0.85

Data not Normal at 5% Significance Level

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.96
5% Shapiro Wilk Critical Value	0.85

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	1.126
SD	2.583
95% DL/2 (t) UCL	2.051
Maximum Likelihood Estimate(MLE) Method	
Mean	7.789
SD	3.817
95% MLE (t) UCL	9.156
95% MLE (Tiku) UCL	11.47

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-1.02
SD	1.29
95% H-Stat (DL/2) UCL	1.856
Log ROS Method	
Mean in Log Scale	-1.157
SD in Log Scale	1.317
Mean in Original Scale	1.082
SD in Original Scale	2.594
95% t UCL	2.01
95% Percentile Bootstrap UCL	2.059
95% BCA Bootstrap UCL	2.733

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.424
Theta Star	4.86
nu star	9.32
A-D Test Statistic	0.628
5% A-D Critical Value	0.781
K-S Test Statistic	0.781
5% K-S Critical Value	0.269

Data appear Gamma Distributed at 5% Significance Level

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0398
Maximum	11.9
Mean	2.077
Median	2.103
SD	2.412
k star	0.858
Theta star	2.421
Nu star	39.46
AppChi2	26.07
95% Gamma Approximate UCL	3.143
95% Adjusted Gamma UCL	3.241

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	1.091
SD	2.535
SE of Mean	0.555
95% KM (t) UCL	2.045
95% KM (z) UCL	2.004
95% KM (jackknife) UCL	2.021
95% KM (bootstrap t) UCL	3.997
95% KM (BCA) UCL	2.239
95% KM (Percentile Bootstrap) UCL	2.02
95% KM (Chebyshev) UCL	3.511
97.5% KM (Chebyshev) UCL	4.558
99% KM (Chebyshev) UCL	6.615

Potential UCLs to Use

95% KM (t) UCL	2.045

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Benzo(a)pyrene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	10
Number of Distinct Detected Data	10	Number of Non-Detect Data	13
		Percent Non-Detects	56.52%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0909	Minimum Detected	-2.398
Maximum Detected	10	Maximum Detected	2.303
Mean of Detected	1.954	Mean of Detected	-0.376
SD of Detected	3.118	SD of Detected	1.527
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	3
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	86.96%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.662	Shapiro Wilk Test Statistic	0.938
5% Shapiro Wilk Critical Value	0.842	5% Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	1	Mean	-0.989
SD	2.176	SD	1.166
95% DL/2 (t) UCL	1.779	95% H-Stat (DL/2) UCL	1.456
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-1.016
		SD in Log Scale	1.144
		Mean in Original Scale	0.977
		SD in Original Scale	2.179
		95% t UCL	1.757
		95% Percentile Bootstrap UCL	1.825
		95% BCA Bootstrap UCL	2.142

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.481
Theta Star	4.061
nu star	9.622
A-D Test Statistic	0.603
5% A-D Critical Value	0.77
K-S Test Statistic	0.77
5% K-S Critical Value	0.279

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.0909
Maximum	10
Mean	1.956
Median	1.959
SD	1.995
k star	1.107
Theta star	1.767
Nu star	50.93
AppChi2	35.54
95% Gamma Approximate UCL	2.803
95% Adjusted Gamma UCL	2.879

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.976
SD	2.132
SE of Mean	0.469
95% KM (t) UCL	1.782
95% KM (z) UCL	1.748
95% KM (jackknife) UCL	1.759
95% KM (bootstrap t) UCL	4.051
95% KM (BCA) UCL	1.777
95% KM (Percentile Bootstrap) UCL	1.8
95% KM (Chebyshev) UCL	3.022
97.5% KM (Chebyshev) UCL	3.908
99% KM (Chebyshev) UCL	5.647

Potential UCLs to Use

95% KM (t) UCL	1.782

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(b)fluoranthene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	10
Number of Distinct Detected Data	10	Number of Non-Detect Data	13
		Percent Non-Detects	56.52%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.14	Minimum Detected	-1.966
Maximum Detected	13.9	Maximum Detected	2.632
Mean of Detected	2.528	Mean of Detected	-0.0996
SD of Detected	4.258	SD of Detected	1.467
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	20
Number treated as Detected	3
Single DL Non-Detect Percentage	86.96%

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.618
5% Shapiro Wilk Critical Value	0.842

Data not Normal at 5% Significance Level

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.935
5% Shapiro Wilk Critical Value	0.842

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	1.25
SD	2.959
95% DL/2 (t) UCL	2.309
Maximum Likelihood Estimate(MLE) Method	
Mean	8.922
SD	4.704
95% MLE (t) UCL	10.61
95% MLE (Tiku) UCL	13.45

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-0.869
SD	1.209
95% H-Stat (DL/2) UCL	1.798
Log ROS Method	
Mean in Log Scale	-0.945
SD in Log Scale	1.219
Mean in Original Scale	1.216
SD in Original Scale	2.967
95% t UCL	2.278
95% Percentile Bootstrap UCL	2.302
95% BCA Bootstrap UCL	3.022

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.488
Theta Star	5.182
nu star	9.754
A-D Test Statistic	0.683
5% A-D Critical Value	0.769
K-S Test Statistic	0.769
5% K-S Critical Value	0.279

Data appear Gamma Distributed at 5% Significance Level

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.14
Maximum	13.9
Mean	2.465
Median	2.433
SD	2.727
k star	1.122
Theta star	2.197
Nu star	51.6
AppChi2	36.1
95% Gamma Approximate UCL	3.523
95% Adjusted Gamma UCL	3.617

Note: DL/2 is not a recommended method.

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	1.242
SD	2.893
SE of Mean	0.637
95% KM (t) UCL	2.335
95% KM (z) UCL	2.289
95% KM (jackknife) UCL	2.303
95% KM (bootstrap t) UCL	4.494
95% KM (BCA) UCL	2.534
95% KM (Percentile Bootstrap) UCL	2.421
95% KM (Chebyshev) UCL	4.017
97.5% KM (Chebyshev) UCL	5.218
99% KM (Chebyshev) UCL	7.576

Potential UCLs to Use

95% KM (t) UCL	2.335

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Benzo(k)fluoranthene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	16
		Percent Non-Detects	69.57%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.127	Minimum Detected	-2.064
Maximum Detected	4.49	Maximum Detected	1.502
Mean of Detected	1.461	Mean of Detected	-0.36
SD of Detected	1.669	SD of Detected	1.434
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	21
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	2
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	91.30%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.819	Shapiro Wilk Test Statistic	0.908
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.621	Mean	-1.145
SD	1.053	SD	0.974
95% DL/2 (t) UCL	0.998	95% H-Stat (DL/2) UCL	0.859
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.281
		SD in Log Scale	1.034
		Mean in Original Scale	0.584
		SD in Original Scale	1.057
		95% t UCL	0.963
		95% Percentile Bootstrap UCL	0.972
		95% BCA Bootstrap UCL	1.078

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.554
Theta Star	2.636
nu star	7.756
A-D Test Statistic	0.354
5% A-D Critical Value	0.734
K-S Test Statistic	0.734
5% K-S Critical Value	0.322

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.127
Maximum	4.49
Mean	1.481
Median	1.474
SD	0.878
k star	2.078
Theta star	0.713
Nu star	95.57
AppChi2	74.02
95% Gamma Approximate UCL	1.912
95% Adjusted Gamma UCL	1.948

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.577
SD	1.037
SE of Mean	0.237
95% KM (t) UCL	0.983
95% KM (z) UCL	0.966
95% KM (jackknife) UCL	0.967
95% KM (bootstrap t) UCL	1.579
95% KM (BCA) UCL	1.293
95% KM (Percentile Bootstrap) UCL	1.128
95% KM (Chebyshev) UCL	1.609
97.5% KM (Chebyshev) UCL	2.055
99% KM (Chebyshev) UCL	2.932

Potential UCLs to Use

95% KM (t) UCL	0.983
95% KM (Percentile Bootstrap) UCL	1.128

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Dibenz(a,h)anthracene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	20
		Percent Non-Detects	86.96%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.078	Minimum Detected	-2.551
Maximum Detected	1.35	Maximum Detected	0.3
Mean of Detected	0.621	Mean of Detected	-1.027
SD of Detected	0.656	SD of Detected	1.436
Minimum Non-Detect	0.36	Minimum Non-Detect	-1.022
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	23
Number treated as Detected	0
Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.94
5% Shapiro Wilk Critical Value	0.767

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.292
SD	0.289
95% DL/2 (t) UCL	0.395
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.986
5% Shapiro Wilk Critical Value	0.767

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-1.452
SD	0.571
95% H-Stat (DL/2) UCL	0.353
Log ROS Method	
Mean in Log Scale	-2.408
SD in Log Scale	0.807
Mean in Original Scale	0.151
SD in Original Scale	0.274
95% t UCL	0.249
95% Percentile Bootstrap UCL	0.251
95% BCA Bootstrap UCL	0.318

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.152
SD	0.272
SE of Mean	0.071
95% KM (t) UCL	0.274
95% KM (z) UCL	0.269
95% KM (jackknife) UCL	0.39
95% KM (bootstrap t) UCL	0.278
95% KM (BCA) UCL	1.35
95% KM (Percentile Bootstrap) UCL	1.35
95% KM (Chebyshev) UCL	0.461
97.5% KM (Chebyshev) UCL	0.595
99% KM (Chebyshev) UCL	0.858

Potential UCLs to Use

95% KM (t) UCL	0.274
95% KM (Percentile Bootstrap) UCL	1.35

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Indeno(1,2,3-cd)pyrene - TS

General Statistics

Number of Valid Data	23	Number of Detected Data	10
Number of Distinct Detected Data	10	Number of Non-Detect Data	13
		Percent Non-Detects	56.52%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.284	Minimum Detected	-1.259
Maximum Detected	8.1	Maximum Detected	2.092
Mean of Detected	1.649	Mean of Detected	-0.172
SD of Detected	2.433	SD of Detected	1.118
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	3
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	86.96%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.626	Shapiro Wilk Test Statistic	0.869
5% Shapiro Wilk Critical Value	0.842	5% Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.868	Mean	-0.9
SD	1.714	SD	1.021
95% DL/2 (t) UCL	1.481	95% H-Stat (DL/2) UCL	1.193
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE yields a negative mean		Mean in Log Scale	-0.828
		SD in Log Scale	0.934
		Mean in Original Scale	0.868
		SD in Original Scale	1.707
		95% t UCL	1.479
		95% Percentile Bootstrap UCL	1.513
		95% BCA Bootstrap UCL	1.827

Data Output from ProUCL
Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.678
Theta Star	2.434
nu star	13.55
A-D Test Statistic	0.901
5% A-D Critical Value	0.753
K-S Test Statistic	0.753
5% K-S Critical Value	0.275

Data follow Appr. Gamma Distribution at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.284
Maximum	8.1
Mean	1.649
Median	1.651
SD	1.556
k star	1.646
Theta star	1.002
Nu star	75.7
AppChi2	56.66
95% Gamma Approximate UCL	2.203
95% Adjusted Gamma UCL	2.25

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data Follow Appr. Gamma Distribution at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.904
SD	1.657
SE of Mean	0.365
95% KM (t) UCL	1.53
95% KM (z) UCL	1.503
95% KM (jackknife) UCL	1.512
95% KM (bootstrap t) UCL	2.86
95% KM (BCA) UCL	1.56
95% KM (Percentile Bootstrap) UCL	1.558
95% KM (Chebyshev) UCL	2.493
97.5% KM (Chebyshev) UCL	3.181
99% KM (Chebyshev) UCL	4.532

Potential UCLs to Use

95% KM (t) UCL	1.53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Input for ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Arsenic	D_Arsenic	Barium	D_Barium	Chromium	Cobalt	D_Cobalt	Iron	D_Iron	Manganese	D_Manganese
WTP3-MW01	WW3021	10	0	165	1	5	50	0	300	0	30	1
WTP3-MW02	WW3022	10.4	1	203	1	5	50	0	59.9	1	125	1
WTP3-MW03	WW3023	10	0	162	1	5	50	0	300	0	521	1
WTP3-MW01	WW3032	15.8	1	411	1	2.9	3	1	2870	1	482	1
WTP3-MW02	WW3033	10.4	1	264	1	5	50	0	130	1	181	1
WTP3-MW03	WW3034	10	0	249	1	5	1.4	1	300	0	466	1

Data Input for ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Dinitrobenzene, 1,3-	D_Dinitrobenzene, 1,3-	Dinitrotoluene, 2,4-	D_Dinitrotoluene, 2,4-	Cyanide, total	D_Cyanide, total
WTP3-MW01	WW3021	0.19	0	0.19	0	10	0
WTP3-MW02	WW3022	0.19	0	0.19	0	13	1
WTP3-MW03	WW3023	0.15	1	0.19	1	23	1
WTP3-MW01	WW3032	0.19	0	0.19	0	10	0
WTP3-MW02	WW3033	0.2	0	0.2	0	10	0
WTP3-MW03	WW3034	0.13	1	0.16	1	10	0

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	UCL MW GW input.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic - GW Overburden

General Statistics

Number of Valid Data	6	Number of Detected Data	3
Number of Distinct Detected Data	2	Number of Non-Detect Data	3
		Percent Non-Detects	50.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	10.4	Minimum Detected	2.342
Maximum Detected	15.8	Maximum Detected	2.76
Mean of Detected	12.2	Mean of Detected	2.481
SD of Detected	3.118	SD of Detected	0.241
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.75	Shapiro Wilk Test Statistic	0.75
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	8.6
SD	4.409
95% DL/2 (t) UCL	12.23
Maximum Likelihood Estimate(MLE) Method	
Mean	9.646
SD	3.478
95% MLE (t) UCL	12.51
95% MLE (Tiku) UCL	13.19

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	2.045
SD	0.501
95% H-Stat (DL/2) UCL	15.85
Log ROS Method	
Mean in Log Scale	2.107
SD in Log Scale	0.458
Mean in Original Scale	8.974
SD in Original Scale	4.12
95% t UCL	12.36
95% Percentile Bootstrap UCL	11.63
95% BCA Bootstrap UCL	11.76

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	11.3
SD	2.012
SE of Mean	1.006
95% KM (t) UCL	13.33
95% KM (z) UCL	12.96
95% KM (jackknife) UCL	N/A
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	15.69
97.5% KM (Chebyshev) UCL	17.58
99% KM (Chebyshev) UCL	21.31

Potential UCLs to Use

95% KM (t) UCL	13.33
95% KM (% Bootstrap) UCL	N/A

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Barium - GW Overburden

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	162
Maximum	411
Mean	242.3
Geometric Mean	229.6
Median	226
SD	92.68
Std. Error of Mean	37.83
Coefficient of Variation	0.382
Skewness	1.42

Log-transformed Statistics

Minimum of Log Data	5.088
Maximum of Log Data	6.019
Mean of log Data	5.436
SD of log Data	0.35

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.858
Shapiro Wilk Critical Value	0.788

Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.917
Shapiro Wilk Critical Value	0.788

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL 318.6

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	328
95% Modified-t UCL (Johnson-1978)	322.2

Assuming Lognormal Distribution

95% H-UCL	350.6
95% Chebyshev (MVUE) UCL	391.7
97.5% Chebyshev (MVUE) UCL	456.7
99% Chebyshev (MVUE) UCL	584.4

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test

k star (bias corrected)	4.835
Theta Star	50.12
MLE of Mean	242.3
MLE of Standard Deviation	110.2
nu star	58.02
Approximate Chi Square Value (.05)	41.51
Adjusted Level of Significance	0.0122
Adjusted Chi Square Value	36.52
Anderson-Darling Test Statistic	0.35
Anderson-Darling 5% Critical Value	0.698
Kolmogorov-Smirnov Test Statistic	0.187
Kolmogorov-Smirnov 5% Critical Value	0.333

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL (Use when n >= 40)	338.7
95% Adjusted Gamma UCL (Use when n < 40)	384.9

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL	304.6
95% Jackknife UCL	318.6
95% Standard Bootstrap UCL	300.1
95% Bootstrap-t UCL	367.7
95% Hall's Bootstrap UCL	563
95% Percentile Bootstrap UCL	308
95% BCA Bootstrap UCL	318
95% Chebyshev(Mean, Sd) UCL	407.2
97.5% Chebyshev(Mean, Sd) UCL	478.6
99% Chebyshev(Mean, Sd) UCL	618.8

Potential UCL to Use

Use 95% Student's-t UCL 318.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Chromium - GW Overburden

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 2

Raw Statistics

Minimum	2.9
Maximum	5
Mean	4.65
Median	5
SD	0.857
Coefficient of Variation	0.184
Skewness	-2.449

Log-transformed Statistics

Minimum of Log Data	1.065
Maximum of Log Data	1.609
Mean of log Data	1.519
SD of log Data	0.222

Warning: There are only 2 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.496
Shapiro Wilk Critical Value	0.788

Data not Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.496
Shapiro Wilk Critical Value	0.788

Data not Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	5.355

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	4.852
95% Modified-t UCL (Johnson-1978)	5.297

Assuming Lognormal Distribution

95% H-UCL	5.768
95% Chebyshev (MVUE) UCL	6.505
97.5% Chebyshev (MVUE) UCL	7.303
99% Chebyshev (MVUE) UCL	8.871

Gamma Distribution Test

k star (bias corrected)	13.92
Theta Star	0.334
MLE of Mean	4.65
MLE of Standard Deviation	1.246
nu star	167
Approximate Chi Square Value (.05)	138.1
Adjusted Level of Significance	0.0122
Adjusted Chi Square Value	128.6
Anderson-Darling Test Statistic	1.72
Anderson-Darling 5% Critical Value	0.697
Kolmogorov-Smirnov Test Statistic	0.507
Kolmogorov-Smirnov 5% Critical Value	0.332

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL	5.622
95% Adjusted Gamma UCL	6.038

Data Distribution

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

95% CLT UCL	5.226
95% Jackknife UCL	N/A
95% Standard Bootstrap UCL	N/A
95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A
95% Chebyshev(Mean, Sd) UCL	6.176
97.5% Chebyshev(Mean, Sd) UCL	6.836
99% Chebyshev(Mean, Sd) UCL	8.132

Potential UCL to Use

Use 95% Student's-t UCL 5.355
or 95% Modified-t UCL 5.297

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Cobalt - GW Overburden

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 3

Raw Statistics

Minimum	1.4
Maximum	25
Mean	17.4
Median	25
SD	11.78
Coefficient of Variation	0.677
Skewness	-0.976

Log-transformed Statistics

Minimum of Log Data	0.336
Maximum of Log Data	3.219
Mean of log Data	2.385
SD of log Data	1.314

Warning: There are only 3 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.656
Shapiro Wilk Critical Value	0.788

Data not Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.695
Shapiro Wilk Critical Value	0.788

Data not Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	27.09

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	23.26
95% Modified-t UCL (Johnson-1978)	26.78

Assuming Lognormal Distribution

95% H-UCL	551.7
95% Chebyshev (MVUE) UCL	68.05
97.5% Chebyshev (MVUE) UCL	88.42
99% Chebyshev (MVUE) UCL	128.4

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test

k star (bias corrected)	0.711
Theta Star	24.47
MLE of Mean	17.4
MLE of Standard Deviation	20.63
nu star	8.533
Approximate Chi Square Value (.05)	3.048
Adjusted Level of Significance	0.0122
Adjusted Chi Square Value	1.993
Anderson-Darling Test Statistic	1.125
Anderson-Darling 5% Critical Value	0.712
Kolmogorov-Smirnov Test Statistic	0.431
Kolmogorov-Smirnov 5% Critical Value	0.339

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL	48.72
95% Adjusted Gamma UCL	74.49

Data Distribution

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

95% CLT UCL	25.31
95% Jackknife UCL	27.09
95% Standard Bootstrap UCL	N/A
95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A
95% Chebyshev(Mean, Sd) UCL	38.37
97.5% Chebyshev(Mean, Sd) UCL	47.45
99% Chebyshev(Mean, Sd) UCL	65.27

Potential UCL to Use 0

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Manganese - GW Overburden

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	30
Maximum	521
Mean	300.8
Median	323.5
SD	213.2
Coefficient of Variation	0.709
Skewness	-0.183

Log-transformed Statistics

Minimum of Log Data	3.401
Maximum of Log Data	6.256
Mean of log Data	5.334
SD of log Data	1.116

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic 0.855
Shapiro Wilk Critical Value 0.788
Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic 0.847
Shapiro Wilk Critical Value 0.788
Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL 476.2

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995) 437
95% Modified-t UCL (Johnson-1978) 475.1

Assuming Lognormal Distribution

95% H-UCL 3714
95% Chebyshev (MVUE) UCL 990.1
97.5% Chebyshev (MVUE) UCL 1273
99% Chebyshev (MVUE) UCL 1828

Gamma Distribution Test

k star (bias corrected) 0.855
Theta Star 351.8
MLE of Mean 300.8
MLE of Standard Deviation 325.3
nu star 10.26
Approximate Chi Square Value (.05) 4.105
Adjusted Level of Significance 0.0122
Adjusted Chi Square Value 2.826

Anderson-Darling Test Statistic 0.471
Anderson-Darling 5% Critical Value 0.708
Kolmogorov-Smirnov Test Statistic 0.3
Kolmogorov-Smirnov 5% Critical Value 0.338
Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL 751.9
95% Adjusted Gamma UCL 1092

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL 444
95% Jackknife UCL 476.2
95% Standard Bootstrap UCL 431.7
95% Bootstrap-t UCL 466.3
95% Hall's Bootstrap UCL 391.4
95% Percentile Bootstrap UCL 435.5
95% BCA Bootstrap UCL 430.2
95% Chebyshev(Mean, Sd) UCL 680.2
97.5% Chebyshev(Mean, Sd) UCL 844.3
99% Chebyshev(Mean, Sd) UCL 1167

Potential UCL to Use

Use 95% Student's-t UCL 476.2

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Dinitrobenzene, 1,3- - GW Overburden

General Statistics

Number of Valid Data	6	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	4
		Percent Non-Detects	66.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.13	Minimum Detected	-2.04
Maximum Detected	0.15	Maximum Detected	-1.897
Mean of Detected	0.14	Mean of Detected	-1.969
SD of Detected	0.0141	SD of Detected	0.101
Minimum Non-Detect	0.19	Minimum Non-Detect	-1.661
Maximum Non-Detect	0.2	Maximum Non-Detect	-1.609

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.111
SD	0.0235
95% DL/2 (t) UCL	0.13
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-2.217
SD	0.199
95% H-Stat (DL/2) UCL	0.133
Log ROS Method	
Mean in Log Scale	N/A
SD in Log Scale	N/A
Mean in Original Scale	N/A
SD in Original Scale	N/A
95% t UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A
95% H-UCL	N/A

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL (Use when n >= 40)	N/A
95% Adjusted Gamma UCL (Use when n < 40)	N/A

Data Distribution Test with Detected Values Only

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.14
SD	0.01
SE of Mean	0.01
95% KM (t) UCL	0.16
95% KM (z) UCL	0.156
95% KM (jackknife) UCL	0.166
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	0.15
95% KM (Percentile Bootstrap) UCL	0.15
95% KM (Chebyshev) UCL	0.184
97.5% KM (Chebyshev) UCL	0.202
99% KM (Chebyshev) UCL	0.239

Potential UCLs to Use

95% KM (t) UCL	0.16
95% KM (% Bootstrap) UCL	0.15

Warning: Recommended UCL exceeds the maximum observation

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Dinitrotoluene, 2,4- - GW Overburden

General Statistics

Number of Valid Data	6	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	4
		Percent Non-Detects	66.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.16	Minimum Detected	-1.833
Maximum Detected	0.19	Maximum Detected	-1.661
Mean of Detected	0.175	Mean of Detected	-1.747
SD of Detected	0.0212	SD of Detected	0.122
Minimum Non-Detect	0.19	Minimum Non-Detect	-1.661
Maximum Non-Detect	0.2	Maximum Non-Detect	-1.609

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A
Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	0.123
SD	0.0418
95% DL/2 (t) UCL	0.157
Maximum Likelihood Estimate(MLE) Method	N/A
MLE method failed to converge properly	

Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	-2.143
SD	0.312
95% H-Stat (DL/2) UCL	0.169
Log ROS Method	
Mean in Log Scale	N/A
SD in Log Scale	N/A
Mean in Original Scale	N/A
SD in Original Scale	N/A
95% t UCL	N/A
95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A
Data not Gamma Distributed at 5% Significance Level	

Data Distribution Test with Detected Values Only
Data do not follow a Discernable Distribution (0.05)

Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.166
SD	0.012
SE of Mean	0.00759
95% KM (t) UCL	0.181
95% KM (z) UCL	0.178
95% KM (jackknife) UCL	N/A
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	0.199
97.5% KM (Chebyshev) UCL	0.213
99% KM (Chebyshev) UCL	0.242
Potential UCLs to Use	
95% KM (t) UCL	0.181
95% KM (% Bootstrap) UCL	N/A

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Cyanide, total - GW Overburden

General Statistics

Number of Valid Data	6	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	4
		Percent Non-Detects	66.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	13	Minimum Detected	2.565
Maximum Detected	23	Maximum Detected	3.135
Mean of Detected	18	Mean of Detected	2.85
SD of Detected	7.071	SD of Detected	0.403
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	9.333	Mean	2.023
SD	7.421	SD	0.666
95% DL/2 (t) UCL	15.44	95% H-Stat (DL/2) UCL	23.56
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Data Output from ProUCL
Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL (Use when n >= 40)	N/A
95% Adjusted Gamma UCL (Use when n < 40)	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	14.67
SD	3.727
SE of Mean	2.152
95% KM (t) UCL	19
95% KM (z) UCL	18.21
95% KM (jackknife) UCL	N/A
95% KM (bootstrap t) UCL	N/A
95% KM (BCA) UCL	N/A
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	24.05
97.5% KM (Chebyshev) UCL	28.1
99% KM (Chebyshev) UCL	36.08

Potential UCLs to Use

95% KM (t) UCL	19
95% KM (% Bootstrap) UCL	N/A

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Input for ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Arsenic	D_Arsenic	Manganese	D_Manganese	Vanadium	D_Vanadium	Methylnaphthalene, 2-
WTP3-BEDGW-001	WW3024	26.8	1	186	1	1.9	1	1.8
WTP3-BEDGW-001	WW3035	10	0	43.1	1	1.7	1	2.8
WTP3-BEDGW-002	WW3025	123	1	663	1	1.6	1	2.2
WTP3-BEDGW-002	WW3036	10	0	15.9	1	1.9	1	1.1
WTP3-BEDGW-003	WW3037	10	0	13.5	1	1.1	1	4.9
WTP3-BEDGW-003	WW3027WW3026	20.75	1	97.4	1	13.1	1	1.85

Data Input for ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	D_Methylnaphthalene, 2-	Naphthalene	D_Naphthalene	Benzene	D_Benzene	Ethylbenzene	D_Ethylbenzene
WTP3-BEDGW-001	WW3024	1	1.1	1	4.6	1	3.8	1
WTP3-BEDGW-001	WW3035	1	1.9	1	3.1	1	4.6	1
WTP3-BEDGW-002	WW3025	1	1.1	1	2.1	1	1.4	1
WTP3-BEDGW-002	WW3036	1	4.8	0	3.2	1	1.2	1
WTP3-BEDGW-003	WW3037	0	4.9	0	15.4	1	3.4	1
WTP3-BEDGW-003	WW3027WW3026	1	2.05	1	8.49	1	3.375	1

Data Input for ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Sample Location	Sample Number	Xylenes, total	D_Xylenes, total	Cyanide, total	D_Cyanide, total
WTP3-BEDGW-001	WW3024	24.4	1	29	1
WTP3-BEDGW-001	WW3035	34.6	1	10	0
WTP3-BEDGW-002	WW3025	7.7	1	53	1
WTP3-BEDGW-002	WW3036	7.8	1	10	0
WTP3-BEDGW-003	WW3037	24.7	1	10	0
WTP3-BEDGW-003	WW3027WW3026	25.55	1	44.5	1

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	UCL BD GW input.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic - GW Bedrock

General Statistics

Number of Valid Data	6	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	3
		Percent Non-Detects	50.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	20.75	Minimum Detected	3.033
Maximum Detected	123	Maximum Detected	4.812
Mean of Detected	56.85	Mean of Detected	3.711
SD of Detected	57.37	SD of Detected	0.962
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.794	Shapiro Wilk Test Statistic	0.855
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	30.93	Mean	2.66
SD	46.08	SD	1.302
95% DL/2 (t) UCL	68.83	95% H-Stat (DL/2) UCL	678.7
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	5.551	Mean in Log Scale	2.141
SD	67.8	SD in Log Scale	1.915
95% MLE (t) UCL	61.33	Mean in Original Scale	29.56
95% MLE (Tiku) UCL	74.48	SD in Original Scale	47.02
		95% t UCL	68.25
		95% Percentile Bootstrap UCL	62.85
		95% BCA Bootstrap UCL	71.14

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	38.8
SD	37.72
SE of Mean	18.86
95% KM (t) UCL	76.8
95% KM (z) UCL	69.82
95% KM (jackknife) UCL	71.57
95% KM (bootstrap t) UCL	341.2
95% KM (BCA) UCL	123
95% KM (Percentile Bootstrap) UCL	123
95% KM (Chebyshev) UCL	121
97.5% KM (Chebyshev) UCL	156.6
99% KM (Chebyshev) UCL	226.5

Potential UCLs to Use

95% KM (t) UCL	76.8
95% KM (Percentile Bootstrap) UCL	123

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Manganese - GW Bedrock

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	13.5
Maximum	663
Mean	169.8
Median	70.25
SD	250.2
Coefficient of Variation	1.473
Skewness	2.109

Log-transformed Statistics

Minimum of Log Data	2.603
Maximum of Log Data	6.497
Mean of log Data	4.239
SD of log Data	1.501

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Warning: There are only 6 Values in this data

Note: It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic 0.706
Shapiro Wilk Critical Value 0.788

Data not Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic 0.947
Shapiro Wilk Critical Value 0.788

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL 375.6

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995) 431.8
95% Modified-t UCL (Johnson-1978) 390.3

Assuming Lognormal Distribution

95% H-UCL 11074
95% Chebyshev (MVUE) UCL 563.6
97.5% Chebyshev (MVUE) UCL 738.1
99% Chebyshev (MVUE) UCL 1081

Gamma Distribution Test

k star (bias corrected) 0.45
Theta Star 377.4
MLE of Mean 169.8
MLE of Standard Deviation 253.2
nu star 5.4
Approximate Chi Square Value (.05) 1.341
Adjusted Level of Significance 0.0122
Adjusted Chi Square Value 0.745

Anderson-Darling Test Statistic 0.342
Anderson-Darling 5% Critical Value 0.725
Kolmogorov-Smirnov Test Statistic 0.187
Kolmogorov-Smirnov 5% Critical Value 0.345

Data appear Gamma Distributed at 5% Significance Level

Data Distribution

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics

95% CLT UCL 337.8
95% Jackknife UCL 375.6
95% Standard Bootstrap UCL 320.8
95% Bootstrap-t UCL 1188
95% Hall's Bootstrap UCL 1032
95% Percentile Bootstrap UCL 348.5
95% BCA Bootstrap UCL 409.7
95% Chebyshev(Mean, Sd) UCL 615
97.5% Chebyshev(Mean, Sd) UCL 807.6
99% Chebyshev(Mean, Sd) UCL 1186

Assuming Gamma Distribution

95% Approximate Gamma UCL 683.7
95% Adjusted Gamma UCL 1231

Potential UCL to Use

Use 95% Approximate Gamma UCL 683.7

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Vanadium - GW Bedrock

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 5

Raw Statistics

Minimum	1.1
Maximum	13.1
Mean	3.55
Geometric Mean	2.283
Median	1.8
SD	4.688
Std. Error of Mean	1.914
Coefficient of Variation	1.32
Skewness	2.427

Log-transformed Statistics

Minimum of Log Data	0.0953
Maximum of Log Data	2.573
Mean of log Data	0.825
SD of log Data	0.879

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.556
Shapiro Wilk Critical Value	0.788

Data not Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.705
Shapiro Wilk Critical Value	0.788

Data not Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	7.406

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	8.724
95% Modified-t UCL (Johnson-1978)	7.722

Assuming Lognormal Distribution

95% H-UCL	14.45
95% Chebyshev (MVUE) UCL	7.92
97.5% Chebyshev (MVUE) UCL	10
99% Chebyshev (MVUE) UCL	14.09

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test

k star (bias corrected)	0.748
Theta Star	4.748
MLE of Mean	3.55
MLE of Standard Deviation	4.105
nu star	8.972
Approximate Chi Square Value (.05)	3.31
Adjusted Level of Significance	0.0122
Adjusted Chi Square Value	2.197
Anderson-Darling Test Statistic	1.211
Anderson-Darling 5% Critical Value	0.711
Kolmogorov-Smirnov Test Statistic	0.462
Kolmogorov-Smirnov 5% Critical Value	0.339

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL (Use when n >= 40)	9.622
95% Adjusted Gamma UCL (Use when n < 40)	14.5

Data Distribution

Data do not follow a Discernable Distribution (0.05)

Nonparametric Statistics

95% CLT UCL	6.698
95% Jackknife UCL	7.406
95% Standard Bootstrap UCL	6.372
95% Bootstrap-t UCL	65.86
95% Hall's Bootstrap UCL	40.76
95% Percentile Bootstrap UCL	7.183
95% BCA Bootstrap UCL	7.45
95% Chebyshev(Mean, Sd) UCL	11.89
97.5% Chebyshev(Mean, Sd) UCL	15.5
99% Chebyshev(Mean, Sd) UCL	22.59

Potential UCL to Use

Use 95% Chebyshev (Mean, Sd) UCL 11.89

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Methylnaphthalene, 2- - GW Bedrock

General Statistics

Number of Valid Data	6	Number of Detected Data	5
Number of Distinct Detected Data	5	Number of Non-Detect Data	1
		Percent Non-Detects	16.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	1.1	Minimum Detected	0.0953
Maximum Detected	2.8	Maximum Detected	1.03
Mean of Detected	1.95	Mean of Detected	0.623
SD of Detected	0.62	SD of Detected	0.344
Minimum Non-Detect	4.9	Minimum Non-Detect	1.589
Maximum Non-Detect	4.9	Maximum Non-Detect	1.589

Warning: There are only 5 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.977
5% Shapiro Wilk Critical Value	0.762

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	2.033
SD	0.591
95% DL/2 (t) UCL	2.52
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.948
5% Shapiro Wilk Critical Value	0.762

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	0.669
SD	0.327
95% H-Stat (DL/2) UCL	2.871
Log ROS Method	
Mean in Log Scale	0.623
SD in Log Scale	0.307
Mean in Original Scale	1.936
SD in Original Scale	0.556
95% t UCL	2.393
95% Percentile Bootstrap UCL	2.275
95% BCA Bootstrap UCL	2.288
95% H-UCL	2.66

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	4.688
Theta Star	0.416
nu star	46.88
A-D Test Statistic	0.259
5% A-D Critical Value	0.679
K-S Test Statistic	0.679
5% K-S Critical Value	0.358

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	1.1
Maximum	2.8
Mean	1.962
Median	1.937
SD	0.556
k star	6.909
Theta star	0.284
Nu star	82.91
AppChi2	62.93
95% Gamma Approximate UCL (Use when n >= 40)	2.585
95% Adjusted Gamma UCL (Use when n < 40)	2.87

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	1.95
SD	0.555
SE of Mean	0.277
95% KM (t) UCL	2.509
95% KM (z) UCL	2.406
95% KM (jackknife) UCL	2.521
95% KM (bootstrap t) UCL	2.596
95% KM (BCA) UCL	2.313
95% KM (Percentile Bootstrap) UCL	2.36
95% KM (Chebyshev) UCL	3.16
97.5% KM (Chebyshev) UCL	3.683
99% KM (Chebyshev) UCL	4.711

Potential UCLs to Use

95% KM (t) UCL	2.509
95% KM (Percentile Bootstrap) UCL	2.36

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Naphthalene - GW Bedrock

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	3	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	1.1	Minimum Detected	0.0953
Maximum Detected	2.05	Maximum Detected	0.718
Mean of Detected	1.538	Mean of Detected	0.388
SD of Detected	0.509	SD of Detected	0.339
Minimum Non-Detect	4.8	Minimum Non-Detect	1.569
Maximum Non-Detect	4.9	Maximum Non-Detect	1.589

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.797	Shapiro Wilk Test Statistic	0.783
5% Shapiro Wilk Critical Value	0.748	5% Shapiro Wilk Critical Value	0.748
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	1.833	Mean	0.554
SD	0.605	SD	0.368
95% DL/2 (t) UCL	2.331	95% H-Stat (DL/2) UCL	2.739
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	0.388
		SD in Log Scale	0.263
		Mean in Original Scale	1.516
		SD in Original Scale	0.396
		95% t UCL	1.842
		95% Percentile Bootstrap UCL	1.762
		95% BCA Bootstrap UCL	1.746

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	3.143
Theta Star	0.489
nu star	25.15
A-D Test Statistic	0.602
5% A-D Critical Value	0.657
K-S Test Statistic	0.657
5% K-S Critical Value	0.395

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	1.1
Maximum	2.05
Mean	1.552
Median	1.581
SD	0.395
k star	8.974
Theta star	0.173
Nu star	107.7
AppChi2	84.74
95% Gamma Approximate UCL	1.972
95% Adjusted Gamma UCL	N/A

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	1.538
SD	0.441
SE of Mean	0.254
95% KM (t) UCL	2.05
95% KM (z) UCL	1.956
95% KM (jackknife) UCL	2.078
95% KM (bootstrap t) UCL	2.118
95% KM (BCA) UCL	1.95
95% KM (Percentile Bootstrap) UCL	1.975
95% KM (Chebyshev) UCL	2.647
97.5% KM (Chebyshev) UCL	3.126
99% KM (Chebyshev) UCL	4.069

Potential UCLs to Use

95% KM (t) UCL	2.05
95% KM (Percentile Bootstrap) UCL	1.975

Warning: Recommended UCL exceeds the maximum observation

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzene - GW Bedrock

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	2.1
Maximum	15.4
Mean	6.148
Median	3.9
SD	5.057
Coefficient of Variation	0.822
Skewness	1.579

Log-transformed Statistics

Minimum of Log Data	0.742
Maximum of Log Data	2.734
Mean of log Data	1.573
SD of log Data	0.738

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Warning: There are only 6 Values in this data

Note: It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic 0.812
Shapiro Wilk Critical Value 0.788

Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic 0.935
Shapiro Wilk Critical Value 0.788

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL 10.31

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995) 10.97
95% Modified-t UCL (Johnson-1978) 10.53

Assuming Lognormal Distribution

95% H-UCL 18.72
95% Chebyshev (MVUE) UCL 13.85
97.5% Chebyshev (MVUE) UCL 17.25
99% Chebyshev (MVUE) UCL 23.91

Gamma Distribution Test

k star (bias corrected) 1.214
Theta Star 5.066
MLE of Mean 6.148
MLE of Standard Deviation 5.581
nu star 14.56
Approximate Chi Square Value (.05) 6.96
Adjusted Level of Significance 0.0122
Adjusted Chi Square Value 5.18

Anderson-Darling Test Statistic 0.399
Anderson-Darling 5% Critical Value 0.704
Kolmogorov-Smirnov Test Statistic 0.238
Kolmogorov-Smirnov 5% Critical Value 0.336

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL 12.87
95% Adjusted Gamma UCL 17.29

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL 9.544
95% Jackknife UCL 10.31
95% Standard Bootstrap UCL 9.22
95% Bootstrap-t UCL 23.1
95% Hall's Bootstrap UCL 28.34
95% Percentile Bootstrap UCL 9.497
95% BCA Bootstrap UCL 10.4
95% Chebyshev(Mean, Sd) UCL 15.15
97.5% Chebyshev(Mean, Sd) UCL 19.04
99% Chebyshev(Mean, Sd) UCL 26.69

Potential UCL to Use

Use 95% Student's-t UCL 10.31

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Ethylbenzene - GW Bedrock

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	1.2
Maximum	4.6
Mean	2.963
Median	3.388
SD	1.363
Coefficient of Variation	0.46
Skewness	-0.492

Log-transformed Statistics

Minimum of Log Data	0.182
Maximum of Log Data	1.526
Mean of log Data	0.97
SD of log Data	0.564

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic	0.882
Shapiro Wilk Critical Value	0.788

Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic	0.825
Shapiro Wilk Critical Value	0.788

Data appear Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL	4.084

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995)	3.758
95% Modified-t UCL (Johnson-1978)	4.065

Assuming Lognormal Distribution

95% H-UCL	6.259
95% Chebyshev (MVUE) UCL	6.012
97.5% Chebyshev (MVUE) UCL	7.313
99% Chebyshev (MVUE) UCL	9.87

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test

k star (bias corrected)	2.346
Theta Star	1.263
MLE of Mean	2.963
MLE of Standard Deviation	1.934
nu star	28.15
Approximate Chi Square Value (.05)	17.04
Adjusted Level of Significance	0.0122
Adjusted Chi Square Value	14.02
Anderson-Darling Test Statistic	0.601
Anderson-Darling 5% Critical Value	0.699
Kolmogorov-Smirnov Test Statistic	0.336
Kolmogorov-Smirnov 5% Critical Value	0.333

Data follow Appr. Gamma Distribution at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL	4.893
95% Adjusted Gamma UCL	5.948

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL	3.878
95% Jackknife UCL	4.084
95% Standard Bootstrap UCL	3.808
95% Bootstrap-t UCL	3.992
95% Hall's Bootstrap UCL	3.629
95% Percentile Bootstrap UCL	3.858
95% BCA Bootstrap UCL	3.733
95% Chebyshev(Mean, Sd) UCL	5.388
97.5% Chebyshev(Mean, Sd) UCL	6.438
99% Chebyshev(Mean, Sd) UCL	8.5

Potential UCL to Use

Use 95% Student's-t UCL 4.084

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Xylenes, total - GW Bedrock

General Statistics

Number of Valid Observations 6

Number of Distinct Observations 6

Raw Statistics

Minimum	7.7
Maximum	34.6
Mean	20.79
Median	24.55
SD	10.79
Coefficient of Variation	0.519
Skewness	-0.38

Log-transformed Statistics

Minimum of Log Data	2.041
Maximum of Log Data	3.544
Mean of log Data	2.88
SD of log Data	0.658

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Relevant UCL Statistics

Normal Distribution Test

Shapiro Wilk Test Statistic 0.855
Shapiro Wilk Critical Value 0.788
Data appear Normal at 5% Significance Level

Lognormal Distribution Test

Shapiro Wilk Test Statistic 0.782
Shapiro Wilk Critical Value 0.788
Data not Lognormal at 5% Significance Level

Assuming Normal Distribution

95% Student's-t UCL 29.67

95% UCLs (Adjusted for Skewness)

95% Adjusted-CLT UCL (Chen-1995) 27.31
95% Modified-t UCL (Johnson-1978) 29.55

Assuming Lognormal Distribution

95% H-UCL 54.24
95% Chebyshev (MVUE) UCL 46.01
97.5% Chebyshev (MVUE) UCL 56.72
99% Chebyshev (MVUE) UCL 77.77

Gamma Distribution Test

k star (bias corrected) 1.81
Theta Star 11.49
MLE of Mean 20.79
MLE of Standard Deviation 15.46
nu star 21.72
Approximate Chi Square Value (.05) 12.13
Adjusted Level of Significance 0.0122
Adjusted Chi Square Value 9.643

Anderson-Darling Test Statistic 0.723
Anderson-Darling 5% Critical Value 0.701
Kolmogorov-Smirnov Test Statistic 0.352
Kolmogorov-Smirnov 5% Critical Value 0.334
Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

95% Approximate Gamma UCL 37.24
95% Adjusted Gamma UCL 46.82

Data Distribution

Data appear Normal at 5% Significance Level

Nonparametric Statistics

95% CLT UCL 28.04
95% Jackknife UCL 29.67
95% Standard Bootstrap UCL 27.43
95% Bootstrap-t UCL 29.52
95% Hall's Bootstrap UCL 25.93
95% Percentile Bootstrap UCL 27.1
95% BCA Bootstrap UCL 26.73
95% Chebyshev(Mean, Sd) UCL 39.99
97.5% Chebyshev(Mean, Sd) UCL 48.29
99% Chebyshev(Mean, Sd) UCL 64.61

Potential UCL to Use

Use 95% Student's-t UCL 29.67

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Cyanide, total - GW Bedrock

General Statistics

Number of Valid Data	6	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	3
		Percent Non-Detects	50.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	29	Minimum Detected	3.367
Maximum Detected	53	Maximum Detected	3.97
Mean of Detected	42.17	Mean of Detected	3.711
SD of Detected	12.17	SD of Detected	0.31
Minimum Non-Detect	10	Minimum Non-Detect	2.303
Maximum Non-Detect	10	Maximum Non-Detect	2.303

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.972	Shapiro Wilk Test Statistic	0.944
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	23.58	Mean	2.66
SD	21.76	SD	1.168
95% DL/2 (t) UCL	41.49	95% H-Stat (DL/2) UCL	331
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	14.22	Mean in Log Scale	3.207
SD	31.59	SD in Log Scale	0.615
95% MLE (t) UCL	40.2	Mean in Original Scale	28.76
95% MLE (Tiku) UCL	46.19	SD in Original Scale	16.81
		95% t UCL	42.59
		95% Percentile Bootstrap UCL	39.16
		95% BCA Bootstrap UCL	41.06
		95% H UCL	66.83

Data Output from ProUCL
Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A

Data not Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL (Use when n >= 40)	N/A
95% Adjusted Gamma UCL (Use when n < 40)	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	35.58
SD	9.628
SE of Mean	4.814
95% KM (t) UCL	45.28
95% KM (z) UCL	43.5
95% KM (jackknife) UCL	47.88
95% KM (bootstrap t) UCL	38.63
95% KM (BCA) UCL	53
95% KM (Percentile Bootstrap) UCL	53
95% KM (Chebyshev) UCL	56.57
97.5% KM (Chebyshev) UCL	65.65
99% KM (Chebyshev) UCL	83.48

Potential UCLs to Use

95% KM (t) UCL	45.28
95% KM (Percentile Bootstrap) UCL	53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

APPENDIX C

TOXICOLOGICAL PROFILES

Appendix C
Introduction to the Toxicological Profiles

1.0 Purpose and Use of the Toxicological Profiles

Human health toxicological profiles are presented for each chemical of potential concern (COPC), each chemical for which documentation of chemical-specific values is required or about which there are chemical-specific issues that require resolution. The toxicological profiles provide documentation of the chemical-specific physical properties and toxicity values used in the risk assessment (RA). They also discuss the identity, classification and uses of the chemical, the common sources of release to the environment and the fate of the chemical in the environment, including the relevance of aquatic and terrestrial food-chain pathways to human health. A brief review of toxicokinetics discusses absorption, distribution, metabolism or biotransformation, excretion of the parent compound and metabolites, and mechanism of toxicity including identifying the ultimate toxicant – i.e., the moiety (parent chemical or metabolite) identified as most likely responsible for the adverse effects associated with the chemical. This information may be helpful to determine whether laboratory animals may serve as appropriate models for toxicity to humans, and to clarify the nature of toxicological interactions with other chemicals. A discussion of dermal exposure provides perspective on the significance of dermal uptake, and documents the development of dermal toxicity values and the extent or rate of dermal uptake from soil or water according to the latest USEPA (2004) guidance.

The noncancer effects evaluation and carcinogenicity evaluation provide an overall perspective on the nature of the adverse effects associated with the chemical, as well as documentation of the toxicity values. Chemical-specific issues or controversies that may influence the interpretation or application of the results of the RA are also discussed herein. The toxicity values used in the RA are summarized in a table.

The overall purpose of the toxicological profiles is to provide perspective on characteristics of each of the chemicals included in the RA so that the numerical risk estimates can be interpreted and applied wisely in the management of the site.

2.0 Chemical Identity

The identity of the chemical or chemical class is given in the title of each profile; additional information or clarification is provided in the *Introduction and Physical Properties* Section as required. The 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, text, or in the case of multiple isomers or members of a chemical class, in the table that provides the physical properties.

3.0 Physical Properties

The toxicological profiles also provide documentation for the physical properties or 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 meters per mole (atm-m^3/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), solubility in water (S) in milligrams per liter (mg/L), and, for volatile organic compounds (VOC), boiling point of pure compound (T_b) in degrees Kelvin (°K), critical temperature (T_c) in °K, and enthalpy of vaporization at the boiling point ($\Delta H_{v,b}$) in calories per mole (cal/mol). Organic chemicals are designated as VOCs or semivolatile organic compounds (SVOC) based on their propensity to volatilize from environmental media. Chemicals designated as VOCs generally have an H greater than 1E-5 atm-m^3/mole (EPA, 2002).

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, 2002) if the data are available. VP, S and H values are limited to those provided for normal ambient temperatures (0 to 30 °C) and the reference temperature is provided.

When values for H are not located, they are calculated as follows, provided the requisite information is available (EPA, 1998):

$$H = \frac{VP \bullet MW}{S}$$

where:

H	=	Henry's law constant (atm-m^3/mole, calculated)
VP	=	vapor pressure (atm)
MW	=	molecular weight (g/mole)
S	=	solubility in water (mg/L).

When values for K_{oc} are not located, they are calculated as follows for phthalates and polyaromatic aromatic hydrocarbons (PAH) provided log K_{ow} is available (EPA, 1998):

$$\log K_{oc} = 0.97 \log K_{ow} - 0.094$$

where:

K_{oc}	=	soil/organic carbon partition coefficient (unitless, calculated)
K_{ow}	=	octanol/water partition coefficient (unitless).

K_{oc} for other organic chemicals is calculated as follows provided log K_{ow} is available (EPA, 1998):

$$\log K_{oc} = 0.78 \log K_{ow} + 0.151$$

where:

K_{oc} = soil/organic carbon partition coefficient (unitless, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

When values for D_a are not located, they are calculated as follows (EPA, 1998):

$$D_a = \frac{1.9}{MW^{2/3}}$$

where:

D_a = diffusivity in air (cm^2/s, calculated)
MW = molecular weight (g/mole).

When values for D_w are not located, they are calculated as follows (EPA, 1998):

$$D_w = \frac{22E{-}5}{MW^{2/3}}$$

where:

D_w = diffusivity in water (cm^2/s, calculated)
MW = molecular weight (g/mole).

Values for T_b, T_c and $\Delta H_{v,b}$ for VOCs are preferentially taken from EPA (2004), unless there is evidence that values provided by other sources (HSDB, 2012; NIST, 2012) are more reliable. If values are not located for these variables, they may be estimated by the most appropriate technique for the specific chemical or class to which it belongs as recommended by Lyman et al. (1990). The estimation method used is identified by footnote in the table of physical properties.

4.0 Environmental Release, Fate and Transport

The toxicological profiles also present the predominant sources of release to the environment as well as a qualitative or semi-quantitative description of the fate and transport of the chemical in air, water, sediment, and soil. No attempt is made to present detailed quantitative data because environmental fate is usually highly dependent on climatic conditions and the characteristics of the medium of interest, both of 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 a few inorganic chemicals and those organic chemicals that are highly lipophilic, persist in the environment, and are resistant to metabolism by lower trophic organisms in the food chain. High lipophilicity is indicated by a log K_{ow} greater than 3 (Lyman et al., 1990). Lipophilicity enhances partitioning to biomedia 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. Toxicokinetic data, when available, clarify the potential for biotransfer. Biotransformation products may be more toxic than the parent compound, but they tend to be short-lived or more quickly removed from the body, reducing the likelihood of significant bioaccumulation. Similarly, 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, with few exceptions. Some SVOCs, however, are highly lipophilic and may persist. Biotransfer factors generally are not estimated unless empirical data suggest that participation in food-chain pathways is likely to be significant.

The biotransfer factors of interest are water-to-fish bioconcentration factors (BCF) or bioaccumulation factors (BAF), or biota-sediment accumulation factors (BSAF), soil-to-plant biotransfer factors (Bp), cattle ingestion-to-beef factors (Bb) and cattle ingestion-to-milk factors (Bm). 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 Bpr; soil-to-plant factors for the vegetative parts of plants are designated Bpv.

Most chemicals in surface water bodies remain predominantly in the dissolved phase in the water column or partition to sediment, which generally settles to the bottom. The difference in concentration between surface water and sediment is usually upwards of an order of magnitude. Theoretically it is appropriate to evaluate biotransfer from both media, using BCF to quantify uptake from water and BSAF to quantify uptake from sediment. Quantification of biotransfer, however, is accompanied by considerable uncertainty and variability because field conditions cannot be readily duplicated in the laboratory where BCF values are generally measured. Therefore, the biotransfer models for either medium are intentionally designed to be very conservative to ensure protection of human health. Consequently, evaluating biotransfer from both water and sediment captures the conservatism of both models and is likely to grossly overestimate total biotransfer. Therefore, most chemicals with the potential to participate significantly in aquatic food chain pathways are evaluated for bioconcentration from surface water *or* bioaccumulation from sediment, depending on which pathway is expected to predominate, but not both.

BCF values are adopted from empirical data when the data are clearly the best choice (i.e., similar results in multiple species of fin fish). When the empirical data are few or inconsistent, BCFs for inorganic chemicals are taken from various sources. BCF values for organic chemicals are generally estimated from the Bintein and Devillers model (Devillers et al., 1996):

$$\log BCF = 0.910 \log K_{ow} - 1.975 \log(6.8E{-}7 K_{ow} + 1) - 0.786$$

where:

BCF = bioconcentration factor (L/kg, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

The Bintein and Devillers model is selected over simpler models adopted by the EPA largely because the Bintein and Devillers approach has undergone scrutiny since first published (Bintein and Devillers, 1993), and considerable effort was expended to validate the model; i.e., to compare modeled and empirical results. The Bintein and Devillers model is probably more realistic than simpler models, particularly for chemicals with higher log K_{ow} values. BSAF values are chosen instead of BCFs for those very highly lipophilic chemicals such as the polychlorinated biphenyls (PCB), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) and selected organochlorine pesticides expected to partition almost entirely to benthic sediment.

Soil-to-plant biotransfer factors (Bp) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on log K_{ow}:

$$\log Bp = 1.588 - 0.578 \log K_{ow}$$

where:

Bp = 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 (Bpr) and the vegetative parts of plants (Bpv) by the Travis and Arms model.

Cattle ingestion-to-beef factors (Bb) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on log K_{ow}:

$$\log Bb = -7.6 + \log K_{ow}$$

where:

Bb = cattle ingestion-to-beef biotransfer factor (days/kg, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

Cattle ingestion-to-milk factors (Bm) for SVOCs are estimated by a simple model by Travis and Arms (1988), which is based only on log K_{ow}:

$$\log Bm = -8.10 + \log K_{ow}$$

where:

Bm = cattle ingestion-to-milk biotransfer factor (days/kg, calculated)
K_{ow} = octanol/water partition coefficient (unitless).

It should be understood that the biotransfer models described above depend only on one or two physical property values that are related largely to the propensity for transfer across biological membranes. Many compounds have relatively large log K_{ow} values, indicating ready passage across membranes; however, they are sufficiently volatile, or are otherwise mobile or labile so

they are unable to persist in biological tissues. For example, many constituents with high log K_{ow} values are efficiently metabolized by lower trophic organisms in the food chain so that significant human exposure does not occur. Such is the case for practically all VOCs and most SVOCs; relatively few compounds participate significantly in food-chain pathways. Therefore, biotransfer is evaluated as a potential pathway only for those chemicals with empirical data that indicate food-chain exposure could be significant.

5.0 Toxicokinetics

A toxicokinetics section was added to the toxicological profiles in early 2004. Toxicokinetics describes the uptake or absorption of the chemical from contact media, the distribution of the chemical (or its metabolites) within the body following absorption, the metabolism or biotransformation of the chemical, and the mechanisms of excretion of the parent compound and its biotransformation products from the body. The toxicokinetics section documents the gastrointestinal (GI) absorption factor (GAF) required to develop toxicity factors for dermal exposure, because dermal risk characterization depends on an absorbed dose rather than an exposure dose. The toxicokinetics section also identifies the compounds that are rapidly metabolized or eliminated, which justifies excluding their evaluation in food-chain pathways even though they may have a large K_{ow} that indicates ready passage across cell membranes. This section also tries to identify the ultimate toxicant and elucidate the most important mechanism(s) of toxicity.

6.0 Dermal Exposure

The toxicological profiles provide the documentation for the GAF, which is used to develop the dermal toxicity values. The toxicological profiles also provide documentation for the dermal absorption factor (ABS), which describes the extent of dermal uptake from soil, and the time for dermal uptake to reach steady state (t*), the permeability coefficient (K_p), the lag time for chemical to cross the stratum corneum (τ), the fraction absorbed (FA), and the ratio of the permeability coefficient for passage across the stratum corneum to the permeability coefficient for passage across the viable epidermis (B), all which are used to estimate the rate of dermal uptake from water. These values are taken from EPA (2004) if available. Otherwise, they are estimated by the EPA (2004) methods.

7.0 Toxicity Evaluation

The toxicological profile contains a brief description of the nature of the 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).

7.1 Noncancer Evaluation

The toxicity values for noncancer effects include a reference dose (RfD) expressed in milligrams per kilogram per day (mg/kg-day) for chronic or subchronic oral exposure, and a reference concentration (RfC), in milligrams per cubic meter (mg/m^3), for chronic or subchronic inhalation exposure. The inhalation RfC in units of mg/m^3 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 m^3/day (EPA, 1989, 1991). In other words, the RfC expressed as mg/m^3 is multiplied by the inhalation rate of 20 m^3/day, and the result is divided by the assumed adult body weight of 70 kg to yield an inhalation RfD expressed as mg/kg-day.

RfD and RfC values 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 experience such an effect is expressed as BMD_{10}. The RfD or RfC is derived by dividing the benchmark level (e.g., NOAEL or BMD_{10}) by a series of uncertainty and modifying factors, which collectively are designated the uncertainty factor (UF).

RfD and RfC values are not currently available for acute toxicity and acute exposure is not evaluated in the RA. 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.

RfD and RfC values are derived for both chronic and subchronic exposure. For purposes of the RA, chronic exposure is defined as equal to or greater than 7 years, i.e., at least 10 percent of expected life span; subchronic exposure is defined as 2 weeks to 7 years.

Under the assumption of monotonicity (i.e., 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, verified subchronic RfD values are unavailable. Provisional subchronic RfDs exist for few chemicals and are compiled in the Health Effects Assessment Summary Tables (HEAST) (EPA, 1997) and some National Center for Environmental Assessment (NCEA) or Provisional Peer Reviewed Toxicity Value (PPRTV) derivations. Although once updated semi-annually, the HEAST is no longer updated, because the EPA (2005) Integrated Risk Information System (IRIS) is generally considered the source of the highest quality toxicity values. For some chemicals the PPRTV derivations are more recent and it is known that summaries on IRIS will be replaced with the PPRTV derivations. In these cases the PPRTV values will be selected preferentially to those on IRIS. Subchronic RfD and RfC values are generally obtained from EPA (1997) or more recent NCEA or PPRTV evaluations, or they may be derived *de novo* from the toxicological data set or 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 component of the UF 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).

7.2 Carcinogenicity Evaluation

The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (EPA, 1986, 2005). EPA (2005) recognizes five weight-of-evidence group classifications for carcinogenicity. Formerly, EPA (1986) used a letter-based system to describe the weight of evidence for carcinogenicity. Reference to this former system is included because many of the carcinogenicity assessments listed on the Integrated Risk Information System (IRIS) use the former letter-based system (EPA, 2012). The five EPA weight-of-evidence classifications are as follows:

- ***Carcinogenic to Humans*** (corresponds to the former Group A - Human Carcinogen).

- ***Likely to be Carcinogenic to Humans*** (includes both the former Group B1 and Group B2-Probable Human Carcinogens)

- ***Suggestive Evidence of Carcinogenic Potential*** (corresponds to the former Group C - Possible Human Carcinogen)

- ***Inadequate Information to Assess Carcinogenic Potential*** (corresponds to the former Group D - Not Classifiable as to Human Carcinogenicity)

- ***Not Likely to be Carcinogenic to Humans*** (corresponds to the former Group E - Evidence of Noncarcinogenicity to Humans).

Toxicity values for cancer risk include 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 ($\mu g/m^3$) in ambient air. These quantitative estimates are generally provided for chemicals in EPA weight-of-evidence Groups A, 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 $\mu g/m^3$ may be converted to an equivalent inhalation SF in units of risk per mg/kg-day by assuming continuous lifetime exposure of humans with a body weight to 70 kg and an inhalation rate of 20 m^3/day. In other words, the URF expressed as risk per $\mu g/m^3$ is divided by the inhalation rate of 20 m^3/day, and multiplied by the assumed body weight of 70 kg and a conversion factor of 1000 µg/mg.

EPA (1986, 2005) generally assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk. A few potential carcinogens are understood to require a threshold for carcinogenic expression. Such chemicals are more appropriately evaluated with an RfD developed as described above.

7.3 Hierarchy for Selecting Toxicity Data

Toxicity values generally are chosen using the following hierarchy, consistent with the EPA Office of Solid Waste and Emergency Response Directive 9285.7-53 (EPA, 2003):

- Tier 1 values: The EPA's (2012) on-line IRIS database containing toxicity values that have undergone the most rigorous Agency review.

- Tier 2 values: EPA's provisional peer-reviewed toxicity values (PPRTV) derivations for the Superfund Technical Support Center (STSC); there may be individual chemicals for which the PPRTV derivations supercede those on IRIS.

- Tier 3 Values: Older NCEA derivations for the STSC, PRRTV screening values, HEAST (EPA, 1997), Minimal Risk Levels (MRL) from the Agency for Toxic Substances Disease Registry (ATSDR) toxicological profiles, U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) values, California Environmental Protection Agency (2012) Toxicity Criteria Database values, or other EPA documents or memoranda.

The primary literature may be surveyed to determine whether sufficient data exist to derive a toxicity value using the EPA methodology. The use of surrogate chemicals is also considered if the chemical structure, adverse effects, and toxic potency of the surrogate and chemical of interest are judged to be sufficiently similar.

The Environmental Council of the States-U.S. Department of Defense (2007) has issued a toxicity value hierarchy that basically supports the EPA (2003) hierarchy but places higher emphasis on the necessity for external peer review.

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

- EPA (2004)

- Empirical data

- PPRTV summaries or NCEA position papers

- Federal agency reviews of the empirical data, such as ATSDR toxicological profiles and various EPA criteria documents

- Other published reviews of the empirical data.

8.0 References

Bintein, S. and J. Devillers, 1993, "Nonlinear Dependence of Fish Bioconcentration on n-Octanol/Water Partition Coefficient," ***SAR and QSAR in Environmental Research***, 1: 29-39.

California Environmental Protection Agency, 2012, ***Toxicity Criteria Database***, Office of Environmental Health Hazard Assessment, Sacramento, California, http://www.oehha.ca.gov/risk/ChemicalDB/index.asp.

Devillers, J., S. Bintein and D. Domine, 1996, "Comparison of BCF Models Based on Log P," ***Chemosphere***, 33(6): 1047-1065.

Environmental Council of the States-U.S. Department of Defense, 2007, ***Identification and Selection of Toxicity Values/Criteria for CERCLA and Hazardous Waste Site Risk Assessments in the Absence of IRIS Values,*** ECO-DOD Sustainability Work Group, Emerging Contaminants Task Group, Risk Assessment Provisional Values Subgroup Issue Paper, 23 April.

Hart, R.W. and L.T. Frame, 1996, "Toxicological Defense Mechanisms and How They May Affect the Nature of Dose-Response Relationships," ***Biological Effects of Low Level Exposure (BELLE) Newsletter***, 5(1): 1-16.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Lyman, W. J., W. F. Reehl and D. H. Rosenblatt, 1990, ***Handbook of Chemical Property Estimation Methods, Environmental Behavior of Organic Compounds***, American Chemical Society, Washington, DC.

National Institute of Standards and Technology (NIST), 2012, ***NIST Chemistry WebBook***, on line.

Travis, C.C. and A.D. Arms, 1988, "Bioconcentration of Organics in Beef, Milk and Vegetation," ***Environmental Science and Technology***, 22(3): 271-274.

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

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

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: 9285.6-03, 25 March.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

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-98-001B, July.

U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, DC, 9355.4-24, December.

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

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2005, ***Guidelines for Carcinogen Risk Assessment***, Risk Assessment Forum, Washington, D.C., March, EPA/630/P-03/001B.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

METALS

ARSENIC (7440-38-2)

1.0 Introduction and Physical Properties

Arsenic is a natural **metalloid**, the 20th most abundant element in the earth's crust that occurs in both inorganic and organic forms (ATSDR, 2000; HSDB, 2012). Elemental arsenic is a steel-grey material that may occur naturally. However, arsenic is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur. Most inorganic and organic arsenic compounds are non-volatile, odorless and tasteless white or colorless powders. Inorganic arsenic occurs naturally in soil and in many kinds of rock, especially in minerals and ores that contain copper or lead. Inorganic arsenic is more toxic than organic forms. Major uses of arsenic in the U.S. include its incorporation into wood preservatives and other agricultural chemicals. It is also used as a metal in various electrical devices and is alloyed with lead and copper in the manufacture of lead bullets or shot (Lewis, 1997). Arsenic is also a component of the chemical warfare agent Lewisite (Opresko et al., 1998). Lewisite is manufactured by the condensation of arsenic trichloride with acetylene in the presence of aluminum, copper or mercuric chloride (Lewis, 1997). Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
74.92[a]	NA	NA	2.9E+1[b]	NA	NA	Note 1[c]	Note 2[c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; 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] Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[b]U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***,, Office of Solid Waste and Emergency Response, OSWER 9355.4-24, December.
[c]Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Arsenic***, U.S. Public Health Service, Atlanta, Georgia, September, on line.

2.0 Environmental Fate and Transport

The production of arsenic and its use in nonferrous alloys and in the manufacture of semiconductors may result in its release to the environment through various waste streams HSDB, 2012). Other important anthropogenic releases are metal smelting, coal burning, and other industrial activities. Arsenic may be present at military sites as a result of training with or demilitarization or disposal of Lewisite. Most (approximately 80 percent) of anthropogenic releases are initially to soil (ATSDR, 2000).

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, 2000). 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 reactions and exist as several different soluble compounds. 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 solubility and mobility.

Arsenic has been shown to bioconcentrate in aquatic organisms, mainly at the water-algae interface (ATSDR, 2000). There is no evidence for biomagnification through the various trophic levels, nor do there appear to be significant differences between bottom-feeders and predatory fish. Arsenic is among the metals listed as being of no concern for bioaccumulation in fish (EPA, 1995). Empirical data suggest that bioconcentration through terrestrial food chain pathways is unlikely to be significant (ATSDR, 2000). Therefore, biotransfer factors are not developed for arsenic.

3.0 Toxicokinetics

All forms of inorganic arsenic are readily absorbed by the lungs and GI tract; the extent of absorption is greater for more soluble compounds than for more insoluble compounds (ATSDR, 2000). Dermal absorption has not been well characterized but is significantly less than inhalation or oral absorption. GI and dermal absorption of arsenic from soil is much lower than from aqueous solution. Distribution is generally widespread throughout the body following absorption.

Metabolism of inorganic arsenic involves reduction of As^{+5} to As^{+3}, and oxidation of As^{+3} to As^{+5} so that arsenic is present systemically as a mixture of arsenate and arsenite (ATSDR, 2000). Arsenite is readily oxidized and methylated primarily in the liver to form the organic compounds monomethyl arsonic acid and dimethyl arsinic acid, which are rapidly excreted in the urine.

4.0 Dermal Exposure

EPA (2004) concluded that a GAF should not be estimated for the purpose of adjusting oral toxicity values for dermal exposure. Therefore, the oral toxicity values described below are used directly without adjustment for evaluating dermal exposure.

EPA (2004) cites empirical data indicating that dermal uptake of arsenic from soil approximates 3 percent. The ABS of 0.03 recommended by EPA (2004) is used herein. Empirical data regarding the uptake of soluble forms of arsenic from water were not located. The EPA (2004) default K_p for inorganic chemicals of 1E-3 cm/hour is selected for arsenic.

5.0 Noncancer Effects Evaluation

Inorganic arsenic may be an essential nutrient, at least for food-producing domestic animals, exerting beneficial effects on growth, health and feed conversion efficiency (Underwood, 1977). A lethal dose of arsenic trioxide in humans is 70-180 mg, approximately 50 to 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 hyper pigmentation and keratosis, as revealed by studies of several hundred Chinese exposed to naturally occurring arsenic in well water (EPA, 2012). Similar effects were observed in persons exposed to high levels of arsenic in water in Utah and the northern part of Mexico. EPA (2012) verified an RfD of 3E-4 mg/kg-day for chronic oral exposure, based on a NOAEL of 8E-4 mg/kg-day for hyper pigmentation 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. EPA (2012) 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. Confidence in the RfD is medium.

The available data do not suggest a significant difference between chronic and subchronic exposure regarding the threshold for noncancer effects. Therefore, EPA (1997) adopted the chronic oral RfD as the provisional subchronic oral RfD for arsenic.

Occupational (predominantly inhalation) exposure is also associated with neurological deficits, anemia, and vascular effects (Ishinishi et al., 1986). However, concomitant exposure to other chemicals cannot be ruled out in the occupational studies. Therefore, the data are not sufficient for estimation of an inhalation RfC.

6.0 Carcinogenicity Evaluation

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, 2012). Oral exposure to high levels in well water is associated with increased risk of skin cancer and several forms of internal cancer, although the role of other chemicals in the internal cancers is unclear. 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, indicating that the common laboratory animals are not good models for carcinogenicity to humans. EPA (2012) 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 (200) noted that arsenic probably functions via several different mechanisms of toxicity not including direct interaction with DNA. These appear to obey thresholds or to generate a non-linear slope that approaches 0 in the low-dose range. The SF probably exaggerates cancer risk in the low dose range associated with most environmental exposures, although the extent is unclear.

An inhalation URF of 4.3E-3 per $\mu g/m^3$, 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 (EPA, 2012).

7.0 Toxicity Summary

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
3E-4	3E-4	S, PVS	ND	ND	NA	A	1.5E+0	A	4.3E-3	1.5E+1

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: S = skin; PVS = peripheral vascular system.
[a]sRfDo, cRfDo and SFo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Arsenic***, Draft for Public Comment, U.S. Public Health Service, Atlanta, Georgia, September, on line.

Goyer, R.A., 1991, "Toxic Effects of Metals," in ***Casarett and Doull's Toxicology, The Basic Science of Poisons***, Fourth Edition, Amdur, M.O., J. Doull and C.D. Klaassen, Eds., Pergamon Press, New York, pp. 623-680.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Ishinishi, N., K. Tsuchiya, M. Vahter and B.A. Fowler, 1986, "Arsenic," In: Friberg, L., G.F. Nordberg and V.B. Vouk, Eds., ***Handbook on the Toxicology of Metals***, Volume II, Second Edition, New York: Elsevier Science Publishers B.V., pp. 43-83.

Lewis, R.J., Sr., 1997, ***Hawley's Condensed Chemical Dictionary***, Thirteenth Edition, John Wiley & Sons, Inc., New York, pp. 92-93.

Opresko, D.M., R.A. Young, R.A. Faust, et al., 1998, "Chemical Warfare Agents: Estimating Oral Reference Doses," ***Reviews in Environmental Contamination and Toxicology***, 156: 1-183.

Underwood, E.J., 1977, ***Trace Elements in Human and Animal Nutrition***, Fourth Edition, New York: Academic Press, pp. 424-429.

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

U.S. Environmental Protection Agency (EPA), 1995, "40 CFR 9, 122, 123, 131, and 132 Final Water Quality Guidance for the Great Lakes System; Final Rule," ***Federal Register***, 60(56); 15366-15425.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

BARIUM (7440-39-3)

1.0 Introduction and Physical Properties

Barium is a naturally occurring alkaline earth **metal** that comprises approximately 0.04 percent of the earth's crust (Reeves, 1986). It is highly reactive and found in nature only in the combined state (ATSDR, 2005). Barium is used in oil and gas drilling muds and in the manufacture of rubber goods, photographic paper, x-ray contrast material, brick and ceramic products, glass, pyrotechnics, oil additives, steel, automotive paints, stabilizers for plastics, pesticides and jet fuel (ATSDR, 2005; HSDB, 2012). Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
137.3[a] (Element)	NA	NA	4.1E+1[b]	NA	NA	NA	Note 1[a,c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable.

[a]Agency for Toxic Substances and Disease Registry (ATSDR), 2005, ***Update Toxicological Profile for Barium***, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, GA, date, on line, September.

[b]U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, OSWER 9355.4-24, December.

[c]Hazardous Substances Data Bank (HSDB), 2012, National Library of Medicine, on line.

Note 1: Barium chloride (typical salt): 3.75E+2 g/L (26° C); Barium sulfate and carbonate, which may form when released to surface water, are practically insoluble.

2.0 Environmental Fate and Transport

Barium is release by natural processes, primarily the weathering of igneous rock and barium-containing minerals, and by anthropogenic processes (ATSDR, 2005; HSDB, 2012). Barium is released primarily to the atmosphere from mining, refining and production of barium and barium-containing chemicals, fossil fuel combustion, coal ash, and entrainment of soil and rock dust in the air. Barium exists as particulates in air that generally do not travel long distances before removal. Wet and dry deposition are the primary removal mechanisms for airborne barium compounds.

Barium released to surface water may form salts of low solubility such as the sulfate or carbonate or sorb to suspended particulates (ATSDR, 2005; HSDB, 2012). Sedimentation is likely to be the most important removal process. Barium forms salts of low solubility in soil, or complexes with organic and inorganic ligands, resulting in low mobility in most soils. Barium is more mobile and soluble in sandy soil than in other soil types. The presence of chlorides or fatty acids such as found in landfills can increase mobility to significant levels.

Empirical data suggest that bioconcentration is important in marine organisms and some terrestrial plants (ATSDR, 2005). Furthermore, food constitutes a major source of human exposure, suggesting that biotransfer is significant. Biotransfer factors for barium are compiled below:

BCF/BSAF	Bpr	Bpv	Bb	Bm
4.0[a]	1.5E-2[b]	1.5E-1[b]	1.5E-4[b]	3.5E-4[b]
BCF = bioconcentration factor (L/kg); BSAF = biota-sediment accumulation factor, unitless; Bpr = soil-to-plant (reproductive portions) biotransfer factor, unitless; Bpv = soil-to-plant (vegetative portions) biotransfer factor, unitless; Bb = soil-to-beef biotransfer factor, days/kg; Bm = soil-to-milk biotransfer factor, days/kg. [a]Risk Assessment Information System (RAIS), 2012, "Chemical-Specific Factors," Oak Ridge National Laboratory, on line. [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.				

3.0 Toxicokinetics

The toxicokinetics of barium was reviewed by ATSDR (2005) from which the following was taken (unless otherwise noted). Absorption from the respiratory tract approximates 50 to 75 percent of barium chloride or barium sulfate from inhalation, intratracheal instillation, or deposition within the nasal cavities. Uptake from the upper respiratory tract epithelium appears to be as efficient as pulmonary uptake. Overall, the rate and extent of uptake from the respiratory tract is influenced by exposure level, particulate size (as it affects region of deposition), and solubility. Uptake from the trachea is somewhat less than uptake from regions proximal or distal to the trachea.

The extent of GI absorption depends on the solubility of the specific compound; barium sulfate is practically insoluble and is essentially not absorbed. Considerable variation exists regarding the reported extent of GI absorption of soluble barium compounds by humans or laboratory animals. Clearly, however, the young absorb ingested barium more efficiently than adults. One estimate of absorption in humans suggests that adults absorb 20 percent, children 1 to 15 years of age absorb 30 percent and infants absorb 60 percent of ingested barium. Studies with adult dogs and rats indicate that GI absorption approximates 7 percent of the ingested amount.

Regardless of route of exposure or administration, absorbed barium is rapidly cleared from the blood and is accumulated in the skeleton. Highest levels in the skeleton are found in areas of active bone growth (periosteal surfaces) during periods of exposure (HSDB, 2012).

Barium is not metabolized. Excretion of absorbed barium following inhalation or ingestion exposure is primarily via the feces. Urinary excretion accounted for 30 percent of total excretion in dogs exposed by inhalation. It is unclear how much fecal output represented excretion of absorbed material through the gut lining or bile and how much it represents unabsorbed material swallowed following ciliary clearance from the respiratory tract.

4.0 Dermal Exposure

Data were not located regarding the extent of dermal absorption of barium from soil or water; however, barium is not expected to cross the intact skin because of the high polarity of the forms in which it is encountered in environmental media (ATSDR, 2005). Therefore, dermal uptake is not expected to be significant and is not evaluated.

5.0 Noncancer Effects Evaluation

Acute oral toxicity is manifested by GI upset, altered cardiac performance and transient hypertension, convulsions, and loss of deep tendon reflexes with onset of muscular paralysis (ATSDR, 2005; HSDB, 2012). The muscular paralysis may be related to severe hypokalemia.

Earlier evaluations associated hypertension and kidney damage with prolonged oral exposure to barium (EPA, 2012a). A previously verified chronic oral RfD of 7E-2 mg/kg-day was based on a NOAEL of 0.21 mg/kg-day in a ten-week study in humans exposed to barium in drinking water and an uncertainty factor of 3. The cardiovascular system and the glomerulus of the kidney appeared to be the target organs for prolonged oral exposure to barium.

More recently, EPA (2012a) reevaluated the toxicity data for prolonged oral exposure to barium. It was noted that the NOAEL of 0.21 mg/kg-day from the human study was the highest level tested, suggesting that higher levels may be without effect. Furthermore, EPA (2012a) concluded that the study authors provided no evidence for hypertension in humans as a significant toxic effect of oral exposure to barium, and the association of chronic low level exposure to barium with hypertension remains equivocal. Animal studies, however, confirm that the kidney appears to be the target organ for prolonged oral exposure to barium; therefore, EPA (2012a) verified a new chronic oral RfD for barium based on nephropathy in male mice.

In the key study, groups of male and female mice and rats were provided drinking water containing barium chloride dihydrate at concentrations of 0 (control), 500, 1250 and 2500 mg/L for two years (EPA, 2012a). The study showed mice to be more sensitive than rats, and the diagnosis of nephropathy was more certain in the males than the females. Dose rates for male mice were estimated at 0, 30, 75 and 160 mg barium/kg-day. Survival was reduced in mice of either sex in the high-dose group. An increased incidence of nephropathy was observed in male mice in the mid- and high dose groups. EPA (2012a) estimated a lower confidence level on the benchmark dose for a 5 percent increased incidence of nephropathy (BMDL) of 63 mg/kg-day. Application of an uncertainty factor of 300 (factors of 10 each for inter- and intraspecies variation, and a factor of 3 for data base deficiencies) yields the newly verified RfD of 2E-1 mg/kg-day for chronic oral exposure. Confidence in the chronic oral RfD is medium.

EPA (1997) adopted the earlier verified chronic oral RfD of 7E-2 mg/kg-day as the provisional RfD for subchronic oral exposure. Given the more recent EPA (2012a) evaluation, it seems prudent to adopt the newly verified oral RfD of 2E-1 mg/kg-day as sufficiently protective for subchronic as well as chronic exposure.

Occupational exposure to various insoluble forms of barium induces benign pneumoconiosis and possibly hypertension (ACGIH, 1991; EPA, 2012a). The human data, however, are inadequate for estimation of an RfC because quantitative exposure data are not sufficient to establish dose-effect relationships. An inhalation reproduction study in rats reported altered hematological and clinical chemistry endpoints, sclerotic changes in the lungs, increased arterial blood pressure and fetotoxicity associated with intermittent exposure to barium carbonate over a 4-month period. An earlier provisional chronic inhalation RfC of 5E-4 mg/m^3 was based on the NOEL for fetotoxicity of 0.8 mg/m^3 in this study (EPA, 1997). An uncertainty factor of 1000 was used for the chronic RfC. EPA (1997) applied an uncertainty factor of 100 to the NOEL from the rat study to estimate a provisional subchronic inhalation RfC of 5E-3 mg/m^3.

EPA (2012a) reevaluated the inhalation exposure data and determined in their 2005 review that the report of the 4-month rat study lacked sufficient detail and statistical analysis to be considered for RfC estimation. They noted specifically that incidence data were not presented for the lung effects, and that the evidence that fetotoxicity is associated with barium exposure is suspect. No mention of fetotoxicity in humans was found in the EPA (2012a) review of the data. EPA (2012a) further declined to estimate an RfC based on lung effects because of the inadequacy of the entire data base.

At this point it must be decided whether to continue to use the provisional chronic and subchronic RfC values provided by EPA (1997) or to use no RfC. The precedent adopted in many EPA applications is to continue to use the latest toxicity values as the best available, even if they have expired or been officially withdrawn, until a better estimation is developed. The EPA (2012a) regional screening levels table, for example, continues to use the provisional RfC. However, there is considerable doubt that fetotoxicity, on which the provisional RfC is based, is an actual consequence of barium exposure (EPA, 2012a). The lung effects, on the other hand, are well known sequela of exposure in both humans and animals. Fortuitously, the NOEL that EPA (1997) reported for fetotoxicity was also a NOEL for lung effects. Therefore, the provisional chronic and subchronic RfC values provided by EPA (1997) will continued to be used in this evaluation as the best available. The target organ, however, is changed from the fetus to the lung. The EPA (1997) provisional chronic and subchronic inhalation RfC values of 5E-4 and 5E-3 mg/m^3 correspond to inhalation RfD values of 1E-4 and 1E-3 mg/kg-day, respectively.

6.0 Carcinogenicity Evaluation

EPA (2012a) classified barium as a cancer weight-of-evidence Group D substance (not classifiable as to carcinogenicity in humans). Cancer risk is not estimated for Group D substances. Barium is considered unlikely to be carcinogenic to humans following oral exposure and its carcinogenic potential cannot be determined following inhalation exposure.

7.0 Toxicity Summary

Toxicity values for barium are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
2E-1	2E-1	K	5E-3/ 1E-3	5E-4/ 1E-4	Lung	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); NA = not applicable.
Target organ or critical effect abbreviations: K = kidney.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 2005, ***Update Toxicological Profile for Barium***, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, GA, date, on line, September.

Hazardous Substances Data Bank (HSDB), 2012, National Library of Medicine, on line.

Reeves, A.L., 1986, "Barium," In: L. Friberg, G.F. Nordberg and V.B. Vouk, eds., ***Handbook on the Toxicology of Metals***, Volume II, New York: Elsevier Science Publishers B.V. pp. 84-94.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 2012a, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

U.S. Environmental Protection Agency (EPA), 2012b, ***Regional Screening Level Table***, April, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

CHROMIUM (7440-47-3)

1.0 Introduction and Physical Properties

Chromium is a naturally occurring **metal** (ATSDR, 2000). It occurs in several valence states; chromium (III) (16065-83-1) and chromium (VI) (18540-29-9) are the forms most commonly encountered in environmental media. Chromium is used largely in the metallurgical, refractory and chemical industries. The largest amount is used in the metallurgical industry in various steels and nonferrous alloys. The second largest use is by the chemical industry in pigments, metal finishing, leather tanning and wood treatment. Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
52.00[a] (element)	NA	NA	1.8E+6 (CrIII) 1.9E+1 (CrVI)[b]	NA	NA	ND	Note 1[a]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable; ND = no data.
Note 1: Chromium compounds vary from insoluble to highly soluble.
[a]Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Toxicological Profile for Chromium***, U.S. Public Health Service, Atlanta, Georgia, September, on line.
U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

2.0 Environmental Fate and Transport

Chromium is released into the atmosphere from natural gas, oil and coal combustion, and from use by the industries mentioned above (ATSDR, 2000). Other sources include wind transport from road dust, cement producing plants, the wearing down of asbestos brake linings from automobiles, incineration of municipal refuse and sewage sludge, exhaust emission from automotive catalytic converters, and emissions from cooling towers that use chromium compounds as rust inhibitors. Significant quantities of chromium are released to surface water from industrial use. Land disposal of chromium-containing commercial products, solid waste and slag from chromate manufacture, and coal ash, primarily from electric utilities and other operations that burn coal, are the major releases to soil.

Chromium releases from combustion processes and ore processing are generally in the form of chromium (III) oxide; however, chromium (VI) has been identified in fly ash from coal combustion at chromate manufacturing and user sites (ATSDR, 2000). Airborne chromium exists in particulate form that may travel great distances from the point of emissions; wet and dry deposition account for the majority of removal from air.

Most chromium released to surface water eventually adsorbs to particles and becomes deposited in bottom sediment, but small quantities may remain in the water in both soluble and insoluble forms (ATSDR, 2000). The soluble forms are usually chromium (VI) salts and soluble chromium (III) compounds. Chromium (VI) may be found in water, but eventually organic matter and other

reducing agents will reduce chromium (VI) to chromium (III). Chromium in soil is present mainly as insoluble chromium (III) carbonates and oxides that are unlikely to be mobile to any significant extent. However, soluble forms may also be present, depending on the form of the chemical released, that may be quite mobile in soil. Also, lower pH facilitates complexation with organic matter and increases mobility.

Empirical evidence suggests that chromium is unlikely to participate significantly in food chain pathways (ATSDR, 2000; EPA, 1995); therefore, biotransfer factors are not compiled.

3.0 Toxicokinetics

Identification of chromium in urine, serum and tissues of occupationally exposed humans confirms that soluble chromium (III) and chromium (VI) compounds are absorbed from the lung (ATSDR, 2000). The rate of absorption, however, depends largely on the physical and chemical characteristics of the chromium compound involved, as shown in numerous animal inhalation studies. Chromium (VI) compounds are more readily absorbed because the chromate anion participates in facilitated diffusion mechanisms not available to chromium (III).

Absorption of dietary sources of chromium from the GI tract in humans ranges from approximately 0.5 to 2 percent, as inferred from urinary excretion data (ATSDR, 2000). The extent of absorption appears to be inversely related to dietary chromium content. A review of several studies suggests that 0.4 to 14.5 percent of orally administered chromium not related to dietary sources is absorbed by the GI tract of humans, but valence and chemical form and nutritional status (fed vs. fasting) appear to influence efficiency of absorption (ATSDR, 2000). Chromium (VI) sources are more efficiently absorbed than chromium (III) sources as described above for inhalation exposure. Experiments with laboratory animals showed that the stomach has the ability to reduce chromium (VI) to chromium (III), reducing the extent of absorption when chromium (VI) compounds were administered *per os* compared with injection directly into the jejunum.

Both chromium (III) and chromium (VI) can penetrate intact human skin, and dermal uptake is increased if the skin is damaged (ATSDR, 2000). In some cases, dermal uptake was sufficient to result in signs of toxicity. The form and the vehicle greatly influence the rate of dermal uptake.

Inhaled particles of chromium compounds can remain in the lungs for years (ATSDR, 2000). Chromium absorbed into the blood is distributed throughout the body with highest levels frequently located in the kidneys. Chromium has been shown to cross the placenta and to be excreted via lactation. Autopsy studies in the US show that highest concentrations in newborns occur in the kidney, liver, aorta, heart, pancreas and spleen, and that tissue levels decline with age.

The main feature of the metabolism of chromium involves reduction of chromium (VI) to chromium (III) via the formation of chromium (V) and chromium (IV) intermediates (ATSDR, 2000). Reduction of chromium (VI) to chromium (III) occurs in the acid milieu of the stomach, primarily by reaction with ascorbate. Ascorbate, glutathione and other substrates effectively reduce absorbed chromium (VI) to chromium (III). Chromium (III) is considered a nutritionally essential element required for the proper metabolism of glucose, proteins and lipids. It acts as part of a complex known as GTF, which facilitates the action of insulin. Although chromium

(III) complexes are generally thought to be inert, there is recent evidence that chromium (III) may be reduced to chromium (II), which could catalyze the Haber-Weiss reaction resulting in the production of genotoxic hydroxyl radicals.

Absorbed chromium is excreted primarily in the urine (ATSDR, 2000).

4.0 Dermal Exposure

EPA (2004) recommends GAFs of 0.013 for chromium (III) and 0.025 for chromium (VI), generally consistent with the toxicokinetic data reviewed above, which are used in this evaluation. The GAF of 0.013 for chromium (III) should be used for total chromium, which is assumed to consist of 6 parts of chromium (III) to 1 part of chromium (VI) (EPA, 2004b, 2012).

Data were not located regarding the extent of dermal uptake of chromium from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of uncertainty. EPA (2004) recommends average K_p values of 1E-4 cm/hour and 1E-3 cm/hour for for chromium (III) and chromium (VI), respectively. The K_p of 1E-3 cm/hour for chromium (III) should be used for total chromium for reasons explained in the previous paragraph.

5.0 Noncancer Effects Evaluation

As mentioned above, chromium (III) is an essential nutrient involved in maintenance of normal metabolism (ATSDR, 2000). EPA (2012) verified an RfD of 1.5E+0 mg/kg-day for chronic oral exposure to chromium (III) by applying an uncertainty factor of 1000 to a NOEL of 1800 g/kg (1.468 mg/kg body weight/day) as an average total ingested dose in a dietary study in which rats were given 600 feedings of chromic oxide baked into bread. No other dose levels were tested. Confidence in the RfD is low. No target organ or critical effect was identified for the toxicity of oral exposure to chromium (III).

The available data do not suggest a significant difference between chronic and subchronic exposure regarding the threshold for the noncancer effects of chromium (III). Therefore, EPA (1997) adopted the verified chronic oral RfD, which at the time was listed on IRIS as 1E+0 mg/kg-day, as the provisional subchronic oral RfD for chromium (III). Subsequently, EPA (2012) recalculated the average daily dose, which led to revising the chronic oral RfD from 1E+0 to 1.5E+0 mg/kg-day. Since the only change between the earlier and the present verified oral RfD reflects a recalculation, it is recommended that the current verified chronic oral RfD of 1.5E+0 mg/kg-day should also be used for subchronic exposure.

EPA (2012) verified an RfD for chronic oral exposure to chromium (VI) of 3E-3 mg/kg-day based on a NOAEL of 25 mg/L (2.5 mg/kg-day) in the drinking water of rats exposed for one year. An overall uncertainty factor of 900 was applied. The uncertainty factor consists of factors of 10 each for inter- and intra-species variation, a factor of 3 to expand from subchronic to chronic exposure, and a modifying factor of 3 to address concerns that relatively low levels may induce GI effects and possibly some forms of cancer in humans. Inclusion of the modifying factor of 3 was a relatively recent (1998) revision to a previously verified derivation. Nonetheless, EPA (2012) notes that confidence in the chronic oral RfD is low.

EPA (1997) presented a provisional subchronic oral RfD of 2E-2 mg/kg-day for chromium (VI) based on the same drinking water study and an uncertainty factor of 200 (not otherwise explained). Presumably, this derivation reflects the earlier IRIS evaluation before inclusion of the modifying factor of 3. However, the concern for GI effects that gave rise to the modifying factor could apply to subchronic as well as chronic exposure. Therefore, it is recommended that a new preliminary subchronic oral RfD should be calculated for chromium (VI). This is done by applying an overall uncertainty factor of 300 to the NOAEL of 2.5 mg/kg-day from the drinking water study. The uncertainty factor of 300 reflects the overall uncertainty factor of 900 used for the chronic RfD without the factor of 3 to expand from subchronic to chronic exposure. The preliminary subchronic oral RfD for chromium (VI) so calculated is 8E-3 mg/kg-day.

The data summarized by EPA (2012) are insufficient to identify a mechanism of toxicity or target organ(s) for chronic oral exposure to chromium (VI). Data from other sources, however, are sufficient to identify potential target organs. Goyer (1991) reported that renal tubular necrosis is the major effect in humans from ingestion of chromium compounds. The context, however, suggests that this effect is associated with acute exposure to high doses (e.g., accidental or attempted suicide ingestion); therefore, the kidney may not be an acceptable candidate as a target organ for chronic oral exposure. Furthermore, a review of human and animal studies by EPA (1998a) did not implicate the kidney as a target organ for chronic oral exposure. EPA (1998a), however, reported GI effects in a cohort of 155 Chinese villagers who consumed water from a well located adjacent to a chromium alloy plant. Symptoms included oral ulcers, diarrhea, abdominal pain, indigestion, and leukocytosis with a left shift. The dose rate of chromium (VI) was estimated at 0.57 mg/kg-day, nearly 200 times the oral RfD. It is likely that the GI symptoms reflect the irritant nature of chromium (VI).

EPA (1998a) also reviewed several reproductive studies. An early and inadequately conducted study reported no effects in rats fed a diet containing 0.125 percent K_2CrO_4. A diet containing 0.25 percent resulted in “subnormal condition” (including rough coat) and “subnormal” offspring; a diet containing 0.5 percent resulted in diarrhea and sterility. Assuming rats consume food equivalent to 5 percent of their body weight each day (EPA, 1980), dietary levels of 0.125, 0.25 and 0.5 percent correspond to chromium (VI) dose rates of 17, 33, and 67 mg/kg-day, respectively. Drinking water studies consistently report developmental effects and impaired reproduction in rats and mice ingesting approximately 20 mg chromium (VI)/kg-day. A well controlled study reported slightly decreased erythrocyte size and hemoglobin content in rats and mice of either sex fed diets containing 400 ppm potassium chromate. The effects were interpreted as “suggestive of a potential bone marrow/erythroid response.” The 400 ppm diet is equivalent to chromium (VI) dose rates of 6.4 mg/kg-day in rats (EPA, 1998a) and approximately 11 mg/kg-day in mice, assuming that mice consume food equivalent to 10 percent of their body weight/day (EPA, 1980). In addition, cytoplasmic vacuolization of hepatocytes was observed in mice fed diets containing 50, 100 or 400 ppm potassium chromate, but it is not clear if either the incidence or intensity occurred in a dose-related manner. The 50 ppm diet, the lowest associated with hepatocellular vacuolization, is equivalent to a chromium (VI) intake rate of approximately 1.3 mg/kg-day. A subsequent study reported decreased erythrocyte hemoglobin content in female mice fed a diet containing 100 ppm potassium chromate, equivalent to a chromium (VI) dose rate of 6.0 mg/kg-day.

The GI signs reported in humans are clearly an indication of adverse effects; therefore, the GI tract is selected as a target organ. The mechanism of toxicity is assumed to be the irritation

induced by tissue contact with chromium (VI). The slight hematologic changes observed in rats and mice and the hepatocellular vacuolization observed in mice do not appear to be sufficiently threatening to be considered adverse. Therefore, target organs selected for chronic oral exposure to chromium (VI) include the GI tract, unborn child (fetus), and reproductive system.

Inhalation (occupational) exposure to chromium may induce respiratory symptoms, changes in lung function and irritation, erosion or perforation of the nasal septum, depending in part on the exposure level (EPA, 2012). No adverse effects were observed in workers exposed to 1E-3 mg/m^3 for 0.2 to 23.6 years (average 2.5 years). EPA (1998b, 2012) reviewed several human and animal studies, and determined that effects observed from inhalation exposure to chromium (VI) are not relevant to exposure to chromium (III). EPA (1998c) concluded that chromium (VI) is the only form of chromium of concern for inhalation exposure.

EPA (2012) developed separate chronic inhalation RfC values for human exposure to chromic acid mists and dissolved chromium (VI) aerosols, and for exposure to chromium (VI) particulates. A verified chronic inhalation RfC of 8E-6 mg/m^3 for chromic acid mists and dissolved chromium (VI) aerosols is based on an adjusted LOAEL of 7.14E-4 mg/m^3 associated with atrophy of the nasal septum in subchronically occupationally exposed humans. An overall uncertainty factor of 90 was used, consisting of factors of 10 for intraspecies variation, 3 to estimate a NOAEL from a LOAEL, and 3 to expand from subchronic to chronic exposure. Confidence in the inhalation RfC is low. The upper respiratory tract is considered the target organ for inhalation exposure to chromic acid mists and dissolved chromium (VI) aerosols. The chronic inhalation RfC is equivalent to a chronic inhalation RfD of 2.3E-6 mg/kg-day.

Inhalation exposure to chromium (VI) particulates is associated with pneumocyte toxicity; i.e., with effects on the lungs themselves. EPA (2012) derived an RfC of 1E-4 mg/m^3 for chronic inhalation exposure to chromium (VI) particulates from an adjusted benchmark concentration of 3.4E-2 mg/m^3 associated with altered enzyme activity in bronchioalveolar lavage fluid from rats exposed to sodium dichromate dust intermittently for up to 90 days. An uncertainty factor of 300 was used, consisting of a factor of 10 to provide additional protection to unusually sensitive individuals, and factors of 3 each to cover for physiologic differences between rats and humans, and to expand from subchronic to chronic exposure. Confidence in the RfC is medium. The RfC is equivalent to a chronic inhalation RfD of 2.9E-5 mg/kg-day. The lung is considered to be the target organ for chronic inhalation exposure to chromium (VI) particulates.

No current EPA-derived subchronic inhalation evaluation exists for chromic acid mists and dissolved chromium (VI) aerosols. However, a preliminary subchronic inhalation RfC can be derived by excluding the uncertainty factor of 3 for expanding from subchronic to chronic exposure. Application of the remaining overall uncertainty factor of 30 to the adjusted LOAEL of 7.14E-4 mg/m^3 yields a preliminary subchronic inhalation RfC of 2E-5 mg/m^3 for chromic acid mists and dissolved chromium (VI) aerosols. The preliminary subchronic inhalation RfC is equivalent to a subchronic inhalation RfD of 6.8E-6 mg/kg-day.

No current EPA-derived subchronic inhalation evaluation exists for chromium (VI) particulates. However, a preliminary subchronic inhalation RfC can be derived by excluding the uncertainty factor of 3 for expanding from subchronic to chronic exposure. Application of the remaining overall uncertainty factor of 100 to the adjusted LOAEL benchmark concentration of 3.4E-2 mg/m^3 yields a preliminary subchronic inhalation RfC of 3E-4 mg/m^3 for chromium (VI)

particulates. The preliminary subchronic inhalation RfC is equivalent to a subchronic inhalation RfD of 9.7E-5 mg/kg-day.

EPA (1998c) noted that exposure to chromic acid mists and dissolved chromium (VI) aerosols is likely to be restricted to occupational settings and that most environmental exposures would involve exposure to chromium (VI) particulates. Therefore, the chronic inhalation RfC and RfD for chromium particulates will be used in this evaluation.

6.0 Carcinogenicity Evaluation

EPA (2012) classified chromium (III) in cancer weight-of-evidence group D – not classified as to carcinogenicity to humans – because of inadequate data. Chromium (VI) is classified in cancer weight-of-evidence group A – known human carcinogen – based on the consistent finding of lung cancer in epidemiologic studies of occupationally exposed workers in chromate production and the chrome pigment industry (EPA, 2012). Conclusions regarding the human data are corroborated by data from animal experiments. There is no evidence that oral exposure to chromium (VI) induces cancer, and EPA (2012) assigned chromium (VI) to Group D for oral exposure.

An inhalation URF of 1.2E-2 per ug/m^3, equivalent to an inhalation SF of 4.2E+1 per mg/kg-day, was based on increased risk of lung cancer deaths in chromate production workers (EPA, 2012). It should be noted that the quantitative assessment is based on the concentration of total chromium to which the workers were exposed, including insoluble (trivalent) and soluble (hexavalent) forms. It was assumed that chromium (VI) constituted not less than one-seventh of the total chromium; i.e., a ratio of 1 part of chromium (VI) to 6 parts of chromium (III). However, the forms of chromium in the air were not identified, and chromium (VI) may have constituted a significantly much greater portion of total airborne chromium. EPA (200) presented the URF of 1.2E-2 per ug/m^3 as a verified potency estimate for chromium (VI), but noted that this estimate may underestimate the potency of exposure to pure chromium (VI) by as much as seven-fold.

7.0 Toxicity Summary

Toxicity values for chromium (III) and chromium (VI) are summarized below. Theoretical noncancer toxicity values are calculated for total chromium assuming a chromium (III)/chromium (VI) ratio of 6 to 1. Note that the URF is based on a mixture of chromium (III) and chromium (VI).

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
Chromium (III)										
1.5E+0	1.5E+0	ND	ND	ND	NA	D	ND	D	ND	ND
Chromium (VI)[b]										
8E-3	3E-3	GI, F, Re	3E-4/ 9.7E-5	1E-4/ 2.9E-5	Lu	D	ND	A	1.2E-2	4.2E+1
Total Chromium[c]										
NA	2.1E-2	GI, F, Re	NA	7E-4/ 2.0E-4	Lu	D	ND	A	1.2E-2	4.2E+1
sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference										

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi

concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: GI = gastrointestinal tract, F = unborn child (fetus), Re = reproductive system, Lu = lung.
[a]sRfDo and cRfDo should be adjusted by the appropriate GAF values described above when used for dermal exposure.
[b]Inhalation RfC/RfD values listed are those for chromium (VI) particulates. Values for chromic acid mists and dissolved chromium (VI) aerosols are not relevant to environmental exposures.
[c]For noncancer effects is based on the assumption that total chromium consists of 1 part of chromium (VI) and 6 parts of chromium (III); note that the URF assumed a mixture of chromium (III) to chromium (VI) at a ratio of approximately 6:1 (EPA 2012; EPA, 2004).

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Chromium***, U.S. Public Health Service, Atlanta, Georgia, September, on line.

Goyer, R.A., 1991, "Toxic Effects of Metals," in ***Casarett and Doull's Toxicology The Basic Science of Poisons***, Fourth Edition, M.O Amdur, J. Doull and C.D. Klaassen, eds., Pergamon Press, New York, pp. 623-680.

U.S. Environmental Protection Agency (EPA), 1980, "Appendix C – Guidelines and Methodology Used in the Preparation of Health Effect Assessment Chapters of the Consent Decree Water Criteria Documents," ***Federal Register***, 45(231): 79347-79357.

U.S. Environmental Protection Agency (EPA), 1995, "40 CFR 9, 122, 123, 131, and 132 Final Water Quality Guidance for the Great Lakes System; Final Rule," ***Federal Register***, 60(56); 15366-15425.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 1998a, ***Toxicological Review of Hexavalent Chromium (CAS No. 18540-29-9) In Support of Summary Information on the Integrated Risk Information System (IRIS)***, August, on line.

U.S. Environmental Protection Agency (EPA), 1998b, ***Combustion Technical Assistance Center (CTAC) Request No. 70: Chromium Values***, National Center for Environmental Assessment, Cincinnati, OH, 22 September.

U.S. Environmental Protection Agency (EPA), 1998c, ***Combustion Technical Assistance Center (CTAC) Request No. 77: Information Regarding Chromium (III) and (VI) for Site-Specific Risk Assessment***, National Center for Environmental Assessment, Cincinnati, OH, 5 October.

U.S. Environmental Protection Agency (EPA), 2003, Telephone conversation between Ted Simon, EPA Region IV, and P. Goetchius, Shaw E & I, 10 October.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

COBALT (7440-48-4)

1.0 Introduction and Physical Properties

Cobalt is a relatively scarce **metal**, constituting about 0.001 percent of the earth's crust (Elinder and Friberg, 1986). It often occurs in association with nickel, silver, lead, copper and iron ores. Cobalt is used in forming special metal alloys with unusual and useful properties (ATSDR, 2004; HSDB, 2012). It is also used in cutting materials, lacquers, varnishes, paint driers, enamels, inks, glazes, glass manufacture, as a catalyst in petroleum refining, and as a supplement in animal and human nutrition. Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
58.93[a]	NA	NA	45[b]	NA	NA	ND	Note 1[c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable; ND = no data.
Note 1: Cobaltous chloride as a typical cobalt salt: soluble.
[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[b]Baes, C.F., R.D. Sharp, H. Sjoreen, and R.W. Shor, ***A Review and Analysis for Assessing Transport of Environmentally Released Radionuclides through Agriculture, ORNL-5786, Oak Ridge National Laboratory*** .
[c]Budavari, S, Ed., 1989, ***The Merck Index, An Encyclopedia of Chemicals, Drugs, and Biologicals***, Eleventh Edition, Merck & Co., Rahway, NJ.

2.0 Environmental Fate and Transport

Cobalt is released to the environment, particularly to the air, largely from industrial processes that involve grinding or polishing hard metal devices that contain cobalt (HSDB, 2012). Other anthropogenic sources include fossil fuel burning, vehicular and aircraft exhaust, production and use of cobalt-containing alloys and chemicals, copper and nickel smelting and refining, disposal of sewage sludge, and application of fertilizers derived from phosphate rock (ATSDR, 2004). Natural sources include soil and soil dust, seawater spray, and volcanic eruptions. Natural releases to the atmosphere slightly exceed anthropogenic releases.

Ionic cobalt compounds exist in the particulate phase in air and these compounds may be removed from the air by wet and dry deposition (HSDB, 2012).

HSDB (2012) reports that K_d values for cobalt range from 0.2 to 3,800 L/kg. The value of 45 L/kg presented above appears to be a reasonable intermediate point. Soils with higher pH and content of clay, natural organics, and hydrous manganese and iron oxides, bind cobalt to a greater degree; as these factors decrease, the mobility of cobalt increases. Microbial activity may increase the solubility of cobalt in soil. Chelating agents increase the solubility of cobalt and enhance its mobility in soil. Cobalt compounds do not volatilize from moist or dry soil surfaces due to their ionic character.

The transport and speciation of cobalt in natural waters and sediments is complicated by many factors (HSDB, 2012). The presence of sewage-derived organics appears to enhance the solubility of cobalt in freshwater by forming soluble complexes. Cobalt exists in the +2 or +3 oxidation state for the majority of its compounds and complexes. Volatilization from water surfaces is not expected, due to the ionic nature of dissolved cobalt compounds.

A few plant species are known to accumulate cobalt; however, translocation to aerial parts is generally insignificant (ATSDR, 2004; HSDB, 2012). Cobalt is bioaccumulated by aquatic organisms, particularly at the lower trophic levels. Biomagnification, however, does not occur and cobalt localizes in the viscera and on the skin, rather than in edible tissues. Therefore, cobalt is not expected to impact human health through the food-chain pathways and biotransfer factors are not provided.

3.0 Toxicokinetics

Inhaled cobalt particles deposit in the upper or lower respiratory tract, depending largely on particulate size (ATSDR, 2004). Uptake may occur by dissolution or phagocytosis; larger particles are removed by ciliary clearance. The extent of pulmonary uptake depends largely on particle size distribution.

GI absorption of ingested cobalt in humans ranges from 18 to 97 percent, depending on the form and dose, and on the nutritional status of the subjects (ATSDR, 2004). Cobalt is absorbed more efficiently in cases of iron deficiency. Animal studies show that soluble forms such as cobalt chloride are absorbed to a much greater extent (13 to 34 percent) than insoluble cobalt oxide (1 to 3 percent).

Experiments with humans indicate that cobalt in hard metal dust can be absorbed through the skin, although the rate or extent of uptake were not quantified (ATSDR, 2004). Experiments in animals indicate that cobalt is absorbed much more efficiently through abraded than intact skin.

Distribution of cobalt within body tissues depends in large measure on the route of exposure (ATSDR, 2004). Cobalt as a component of cyanocobalamin (vitamin B12) is generally distributed among the body tissues. Highest levels following inhalation exposure are found in the tissues and lymph nodes of the respiratory tract. Lesser but elevated levels are found in liver, spleen and kidney. Highest levels are found in the liver following ingestion exposure.

Elimination also depends on route of exposure (ATSDR, 2004). Inhaled particulates are cleared by mucociliary elevation, phagocytosis and dissolution. Elevated particles are swallowed and subjected to GI absorption or throughput in the feces. Absorbed cobalt is excreted primarily through the urine.

4.0 Dermal Exposure

The provisional chronic oral RfD of 3E-4 for cobalt was derived from a study in which humans were treated orally with cobalt (EPA, 2008). A GAF of 1, as recommended by EPA (2004) is selected for cobalt.

Data were not located regarding the extent of dermal uptake of cobalt from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of uncertainty. The EPA (2004) K_p for cobalt of 4E-4 cm/hour is selected for cobalt.

5.0 Noncancer Effects Evaluation

Human health effects following oral exposure to cobalt include decreased iodine uptake by the thyroid, dermatitis in sensitized individuals, increased erythrocyte production and hemoglobin levels, and cardiomyopthy. Related effects to each of these, except dermatitis, are supported by animal studies. Other effects observed in animal studies include neurobehavioral and testicular; these effects were observed only at relatively high doses. Thyroid toxicity was selected as the critical effect for the derivation of provisional oral reference doses.
Cobalt is nutritionally essential as a cofactor in cyanocobalamin ATSDR, 2004). The element is ubiquitous and universally present in the diet. Data from a dietary survey performed in the 1980s indicate that daily U.S. dietary intakes of cobalt are in the range of 3E-3 to 1.1E-2 mg/day (4E-5 to 2E-4 mg/kg-day, assuming an average body weight of 70 kg). Chronic ingestion from the consumption of beer containing high concentrations of cobalt is associated with "beer-cobalt cardiomyopathy," which includes polycythemia and goiter, as well as marked myocardial degeneration and mortality. However, confounding variables were identified and a dose-response could not be derived from the associated studies (EPA, 2008).

A consistently produced effect of exogenously administered cobalt in humans is the erythropoietic effect of stimulating erythrocyte production resulting in increased blood hemoglobin concentration (EPA, 2002). Cobalt chloride has been used therapeutically at dose rates of 1.6E-1 to 3.2E-1 mg cobalt/kg-day in anemic, anephric dialysis patients for 12 to 32 weeks to induce a significant, but reversible, rise in blood hemoglobin concentration. Clinical studies demonstrating this effect identified an effect level of 1.8E-1 mg/kg-day, which EPA (2002) had previously designated a LOAEL. However, EPA (2008) has since identified confounding variables, and has judged the effects of cobalt in some of the patients in pertinent studies as beneficial rather than adverse.
A LOAEL of 1 mg/kg-day for subchronic thyroid toxicity as the critical oral effect was identified by EPA (2008) from a subchronic study by Roche and Layrisse (1956). A provisional subchronic RfD of 3E-3 mg/kg-day was derived assuming a composite UF of 300. This assumes a UF of 10 for LOAEL to NOAEL conversion, and a UF of 10 for inter-individual variability. An additional UF of 3 was added due to a lack of multigenerational studies, since testicular degeneration and sperm function were noted in some animal studies.

The provisional chronic oral RfD of 3E-4 mg/kg-day was derived as described for the subchronic RfD, with an additional UF of 10 added to extrapolate from subchronic to chronic exposure for a composite UF of 3,000 (EPA, 2008). Confidence in the principal study is described as low-to-medium.

The human and animal database indicate that symptoms of inhaled cobalt include respiratory tract irritation and altered pulmonary function. There were identified as the critical effects for exposure to inhaled cobalt for the derivation of RfDs. A NOAEL adjusted for continuous exposure of 1.9 $\mu g/m^3$ was identified by EPA (2008). A subchronic RfC of 2E-5 mg/m^3 was derived by EPA (2008) assuming a composite UF of 100, assuming a UF of 10 for database insufficiencies and a UF of 10 for inter-individual variability. The preliminary subchronic inhalation RfC is equivalent to a preliminary subchronic inhalation RfD of 5.7E-5 mg/kg-day.

A provisional chronic RfC of 6E-6 mg/m3 was derived as described above for the subchronic RfC, but with an additional UF of 3 for the extrapolation from subchronic to chronic exposure

(EPA, 2008). Thus, the composite UF is 300. This provisional RfC equals an inhalation RfD of 1.7E-6 mg/kg-day.

6.0 Carcinogenicity Evaluation

Human or animal studies examining the carcinogenicity of cobalt associated with oral exposure were not located. Therefore, cobalt is classified as having "inadequate information to assess carcinogenic potential" via the oral pathway, thus no cancer slope factor was derived (EPA, 2008).

Cobalt is described as "likely to be carcinogenic to humans by the inhalation route," based on limited evidence of carcinogenicity in humans (occupational studies) and sufficient evidence of carcinogenicity in animals (EPA, 2008). Respiratory tract tumors have been suggested in occupational studies as the result of inhaled cobalt. Statistically increased incidence of respiratory tract tumors have been observed in animal studies. Limited evidence supports genotoxicity and cytotoxicity, followed by cellular regeneration as potential modes of cobalt tumorigenicity. A mutagenic effect may be plausible for inhaled cobalt, but has not been clearly established (EPA, 2008).

Human inhalation studies were not sufficiently detailed to use in the derivation of a URF. Rats and mice exposed via inhalation to cobalt sulfate heptahydrate for 2 years developed alveolar and bronchial lung tumors (neoplasms and adenomas). EPA (2008) identified a benchmark dose level of In the absence of an identified mode of action, EPA developed a provisional URF by linear extrapolation of benchmark dose level of 0.011 mg/m^3. Using a benchmark response of 10 percent in extra risk, a provisional URF of 9E-3$(\mu g/m^3)^{-1}$ was derived for cobalt sulfate. This equals an inhalation SF of 3.2E+1 $(mg/kg\text{-}day)^{-1}$.

7.0 Toxicity Summary

Toxicity values for cobalt are summarized as follows:

Noncancer Effects						Carcinogenicity				
Oral Exposure			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
3E-3	3E-4	Thyroid	2E-5/5.7E-5	6E-6/ 1.7E-6	RT	ND	ND	B	9E-3	3.2E+1

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: RT = respiratory tract.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 2004, ***Toxicological Profile for Cobalt***, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, Georgia, April.

Elinder, C.-G and L. Friberg, 1986, "Cobalt," In: Friberg, L., G.F. Nordberg and V.B. Vouk, Eds., ***Handbook on the Toxicology of Metals,*** Second Edition, Volume II: Specific Metals, Elsevier Science Publishers, New York, NY, pp. 211-232.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Roche, M., and M. Layrisse, 1956, "The Effect of Cobalt on Thyroidal Uptake of I^{131}", ***Journal of Clinical Endocrinology and Metabolism***, Volume 16, pp. 831-833.

U.S. Environmental Protection Agency (EPA), 2002, ***Risk Assessment Issue Paper for: Derivation of a Provisional RfD for Cobalt and Compounds (CASRN 7440-48-4)***, National Center for Environmental Assessment, Cincinnati, OH, 15 January.

U.S. Environmental Protection Agency (EPA), 2004, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final***, Office of Emergency and Remedial Response, EPA/540/R/99/005, OSWER 9285.7-02EP, July.

U.S. Environmental Protection Agency (EPA), 2008, ***Provisional Peer-Reviewed Toxicity Values for Cobalt (CASRN 7440-48-4)***, National Center for Environmental Assessment, Cincinnati, OH, 25 August.

IRON (7439-89-6)

1.0 Introduction and Physical Properties

Iron is a very abundant, ubiquitous, naturally occurring **metal** that constitutes approximately 5 percent of the earth's crust (Spivey Fox and Rader, 1988). It is the second most prevalent metal in the earth's crust following aluminum (HSDB, 2012). Its primary use is in making steels and other metals that have a wide range of application. Less than one percent of iron is used to make iron compounds that have application in dyes and pigments, water treatment, organic chemical synthesis, and medicinal preparations. Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
55.85[a] (Element)	NA	NA	25[b]	NA	NA	ND	Note 1[a]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable; ND = no data.
Note 1: Ferrous sulfate as a typical iron salt: soluble.
[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[b] Baes, C.F., R.D. Sharp, H. Sjoreen, and R.W. Shor, ***A Review and Analysis for Assessing Transport of Environmentally Released Radionuclides through Agriculture, ORNL-5786, Oak Ridge National Laboratory*** .

2.0 Environmental Fate and Transport

There is little information available regarding the anthropogenic release of iron and its fate in the environmental, probably because of its prevalence in nature. Clearly, however, mining and handling of iron ores releases dust containing iron oxides (HSDB, 2012). Presumably the manufacture and use of iron compounds may result in release to the environment, but data were not located.

Insoluble iron compounds are most likely to occur in air as particulates, and are expected to deposit to soil and surface water (HSDB, 2012). Although data are unavailable, soluble compounds are expected to leach to groundwater, and to remain in solution in both groundwater and surface water. The extent of partitioning to sediment is expected to depend on water pH, organic matter and reduction-oxidation potential of the water system.

Biouptake of iron is known to occur, because the element is a nutritionally required trace element that is a structural component of heme proteins and some enzymes, which are common to mammals and several other orders of living organisms (Spivey Fox and Rader, 1988). However, there is no evidence that iron bioconcentrates in either aquatic or terrestrial food chain pathways. Therefore, biotransfer factors for iron are not presented.

3.0 Toxicokinetics

The GI absorption of iron is regulated by homeostatic mechanisms sited largely in the intestinal mucosa (Goyer, 1991; EPA, 2006). Approximately 2 to 15 percent of dietary iron is ordinarily absorbed; however, several dietary factors may increase or decrease absorption (HSDB, 2012). Dietary iron from animal sources is absorbed more readily (10 to 25 percent) than iron from

vegetables and grains (1 to 10 percent) (Elinder, 1986). Absorption is greatly increased at times of unusual need (rapid growth of childhood, pregnancy, blood loss). Divalent (ferrous) iron is absorbed into the intestinal mucosal cells and released to the blood plasma where it is oxidized to the trivalent (ferric) form, which binds with a specific protein, transferrin, for transport to storage sites.

Approximately 67 percent of iron in the body is associated with hemoglobin in the erythrocytes, 10 percent is associated with myoglobin and various iron-containing enzymes, and the remainder is bound to ferritin or hemosiderin, which are intracellular storage forms (Goyer, 1991). Ferritin and hemosiderin bind iron in a manner that renders it inactive for beneficial use (e.g., hemoglobin synthesis) and inactive as a toxicant. Some of the iron taken up by the cells of the reticuloendothelial system remains stored and some enters a labile pool that is available for erythropoiesis.

Excess iron is generally excreted, in part in shed intestinal epithelial cells, or in the bile or urine (Goyer, 1991). In cases of very high iron intake, excretion may be unable to remove iron as quickly as it is absorbed. Iron overload results, which stimulates increased synthesis of ferritin and increased iron storage, particularly in the liver, pancreas, spleen, various endocrine organs and the heart.

4.0 Dermal Exposure

As noted above, the GI absorption of iron appears to be under homeostatic control in normal humans (EPA, 2006), which suggests that GI absorption could vary widely between individuals depending on nutritional status. Given the uncertainty about the GI absorption of iron, a default GAF of 1 (EPA, 2004) is chosen for this evaluation.

Data were not located regarding the extent of dermal uptake of iron from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of uncertainty. Empirical data regarding the uptake of soluble forms of iron from water were not located. The EPA (2004) default K_p for inorganic chemicals of 1E-3 cm/hour is selected for iron.

5.0 Noncancer Effects Evaluation

Iron is a nutritionally required trace element that forms an integral part of hemoglobin, myoglobin and several enzymes (Spivey Fox and Rader, 1988). The NAS (1989) Recommended Daily Allowance (RDA) for iron is 10 mg/day (0.13 mg/kg-day) for adult males; 15 mg/day (0.24 to 0.33 mg/kg-day) for females aged 11 to 50 years; 30 mg/day (0.443 mg/kg-day) for pregnant females; and 10 mg/day (0.36 to 1.11 mg/kg-day) for children aged 6 months to 10 years.

Both acute and chronic toxicity syndromes are associated with ingestion exposure to iron. Acute toxicity generally involves children (Goyer, 1991). Acute ingestion of large quantities (e.g., children may ingest several ferrous sulfate tablets with candy-like coating) results in severe GI irritation and, in some cases, liver damage. Liver cirrhosis and blood coagulation defects (indicative of reduced circulating levels of blood clotting factors produced by the liver) are observed as sequellae to severe acute toxicity.

Three chronic toxicity syndromes that result in iron overload have been observed in humans (Goyer et al., 1991). The first chronic syndrome is idiopathic hemochromotosis, which arises from a genetic derangement of the homeostatic mechanisms that control iron absorption. This syndrome involves greatly increased GI absorption of iron, regardless of the level of iron in the diet, which results in massive iron overload.

The second chronic syndrome is iron overload resulting from high dietary intake (Goyer, 1991). Although high dietary intake seldom results in iron overload in humans with normal homeostatic control of iron absorption, rare exceptions occur (EPA, 2006). One such exception is the occurrence of iron overload in Bantus who regularly consumed Kaffir beer, an acid beer brewed in iron vessels. This syndrome is not entirely understood; however, the iron in Kaffir beer appears to have exceptionally high bioavailability – equivalent to that of nutritional iron supplements especially formulated for bioavailability – which may account for the increased absorption and iron overload. Other exceptions include persons who take large amounts of tonics or nutritional supplements containing iron.

The third chronic syndrome involves persons requiring multiple blood transfusions over a period of time (Goyer, 1991). This results in the parenteral administration of large quantities of iron that are released as the transfused erythrocytes expire and are removed from the circulation by the reticuloendothelial system. As noted above, excretion cannot keep up with unusually high circulating levels of iron, such as results from multiple blood transfusions. Clearly, the third syndrome has no relevance to environmental exposure.

Regardless of the chronic syndrome that produces it, the effects of iron overload involve the same pathogenesis (Goyer, 1991). Iron stores in the body increase from the normal level of 3 to 5 g, to levels of 20 to 40 g. The cells are induced to increase production of ferritin, which binds the iron cation inactivating its toxicity. Increasingly larger proportions of iron are located in hemosiderin than in ferritin. Hemosiderin is a larger storage protein, probably formed primarily from ferritin. The iron in hemosiderin is essentially completely unavailable and nontoxic. Hemosiderosis is the term given to large accumulations of hemosiderin that do not result in adverse effects because the iron is unavailable. Extremely large accumulations of hemosiderin that result in impaired cellular function is termed hemochromotosis. Hemochromotosis of the liver, endocrine glands and heart is associated with reduced liver function, eventually liver cirrhosis, pancreatic fibrosis, diabetes mellitus, other endocrine disruption and cardiovascular effects.

Goyer (1991) and EPA (2006) reviewed the available data regarding the toxicity of iron. Neither source located any data clearly associating *environmental* exposure with toxicity. EPA (1996) reviewed a study associating high circulating ferritin levels and high dietary iron intakes with myocardial infarction in Finnish men, but association with other factors (e.g., high levels of red meat consumption) confounds interpretation of this study. Furthermore, attempts to produce an animal model of chronic iron toxicity have failed, presumably because of the efficacy of the homeostatic mechanisms that regulate iron absorption from the GI tract.

EPA (1996) reasoned previously that a NOEL for chronic iron overload could be inferred from the estimates of dietary intake and iron status (circulating ferritin levels) established by the second National Health and Nutrition Examination Survey (NHANES II) data base. The

NHANES II study determined that average dietary iron intakes, which ranged from 0.15 to 0.27 mg/kg-day, were associated with normal iron status. More recently, EPA (2006) has concluded that the assignment of a LOAEL based on iron overload for normal individuals cannot be determined based on existing data because of confounding factors in the studies.

EPA (2006) has determined that gastrointestinal toxicity, commonly associated with therapeutic use of iron supplements, is the critical effect. A provisional subchronic and chronic oral RfD of 0.7 mg/kg-day was derived, based on a LOAEL of 1 mg/kg-day and a UF of 1.5 (EPA, 2006). The same value was derived for both subchronic and chronic exposures because clinical experience with iron supplements indicates that the gastrointestinal irritation is associated with treatment and does not intensify with duration. Further, the effect is reversible once treatment is discontinued. A higher UF was not selected because of the reversibility and the effect is not regarded as serious (EPA, 2006).

Inhalation (occupational) exposure to iron oxide fumes may lead to radiographic densities in the lungs without demonstrable clinical effects (ACGIH, 1991). Inhalation of dusts or mists of ferric salts may irritate the respiratory tract. Inhalation data are insufficient for derivation of an inhalation RfC or RfD (EPA, 2012).

6.0 Carcinogenicity Evaluation

Data regarding the potential carcinogenicity of iron were not located. Neither a cancer weight-of-evidence classification nor cancer potency factors are available (EPA, 2012).

7.0 Toxicity Summary

Toxicity values for iron are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
7E-1	7E-1	GI	ND	ND	NA	ND	ND	ND	ND	ND

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: GI = gastrointestinal.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

In most cases, it is inappropriate to apply the toxicity values summarized above to environmental exposure.

8.0 References

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, ACGIH, Cincinnati, OH, pp. 803-809.

Elinder, C.-G., 1986, "Iron," in Friberg, L., G.F. Nordberg and V.B. Vouk, eds., ***Handbook on the Toxicology of Metals,*** Second Edition, Volume II: Specific Metals, Elsevier Science Publishers, New York, NY, pp. 276-297.

Goyer, R.A., 1991, "Toxic Effects of Metals," in ***Casarett and Doull's Toxicology, The Basic Science of Poisons, Fourth Edition***, M.O. Amdur, J. Doull and C.D. Klaassen, eds., Pergamon Press, New York, pp 623-680.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

National Academy of Sciences (NAS), 1989, ***Recommended Daily Allowances, 10th Edition***, National Academy Press, Washington, DC. (Cited in EPA, 1996).

Spivey Fox, M.R. and J.I. Rader, 1988, "Iron," in Seiler, H.G. and H. Sigel, eds., ***Handbook on Toxicity of Inorganic Compounds***, Marcel Dekker, Inc., New York, pp. 345-354.

U.S. Environmental Protection Agency (EPA), 1996, ***Risk Assessment Issue Paper for: Derivation of a Provisional RfD for Iron (CASRN 7439-89-6)***, National Center for Environmental Assessment, Cincinnati, OH, 23 July. 2008

U.S. Environmental Protection Agency (EPA), 2004, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final***, Office of Emergency and Remedial Response, EPA/540/R/99/005, OSWER 9285.7-02EP, July.

U.S. Environmental Protection Agency (EPA), 2005a, ***Provisional Peer-Reviewed Toxicity Values for Iron and Compounds (CASRN 7439-89-6), Derivation of a Carcinogenicity Assessment***, National Center for Environmental Assessment, Cincinnati, OH, 29 July.

U.S. Environmental Protection Agency (EPA), 2005b, ***Provisional Peer-Reviewed Toxicity Values for Iron and Compounds (CASRN 7439-89-6), Derivation of n Inhalation RfC***, National Center for Environmental Assessment, Cincinnati, OH, 16 June.

U.S. Environmental Protection Agency (EPA), 2006, ***Provisional Peer-Reviewed Toxicity Values for Iron and Compounds (CASRN 7439-89-6), Derivation of Chronic and Subchronic Oral RfDs***, National Center for Environmental Assessment, Cincinnati, OH, 29 July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

INORGANIC MANGANESE (7439-96-5)

1.0 Introduction and Physical Properties

Manganese is a naturally occurring **metal** found in the earth's crust in the form of numerous minerals such as pyrolusite, romanechite, manganite and hausmannite (ATSDR, 2000; HSDB, 2012; Keen and Leach, 1988). It occurs ubiquitously in the environment, constituting approximately 0.085 percent of the earth's crust, commonly in valence states of +2, +4 and +7; valences of +1, +3, +5 and +6 are rare. Manganese is 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, diagnostic contrast media and fungicides. Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
54.938[a] (Elemental)	NA	NA	65[b]	NA	NA	NA	Note 1[c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable.
Note 1: Metallic manganese decomposes in the presence of water. Manganous chloride as a typical manganese salt: 7.23E+5 mg/L (25° C).
[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[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.
[c]Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Manganese***, U.S. Public Health Service, Atlanta, Georgia, September, on line.

2.0 Environmental Fate and Transport

Inorganic manganese compounds enter the atmosphere and other environmental compartments from the weathering of rocks and windblown soil (HSDB, 2012). Anthropogenic sources of atmospheric manganese include metal processing, disposal and use of manganese-containing materials (antiseptics, catalysts, dietary supplements, dry cells, feed additives, fertilizers, pesticides and pigments), resuspension of manganese-containing soil dust, and fly ash emissions from incinerators (ATSDR, 2000; HSDB, 2012). Another source of atmospheric manganese is the combustion of gasoline containing organic manganese anti-knock ingredients such as methylcyclopentadienyl manganese tricarbonyl (MMT). It is unclear whether manganese from this source remains as an organic form or is converted to an inorganic form. The use of MMT in gasoline has been discontinued because of deleterious effects on catalytic converters. 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, 2000). Manganese in fly ash exists as chlorides and oxides that are relatively soluble and mobile in the environment.

Manganese in water exists as any of several sparingly soluble salts that attach to suspended sediment (ATSDR, 2000). 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 irreversibly bind to clay, but higher concentrations often manifest considerable mobility.

Manganese may accumulate in various kinds of plants such as legumes, nuts, heather, and tea, and in the lower aquatic trophic levels, but not significantly in the higher aquatic trophic levels or most terrestrial animals (ATSDR, 2000; HSDB, 2012). This indicates that food-chain pathways are unlikely to be significant for human health; therefore, biotransfer factors are not compiled or estimated.

3.0 Toxicokinetics

Manganese is nutritionally essential for humans (ATSDR, 2000). Stable tissue levels are maintained by homeostatic regulation of GI absorption and biliary excretion.

Manganese is absorbed by the respiratory tract (ATSDR, 2000), although data quantifying the extent of absorption were not located. Smaller particles are probably retained in the lung eventually to be absorbed; larger particles are probably removed by mucocilliary elevation and swallowed so that they become available for GI absorption. The more soluble compounds are more readily absorbed by the respiratory tract. Studies in rats given radiolabeled manganese by intranasal administration suggest that olfactory uptake and direct transmission to the brain may occur.

GI absorption of manganese in humans averages 3 to 5 percent, but homeostatic mechanisms reduce the extent of absorption at higher doses (ATSDR, 2000). The more soluble compounds are more readily absorbed. Iron deficiency enhances manganese uptake. Absorption appears to be more efficient and resulting tissue levels appear to be higher in infants than adults.

Quantitative data regarding dermal uptake of manganese were not located.

Normal tissue levels of manganese in humans range from 0.1 to 1 mg/kg wet weight with highest levels in liver, pancreas and kidney, and lowest levels in bone and fat (ATSDR, 2000). Animal studies (inhalation, intranasal, intratracheal and oral administration) confirm that many tissues including the brain, and in some instances specific regions of the brain, show significant increases in manganese levels after treatment. Tissue levels recede toward normal after treatment ceases.

Metabolism of manganese appears to be limited to oxidation-reduction changes in valence state (ATSDR, 2000). The evidence suggests that manganese (+2) is oxidized to manganese (+3), which alters its tissue distribution and slows excretion. Manganese is removed from the blood in the liver and is excreted principally through the bile. Urine, sweat and milk represent minor excretory routes. Animal studies show that the young are less efficient than adults in excreting manganese, although the young do not appear to be more sensitive to its effects.

4.0 Dermal Exposure

Data were not located regarding the extent of dermal uptake of manganese from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of

uncertainty. Empirical data regarding the uptake of soluble forms of manganese from water were not located. ATSDR (2000), however, notes that the uptake of manganese across intact skin is "extremely limited," suggesting that uptake of toxicologically significant amounts is unlikely. EPA (2004) provides no chemical-specific estimate of K_p for manganese; therefore, the default K_p value of 1E-3 cm/hr is used to estimate dermal uptake of manganese from water.

5.0 Noncancer Effects Evaluation

Manganese is nutritionally required by humans for normal growth and health (EPA, 2012). 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.

EPA (2012) verified a chronic 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 (2012) recommends that the contribution of background diet should be subtracted and that a modifying factor of 3 should be used to adjust for use when oral exposure involves drinking water and non-dietary ingestion. The oral RfD resulting from these manipulations is 2.4E-2 mg/kg-day, which will be used for drinking water and incidental ingestion of non-dietary items. The CNS is the target organ for chronic oral exposure to manganese. EPA (1997) effectually adopts the chronic oral RfD as sufficiently protective for subchronic oral exposure.

The NOAEL described above is associated with a dose rate of approximately 10 mg/day for an adult. However, EPA (2002) notes that normal intake levels may well exceed 10 mg/day, especially with diets containing substantial amounts of whole-grain cereals, nuts, green leafy vegetables, and tea. Adverse effects have not been reported at dietary levels of 10 mg/day. It is likely that larger dose rates are innocuous as well.

Occupational exposure to high concentrations in air induces a generally typical spectrum of neurological effects, and increased incidence of pneumonia (ACGIH, 1991). EPA (2012) presents a verified chronic inhalation RfC of 5E-5 mg/m^3 (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. The uncertainty factor consists of three factors of 10 each to provide additional protection for unusually sensitive individuals, to extrapolate a NOAEL from a LOAEL, and to address database limitations including the less-than-chronic periods of exposure, the lack of developmental toxicity data, and uncertainty regarding potential but unquantified differences in the toxicity of different forms of manganese. Confidence in the RfC is medium. The CNS is the target organ for inhalation exposure to manganese. The chronic inhalation RfC is adopted as sufficiently protective for subchronic inhalation exposure.

6.0 Carcinogenicity Evaluation

EPA (2012) 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.

7.0 Toxicity Summary

Noncancer Effects						Carcinogenicity				
Oral Exposure			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
1.4E-1[a]/ 2.4E-2[b]	1.4E-1[a]/ 2.4E-2[b]	CNS	5E-5/ 1.4E-4	5E-5/ 1.4E-5	CNS	D	ND	D	ND	ND

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data.
Target organ or critical effect abbreviations: CNS = central nervous system.
[a]Dietary items other than drinking water.
[b]Ingestion of environmental media and drinking water.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Manganese***, U.S. Public Health Service, Atlanta, Georgia, September, on line.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, ACGIH, Cincinnati, OH, pp. 876-878.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Keen and Leach, 1988, "Manganese," in Seiler, H.G. and H. Sigel, eds., ***Handbook on Toxicity of Inorganic Compounds***, Marcel Dekker, Inc., New York, pp. 405-415.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

THALLIUM (7440-28-0)

1.0 Introduction and Physical Properties

Thallium is a naturally occurring metal with an abundance of about 0.3-0.6 ppm in the earth□s crust (HSDB, 2012). Thallium compounds are used in a variety of applications, including pharmaceuticals, semiconductors, photoelectric cells, optical systems, ore separation, glass production, and as oxidizing agents in organic synthesis (ATSDR, 1992; HSDB, 2012). An important former use of thallium and its compounds (before 1972) was in pesticide formulations for the control of insects and rodents. Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
204.38[a] (Elemental)	NA	NA	7.1E+1[b,c]	NA	NA	NA	Note 1[a]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable.
Note 1: Thallium sulfate as a typical thallium salt: 4.87E+4 mg/L (20˚ C).
[a]Agency for Toxic Substances and Disease Registry, (ATSDR), 1992, ***Toxicological Profile for Thallium***, U.S. Public Health Service, Atlanta, Georgia, July, on line.
[b]U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, OSWER 9355.4-24, December.
[c]pH = 6.8.

2.0 Environmental Fate and Transport

Thallium is released to the atmosphere largely from coal-burning power plants, cement factories, and ferrous and nonferrous smelting operations (ATSDR, 1992; HSDB, 2012). Facilities that produce or use thallium or its compounds account for a much smaller part of the total release.

Thallium in air exists as oxide, hydroxide, sulfate or sulfide particles (ATSDR, 1992; HSDB, 2012). The hydroxide and sulfate are water soluble and may partition to water vapor for eventual removal in precipitation. The less soluble particulate forms are probably removed by dry deposition.

Thallium released to surface water usually occurs as the monovalent ion that forms soluble salts with several anions (ATSDR, 1992; HSDB, 2012). Adsorption to suspended particulates may also occur, but the soluble forms remain in the water column.

Although empirical data are sparse, the high solubility of several thallium salts suggests that mobility in soil could be high and the potential for leaching could be significant (ATSDR, 1992).

Thallium has been identified by the EPA (1995) as a chemical that is not a bioaccumulative chemical of concern in fish; therefore, a BCF is not included for thallium. Other data, however, indicate that thallium has the potential to bioaccumulate and possibly to biomagnify in terrestrial food chain pathways (ATSDR, 1992; HSDB, 2012). Biotransfer factors for selenium are compiled below:

BCF	Bpr	Bpv	Bb	Bm
NA[a]	4.0E-4[b]	4.0E-4[b]	4E-2[b]	

BCF = bioconcentration factor, L/kg; Bpr = soil-to-plant (reproductive portions) biotransfer factor, unitless; Bpv = soil-to-plant (vegetative portions) biotransfer factor, unitless; Bb = soil-to-beef biotransfer factor, days/kg; Bm = soil-to-milk biotransfer factor, days/kg; NA = not applicable.
[a]See above.
[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.

3.0 Toxicokinetics

Data regarding absorption from the respiratory tract following inhalation exposure were not located; however, small particles are probably absorbed to some extent and larger particles are probably removed by mucocilliary clearance and swallowed, where they become available for GI absorption. Thallium compounds appear to be completely absorbed from the GI tract in humans and laboratory animals (ATSDR, 1992). Quantitative data regarding dermal uptake of thallium were not located, although HSDB (2012) states that absorption through the skin occurs readily.

Tissue levels in acutely poisoned humans appear to be highest in the brain in regions dense with neurons, such as the gray matter (HSDB, 2012). Tissue distribution testing in a single human volunteer cancer patient treated orally with a small dose of radiolabeled thallium indicated that highest concentrations were located in scalp hair followed by kidney, heart, bone, spleen and brain (ATSDR, 1992). Distribution in orally treat laboratory animals is rapid and widespread, with higher levels generally associated with the kidney. The rank of levels in other tissues is more variable (ATSDR, 1992), but high levels are ordinarily found in the testis (HSDB, 2012).

The biological half-life in rats in one study was 3.3 days, indicating that excretion is efficient (ATSDR, 1992). Excretion in humans may be somewhat slower. Excretion appears to be primarily through the urine in humans, and through the urine and feces. However, the data are somewhat confusing because animal studies indicate that the ratio of fecal to urinary excretion increases with time. This suggests that biliary excretion and enterohepatic recirculation may be operative, which could result in underestimation of fecal excretion in the human study.

4.0 Dermal Exposure

As noted above, GI absorption of thallium is essentially complete. EPA (2004) concluded that a GAF should not be estimated for thallium for the purpose of adjusting oral toxicity values for dermal exposure. Therefore, the oral toxicity values described below are used directly without adjustment for evaluating dermal exposure.

Thallium may be readily absorbed by the skin (HSDB, 2012); however, data were not located regarding the extent of dermal uptake of thallium from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of uncertainty. Empirical data regarding the uptake of soluble forms of thallium from water were not located. The EPA (2004) default K_p for inorganic chemicals of 1E-3 cm/hour is selected for thallium.

5.0 Noncancer Effects Evaluation

Thallium is highly toxic. Acute oral exposure to thallium and its compounds may cause death preceded by neurological disturbances and effects on the lungs, heart and liver (ATSDR, 1992). Formerly, thallium was used medicinally to induce alopecia to facilitate treatment of ringworm of the scalp, sometimes with disastrous results. The critical effect of chronic oral exposure to low levels of thallium compounds in animals and humans is alopecia (ACGIH, 1992; EPA, 2012). EPA (2012) had previously verified chronic oral RfDs for several thallium salts (thallium acetate, thallium carbonate, thallium chloride, thallium nitrate and thallium sulfate) based on a study with thallium sulfate; these RfDs were removed from IRIS in September 2009.

Currently, IRIS (EPA, 2012) describes a 90-day oral thallium toxicity study in rats (Midwest Research Institute [MRI], 1988) as having been considered a candidate study from which to derive a verifiable RfD. The critical effect of the MRI study is alopecia. Based on this study, a benchmark dose of 0.01 mg/kg-day was developed, and to this a total uncertainty factor of 3,000 was applied to yield candidate RfDs of 3E-6 mg/kg-day (clinical observations) and 1E-5 mg/kg-day (hair follicle atrophy). However, EPA determined that the available toxicity data base contains studies of generally poor quality that are insufficient from which to derive an RfD.

EPA (2010) provides a provisional screening value for thallium in an appendix to the *Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds*, but EPA (as described in IRIS) found the data base insuffient for the derivation of a PPRTV. In this evaluation, EPA (2010) evaluates the same MRI study that was evaluated in IRIS and identifies NOAEL of 0.4 mg/kg-day. To this NOAEL, the total uncertainty factor of 3,000 is applied to derive a screening chronic toxicity value of 1E-5 mg/kg-day for thallium. A subchronic screening toxicity value of 4E-5 was dereived using and a total uncertainty factor of 1,000. Although these provisional screening toxicity values may be used in risk assessments, EPA (2010) cautions that there is considerably more uncertainty associated with such screening values than the PPRTV values that

Inhalation exposure data are very limited. An occupational study suggests that neurological effects may develop following prolonged inhalation exposure (ATSDR, 1992). The nervous system appears to be more sensitive than the skin as a target organ for inhalation exposure. The data are inadequate for estimation of an RfC (EPA, 2012; 2010).

6.0 Carcinogenicity Evaluation

Several thallium compounds (thallium oxide, thallium acetate, thallium carbonate, thallium chloride, thallium nitrate, thallium sulfate) are classified as cancer weight-of-evidence Group D substances (not classifiable as to carcinogenicity to humans) (EPA, 2012). No weight-of-evidence classification was located for thallium alone, but the Group D classification can be applied to thallium. Quantitative cancer risk estimates are not derived for Group D chemicals.

7.0 Toxicity Summary

Toxicity values for thallium are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
4E-5	1E-5	hair	ND	ND	NA	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 1992, ***Toxicological Profile for Thallium***, U.S. Public Health Service, Atlanta, Georgia, July, on line.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
Midwest Research Institute (MRI), 1988, ***Toxicity of Thallium (I) Sulfate (CAS No. 7446-18-6) in Sprague-Dawley Rats. Vol. 2. Subchronic (90-day) Study [Revised Final Report]***, Prepared by Dynamac Corporation, Rockville, MD, for the Office of Solid Waste, Washington, DC; Project No. 8702-L(18); Work Assignment No. 111148-008.

U.S. Environmental Protection Agency (EPA), 1995, "40 CFR 9, 122, 123, 131, and 132 Final Water Quality Guidance for the Great Lakes System; Final Rule," ***Federal Register***, 60(56); 15366-15425.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2004, ***Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds***, Final, National Center for Environmental Assessment, Cincinnati, Ohio, October.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

VANADIUM (7440-62-2)

1.0 Introduction and Physical Properties

Vanadium is a widespread **metal**, comprising about 0.014 percent of the earth's crust (Wennig and Kirsch, 1988) with an average concentration of approximately 150 mg/kg (ATSDR, 1992). It may exist in six oxidation states (-1, 0, +2, +3, +4 and +5); +3, +4 and +5 are most important in environmental and biological media. Vanadium is always found combined in nature, generally with oxygen, and occurs in upwards of 50 different mineral ores. It is also associated with fossil fuels. Vanadium is used predominantly in the production of special steels and alloys, some of which have unique application in nuclear power technology (Lagerkvist et al., 1986; HSDB, 2012). Relevant physical properties are compiled below:

MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
50.942[a] (Element)	NA	NA	155[b, c]	NA	NA	NA	Note 1[b]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable; ND = no data.
Note 1: Vanadium pentoxide as a typical vanadium compound: 8E+3 mg/L (reference temperature not given).
[a]Agency for Toxic Substances and Disease Registry (ATSDR), 1992, ***Toxicological Profile for Vanadium***, U.S. Department of Health and Human Services, Atlanta, Georgia, July, on line.
[b]From EPA (2012) EPISuite™ data base.

2.0 Environmental Fate and Transport

Vanadium compounds are released naturally to air through the formation of continental dust, marine aerosols, and volcanic emissions (ATSDR, 1992; HSDB, 2012). Natural release greatly exceeds anthropogenic release. The most important anthropogenic contribution is from the combustion of fuel oil and other fossil fuels, with significant local contributions also from metallurgical and other industrial operations. Most anthropogenic releases to the atmosphere occur in the form of simple or complex vanadium oxides. Vanadium exists as particulates in the atmosphere. Small particles may remain in air for long periods of time and travel long distances. Removal is limited to wet and dry deposition.

The natural release of vanadium to water and soils occurs primarily as a result of weathering of rocks and soil erosion (ATSDR, 1992; HSDB, 2012). Anthropogenic sources include deposition from the atmosphere and the production and industrial use of vanadium and its compounds. Application of mineral fertilizers may lead to the accumulation of vanadium compounds in soil. Natural releases to water and sediment greatly exceed anthropogenic sources, although water pollution in the area of heaped-up or landfilled mine waste can be extensive in mining areas.

The behavior of vanadium in soils is not yet fully understood; however, it is known that the mobility of vanadium in soils is affected by pH (ATSDR, 1992; HSDB, 2012). Vanadium is fairly mobile in neutral or alkaline soils, relative to other metals, but its mobility decreases in acidic soils. Leaching is a potentially significant process, but great variability is expected based on soil characteristics as indicated by the range for K_d given above.

Vanadium in surface water exists largely as vanadyl and vanadate species (ATSDR, 1992; HSDB, 2012). Both forms are known to bind strongly to mineral or biogenic surfaces by

adsorption or complexation, reducing the amount of soluble vanadium found in water. Biochemical removal may occur in marine environments. Some marine organisms particularly, the ascidians (sea squirts), bioconcentrate vanadium and may attain body concentrations approximately 10,000 times greater than the ambient seawater. The potential for bioconcentration appears to be greater among the lower phyla.

Vanadium in freshwater has some potential for bioconcentration. A study in bluegills estimated BCFs of 51 to 92 L/kg; however, details of the study were not located (HSDB, 2012). Although empirical data are limited, it appears that biomagnification in terrestrial food chains is unlikely (ATSDR, 1992). The potential for bioconcentration in terrestrial plants appears to be greater among the lower phyla than among the seed producers. Since vanadium is unlikely to participate significantly in aquatic and terrestrial food-chain pathways relevant to humans, biotransfer factors are not compiled or estimated.

3.0 Toxicokinetics

Excretion studies with occupationally exposed humans and intratracheal administration studies with vanadyl chloride in rats suggest that pulmonary absorption occurs (ATSDR, 1992). Although quantitative data are not available, it appears that water soluble forms may be more readily absorbed from the lung. Vanadium is poorly absorbed from the GI tract (Lagerkvist et al., 1986). GI uptake of vanadium pentoxide in rats was estimated at about 2.6 percent of the administered dose. GI uptake of oxytartarovanadate by humans was estimated at 0.1 to 1 percent of the administered dose. GI absorption may be somewhat higher in the young than in adults. The International Commission on Radiological Protection (ICRP) (1960) estimate for GI absorption by humans of soluble vanadium compounds is 2 percent. Data regarding dermal uptake of vanadium were not located.

Absorbed vanadium is transported primarily in the blood plasma rather than in the cellular elements (ATSDR, 1992). Distribution following inhalation or oral exposure is generally widespread, with highest levels initially found in the lung, liver and kidney. The kidney is the primary excretory organ, which probably accounts for the relatively high levels observed in this organ during or shortly after administration. Vanadium that is not excreted eventually partitions to the skeleton where it may displace the phosphate radical and persist.

The kinetics of vanadium metabolism are not well understood. Metabolism is limited to interconversion between the vanadyl form (valence of +4) and the vanadate form (valence of +5) that presumably reaches equilibrium (ATSDR, 1992). This interconversion may occur within the GI tract as well as systemically following absorption (EPA, 2000). Vanadate is considered to be the more toxic form because it reacts with several enzymes and is a potent inhibitor of energy metabolism in cell membranes. This is a moot point, however, because of the equilibrium that would be reached following exposure to vanadium of either valence.

The kidney is the main excretory organ for systemically absorbed vanadium (ATSDR, 1992).

4.0 Dermal Exposure

The estimate of GI absorption of 2.6 percent by rats described above is recommended by EPA (2004) as the GAF of 0.026 for vanadium.

Data were not located regarding the extent of dermal uptake of vanadium from soil, and EPA (2004) provides no estimate of the extent of dermal absorption (ABS). EPA (2004) recommends that dermal uptake from soil should not be quantified for chemicals without ABS recommendations, but that these chemicals should be discussed qualitatively as a source of uncertainty. Empirical data regarding the uptake of soluble forms of vanadium from water were not located. The EPA (2004) default K_p for inorganic chemicals of 1E-3 cm/hour is selected for vanadium.

5.0 Noncancer Effects Evaluation

EPA (2012a) reported the results of an unpublished study in which rats were exposed to dietary levels of 10 or 100 ppm vanadium as vanadium pentoxide (approximately 17.9 or 179 ppm vanadium pentoxide) for 2.5 years. The criteria used to evaluate vanadium toxicity were limited to growth rate, survival, and hair cystine content. The only significant change reported was a decrease in the amount of cystine in the hair of rats in the high dose group. Therefore, the lower dose level (17.9 ppm vanadium pentoxide) was designated a NOAEL. The NOAEL is equivalent to a dose rate of 0.895 mg vanadium pentoxide/kg-day, assuming rats eat food equivalent to 5 percent of their body weight each day. Application of an uncertainty factor of 100 yields the verified chronic oral RfD of 9E-3 mg vanadium pentoxide/kg-day. The oral RfD of 9E-3 mg/kg-day should be applied only to vanadium pentoxide. Confidence in the oral RfD is low. An oral chronic RfD for vanadium of 5E-3 mg/kg-day is derived from the vanadium pentoxide RfD. This is done by multiplying the vanadium pentoxide RfD (9E-3 mg/kg-day) by the molecular weight of vanadium (101.9) in the vanadium pentoxide molecule (V_sO_5) divided by the molecular weight of vanadium pentoxide (181.9) as follow: 9E-3(mg/kg-day) × 101.9/181.0 = 5E-3(mg/kg-day). This approach is also used by EPA (2012b). The chronic RfD is also used as the subchronic RfD.

The only effect observed from exposure to vanadium pentoxide was reduced cystine content of the hair (EPA, 2012a). It is unclear if this resulted in fragile or otherwise damaged hair shafts, and it is unclear whether it reflects altered hair follicle function or a more central effect on protein metabolism. Hair is assumed to be the target organ for vanadium.

Effects in humans exposed by inhalation include upper and lower respiratory tract irritation (ATSDR, 1992). The respiratory tract is the target organ for inhalation exposure, but the data are inadequate for derivation of an inhalation RfC or RfD.

6.0 Carcinogenicity Evaluation

No empirical information was located regarding the carcinogenicity of vanadium.

7.0 Toxicity Summary

Toxicity values for vanadium and unspeciated vanadium compounds, and for vanadium pentoxide are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfc/ sRfD	cRfC/ cRfD	TO	WOE	SFo	WOE	URFi	SFi
Vanadium and Compounds										
5E-3	5E-3	hair	ND	ND	NA	ND	ND	ND	ND	ND
Vanadium Pentoxide										

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfc/ sRfD	cRfC/ cRfD	TO	WOE	SFo	WOE	URFi	SFi
9E-3	9E-3	hair	ND	ND	NA	ND	ND	ND	ND	ND

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per milligram per cubic meter); SFi = inhalation cancer slope factor (risk per microgram per kilogram-day); ND = no data; NA = not applicable.
Target organ abbreviations: K = kidney.
[a]sRfDo and cRfDo should by multiplied by the GAF of 0.026 when applied to dermal exposure.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 1992, ***Toxicological Profile for Vanadium***, U.S. Department of Health and Human Services, Atlanta, Georgia, July, on line.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

International Commission on Radiological Protection (ICRP), 1960, ***Report of Committee II on Permissible Dose for Internal Radiation. Recommendations of the ICRP***, Publ. No. 2, Pergamon Press, Oxford, England, p. 163.

Lagerkvist, B., G.F. Nordberg and V. Vouk, 1986, "Vanadium," in: Friberg, L., G.F. Nordberg and V.B. Vouk, eds., ***Handbook on the Toxicology of Metals***, Volume II, Second Edition, New York: Elsevier Science Publishers B.V., pp. 638-663.

U.S. Environmental Protection Agency (EPA), 2000, ***Provisional Toxicity Value Assessment for HWIR: RfD for Vanadium (CASRN 7440-62-2)***, National Center for Environmental Assessment, Cincinnati, OH, May.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP, July.

U.S. Environmental Protection Agency (EPA), 2012a, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line, accessed.

U.S. Environmental Protection Agency (EPA), 2012b, ***Regional Screening Level Table, User's Guide (April)***, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

Wennig, R. and N. Kirsch, 1988, "Vanadium," in Seiler, H.G. and H. Sigel, ***Handbook on Toxicity of Inorganic Compounds***, Marcel Dekker, Inc., New York, pp. 749-765.

POLYCHLORINATED BIPHENYLS (PCBs)

1.0 Introduction and Physical Properties

The nomenclature of the PCBs is somewhat unique, including the terms homologue and congener. The PCB molecule consists of two joined phenyl groups. The carbon atoms are numbered 1 through 6 on one ring and 1′ through 6′ on the other ring. Numbering proceeds consecutively starting with the carbon atom attached to the other ring. The term homologue refers to the degree of chlorination. Since one carbon atom in each phenyl group is bonded to the other ring, five carbon atoms on each phenyl group – a total of 10 carbon atoms – are available for bonding to chlorine atoms. Consequently, there are ten possible *homologues* of PCBs – monochlorinate biphenyls, dichlorinated biphenyls, through decachlorinated biphenyls. Congener refers to the exact placement of each chlorine atom. For example, there are three congeners of monochlorinated biphenyls: 2-PCB, 3-PCB and 4-PCB. The term isomer is often incorrectly used instead of congener with the PCBs. Free rotation around the C-C bond, however, precludes stereoisomerism, which limits the number of theoretically possible congeners.

The PCBs are a class of chemicals generally considered to be **SVOC**s including 209 possible individual congeners (ATSDR, 2000). The PCBs formerly manufactured and used in the U.S. are called Aroclors. The Aroclors are mixtures of several PCB congeners and related compounds. Many individual PCB congeners are common to all or many of the different Aroclors. The Aroclors differ from one another primarily in the relative proportions of the different congeners. ATSDR (2000) provides a summary of the proportion of each homologue in commercial mixtures of the various Aroclors. Of interest to this evaluation is the observation that Aroclor-1016 and Aroclor-1221 contain no homologues with 5 or more chlorines. Most Aroclors occur as oily or viscous liquids at room temperatures, although Aroclor-1260 occurs as a sticky resin. 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 is often performed using EPA Method SW8082. Method SW8082 is usually performed as a "finger printing" procedure and the results are reported as the commercial Aroclor(s) that most closely reflect the fingerprint(s) (ATSDR, 2000). Recently, however, concern has arisen that some individual PCB congeners may behave toxicologically in the same manner as the polychlorinated dibenzo-p-dioxins (PCDD), and that they may have greater toxic potency than is reflected in the toxicity assessment of the commercial Aroclors. This problem may be exacerbated by weathering, which may preferentially remove the less toxic (generally less highly chlorinated) congeners, leading to a relative concentration of the more highly chlorinated congeners. The more highly chlorinated congeners are generally the more persistent and the more toxic (ATSDR, 2000; EPA, 2012). For this reason, Method SW8082 has been expanded so that the analytical results can be reported in terms of selected specific congeners. In addition, EPA Method E1668 is a very high-resolution protocol (highly sensitive and highly selective) that reports individual congeners as well as totals for each of the homologues. Method E1668 is seldom used for environmental media, with the exception of incinerator emissions testing, because of its unusually high cost.

EPA (2000) identified 12 individual PCB congeners with dioxin-like activity. The PCB mixtures and dioxin-like congeners analyzed by the EPA methods mentioned above are compiled below:

PCB Mixture or Congener	CASRN	IUPAC No.	Method 8082	Method 1668
Aroclor-1016	12674-11-2	NA	Yes	No
Aroclor-1221	11104-28-2	NA	Yes	No
Aroclor-1232	11141-16-5	NA	Yes	No
Aroclor-1242	53469-21-9	NA	Yes	No
Aroclor-1248	12672-29-6	NA	Yes	No
Aroclor-1254	11097-69-1	NA	Yes	No
Aroclor-1260	11096-82-5	NA	Yes	No
3,3′,4,4′-Tetrachlorobiphenyl	**32598-13-3**	**77**	**Probably[a]**	**Yes**
3,4,4′,5-Tetrachlorobiphenyl	**70362-50-4**	**81**	**Probably[a]**	**Yes**
2,3,3′,4,4′-Pentachlorobiphenyl	**32598-14-4**	**105**	**Probably[a]**	**Yes**
2,3,4,4′,5-Pentachlorobiphenyl	**74472-37-0**	**114**	**Probably[a]**	**Yes**
2,3′,4,4′,5-Pentachlorobiphenyl	**31508-00-6**	**118**	**Probably[a]**	**Yes**
2′,3,4,4′,5-Pentachlorobiphenyl 2,3′,4,4′,5′-Pentachlorobiphenyl)	**65510-44-3**	**123**	**Probably[a]**	**Yes**
3,3′,4,4′,5-Pentachlorobiphenyl	**57465-28-8**	**126**	**Probably[a]**	**Yes**
2,3,3′,4,4′,5-Hexachlorobiphenyl	**38380-08-4**	**156**	**Probably[a]**	**Yes**
2,3,3′,4,4′,5′-Hexachlorobiphenyl	**69782-90-7**	**157**	**Probably[a]**	**Yes**
2,3′,4,4′,5,5′-Hexachlorobiphenyl	**52663-72-6**	**167**	**Probably[a]**	**Yes**
3,3′,4,4′,5,5′-Hexachlorobiphenyl	**32774-16-6**	**169**	**Probably[a]**	**Yes**
2,3,3′,4,4′,5,5′-Heptachlorobiphenyl	**39635-31-9**	**189**	**Probably[a]**	**Yes**
Total Monochlorobiphenyls	NA	NA	No	Yes
Total Dichlorobiphenyls	NA	NA	No	Yes
Total Trichlorobiphenyls	NA	NA	No	Yes
Total Tetrachlorobiphenyls	NA	NA	No	Yes
Total Pentachlorobiphenyls	NA	NA	No	Yes
Total Hexachlorobiphenyls	NA	NA	No	Yes
Total Heptachlorobiphenyls	NA	NA	No	Yes
Total Octachlorobiphenyls	NA	NA	No	Yes
Total Nonachlorobiphenyls	NA	NA	No	Yes
Total Decachlorobiphenyls	NA	NA	No	Yes

PCB = polychlorinated biphenyl; CASRN = Chemical Abstract Service Registry Number; IUPAC No. = congener-specific identification number assigned by the International Union of Pure and Applied Chemists. The specific congeners are sometimes called PCB-77, PCB-81, etc., and are sometimes *inappropriately* called Aroclor-77, Aroclor-81, etc. Technically, the term Aroclor should be reserved for chemical mixtures, where the name Aroclor is followed by a four-digit identifier code.
Dioxin-like congeners are bolded.
[a]Although the congeners listed have not been tested by Method 8082, it is likely that they could be quantified by the method. Other non-dioxin-like congeners can routinely be analyzed by this method.

Data regarding the physical properties of the individual PCB congeners are very limited. The physical characteristics of the Aroclor mixtures have been much more thoroughly evaluated. Although the Aroclors described below are classified as SVOCs, largely on the basis of MW, their H values suggest that volatilization could be important. Furthermore, the MW values provided are proportional averages based on the composition of the various Aroclor mixtures. Several individual PCB congeners have MW values below the limit of 200 g/mole ordinarily used to distinguish VOCs from SVOCs. For these reasons it is recommended that the Aroclors should be evaluated in exposure pathways (such as vapor intrusion into indoor air) that involve volatilization. Relevant physical properties are compiled below:

MW[a]	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
Aroclor-1016 (12674-11-2)										
257.9[b]	5.6[b]	2.9E-4[b] (25°C)	4.96[c]	4.69E-2[d] (25°C)[e]	6.8E-6[c] (25°C)	5.3E-7[b] (25°C)	4.2E-1[b] (25°C)	340.50[f]	475.22[f]	1.8E+4[f]
Aroclor-1221 (11104-28-2)										
200.7[b]	4.7[b]	7.36E-4[b] (25°C)	2.44[c]	5.54E-2[d] (25°C)[e]	7.5E-6[c] (25°C)	8.8E-6[b] (25°C)	5.9E-1[b] (24°C)	571[b]	ND	ND
Aroclor-1232 (11141-16-5)										
232.2[B]	5.1[B]	8.64E-4[c] (25°C)[e]	2.83[c]	5.03E-2[d] (25°C)[e]	7.2E-6[c] (20°C)	5.34E-6[b] (25°C)	4.5E-1[b] (25°C)	581[b]	ND	ND
Aroclor-1242 (53469-21-9)										
266.5[b]	5.6[b]	5.2E-4[b] (25°C)	4.59[c]	4.59E-2[d] (25°C)[e]	6.1E-6[c] (20°C)	5.34E-7[b] (25°C)	2.4E-1[b] (25°C)	345.5[f]	482.20[f]	1.8E+4[f]
Aroclor-1248 (12672-29-6)										
299.5[g]	6.2[g]	2.8E-3[g] (25°C)	5.64[c]	4.24E-2[d] (25°C)[e]	6.6E-6[c] (20°C)	6.5E-7[g] (25°C)	5.7E-2[g] (24°C)	631[g]	ND	ND
Aroclor-1254 (11097-69-1)										
326.4[h]	6.5[b]	2.83E-4[h] (25°C)	4.67[h]	3.99E-2[d] (25°C)[e]	5.6E-6[c] (20°C)	1.01E-7[b] (25°C)	3.5E-2[b] (24°C)	377.50[f]	512.27[f]	1.9E+4[f]
Aroclor-1260 (11096-82-5)										
375.7[b]	6.8[b]	4.6E-3[b] (25°C)	6.42[c]	3.65E-2[d] (25°C)[e]	5.3E-6[c] (20°C)	5.33E-8[b] (25°C)	8.0E-2[b] (24°C)	402.50[f]	539.37[f]	1.9E+4[f]
Aroclor-1262 (1336-36-3)										
389[b]	ND	ND	ND	3.57E-2[d] (25°C)[e]	4.13E-6[d] (25°C)[e]	ND	5.2E-2[b] (24°C)	680.7[b]	ND	ND
Aroclor-1268 (11100-14-4)										
453[b]	ND	ND	ND	3.22E-2[d] (25°C)[e]	3.73E-6[d] (25°C)[e]	ND	3.0E-1[b] (24°C)	ND	ND	ND

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point of pure liquid compound (°K); T_c = critical temperature (°K); $\Delta H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole); I = insoluble; ND = no data.

[a]Average molecular mass for the proportions of individual congeners in the commercial product.

[b]Agency for Toxic Substances and Disease Registry (ATSDR), 2000, ***Update Toxicological Profile for Polychlorinated Biphenyls***, U.S. Department of Health and Human Services, Atlanta, Georgia, November, on line.

[c]Montgomery, J.H., 1996, ***Groundwater Chemicals Desk Reference, Second Edition***, Lewis Publishers, New York.

[d]Calculated as described in Introduction to Toxicological profiles.

[e]Assumed.

[f]U.S. Environmental Protection Agency (EPA), 1997, ***User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings***, prepared by Environmental Quality Management, Inc. for the Office of Emergency and Remedial Response, Washington, DC, September.

[g]Earlier version (1995 Draft for Public Comment) of ATSDR Toxicological profile.

[h]U.S. Environmental Protection Agency (EPA), 2012, *EPISuite electronic database*.

2.0 Environmental Fate and Transport

Former PCB releases occurred as a result of their manufacture, use, disposal, and leakage from damaged PCB-containing equipment (ATSDR, 2000). 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, 2012). 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, 2000; HSDB, 2012). 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 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, 2000). PCBs sorb tightly to constituents of soil with adsorption generally increasing with the degree of chlorination. Although the lesser chlorinated biphenyls may exhibit some mobility in soil, PCBs generally will 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 the PCBs. In general, persistence of the PCBs increases with an increase in the degree of chlorination (ATSDR, 2000; HSDB, 2012). 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, -1254 and -1260) are quite resistant to biodegradation. The position of chlorination within a given homologue also determines the extent of biodegradation. Although biodegradation of the more highly 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, 2000). 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:

BSAF	Bpr[a,b]	Bpv[a,b]	Bb[a]	Bm[a]
Aroclor-1016				
See below	2.24E-2	2.24E-2	1.00E-2	3.16E-3
Aroclor-1221				
See below	7.44E-2	7.44E-2	1.26E-3	3.98E-4
Aroclor-1232				
See below	4.37E-2	4.37E-2	3.16E-3	1.00E-3
Aroclor-1242				
See below	2.24E-2	2.24E-2	1.00E-2	3.16E-3
Aroclor-1248				
See below	1.01E-2	1.01E-2	3.98E-2	1.26E-2
Aroclor-1254				
See below	6.78E-3	6.78E-3	7.94E-2	2.51E-2
Aroclor-1260				
See below	4.55E-3	4.55E-3	1.58E-1	5.01E-2
Aroclor-1262				
See below	ND	ND	ND	ND
Aroclor-1268				
See below	ND	ND	ND	ND

BSAF = biota-sediment accumulation factor, unitless; Bpr = soil-to-plant (reproductive portions) biotransfer factor, unitless; Bpv = soil-to-plant (vegetative portions) biotransfer factor, unitless; Bb = soil-to-beef biotransfer factor, days/kg; Bm = soil-to-milk biotransfer factor, days/kg; ND = no data.
[a]Calculated as described in Introduction to the Toxicological profiles.
[b]The methodology for estimating biotransfer of organic chemicals to plants does not differentiate vegetative and reproductive portions.

EPA (1995) reported a biota/sediment absorption factor (BSAF) for total PCBs of 1.85 for trout in the Great Lakes ecosystem. The BSAF of 1.85 is applied to all PCBs in this evaluation.

3.0 Data for Evaluating Dermal Exposure

Toxicokinetic data from laboratory animals suggest that the efficiency of GI absorption is roughly inversely related to the degree of chlorination (ATSDR, 2000). The GI absorption of mono- to hexachlorinated biphenyls exceeds 90 percent. Dichlorobiphenyl GI absorption efficiency is approximately 95 percent, but the absorption efficiency of octachlorobiphenyl approximates only 75 percent. GI absorption efficiency of Aroclor-1254 approximates 85.4 percent in ferrets and greater than 90 percent in monkeys. EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. Therefore, no GAF is developed for the PCBs and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

The PCBs appear to be readily absorbed by the skin when applied as neat compound or mixed with a suitable vehicle (ATSDR, 2000), but efficiency falls when soil is the medium of exchange. The EPA (2004) recommended ABS of 0.14 for PCBs is used in this evaluation. EPA (2004) provides values for K_p, τ, FA and B for 4-chlorobiphenyl and hexachlorobiphenyl. Generally, the more highly chlorinated PCB congeners are the more persistent in the environment; therefore, the values for hexachlorobiphenyl provided below are applied to all PCBs in this evaluation.

Chemical	K_p	τ	FA	B
Hexachlorobiphenyl	4.3E-1	1.13E+1	0.5	3.2
K_p = permeability coefficient (cm/hour); τ= lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).				

4.0 Noncancer Effects Evaluation

The acute oral toxicity of the PCBs is low to moderate, as indicated by LD_{50} values in laboratory animals ranging from 750 mg/kg (mink) to 4250 mg/kg (rats) (ATSDR, 2000). Mink appear to be unusually sensitive, which is also true for prolonged oral exposure. Death appears to be due to respiratory depression and dehydration from diarrhea.

The best known incident involving oral exposure of humans to PCBs 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 to various Aroclors leads to liver damage, signs of chloracne, immunological effects, and neurological impairment, particularly of the young (EPA, 2012). 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. 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.

EPA (1997) derived a provisional RfD for subchronic oral exposure to Aroclor-1254 of 5E-5 by applying an uncertainty factor of 100 to the LOAEL from the monkey study described above.

A verified oral RfD of 7E-5 mg/kg-day for Aroclor-1016 is based on a NOAEL of 7E-3 mg/kg-day in a perinatal and neurobehavioral toxicity study in monkeys (EPA, 2012). An uncertainty factor of 100 was applied to the NOAEL. The uncertainty factor of 100 consists of factors of 3 each to extrapolate from monkeys to humans, to provide greater protection for more sensitive humans, to account for deficiencies in the database, and to expand from a subchronic study to chronic exposure. The LOAEL (2.8E-2 mg/kg-day) was associated with low birth weights. The

fetus is considered to be the most sensitive member of the population. The fetus and nervous system are selected as "target organs" for prolonged oral exposure to Aroclor-1016. Confidence in the oral RfD is medium.

There is no EPA-derived subchronic oral RfD for exposure to Aroclor-1016. However, a preliminary RfD can be derived from the NOAEL of 7E-3 mg/kg-day in the monkey study described above by application of an uncertainty factor of 30. The uncertainty factor of 30 includes all the factors described above except the factor of 3 to expand from subchronic to chronic exposure. The preliminary subchronic oral RfD so derived is 2.3E-4 mg/kg-day, which is expressed as 2E-4 mg/kg-day when rounded to one significant figure.

The similarities in the nature of the adverse effects and the thresholds for these effects for various Aroclors suggest that the adverse effects and thresholds across all the Aroclors may be similar. That this may be true is supported by the fact that many of the same PCB congeners are present in the different Aroclors, which differ from one another primarily only in the relative proportions of the individual congeners. Therefore, it is reasonable to apply the RfDs described above to any of the Aroclor mixtures, or to total PCBs. The chronic and subchronic oral RfDs developed for Aroclor-1016 rather than those developed for Aroclor-1254 are selected as surrogates for evaluating the adverse effects of the other Aroclors or total PCBs. The RfDs developed for Aroclor-1016 are preferred because they include less uncertainty than the RfDs developed for Aroclor-1254. Therefore, the verified chronic oral RfD of 7E-5 mg/kg-day and the preliminary subchronic oral RfD of 2E-4 mg/kg-day developed for Aroclor-1016 are applied to the Aroclors other than Aroclor-1254 or to total PCBs.

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, 2000). Concurrent exposure to PCB contaminants, such as polychlorinated dibenzofurans, 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.

5.0 Carcinogenicity Evaluation

EPA (2012) declined to evaluate the carcinogenicity of the individual Aroclor mixtures. Instead, EPA (2012) 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 (2012) established a three-tiered approach for estimating the cancer potency of exposure to PCBs.

<u>High-Risk Tier</u> A SF of 2.0E+0 per mg/kg-day is verified as an upper-bound potency factor for exposure to PCBs in the high-risk tier (EPA, 2012). The high-risk tier includes ingestion in the food chain, incidental ingestion of soil or sediment, inhalation of dust or aerosol, or dermal contact with soil or sediment if a dermal absorption factor is applied. The high-risk SF of 2.0E+0 per mg/kg-day is used for mixtures containing any congeners considered to be persistent

or acting in a dioxin-like manner, and for any early life exposures (e.g., residential scenario, which includes both adults and children). In this context, persistent congeners are those with five or more chlorines. The 12 PCB congeners considered to act in a dioxin-like manner were identified above. The SF of 2.0E+0 per mg/kg-day is equivalent to a URF (for dust or aerosol inhalation) of 5.7E-4 per $\mu g/m^3$.

The high-risk tier SF for central tendency (CT) assessment is 1.0E+0 per mg/kg-day. The SF of 1.0E+0 per mg/kg-day is equivalent to a URF (for dust or aerosol inhalation) of 2.9E-4 per $\mu g/m^3$.

Low-Risk Tier EPA (2012) verified an upper-bound SF of 4E-1 per mg/kg-day for the low-risk tier, which includes ingestion of water-soluble congeners (assumed to be PCBs detected in drinking water), inhalation of evaporated congeners, and dermal exposure if no absorption factor is applied. The SF of 4E-1 per mg/kg-day is equivalent to a URF for vapor inhalation of 1E-4 per $\mu g/m^3$. A SF of 3E-1 per mg/kg-day is recommended for the low-risk CT evaluation. The SF of 3E-1 per mg/kg-day is equivalent to a URF (for vapor inhalation) of 9E-5 per $\mu g/m^3$.

Lowest-Risk Tier EPA (2012) verified an upper-bound SF of 7E-2 per mg/kg-day for the lowest-risk tier, which is restricted to data sets for which homologue-or congener-specific data verify that congeners containing 5 or more chlorines constitute less than 0.5 percent of the total PCBs. The SF of 7E-2 per mg/kg-day is equivalent to a URF for inhalation of 2E-5 per $\mu g/m^3$. These values are used in for Aroclor 1016. An SF of 4E-2 per mg/kg-day is recommended for the low-risk CT evaluation. The SF of 4E-2 per mg/kg-day is equivalent to a URF for vapor inhalation of 1E-5 per $\mu g/m^3$.

An alternative method of PCB cancer risk assessment was proposed by EPA (2000, 2012) for sites where congener-specific analytical results are available. This method involves application of toxicity equivalency factors (TEF) adopted by EPA (2000) to the 12 dioxin-like congeners identified above. TEFs are factors that express the toxicity of the dioxin-like congeners relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD or "dioxin"), the reference compound. EPA (1997) presented a provisional oral and inhalation SF for 2,3,7,8-TCDD of 1.5E+5 per mg/kg-day. As explained in the toxicological profile for polychlorinated dibenzo-p-dioxins and dibenzofurans, the inhalation SF is more accurately expressed as 1.1E+5 per mg/kg-day, which is equivalent to 3.3E+1 per $\mu g/m^3$, or 3.3E+4 per mg/m^3. Application of the EPA (2000) TEFs to the dioxin-like PCB congeners yields the cancer potency factors presented below:

Dioxin-Like PCB Congener	IUPAC No.	TEF	SFo	URFi	SFi
3,3′,4,4′-Tetrachlorobiphenyl	77	0.0001	1.5E+1	3.3E+0	1.1E+1
3,4,4′,5-Tetrachlorobiphenyl	81	0.0001	1.5E+1	3.3E+0	1.1E+1
2,3,3′,4,4′-Pentachlorobiphenyl	105	0.0001	1.5E+1	3.3E+0	1.1E+1
2,3,4,4′,5-Pentachlorobiphenyl	114	0.0005	7.5E+1	1.7E+1	5.5E+1
2,3′,4,4′,5-Pentachlorobiphenyl	118	0.0001	1.5E+1	3.3E+0	1.1E+1
2′,3,4,4′,5-Pentachlorobiphenyl 2,3′,4,4′,5′-Pentachlorobiphenyl)	123	0.0001	1.5E+1	3.3E+0	1.1E+1
3,3′,4,4′,5-Pentachlorobiphenyl	126	0.1	1.5E+4	3.3E+3	1.1E+4
2,3,3′,4,4′,5-Hexachlorobiphenyl	156	0.0005	7.5E+1	1.7E+1	5.5E+1
2,3,3′,4,4′,5′-Hexachlorobiphenyl	157	0.0005	7.5E+1	1.7E+1	5.5E+1
2,3′,4,4′,5,5′-Hexachlorobiphenyl	167	0.00001	1.5E+0	3.3E-1	1.1E+0
3,3′,4,4′,5,5′-Hexachlorobiphenyl	169	0.01	1.5E+3	3.3E+2	1.1E+3

Dioxin-Like PCB Congener	IUPAC No.	TEF	SFo	URFi	SFi
2,3,3′,4,4′,5,5′-Heptachlorobiphenyl	189	0.0001	1.5E+1	3.3E+0	1.1E+1

IUPAC No. = unique sequentially numbered congener identifier proposed by the International Union of Pure and Applied Chemists; TEF = toxicity equivalency factor (EPA, 2000); SFo = oral slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per milligram per cubic meter); SFi = inhalation slope factor (risk per milligram per kilogram-day).

6.0 Toxicity Summary

Cancer potency factors for the dioxin-like congeners are summarized above. Toxicity values for PCBs other than the dioxin-like congeners, are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
Aroclor-1016[b]										
2E-4	7E-5	F	ND	ND	NA	Please see below.				
Aroclor-1254										
5E-5	2E-5	Is, S	ND	ND	NA	Please see below.				
PCBs, High-Risk, Upper Bound (Reasonable Maximum Exposure) Assumptions										
Please see above, including footnote “b.”						B2	2.0E+0	B2	5.7E-1[c]	2.0E+0[c]
PCBs, High-Risk, Central Tendency Exposure Assumptions										
Please see above, including footnote “b.”						B2	1.0E+0	B2	2.9E-1[c]	1.0E+0[c]
PCBs, Low-Risk, Upper Bound (Reasonable Maximum Exposure) Assumptions										
Please see above, including footnote “b.”						B2	4E-1	B2	1E-1[d]	4E-1[d]
PCBs, Low-Risk, Central Tendency Exposure Assumptions										
Please see above, including footnote “b.”						B2	3E-1	B2	9E-2[d]	3E-1[d]
PCBs, Lowest-Risk, Upper Bound (Reasonable Maximum Exposure) Assumptions										
Please see above, including footnote “b.”						B2	7E-2	B2	2E-2	7E-2
PCBs, Lowest-Risk, Central Tendency Exposure Assumptions										
Please see above, including footnote “b.”						B2	4E-2	B2	1E-2	4E-2

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per milligram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data.
Target organ abbreviations: F = unborn child; Is = immune system; S = skin; NA = not applicable.
[a]sRfDo, cRfDo and SFo should be used for dermal exposure without adjustment for GI absorption.
[b]sRfDo and cRfDo derived for Aroclor-1016 should be applied to all other Aroclor mixtures except Aroclor-1254. They should also be applied to total PCBs, but not to specific PCB homologues congeners.

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
[c]Reasonable maximum exposure evaluation of inhalation pathways including dusts or aerosols. [d]Reasonable maximum exposure evaluation of inhalation pathways limited to vapors, excluding dusts or aerosols.										

7.0 PCB Risk Assessment

The approach to risk assessment of PCB-contaminated sites depends on the analytical data available. Typically, PCB analysis is limited to Method 8082 for the seven commonly encountered Aroclors. When this is the case, the hazard associated with noncancer effects is evaluated with the oral RfDs provided in the table above. Cancer risk is evaluated with the upper bound (reasonable maximum exposure) SFo and URFi or SFi from the "High-Risk" or "Low-Risk" scenarios, depending on the Aroclors identified, and the receptors and exposure pathways evaluated.

If homologue-specific analytical results are available in addition to results for the seven common Aroclors, it will be necessary to decide which is the better data set. This decision will depend, at least in part, on the samples included in each data set. Generally, the data set that better represents contamination across the area of investigation or a given exposure unit should be used in the risk assessment. If the same samples were analyzed for both Aroclors and specific homologues so that representativeness is not an issue, EPA (2012) generally considers that the homologue data are preferable because they are based on greater sensitivity (lower reporting limits) and are more likely to reflect selective removal of the more labile and mobile congeners due to weathering. Homologue-specific analytical results in the absence of data for the seven common Aroclors can be evaluated directly in the risk assessment.

The homologues should not be evaluated individually for noncancer hazard using the oral RfDs provided above. However, their sum (total PCBs) can be evaluated with the oral RfD for Aroclor-1016, assuming that the total PCBs reflect the characteristics of a mixture not unlike one or more of the Aroclors. If this assumption is not reasonable, the reason should be clearly stated, total PCBs should not be evaluated for noncancer hazard, and the uncertainty imparted to the risk assessment (probably a non-conservative bias) should be discussed. For example, it might be that only the most highly chlorinated homologues persist and are identified from an "old" release.

Cancer risk is estimated for total PCBs rather than the individual homologues. If the penta-, hexa-, hepta-, octa-, nona- and deca-chlorinated homologues together constitute not more than 0.5 percent of the total PCB, the SFo and URFi or SFi for the "Lowest-Risk" scenario should be used. If the penta-, hexa-, hepta-, nona- and deca-chlorinated homologues together constitute more than 0.5 percent of the total PCB, the SFo and URFi or SFi for the "High-Risk" or "Low-Risk" scenario should be used, depending on the receptors and exposure pathways evaluated.

It is unlikely that congener-specific data will be the only PCB data available. Should that be the case, however, the noncancer hazard can be estimated for total PCBs as described in the previous paragraph. For cancer risk assessment, the dioxin-like congeners should be assessed as

explained below. The non-dioxin-like congeners should be summed. If the penta-, hexa-, hepta-, nona- and deca-chlorinated congeners together constitute not more than 0.5 percent of the total PCB, the SFo and URFi or SFi for the "Lowest-Risk" scenario should be used. If the penta-, hexa-, hepta-, nona- and deca-chlorinated congeners together constitute more than 0.5 percent of the total PCB, the SFo and URFi or SFi for the "High-Risk" or "Low-Risk" scenario should be used, depending on the receptors and exposure pathways evaluated. The cancer risks from the non-dioxin-like and the dioxin-like congeners (see next paragraph) should be summed.

It is more likely that limited congener-specific data will be available *in addition to* data for the Aroclors or homologues. (Limited in the number of congeners analyzed and/or the number of samples analyzed for individual congeners.) For cancer risk assessment, EPA (2012) recommends evaluating the Aroclors or homologues as described above, after reducing their exposure-point concentrations by the contribution from the dioxin-like congeners. In most cases the concentrations of the dioxin-like congeners will be so much lower than the concentrations of the Aroclors or homologues that their subtraction would make little difference. The cancer risk for the dioxin-like congeners is assessed by using the TEF-based SFo and URFi or SFi values presented above. The two sets of risk estimates are then summed.

The newer trends in PCB analysis and risk assessment introduce additional sources of uncertainty to the assessment. PCBs tend to be somewhat ubiquitous because of their once-common use, potential for widespread dispersion, and persistence in environmental media (ATSDR, 2000). Method 1668 is a high-resolution method that is likely to identify very low "anthropogenic background" levels of PCBs that may not be reflected in the results of Aroclor analysis using Method 8082. This may impart an overly conservative bias to the risk assessment. Another source of uncertainty may arise from analyzing only a limited number or proportion of PCB-bearing samples for individual congeners. The limited analysis could impart either a conservative or non-conservative bias to the risk assessment, depending on the relative level of contamination in the samples selected for analysis of individual congeners.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 2000, ***Update Toxicological Profile for Polychlorinated Biphenyls***, U.S. Public Health Service, Atlanta, Georgia, November, on line.

Gaffey, W.R., 1983, "The epidemiology of PCBs," In: ***PCBs: Human and Environmental Hazards***, F.M. D'itri and M.A. Kamrin, Eds., Boston: Butterworth Publishers.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

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

U.S. Environmental Protection Agency (EPA), 1995, ***Great Lakes Water Quality Initiative, Technical Support Document for the Procedure to Determine Bioaccumulation Factors***, EPA.820.8.95.CC5, PB95-187290.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

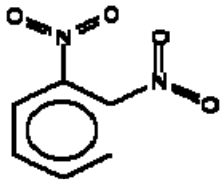
U.S. Environmental Protection Agency (EPA), 2000, ***Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Part II: Health Assessment for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) and Related Compounds***, Draft Final, National Center for Environmental Assessment, May.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

EXPLOSIVES

DINITROBENZENES



1,2-Dinitrobenzene

1.0 Introduction and Physical Properties

The dinitrobenzenes are **SVOCs** that occur as white to pale yellow crystals at ambient temperatures (HSDB, 2012). The dinitrobenzenes exist in three isomeric forms: 1,2-dinitrobenzene (ortho- or o-dinitrobenzene), 1,3-dinitrobenzene (meta- or m-dinitrobenzene), and 1,4-dinitrobenzene (para- or p-dinitrobenzene). These compounds are used in organic synthesis, particularly in the manufacture of dyes, in explosives (2,4,6-trinitrotoluene), and as a camphor substitute in the production of celluloids (ACGIH, 1991; ATSDR, 1995; HSDB, 2012; Lewis, 1997). 1,3-Dinitrobenzene, the isomer most frequently encountered in the environment, is also used in the preparation of m-phenylenediamine, in the detection of 17-ketosteroids, and in the production of aminocresols and other aromatic amines (HSDB, 2012). Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
1,2-Dinitobenzene (528-29-0)										
1.68.11	1.69	5.3E-8 (25°C)	2.30	6.24E-2[a] (25°C)[b]	7.22E-6[a] (25°C)[b]	5.99E-8 (25°C)	1.33E+2[c] (25°C)	NA	NA	NA
1,3-Dinitrobenzene (99-65-0)										
1.68.11	1.49	4.9E-8 (25°C)	2.19	6.24E-2[a] (25°C)[b]	7.22E-6[a] (25°C)[b]	2.63E-7 (25°C)	5.33E+2[c] (25°C)	NA	NA	NA
1,4-Dinitrobenzene (98-06-6)										
1.68.11	1.46	8.4E-8 (25°C)	2.17	6.24E-2[a] (25°C)[b]	7.22E-6[a] (25°C)[b]	8.60E-8 (25°C)	6.9E+1[c] (25°C)	NA	NA	NA

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);)$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole); ND = no data; NA = not applicable.
Note: Source of above values, except as footnoted: EPA (2012) EPISuite™ data base.
[a]Calculated as described in Introduction to Toxicity Profiles.
[b]Assumed standard temperature.
[c]Hazardous Substances Data Base (HSDB), 2012, National Library of Medicine, on line.

2.0 Environmental Fate and Transport

Environmental release of the dinitrobenzenes may result from their use as intermediates in organic syntheses, during the production of 2,4,6-trinitrotoluene (TNT) and in the production of dyes (ATSDR, 1995; HSDB, 2012). Its presence in environmental media at former ordnance

works may reflect its formation as a degradation product of TNT or other nitroaromatic explosive compounds.

Dinitrobenzene released to soil may adsorb to clay but adsorption to soils that are not predominantly clay is expected to be weak (HSDB, 2012). Therefore, the dinitrobenzenes are expected to be mobile or highly mobile in many soils and may readily leach to groundwater. Volatilization from soil surfaces may occur but this expected to be slow. Reduction to aromatic amines may occur under anaerobic conditions.

The dinitrobenzenes are expected to exist largely in the vapor phase in air (ATSDR, 1995). These chemicals are expected to react with photochemically generated hydroxyl radicals with an estimated half-life of upwards of 500 days (HSDB, 2012). Direct photolysis in the atmosphere may also occur, but a rate cannot be estimated.

The dinitrobenzenes may biodegrade in water and volatilization may occur, but these removal processes are expected to be slow (HSDB, 2012). Direct photolysis may also occur, but rate data are not available. These compounds are not expected to partition strongly to sediment.

The low log K_{ow} values for these compounds suggest that bioconcentration or bioaccumulation is unlikely to be important (HSDB, 2012). Empirical data for 1,4-dinitrobenzene supports this assumption; therefore, biotransfer factors are not estimated for the dinitrobenzenes.

3.0 Toxicokinetics

Toxicokinetic data for the dinitrobenzenes are limited to the 1,3-isomer. Occupational studies associate exposure to 1,3-dinitrobenzene with cyanosis resulting from conversion of hemoglobin to methemoglobin, indicating that uptake through the respiratory tract is significant (ATSDR, 1995). A significant contribution from dermal uptake cannot be ruled out.

Urinary excretion data from rabbits given single oral doses of 1,3-dinitrobenzene indicate that at least 65 to 93 percent of the ingested dose is absorbed (ATSDR, 1995). Dermal uptake of 1,3-dinitrobenzene appears to be substantial as indicated by the observation of cyanosis in occupational exposure where dermal contact was known to occur and in a volunteer who applied the compound in ointment to his skin. Experiments with solutions applied to the skin of guinea pigs suggest that the nature of the solvent appears to influence the rate of dermal uptake.

Data regarding the tissue distribution of absorbed dinitrobenzenes were not located.

Studies with 1,3-dinitrobenzene in rats indicate that reduction of one of both nitro groups to the corresponding amino moiety is the first step in dinitrobenzene metabolism (ATSDR, 1995). The amino group(s) thus formed are subject to acetylation or conjugation with glucuronic acid or sulfate. Ring hydroxylation and oxidative remove of amine groups are relatively minor pathways in rats. Comparative studies indicate that hamsters are considerably less sensitive than rats to the toxicity of 1,3-dinitrobenzene. This may be attributed to the increased rate of ring hydroxylation by hamsters compared with rats; ring hydroxylation may hasten conjugation and excretion thereby reducing toxicity.

Excretion of metabolites of 1,3-dinitrobenzene is predominantly through the urine (ATSDR, 1995).

4.0 Dermal Exposure

EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. Therefore, no GAF is developed for the dinitrobenzenes and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

Data for the 1,3-isomer indicate that the dinitrobenzenes are readily absorbed through the skin (ATSDR, 1995). However, data regarding the extent of dermal uptake from soil were not located. In the absence of empirical data, the EPA (2004) default ABS of 0.1 for SVOCs is selected for this evaluation.

t*, K_p, τ, FA and B values are estimated by the EPA (2004) methodology as follows:

Chemical	t*	K_p	τ	FA	B
1,2-Dinitrobenzene	2.20	2.37E-3	0.92	1	0
1,3-Dinitrobenzene	2.20	1.75E-3	0.92	1	0
1,4-Dinitrobenzene	2.20	1.67E-3	0.92	1	0

t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).

5.0 Noncancer Effects Evaluation

Acute oral LD_{50} values are limited to 83 mg/kg for 1,3-dinitrobenzene in rats (ATSDR, 1995; HSDB, 2012). Acute exposure is associated with cyanosis resulting from the oxidation of hemoglobin to methemoglobin in the erythrocytes. Methemoglobin is unable to release oxygen to the tissues resulting in tissue anoxia. Doses approximately one-half the oral LD_{50} are also associated with testicular degeneration and impaired fertility.

Prolonged oral exposure of laboratory animals to 1,3-dinitrobenzene is associated with reduced blood hemoglobin concentrations, testicular degeneration, and equivocal evidence of neurotoxicity (ATSDR, 1995; EPA, 2012a). EPA (2012a) verified an RfD for chronic oral exposure of 1E-4 mg/kg-day based on a NOAEL of 3 ppm (0.4 mg/kg-day) in a 16-week drinking water study in male and female rats. An uncertainty factor of 3000 (10 for extrapolation from subchronic to chronic exposure, 10 for extrapolation across species, 10 for sensitive human subgroups, and 3 for the lack of chronic and reproductive toxicity data) was applied to the NOAEL to derive the RfD. The LOAEL, 8 ppm (1.1 mg/kg-day), was associated with increased spleen weights, an indication of accelerated erythrocyte turnover. The concentration of 20 ppm (2.7 mg/kg-day) was associated with decreased body weight gain in females, decreased hemoglobin concentrations and testicular atrophy in males, and splenic enlargement and hemosiderin deposits in rats of either sex. The erythrocyte is the more sensitive target organ for prolonged oral exposure to 1,3-dinitrobenzene. Effects on the spleen are judged to be secondary to erythrocyte destruction. Confidence in the verified chronic oral RfD is low.

Data regarding the toxicity of prolonged oral exposure to the other dinitrobenzene isomers were not located in the available literature. EPA (1997) derived provisional oral RfD values for 1,2-dinitrobenzene and 1,4-dinitrobenzene of 1E-4 mg/kg-day by analogy to 1,3-dinitrobenzene, which are the values currently listed on the EPA (2012b) Regional Screening Level Table.

Human (occupational) exposure to the dinitrobenzenes is associated with effects on the liver, aplastic anemia, yellowing of the skin, cornea and conjunctiva, and several overt symptoms including headache, burning pain and paresthesias in the feet, ankles, hands, and forearms, cyanosis, visual disturbance, central scotomas, bad taste, burning mouth, and dry throat (ACGIH, 1991; HSDB, 2005). The skin, conjunctiva, and ocular fundus may show bluish discoloration from formation of methemoglobin. Vision has been affected in numerous cases of occupational exposure. The vision fields have been slightly contracted, and visual acuity has been much reduced, with central scotomas, particularly for red and green. Partial optic atrophy has been observed in some cases. Dermal exposure is thought to play a major role in the effects associated with occupational exposure (ACGIH, 1991). The data are insufficient for development of an inhalation RfC for any of the dinitrobenzenes.

6.0 Carcinogenicity Evaluation

EPA (2012a) classified 1,2- and 1,3-dinitrobenzene in weight-of-evidence cancer Group D – not classifiable as to human carcinogenicity – because of a lack of relevant human or animal data. Data regarding the carcinogenicity of 1,4-dinitrobenzene were not located. URFs and SFs are not available for any of the dinitrobenzenes.

7.0 Toxicity Summary

Toxicity values for the dinitrobenzenes are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
1,2- and 1,3-Dinitrobenzene										
1E-3	1E-4	E,Sp	ND/ ND	ND/ ND	NA	D	NA	D	NA	NA
1,4-Dinitrobenzene										
1E-3	1E-4	E,Sp	ND/ ND	ND/ ND	NA	ND	ND	ND	ND	ND

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: E = erythrocyte, Sp = Spleen.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 1995, ***Toxicological Profile for 1,3-Dinitrobenzene and 1,3,5-Trinitrobenzene***, U.S. Department of Health and Human Services, June, on line.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, Cincinnati, OH, pp. 502-503.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Lewis, R.J., Sr., 1997, ***Hawley's Condensed Chemical Dictionary***, Thirteenth Edition, John Wiley & Sons, Inc., New York, p. 405.

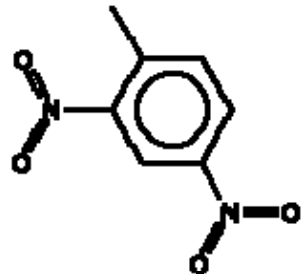
U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP, NTIS No. PB99-963312, July.

U.S. Environmental Protection Agency (EPA), 2012a, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

U.S. Environmental Protection Agency (EPA), 2012b, ***Regional Screening Level Table, (April)***, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

DINITROTOLUENES (DNT)



(2,4-Dinitrotoluene)

1.0 Introduction and Physical Properties

The dinitrotoluenes (DNT) are **SVOCs** that occur as yellow to orange to red needles or crystals at ambient temperatures (HSDB, 2012). They are used predominantly as intermediates in the production of polyurethanes, dyes, rubber, plastics, toluidines, toluenediisocyanates, flexible and rigid foams, surface coatings, and other organic chemicals (ATSDR, 1998; HSDB, 2012). The DNTs are also used as gelatinizing and waterproofing agents in the production of explosives. The DNTs may appear in environmental media as break down products of 2,4,6-trinitrotoluene (TNT). Isomers include 2,3-, 2,4-, 2,5-, 2,6-, 3,4- and 3,5-DNT. Analysis of technical grade DNT yielded the following results: 76.49 percent 2,4-DNT, 18.83 percent 2,6-DNT, 0.65 percent 2,5-DNT, 2.43 percent 3,4-DNT, 1.54 percent 2,3-DNT, 0.040 percent 3,5-DNT, 0.050 percent trinitrotoluene, 0.005 percent cresols, 0.003 percent mononitrobenzene, and 0.003 percent, 0.0005 percent, and 0.006 percent ortho-, meta-, and para-, mononitrotoluenes, respectively. The compounds of most interest in environmental exposure are limited to 2,4- and 2,6-DNT. Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
2,3-Dinitrotoluene (602-01-7)										
182.14[a]	2.2[a]	9.3E-8[a] (25°C)[b]	2.57[a]	5.91E-2[c] (25°C)[b]	6.85E-6[c] (25°C)[b]	5.26E-7[a] (25°C)	2.2E+2[d] (25°C)[b]	ND	ND	ND
2,4-Dinitrotoluene (121-14-2)										
182.1[e]	1.98[e]	8.40E-8[i] (25°C)	2.46[i]	2.03E-1[f] (25°C)	7.06E-6[f] (25°C)	1.93E-7[a] (22°C)	2.70E+2[f] (20-25°C)	590.0[g]	814.0[g]	1.35E+4[g]
2,5-Dinitrotoluene (619-15-8)										
182.14[a]	2.2[a]	9.3E-8[a] (25°C)[b]	2.56[a]	5.91E-2[c] (25°C)[b]	6.85E-6[c] (25°C)[b]	5.26E-7[a] (25°C)	2.2E+2[d] (25°C)[b]	ND	ND	ND
2,6-Dinitrotoluene (606-20-2)										
182.1[e]	1.72[e]	7.47E-8[i] (25°C)[b]	2.46[i]	5.91E-2[c] (25°C)[b]	6.85E-6[c] (25°C)[b]	7.46E-7[a] (25°C)	1.82E+2[h] (20-25°C)	558.0[g]	770.0[g]	1.29E+4[g]
3,4-Dinitrotoluene (610-39-9)										
182.14[a]	2.08[a]	9.3E-8[a] (25°C)[b]	2.56[a]	5.91E-2[c] (25°C)[b]	6.85E-6[c] (25°C)[b]	5.26E-7[a] (25°C)	1.00E+2[a] (25°C)	ND	ND	ND
3,5-Dinitrotoluene (618-85-9)										
182.14[a]	2.2[a]	9.3E-8[a] (25°C)[b]	2.56[a]	5.91E-2[c] (25°C)[b]	6.85E-6[c] (25°C)[b]	2.50E-6[a] (25°C)	ND	ND	ND	ND

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole); ND = no data.

[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

[b]Assumed.

[c]Calculated as described in Introduction to Toxicity Profiles.

[d]Syracuse Research Corporation (SRC), 2004, *CHEMFATE Data Base*, on line.

[e]U.S. Environmental Protection Agency (EPA), 2004 *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final*, Office of Emergency and Remedial Response, EPA/540/R/99/005, OSWER 9285.7-02EP July.

[f]U.S. Environmental Protection Agency (EPA), 2002, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, Final, Office of Solid Waste and Emergency Response, OSWER 9355.4-24, December.

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$

[g]U.S. Environmental Protection Agency (EPA), 2003, *Users Guide for Evaluating Subsurface Vapor Intrusion into Buildings*, Office of Emergency and Remedial Response, Washington, DC, 19 June.
[h]U.S. Environmental Protection Agency (EPA), 1996, *Soil Screening Guidance: Technical Background Document*, Office of Emergency and Remedial Response, Washington, DC, EPA/540/R-95/128, Publication 9355.4-17A, PB96-963502, May.
[i]U.S. Environmental Protection Agency (EPA), 2012, *EPISuite electronic database*.
[j]Conservatively assumed to be based on the same Kow as 2,4-DNT.

The physical properties of 2,4-DNT can be used for the DNT mixture (25321-14-6) because the 2,4-isomer predominates in the technical grade product.

2.0 Environmental Fate and Transport

The DNTs are released into the environment in waste streams from processes in which they are manufactured or used (ATSDR, 1998; HSDB, 2012). Also, they may form from degradation of TNT in gunpowder or explosives, particularly at TNT manufacturing or military sites. DNTs released to soil are expected to exhibit moderate mobility and may leach to groundwater. No information on biodegradation in soil was found; however, biodegradation may be an important fate process in soil based on the observation that all DNT isomers in surface water to which yeast extract was added were metabolized. DNTs are not expected to hydrolyze in soils.

DNTs released to water, may exhibit weak to moderate adsorption to sediment (ATSDR, 1998; HSDB, 2012). Evaporation from water is not expected to be an important removal process, based on the low Henry's Law constants for these compounds. Biodegradation may be an important fate process in water, as indicated above. DNTs in water may be susceptible to photolysis, based on the behavior of 2,4-DNT, which had photolytic half-lives ranging from 2.7 to 9.6 hours in natural water environments and 43 hours in distilled water.

DNTs released to the atmosphere are expected to exist solely in the vapor phase (HSDB, 2012). They may be susceptible to direct and indirect photolysis. The half-life for reaction with photochemically produced hydroxyl radicals is 84 days.

Bioconcentration of the DNTs is expected to be negligible (ATSDR, 1998; EPA, 1995; HSDB, 2012); therefore, biotransfer factors are not estimated.

3.0 Toxicokinetics

The rapid disappearance of radioactivity from the small intestine of rats following oral administration of radiolabeled 2,4- or 2,6-DNT suggests that absorption from the GI tract is rapid and essentially complete (ATSDR, 1998; EPA, 1992). Species differences in the excretion of the DNTs, however, confound quantification of the extent of GI absorption. Fecal excretion and the GI tract (tissue + contents) accounted for 9.2 to 17.3 percent of the dose of radioactivity 24 hours after oral administration of radiolabeled 2,4-DNT to rats, rabbits, dogs and monkeys (EPA, 1992). Fecal excretion and the GI tract accounted for 83.1 to 85 percent of an oral dose in mice in the same study. Biliary excretion appears to be more important in mice than in the other species tested. Together, the data for the 2,4-isomer suggest that the GI absorption of the DNTs is practically complete.

Body distribution of radioactivity was followed after administration of a ^{14}C-labeled oral dose of 2,4-DNT in male and female rats (ATSDR, 1998). Levels of radioactivity in the liver and kidneys exceeded levels in the plasma or erythrocytes by 5- to 10-fold; levels in other tissues

were lower than those in blood. The greater concentrations in the liver and kidneys probably represent metabolites rather than parent compound.

Metabolism of the DNTs involves both oxidative and reductive reactions as well as alkylation (ATSDR, 1998). Oxidative reactions occur primarily in the liver and involve stepwise enzymatic oxidation of the methyl group to the corresponding dinitrobenzyl alcohol, dinitrobenzylaldehyde and dinitrobenzoic acid. Dinitrobenzyl alcohol is subject to conjugation, particularly with gluconuric acid, before excretion via the urine or bile. Acetylation of one of the nitro groups of the dinitrobenzoic acid may also occur, yielding the corresponding (n-acetyl)amino nitrobenzoic acid, which is observed as a minor urinary metabolite.

Two types of reduction reactions involving metabolites excreted via the bile or GI tract are accomplished anaerobically by intestinal microflora (ATSDR, 1998). The first reaction involves lysis of the glucuronide conjugate described above to release the corresponding benzyl alcohol. The second reaction involves nitroreduction, resulting in transforming one or both of the nitro groups to amine groups, probably through nitroso and hydroxylamino intermediates. The amino and hydroxylamino benzyl alcohols are reabsorbed, completing the enterohepatic cycle.

The amine group on the reabsorbed benzyl alcohol is subject to partial oxidation in the liver to yield the corresponding hydroxylamino compound, potentially providing a second pathway for formation of these compounds (ATSDR, 1998). The hydroxylamino compounds may conjugate with sulfate, forming an unstable product that decomposes to yield carbonium or nitrenium ions that bond covalently with hepatic macromolecules, giving rise to the first stages of hepatic carcinogenesis. From the foregoing, it appears that microbial transformation and hepatic recirculation are involved in the carcinogenicity observed in laboratory rodents (Section 6.0).

4.0 Dermal Exposure

EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. Therefore, no GAF is developed for the DNTs and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

Urinary excretion data obtained from workers exposed to the DNTs indicates that dermal absorption occurs (ATSDR, 1998) but multiple exposure routes were involved and the extent of dermal uptake cannot be quantified. Empirical data regarding dermal uptake from soil were not located. ABS values of 0.102 and 0.099 were used for 2,4-DNT and 2,6-DNT, respectively (EPA, 2012a) t*, K_p, τ, FA and B values are provided by EPA (2004) or estimated by the EPA (2004) methods as follows:

Chemical	t*	K_p	τ	FA	B
2,3-Dinitrotoluene[a]	2.64	4.29E-3	1.10	1	0.0
2,4-Dinitrotoluene[b]	2.69	3.1E-3	1.12	1	0.0
2,5-Dinitrotoluene[a]	2.64	4.29E-3	1.10	1	0.0
2,6-Dinitrotoluene[b]	2.69	2.1E-3	1.12	1	0.0
3,4-Dinitrotoluene[a]	2.64	3.57E-3	1.10	1	0.0
3,5-Dinitrotoluene[a]	2.64	4.84E-3	1.10	1	0.0
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability					

Chemical	t*	K_p	τ	FA	B
coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless). [a]Estimated as described in Introduction to Toxicity Profiles. [b]U.S. Environmental Protection Agency (EPA), 2004, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final***, Office of Emergency and Remedial Response, EPA/540/R/99/005, OSWER 9285.7-02EP, July.					

The estimated values for K_p for all the DNTs fell within the effective prediction domain.

5.0 Noncancer Effects Evaluation

Data regarding the toxicity of oral exposure to 2,3-DNT are limited to the statement that the 2,4-, 2,6- and 3,4-isomers are more toxic to rats than the 2,3- or 2,5-isomers (HSDB, 2012).

Acute oral exposure to 2,4-DNT induces methemoglobinemia; dogs appear to be more sensitive than rats, which are more sensitive than mice (ATSDR, 1998). Oral LD_{50} values include 270 mg/kg for rats, 1630 mg/kg for mice and 1300 mg/kg for guinea pigs (ATSDR, 1998; HSDB, 2012), establishing the rat as the species most sensitive to acute oral exposure. Subchronic or chronic oral exposure to 2,4-DNT in rats is associated with depressed weight gain, reticulocytosis and splenic hemosiderosis, and decreased spermatogenesis (HSDB, 2012). Some rats had widespread and stiff-legged gaits and demyelination in the cerebellum and brain stem. A verified chronic oral RfD of 2E-3 mg/kg-day for 2,4-DNT is based on neurotoxicity, hematologic effects and biliary tract hyperplasia in dogs given capsules containing the test substance for 2 years (EPA, 2012b). Progressive paralysis, accompanied by degenerative lesions in the central nervous system, were observed in dogs treated with 10 mg/kg-day. Hematologic effects, including methemoglobinemia and its sequelae, were observed in dogs treated with 1.5 mg/kg-day, which is the LOAEL for this study. No adverse effects were observed in dogs treated with 0.2 mg/kg-day. Application of an uncertainty factor of 100 to the NOAEL of 0.2 mg/kg-day yields an RfD of 2E-3 mg/kg-day. Confidence in the RfD is high. The CNS, erythrocyte and liver appear to be the target organs for prolonged oral exposure, at least in dogs. EPA (1997) adopted the verified chronic oral RfD as the preliminary RfD for subchronic oral exposure.

HSDB (2012) reports oral LD_{50} values for 2,5-DNT of 707 mg/kg for rats and 1231 mg/kg for mice. Data regarding the effects of prolonged oral exposure were not reported.

Oral LD_{50} values for 2,6-DNT for rats (177 to 665 mg/kg) are similar to those for mice (621 to 714 mg/kg) (ATSDR, 1998; HSDB, 2012). Dogs, however, appear to be more sensitive than rodents in subchronic studies. A provisional chronic oral RfD of 1E-3 mg/kg-day for 2,6-DNT is based on a 13-week dietary study with 2,6-DNT in dogs (EPA, 2005). The NOAEL in this study was 4 mg/kg-day, somewhat higher than the LOAEL for 2,4-DNT. An uncertainty factor of 3000 was applied. The CNS, erythrocyte, and liver appear to be the target organs for prolonged oral exposure to 2,6-DNT. The oral data in dogs suggest that the 2,6-isomer is somewhat less toxic than the 2,4-isomer for prolonged oral exposure. The oral RfD for the 2,6-isomer, however, is less than the oral RfD for the 2,4-isomer. This apparent contradiction is an artifact of the lesser quality data base for 2,6-DNT and, consequently, the higher uncertainty factor used to derive the RfD for the 2,6-isomer. EPA (1997) derived a provisional subchronic oral RfD of 1E-2 mg/kg-day by applying an uncertainty factor of 300 to the NOAEL of 4 mg/kg-day in the 13-week dog study.

The verified chronic oral RfD of 2E-3 mg/kg-day and the provisional subchronic oral RfD of 2E-3 mg/kg-day for 2,4-DNT can be used for DNT mixtures and the other DNT isomers for which oral exposure data sufficient for RfD derivation are not available. The RfD for 2,4-DNT is chosen over the 2,6-DNT RfD for other isomers because the 2,4-isomer predominates in the technical product and because the RfD for the 2,4-isomer is compromised by much less uncertainty.

Occupational studies indicate that acute exposure to the DNTs produces methemoglobinemia, which causes headache, irritability, dizziness, weakness, nausea, vomiting, dyspnea, drowsiness, unconsciousness and, in extreme cases, death (ACGIH, 1991). Occupational exposure may lead to increased risk of ischemic heart disease, possibly arising from decreased oxygen-carrying capacity of the blood. The data are insufficient to develop inhalation RfCs for the DNT isomers.

6.0 Carcinogenicity Evaluation

Carcinogenicity data for the DNTs are somewhat confusing. Treatment of rats and mice with purified 2,4-DNT generally yields no increased incidence of neoplasia, but treatment with technical grade DNT, 2,4-DNT containing as little as 2 percent 2,6-DNT, or with 2,6-DNT itself generally yields a positive neoplastic response (EPA, 2012b). Initiation/promotion tests suggest that 2,6-DNT may be a complete carcinogen and 2,4-DNT may be a promoter.

EPA (2012b) classified the 2,4-/2,6-DNT mixture in EPA cancer weight-of-evidence Group B2 (probable human carcinogen) on the basis of multiple tumor types in male and female rats and renal tumors in male mice in several dietary studies. Occupational data provide no evidence of carcinogenicity in humans, but the studies reviewed lack the power to reveal small differences in cancer risk (ACGIH, 1991). EPA (2012b) verified an oral SF of 6.8E-1 per mg/kg-day for exposure to the 2,4-/2,6-DNT mixture based on an increased incidence of a variety of tumors in female rats. The test material contained approximately 98 percent 2,4-DNT and 2 percent 2,6-DNT. The B2 classification and the oral SF of 6.8E-1 per mg/kg-day are used in this evaluation for 2,6-DNT and the 2,4-/2,6-DNT mixture. Given the uncertainty about to potential carcinogenicity of the 2,4-isomer alone, and the likelihood that small amounts of the 2,6-isomer may be present, it is deemed prudent to apply the B2 classification and the oral SF of 6.8E-1 per mg/kg-day to the 2,4-isomer as well. The data are insufficient for development of potency factors for inhalation exposure. Data regarding the carcinogenicity of the other DNT isomers were not located.

7.0 Toxicity Summary

Toxicity values for the DNTs are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a, b]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
2,4-Dinitrotoluene										
2E-3	2E-3	E, CNS, L	ND	ND	NA	B2	6.8E-1	ND	ND	ND
2,6-Dinitrotoluene										
1E-2	1E-3	E, CNS, L	ND	ND	NA	B2	6.8E-1	ND	ND	ND

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a, b]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ abbreviations: E = erythrocyte; CNS = central nervous system; L = liver.
[a]sRfDo, cRfDo and SFo should be used for dermal exposure without adjustment for GI absorption.
[b]The cancer evaluation for the 2,4-/2,6-DNT mixture is applied to any DNT mixture containing 2,4- and 2,6-DNT (e.g., the technical grade material) as well as the individual 2,4- and 2,6-isomers.

The oral RfD values for 2,4-DNT should be applied to the technical grade material, any 2,4-/2,6 mixture, and any isomers other than pure 2,6-DNT. The cancer weight-of-evidence group and the verified oral SF for the 2,4-/2,6-DNT mixture should not be applied to isomers other than 2,4- and 2,6-DNT because the potential for the other isomers to cause cancer has not been evaluated.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 1998, ***Update Toxicological Profile for 2,4-Dinitrotoluene and 2,6-Dinitrotoluene***, U.S. Department of Health and Human Services, Atlanta, Georgia, December, PB/99/122004, December.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, ACGIH, Cincinnati, OH, pp. 506-511.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1992, ***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), 1995, "Final Water Quality Guidance for the Great Lakes System; Final Rule," (40 CFR 9, 122, 123, 131, and 132), ***Federal Register***, 60(56): 15365-15425.

U.S. Environmental Protection Agency (EPA), 2004, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final***, Office of Emergency and Remedial Response, EPA/540/R/99/005, OSWER 9285.7-02EP, July.

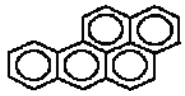
U.S. Environmental Protection Agency (EPA), 2004, ***Provisional Peer-Reviewed Toxicity Values for 2,6-Dintirotoluene (606-20-2)***, SRC-TR-03-001, 13 December..

U.S. Environmental Protection Agency (EPA), 2012a, ***Regional Screening Level Table, (April)***, on line at www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm.

U.S. Environmental Protection Agency (EPA), 2012b, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

SEMIVOLATILE ORGANIC COMPOUNDS

POLYNUCLEAR AROMATIC HYDROCARBONS a.k.a. POLYCYCLIC AROMATIC HYDROCARBONS a.k.a. POLYAROMATIC HYDROCARBONS (PAH) (130498-29-2)



Benzo(a)Pyrene
(A representative and the most studied member of this class of compounds.)

1.0 Introduction and Physical Properties

The PAHs regularly observed in environmental media and addressed in this profile include acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene and pyrene. All exist as solids at room temperature. Classification as **SVOC** or **VOC** is made in the following table. PAHs are the products of incomplete combustion of fossil fuels or other organic matter, hence include both natural and anthropogenic sources (ATSDR, 1995a; HSDB, 2012). Several are also components of crude oil. Naphthalene is used in the synthesis of phthalic anhydride, the insecticide carbaryl, leather tanning agents and surface active agents, and is a component of diesel and other fuels (ATSDR, 1995b). Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
Acenaphthene (83-32-9) **(VOC)**										
154.21[a]	3.92[a]	1.55E-4[b] (25°C)	3.85[b]	4.21E-2[b] (25°C)	7.69E-6[b] (25°C)	3.29E-6[a] (25°C)	4.24E+0[b] (20-25°C)	550.54[c]	803.15[c]	1.22E+4[c]
Acenaphthylene (208-96-8) **(VOC)**										
152.20[a]	4.07[a]	1.13E-5[a] (25°C)	3.42[a]	6.67E-2[d] (25°C)[e]	7.72E-6[d] (25°C)[e]	1.20E-6[a] (25°C)	3.93E+0[a] (25°C)	543.2[a]	797[f]	1.1E+4[g]
Anthracene (120-12-7) **VOC)**										
178.23[a]	4.45[a]	6.51E-5[b] (25°C)	4.47[b]	3.24E-2[b] (25°C)	7.74E-6[b] (25°C)	3.51E-9[a] (25°C)	4.34E-2[b] (20-25°C)	615.18[c]	873.00[c]	1.31E+4[c]
Benzo(a)anthracene (56-55-3) **(SVOC)**										
228.3[h]	5.66[h]	3.34E-6[b] (25°C)	5.60[b]	5.10E-2[b] (25°C)	9.00E-6[b] (25°C)	2.50E-9[a] (25°C)	9.40E-3[b] (20-25°C)	708.15[c]	1004.8[c]	1.60E+4[c]
Benzo(a)pyrene (50-32-8) **(SVOC)**										
252.3[a]	6.10[h]	4.57E-7[k] (25°C)	6.01[b]	4.30E-2[b] (25°C)	9.00E-6[b] (25°C)	7.22E-12[a] (25°C)	1.62E-3[b] (20-25°C)	715.90[c]	969.27[c]	1.90+4[c]
Benzo(b)fluoranthene (205-99-2) **(VOC)**										
252.3[h]	6.12[h]	6.57E-7[k] (25°C)	6.09[b]	2.26E-2[b] (25°C)	5.56E-6[b] (25°C)	6.58E-10[a] (20°C)	1.50E-3[b] (20-25°C)	715.90[c]	969.27[c]	1.70+4[c]
Benzo(k)fluoranthene (207-08-9) **(SVOC)**										
252.32[a]	6.84[a]	8.29E-7[b] (25°C)	6.09[b]	2.26E-2[b] (25°C)	5.56E-6[b] (25°C)	1.28E-12[a] (25°C)	8.00E-4[b] (20-25°C)	753.15[c]	1019.7[c]	1.80E+4[c]
Benzo(g,h,i)perylene (191-24-2) **(SVOC)**										
276.34[a]	6.63[a]	2.66E-7[a] (20°C)	4.98[a]	4.48E-2[d] (25°C)[e]	5.19E-6[d] (25°C)[e]	1.3E-13[a] (25°C)	2.6E-4[a] (25°C)	823[a]	1097[f]	1.96E+4[g]
Chrysene (218-01-9) **(VOC)**										
228.3[h]	5.66[h]	9.46E-5[b] (25°C)	5.60[b]	2.48E-2[b] (25°C)	6.21E-6[b] (25°C)	8.20E-12[a] (25°C)	1.60E-3[b] (20-25°C)	714.15[c]	979.0[c]	1.65E+4[c]
Dibenz(a,h)anthracene (53-70-3) **(SVOC)**										
278.4[h]	6.84[h]	4.89E-7[k] (25°C)	5.68[k]	2.02E-2[b] (25°C)	5.18E-6[b] (25°C)	1.32E-13[a] (20°C)	2.49E-3[b] (20-25°C)	743.24[c]	990.41[c]	3.00E+4[c]
Fluoranthene (206-44-0) **(VOC)**										
202.3[h]	4.95[h]	1.61E-5[b] (25°C)	5.03[b]	3.02E-2[b] (25°C)	6.35E-6[b] (25°C)	1.21E-8[a] (25°C)	2.06E-1[b] (20-25°C)	655.95[c]	905.0[c]	1.38E+4[c]

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
Fluorene (86-73-7) **(VOC)**										
166.21[a]	4.18[i]	6.37E-5[b] (25°C)	4.14[b]	3.63E-2[b] (25°C)	7.88E-6[b] (25°C)	4.21E-7[a] (20°C)	1.98E+0[b] (20-25°C)	570.44[c]	870.0[c]	1.27E+4[c]
Indeno(1,2,3-cd)pyrene (193-39-5) **(SVOC)**										
276.3[h]	6.58[h]	1.60E-6[b] (25°C)	6.54[b]	1.90E-2[b] (25°C)	5.66E-6[b] (25°C)	1.71E-13[a] (25°C)	2.20E-5[b] (20-25°C)	809.15[c]	1078.2[c]	1.90E+4[c]
Naphthalene (91-20-3) **(VOC)**										
128.2[h]	3.30[h]	4.40E-4[k] (25°C)	3.30[b]	5.90E-2[b] (25°C)	7.50E-6[b] (25°C)	1.12E-4[a] (25°C)	3.10E+1[b] (20-25°C)	491.14[c]	748.40[c]	1.04E+4[c]
Phenanthrene (85-01-8) **(VOC)**										
178.2[h]	4.46[h]	1.24E-4[a] (25°C)	4.36[a]	6.00E-2[d] (25°C)[e]	6.95E-6[d] (25°C)[e]	8.95E-7[a] (25°C)	1.29E+0[a] (25°C)	613.2[a]	869.2[j]	1.42E+4[a]
Pyrene (129-00-0) **(VOC)**										
202.26[a]	4.88[a]	1.1E-5[b] (25°C)	5.02[b]	2.72E-2[b] (25°C)	7.24E-6[b] (25°C)	1.17E-7[a] (25°C)	1.35E-1[b] (20-25°C)	667.95[c]	936.0[c]	1.44E+4[c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole); ND = no data.

[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

[b]U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

[c]U.S. Environmental Protection Agency (EPA), 2000, ***User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings, Revised***, Office of Emergency and Remedial Response, Washington, DC, December.

[d]Calculated as described in Introduction to Toxicological profiles.

[e]Assumed.

[f]Estimated from Equation 12-4 in Lyman, W.J., W.F. Reehl and D.H. Rosenblatt, 1990, ***Handbook of Chemical Property Estimation Methods***, American Chemical Society, Washington, DC.

[g]Estimated from Equation 13-5 in Lyman, W.J., W.F. Reehl and D.H. Rosenblatt, 1990, ***Handbook of Chemical Property Estimation Methods***, American Chemical Society, Washington, DC.

[h]U.S. Environmental Protection Agency (EPA), 2004, ***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.

[i]Syracuse Research Corporation (SRC), 2004, ***CHEMFATE Search Results***, on line, accessed 23 April.

[j]National Institute of Standards and Technology (NIST), 2004, Standard Reference Data Program, Online Data Bases, accessed 23 April.

[k]U.S. Environmental Protection Agency (EPA), 2012, *EPISuite electronic database*.

2.0 Environmental Fate and Transport

The PAHs are ubiquitous products of incomplete combustion; natural sources include volcanoes and forest fires (ATSDR, 1995a,b; HSDB, 2012). 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. Industrial sources include coal mining, processing and storing, wood treatment (creosote), manufactured gas plants (coal tar), power generation, production of coal tar, coke and asphalt, petroleum cracking and industrial and municipal incineration. 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. Indoor sources include unvented kerosene heaters and gas cooking and heating appliances. Naphthalene is released during its manufacture and processes that involve its use (e.g., vaporization from moth balls).

Although PAHs generally occur in mixtures, certain chemicals tend to predominate in different sources so that the PAH pattern observed in a given medium may provide a clue to the source. The following compilation relates individual PAHs and sources:

Source[a]	Individual PAHs
Residential wood burning	Acenaphthylene
Auto emissions	Benzo(g,h,i)perylene, pyrene
Diesel exhaust particulates	Fluoranthene, phenanthrene, pyrene
Diesel exhaust vapors	Phenanthrene, anthracene

Source[a]	Individual PAHs
Diesel total emissions	Acenaphthene, fluorene, phenanthrene
Fly ash & bottom ash from U.S. municipal waste incinerators	Phenanthrene
Fly ash from U.K. municipal waste incinerators	Benzo(g,h,i)perylene
Particulate emissions from municipal waste incinerator	Benzo(a)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene
Municipal/medical waste incinerator	Benzo(a)anthracene, benzo(g,h,i)perylene
Rotary kiln incinerator charged with polyethylene, no afterburner	Fluoranthene, phenanthrene, pyrene (see next entry)
Rotary kiln incinerator charged with polyethylene with afterburner	Benzo(a)anthracene, phenanthrene (total PAH emissions reduced 100-fold compared with no afterburner)
Coal tar pitch emissions	Phenanthrene and pyrene 20 to 80 X > benzo(a)pyrene, benzo(g,h,i)perylene
Natural gas home appliances – fine particulate emissions	Chrysene, fluoranthene, pyrene, triphenylene
Groundwater near coal & oil gasification plant	Acenaphthylene, acenaphthene, fluorene, phenanthrene, fluoranthene, pyrene, chrysene
Groundwater near wood treatment facilities	Benzo(a)pyrene, phenanthrene
[a]Agency for Toxic Substances and Disease Registry, (ATSDR), 1995, ***Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs)***, U.S. Public Health Service, Atlanta, Georgia, August, on line.	

Data compiled for soils are not included in the table above because the lists are long and the variation from one site to another is great, so that the information is not useful for identifying sources. Similarly, sediment is a sink for PAHs from all sources including atmospheric deposition from far distant locations, and the patterns observed in sediment do not necessarily reflect a nearby source (ATSDR, 1995a). Generally, PAHs associated with combustion exhibit highly condensed ring structures and little alkylation (i.e., benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, benzo(e)pyrene, chrysene, fluoranthene, pyrene).

Crude petroleum and products made from crude petroleum (e.g., asphalts, fuels, oils) contain PAHs, but the patterns observed depend on the location of the source (ATSDR, 1995a; Potter and Simmons, 1998). Phenanthrene and alkylated forms of PAHs, particularly the methylnaphthalenes, often predominate in petroleum products.

The partitioning and fate of the PAHs in environmental media depend largely on VP (tendency to exist in air as a vapor), H (indicator of partitioning between air and water) and K_{oc} (indicator of affinity to bind to organic matter in soil and sediment). ATSDR (1995a) noted that H and K_{oc} are roughly directly related to MW, and that VP is roughly inversely related to MW. Therefore, they grouped the PAHs into the following categories to facilitate understanding their behavior in the environment:

- Low MW (152 to 178 g/mole) – acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene

- Medium MW (approximately 202 g/mole) – fluoranthene, pyrene

- High MW (228 to 278 g/mole) – benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene.

PAHs exist in the atmosphere as vapors or adsorbed to particulates, the proportion depending on the vapor pressure of the individual chemical and atmospheric conditions such as temperature and humidity (ATSDR, 1995a, b; HSDB, 2012). Generally, the two- and three-ring compounds (low and medium MW except pyrene) exist predominantly as vapors; the four-ring compounds exist in both the vapor and particulate phase, and compounds with 5 or more rings (benzo[a]pyrene, benzo[g,h,i]perylene exist predominantly as particulates. Increasing atmospheric temperature and relative humidity favors existence in the vapor phase. PAHs may travel short or long distances before removal from the air. Vapor forms are subject to chemical oxidation processes in the air, which reduces the distance they may travel. Residence time and transport distance is inversely related to the size of the particles on which the PAHs are adsorbed. Small particles may have residence times of weeks, permitting transport for hundreds or upwards of a thousand miles. Wet and dry deposition accounts for removal of the particulates.

The predominant sources of PAHs in surface water are deposition from the atmosphere, industrial and sewage effluent and oil spills (ATSDR, 1995a,b). Runoff and erosion can also contribute PAHs to surface water bodies. Volatilization is a significant fate process for PAHs with H values of 1E-5 atm-m^3/mole or greater (generally the low and medium MW compounds). Volatilization is a very limited removal process for most of the high MW compounds. Volatilization is enhanced by high temperature, turbulence and high wind. Sorption to benthic or suspended sediment and biodegradation are competing removal processes. Generally, volatilization and biodegradation are the predominant removal processes for the low MW compounds, and volatilization and sorption are the predominant removal processes for medium and high MW compounds. Naphthalene is relatively water soluble and may remain largely in solution. PAHs in sediment may biodegrade, recycle back to the water column (lower MW compounds) or accumulate in the lower trophic levels of living organisms.

Deposition from the atmosphere is the principal source of PAHs in soil (ATSDR, 1995a,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 high lipophilicity of many PAHs evidenced by high log K_{ow} values suggest that the PAHs might cross biologic membranes and participate significantly in food-chain pathways involving fish, fruit and vegetable, and meat and milk consumption. This, however, is not the case. For example, the PAHs are efficiently metabolized and excreted by fin fish, greatly reducing the likelihood of bioconcentration from water or bioaccumulation from sediment (ATSDR, 1995a). Consequently, there are often great discrepancies between modeled BCF values and empirical BCF values, where care was taken to identify the parent compound rather than PAH metabolites in fish tissue. This distinction is necessary because aromatic fragments from PAH metabolism are readily assimilated as normal endogenous components of biological tissue. PAH concentrations in aquatic food-chain systems usually decrease with increasing trophic level, reflecting the generally greater efficiency of metabolism in the higher trophic organisms.

Approximate tissue-to-sediment PAH concentration ratios were reported to be 0.6 to 1.2 for amphipods, 0.1 for clams, and 0.05 for fin fish and shrimp.

It has been reported that terrestrial plants can accumulate PAHs from soil by uptake through the roots (ATSDR, 1995a). More careful investigation, however, reveals that root uptake is quite low, and there is no evidence of bioconcentration or biomagnification. For example, PAH ratios in vegetation to soil in one survey ranged from 0.001 to 0.18 for total PAHs, and from 0.002 to 0.33 for benzo(a)pyrene. It is likely that most of the PAH contamination on the vegetation resulted from atmospheric deposition. Increased concentrations in vegetation have not been observed when soil PAH concentrations were greatly increased by amendment with sewage sludge. Data from carrots (*Daucus carotu*) showed that PAHs adhere to the outer skin of the root but show little tendency to penetrate to deeper layers, and even less tendency to translocate to aerial parts.

The inability of plants to bioconcentrate PAHs from soil reduces concern for bioconcentration in agricultural products such as meat and milk. It should be noted, however, that measurable concentrations of PAHs may accumulate on the aerial parts of plants because of deposition from the atmosphere (ATSDR, 1995a). Also, food-producing animals ingest a substantial amount of soil while grazing or consuming mechanically harvested forage crops. Mammals, however, efficiently metabolize the PAHs to polar compounds that are readily excreted, reducing concern for bioconcentration.

In summary, the PAHs are highly lipophilic, which implies significance in food-chain exposure pathways. Empirical data, however, show that fish and mammals efficiently metabolize and eliminate these compounds. Furthermore, bioconcentration in plants because of uptake from soil is not significant. Therefore, it is unlikely that the PAHs would participate significantly in food-chain pathways, and biotransfer factors are not estimated.

3.0 Toxicokinetics

The PAHs are absorbed by all routes of exposure, but the rate and extent depends on the compound, the species of animal and the vehicle (or nature of the particulates) (ATSDR, 1995a). PAHs are readily absorbed during inhalation exposure; however, intratracheal instillation studies indicate that particle size is the most important determiner of the extent of pulmonary uptake.

Toxicokinetic studies of several PAHs summarized by ATSDR (1995a) provide limited quantitative information regarding the extent of GI absorption. Limitations arise largely because biliary excretion complicates quantification of uptake from the GI tract. A study of benzo(a)pyrene in rats suggests that GI absorption ranges from 38 to 58 percent. A study in rats reported absorption efficiency for anthracene ranging from 53 to 74 percent. GI absorption of pyrene, chrysene and dibenzo(a,h)anthracene is described as high. Administration of the test compound in oil or in a high-fat diet appears to increase the extent of GI absorption.

Empirical data with pure compound dissolved or suspended in various vehicles suggest that dermal uptake of benzo(a)pyrene is extensive (ATSDR, 1995a). One occupational study reported that approximately 75 percent of systemically absorbed pyrene entered the body through dermal uptake rather than through inhalation exposure. Combining PAHs with soil appears to significantly reduce the extent of dermal uptake compared with oleaginous or acetone vehicles.

Anecdotal evidence from using cloth diapers stored in contact with naphthalene indicates that naphthalene is absorbed by the skin, but quantitative data are not available (ATSDR, 1995b).

Distribution of absorbed PAHs is generally widespread, with highest levels located initially in lipid-rich tissues (ATSDR, 1995a). Highest levels of metabolites (radioactivity following administration of radiolabeled compounds) are located in the liver and GI tract, even after inhalation exposure, probably reflecting extensive metabolism in the liver followed by biliary excretion. Ciliary clearance and deglutition probably contribute to levels associated with the GI tract. Concentrations of radioactivity following administration of radiolabeled compound reveal fetal levels approximately 2- to 10-fold lower than maternal levels, although this depends on the specific compound administered.

Metabolism of the PAHs, particularly benzo(a)pyrene, has been extensively studied (ATSDR, 1995a). Metabolism proceeds rapidly, yielding products that are more water soluble and readily excreted than the parent compound. All tissues have the ability to metabolize the PAHs, potentially to carcinogenic intermediates, which probably accounts for the observation that cancers occur at the point of contact. There is considerable variability in tissue metabolic activity; however, the liver is probably the most active in most cases.

ATSDR (1995a) distinguishes between “alternant” and “nonalternant” PAHs, based on the nature of the electron density associated with the molecule, which influences how that compound is metabolized to its ultimate carcinogen. Alternant PAHs (e.g., benzo[a]pyrene, benzo[a]anthracene, chrysene, dibenz[a,h]anthracene) exhibit a uniformly distributed electron density. Nonalternant PAHs (e.g., fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-cd]pyrene) behave more like two separate molecules because of uneven electron distribution.

Alternant PAHs (based on data for benzo[a]pyrene) are initially metabolized by the microsomal cytochrome P-450 system to several arene oxides (ATSDR, 1995a). These may re-arrange spontaneously to phenols or undergo hydration to form the corresponding trans-dihydrodiols. Further oxidation of the dihydrodiols results in formation of quinones, phenol diols and dihydrodiol epoxides. Phenols may be formed by direct insertion of oxygen into a ring. Many of the metabolites resulting from the reactions described above are subject to conjugation with various substrates followed rapidly by excretion. The dihydrodiol epoxides that form in the “bay” region (the three-sided concave region formed by the fusion of three benzene rings) are most likely the ultimate carcinogens that covalently bind to macromolecules such as DNA, resulting in alkylation or other adducts that yield genetic errors.

Metabolism of the nonalternant PAHs differs from the alternant PAHs in that more extensive oxidation to hydroxy-epoxy-diols may be important to achieve genotoxicity (ATSDR, 1995a). Dihydrodiol epoxide formation in the bay region is associated with carcinogenicity of the PAHs generally; however, some of the nonalternant PAHs yield reactive metabolites that deviate from the classical bay region model.

PAH metabolites are readily excreted, largely through the bile, although some metabolites are excreted by the kidney (ATSDR, 1995a). The extent of elimination is species specific. In one inhalation study rats excreted metabolites much more efficiently than dogs or monkeys.

4.0 Dermal Exposure

EPA (2004) recommends that oral toxicity values for the PAHs should not be adjusted when applied to dermal exposure because GI absorption probably exceeds 50 percent. Therefore, no GAF is estimated and the oral toxicity values described below should be used for dermal exposure without adjustment.

Empirical data with pure compound dissolved or suspended in various vehicles suggest that dermal uptake of benzo(a)pyrene is extensive (ATSDR, 1995a). Anecdotal evidence from using cloth diapers stored in contact with naphthalene indicates that naphthalene is absorbed by the skin, but quantitative data are not available (ATSDR, 1995b). EPA (2004) reviewed empirical data regarding dermal uptake of benzo(a)pyrene and recommended an ABS of 0.13 for the PAHs. However, EPA (2004) also notes that VOCs tend to volatilize from soil when applied to the skin, reducing dermal uptake to toxicologically insignificant levels. Therefore, the ABS of 0.13 is applied to all the PAHs identified above as SVOCs. Dermal uptake of the PAHs identified as VOCs is not quantified.

Values for t*, K_p, τ, FA and B are provided or estimated as follows:

Chemical	t*	K_p	τ	FA	B
Acenaphthene[a]	1.84	8.39E-2	7.67E-1	1	0.4
Acenaphthylene[a]	1.79	1.08E-1	7.47E-1	1	0.5
Anthracene[a]	4.06	1.38E-1	1.05E+0	1	0.7
Benzo(a)anthracene[b]	8.53	4.7E-1	2.03E+0	1.0	2.8
Benzo(a)pyrene[b]	11.67	7.0E-1	2.69E+0	1.0	4.3
Benzo(b)fluoranthene[b]	12.03	7.0E-1	2.77E+0	1.0	4.3
Benzo(k)fluoranthene[a]	12.40	2.00E+0	2.72E+0	0.4	12
Benzo(g,h,i)perylene[a]	8.89	1.07E+0	3.70E+0	0.7	6.8
Chrysene[b]	8.53	4.7E-1	2.03E+0	1.0	2.8
Dibenz(a,h)anthracene[b]	17.57	1.5E+0	3.88E+0	0.6	9.7
Fluoranthene[b]	5.68	2.2E-1	1.45E+0	1.0	1.2
Fluorene[a]	2.15	1.07E-1	8.95E-1	1	0.5
Indeno(1,2,3-cd)pyrene[b]	16.83	1.0E+0	3.78E+0	0.6	6.7
Naphthalene[b]	1.34	4.7E-2	5.6E-1	1	0.2
Phenanthrene[b]	4.11	1.4E-1	1.06E+0	1	0.7
Pyrene[a]	3.42	1.94E-1	1.43E+0	1	1.1

t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).
[a]Estimated as described in Introduction to Toxicological profiles.
[b]Provided by U.S. Environmental Protection Agency (EPA), 2004, ***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.

5.0 Noncancer Effects Evaluation

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. The Group D PAHs have not been evaluated for carcinogenicity by toxicity testing; therefore, cancer SFs or URFs cannot be estimated for these compounds (EPA, 1986, 2012a). Risk evaluation of these compounds is limited to noncancer effects. It is theoretically possible that cancer risk could be the "driver" for some of these compounds. However, the mechanism of carcinogenicity of the PAHs is fairly well understood to be correlated with molecular morphology and the propensity to

form certain active metabolites (ATSDR, 1995a). The Group D PAHs either do not fit the morphologic mold or have been shown empirically to be unlikely to cause cancer, reducing greatly the uncertainty that significant cancer risk is being overlooked.

Cancer SFs and URFs are available for the Group B2 compounds, but noncancer RfDs or RfCs are not. Therefore, risk evaluation of these compounds is 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 until recently.

Recent data support this assumption. De Jong et al. (2008) 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. Fore stomach lesions were found in the 30 and 90 mg/kg groups. 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 a NOAEL of 2.1 mg/kg-day when adjusted for continuous exposure. 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 the noncancer effects of benzo(a)pyrene is essentially limited to one study and several toxicological endpoints (e.g., developmental, reproductive, neurological) were not investigated.

The sole purpose for developing this oral RfD is to evaluate the potential for noncancer effects to be the driver for the Group B2 PAHs. The RfD was not developed with sufficient rigor to be used in the risk assessment of the noncancer effects of benzo(a)pyrene. The oral SF for benzo(a)pyrene is 7.3 per mg/kg-day (please see below), from which it is estimated that the oral RfD is equivalent to a cancer risk of 1.5E-2. This cancer risk is orders of magnitude above the EPA (1990) risk management range of 1E-6 to 1E-4, strengthening the position that noncancer effects are unlikely to be the driver for the Group B2 PAHs.

Data regarding the toxicity of acute oral exposure to the PAHs are generally scarce. Prolonged oral exposure to the Group D PAHs is associated with a number of renal, hematologic and other effects, depending on the compound.

Subchronic (90 day) gavage treatment of mice with acenaphthene is associated with histopathologic evidence of liver hypertrophy. A verified RfD of 6E-2 mg/kg-day for chronic oral exposure was derived from the NOAEL of 175 mg/kg-day and an uncertainty factor of 3000 (EPA, 2012a). The LOAEL in this study was 350 mg/kg-day. Confidence in the RfD is low. The liver is considered the target organ for prolonged oral exposure to acenaphthene. EPA (1997) derived a provisional subchronic oral RfD for acenaphthene of 6E-1 mg/kg-day from the same mouse study using an uncertainty factor of 300.

A verified RfD of 3E-1 mg/kg-day for chronic oral exposure to anthracene was derived from a NOEL of 1000 mg/kg-day, the highest dose tested, in a 90-day gavage study in mice (EPA,

2012a). An uncertainty factor of 3000 was applied. Confidence in the RfD is low. The data are inadequate to identify a target organ for prolonged oral exposure to anthracene. EPA (1997) derived a provisional subchronic oral RfD for anthracene of 3E+0 mg/kg-day from the same mouse study using an uncertainty factor of 300.

Subchronic exposure to fluoranthene induces liver and kidney effects and hematologic alterations in orally treated mice (EPA, 2012a). A verified RfD of 4E-2 mg/kg-day for chronic oral exposure was derived from a NOAEL of 125 mg/kg-day in a 13-week gavage study. The LOAEL was 250 mg/kg-day in this study. An uncertainty factor of 3000 was applied. Confidence in the oral RfD is low. The kidney, liver and blood cells are chosen as the target organs for prolonged oral exposure to fluoranthene. EPA (1997) derived a provisional subchronic oral RfD for fluoranthene of 4E-1 mg/kg-day from the same mouse study using an uncertainty factor of 300.

Subchronic exposure to fluorene induces hemolytic anemia in orally treated mice (EPA, 2012a). A verified RfD of 4E-2 mg/kg-day for chronic oral exposure was derived from a NOAEL of 125 mg/kg-day in a 13-week gavage study. The LOAEL was 250 mg/kg-day in this study. An uncertainty factor of 3000 was applied. Confidence in the oral RfD is low. The erythrocyte is the target organ for prolonged oral exposure to fluorene. EPA (1997) derived a provisional subchronic oral RfD for fluorene of 4E-1 mg/kg-day from the same mouse study using an uncertainty factor of 300.

Single-dose LD_{50} values for naphthalene include 533 to 710 mg/kg for mice and 2200 to 2400 mg/kg for rats, establishing the mouse as more sensitive to the lethal effects of acute oral exposure (ATSDR, 1995b). Decreased terminal body weights, accompanied by a remarkable absence of hematological and histopathological effects, were observed in rats treated by gavage for 13 weeks (EPA, 2012a). The LOAEL in this study was 142 mg/kg-day associated with greater than 10 percent reduction in terminal body weights. The NOAEL was 71 mg/kg-day. The high dose rate, 286 mg/kg-day was a FEL associated with increased mortality. Application of an uncertainty factor of 3000 (10 to extrapolate from rats to humans, 10 to protect sensitive humans, 10 to extrapolate from subchronic to chronic exposure, and 3 for database deficiencies) to the NOAEL of 71 mg/kg-day yields the verified chronic oral RfD of 2E-2 mg/kg-day. Confidence in the RfD is low. A preliminary subchronic oral RfD can be derived for naphthalene by applying an uncertainty factor of 300 to the NOAEL of 71 mg/kg-day described above. The uncertainty factor of 300 reflects the chronic uncertainty factor of 3000 without the factor of 10 to expand from subchronic to chronic exposure. The preliminary subchronic oral RfD so derived is 2E-1 mg/kg-day.

The key study described above is not sufficient to identify target organs for prolonged oral exposure to naphthalene. Adults, children and neonates exposed to moth balls exhibit hemolytic anemia, evidence of liver disease and neurological deficits (EPA, 1993a, 1998). The liver effects and neurological deficits may be secondary to hemolytic anemia and reduced oxygen-carrying capacity of the blood. Hemolytic anemia and cataract formation have been seen also in orally exposed humans (EPA, 1998). The data suggest that the erythrocyte may be the most sensitive tissue in humans. Among common species of laboratory mammals, hemolytic anemia is seen only in dogs (EPA, 1998). Cataracts are seen in several laboratory mammals, but only at relatively high doses. The key study identifies reduced body weight as the critical effect in rats. Rats, however, do not exhibit hemolytic anemia, and exhibit cataracts only at very high doses,

suggesting that rats may not be a totally acceptable model for the toxicity of naphthalene to humans. Therefore, based on the effects observed in humans, the erythrocyte and eye are selected as target organs for prolonged oral exposure to naphthalene. Reduced body weight is also included as a critical effect because this was the only endpoint observed in rats in the key study.

EPA (1993a, 2012a) reported a 2-year study in which mice were exposed to naphthalene vapors for 6 hours/day on 5 days/week. Inflammation of the nasal and olfactory epithelium was the most consistently observed sign; granulomatous lesions in the lungs were also observed. There was equivocal evidence of hematologic involvement. The lowest exposure concentration, 10 ppm, was a LOAEL for the nasal effects, which are considered the critical effects of inhalation exposure. The LOAEL is equivalent to a human equivalent concentration of 9.3 mg/m^3 (EPA, 2012a). Application of an uncertainty factor of 3000 yields a verified chronic inhalation RfC of 3E-3 mg/m^3, which is equivalent to a chronic inhalation RfD of 8.6E-4 mg/kg-day. The nasal and olfactory epithelia are the target organs for inhalation exposure to naphthalene. Confidence in the RfC is medium. The chronic inhalation RfC of 3E-3 mg/m^3, equivalent to an inhalation RfD of 8.6E-4 mg/kg-day, is adopted as sufficiently protective for subchronic inhalation exposure as well.

Subchronic exposure to pyrene induces mild renal tubular degeneration and reduced kidney weight in orally treated mice (EPA, 2012a). A verified RfD of 3E-2 mg/kg-day for chronic oral exposure was derived from a NOAEL of 75 mg/kg-day in a 13-week gavage study. The LOAEL was 125 mg/kg-day in this study. An uncertainty factor of 3000 was applied. Confidence in the oral RfD is low. The kidney tubule is chosen as the target organ for chronic oral exposure to pyrene. EPA (1997) derived a provisional subchronic oral RfD for pyrene of 3E-1 mg/kg-day from the same mouse study using an uncertainty factor of 300.

Data regarding prolonged oral exposure are not available for several of the Group D PAHs, which hinders estimation of an RfD or RfC and compromises evaluation of the potential for noncancer effects. Therefore, surrogates are used to develop toxicity values for the noncancer effects.

Generally surrogates are chosen on the basis of the following hierarchy:

- Toxicological similarity (effects and dose-response relationship).
- Toxicokinetic similarity, assuming that likeness in absorption, distribution and especially products of biotransformation suggests toxicological similarity.
- Structural similarity, assuming that likeness in structure suggests similarity in toxicokinetics.

Selection of defensible surrogates for the PAHs is compromised because toxicological and toxicokinetic data are virtually non-existent (except for benzo[a]pyrene), and the structural similarities often are not very convincing, which imparts a great deal of uncertainty to the effort. Therefore, the most defensible approach for some of the PAHs is to select the most conservative surrogate; i.e., the PAH with the smallest verified oral RfD, which happens to be pyrene.

Data regarding the effects of chronic or subchronic exposure to acenaphthylene were not located in the available literature. Acenaphthene is adopted as a reasonable surrogate for acenaphthylene based on structural similarity, since the surrogate differs from the principal chemical only in the presence of two hydrogen atoms and the absence of a double bond. Therefore, the verified chronic oral RfD of 6E-2 mg/kg-day for acenaphthene is adopted as the RfD for chronic oral exposure to acenaphthylene. The liver, which is the target organ for acenaphthene, is adopted for oral exposure to acenaphthylene. Similarly, the provisional subchronic oral RfD of 6E-1 mg/kg-day for acenaphthene is adopted as the RfD for subchronic oral exposure to acenaphthylene.

Data regarding the effects of chronic or subchronic exposure to benzo(g,h,i)perylene were not located in the available literature. Pyrene is adopted as a reasonable surrogate for benzo(g,h,i)perylene based somewhat on structural similarity, but more on the selection of a conservative approach as justified above. Therefore, the verified oral RfD of 3E-2 mg/kg-day for pyrene is adopted as the oral RfD for chronic exposure to benzo(g,h,i)perylene. Similarly, the provisional subchronic oral RfD of 3E-1 mg/kg-day for pyrene is adopted as the RfD for subchronic oral exposure to benzo(g,h,i)perylene. The kidney tubule, which is the target organ for pyrene, is adopted for oral exposure to benzo(g,h,i)perylene.

Relevant data regarding chronic or subchronic exposure to phenanthrene were not located. Potential surrogates based on similarity in chemical structure include anthracene and pyrene. Pyrene is selected as the surrogate only because it is the more conservative choice. Therefore, the verified oral RfD of 3E-2 mg/kg-day for pyrene is adopted as the oral RfD for chronic exposure to phenanthrene. Similarly, the provisional subchronic oral RfD of 3E-1 mg/kg-day for pyrene is adopted as the RfD for subchronic oral exposure to phenanthrene. The kidney tubule, which is the target organ for pyrene, is adopted for oral exposure to phenanthrene.

Data regarding inhalation exposure sufficient for development of inhalation RfCs were not located for any of the PAHs with the exception of naphthalene as noted above.

6.0 Carcinogenicity Evaluation

Acenaphthylene, anthracene, benzo(g,h,i)perylene, fluoranthene, fluorene, phenanthrene and pyrene are classified in EPA cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans) because of a lack of human data and inadequate animal data (EPA, 2012a). Data regarding the carcinogenicity of acenaphthene were not located. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene are classified in EPA weight-of-evidence Group B2 (probable human carcinogens) (EPA, 1997, 2012a). Benzo(a)pyrene is the most extensively studied member of the class, inducing tumors in tissues at the point of contact of practically 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, 1995a). 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, 1995a).

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, 2012a). 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. Although the carcinogenicity of benzo(a)pyrene in animals managed in an unnatural manner in laboratory conditions has been well established, the potential for carcinogenicity to humans in environmental settings involving exposure to low concentrations remains unclear.

EPA (2012a) verified a SF for oral exposure to benzo(a)pyrene of 7.3E+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 potential 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. These values and the corresponding oral SFs, based on a relative potency for benzo(a)pyrene of 1.0, are presented below:

Relative Potency Estimates for PAHs				
			Inhalation	
PAH	Relative Potency	Oral Slope Factor (per mg/kg-day)	Unit Risk Factor (per µg/m^3)	Slope Factor (per mg/kg-day)
Benzo(a)pyrene	1.0	7.3E+0	8.8E-4	3.1E+0
Benzo(a)anthracene	0.1	7.3E-1	8.8E-5	3.1E-1
Benzo(b)fluoranthene	0.1	7.3E-1	8.8E-5	3.1E-1
Benzo(k)fluoranthene	0.01	7.3E-2	8.8E-6	3.1E-2
Chrysene	0.001	7.3E-3	8.8E-7	3.1E-3
Dibenz(a,h)anthracene	1.0	7.3E+0	8.8E-4	3.1E+0
Indeno(1,2,3-cd)pyrene	0.1	7.3E-1	8.8E-5	3.1E-1

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 7.3E+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 3.1E+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 URFs and SFs for the other Group B2 PAHs presented above.

EPA (2012a) classified naphthalene in EPA cancer weight-of-evidence group C – possible human carcinogen – based on benign respiratory tumors and one carcinoma in female mice exposed to naphthalene by inhalation. Cancer potency factors are not available on IRIS because the data were regarded as insufficient based on a 1998 review (EPA, 2012a). The EPA (2012a) review included an NTP (1992) inhalation study in mice that yielded equivocal data for carcinogenicity of the upper respiratory tract. A well executed National Toxicology Program (NTP) (2000) two-year intermittent exposure inhalation study was conducted to clarify the potential for carcinogenicity by the inhalation route..

The California Environmental Protection Agency (Cal EPA) (2012) derived an inhalation unit risk factor (URF) of 3.4E-5 per $\mu g/m^3$. This URF is as the basis of the Regional Screening Level for naphthalene in soil, air and groundwater (EPA, 2012b). The URF is based on the incidence of nasal tumors in male rats described in the NTP (2000) study. The Cal EPA derivation was performed in 2004 using dose-response extrapolation similar to the EPA (2012a) methodology. The Cal EPA URF for naphthalene qualifies as a Tier 3 derivation under the EPA (2003) hierarchy for selecting toxicity values for use in risk characterization and from which to estimate cleanup levels.

7.0 Toxicity Summary

Toxicity values for the PAHs are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
Acenaphthene										
6E-1	6E-2	L	ND	ND	NA	ND	NA	ND	NA	NA
Acenaphthylene										
6E-1	6E-2	L	ND	ND	NA	D	NA	D	NA	NA
Anthracene										
3E+0	3E-1	ND	ND	ND	NA	D	NA	D	NA	NA
Benzo(a)anthracene										
ND	ND	NA	ND	ND	NA	B2	7.3E-1	B2	8.8E-5	3.1E-1
Benzo(a)pyrene										
ND	ND	NA	ND	ND	NA	B2	7.3E+0	B2	8.8E-4	3.1E+0
Benzo(b)fluoranthene										
ND	ND	NA	ND	ND	NA	B2	7.3E-1	B2	8.8E-5	3.1E-1
Benzo(k)fluoranthene										
ND	ND	NA	ND	ND	NA	B2	7.3E-2	B2	8.8E-6	3.1E-2
Benzo(g,h,i)perylene										
3E-1	3E-2	K	ND	ND	NA	D	NA	D	NA	NA
Chrysene										
ND	ND	NA	ND	ND	NA	B2	7.3E-3	B2	8.8E-7	3.1E-3
Dibenz(a,h)anthracene										
ND	ND	NA	ND	ND	NA	B2	7.3E+0	B2	8.8E-4	3.1E+0
Fluoranthene										
4E-1	4E-2	L,K,B	ND	ND	NA	D	NA	D	NA	NA
Fluorene										

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
4E-1	4E-2	E	ND	ND	NA	D	NA	D	NA	NA
Indeno(1,2,3-cd)pyrene										
ND	ND	NA	ND	ND	NA	B2	7.3E-1	B2	8.8E-5	3.1E-1
Naphthalene										
2E-1	2E-2	E, Ey, BW	3E-3/ 8.6E-4	3E-3/ 8.6E-4	Ne, Oe	C	ND	C	3.4E-5	1.2E-1
Phenanthrene										
3E-1	3E-2	K	ND	ND	NA	D	NA	D	NA	NA
Pyrene										
3E-1	3E-2	K	ND	ND	NA	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); ND = no data; NA = not applicable.
Target organ or critical effect abbreviations: B = blood cells; BW = reduced body weight; E = erythrocyte; Ey = eye; L = liver; K = kidney; Ne = nasal epithelium; Oe = olfactory epithelium.
[a]sRfDo, cRfDo and SFo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 1995a, ***Update Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs)***, U.S. Public Health Service, Atlanta, Georgia, August, on line.

Agency for Toxic Substances and Disease Registry, (ATSDR), 1995b, ***Update Toxicological Profile for Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene***, U.S. Public Health Service, Atlanta, Georgia, August, on line.

California Environmental Protection Agency (Cal EPA), 2012, ***Toxicity Criteria Database***, Office of Environmental Health Hazard Assessment (OEHHA), http://www.oehha.ca.gov/risk/ChemicalDB/start.asp.

De Jong, W.H., E.D. Kroes, J.G. Vos and H. Van Loveren, 1999, "Detection of Immunotoxicity of Benzo[a]pyrene in a Subacute Toxicity Study after Oral Exposure in Rats," ***Toxicological Sciences*** 50: 214-220.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

Krewski, D., T. Thorslund and J. Withey, 1989, "Carcinogenic Risk Assessment of Complex Mixtures," ***Toxicology and Industrial Health***, 5: 851-867.

Lewtas, J., 1988, "Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources," ***Fundamental and Applied Toxicology***, 10: 571-589.

National Toxicology Program (NTP), 1992, ***Toxicology and Carcinogenesis Studies of Naphthalene (CAS No. 91-20-3) in B6C3F$_1$ Mice (Inhalation Studies)***, Technical Report Series No. 410 NIH Publication No. 92-3141, NTP, Research Triangle Park, NC.
Potter, T.L. and K.E. Simmons, 1998, ***Composition of Petroleum Mixtures***, Volume 2, Total Petroleum Hydrocarbon Criteria Working Group Series, University of Massachusetts, Amherst, May.

National Toxicology Program (NTP), 2000, ***Toxicology and Carcinogenesis Studies of Naphthalene (CAS No. 91-20-3) in F344/N Rats (Inhalation Studies)***, Technical Report Series No. 500 NIH Publication No. 00-4434, NTP, Research Triangle Park, NC.

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

U.S. Environmental Protection Agency (EPA), 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," ***Federal Register*** 55(46): 8666-8865.

U.S. Environmental Protection Agency (EPA), 1993a, ***Risk Assessment Issue Paper for: Derivation of a Subchronic RfC for Naphthalene (CASRN 91-20-3)***, National Center for Environmental Assessment, Cincinnati, Ohio, March 12.

U.S. Environmental Protection Agency (EPA), 1993b, ***Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons***, Office of Health and Environmental Assessment, Cincinnati, OH, EPA/600/R-93/089, March.

U.S. Environmental Protection Agency (EPA), 1994, ***Risk Assessment Issue Paper: Status of Inhalation Cancer Unit Risk for Benzo(a)Pyrene (CAS No. 50-32-8)***, National Center for Environmental Assessment, Cincinnati, OH, November 18.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, Washington, DC, 9200.6-303(97-1), EPA 540/R-97-036, PB97-921199.

U.S. Environmental Protection Agency (EPA), 1998, ***Toxicological Review of Naphthalene (CAS No. 91-20-3) In Support of Summary Information on the Integrated Risk Information System (IRIS)***, August.

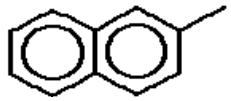
U.S. Environmental Protection Agency (EPA), 2003, ***Human Health Toxicity Values in Superfund Risk Assessments***, Memorandum from M.B. Cook, Director Office of Superfund Remediation and Technology Innovation to Superfund National Policy Managers, Regions 1 – 10, OSWER Directive 9285.7-53, 5 December.

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

U.S. Environmental Protection Agency (EPA), 2012a, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

U.S. Environmental Protection Agency (EPA), 2012b, ***Regional Screening Table***, http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm, April.

METHYLNAPHTHALENES



2-Methylnaphthalene

1.0 Introduction and Physical Properties

The methylnaphthalenes are the simplest alkylated polyaromatic hydrocarbons (PAH). Two monomethylnaphthalene isomers are possible: 1-methylnaphthalene (occasionally incorrectly called 4-methylnaphthalene) (90-12-0) and 2-methylnaphthalene (91-57-6). A commercial preparation of mixed isomers (1321-94-4) is mentioned (ATSDR, 2005; HSDB, 2012), but the proportion of the individual isomers was not reported. Both 1- and 2-methylnaphthalene are **VOCs**. 1-Methylnaphthalene occurs as a colorless liquid in the pure form at ambient temperatures (HSDB, 2012). 2-Methylnaphthalene reportedly occurs as a solid, but the melting point is 34.6 °C (approximately 94 °F), indicating that at high ambient temperatures the compound would occur as a liquid.

1-Methylnaphthalene is a component of petroleum and a product of incomplete combustion (HSDB, 2012). The compound is also used as a chemical intermediate and a general solvent. 2-Methylnaphthalene is used as an intermediate in organic chemical synthesis, as a dye carrier, in the manufacture of pesticides, as an adjuvant in pesticide formulations, and, in its pure form, in the manufacture of vitamin K. 2-Methylnaphthalene also is a component of crude oil and a product of combustion, which is produced and released to the environment during natural fires. Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
1-Methylnaphthalene (90-12-0)										
142.19[a]	3.87[a]	5.14E-4[a] (25°C)	3.36[a]	6.97E-2[b] (25°C)[c]	8.08E-6[b] (25°C)[c]	8.82E-5[a] (25°C)	2.58E+1[a] (25°C)	515[d]	772[d]	1.37E+4[d]
2-Methylnaphthalene (91-57-6)										
142.20[a]	3.86[e]	5.18E-4[e] (25°C)[c]	3.60[ae]	6.97E-2[b] (25°C)[c]	8.08E-6[b] (25°C)[c]	7.24E-5[a] (25°C)	41.4E+1[e] (25°C)	514[d]	761[d]	1.08E+4[d]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);. $H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole); ND = no data.

[a]Hazard Substances Data Bank (HSDB), 2012, National Library of Medicine.
[b]Calculated as described in Introduction to Toxicity Profiles.
[c]Assumed.
[d]National Institute of Standards and Technology (NIST), 2012, *NIST Chemistry WebBook*, on line.
[e] U.S. Environmental Protection Agency (EPA), 2012, *EPISuite electronic database*.

2.0 Environmental Fate and Transport

Emissions from petroleum refining, coal tar distillation, and gasoline and diesel fueled engines are major contributors of methylnaphthalenes to the environment (HSDB, 2012). Because of the widespread use of the methylnaphthalenes in a variety of products, they are also released to the environment in manufacturing effluents, the disposal of waste byproducts, through landfills,

municipal waste water treatment facilities and waste incinerators. Forest fires and uncontrolled combustion are relatively insignificant contributors (ATSDR, 2005).

Based upon their relatively high vapor pressure, the methylnaphthalenes are expected to exist entirely in the vapor phase in ambient air (HSDB, 2012). Direct photolysis of the methylnaphthalenes is likely to occur; however, only aqueous photolysis data are available. Reactions of the methylnaphthalenes with photochemically produced hydroxyl radicals (half-life = 7.4 hours) and ozone (half-life = 29 to 88 days) are likely to be important removal processes in ambient air. The formation of nitro derivatives in night-time air is also likely to be an important removal process for these compounds.

Data regarding the biodegradation of the methylnaphthalenes in soil were not available (HSDB, 2012). However, based upon aqueous screening test data and die-away tests for ground and marine water, the methylnaphthalenes are expected to biodegrade fairly rapidly in soils acclimated to PAHs and at a moderate rate in unacclimated soils. The methylnaphthalenes are not expected to undergo hydrolysis in soils; however, they are expected to undergo direct photolysis in sunlit surface soils. Mobility in soil is likely to be very low. Volatilization from moist soils may be a significant removal mechanism, although it will be attenuated by adsorption.

The methylnaphthalenes will partition from the water column to organic matter contained in sediments and suspended solids (HSDB, 2012). Volatilization is likely to be an important removal process for these compounds. Volatilization half-lives for a model river and model lake were estimated to be 5.5 hours and 5.3 days, respectively. The methylnaphthalenes are expected to degrade rapidly in marine water and waters acclimated to PAHs. Degradation is expected to be less rapid in unacclimated aquatic systems. The methylnaphthalenes are not expected to undergo hydrolysis in water; however, direct photolysis in sunlit waters is likely to be a significant removal process. The direct photolysis half-life for midday, midsummer sunlight at 40˚ N latitude was predicted to be 22 and 54 hours for 1- and 2-methylnaphthalene, respectively, in water solution.

The methylnaphthalenes are not expected to participate significantly in food-chain pathways (ATSDR, 2005; HSDB, 2012); therefore, biotransfer factors are not provided.

3.0 Toxicokinetics

Data regarding the toxicokinetics of the methylnaphthalenes are very limited. Data regarding the toxicokinetics of naphthalene, often used as a surrogate for the methylnaphthalenes, is somewhat more complete.

The observation that inhalation exposure to naphthalene leads to adverse effects in humans suggests that the methylnaphthalenes are also absorbed by the respiratory tract (ATSDR, 2005).

An excretion study with radiolabeled 2-methylnaphthalene in guinea pigs suggests that GI absorption is rapid and nearly complete, as 80 percent of the administered dose of radioactivity was recovered from the urine within 24 hours (ATSDR, 2005).

Data were not located regarding dermal uptake of the methylnaphthalenes. However, serious adverse health effects have been observed in humans dermally exposed to naphthalene, and animal studies show that naphthalene is rapidly and extensively absorbed through the skin, although using soil as the vehicle slows dermal absorption (ATSDR, 2005). These observations suggest that dermal uptake of the methylnaphthalenes may be significant.

Limited distribution data following oral administration of radiolabeled 2-methylnaphthalene to guinea pigs revealed the presence of radioactivity in the liver almost immediately after treatment (ATSDR, 2005). Relatively high levels were located in the gall bladder, liver and kidney, all of which represent excretion. Data from orally administered naphthalene suggests that distribution to adipose tissue is probably substantial, and that the methylnaphthalenes will probably cross the placenta and distribute to milk. As stated above, naphthalene is often used as a surrogate for the methylnaphthalenes because of structural similarity. Similarity in structure implies similarity in physical, chemical, toxicokinetic and toxicological characteristics.

The sole initial step in naphthalene metabolism is oxidation at the 1,2-position to form the epoxide, 1,2-naphthalene oxide (ATSDR, 2005). The epoxide may rearrange spontaneously to form 1- and 2-naphthol, or undergo enzymatic conversion to 1,2-dihydroxy, 1,2-dihydronaphthalene. The epoxide formed in the first step is recognized as an intermediate that reacts with tissue macromolecules inducing toxic effects, particularly in the lung. 1-Naphthol may undergo further oxidation to form 1,4-naphthoquinone, which has also been shown to interact with macromolecules, particularly in the liver. 1,2-Dihydroxy, 1,2-dihydronaphthalene may undergo further oxidation to form 1,2-naphthoquinone or 1,2-dihydroxy-3,4-epoxy-1,2,3,4-tetrahydronaphthalene. 1,2-Naphthoquinone may be the ultimate toxicant associated with naphthalene-induced cataracts. The toxicological significance of 1,2-dihydroxy-3,4-epoxy-1,2,3,4-tetrahydronaphthalene is unclear.

The presence of the methyl group on 1- or 2-methylnaphthalene may greatly alter the metabolic scheme for these chemicals compared with naphthalene. Data are available only for 2-methylnaphthalene, but the metabolism of 1-methylnaphthalene may be similar. The predominant pathway of 2-methylnaphthalene metabolism involves stepwise oxidation of the methyl group to form 2-hydroxymethylnaphthalene and 2-naphthoic acid, possibly through the aldehyde intermediate (ATSDR, 2005). This pathway accounts for 50 to 80 percent of 2-methylnaphthalene, depending on the species. The end products of this pathway are conjugated with glycine or glucuronic acid and excreted. Ring epoxidation at the 3,4-, 5,6- or 7,8- positions accounts for 15 to 20 percent of 2-methylnaphthalene. These epoxides may be subject to conjugation or may be further oxidized to form the corresponding dihydrols and other derivatives, which in turn undergo conjugation. Experiments with mice suggest that glutathione conjugation may be an important detoxication mechanism. Although data regarding the biological activity of methylnaphthalene metabolites is not as complete as data regarding the biological activity of the naphthalene metabolites, the differences in the metabolites formed are considerable.

Data regarding excretion of the methylnaphthalenes is limited to a study of 2-methylnaphthalene in guinea pigs. Approximately 80 percent of the radiolabel from a single oral dose was recovered within 24 hours in the urine; approximately 10 percent was recovered from the feces. Conjugated metabolites of the products of methyl group oxidation accounted for approximately 76 percent of

the recovered radioactivity. Approximately 18 percent of the recovered radiolabel represented epoxidation at the 7,8- positions.

4.0 Dermal Exposure

EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly (50 percent) less than complete. Therefore, no GAF is developed for the methylnaphthalenes and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

Data were not located regarding the dermal uptake of the methylnaphthalenes from soil. VOCs tend to volatilize from soil when applied to the skin, reducing dermal uptake to toxicologically insignificant levels (EPA, 2004). Therefore, dermal uptake of the methylnaphthalenes from soil is not evaluated. t*, K_p, τ, FA and B values are estimated by the EPA (2004) method as follows:

Chemical	t*	K_p	τ	FA	B
1-Methylnaphthalene	1.58	9.08E-2	0.657	1	0.42
2-Methylnaphthalene	1.58	8.94E-2	0.657	1	0.41
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).					

5.0 Noncancer Effects Evaluation

Data regarding the effects of human exposure to 1-methylnaphthalene were not located. Subchronic and chronic dietary studies with 1-methylnaphthalene in mice suggest that the toxic potency is low. An increased incidence of pulmonary alveolar proteinosis was the only lesion observed in mice treated at a dose rate of 73 mg/kg-day (lowest dose rate tested) in an 81-week study, but not in mice treated at a dose rate of approximately 1200 mg/kg-day (highest dose rate tested) in a 13-week study (EPA, 1998). These observations suggest that duration of exposure is very important in the toxicity of 1-methylnaphthalene. No RfD has been verififed for 1-methylnaphthalene. The ATSDR (2005) derived a chronic minimum risk level (MRL) of 7E-2 mg/kg-day. It is recommended that this MRL be used in risk assessment, but with the uncertainty of this value acknowledged.

Effects in humans from exposure to low levels of 2-methylnaphthalene appear to be limited to skin irritation and photosensitization (HSDB, 2012). Acute exposure to high levels may induce headaches, nausea, vomiting, diarrhea, anemia, jaundice, euphoria, dermatitis, visual disturbances, convulsions and coma.

EPA (2012) has provided a verified RfD of 4E-3 mg/kg-day based on pulmonary alveolar proteinosis in an 81-week oral study in mice (Murata et al., 1997). The 2-methylnaphthalene was administered at various dose levels in food. A statistically significant increase in the critical effect was observed in the lowest dose administered (50.3/54.3 mg/kg-day [female/male]). A benchmark dose level assuming 5 percent extra risk of pulmonary alveolar proteinosis of 4.7 mg/kg-day, with a 95 percent lower confidence limit of 3.5 mg/kg-day. UF values of 10 each were applied for interspecies differences, intraspecies variation, and database deficiencies for a

composite UF of 1,000. Confidence in the RfD is regarded as low (EPA, 2012). No EPA-derived subchronic oral RfD is available for the methylnaphthalenes. However, a preliminary subchronic oral RfD is assumed to be equal to the chronic RfD.

Data regarding chronic inhalation exposure of humans or animals to 1- or 2-methylnaphthalene were not located in the available literature. EPA (2012) concluded that an RfC cannot be calculated for 2-methylnaphthalene due to inadequate data. Neither were any epidemiological studies or case studies located which examined the potential effects of 1-methylnaphthalene or 2-methylnaphthalene (EPA, 2012). Therefore, no RfC is identified for either compound.

6.0 Carcinogenicity Evaluation

Under EPA's guidelines for carcinogen risk assessment, the database regarding the carcinogenicity of 2-methylnaphthalene in mice and the lack of human carcinogenicity data are inadequate to assess human carcinogenic potential (EPA, 2012). Therefore no oral SF has been idenifed. Although Murata et al., (1997) identified an increased incidence of pulmonary tumors in male mice at the lowest dose, the results of the study did not indicate an increased incidence of tumors at the high dose, nor were increased incidences of tumor observed in female mice. No studies were identified that suggest that inhalation exposure to 2-methylnaphthelene may cause cancer. Therefore, no unit risk has been verified (EPA, 2012). Neither was any information located to suggest that 1-methylnaphthalene is carcinogenic.

7.0 Toxicity Summary

Toxicity values for 1- and 2-methylnaphthalene are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
1-Methylnaphthalene										
7E-2	7E-2	Lung	ND	NA	NA	D	NA	D	NA	NA
2-Methylnaphthalene										
4E-3	4E-3	Lung	ND	NA	NA	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); NA = not applicable.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 2005, ***Update Toxicological Profile for Naphthalene, 1-Methylnaphthalene, and 2-Methylnaphthalene***, U.S. Department of Health and Human Services, Atlanta, GA, August

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line,.

Murata, Y., A. Denda, H. Maruyama et al., 1997, "Short Communication: Chronic Toxicity and Carcinogenicity Studies of 2-Methylnapthalene in B6C3F1 Mice," ***Fundamental and Applied Toxicology***, Volume 36, pp. 90-93.

U.S. Environmental Protection Agency (EPA), 1998, ***Toxicological Review of Naphthalene (CAS No. 91-20-3) In Support of Summary Information on the Integrated Risk Information System (IRIS)***, August.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP, NTIS No. PB99-963312, July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

VOLATILE ORGANIC COMPOUNDS

BENZENE (71-43-2)

1.0 Introduction and Physical Properties

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, 1997). It occurs as a colorless or slightly yellow liquid, or as a solid at temperatures below approximately 5.5 EC (HSDB, 2012). 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 as a component of gasoline. Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
78.1[a]	2.13[a]	5.56E-3[b] (25°C)	1.77[b]	8.80E-2[b] (25°C)	9.80E-6[b] (25°C)	1.25E-1[c] (25°C)	1.75E+3[b] (20-25°C)	353.24[d]	562.16[d]	7.34E+3[d]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole).

[a]U.S. Environmental Protection Agency (EPA), 2004, *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.

[b]U.S. Environmental Protection Agency (EPA), 2002, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, Final, Office of Solid Waste and Emergency Response, OSWER 9355.4-24, December.

[c]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

[d]U.S. Environmental Protection Agency (EPA), 2003, *Users Guide for Evaluating Subsurface Vapor Intrusion into Buildings*, Office of Emergency and Remedial Response, Washington, DC, 19 June.

2.0 Environmental Fate and Transport

Benzene enters the atmosphere primarily from fugitive emissions and automobile exhaust because of its presence in gasoline (ATSDR, 1997; HSDB, 2012). Other important sources are emissions associated with its production and use as a solvent, as an industrial intermediate in the production of the 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 and associated plumbing.

Benzene released to the atmosphere will exist almost exclusively in the vapor phase (ATSDR, 1997; HSDB, 2012). 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 containing nitrogen oxides or sulfur dioxide is accelerated with the half-life being reported as 4 to 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, 1997; HSDB, 2012). Benzene may be subject to biodegradation under aerobic conditions. Microbial transformation proceeds through formation of cis-dihydrodiols to catechols, which lead to destruction 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, 1997; HSDB, 2012). Benzene released to surface water will be subject to rapid volatilization. It is not expected to sorb to sediment or to hydrolyze significantly. Biodegradation is unlikely to be a significant fate process in sediment.

Benzene is not expected to participate significantly in food-chain pathways (ATSDR, 1997; EPA, 1995; HSDB, 2012); therefore, biotransfer factors are not provided.

3.0 Toxicokinetics

Benzene is rapidly and readily absorbed during inhalation exposures of humans or laboratory animals to vapors (ATSDR, 1997). However, the extent of uptake and retention decrease with increasing concentration or time of exposure, reflecting saturation of the metabolic processes that remove the substance from the blood. Excretion data from laboratory animals show that absorption is rapid and essentially complete following oral administration. Dermal uptake of liquid benzene through intact skin has been demonstrated in humans and may be toxicologically significant. The extent of dermal uptake of benzene vapor has not been quantified in humans, but experiments in laboratory animals suggest this exposure route also may be toxicologically significant.

Benzene is widely distributed following any route of exposure (ATSDR, 1997). Highest levels were located in adipose and other tissues high in fat such as the brain following inhalation exposure. Highest levels following oral administration were located in liver, kidney and bone marrow.

Quantitative aspects of the metabolism of benzene are somewhat species-, exposure route- and dose-dependent (ATSDR, 1997), but certain relevant generalizations pertain. The first metabolic step appears to be cytochrome P-450-catalyzed oxidation of benzene to benzene epoxide in the liver, which rearranges to phenol. Phenol is transformed to hydroxyquinone, which is further oxidized to benzoquinone, considered to be a major toxicant in bone marrow. Alternatively, phenol may be further oxidized to catechol and possibly to trihydroxybenzene. Phenol and all its derivatives except benzoquinone have been shown to undergo detoxication by conjugation with glucuronide or sulfate, followed by excretion.

A second general pathway involves the further oxidation of benzene oxide to benzene dihydrodiol, which leads to ring-opening and the formation of muconic dialdehyde, a known hematotoxin, primarily in the liver (ATSDR, 1997).

Absorbed benzene is excreted through the lungs as unchanged compound, and through the urinary tract as conjugated metabolites (ATSDR, 1997). Urinary excretion predominates.

Nothing in this review of toxicokinetics suggests that laboratory animals would not serve as appropriate models for the toxicity of benzene to humans.

4.0 Dermal Exposure

EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. Therefore, no GAF is developed for benzene and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

As mentioned above, benzene in the liquid and vapor form are absorbed through the skin (ATSDR, 1997). Combining benzene with soil slows dermal uptake. EPA (2004) notes that VOCs tend to volatilize from soil when applied to the skin, reducing dermal uptake to toxicologically insignificant levels. Therefore, dermal uptake of benzene from soil is not evaluated. EPA (2004) provides t*, K_p, τ, B and FA values as follows:

Chemical	t*	K_p	τ	FA	B
Benzene	0.70	1.5E-2	0.29	1	0.1
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).					

5.0 Noncancer Effects 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, 1997). Oral dosing in animals induces hematopoietic and immune effects. EPA (2012) verified a chronic oral RfD of 4E-3 mg/kg-day, based on hematological effects (reduced lymphocyte count) in a cross-sectional occupational study of 44 workers exposed to benzene. The workers were exposed for 0.7 to 16 years, with a mean of 6.3 years. Because the mean fell below 7 years, the minimal length considered to be chronic, the study is judged to be subchronic in duration. The control group consisted of an equal number of age- and gender-matched unexposed workers. The exposed workers were divided into two equal groups of 22: those exposed to airborne concentrations below and those exposed to airborne concentrations above the median concentration for all workers of 99 mg/m^3. An exposure-adjusted benchmark concentration (BMC) for minimal hematologic effects of 8.2 mg/m^3 was estimated. Assuming that uptake from the respiratory tract is approximately 50 percent of that from the GI tract allowed application of inhalation-to-oral extrapolation to estimate a benchmark dose (BMD) of 1.2 mg/kg-day. Application of an uncertainty factor of 300 to the BMD yielded the verified chronic oral RfD of 4E-3 mg/kg-day. The uncertainty factor of 300 consists of factors of 3 each for extrapolation from a BMC for minimal adverse effects to a BMC for no adverse effects, to expand from subchronic to chronic exposure, and to reflect deficiencies in the data base; a factor of 10 was used to provide additional protection for more sensitive human subpopulations. The blood cells (specifically inhibited hematopoiesis) are the target for prolonged oral exposure to benzene. Confidence in the chronic oral RfD is medium.

A preliminary subchronic oral RfD can be developed from the BMD described above. The subchronic oral RfD is derived by applying an uncertainty factor of 100 to the BMD of 1.2 mg/kg-day. The uncertainty factor of 100 reflects the uncertainty factor of 300 developed by EPA (2012) without the factor of 3 to expand from subchronic to chronic exposure. The preliminary subchronic oral RfD so derived is 1.2E-2 mg/kg-day, which is rounded to 1E-2 mg/kg-day.

A verified chronic inhalation RfC of 3E-2 mg/m^3 for benzene was based on the exposure-adjusted BMC of 8.2 mg/m^3 in the occupational exposure study from which the oral RfD values were derived (EPA, 2012). Application of the uncertainty factor of 300 (as described for the verified chronic oral RfD) to the BMC of 8.2 mg/m^3 yielded the chronic RfC of 3E-2 mg/m^3. The RfC is equivalent to an inhalation RfD of 8.6E-3 mg/kg-day. Confidence in the chronic inhalation RfC is medium. The blood cells (specifically inhibited hematopoiesis) are the target for prolonged inhalation exposure to benzene. A preliminary subchronic inhalation RfC can be derived by application of an uncertainty factor of 100 to the BMC of 8.2 mg/m^3 in the same manner as was done to derive the subchronic oral RfD. The subchronic inhalation RfC so derived is 8.2E-2 mg/m^3, rounded to 8E-2 mg/m^3. The preliminary subchronic inhalation RfC is equivalent to an inhalation RfD of 2.3E-2 mg/kg-day.

6.0 Carcinogenicity Evaluation

Benzene is classified as an EPA cancer weight-of-evidence Group A chemical – a known human carcinogen for all routes of exposure based upon convincing human evidence as well as supporting evidence from animal studies (EPA, 2012). Epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia, and also provide supportive evidence for chronic nonlymphocytic leukemia and chronic lymphocytic leukemia. Other neoplastic conditions in humans that are associated with benzene exposure include 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 range for inhalation exposure of 2.2E-6 to 7.8E-6 per µg/m^3 was based on the incidence of leukemia in humans exposed to benzene while employed in the Pliofilm industry (EPA, 2012). 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 (2012) 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 µg/m^3, is conservatively selected for this evaluation. The URF of 7.8E-6 per µg/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, 2012). 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 as described for the chronic oral RfD derivation. 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 conservatively selected as the oral SF for this evaluation.

7.0 Toxicity Summary

Toxicity values for benzene are summarized as follows:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure[a]		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
1E-2	4E-3	Bc	8E-2/ 2.3E-2	3E-2/ 8.6E-3	Bc	A	5.5E-2	A	7.8E-6	2.7E-2

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day).
Target organ abbreviations: Bc = blood cells.
[a]sRfDo, cRfDo and SFo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 1997, ***Update Toxicological Profile for Benzene***, U.S. Department of Health and Human Services, Atlanta, Georgia, September, on line.

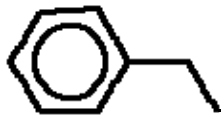
Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1995, "Final Water Quality Guidance for the Great Lakes System; Final Rule," (40 CFR 9, 122, 123, 131, and 132), ***Federal Register***, 60(56): 15365-15425.

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

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

ETHYLBENZENE (PHENYLETHANE) (100-41-4)



1.0 Introduction and Physical Properties

Ethylbenzene, also known as phenylethane, is a **VOC** that exists in the pure state as a colorless liquid at ambient temperatures (HSDB, 2012). It is used primarily as a precursor in the manufacture of styrene (ATSDR, 1999). It is also used as a solvent and diluent, and as an intermediate in the manufacturing of cellulose acetate, rubber and other organic compounds (ATSDR, 1999; HSDB, 2012). It is also a constituent of asphalt, naphtha, and automotive and aviation fuels. Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
106.2[a]	3.15[a]	7.88E-3[b] (25°C)	2.56[b]	7.50E-2[b] (25°C)	7.80E-6[b] (25°C)	1.26E-2[c] (25°C)	1.69E+2[b] (20-25°C)	409.34[d]	617.20[d]	8.50E+3[d]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole).
[a]U.S. Environmental Protection Agency (EPA), 2004, ***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, EPA/540/R/99/005, OSWER 9285.7-02EP, July.
[b]U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.
[c]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[d]U.S. Environmental Protection Agency (EPA), 2003, ***User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings***, Office of Emergency and Remedial Response, Washington, DC, June 19.

2.0 Environmental Fate and Transport

Ethylbenzene enters the atmosphere primarily from fugitive emissions and exhaust connected with its use in gasoline (ATSDR, 1999; HSDB, 2012). More localized sources to the air and other environmental media include fugitive emissions, waste water and spills from its production and industrial use, leaking underground storage tanks, land disposal of ethylbenzene-containing waste, and municipal and hazardous waste combustion.

Ethylbenzene exists in the air in the vapor phase (ATSDR, 1999; HSDB, 2012). It is somewhat water soluble and may be removed by precipitation; however, it is likely to reenter the air by volatilization. Ethylbenzene is transformed in air by various oxidative processes to yield ethylphenols, benzaldehyde, acetophenone, and m- and p-nitroethylbenzene. Reaction with photolytically generated hydroxyl radicals is probably the most significant reaction, with a half-life estimated to be 55 hours, suggesting that ethylbenzene will not persist in the air or travel long distances.

Ethylbenzene released to soil will volatilize rapidly (ATSDR, 1999; HSDB, 2012). That which infiltrates is expected to be quite mobile in soil and may leach to groundwater because sorption to soil particles is not sufficiently strong to retard movement. Biodegradation in soil in aerobic conditions involves oxidation of the ethyl side chain, ring hydroxylation and ring cleavage, and may be a significant source of removal. Anaerobic degradation is expected to be insignificant.

Ethylbenzene released to surface water will volatilize rapidly to air (ATSDR, 1999; HSDB, 2012). Biodegradation in aerobic conditions will significantly reduce water-borne concentrations. Photolysis and hydrolysis are unlikely to be significant. Ethylbenzene partitions weakly to sediment.

Ethylbenzene is not expected to participate significantly in food-chain pathways (ATSDR, 1999; EPA, 1995; HSDB, 2012); therefore, biotransfer factors are not provided.

3.0 Toxicokinetics

Ethylbenzene is rapidly absorbed during inhalation exposure, with retention near or exceeding 50 percent of the inhaled concentration (ATSDR, 1999). The compound is similarly rapidly absorbed following oral administration. Excretion data in rabbits suggest that a minimum of 72 to 92 of an oral dose is absorbed. Liquid ethylbenzene applied to the skin of humans is rapidly absorbed, but ethylbenzene vapor is poorly absorbed.

Ethylbenzene appears to be efficiently and widely distributed throughout the body following inhalation exposure (ATSDR, 1999). The same is expected following oral and dermal exposure, but data are lacking.

Metabolism in humans of absorbed ethylbenzene following either inhalation or oral exposure predominantly involves successive oxidation of the ethyl side-chain through 1-phenylethanol, acetophenone, ω-hydroxyacetophenone, and 1-phenyl-1,2-ethanediol to form mandelic acid and phenylglyoxylic acid (ATSDR, 1999). Small quantities of the first 4 intermediates are conjugated and excreted in the urine. Mandelic acid and phenylglyoxylic acid are excreted without conjugation and comprise the majority of excreted metabolites. A minor metabolic pathway involves epoxide formation and hydroxylation of the phenyl ring with or without oxidation of the ethyl group to yield small quantities of metabolites that are conjugated and excreted. Experiments with laboratory animals reveal species differences in the predominance of certain metabolites, but the pathways described above appear to hold. There is no evidence that the metabolites are more toxic than the parent compound.

Excretion of metabolites, primarily through the urine, is rapid and extensive in humans and laboratory animals (ATSDR, 1999). Pulmonary excretion of carbon dioxide is a minor pathway.

Nothing in this review of toxicokinetics suggests that laboratory animals would not serve as appropriate models for the toxicity of ethylbenzene to humans.

4.0 Dermal Exposure

EPA (2004) notes that organic chemicals are generally well absorbed from the GI tract, and recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. GI absorption of ethylbenzene is extensive as discussed in Section 3.0. Therefore, no GAF is developed for ethylbenzene and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

Data were not located for dermal uptake of ethylbenzene from soil. VOCs tend to volatilize from soil when applied to the skin, reducing dermal uptake to toxicologically insignificant levels

(EPA, 2004). Therefore, dermal uptake of ethylbenzene from soil is not evaluated. Values for t*, K_p, τ, FA and B are provided by EPA (2004) as follows:

Chemical	t*	K_p	τ	FA	B
Ethylbenzene	1.01	4.9E-2	0.42	1.0	0.2
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).					

5.0 Noncancer Effects Evaluation

An oral LD_{50} in rats of 5.46 g/kg (HSDB, 2012) suggests that the acute toxicity of ingested ethylbenzene is low. Subchronic to chronic oral exposure of laboratory animals to ethylbenzene induces mild liver and kidney lesions (EPA, 2012). EPA (2012) presents a verified chronic oral RfD for ethylbenzene of 1E-1 mg/kg-day based on a NOEL for liver and kidney lesions in female rats of 136 mg/kg-day in a six-month gavage study. The LOAEL in this study was 408 mg/kg-day. An uncertainty factor of 1000 was applied to the NOEL to derive the chronic oral RfD. The uncertainty factor consists of factors of 10 each to extrapolate from animals to humans, to provide additional protection for more sensitive humans, and to expand from subchronic to chronic exposure. Confidence in the oral RfD is low. The liver and kidney are the target organs for prolonged oral exposure to ethylbenzene.

No EPA-derived subchronic oral RfD is available for ethylbenzene. A preliminary subchronic oral RfD can be made, however, by applying an uncertainty factor of 100 to the NOEL of 136 mg/kg-day in the 6-month rat study described above. The uncertainty factor of 100 reflects the chronic uncertainty factor of 1000 without the factor of 10 for expansion from subchronic to chronic exposure. The preliminary subchronic oral RfD so derived is 1E+0 mg/kg-day.

Acute inhalation exposure induces irritation of the mucous membranes in animals and humans (ACGIH, 1991). Prolonged inhalation exposure induces liver enzymes and results in elevated liver and kidney weights; prolonged exposure to relatively high levels is associated with mild histopathological lesions of the liver, kidney and testes (ACGIH, 1991; EPA, 2012). EPA (2012) considered that the effects on the liver at the lower exposure concentrations are adaptive rather than adverse. EPA (2012) presented a verified chronic inhalation RfC of 1E+0 mg/m^3 derived from a human equivalent adjusted NOAEL of 434 mg/m^3 from studies on developmental effects in rats and rabbits. An uncertainty factor of 300 was used. The human equivalent adjusted LOAEL of 4340 mg/m^3 was associated with equivocal evidence of reduced fetal size in rabbits, an increased incidence of extra ribs in rat fetuses, and increased liver, kidney and spleen weights in the rats. The inhalation RfC is equivalent to 2.9E-1 mg/kg-day. Confidence in the RfC is low. The chronic inhalation RfC is adopted as being sufficiently conservative for subchronic as well as chronic inhalation exposure.

The key study from which the inhalation RfC is derived does not clearly identify target organ(s) for inhalation exposure to ethylbenzene. The entire inhalation exposure data base, however, suggests that the liver, kidneys and fetus may be the most significant target organs for prolonged inhalation exposure.

6.0 Carcinogenicity Evaluation

Ethylbenzene is currently verified as a cancer weight-of-evidence Group D compound (not classifiable as carcinogenicity to humans) (EPA, 2012) based on an absence of human or animal cancer studies. Cancer potency factors are not estimated for Group D compounds.

7.0 Toxicity Summary

Toxicity values for ethylbenzene are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
1E+0	1E-1	L, K	1E+0/ 2.9E-1	1E+0/ 2.9E-1	L, K, F	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); NA = not applicable.
Target organ or critical effect abbreviations: L = liver; K = kidney; F = fetus.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry, (ATSDR), 1999, ***Update Toxicological Profile for Ethylbenzene***, U.S. Department of Health and Human Services, Atlanta, Georgia, July, on line.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, Cincinnati, OH, p. 581-584.

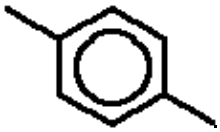
Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1995, "Final Water Quality Guidance for the Great Lakes System; Final Rule," (40 CFR 9, 122, 123, 131, and 132), ***Federal Register***, 60(56): 15365-15425.

U.S. Environmental Protection Agency (EPA), 2004, ***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, EPA/540/R/99/005, OSWER 9285.7-02EP, July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

XYLENES (DIMETHYLBENZENE), TOTAL (1330-20-7)



p-Xylene

1.0 Introduction and Physical Properties

The xylenes, also known as dimethylbenzenes, exist as three isomers: 2-xylene (1,2-dimethylbenzene, ortho- or o-xylene) (95-47-6), 3-xylene (1,3-dimethylbenzene, meta- or m-xylene) (108-38-3) and 4-xylene (1,4-dimethylbenzene, para- or p-xylene) (106-42-3) (HSDB, 2012). The o-, m-, and p-xylene nomenclature will be used herein to be consistent with the manner in which xylene concentrations in environmental media are usually reported by the analytical laboratories.

The xylenes are **VOCs** derived from coal tar, coal gas, and petroleum distillation (ATSDR, 1995; HSDB, 2012). They occur as clear liquids in the pure state at most ambient temperatures, although 4-xylene occurs as colorless plates or prisms at temperatures below 56EF (13.33EC). 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, 1995; HSDB, 2012). They are components of aviation gasoline, asphalt and naphtha, and automobile exhaust. Technical xylene consists of approximately 44 percent m-xylene, 20 percent o-xylene, 20 percent p-xylene, and 15 percent ethylbenzene. Relevant physical properties are compiled below:

MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
o-Xylene (95-47-6)										
106.16[a]	3.12[a]	5.20E-3[b] (25°C)	2.56[b]	8.70E-2[b] (25°C)	1.00E-5[b] (25°C)	8.70E-3[a] (25°C)	1.78E+2[b] (20-25°C)	417.60[c]	630.30[c]	8.66E+3[c]
m-Xylene (108-38-3)										
106.2[d]	3.20[d]	7.34E-3[b] (25°C)	2.61[b]	7.00E-2[b] (25°C)	7.80E-6[b] (25°C)	1.09E-2[a] (25°C)	1.16E+2[b] (20-25°C)	412.27[c]	617.05[c]	8.52E+3[c]
p-Xylene (106-42-3)										
106.16[a]	3.15[a]	7.66E-3[b] (25°C)	2.59[b]	7.69E-2[b] (25°C)	8.44E-6[b] (25°C)	1.16E-2[a] (25°C)	1.85E+2[b] (20-25°C)	411.52[c]	616.20[c]	8.53E+3[c]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole).

[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

[b]U.S. U.S. Environmental Protection Agency (EPA), 2002, ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites***, Office of Solid Waste and Emergency Response, Washington, D.C., 9355.4-24, December.

[c]U.S. Environmental Protection Agency (EPA), 2000, ***User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings, Revised***, Office of Emergency and Remedial Response, Washington, DC, December.

[d]U.S. Environmental Protection Agency (EPA), 2004, ***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.

It is recommended that the physical properties for m-xylene should be applied to mixed xylene isomers or data where the specific isomer is not identified, because m-xylene is the major component of the technical mixture and is likely to predominate following xylene releases.

2.0 Environmental Fate and Transport

Naturally occurring sources of xylenes are petroleum, forest fires and volatiles from plants (ATSDR, 1995; HSDB, 2012). The production and use of xylenes in petroleum products and as chemical solvents and intermediates may result in their release to the environment as fugitives and through various waste streams. Off-gassing from landfills and automobile exhaust are other significant sources. Spills, leaking underground storage tanks and associated plumbing, 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, 1995; HSDB, 2012). 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, 1995). 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_{oc} values have been reported in soil samples with differing pH and organic carbon content (HSDB, 2012), 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, 1995). 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, 2012).

Xylenes are not expected to participate significantly in food-chain pathways (ATSDR, 1995; HSDB, 2012); therefore, biotransfer factors are not provided.

3.0 Toxicokinetics

Xylenes are rapidly and extensively absorbed during inhalation and following oral exposure (ATSDR, 1995). In humans, approximately 50 to 73 percent of the inhaled concentration is retained. In laboratory animals, approximately 90 percent of an ingested dose is absorbed. Liquid xylene is absorbed through the skin of humans, but dermal uptake of xylene vapors approximates only 1 percent of inhalation uptake. A study in rats showed that dermal uptake of xylene adsorbed to soil is much slower than dermal uptake of the neat liquid.

Absorbed xylene is largely bound to serum protein in the blood and is distributed rapidly and widely throughout the body, but particularly to highly vascular tissues and those high in lipid content (e.g., blood, brain, liver) (ATSDR, 1995). Levels in fetal tissues approximate 2 percent of those measured in maternal brain.

The predominant metabolic pathway in humans and animals for all xylene isomers is oxidation of one of the methyl groups to the corresponding alcohol, with further oxidation to the corresponding methylbenzoic acid (ATSDR, 1995). The methylbenzoic acids conjugate with

glycine to form the corresponding methylhippuric acids, which are the major urinary metabolites. Much lesser quantities of the alcohols and o-methylbenzoic acid are also excreted in the urine. Methylbenzaldehyde, proposed as the ultimate toxicant because it inactivates enzymes involved in electron transport, has been identified in laboratory animals but not in humans. Metabolism in laboratory animals differs from that in humans largely in the nature of the conjugates that are formed. Ring hydroxylation to form phenolic compounds represents a minor metabolic pathway is both humans and animals.

The xylenes are rapidly excreted from the body, largely in the form of urinary metabolites (ATSDR, 1955) as described above. Approximately 5 percent of an oral dose is eliminated in the breath as unchanged compound. Residues are slightly more persistent in adiposa and muscle tissue than other tissues of the body, but no organ or tissue accumulates xylene residues.

4.0 Dermal Exposure

EPA (2004) recommends that oral toxicity values should not be adjusted when used for dermal exposure unless empirical data demonstrate that GI absorption is significantly less than complete. Xylenes are nearly completely absorbed from the GI tract; therefore, no GAF is developed for the xylenes and the oral toxicity values described below should be used for dermal exposure without adjustment for GI absorption.

Xylene in soil is absorbed by the skin, albeit very slowly, but quantitative data were not located. VOCs tend to volatilize from soil when applied to the skin, reducing dermal uptake to toxicologically insignificant levels (EPA, 2004). Therefore, dermal uptake of xylenes from soil is not evaluated. Values for t*, K_p, τ, FA and B are provided by EPA (2004) for m-xylene as follows:

Chemical	t*	K_p	τ	FA	B
m-Xylene	1.01	5.3E-2	0.42	1.0	0.2
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).					

The dermal uptake parameters presented by EPA (2004) for m-xylene are applied to all the xylene isomers as well as to total xylenes.

5.0 Noncancer Effects Evaluation

Oral LD_{50} values for xylenes include 3.5 to 8.6 g/kg in rats and 1.6 to 5.6 g/kg in mice (HSDB, 2012), 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 reduced body weight and survival without histopathological alterations in the internal organs (EPA, 2012). EPA (2012) confirmed a previously verified chronic oral RfD for total xylenes of 2E-1 mg/kg-day based on a NOAEL of 250 mg/kg, equivalent to a continuous dose rate of 179 mg/kg-day, for decreased body weight and survival in male rats in chronic gavage studies with mixed xylenes. The LOAEL was 500 mg/kg, equivalent to 357 mg/kg-day. Mice were also included in the study. The LOAEL in mice was 1000 mg/kg, equivalent to 714 mg/kg-day, associated with hyperactivity, which was consistently observed at 5 to 30 minutes after treatment. The mice did not exhibit the effects on body weight or survival that was

observed with the rats, establishing the rat as the more sensitive species to prolonged oral exposure. An uncertainty factor of 1000 was applied to the rat NOAEL to derive the verified chronic oral RfD. Confidence in the chronic oral RfD is medium.

EPA (1997) presented provisional chronic oral RfDs for o-xylene and m-xylene of 2E+0 mg/kg-day based on an earlier IRIS evaluation of the same rat and mouse gavage study. Given the EPA (2012) re-evaluation of this study and the lowering of the chronic oral RfD by an order of magnitude, it seems prudent to adopt the verified chronic oral RfD of 2E-1 mg/kg-day for use with mixed xylenes and all xylene isomers. The critical effects of prolonged oral exposure to xylenes are reduced body weight and reduced survival. The verified chronic oral RfD is adopted as sufficiently protective for subchronic oral exposure to mixed xylenes and all 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. EPA (2012) verified a chronic inhalation RfC of 1E-1 mg/m^3 based on CNS effects. In the key study, male rats were intermittently exposed to m-xylene at airborne concentrations of 0, 50 or 100 ppm for three months. Endpoints evaluated included spontaneous motor activity and motor coordination as measured by performance on a rotorod. Body and organ weights and limited blood chemistry and hematological parameters were also evaluated, but minor alterations in these endpoints were not attributed to exposure to m-xylene. The study identified 50 ppm as the NOAEL and 100 ppm as the LOAEL for impaired rotorod performance. The NOAEL is equivalent to an adjusted human equivalent concentration of 39 mg/m^3. Application of an uncertainty factor of 300 to the NOAEL yields the verified chronic inhalation RfC of 1E-1 mg/m^3, which is equivalent to a chronic inhalation RfD of 2.9E-2 mg/kg-day. The uncertainty factor consists of a factor of 10 to provide greater protection for more sensitive individuals, and factors of 3 each to extrapolate from animals to humans, to expand from subchronic to chronic exposure, and to account for deficiencies in the data base. The CNS is considered to be the target organ for prolonged inhalation exposure to xylenes. Confidence in the chronic inhalation RfC is medium.

No EPA-derived subchronic inhalation RfC is available for exposure to xylene. However, a preliminary subchronic inhalation RfC can be derived by applying an uncertainty factor of 100 to the NOAEL of 39 mg/m^3 in the subchronic rotorod study in rats described above. The uncertainty factor of 100 reflects the chronic uncertainty factor of 300 without the factor of 3 to expand from subchronic to chronic exposure. The preliminary subchronic inhalation RfC so derived is 4E-1 mg/m^3, which is equivalent to a subchronic inhalation RfD of 1.1E-1 mg/kg-day.

6.0 Carcinogenicity Evaluation

Xylene was previously characterized as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans). Using a more descriptive characterization, EPA (2012) concluded that the cancer *data are inadequate for an assessment of the carcinogenic potential of xylenes*. Adequate human data on the carcinogenicity of the xylenes are not available, and the available animal data are inconclusive as to the ability of xylenes to cause a carcinogenic response. Evaluations of the genotoxic effects of xylenes have consistently given negative results. Potency factors are not available.

7.0 Toxicity Summary

Toxicity values for the xylenes are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
2E-1	2E-1	BW, Su	4E-1/ 1.1E-1	1E-1/ 2.9E-2	CNS	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); NA = not applicable.
Target organ or critical effect abbreviations: BW = reduced body weight; Su = reduced survival; CNS = central nervous system.
[a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 1995, ***Update Toxicological Profile for Xylenes***, U.S. Department of Health and Human Services, Atlanta, Georgia, August, on line.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, ***Documentation of the Threshold Limit Values and Biological Exposure Indices***, Sixth Edition, Cincinnati, OH, pp. 1732-1740.

Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, NTIS No. PB97-921199.

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

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

MISCELLANEOUS

CYANIDE ANION (57-12-5), FREE CYANIDE, HYDROGEN CYANIDE (74-90-8)

Cyanide Anion

1.0 Introduction and Physical Properties

The term cyanide is properly used to mean the cyanide anion illustrated above. The term is also used herein to represent any form of cyanide, particularly if the form was not specified in the literature cited. The term free cyanide generally means the cyanide anion, hydrogen cyanide and some cyanide salts (e.g., sodium cyanide, potassium cyanide) that readily dissociate and release cyanide in water solutions within the biological pH range (ATSDR, 2006). Chlorine-amenable cyanide includes free cyanide as well as most organic complexes and most simple metal complexes. The chlorine-amenable fraction excludes iron cyanides, which resist degradation with release of cyanide. Total cyanide includes all of the above.

Concentrations of cyanide reported by various analytical procedures do not necessarily reflect the amount that is bioavailable, and data are not available with which to quantify bioavailability (ATSDR, 2006). Free cyanide and simple water soluble complexes (part of the chlorine-amenable fraction) are expected to be highly bioavailable. More complicated organic complexes and many metal complexes are expected to be somewhat less bioavailable, but the nature of the specific compound and pH of the matrix will greatly influence bioavailability. A reasonably conservative approach (adopted herein) is to evaluate total cyanide in the RA. A more reasonable approach, including only chlorine-amenable cyanide in the RA, might be justified if there were large differences between concentrations of chlorine-amenable and total cyanide. Large differences (upwards of an order of magnitude) might be expected in mining situations where metal complexes are expected to predominate.

Hydrogen cyanide is used in the synthesis of a wide range of organic chemicals (ATSDR, 2006; HSDB, 2012). Cyanide salts are used in metal treatment, ore extraction, as anticaking agents in road salt, and in a wide variety of other uses. Hydrogen cyanide has been used formerly to fumigate grain to control insects and rodents, and to exterminate rodents in their burrows. The cyanide anion is an **inorganic** substance. Hydrogen cyanide is a liquid, or gas above 26.5 EC (HSDB, 2012), and behaves very much like a **VOC** in the environment. Relevant physical properties of inorganic cyanide and hydrogen cyanide are compiled below:

Cyanide Anion (57-12-5)							
MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
26.02[a]	NA	NA	NA	NA	NA	NA	Note 1[b]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; K_d = soil/water partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; NA = not applicable.
Note 1: Several simple complexes or salts (e.g., hydrogen cyanide, sodium cyanide, potassium cyanide) are highly soluble in water, while other salts and organic complexes are sparingly soluble or practically insoluble in water.
[a]Howard, P.H. and M. Neal, 1992, ***Dictionary of Chemical Names and Synonyms***, Lewis Publishers, Ann Arbor.
[b]Agency for Toxic Substances and Disease Registry (ATSDR), 1997, ***Update Toxicological Profile for Cyanide***,

Cyanide Anion (57-12-5)							
MW	log K_{ow}	H	K_d	D_a	D_w	VP	S
U.S. Department of Health and Human Services, Atlanta, GA, on line, September.							

Hydrogen Cyanide (74-90-8)										
MW	log K_{ow}	H	log K_{oc}	D_a	D_w	VP	S	T_b	T_c	$\Delta H_{v,b}$
27.03[a]	-0.25[a]	1.33E-4[a] (25°C)[b]	-0.044[c]	2.11E-1[c] (25°C)[b]	2.44E-5[c] (25°C)[b]	9.76E-1[a] (25°C)	1E+6[a] (25°C)	298.8[a]	456.7[a]	6.02E+3[a]

MW = molecular weight (g/mole); log K_{ow} = base 10 logarithm of the octanol/water partition coefficient (unitless); H = Henry's Law constant (atm-m^3/mole) at the reference temperature; log K_{oc} = base 10 logarithm of the soil/organic carbon partition coefficient (L/kg); D_a = diffusivity in air (cm^2/second); D_w = diffusivity in water (cm^2/second); VP = vapor pressure (atm) at the reference temperature; S = solubility in water (mg/L) at the reference temperature; T_b = normal boiling point (at 1 atm) of pure liquid compound (°K); T_c = critical temperature (°K);.$H_{v,b}$ = enthalpy of vaporization at the boiling point (cal/mole).
[a]Hazardous Substance Data Bank (HSDB), 2012, National Library of Medicine, on line.
[b]Assumed.
[c]Calculated as described in Introduction to Toxicity Profiles.

2.0 Environmental Fate and Transport

Cyanide is a naturally occurring substance (ATSDR, 2008; HSDB, 2012). Hydrogen cyanide may be produced naturally by microorganisms as well as from the degradation of cyanogenic glycosides, which are produced naturally by many plants. Several species of blue-green algae liberate hydrogen cyanide in the process of nitrate metabolism. Laetrile and amygdalin, which occur in substantial concentrations in several fruit pits (e.g., cherries, peaches, apricots, apples, pears) liberate cyanide following ingestion.

Major releases to the environment occur from metal treatment and ore extraction (primarily to water) and in automobile exhaust (primarily to the atmosphere) (ATSDR,2008). The production of hydrogen cyanide and its use as a starting material in the manufacture of acrylates, cyanide salts, herbicides and dyes as well as its former use as a fumigant may result in its release to the environment through various waste streams (HSDB, 2012). It also may be liberated from blast furnaces, gas works, coke ovens and oil shale retorting operations. Most hydrogen cyanide is emitted primarily to the atmosphere or waste water. Various cyanide salts may be released during their use in ore extraction and other metallurgic operations. Materials containing cyanide compounds disposed on land may cause elevated levels of cyanide in underlying strata and in groundwater. Cigarette smoke contains low levels of hydrogen cyanide.

Hydrogen cyanide released to the atmosphere is expected to remain solely in the vapor phase and to react slowly with photochemically generated hydroxyl radicals (HSDB, 2012). A half-life of approximately 300 to 550 days has been estimated for this reaction. Hydrogen cyanide is expected to be resistant to direct photolysis. The relatively slow rate of degradation suggests that hydrogen cyanide has the potential for transport over long distances before being removed by physical or chemical processes. Since hydrogen cyanide is miscible in water, wet deposition may be the most important removal process. Metal cyanide particles released to the air in dust are expected to be removed by both wet and dry deposition.

Cyanide may occur in the form of hydrogen cyanide, metal salts, or immobile metallocyanide complexes in soil (ATSDR, 2008; HSDB, 2012). It is expected that volatilization of hydrogen cyanide would be an important mechanism for cyanide removal from dry soil surfaces and from moist soil surfaces with pH less than 9.2. Hydrogen cyanide and many cyanide salts are very water soluble and are expected to be highly mobile in soil, readily leaching to deeper levels and to groundwater. Concentrations sufficiently low so as not to be toxic to microorganisms may undergo biodegradation in subsurface soil. Microbial degradation may yield formamide, or

complete mineralization may yield carbon dioxide and ammonia. Degradation of low concentrations in soil may substantially reduce the potential for leaching to groundwater.

Hydrogen cyanide is not expected to adsorb to suspended solids and sediment in water (HSDB, 2012). Volatilization from water surfaces is expected to be the most important removal mechanism. Biodegradation may be an important removal mechanism for low concentrations that are not toxic to microorganisms as explained for soil.

Hydrogen cyanide is volatile and labile at low concentrations. Its low log K_{ow} suggests that bioconcentration is unlikely to be significant. Some metal complexes have been shown to biotransfer, but the toxicity of these complexes is much less than that of hydrogen cyanide because of their very low solubility (ATSDR, 2008). There is no evidence of biomagnification in the food chain (ATSDR, 2008), and EPA (1995) has determined that cyanide is not a threat to human health through fish consumption. Biotransfer factors are not estimated for cyanide for these reasons.

3.0 Toxicokinetics

Inhalation exposure of humans to hydrogen cyanide results in very rapid absorption and high systemic retention (approximately 58 percent retention) (ATSDR,2008). Absorption is similarly rapid following oral exposure. Excretion data from orally treated animals suggest a minimum absorption factor of approximately 50 percent, but the extent of absorption is probably much higher. Dermal absorption of hydrogen cyanide by humans is inferred from toxicity data and supported by data from experimental animals. It is likely that some cyanide salts may also be absorbed but the extent has not been quantified.

Cyanide is rapidly and widely distributed throughout the body following absorption (ATSDR,2008).

The primary detoxication pathway involves the action of the enzyme rhodanese to combine cyanide with sulfane sulfur to yield thiocyanate, which is rapidly excreted through the urine (ATSDR, 2008). Rhodanese activity is located in most tissues of the body; the relative activity largely dependent on species. Highest levels are not generally found in the liver, which is often the primary site of metabolism for environmental contaminants. Minor detoxication pathways include pulmonary excretion of hydrogen cyanide, conversion of cyanide to carbon dioxide or other constituents that enter the single-carbon pool, and incorporation into cyanocobalamin (vitamin B_{12}). Elimination occurs rapidly, resulting in a half-life for cyanide of approximately 6 hours in humans. The incorporation of carbon into the single-carbon pool may account for the low estimate of extent of GI absorption from excretion data.

Hydrogen cyanide is the toxic moiety, complexing with ferric iron in various metalloenzymes, inhibiting mitochondrial cytochrome c oxidase and resulting in histotoxic anoxia (ATSDR,2008). Several changes follow that exacerbate the original biochemical lesion.

4.0 Dermal Exposure

GI absorption of cyanide almost certainly exceeds 50 percent as noted in Section 3.0. EPA (2004) suggests that oral toxicity values should not be adjusted when used for dermal exposure

unless GI absorption is less than 50 percent. Therefore, the oral toxicity values described below are adopted without modification for use for dermal exposure

EPA (1991) stated that, "performing an oral-to-dermal extrapolation would not be appropriate because of the uncertainty that the oral RfD for cyanide would provide protection for the effects caused by dermal exposure." The available data, however, suggest that the effects following oral and dermal exposure are similar (ATSDR, 2008). Furthermore, nothing in the toxicokinetic data suggest that detoxication would occur more efficiently following oral exposure so that the oral RfD may not be sufficiently protective for dermal exposure. Therefore, it is judged that the oral RfD is an appropriate value with which to evaluate the toxicity of dermal exposure to cyanide.

Two scenarios are relevant to dermal exposure to cyanide. The first scenario is exposure to cyanide in soil. Cyanide present in soil as hydrogen cyanide would be likely to volatilize so that dermal exposure is expected to be insignificant, as noted by EPA (2004) for other VOCs. Therefore, dermal exposure to hydrogen cyanide in soil is not quantified. It is possible that cyanide may exist as various salts or complexes in soil. Although these compounds may be dermally absorbed, the extent has not been quantified, so no ABS is available with which to quantify dermal uptake. Therefore, dermal uptake of cyanide from soil is not quantified, as recommended by EPA (2004).

The second scenario is exposure to cyanide in water, which may occur as hydrogen cyanide or soluble salts. Cyanide in water will be assumed to be present entirely as hydrogen cyanide to simplify the evaluation. Values for t*, K_p, τ, B and FA estimated by the EPA (2004) methodology follow:

Chemical	t*	K_p	τ	FA	B
Hydrogen Cyanide	0.36	7.65E-4	0.15	1	0.0
t* = time for dermal uptake to reach steady state (hours); K_p = permeability coefficient (cm/hour); τ = lag time for chemical to cross stratum corneum (hours); FA = fraction absorbed (unitless); B = ratio of the permeability coefficient for passage across the stratum corneum relative to the permeability coefficient for passage across the viable epidermis (unitless).					

5.0 Noncancer Effects Evaluation

Oral LD_{50} values in laboratory animals range from 8 to 22 mg/kg, depending on the particular cyanide compound and laboratory species (ATSDR, 2008; HSDB, 2012), indicating that the acute oral toxicity of cyanide is high. An updated, verified chronic oral RfD of 6E-4 mg/kg-day for hydrogen cyanide and cyanide salts was derived in September 2010 from a National Toxicology Program (NTP) examination of cyanide over a wide range of concentrations in both male and female rats and mice, under subchronic (91-day) conditions. Confidence in the RfD is low to medium.

Reproductive effects were observed in males of both species, though rats appeared to be more sensitive. A statistically significant decrease (7%) in cauda epididymis weight was observed at doses of 1.4 mg/kg-day or greater. This effect was identified by EPA as the critical effect. Other male reproductive effects (i.e., decrease in testis weight, number of spermatid heads, spermatid concentration) were found to be statistically significant at higher doses (≥12.5 mg/kg-day).

EPA Benchmark Dose Software was used to derive a benchmark dose (BMD) of 3.5 mg/kg-day, and a benchmark dose lower confidence limit of 1.9 mg/kg-day (BMDL). An overall UF of 3,000 was applied to this value to derive the updated RfD of 6E-4 mg/kg-day. This UF includes a 10-fold factor for extrapolation from subchroinc to chronic, a 10-fold factor to account for variation in sensitivities among humans in the population, and a 3-fold factor to account for deficiencies in the data base. It is noted that the previous RfD, based on thyroid and central nervous system effects, was 2E-2 mg/kg-day.

Use of the RfD for free cyanide to calculate RfDs of other cyanide compounds may be merited, but the ability of the individual cyanogenic species to dissociate and release free cyanide in aqueous solution (and at physiological pHs) should be taken into consideration. If dissociation of the compound is expected, then liberated cations should be considered for potential toxicity independent of CN^-. Also, some metallocyanides, such as copper cyanide, have chemical-specific data and are not included in this analysis.

EPA (2012) lists a verified a chronic inhalation RfC of 8E-4 mg/m^3 for hydrogen cyanide and cyanide salts based on thyroid effects and altered iodide uptake in occupationally exposed humans. The key study involved 36 non-smoking male workers employed in the electroplating sections of three factories in Egypt exposed for 5 to 10 years (1 man exposed for 15 years). Twenty non-smoking unexposed male volunteers served as controls. Breathing-zone cyanide concentrations ranged from 4.63 to 13.69 mg/m^3, with a mean of 7.07 to 11.45 mg/m^3. Symptoms reported more frequently in the exposed workers included (in decreasing order of frequency) headache, weakness, and changes in the senses of taste and smell. Lacrimation, abdominal colic, and precordial (lower stomach) pain, salivation, and nervous instability occurred less frequently. Twenty of the exposed workers had thyroid enlargement to a mild or moderate degree, and thyroid function (iodine uptake) was altered. The lowest mean concentration recorded in the three factories, 7.07 mg/m^3, corresponding to an exposure-adjusted concentration of 2.5 mg/m^3, was designated a LOAEL. Application of an uncertainty factor of 3,000 (a factor of 10 to estimate a NOAEL from a LOAEL, a 10-fold factor to account for variation in sensitivities among humans in the population, 10-fold factor to account for deficiencies in the data base, and a 3-fold factor to account for extrapolation from a largely subchronic study to a chronic RfC)yields the verified chronic inhalation RfC of 8E-4 mg/m^3. The chronic RfC is equivalent to a chronic inhalation RfD of 2.3E-4 mg/kg-day. Confidence in the verified RfC is low to medium.

6.0 Carcinogenicity Evaluation

EPA (2012) classified the cyanide data base as inadequate to assess carcinogenicity because of a lack of data in humans or laboratory animals. Cancer potency factors are not derived for these formerly Group D chemicals.

7.0 Toxicity Summary

Toxicity values for cyanide/hydrogen cyanide are summarized below:

Noncancer Effects						Carcinogenicity				
Oral Exposure[a]			Inhalation Exposure			Oral Exposure		Inhalation Exposure		
sRfDo	cRfDo	TO	sRfC/ sRfDi	cRfC/ cRfDi	TO	WOE	SFo	WOE	URFi	SFi
6E-3	6E-4	Repro	3E-3/ 8.6E-4	8E-4/ .3E-4	T	D	NA	D	NA	NA

sRfDo = subchronic oral reference dose (milligrams per kilogram-day); cRfDo = chronic oral reference dose (milligrams per kilogram-day); TO = target organ(s) or critical effect(s); sRfC = subchronic inhalation reference concentration (milligrams per cubic meter); sRfDi = subchronic inhalation reference dose (milligrams per kilogram-day); cRfC = chronic inhalation reference concentration (milligrams per cubic meter); cRfDi = chronic inhalation reference dose (milligrams per kilogram-day); WOE = cancer weight-of-evidence evaluation; SFo = oral cancer slope factor (risk per milligram per kilogram-day); URFi = inhalation unit risk factor (risk per microgram per cubic meter); SFi = inhalation cancer slope factor (risk per milligram per kilogram-day); NA = not applicable.
Target organ or critical effect abbreviations: Repro = reproductive system; T = thyroid, [a]sRfDo and cRfDo should be used for dermal exposure without adjustment for GI absorption.

8.0 References

Agency for Toxic Substances and Disease Registry (ATSDR), 2006, ***Toxicological Profile for Cyanide***, U.S. Department of Health and Human Services, Atlanta, GA, June.

Hazardous Substance Data Bank (HSDB), 2004, National Library of Medicine, on line.

U.S. Environmental Protection Agency (EPA), 1991, ***Risk Assessment Issue Paper for: Dermal Absorption of Cyanide (CASRN 57-12-5)***, National Center for Environmental Assessment, Cincinnati, OH, 3 June.

U.S. Environmental Protection Agency (EPA), 1995, "Final Water Quality Guidance for the Great Lakes System; Final Rule," (40 CFR 9, 122, 123, 131, and 132), ***Federal Register***, 60(56): 15365-15425.

U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables, FY 1997 Update***, Office of Solid Waste and Emergency Response, 9200.6-303 (97-1), EPA-540-R-97-036, PB97-921199, July.

U.S. Environmental Protection Agency (EPA), 2004, ***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, DC, EPA/540/R/99/005, OSWER 9285.7-02EP, NTIS No. PB99-963312, July.

U.S. Environmental Protection Agency (EPA), 2012, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

APPENDIX D

RISK CHARACTERIZATION SPREADSHEETS

Table D-1

Groundskeeper, Current Scenarios, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	7.64E-01	2.67E-07	7.48E-07	1.87E-08	1.07E-02	2.14E-08	2.47E-07	6.91E-07	1.73E-08	9.87E-03
Aroclor 1254	5.40E-01	1.89E-07	5.28E-07	3.77E-07	2.64E-02	1.51E-08	1.74E-07	4.88E-07	3.49E-07	2.44E-02
Aroclor 1260	2.04E-01	7.13E-08	2.00E-07	1.43E-07	NA	5.71E-09	6.59E-08	1.84E-07	1.32E-07	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	8.20E+00	2.87E-06	8.02E-06	2.09E-06	NA	2.13E-07	2.46E-06	6.88E-06	1.79E-06	NA
Benzo(a)pyrene	6.96E+00	2.43E-06	6.81E-06	1.78E-05	NA	1.81E-07	2.09E-06	5.84E-06	1.52E-05	NA
Benzo(b)fluoranthene	9.35E+00	3.27E-06	9.15E-06	2.39E-06	NA	2.43E-07	2.80E-06	7.85E-06	2.05E-06	NA
Benzo(k)fluoranthene	2.21E+00	7.72E-07	2.16E-06	5.63E-08	NA	5.74E-08	6.62E-07	1.85E-06	4.83E-08	NA
Dibenz(a,h)anthracene	8.54E-01	2.98E-07	8.36E-07	2.18E-06	NA	2.22E-08	2.56E-07	7.17E-07	1.87E-06	NA
Indeno(1,2,3-cd)pyrene	5.55E+00	1.94E-06	5.43E-06	1.42E-06	NA	1.44E-07	1.66E-06	4.66E-06	1.21E-06	NA
Total ILCR or HI				**2.64E-05**	**3.71E-02**				**2.27E-05**	**3.43E-02**

Table D-1

Groundskeeper, Current Scenarios, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	Inhalation ILCR	Inhalation HQ	**All Pathways Total ILCR**	**All Pathways Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	7.64E-08	5.34E-09	1.50E-08	3.74E-10	NA	**3.63E-08**	**2.05E-02**
Aroclor 1254	5.40E-08	3.77E-09	1.06E-08	7.55E-09	NA	**7.34E-07**	**5.08E-02**
Aroclor 1260	2.04E-08	1.43E-09	3.99E-09	2.85E-09	NA	**2.77E-07**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	8.20E-07	5.73E-08	1.60E-07	1.78E-08	NA	**3.90E-06**	**NA**
Benzo(a)pyrene	6.96E-07	4.87E-08	1.36E-07	1.51E-07	NA	**3.31E-05**	**NA**
Benzo(b)fluoranthene	9.35E-07	6.54E-08	1.83E-07	2.03E-08	NA	**4.45E-06**	**NA**
Benzo(k)fluoranthene	2.21E-07	1.54E-08	4.32E-08	4.78E-10	NA	**1.05E-07**	**NA**
Dibenz(a,h)anthracene	8.54E-08	5.97E-09	1.67E-08	1.85E-08	NA	**4.07E-06**	**NA**
Indeno(1,2,3-cd)pyrene	5.55E-07	3.88E-08	1.09E-07	1.20E-08	NA	**2.64E-06**	**NA**
Total ILCR or HI				**2.31E-07**	**NA**	**4.94E-05**	**7.14E-02**

EPC - Exposure-point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/m^3 - Milligrams per cubic meter.

Table D-2

Groundskeeper, Future Scenario, Exposure to Total Soil
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	1.12E-07	3.14E-07	7.85E-09	4.49E-03	8.99E-09	1.04E-07	2.90E-07	7.26E-09	4.15E-03
Aroclor 1254	4.09E-01	1.43E-07	4.00E-07	2.86E-07	2.00E-02	1.15E-08	1.32E-07	3.70E-07	2.64E-07	1.85E-02
Aroclor 1260	1.30E-01	4.54E-08	1.27E-07	9.09E-08	NA	3.64E-09	4.20E-08	1.18E-07	8.40E-08	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	2.05E+00	7.15E-07	2.00E-06	5.22E-07	NA	5.32E-08	6.13E-07	1.72E-06	4.48E-07	NA
Benzo(a)pyrene	1.78E+00	6.23E-07	1.74E-06	4.55E-06	NA	4.63E-08	5.34E-07	1.50E-06	3.90E-06	NA
Benzo(b)fluoranthene	2.34E+00	8.16E-07	2.28E-06	5.96E-07	NA	6.07E-08	7.00E-07	1.96E-06	5.11E-07	NA
Benzo(k)fluoranthene	1.13E+00	3.94E-07	1.10E-06	2.88E-08	NA	2.93E-08	3.38E-07	9.47E-07	2.47E-08	NA
Dibenz(a,h)anthracene	5.62E-01	1.96E-07	5.50E-07	1.43E-06	NA	1.46E-08	1.69E-07	4.72E-07	1.23E-06	NA
Indeno(1,2,3-cd)pyrene	1.53E+00	5.35E-07	1.50E-06	3.90E-07	NA	3.98E-08	4.59E-07	1.28E-06	3.35E-07	NA
Total ILCR or HI				**7.90E-06**	**2.45E-02**				**6.80E-06**	**2.26E-02**

Table D-2

Groundskeeper, Future Scenario, Exposure to Total Soil
Waste Water Treatment Plant No. 3, Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	Inhalation ILCR	Inhalation HQ	**All Pathways Total ILCR**	**All Pathways Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	3.21E-08	2.24E-09	6.28E-09	1.57E-10	NA	**1.53E-08**	**8.63E-03**
Aroclor 1254	4.09E-08	2.86E-09	8.00E-09	5.72E-09	NA	**5.56E-07**	**3.85E-02**
Aroclor 1260	1.30E-08	9.09E-10	2.54E-09	1.82E-09	NA	**1.77E-07**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	2.05E-07	1.43E-08	4.00E-08	4.43E-09	NA	**9.74E-07**	**NA**
Benzo(a)pyrene	1.78E-07	1.25E-08	3.49E-08	3.86E-08	NA	**8.48E-06**	**NA**
Benzo(b)fluoranthene	2.34E-07	1.63E-08	4.57E-08	5.06E-09	NA	**1.11E-06**	**NA**
Benzo(k)fluoranthene	1.13E-07	7.88E-09	2.21E-08	2.44E-10	NA	**5.37E-08**	**NA**
Dibenz(a,h)anthracene	5.62E-08	3.93E-09	1.10E-08	1.22E-08	NA	**2.68E-06**	**NA**
Indeno(1,2,3-cd)pyrene	1.53E-07	1.07E-08	2.99E-08	3.31E-09	NA	**7.29E-07**	**NA**
Total ILCR or HI				**7.15E-08**	**NA**	**1.48E-05**	**4.71E-02**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/m^3 - Milligrams per cubic meter.

Table D-3

Groundskeeper, Future Scenario, Exposure to Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact					All Pathways	
		Cancer	Noncancer			Dose	Cancer	Noncancer				
Chemicals of Potential Concern	EPC mg/L	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	Absorbed mg/cm^2-day	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Inorganics												
Arsenic	7.68E-02	2.68E-04	7.51E-04	4.03E-04	2.50E+00	7.68E-08	8.86E-07	2.48E-06	1.33E-06	8.27E-03	**4.04E-04**	**2.51E+00**
Manganese	6.63E-01	2.32E-03	6.49E-03	NA	1.38E-01	6.63E-07	7.65E-06	2.14E-05	NA	1.13E-02	**NA**	**1.49E-01**
Vanadium	1.19E-02	4.16E-05	1.16E-04	NA	2.33E-02	1.19E-08	1.37E-07	3.84E-07	NA	2.95E-03	**NA**	**2.62E-02**
Semivolatile Organic Compounds												
Methylnaphthalene, 2-	2.51E-03	8.77E-06	2.45E-05	NA	6.14E-03	5.03E-07	5.80E-06	1.62E-05	NA	4.06E-03	**NA**	**1.02E-02**
Naphthalene	1.98E-03	6.90E-06	1.93E-05	NA	9.66E-04	1.92E-07	2.21E-06	6.20E-06	NA	3.10E-04	**NA**	**1.28E-03**
Volatile Organic Compounds												
Benzene	1.03E-02	3.60E-05	1.01E-04	1.98E-06	2.52E-02	2.30E-07	2.65E-06	7.43E-06	1.46E-07	1.86E-03	**2.13E-06**	**2.71E-02**
Ethylbenzene	4.08E-03	1.43E-05	4.00E-05	NA	4.00E-04	3.58E-07	4.13E-06	1.16E-05	NA	1.16E-04	**NA**	**5.15E-04**
Xylenes	2.97E-02	1.04E-04	2.90E-04	NA	1.45E-03	2.82E-06	3.25E-05	9.10E-05	NA	4.55E-04	**NA**	**1.91E-03**
General Chemistry												
Cyanide, total	4.53E-02	1.58E-04	4.43E-04	NA	7.38E-01	4.53E-08	5.22E-07	1.46E-06	NA	2.44E-03	**NA**	**7.41E-01**
Total ILCR or HI				**4.05E-04**	**3.44E+00**				**1.47E-06**	**3.17E-02**	**4.06E-04**	**3.47E+00**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-4

Groundskeeper, Future Scenario, Exposure to Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact					All Pathways	
		Cancer	Noncancer			Dose	Cancer	Noncancer				
	EPC	Dose	Dose			Absorbed	Dose	Dose			**Total**	**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	mg/kg-day	ILCR	HQ	mg/cm^2-day	mg/kg-day	mg/kg-day	ILCR	HQ	**ILCR**	**HI**
Inorganics												
Arsenic	1.33E-02	4.66E-05	1.30E-04	6.99E-05	4.35E-01	1.33E-08	1.54E-07	4.30E-07	2.31E-07	1.43E-03	**7.01E-05**	**4.36E-01**
Barium	3.19E-01	1.11E-03	3.12E-03	NA	1.56E-02	3.19E-07	3.67E-06	1.03E-05	NA	7.35E-04	**NA**	**1.63E-02**
Chromium, Total	2.90E-03	1.01E-05	2.84E-05	NA	1.35E-03	2.90E-09	3.34E-08	9.36E-08	NA	3.47E-04	**NA**	**1.70E-03**
Cobalt	3.00E-03	1.05E-05	2.94E-05	NA	9.78E-02	1.20E-09	1.38E-08	3.87E-08	NA	1.29E-04	**NA**	**9.80E-02**
Iron	1.60E+00	5.59E-03	1.57E-02	NA	2.24E-02	1.60E-06	1.85E-05	5.17E-05	NA	NA	**NA**	**2.24E-02**
Manganese	0.4762	0.0016641	0.0046595	NA	0.099138	4.762E-07	5.492E-06	1.538E-05	NA	8.09E-03	**NA**	**1.07E-01**
Nitroaromatics												
Dinitrobenzene, 1,3-	1.50E-04	5.24E-07	1.47E-06	NA	1.47E-02	6.95E-10	8.01E-09	2.24E-08	NA	2.24E-04	**NA**	**1.49E-02**
Dinitrotoluene, 2,4-	1.81E-04	6.33E-07	1.77E-06	4.30E-07	8.86E-04	1.64E-09	1.89E-08	5.30E-08	1.29E-08	2.65E-05	**4.43E-07**	**9.12E-04**
General Chemistry												
Cyanide, total	1.90E-02	6.64E-05	1.86E-04	NA	3.10E-01	1.90E-08	2.19E-07	6.14E-07	NA	1.02E-03	**NA**	**3.11E-01**
Total ILCR or HI				**7.03E-05**	**9.96E-01**				**2.43E-07**	**1.20E-02**	**7.05E-05**	**1.01E+00**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-5

Indoor Worker, Future Scenario, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion					
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	7.64E-01	1.33E-07	3.74E-07	9.34E-09	5.34E-03	**9.34E-09**	**5.34E-03**
Aroclor 1254	5.40E-01	9.44E-08	2.64E-07	1.89E-07	1.32E-02	**1.89E-07**	**1.32E-02**
Aroclor 1260	2.04E-01	3.56E-08	9.98E-08	7.13E-08	NA	**7.13E-08**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	8.20E+00	1.43E-06	4.01E-06	1.05E-06	NA	**1.05E-06**	**NA**
Benzo(a)pyrene	6.96E+00	1.22E-06	3.41E-06	8.88E-06	NA	**8.88E-06**	**NA**
Benzo(b)fluoranthene	9.35E+00	1.63E-06	4.58E-06	1.19E-06	NA	**1.19E-06**	**NA**
Benzo(k)fluoranthene	2.21E+00	3.86E-07	1.08E-06	2.82E-08	NA	**2.82E-08**	**NA**
Dibenz(a,h)anthracene	8.54E-01	1.49E-07	4.18E-07	1.09E-06	NA	**1.09E-06**	**NA**
Indeno(1,2,3-cd)pyrene	5.55E+00	9.69E-07	2.71E-06	7.08E-07	NA	**7.08E-07**	**NA**
Total ILCR or HI						**1.32E-05**	**1.85E-02**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.

Table D-6

Indoor Worker, Future Scenario, Exposure to Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact					All Pathways	
		Cancer	Noncancer			Dose	Cancer	Noncancer				
	EPC	Dose	Dose			Absorbed	Dose	Dose			Total	Total
Chemicals of Potential Concern	mg/L	mg/kg-day	mg/kg-day	ILCR	HQ	mg/cm^2-day	mg/kg-day	mg/kg-day	ILCR	HQ	ILCR	HI
Inorganics												
Arsenic	7.68E-02	2.68E-04	7.51E-04	4.03E-04	2.50E+00	7.68E-08	8.86E-07	2.48E-06	1.33E-06	8.27E-03	**4.04E-04**	**2.51E+00**
Manganese	6.63E-01	2.32E-03	6.49E-03	NA	1.38E-01	6.63E-07	7.65E-06	2.14E-05	NA	1.13E-02	**NA**	**1.49E-01**
Vanadium	1.19E-02	4.16E-05	1.16E-04	NA	2.33E-02	1.19E-08	1.37E-07	3.84E-07	NA	2.95E-03	**NA**	**2.62E-02**
Semivolatile Organic Compounds												
Methylnaphthalene, 2-	2.51E-03	8.77E-06	2.45E-05	NA	6.14E-03	2.24E-07	2.59E-06	7.24E-06	NA	1.81E-03	**NA**	**7.95E-03**
Naphthalene	1.98E-03	6.90E-06	1.93E-05	NA	9.66E-04	1.92E-07	2.21E-06	6.20E-06	NA	3.10E-04	**NA**	**1.28E-03**
Volatile Organic Compounds												
Benzene	1.03E-02	3.60E-05	1.01E-04	1.98E-06	2.52E-02	2.30E-07	2.65E-06	7.43E-06	1.46E-07	1.86E-03	**2.13E-06**	**2.71E-02**
Ethylbenzene	4.08E-03	1.43E-05	4.00E-05	NA	4.00E-04	3.58E-07	4.13E-06	1.16E-05	NA	1.16E-04	**NA**	**5.15E-04**
Xylenes	2.97E-02	1.04E-04	2.90E-04	NA	1.45E-03	2.82E-06	3.25E-05	9.10E-05	NA	4.55E-04	**NA**	**1.91E-03**
General Chemistry												
Cyanide, total	4.53E-02	1.58E-04	4.43E-04	NA	7.38E-01	4.53E-08	5.22E-07	1.46E-06	NA	2.44E-03	**NA**	**7.41E-01**
Total ILCR or HI				**4.05E-04**	**3.44E+00**				**1.47E-06**	**2.95E-02**	**4.06E-04**	**3.47E+00**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-7

Indoor Worker, Future Scenario, Exposure to Overburden Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact					All Pathways	
		Cancer	Noncancer			Dose	Cancer	Noncancer				
Chemicals of Potential Concern	EPC mg/L	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	Absorbed mg/cm^2-day	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Inorganics												
Arsenic	1.33E-02	4.66E-05	1.30E-04	6.99E-05	4.35E-01	1.33E-08	1.54E-07	4.30E-07	2.31E-07	1.43E-03	**7.01E-05**	**4.36E-01**
Barium	3.19E-01	1.11E-03	3.12E-03	NA	1.56E-02	3.19E-07	3.67E-06	1.03E-05	NA	7.35E-04	**NA**	**1.63E-02**
Chromium, Total	2.90E-03	1.01E-05	2.84E-05	NA	1.35E-03	2.90E-09	3.34E-08	9.36E-08	NA	3.47E-04	**NA**	**1.70E-03**
Cobalt	3.00E-03	1.05E-05	2.94E-05	NA	9.78E-02	1.20E-09	1.38E-08	3.87E-08	NA	1.29E-04	**NA**	**9.80E-02**
Iron	1.60E+00	5.59E-03	1.57E-02	NA	2.24E-02	1.60E-06	1.85E-05	5.17E-05	NA	NA	**NA**	**2.24E-02**
Manganese	4.76E-01	1.66E-03	4.66E-03	NA	9.91E-02	4.76E-07	5.49E-06	1.54E-05	NA	8.09E-03	**NA**	**1.07E-01**
Nitroaromatics												
Dinitrobenzene, 1,3-	1.50E-04	5.24E-07	1.47E-06	NA	1.47E-02	6.95E-10	8.01E-09	2.24E-08	NA	2.24E-04	**NA**	**1.49E-02**
Dinitrotoluene, 2,4-	1.81E-04	6.33E-07	1.77E-06	4.30E-07	8.86E-04	1.64E-09	1.89E-08	5.30E-08	1.29E-08	2.65E-05	**4.43E-07**	**9.12E-04**
General Chemistry												
Cyanide, total	1.90E-02	6.64E-05	1.86E-04	NA	3.10E-01	1.90E-08	2.19E-07	6.14E-07	NA	1.02E-03	**NA**	**3.11E-01**
Total ILCR or HI				**7.03E-05**	**9.96E-01**				**2.43E-07**	**1.20E-02**	**7.05E-05**	**1.01E+00**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-8

Construction Worker, Current and Future Scenarios, Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

(Page 1 of 2)

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	7.40E-09	1.03E-06	5.18E-10	1.48E-02	1.35E-08	3.11E-09	4.34E-07	2.18E-10	6.20E-03
Aroclor 1254	4.09E-01	9.43E-09	1.32E-06	1.89E-08	6.59E-02	1.72E-08	3.96E-09	5.53E-07	7.92E-09	2.77E-02
Aroclor 1260	1.30E-01	3.00E-09	4.19E-07	6.00E-09	NA	5.46E-09	1.26E-09	1.76E-07	2.52E-09	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	2.05E+00	4.72E-08	6.59E-06	3.44E-08	NA	7.98E-08	1.84E-08	2.57E-06	1.34E-08	NA
Benzo(a)pyrene	1.78E+00	4.11E-08	5.74E-06	3.00E-07	NA	6.95E-08	1.60E-08	2.24E-06	1.17E-07	NA
Benzo(b)fluoranthene	2.34E+00	5.39E-08	7.52E-06	3.93E-08	NA	9.11E-08	2.10E-08	2.93E-06	1.53E-08	NA
Benzo(k)fluoranthene	1.13E+00	2.60E-08	3.63E-06	1.90E-09	NA	4.40E-08	1.01E-08	1.42E-06	7.41E-10	NA
Dibenz(a,h)anthracene	5.62E-01	1.30E-08	1.81E-06	9.46E-08	NA	2.19E-08	5.06E-09	7.06E-07	3.69E-08	NA
Indeno(1,2,3-cd)pyrene	1.53E+00	3.53E-08	4.93E-06	2.58E-08	NA	5.97E-08	1.38E-08	1.92E-06	1.00E-08	NA
Total ILCR or HI				**5.21E-07**	**8.06E-02**				**2.04E-07**	**3.39E-02**

Table D-8

Construction Worker, Current and Future Scenarios, Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	Inhalation ILCR	Inhalation HQ	**All Pathways Total ILCR**	**All Pathways Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	1.12E-07	1.57E-10	2.19E-08	1.10E-11	NA	**7.47E-10**	**2.10E-02**
Aroclor 1254	1.43E-07	2.00E-10	2.79E-08	4.00E-10	NA	**2.72E-08**	**9.35E-02**
Aroclor 1260	4.55E-08	6.36E-11	8.88E-09	1.27E-10	NA	**8.64E-09**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	7.16E-07	1.00E-09	1.40E-07	3.10E-10	NA	**4.82E-08**	**NA**
Benzo(a)pyrene	6.24E-07	8.72E-10	1.22E-07	2.70E-09	NA	**4.20E-07**	**NA**
Benzo(b)fluoranthene	8.17E-07	1.14E-09	1.59E-07	3.54E-10	NA	**5.50E-08**	**NA**
Benzo(k)fluoranthene	3.95E-07	5.52E-10	7.70E-08	1.71E-11	NA	**2.66E-09**	**NA**
Dibenz(a,h)anthracene	1.97E-07	2.75E-10	3.84E-08	8.52E-10	NA	**1.32E-07**	**NA**
Indeno(1,2,3-cd)pyrene	5.36E-07	7.49E-10	1.05E-07	2.32E-10	NA	**3.60E-08**	**NA**
Total ILCR or HI				**5.01E-09**	**NA**	**7.31E-07**	**1.14E-01**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/m^3 - Milligrams per cubic meter.

Table D-9

Construction Worker, Current and Future Scenarios, Exposure to Sediment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact					All Pathways	
		Cancer	Noncancer			Dose	Cancer	Noncancer				
Chemicals of Potential Concern	EPC mg/kg	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	Absorbed mg/cm^2-day	Dose mg/kg-day	Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Inorganics												
Arsenic	7.20E+00	1.66E-07	2.32E-05	2.49E-07	7.73E-02	6.48E-08	1.49E-08	2.09E-06	2.24E-08	6.96E-03	**2.72E-07**	**8.42E-02**
Chromium, total	1.51E+01	3.48E-07	4.86E-05	NA	2.32E-03	NA	NA	NA	NA	NA	**NA**	**2.32E-03**
Manganese	1.87E+03	4.31E-05	6.02E-03	NA	1.28E-01	NA	NA	NA	NA	NA	**NA**	**1.28E-01**
Thallium	1.20E+00	2.77E-08	3.86E-06	NA	3.86E-01	NA	NA	NA	NA	NA	**NA**	**3.86E-01**
Semivolatile Organic Compounds												
Benzo(a)pyrene	1.20E-01	2.77E-09	3.86E-07	2.02E-08	NA	4.68E-09	1.08E-09	1.51E-07	7.88E-09	NA	**2.81E-08**	**NA**
Benzo(b)fluoranthene	1.91E-01	4.41E-09	6.15E-07	3.22E-09	NA	7.45E-09	1.72E-09	2.40E-07	1.25E-09	NA	**4.47E-09**	**NA**
Total ILCR or HI				**2.73E-07**	**5.94E-01**				**3.16E-08**	**6.96E-03**	**3.04E-07**	**6.01E-01**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per centimeter squared.

Table D-10

Construction Worker, Current and Future Scenario, Exposure to Surface Water
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Dermal Contact				
		Dose	Cancer	Noncancer		
Chemicals of Potential Concern	EPC mg/L	Absorbed mg/cm^2-day	Dose mg/kg-day	Dose mg/kg-day	**Total ILCR**	**Total HI**
Inorganics						
Arsenic	7.20E-03	2.88E-08	6.64E-09	9.27E-07	**9.96E-09**	**3.09E-03**
Chromium, Total	5.65E-03	2.26E-08	5.21E-09	7.28E-07	**NA**	**2.70E-03**
Cobalt	5.95E-03	9.52E-09	2.20E-09	3.07E-07	**NA**	**1.02E-03**
Iron	1.13E+01	4.52E-05	1.04E-05	1.46E-03	**NA**	**NA**
Manganese	1.98E+00	7.92E-06	1.83E-06	2.55E-04	**NA**	**1.34E-01**
Total ILCR or HI					**9.96E-09**	**1.41E-01**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-11

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion			Dermal Contact				
	EPC	Adult Dose	Child Dose	Resident	Adult Dose Absorbed	Adult Dose	Child Dose Absorbed	Child Dose	Resident
Chemicals of Potential Concern	mg/kg	mg/kg-day	mg/kg-day	ILCR	mg/cm^2-day	mg/kg-day	mg/cm^2-day	mg/kg-day	ILCR
Polychlorinated biphenyls (PCB)									
Aroclor 1016	3.21E-01	1.36E-07	3.17E-07	3.17E-08	3.15E-09	8.42E-08	8.99E-09	1.38E-07	1.55E-08
Aroclor 1254	4.09E-01	1.73E-07	4.03E-07	1.15E-06	4.01E-09	1.07E-07	1.15E-08	1.76E-07	5.66E-07
Aroclor 1260	1.30E-01	5.50E-08	1.28E-07	3.66E-07	1.27E-09	3.41E-08	3.64E-09	5.58E-08	1.80E-07
Semivolatile Organic Compounds									
Benzo(a)anthracene	2.05E+00	8.64E-07	2.02E-06	2.10E-06	1.86E-08	4.98E-07	5.32E-08	8.16E-07	9.59E-07
Benzo(a)pyrene	1.78E+00	7.53E-07	1.76E-06	1.83E-05	1.62E-08	4.34E-07	4.63E-08	7.11E-07	8.36E-06
Benzo(b)fluoranthene	2.34E+00	9.87E-07	2.30E-06	2.40E-06	2.12E-08	5.69E-07	6.07E-08	9.31E-07	1.10E-06
Benzo(k)fluoranthene	1.13E+00	4.77E-07	1.11E-06	1.16E-07	1.03E-08	2.75E-07	2.93E-08	4.50E-07	5.29E-08
Dibenz(a,h)anthracene	5.62E-01	2.38E-07	5.54E-07	5.78E-06	5.11E-09	1.37E-07	1.46E-08	2.24E-07	2.64E-06
Indeno(1,2,3-cd)pyrene	1.53E+00	6.47E-07	1.51E-06	1.57E-06	1.39E-08	3.73E-07	3.98E-08	6.10E-07	7.18E-07
Total ILCR				**3.19E-05**					**1.46E-05**

Table D-11

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Adult Dose mg/kg-day	Inhalation Child Dose mg/kg-day	Inhalation Resident ILCR	**All Pathways Total ILCR**
Polychlorinated biphenyls (PCB)					
Aroclor 1016	6.32E-10	5.94E-11	3.46E-11	6.58E-12	**4.72E-08**
Aroclor 1254	8.06E-10	7.57E-11	4.41E-11	2.40E-10	**1.72E-06**
Aroclor 1260	2.56E-10	2.41E-11	1.40E-11	7.62E-11	**5.46E-07**
Semivolatile Organic Compounds					
Benzo(a)anthracene	4.03E-09	3.78E-10	2.21E-10	1.86E-10	**3.06E-06**
Benzo(a)pyrene	3.51E-09	3.30E-10	1.92E-10	1.62E-09	**2.67E-05**
Benzo(b)fluoranthene	4.60E-09	4.32E-10	2.52E-10	2.12E-10	**3.50E-06**
Benzo(k)fluoranthene	2.22E-09	2.09E-10	1.22E-10	1.02E-11	**1.69E-07**
Dibenz(a,h)anthracene	1.11E-09	1.04E-10	6.07E-11	5.10E-10	**8.42E-06**
Indeno(1,2,3-cd)pyrene	3.01E-09	2.83E-10	1.65E-10	1.39E-10	**2.29E-06**
Total ILCR				**3.00E-09**	**4.64E-05**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per square meter.
mg/m^3 - Milligrams per cubic meter.

Table D-12

On-Site Child Resident, Future Scenario, Noncancer Hazard from Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Concentration	Inhalation		**All**
	EPC	Child Dose	Child Resident	Dose Absorbed	Child Dose	Child Resident	in Air C_a	Child Dose	Child Resident	**Pathways Total**
Chemicals of Potential Concern	mg/kg	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	3.69E-06	5.28E-02	8.99E-09	1.61E-06	2.30E-02	6.32E-10	4.04E-10	NA	**7.58E-02**
Aroclor 1254	4.09E-01	4.71E-06	2.35E-01	1.15E-08	2.05E-06	1.02E-01	8.06E-10	5.15E-10	NA	**3.38E-01**
Aroclor 1260	1.30E-01	1.50E-06	NA	3.64E-09	6.52E-07	NA	2.56E-10	1.64E-10	NA	**NA**
Semivolatile Organic Compounds										
Benzo(a)anthracene	2.05E+00	2.35E-05	NA	5.32E-08	9.52E-06	NA	4.03E-09	2.57E-09	NA	**NA**
Benzo(a)pyrene	1.78E+00	2.05E-05	NA	4.63E-08	8.29E-06	NA	3.51E-09	2.24E-09	NA	**NA**
Benzo(b)fluoranthene	2.34E+00	2.69E-05	NA	6.07E-08	1.09E-05	NA	4.60E-09	2.94E-09	NA	**NA**
Benzo(k)fluoranthene	1.13E+00	1.30E-05	NA	2.93E-08	5.25E-06	NA	2.22E-09	1.42E-09	NA	**NA**
Dibenz(a,h)anthracene	5.62E-01	6.47E-06	NA	1.46E-08	2.62E-06	NA	1.11E-09	7.08E-10	NA	**NA**
Indeno(1,2,3-cd)pyrene	1.53E+00	1.76E-05	NA	3.98E-08	7.12E-06	NA	3.01E-09	1.93E-09	NA	**NA**
Total HI			**2.88E-01**			**1.25E-01**			**NA**	**4.14E-01**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per square meter.
mg/m^3 - Milligrams per cubic meter.

Table D-13

On-Site Adult Resident, Future Scenario, Noncancer Hazard from Exposure to Total Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Concentration	Inhalation		**All**
	EPC	Adult Dose	Adult Resident	Dose Absorbed	Adult Dose	Adult Resident	in Air C_a	Adult Dose	Adult Resident	**Pathways Total**
Chemicals of Potential Concern	mg/kg	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	3.96E-07	5.65E-03	3.15E-09	2.46E-07	3.51E-03	6.32E-10	1.73E-10	NA	**9.16E-03**
Aroclor 1254	4.09E-01	5.04E-07	2.52E-02	4.01E-09	3.13E-07	1.56E-02	8.06E-10	2.21E-10	NA	**4.09E-02**
Aroclor 1260	1.30E-01	1.60E-07	NA	1.27E-09	9.95E-08	NA	2.56E-10	7.02E-11	NA	**NA**
Semivolatile Organic Compounds										
Benzo(a)anthracene	2.05E+00	2.52E-06	NA	1.86E-08	1.45E-06	NA	4.03E-09	1.10E-09	NA	**NA**
Benzo(a)pyrene	1.78E+00	2.20E-06	NA	1.62E-08	1.27E-06	NA	3.51E-09	9.62E-10	NA	**NA**
Benzo(b)fluoranthene	2.34E+00	2.88E-06	NA	2.12E-08	1.66E-06	NA	4.60E-09	1.26E-09	NA	**NA**
Benzo(k)fluoranthene	1.13E+00	1.39E-06	NA	1.03E-08	8.01E-07	NA	2.22E-09	6.09E-10	NA	**NA**
Dibenz(a,h)anthracene	5.62E-01	6.93E-07	NA	5.11E-09	3.99E-07	NA	1.11E-09	3.03E-10	NA	**NA**
Indeno(1,2,3-cd)pyrene	1.53E+00	1.89E-06	NA	1.39E-08	1.09E-06	NA	3.01E-09	8.26E-10	NA	**NA**
Total HI			**3.09E-02**			**1.92E-02**			**NA**	**5.00E-02**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per square meter.
mg/m^3 - Milligrams per cubic meter.

Table D-14

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion			Dermal Contact					Inhalation of VOCs				All
		Adult	Child		Dose	Adult	Dose	Child		Concentration	Adult	Child		Pathways
	EPC	Dose	Dose		Absorbed	Dose	Absorbed	Dose		in Air	Dose	Dose		Total
Chemicals of Potential Concern	mg/L	mg/kg-day	mg/kg-day	ILCR	mg/cm^2-day	mg/kg-day	mg/cm^2-day	mg/kg-day	ILCR	mg/m^3	mg/kg-day	mg/kg-day	ILCR	ILCR
Inorganics														
Arsenic	7.68E-02	7.21E-04	4.21E-04	1.71E-03	1.54E-08	1.44E-06	2.56E-08	9.25E-07	3.55E-06	NA	NA	NA	NA	**1.72E-03**
Manganese	6.63E-01	6.23E-03	3.63E-03	NA	1.33E-07	1.25E-05	2.21E-07	7.98E-06	NA	NA	NA	NA	NA	**NA**
Vanadium	1.19E-02	1.12E-04	6.52E-05	NA	2.38E-09	2.23E-07	3.96E-09	1.43E-07	NA	NA	NA	NA	NA	**NA**
Semivolatile Organic Compounds														
Methylnaphthalene, 2-	0.002509	2.357E-05	1.375E-05	NA	1.12E-07	1.06E-05	1.45E-07	5.24E-06	NA	1.25E-03	1.18E-04	6.86E-05	NA	**NA**
Naphthalene	1.98E-03	1.86E-05	1.08E-05	NA	4.29E-08	4.03E-06	5.54E-08	2.00E-06	NA	9.88E-04	9.27E-05	5.40E-05	1.76E-05	**1.76E-05**
Volatile Organic Compounds														
Benzene	1.03E-02	9.68E-05	5.65E-05	8.43E-06	5.15E-08	4.83E-06	6.64E-08	2.40E-06	3.98E-07	5.16E-03	4.84E-04	2.82E-04	2.07E-05	**2.95E-05**
Ethylbenzene	4.08E-03	3.84E-05	2.24E-05	NA	8.02E-08	7.53E-06	1.03E-07	3.74E-06	NA	2.04E-03	1.92E-04	1.12E-04	NA	**NA**
Xylenes	2.97E-02	2.79E-04	1.63E-04	NA	6.30E-07	5.92E-05	8.13E-07	2.94E-05	NA	1.48E-02	1.39E-03	8.12E-04	NA	**NA**
General Chemistry														
Cyanide, total	4.53E-02	4.25E-04	2.48E-04	NA	9.06E-09	8.51E-07	1.51E-08	5.45E-07	NA	NA	NA	NA	NA	**NA**
Total ILCR				**1.72E-03**					**3.95E-06**				**3.83E-05**	**1.76E-03**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-15

On-Site Child Resident, Future Scenario, Noncancer Risk from Exposure to Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Inhalation of VOCs			**All**
		Child		Dose	Child		Concentration	Child		**Pathways**
	EPC	Dose		Absorbed	Dose		in Air	Dose		**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Inorganics										
Arsenic	7.68E-02	4.91E-03	1.64E+01	2.56E-08	1.08E-05	3.60E-02	NA	NA	NA	**1.64E+01**
Manganese	6.63E-01	4.24E-02	9.02E-01	2.21E-07	9.32E-05	4.90E-02	NA	NA	NA	**9.51E-01**
Vanadium	1.19E-02	7.60E-04	1.52E-01	3.96E-09	1.67E-06	1.29E-02	NA	NA	NA	**1.65E-01**
Semivolatile Organic Compounds										
Methylnaphthalene, 2-	0.002509	1.60E-04	4.01E-02	1.45E-07	6.12E-05	1.53E-02	1.25E-03	8.01E-04	NA	**5.54E-02**
Naphthalene	1.98E-03	1.26E-04	6.31E-03	5.54E-08	2.34E-05	1.17E-03	9.88E-04	6.30E-04	7.33E-01	**7.40E-01**
Volatile Organic Compounds										
Benzene	1.03E-02	6.59E-04	1.65E-01	6.64E-08	2.80E-05	7.01E-03	5.16E-03	3.29E-03	3.83E-01	**5.54E-01**
Ethylbenzene	4.08E-03	2.61E-04	2.61E-03	1.03E-07	4.36E-05	4.36E-04	2.04E-03	1.30E-03	4.49E-03	**7.54E-03**
Xylenes	2.97E-02	1.90E-03	9.48E-03	8.13E-07	3.43E-04	1.71E-03	1.48E-02	9.47E-03	3.26E-01	**3.38E-01**
General Chemistry										
Cyanide, total	4.53E-02	2.89E-03	4.82E+00	1.51E-08	6.36E-06	1.06E-02	NA	NA	NA	**4.83E+00**
Total HI			**2.25E+01**			**1.34E-01**			**1.45E+00**	**2.40E+01**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-16

On-Site Adult Resident, Future Scenario, Noncancer Hazard from Exposure to Bedrock Groundwater
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Inhalation of VOCs			**All**
		Noncancer		Dose	Adult		Concentration	Adult		**Pathways**
	EPC	Dose		Absorbed	Dose		in Air	Dose		**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Inorganics										
Arsenic	7.68E-02	2.10E-03	7.01E+00	1.54E-08	4.21E-06	1.40E-02	NA	NA	NA	**7.03E+00**
Manganese	6.63E-01	1.82E-02	3.86E-01	1.33E-07	3.63E-05	1.91E-02	NA	NA	NA	**4.06E-01**
Vanadium	1.19E-02	3.26E-04	6.52E-02	2.38E-09	6.52E-07	5.01E-03	NA	NA	NA	**7.02E-02**
Semivolatile Organic Compounds										
Methylnaphthalene, 2-	0.002509	6.87E-05	1.72E-02	1.12E-07	3.08E-05	7.70E-03	1.25E-03	3.44E-04	NA	**2.49E-02**
Naphthalene	1.98E-03	5.41E-05	2.71E-03	4.29E-08	1.18E-05	5.88E-04	9.88E-04	2.70E-04	3.14E-01	**3.18E-01**
Volatile Organic Compounds										
Benzene	1.03E-02	2.82E-04	7.06E-02	5.15E-08	1.41E-05	3.53E-03	5.16E-03	1.41E-03	1.64E-01	**2.38E-01**
Ethylbenzene	4.08E-03	1.12E-04	1.12E-03	8.02E-08	2.20E-05	2.20E-04	2.04E-03	5.59E-04	1.93E-03	**3.27E-03**
Xylenes	2.97E-02	8.13E-04	4.06E-03	6.30E-07	1.73E-04	8.63E-04	1.48E-02	4.06E-03	1.40E-01	**1.45E-01**
General Chemistry										
Cyanide, total	4.53E-02	1.24E-03	2.07E+00	9.06E-09	2.48E-06	4.14E-03	NA	NA	NA	**2.07E+00**
Total HI			**9.63E+00**			**5.52E-02**			**6.21E-01**	**1.03E+01**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-17

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Overburden Groundwater
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion			Dermal Contact					Inhalation of VOCs				**All**
		Adult	Child		Dose	Adult	Dose	Child		Concentration	Adult	Child		**Pathways**
	EPC	Dose	Dose		Absorbed	Dose	Absorbed	Dose		in Air	Dose	Dose		**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	mg/kg-day	ILCR	mg/cm^2-day	mg/kg-day	mg/cm^2-day	mg/kg-day	ILCR	mg/m^3	mg/kg-day	mg/kg-day	ILCR	**ILCR**
Inorganics														
Arsenic	1.33E-02	1.25E-04	7.30E-05	2.97E-04	2.67E-09	2.50E-07	4.44E-09	1.61E-07	6.16E-07	NA	NA	NA	NA	**2.98E-04**
Barium	3.19E-01	2.99E-03	1.75E-03	NA	6.37E-08	5.99E-06	1.06E-07	3.84E-06	NA	NA	NA	NA	NA	**NA**
Chromium, Total	2.90E-03	2.72E-05	1.59E-05	NA	5.80E-10	5.45E-08	9.66E-10	3.49E-08	NA	NA	NA	NA	NA	**NA**
Cobalt	3.00E-03	2.82E-05	1.64E-05	NA	2.40E-10	2.25E-08	4.00E-10	1.45E-08	NA	NA	NA	NA	NA	**NA**
Iron	1.60E+00	1.50E-02	8.77E-03	NA	3.20E-07	3.01E-05	5.33E-07	1.93E-05	NA	NA	NA	NA	NA	**NA**
Manganese	4.76E-01	4.47E-03	2.61E-03	NA	9.52E-08	8.95E-06	1.59E-07	5.73E-06	NA	NA	NA	NA	NA	**NA**
Nitroaromatics														
Dinitrobenzene, 1,3-	1.50E-04	1.41E-06	8.22E-07	NA	3.11E-10	2.92E-08	4.01E-10	1.45E-08	NA	7.50E-05	7.04E-06	4.10E-06	NA	**NA**
Dinitrotoluene, 2,4-	1.81E-04	1.70E-06	9.92E-07	1.83E-06	7.34E-10	6.89E-08	9.47E-10	3.43E-08	7.02E-08	9.05E-05	8.50E-06	4.95E-06	NA	**1.90E-06**
General Chemistry														
Cyanide, total	1.90E-02	1.78E-04	1.04E-04	NA	3.80E-09	3.57E-07	6.33E-09	2.29E-07	NA	NA	NA	NA	NA	**NA**
Total ILCR				**2.99E-04**					**6.87E-07**					**3.00E-04**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-18

On-Site Child Resident, Future Scenario, Noncancer Hazard from Exposure to Overburden Groundwater
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Inhalation of VOCs			**All**
		Child		Dose	Child		Concentration	Child		**Pathways**
	EPC	Dose		Absorbed	Dose		in Air	Dose		**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Inorganics										
Arsenic	1.33E-02	8.52E-04	2.84E+00	4.44E-09	1.87E-06	6.24E-03	NA	NA	NA	**2.85E+00**
Barium	3.19E-01	2.04E-02	1.02E-01	1.06E-07	4.48E-05	3.20E-03	NA	NA	NA	**1.05E-01**
Chromium, Total	2.90E-03	1.85E-04	8.83E-03	9.66E-10	4.07E-07	1.51E-03	NA	NA	NA	**1.03E-02**
Cobalt	3.00E-03	1.92E-04	6.39E-01	4.00E-10	1.69E-07	5.62E-04	NA	NA	NA	**6.40E-01**
Iron	1.60E+00	1.02E-01	1.46E-01	5.33E-07	2.25E-04	NA	NA	NA	NA	**1.46E-01**
Manganese	0.4762	3.04E-02	6.48E-01	1.59E-07	6.69E-05	3.52E-02	NA	NA	NA	**6.83E-01**
Nitroaromatics										
Dinitrobenzene, 1,3-	1.50E-04	9.59E-06	9.59E-02	4.01E-10	1.69E-07	1.69E-03	7.50E-05	4.79E-05	NA	**9.76E-02**
Dinitrotoluene, 2,4-	1.81E-04	1.16E-05	5.79E-03	9.47E-10	4.00E-07	2.00E-04	9.05E-05	5.78E-05	NA	**5.99E-03**
General Chemistry										
Cyanide, total	1.90E-02	1.21E-03	2.02E+00	6.33E-09	2.67E-06	4.45E-03	NA	NA	NA	**2.03E+00**
Total HI			**6.51E+00**			**5.31E-02**				**6.56E+00**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-19

On-Site Adult Resident, Future Scenario, Noncancer Hazard from Exposure to Overburden Groundwater
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			Inhalation of VOCs			**All**
		Noncancer		Dose	Adult		Concentration	Adult		**Pathways**
	EPC	Dose		Absorbed	Dose		in Air	Dose		**Total**
Chemicals of Potential Concern	mg/L	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	mg/m^3	mg/kg-day	HQ	**HI**
Inorganics										
Arsenic	1.33E-02	3.65E-04	1.22E+00	2.67E-09	7.30E-07	2.43E-03	NA	NA	NA	**1.22E+00**
Barium	3.19E-01	8.73E-03	4.36E-02	6.37E-08	1.75E-05	1.25E-03	NA	NA	NA	**4.49E-02**
Chromium, Total	2.90E-03	7.95E-05	3.78E-03	5.80E-10	1.59E-07	5.89E-04	NA	NA	NA	**4.37E-03**
Cobalt	3.00E-03	8.22E-05	2.74E-01	2.40E-10	6.58E-08	2.19E-04	NA	NA	NA	**2.74E-01**
Iron	1.60E+00	4.39E-02	6.27E-02	3.20E-07	8.77E-05	NA	NA	NA	NA	**6.27E-02**
Manganese	0.4762	1.30E-02	2.78E-01	9.52E-08	2.61E-05	1.37E-02	NA	NA	NA	**2.91E-01**
Nitroaromatics										
Dinitrobenzene, 1,3-	1.50E-04	4.11E-06	4.11E-02	3.11E-10	8.51E-08	8.51E-04	7.50E-05	2.05E-05	NA	**4.19E-02**
Dinitrotoluene, 2,4-	1.81E-04	4.96E-06	2.48E-03	7.34E-10	2.01E-07	1.01E-04	9.05E-05	2.48E-05	NA	**2.58E-03**
General Chemistry										
Cyanide, total	1.90E-02	5.21E-04	8.68E-01	3.80E-09	1.04E-06	1.74E-03	NA	NA	NA	**8.69E-01**
Total HI			**2.79E+00**			**2.09E-02**				**2.81E+00**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.
mg/m^3- Milligrams per cubic meter.

Table D-20

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Sediment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion			Dermal Contact					All
		Adult	Child		Dose	Adult	Dose	Child		Pathways
Chemicals of Potential Concern	EPC mg/kg	Dose mg/kg-day	Dose mg/kg-day	Resident ILCR	Absorbed mg/cm^2-day	Dose mg/kg-day	Absorbed mg/cm^2-day	Dose mg/kg-day	Resident ILCR	**Total ILCR**
Inorganics										
Arsenic	7.20E+00	3.38E-07	7.89E-07	1.69E-06	1.51E-09	6.01E-09	4.32E-09	9.85E-09	2.38E-08	**1.71E-06**
Chromium, total	1.51E+01	7.09E-07	1.65E-06	NA	NA	NA	NA	NA	NA	**NA**
Manganese	1.87E+03	8.78E-05	2.05E-04	NA	NA	NA	NA	NA	NA	**NA**
Thallium	1.20E+00	5.64E-08	1.32E-07	NA	NA	NA	NA	NA	NA	**NA**
Semivolatile Organic Compounds										
Benzo(a)pyrene	1.20E-01	5.64E-09	1.32E-08	1.37E-07	1.09E-10	4.34E-10	3.12E-10	7.11E-10	8.36E-09	**1.46E-07**
Benzo(b)fluoranthene	1.91E-01	8.97E-09	2.09E-08	2.18E-08	1.74E-10	6.91E-10	4.97E-10	1.13E-09	1.33E-09	**2.32E-08**
Total ILCR				**1.85E-06**					**3.35E-08**	**1.88E-06**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
mg/kg - Milligram per kilogram.
mg/cm^2 - Milligrams per centimeter squared.

Table D-21

On-Site Child Resident, Future Scenario, Noncancer Hazard from Exposure to Sediment
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			All
		Child		Dose	Child		Pathways
	EPC	Dose	Child	Absorbed	Dose	Child	Total
Chemicals of Potential Concern	mg/kg	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	HI
Inorganics							
Arsenic	7.20E+00	9.21E-06	3.07E-02	4.32E-09	1.15E-07	3.83E-04	**3.11E-02**
Chromium, total	1.51E+01	1.93E-05	9.19E-04	NA	NA	NA	**9.19E-04**
Manganese	1.87E+03	2.39E-03	5.09E-02	NA	NA	NA	**5.09E-02**
Thallium	1.20E+00	1.53E-06	1.53E-01	NA	NA	NA	**1.53E-01**
Semivolatile Organic Compounds							
Benzo(a)pyrene	1.20E-01	1.53E-07	NA	3.12E-10	8.30E-09	NA	**NA**
Benzo(b)fluoranthene	1.91E-01	2.44E-07	NA	4.97E-10	1.32E-08	NA	**NA**
Total HI			**2.36E-01**			**3.83E-04**	**2.36E-01**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
mg/kg - Milligram per kilogram.
mg/cm^2 - Milligrams per centimeter squared.

Table D-22

On-Site Adult Resident, Future Scenario, Noncancer Hazard from Exposure to Sediment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion		Dermal Contact			**All**
		Adult		Dose	Adult		**Pathways**
	EPC	Dose	Adult	Absorbed	Dose	Adult	**Total**
Chemicals of Potential Concern	mg/kg	mg/kg-day	HQ	mg/cm^2-day	mg/kg-day	HQ	**HI**
Inorganics							
Arsenic	7.20E+00	9.86E-07	3.29E-03	1.51E-09	1.75E-08	5.85E-05	**3.35E-03**
Chromium, total	1.51E+01	2.07E-06	9.85E-05	NA	NA	NA	**9.85E-05**
Manganese	1.87E+03	2.56E-04	5.45E-03	NA	NA	NA	**5.45E-03**
Thallium	1.20E+00	1.64E-07	1.64E-02	NA	NA	NA	**1.64E-02**
Semivolatile Organic Compounds							
Benzo(a)pyrene	1.20E-01	1.64E-08	NA	1.09E-10	1.27E-09	NA	**NA**
Benzo(b)fluoranthene	1.91E-01	2.62E-08	NA	1.74E-10	2.02E-09	NA	**NA**
Total HI			**2.53E-02**			**5.85E-05**	**2.53E-02**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per centimeter squared.

Table D-23

On-Site Resident, Future Scenario, Cancer Risk from Exposure to Surface Water
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Dermal Contact				
		Adult Dose	Adult	Child Dose	Child	
Chemicals of Potential Concern	EPC mg/L	Absorbed mg/cm^2-day	Dose mg/kg-day	Absorbed mg/cm^2-day	Dose mg/kg-day	**Total ILCR**
Inorganics						
Arsenic	7.20E-03	2.16E-08	1.06E-07	2.16E-08	4.92E-08	**2.32E-07**
Chromium, Total	5.65E-03	1.70E-08	8.28E-08	1.70E-08	3.86E-08	**NA**
Cobalt	5.95E-03	7.14E-09	3.49E-08	7.14E-09	1.63E-08	**NA**
Iron	1.13E+01	3.39E-05	1.66E-04	3.39E-05	7.73E-05	**NA**
Manganese	**1.98E+00**	**5.94E-06**	**2.90E-05**	**5.94E-06**	**1.35E-05**	**NA**
Total ILCR						**2.32E-07**

EPC - Exposure point concentration.
ILCR - Incremental Lifetime Cancer Risk.
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-24

On-Site Child Resident, Future Scenario, Noncancer Hazard from Exposure to Surface Water
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Dermal Contact		
Chemicals of Potential Concern	EPC mg/L	Child Dose Absorbed mg/cm^2-day	Child Dose mg/kg-day	HQ
Inorganics				
Arsenic	7.20E-03	2.16E-08	5.74E-07	**1.91E-03**
Chromium, Total	5.65E-03	1.70E-08	4.51E-07	**1.67E-03**
Cobalt	5.95E-03	7.14E-09	1.90E-07	**6.33E-04**
Iron	1.13E+01	3.39E-05	9.02E-04	**NA**
Manganese	1.98E+00	5.94E-06	1.58E-04	**8.31E-02**
Total HI				**8.74E-02**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-25

On-Site Adult Resident, Future Scenario, Noncancer Hazard from Exposure to Surface Water
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Dermal Contact		
Chemicals of Potential Concern	EPC mg/L	Adult Dose Absorbed mg/cm^2-day	Adult Dose mg/kg-day	**HQ**
Inorganics				
Arsenic	7.20E-03	2.16E-08	3.08E-07	**1.03E-03**
Chromium, Total	5.65E-03	1.70E-08	2.41E-07	**8.94E-04**
Cobalt	5.95E-03	7.14E-09	1.02E-07	**3.39E-04**
Iron	1.13E+01	3.39E-05	4.83E-04	**NA**
Manganese	1.98E+00	5.94E-06	8.46E-05	**4.45E-02**
Total HI				**4.68E-02**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
mg/L - Milligrams per liter.
mg/cm^2 - Milligrams per square meter.
mg/kg - Milligrams per kilogram.

Table D-26

Adult Hunter, Future Scenario, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

(Page 1 of 2)

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	Adult Hunter ILCR	Adult Hunter HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	Adult Hunter ILCR	Adult Hunter HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	7.64E-01	1.79E-08	4.19E-08	1.26E-09	5.98E-04	2.14E-08	1.66E-08	3.87E-08	1.16E-09	5.53E-04
Aroclor 1254	5.40E-01	1.27E-08	2.96E-08	2.54E-08	1.48E-03	1.51E-08	1.17E-08	2.73E-08	2.34E-08	1.37E-03
Aroclor 1260	2.04E-01	4.79E-09	1.12E-08	9.58E-09	NA	5.71E-09	4.43E-09	1.03E-08	8.85E-09	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	8.20E+00	1.93E-07	4.49E-07	1.41E-07	NA	2.13E-07	1.65E-07	3.86E-07	1.21E-07	NA
Benzo(a)pyrene	6.96E+00	1.63E-07	3.81E-07	1.19E-06	NA	1.81E-07	1.40E-07	3.27E-07	1.02E-06	NA
Benzo(b)fluoranthene	9.35E+00	2.20E-07	5.12E-07	1.60E-07	NA	2.43E-07	1.88E-07	4.40E-07	1.38E-07	NA
Benzo(k)fluoranthene	2.21E+00	5.19E-08	1.21E-07	3.79E-09	NA	5.74E-08	4.45E-08	1.04E-07	3.25E-09	NA
Dibenz(a,h)anthracene	8.54E-01	2.01E-08	4.68E-08	1.46E-07	NA	2.22E-08	1.72E-08	4.01E-08	1.26E-07	NA
Indeno(1,2,3-cd)pyrene	5.55E+00	1.30E-07	3.04E-07	9.51E-08	NA	1.44E-07	1.12E-07	2.61E-07	8.16E-08	NA
Total ILCR and HI				**1.78E-06**	**2.08E-03**				**1.53E-06**	**1.92E-03**

Table D-26

Adult Hunter, Future Scenario, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Forage C_p mg/kg	Concentration in Venison C_v mg/kg	Consumption of Venison: Cancer Dose mg/kg-day	Consumption of Venison: Noncancer Dose mg/kg-day	Consumption of Venison: ILCR	Consumption of Venison: HQ	**All Pathways: Total ILCR**	**All Pathways: Total HI**
Polychlorinated biphenyls (PCB)								
Aroclor 1016	2.14E-02	1.12E-06	8.52E-11	1.99E-10	5.97E-12	2.84E-06	**2.42E-09**	**1.15E-03**
Aroclor 1254	4.58E-03	1.90E-06	1.45E-10	3.38E-10	2.90E-10	1.69E-05	**4.91E-08**	**2.86E-03**
Aroclor 1260	1.16E-03	9.57E-07	7.30E-11	1.70E-10	1.46E-10	NA	**1.86E-08**	**NA**
Semivolatile Organic Compounds								
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	**2.61E-07**	**NA**
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	**2.22E-06**	**NA**
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	**2.98E-07**	**NA**
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	**7.03E-09**	**NA**
Dibenz(a,h)anthracene	NA	NA	NA	NA	NA	NA	**2.72E-07**	**NA**
Indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA	NA	**1.77E-07**	**NA**
Total ILCR and HI					**4.42E-10**	**1.97E-05**	**3.30E-06**	**4.02E-03**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
ILCR - Incremental Lifetime Cancer Risk.
mg/kg - Milligrams per kilogram.
mg/cm^2 - Milligrams per square meter.

Table D-27

Hunter's Child, Future Scenario, Exposure to Surface Soil
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	EPC mg/kg	Concentration in Forage C_p mg/kg	Concentration in Venison C_v mg/kg	Consumption of Venison: Cancer Dose mg/kg-day	Consumption of Venison: Noncancer Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Polychlorinated biphenyls (PCB)									
Aroclor 1016	7.64E-01	2.14E-02	1.12E-06	3.06E-11	3.57E-10	2.14E-12	5.10E-06	**2.14E-12**	**5.10E-06**
Aroclor 1254	5.40E-01	4.58E-03	1.90E-06	5.20E-11	6.06E-10	1.04E-10	3.03E-05	**1.04E-10**	**3.03E-05**
Aroclor 1260	2.04E-01	1.16E-03	9.57E-07	2.62E-11	3.06E-10	5.24E-11	NA	**5.24E-11**	**NA**
Semivolatile Organic Compounds									
Benzo(a)anthracene	8.20E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(a)pyrene	6.96E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(b)fluoranthene	9.35E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(k)fluoranthene	2.21E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Dibenz(a,h)anthracene	8.54E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Indeno(1,2,3-cd)pyrene	5.55E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Total ILCR and HI						**1.59E-10**	**3.54E-05**	**1.59E-10**	**3.54E-05**

EPC - Exposure point concentration.
HQ - Hazard quotient; HI - Hazard index
ILCR - Incremental Lifetime Cancer Risk.
mg/kg - Milligrams per kilogram.

APPENDIX E

ANALYTICAL DATA SETS USED IN THE BHHRA

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW301					PBOW99-SSW302					PBOW99-SSW303					PBOW99-SSW304					PBOW99-SSW305					PBOW99-SSW306				
SAMPLE_NO		PBOW99SSW301					PBOW99SSW302					PBOW99SSW303					PBOW99SSW304					PBOW99SSW305					PBOW99SSW306				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																															
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.26	0.25	0.25		
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Dinitrobenzene, 1,3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Dinitrotoluene, 2,4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Dinitrotoluene, 2,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
HMX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U	
Nitrobenzene	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Nitrotoluene, 2-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Nitrotoluene, 3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Nitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
RDX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U	
Tetryl	mg/kg	0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U	
Trinitrobenzene, 1,3,5-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U	
Trinitrotoluene, 2,4,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.88	0.25	0.25		
METALS (UNFILTERED)																															
Aluminum	mg/kg	8820	22.9	22.9			7860	21.8	21.8			7480	24	24			7540	22.4	22.4			7500	22.1	22.1			5130	20.9	20.9		
Antimony	mg/kg	3.45	6.9	6.9	U		3.3	6.6	6.6	U		3.6	7.2	7.2	U		3.35	6.7	6.7	U		3.3	6.6	6.6	U		3.15	6.3	6.3	U	
Arsenic	mg/kg	7.1	1.1	1.1			7.2	1.1	1.1			6.1	1.2	1.2			7.3	1.1	1.1			6.7	1.1	1.1			3.9	1	1		
Barium	mg/kg	67.3	22.9	22.9			62.5	21.8	21.8			49.6	24	24			50.3	22.4	22.4			63.6	22.1	22.1			29.7	20.9	20.9		
Beryllium	mg/kg	0.63	0.57	0.57			0.275	0.55	0.55	U		0.3	0.6	0.6	U		0.28	0.56	0.56	U		0.275	0.55	0.55	U		0.26	0.52	0.52	U	
Cadmium	mg/kg	0.285	0.57	0.57	U		0.275	0.55	0.55	U		0.3	0.6	0.6	U		0.28	0.56	0.56	U		0.275	0.55	0.55	U		0.26	0.52	0.52	U	
Calcium	mg/kg	4250	573	573			40000	546	546			60700	600	600			8070	559	559			40200	554	554			15000	524	524		
Chromium	mg/kg	13.2	1.1	1.1			14.9	1.1	1.1			12.7	1.2	1.2			11.1	1.1	1.1			12.3	1.1	1.1			8.6	1	1		
Cobalt	mg/kg	6.8	5.7	5.7			7	5.5	5.5			3	6	6	U		6.2	5.6	5.6			8.8	5.5	5.5			2.6	5.2	5.2	U	
Copper	mg/kg	13.9	2.9	2.9			15.2	2.7	2.7			15.4	3	3			14.1	2.8	2.8			13.1	2.8	2.8			7.1	2.6	2.6		
Iron	mg/kg	16300	11.5	11.5			16200	10.9	10.9			14200	12	12			16100	11.2	11.2			14500	11.1	11.1			10300	10.5	10.5		
Lead	mg/kg	11.6	0.34	0.34			72.7	0.33	0.33			33.9	0.36	0.36			60.1	0.34	0.34			12.6	0.33	0.33			9.6	0.31	0.31		
Magnesium	mg/kg	2250	573	573			8090	546	546			8100	600	600			3370	559	559			7610	554	554			4230	524	524		
Manganese	mg/kg	346	1.7	1.7			324	1.6	1.6			283	1.8	1.8			281	1.7	1.7			606	1.7	1.7			170	1.6	1.6		
Mercury	mg/kg	0.047	0.038	0.038			0.11	0.036	0.036			0.16	0.04	0.04			0.044	0.037	0.037			0.0185	0.037	0.037	U		0.0175	0.035	0.035	U	
Nickel	mg/kg	16.5	4.6	4.6			18	4.4	4.4			14.6	4.8	4.8			14.8	4.5	4.5			17.7	4.4	4.4			8.4	4.2	4.2		
Potassium	mg/kg	746	573	573			936	546	546			830	600	600			724	559	559			715	554	554			262	524	524	U	
Selenium	mg/kg	0.96	0.57	0.57			0.6	0.55	0.55			0.65	0.6	0.6			0.92	0.56	0.56			0.57	0.55	0.55			0.26	0.52	0.52	U	
Silver	mg/kg	0.55	1.1	1.1	U		0.55	1.1	1.1	U		0.6	1.2	1.2	U		0.55	1.1	1.1	U		0.55	1.1	1.1	U		0.5	1	1	U	
Sodium	mg/kg	286.5	573	573	U		273	546	546	U		300	600	600	U		279.5	559	559	U		277	554	554	U		262	524	524	U	
Thallium	mg/kg	1.1	1.1	1.1			1.1	1.1	1.1			0.6	1.2	1.2	U		0.55	1.1	1.1	U		1.1	1.1	1.1			0.5	1	1	U	
Vanadium	mg/kg	21.5	5.7	5.7			20.6	5.5	5.5			19.7	6	6			19.9	5.6	5.6			19.5	5.5	5.5			14.8	5.2	5.2		
Zinc	mg/kg	47.9	2.3	2.3			105	2.2	2.2			67.4	2.4	2.4			44	2.2	2.2			42.2	2.2	2.2			33.8	2.1	2.1		
PESTICIDES/PCBS																															
Aroclor 1016	mg/kg						0.09	0.18	0.18	U	UJ	0.0395	0.079	0.079	U																
Aroclor 1221	mg/kg						0.09	0.18	0.18	U	UJ	0.0395	0.079	0.079	U																
Aroclor 1232	mg/kg						0.09	0.18	0.18	U	UJ	0.0395	0.079	0.079	U																
Aroclor 1242	mg/kg						0.09	0.18	0.18	U	UJ	0.0395	0.079	0.079	U																
Aroclor 1248	mg/kg						0.09	0.18	0.18	U	UJ	0.0395	0.079	0.079	U																
Aroclor 1254	mg/kg						1	0.18	0.18	AP	J	0.25	0.079	0.079	AP																
Aroclor 1260	mg/kg						0.23	0.46	0.46	U,G	UJ	0.115	0.23	0.23	U,G																
SEMIVOLATILES																															
Acenaphthene	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW301					PBOW99-SSW302					PBOW99-SSW303					PBOW99-SSW304					PBOW99-SSW305					PBOW99-SSW306				
SAMPLE_NO		PBOW99SSW301					PBOW99SSW302					PBOW99SSW303					PBOW99SSW304					PBOW99SSW305					PBOW99SSW306				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg						0.18	0.36	0.36	U		1.1	0.4	0.4																	
ACETOPHENONE	mg/kg																														
Anthracene	mg/kg						0.18	0.36	0.36	U		1.7	0.4	0.4																	
Atrazine	mg/kg																														
Benzaldehyde	mg/kg																														
Benzo(a)anthracene	mg/kg						1.2	0.36	0.36			4.5	0.4	0.4																	
Benzo(a)pyrene	mg/kg						1.3	0.36	0.36			4.2	0.4	0.4																	
Benzo(b)fluoranthene	mg/kg						1.2	0.36	0.36			4.3	0.4	0.4																	
Benzo(ghi)perylene	mg/kg						0.69	0.36	0.36			2.4	0.4	0.4																	
Benzo(k)fluoranthene	mg/kg						1.1	0.36	0.36			3	0.4	0.4																	
Benzoic acid	mg/kg																														
Benzyl alcohol	mg/kg																														
BIBENZENE	mg/kg																														
Bis(2-chloroethoxy)methane	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Bis(2-chloroethyl)ether	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Bis(2-chloroisopropyl)ether	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Bis(2-ethylhexyl)phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Bromophenyl phenyl ether, 4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Butyl benzyl phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Caprolactam	mg/kg																														
Carbazole	mg/kg																														
Chloro-3-methylphenol, 4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Chloroaniline, 4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Chloronaphthalene, 2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Chlorophenol, 2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Chlorophenyl phenyl ether, 4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Chrysene	mg/kg						1.2	0.36	0.36			4	0.4	0.4																	
Dibenz(a,h)anthracene	mg/kg						0.18	0.36	0.36	U		0.72	0.4	0.4																	
Dibenzofuran	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dichlorobenzene, 1,2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dichlorobenzene, 1,3-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dichlorobenzene, 1,4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dichlorobenzidine, 3,3'-	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
Dichlorophenol, 2,4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Diethyl phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dimethyl phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dimethylphenol, 2,4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Di-n-butyl phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dinitro-2-methylphenol, 4,6-	mg/kg						0.85	1.7	1.7	U	UJ	0.95	1.9	1.9	U																
Dinitrophenol, 2,4-	mg/kg						0.85	1.7	1.7	U	UJ	0.95	1.9	1.9	U																
Dinitrotoluene, 2,4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Dinitrotoluene, 2,6-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Di-n-octyl phthalate	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
DIPHENYLAMINE	mg/kg																														
Fluoranthene	mg/kg						2.1	0.36	0.36			8.9	0.79	0.79	D																
Fluorene	mg/kg						0.18	0.36	0.36	U		0.61	0.4	0.4																	
Hexachlorobenzene	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Hexachlorobutadiene	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Hexachlorocyclopentadiene	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW301					PBOW99-SSW302					PBOW99-SSW303					PBOW99-SSW304					PBOW99-SSW305					PBOW99-SSW306				
SAMPLE_NO		PBOW99SSW301					PBOW99SSW302					PBOW99SSW303					PBOW99SSW304					PBOW99SSW305					PBOW99SSW306				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Indeno(1,2,3-cd)pyrene	mg/kg						0.87	0.36	0.36			2.9	0.4	0.4																	
Isophorone	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Methylnaphthalene, 2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Methylphenol, 2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Methylphenol, 4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Naphthalene	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Nitroaniline, 2-	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
Nitroaniline, 3-	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
Nitroaniline, 4-	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
Nitrobenzene	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Nitrophenol, 2-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Nitrophenol, 4-	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
n-Nitrosodimethylamine	mg/kg																														
n-Nitroso-di-n-propylamine	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
n-Nitrosodiphenylamine	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Pentachlorophenol	mg/kg						0.85	1.7	1.7	U		0.95	1.9	1.9	U																
Phenanthrene	mg/kg						0.58	0.36	0.36			4.4	0.4	0.4																	
Phenol	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Pyrene	mg/kg						1.9	0.36	0.36			8.2	0.79	0.79	D																
Trichlorobenzene, 1,2,4-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Trichlorophenol, 2,4,5-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
Trichlorophenol, 2,4,6-	mg/kg						0.18	0.36	0.36	U		0.2	0.4	0.4	U																
VOLATILES																															
Benzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Bromobenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Bromochloromethane	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Bromodichloromethane	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Bromoform	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Bromomethane	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Carbon tetrachloride	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Chlorobenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Chloroethane	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Chloroform	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Chloromethane	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Chlorotoluene, 2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Chlorotoluene, 4-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dibromo-3-chloropropane, 1,2-	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Dibromochloromethane	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dibromoethane, 1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dibromomethane	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichlorobenzene, 1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichlorobenzene, 1,3-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichlorobenzene, 1,4-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichlorodifluoromethane	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Dichloroethane, 1,1-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloroethane, 1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloroethene, 1,1-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloroethene, cis-1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW301					PBOW99-SSW302					PBOW99-SSW303					PBOW99-SSW304					PBOW99-SSW305					PBOW99-SSW306				
SAMPLE_NO		PBOW99SSW301					PBOW99SSW302					PBOW99SSW303					PBOW99SSW304					PBOW99SSW305					PBOW99SSW306				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloropropane, 1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloropropane, 1,3-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloropropane, 2,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Dichloropropene, 1,1-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Ethylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Hexachlorobutadiene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Isopropylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Methylene chloride	mg/kg						0.012	0.0055	0.0055			0.013	0.006	0.006																	
Naphthalene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
n-Butylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
n-Propylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
p-Isopropyltoluene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
sec-Butylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Styrene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
tert-Butylbenzene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Tetrachloroethane, 1,1,1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Tetrachloroethane, 1,1,2,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Tetrachloroethene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Toluene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichlorobenzene, 1,2,3-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichlorobenzene, 1,2,4-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichloroethane, 1,1,1-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichloroethane, 1,1,2-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichloroethene	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trichlorofluoromethane	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Trichloropropane, 1,2,3-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trimethylbenzene, 1,2,4-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Trimethylbenzene, 1,3,5-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Vinyl chloride	mg/kg						0.0055	0.011	0.011	U		0.006	0.012	0.012	U																
Xylenes, m,p-	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
Xylenes, total	mg/kg						0.00275	0.0055	0.0055	U		0.003	0.006	0.006	U																
WATER QUALITY																															
% moisture	Percent	12.8	0.1	0.1			8.4	0.1	0.1			16.7	0.1	0.1			10.6	0.1	0.1			9.7	0.1	0.1			4.5	0.1	0.1		
% Solids	Percent																														
pH	pH_units	7.5	0.1	0.1																											
Total organic carbon	mg/kg																														

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW307					PBOW99-SSW307					PBOW99-SSW309					PBOW99-SSW310					WWTP3-SB01					WWTP3-SB01				
SAMPLE_NO		PBOW99SSW307					PBOW99SSW308					PBOW99SSW309					PBOW99SSW310					WW0034					WW0035				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					10-Dec-08					10-Dec-08				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					_7 - 1_7 Ft					5 - 5_7 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																															
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.33	0.25	0.25			0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Dinitrobenzene, 1,3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Dinitrotoluene, 2,4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Dinitrotoluene, 2,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
HMX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Nitrobenzene	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Nitrotoluene, 2-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Nitrotoluene, 3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Nitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
RDX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.25	0.5	0.5	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Tetryl	mg/kg	0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.325	0.65	0.65	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Trinitrobenzene, 1,3,5-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
Trinitrotoluene, 2,4,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.125	0.25	0.25	U		0.1555	0.311	0.155	U	UJ	0.1335	0.267	0.133	U	U
METALS (UNFILTERED)																															
Aluminum	mg/kg	5190	20.8	20.8			1020	27	27			9470	23.5	23.5			8270	21.9	21.9			8510	1.74	0.87			7830	1.77	0.885		
Antimony	mg/kg	3.1	6.2	6.2	U		4.05	8.1	8.1	U		3.5	7	7	U		3.3	6.6	6.6	U		0.396	0.435	0.218	J	J	0.274	0.442	0.221	J	J
Arsenic	mg/kg	4	1	1			6.8	1.4	1.4			6.4	1.2	1.2			6.7	1.1	1.1			20.8	0.87	0.435			5.03	0.885	0.442		
Barium	mg/kg	31.4	20.8	20.8			75.3	27	27			74.7	23.5	23.5			57.6	21.9	21.9			52.2	0.174	0.087			47	0.177	0.0885		
Beryllium	mg/kg	0.26	0.52	0.52	U		0.34	0.68	0.68	U		0.59	0.59	0.59			0.275	0.55	0.55	U		8.44	0.174	0.087			5.32	0.177	0.0885		
Cadmium	mg/kg	0.26	0.52	0.52	U		0.34	0.68	0.68	U		0.295	0.59	0.59	U		0.275	0.55	0.55	U		0.247	0.435	0.218	J	J	0.221	0.442	0.221	U	U
Calcium	mg/kg	5180	519	519			6880	676	676			6090	587	587			13200	548	548			9040	4.35	2.18			23600	4.42	2.21		
Chromium	mg/kg	10	1	1			16.5	1.4	1.4			14.9	1.2	1.2			13.4	1.1	1.1			13.9	0.435	0.218			12.7	0.442	0.221		
Cobalt	mg/kg	2.6	5.2	5.2	U		8.1	6.8	6.8			7.2	5.9	5.9			7.5	5.5	5.5			9.78	0.174	0.087			6.2	0.177	0.0885		
Copper	mg/kg	7.3	2.6	2.6			15.9	3.4	3.4			14.5	2.9	2.9			14	2.7	2.7			22	0.435	0.218			19.4	0.442	0.221		
Iron	mg/kg	10500	10.4	10.4			18200	13.5	13.5			17000	11.7	11.7			16300	11	11			29000	3.48	1.74			15700	1.77	0.885		
Lead	mg/kg	11.6	0.31	0.31			16.8	0.41	0.41			14.6	0.35	0.35			11.7	0.33	0.33			21.5	0.435	0.218			10.2	0.442	0.221		
Magnesium	mg/kg	1860	519	519			3230	676	676			2910	587	587			4970	548	548			4420	1.74	0.87			8480	1.77	0.885		
Manganese	mg/kg	171	1.6	1.6			407	2	2			451	1.8	1.8			348	1.6	1.6			226	0.174	0.087			260	0.177	0.0885		
Mercury	mg/kg	0.035	0.034	0.034			0.056	0.045	0.045			0.048	0.039	0.039			0.036	0.036	0.036			0.597	0.0223	0.0112			0.0163	0.0249	0.0124	J	J
Nickel	mg/kg	9.8	4.2	4.2			18.4	5.4	5.4			17.5	4.7	4.7			17	4.4	4.4			24.1	0.261	0.131			17.5	0.265	0.133		
Potassium	mg/kg	259.5	519	519	U		936	676	676			833	587	587			780	548	548			494	21.8	10.9			458	22.1	11.1		
Selenium	mg/kg	0.26	0.52	0.52	U		1.2	0.68	0.68			1.1	0.59	0.59			1.1	0.55	0.55			0.628	0.87	0.435	J	J	0.4425	0.885	0.442	U	U
Silver	mg/kg	0.5	1	1	U		0.7	1.4	1.4	U		0.6	1.2	1.2	U		0.55	1.1	1.1	U		0.2175	0.435	0.218	U	U	0.221	0.442	0.221	U	U
Sodium	mg/kg	259.5	519	519	U		338	676	676	U		293.5	587	587	U		274	548	548	U		57	8.7	4.35			66.1	8.85	4.42		
Thallium	mg/kg	0.5	1	1	U		0.7	1.4	1.4	U		0.6	1.2	1.2	U		1.1	1.1	1.1			0.266	0.435	0.218	J	J	0.221	0.442	0.221	U	U
Vanadium	mg/kg	14.9	5.2	5.2			24	6.8	6.8			22	5.9	5.9			21.1	5.5	5.5			23.2	0.174	0.087			18.9	0.177	0.0885		
Zinc	mg/kg	34.2	2.1	2.1			59.5	2.7	2.7			55.5	2.3	2.3			46.4	2.2	2.2			74.4	2.18	1.09			51.1	2.21	1.11		
PESTICIDES/PCBS																															
Aroclor 1016	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1221	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1232	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1242	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1248	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1254	mg/kg																					0.0203	0.0406	0.00813	U	U	0.02065	0.0413	0.00827	U	U
Aroclor 1260	mg/kg																					0.18	0.0406	0.00813	P	J	0.02065	0.0413	0.00827	U	U
SEMIVOLATILES																															
Acenaphthene	mg/kg																					0.478	0.405	0.00729			0.2085	0.417	0.00751	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW307					PBOW99-SSW307					PBOW99-SSW309					PBOW99-SSW310					WWTP3-SB01					WWTP3-SB01				
SAMPLE_NO		PBOW99SSW307					PBOW99SSW308					PBOW99SSW309					PBOW99SSW310					WW0034					WW0035				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					10-Dec-08					10-Dec-08				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					_7 - 1_7 Ft					5 - 5_7 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg																					0.209	0.405	0.00486	J	J	0.2085	0.417	0.00501	U	U
ACETOPHENONE	mg/kg																														
Anthracene	mg/kg																					1.5	0.405	0.00875			0.2085	0.417	0.00902	U	U
Atrazine	mg/kg																														
Benzaldehyde	mg/kg																														
Benzo(a)anthracene	mg/kg																					3.25	0.405	0.0266			0.2085	0.417	0.0274	U	U
Benzo(a)pyrene	mg/kg																					2.41	0.405	0.0266			0.2085	0.417	0.0274	U	U
Benzo(b)fluoranthene	mg/kg																					3.58	0.405	0.0674			0.2085	0.417	0.0695	U	U
Benzo(ghi)perylene	mg/kg																					1.54	0.405	0.0987			0.2085	0.417	0.102	U	U
Benzo(k)fluoranthene	mg/kg																					1.08	0.405	0.123			0.2085	0.417	0.126	U	U
Benzoic acid	mg/kg																					0.2025	0.405	0.0987	U	U	0.2085	0.417	0.102	U	U
Benzyl alcohol	mg/kg																					0.2025	0.405	0.0987	U	U	0.2085	0.417	0.102	U	U
BIBENZENE	mg/kg																														
Bis(2-chloroethoxy)methane	mg/kg																					0.2025	0.405	0.00851	U	U	0.2085	0.417	0.00877	U	U
Bis(2-chloroethyl)ether	mg/kg																					0.2025	0.405	0.0103	U	U	0.2085	0.417	0.0106	U	U
Bis(2-chloroisopropyl)ether	mg/kg																					0.2025	0.405	0.0176	U	U	0.2085	0.417	0.0182	U	U
Bis(2-ethylhexyl)phthalate	mg/kg																					0.2025	0.405	0.0374	U	U	0.2085	0.417	0.0386	U	U
Bromophenyl phenyl ether, 4-	mg/kg																					0.2025	0.405	0.0145	U	U	0.2085	0.417	0.0149	U	U
Butyl benzyl phthalate	mg/kg																					0.2025	0.405	0.0164	U	U	0.2085	0.417	0.0169	U	U
Caprolactam	mg/kg																														
Carbazole	mg/kg																					0.432	0.405	0.0405			0.2085	0.417	0.0417	U	U
Chloro-3-methylphenol, 4-	mg/kg																					0.2025	0.405	0.00996	U	U	0.2085	0.417	0.0103	U	U
Chloroaniline, 4-	mg/kg																					0.2025	0.405	0.0351	U	UJ	0.2085	0.417	0.0362	U	UJ
Chloronaphthalene, 2-	mg/kg																					0.2025	0.405	0.00644	U	U	0.2085	0.417	0.00664	U	U
Chlorophenol, 2-	mg/kg																					0.2025	0.405	0.00498	U	U	0.2085	0.417	0.00513	U	U
Chlorophenyl phenyl ether, 4-	mg/kg																					0.2025	0.405	0.031	U	U	0.2085	0.417	0.0319	U	U
Chrysene	mg/kg																					2.98	0.405	0.016			0.2085	0.417	0.0165	U	U
Dibenz(a,h)anthracene	mg/kg																					0.397	0.405	0.0915	J	J	0.2085	0.417	0.0943	U	U
Dibenzofuran	mg/kg																					0.436	0.405	0.00681			0.2085	0.417	0.00701	U	U
Dichlorobenzene, 1,2-	mg/kg																					0.2025	0.405	0.00936	U	U	0.2085	0.417	0.00964	U	U
Dichlorobenzene, 1,3-	mg/kg																					0.2025	0.405	0.0147	U	U	0.2085	0.417	0.0152	U	U
Dichlorobenzene, 1,4-	mg/kg																					0.2025	0.405	0.0079	U	U	0.2085	0.417	0.00814	U	U
Dichlorobenzidine, 3,3'-	mg/kg																					0.2025	0.405	0.0401	U	UJ	0.2085	0.417	0.0413	U	UJ
Dichlorophenol, 2,4-	mg/kg																					0.2025	0.405	0.0145	U	U	0.2085	0.417	0.0149	U	U
Diethyl phthalate	mg/kg																					0.2025	0.405	0.0164	U	U	0.2085	0.417	0.0169	U	U
Dimethyl phthalate	mg/kg																					0.2025	0.405	0.0124	U	U	0.2085	0.417	0.0128	U	U
Dimethylphenol, 2,4-	mg/kg																					0.2025	0.405	0.0107	U	U	0.2085	0.417	0.011	U	U
Di-n-butyl phthalate	mg/kg																					0.2025	0.405	0.00875	U	U	0.2085	0.417	0.00902	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg																					0.2025	0.405	0.0407	U	U	0.2085	0.417	0.042	U	U
Dinitrophenol, 2,4-	mg/kg																					0.2025	0.405	0.0645	U	U	0.2085	0.417	0.0665	U	U
Dinitrotoluene, 2,4-	mg/kg																					0.2025	0.405	0.0142	U	U	0.2085	0.417	0.0147	U	U
Dinitrotoluene, 2,6-	mg/kg																					0.2025	0.405	0.00972	U	U	0.2085	0.417	0.01	U	U
Di-n-octyl phthalate	mg/kg																					0.2025	0.405	0.0762	U	U	0.2085	0.417	0.0785	U	U
DIPHENYLAMINE	mg/kg																					0.2025	0.405	0.0401	U	U	0.2085	0.417	0.0413	U	U
Fluoranthene	mg/kg																					6.82	0.809	0.0175			0.2085	0.417	0.00902	U	U
Fluorene	mg/kg																					0.581	0.405	0.0171			0.2085	0.417	0.0177	U	U
Hexachlorobenzene	mg/kg																					0.2025	0.405	0.0252	U	U	0.2085	0.417	0.0259	U	U
Hexachlorobutadiene	mg/kg																					0.2025	0.405	0.0384	U	U	0.2085	0.417	0.0396	U	U
Hexachlorocyclopentadiene	mg/kg																					0.2025	0.405	0.0129	U	UJ	0.2085	0.417	0.0133	U	UJ

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW307					PBOW99-SSW307					PBOW99-SSW309					PBOW99-SSW310					WWTP3-SB01					WWTP3-SB01				
SAMPLE_NO		PBOW99SSW307					PBOW99SSW308					PBOW99SSW309					PBOW99SSW310					WW0034					WW0035				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					10-Dec-08					10-Dec-08				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					_7 - 1_7 Ft					5 - 5_7 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg																					0.2025	0.405	0.0124	U	U	0.2085	0.417	0.0128	U	U
Indeno(1,2,3-cd)pyrene	mg/kg																					2.14	0.405	0.131			0.2085	0.417	0.135	U	U
Isophorone	mg/kg																					0.2025	0.405	0.00486	U	U	0.2085	0.417	0.00501	U	U
Methylnaphthalene, 2-	mg/kg																					0.721	0.405	0.106			0.2085	0.417	0.109	U	U
Methylphenol, 2-	mg/kg																					0.2025	0.405	0.00608	U	U	0.2085	0.417	0.00626	U	U
Methylphenol, 4-	mg/kg																					0.2025	0.405	0.0126	U	U	0.2085	0.417	0.013	U	U
Naphthalene	mg/kg																					0.677	0.405	0.0096			0.2085	0.417	0.00989	U	U
Nitroaniline, 2-	mg/kg																					0.2025	0.405	0.0175	U	U	0.2085	0.417	0.018	U	U
Nitroaniline, 3-	mg/kg																					0.2025	0.405	0.0137	U	U	0.2085	0.417	0.0142	U	U
Nitroaniline, 4-	mg/kg																					0.2025	0.405	0.143	U	U	0.2085	0.417	0.148	U	U
Nitrobenzene	mg/kg																					0.2025	0.405	0.0132	U	U	0.2085	0.417	0.0136	U	U
Nitrophenol, 2-	mg/kg																					0.2025	0.405	0.0143	U	U	0.2085	0.417	0.0148	U	U
Nitrophenol, 4-	mg/kg																					0.2025	0.405	0.0328	U	U	0.2085	0.417	0.0338	U	U
n-Nitrosodimethylamine	mg/kg																					0.2025	0.405	0.0122	U	U	0.2085	0.417	0.0125	U	U
n-Nitroso-di-n-propylamine	mg/kg																					0.2025	0.405	0.0145	U	U	0.2085	0.417	0.0149	U	U
n-Nitrosodiphenylamine	mg/kg																					0.2025	0.405	0.00571	U	U	0.2085	0.417	0.00589	U	U
Pentachlorophenol	mg/kg																					0.2025	0.405	0.0363	U	U	0.2085	0.417	0.0374	U	U
Phenanthrene	mg/kg																					4.49	0.405	0.00984			0.2085	0.417	0.0101	U	U
Phenol	mg/kg																					0.2025	0.405	0.00486	U	U	0.2085	0.417	0.00501	U	U
Pyrene	mg/kg																					4.58	0.405	0.0162			0.2085	0.417	0.0167	U	U
Trichlorobenzene, 1,2,4-	mg/kg																					0.2025	0.405	0.00996	U	U	0.2085	0.417	0.0103	U	U
Trichlorophenol, 2,4,5-	mg/kg																					0.2025	0.405	0.0348	U	U	0.2085	0.417	0.0358	U	U
Trichlorophenol, 2,4,6-	mg/kg																					0.2025	0.405	0.0273	U	U	0.2085	0.417	0.0282	U	U
VOLATILES																															
Benzene	mg/kg																														
Bromobenzene	mg/kg																														
Bromochloromethane	mg/kg																														
Bromodichloromethane	mg/kg																														
Bromoform	mg/kg																														
Bromomethane	mg/kg																														
Carbon tetrachloride	mg/kg																														
Chlorobenzene	mg/kg																														
Chloroethane	mg/kg																														
Chloroform	mg/kg																														
Chloromethane	mg/kg																														
Chlorotoluene, 2-	mg/kg																														
Chlorotoluene, 4-	mg/kg																														
Dibromo-3-chloropropane, 1,2-	mg/kg																														
Dibromochloromethane	mg/kg																														
Dibromoethane, 1,2-	mg/kg																														
Dibromomethane	mg/kg																														
Dichlorobenzene, 1,2-	mg/kg																														
Dichlorobenzene, 1,3-	mg/kg																														
Dichlorobenzene, 1,4-	mg/kg																														
Dichlorodifluoromethane	mg/kg																														
Dichloroethane, 1,1-	mg/kg																														
Dichloroethane, 1,2-	mg/kg																														
Dichloroethene, 1,1-	mg/kg																														
Dichloroethene, cis-1,2-	mg/kg																														

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SSW307					PBOW99-SSW307					PBOW99-SSW309					PBOW99-SSW310					WWTP3-SB01					WWTP3-SB01				
SAMPLE_NO		PBOW99SSW307					PBOW99SSW308					PBOW99SSW309					PBOW99SSW310					WW0034					WW0035				
SAMPLE DATE		2-Sep-99					2-Sep-99					2-Sep-99					2-Sep-99					10-Dec-08					10-Dec-08				
DEPTH		0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					_7 - 1_7 Ft					5 - 5_7 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg																														
Dichloropropane, 1,2-	mg/kg																														
Dichloropropane, 1,3-	mg/kg																														
Dichloropropane, 2,2-	mg/kg																														
Dichloropropene, 1,1-	mg/kg																														
Ethylbenzene	mg/kg																														
Hexachlorobutadiene	mg/kg																														
Isopropylbenzene	mg/kg																														
Methylene chloride	mg/kg																														
Naphthalene	mg/kg																														
n-Butylbenzene	mg/kg																														
n-Propylbenzene	mg/kg																														
p-Isopropyltoluene	mg/kg																														
sec-Butylbenzene	mg/kg																														
Styrene	mg/kg																														
tert-Butylbenzene	mg/kg																														
Tetrachloroethane, 1,1,1,2-	mg/kg																														
Tetrachloroethane, 1,1,2,2-	mg/kg																														
Tetrachloroethene	mg/kg																														
Toluene	mg/kg																														
Trichlorobenzene, 1,2,3-	mg/kg																														
Trichlorobenzene, 1,2,4-	mg/kg																														
Trichloroethane, 1,1,1-	mg/kg																														
Trichloroethane, 1,1,2-	mg/kg																														
Trichloroethene	mg/kg																														
Trichlorofluoromethane	mg/kg																														
Trichloropropane, 1,2,3-	mg/kg																														
Trimethylbenzene, 1,2,4-	mg/kg																														
Trimethylbenzene, 1,3,5-	mg/kg																														
Vinyl chloride	mg/kg																														
Xylenes, m,p-	mg/kg																														
Xylenes, total	mg/kg																														
WATER QUALITY																															
% moisture	Percent	3.7	0.1	0.1			26	0.1	0.1			14.8	0.1	0.1			8.8	0.1	0.1												
% Solids	Percent																														
pH	pH_units																														
Total organic carbon	mg/kg																					33.5	24.7	0.618	B	B					

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB01					WWTP3-SB01					WWTP3-SB02					WWTP3-SB02					WWTP3-SB02				
SAMPLE_NO		WW0036					WW0037					WW0038					WW0039					WW0040				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08				
DEPTH		8 - 10 Ft					8 - 10 Ft					_5 - 1_5 Ft					5 - 5_5 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																										
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Dinitrobenzene, 1,3-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Dinitrotoluene, 2,4-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Dinitrotoluene, 2,6-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
HMX	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Nitrobenzene	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Nitrotoluene, 2-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Nitrotoluene, 3-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Nitrotoluene, 4-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
RDX	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Tetryl	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Trinitrobenzene, 1,3,5-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
Trinitrotoluene, 2,4,6-	mg/kg	0.1605	0.321	0.16	U	U	0.142	0.284	0.142	U	U	0.1415	0.283	0.142	U	UJ	0.1465	0.293	0.146	U	U	0.1365	0.273	0.136	U	U
METALS (UNFILTERED)																										
Aluminum	mg/kg	7810	1.67	0.834			7980	1.97	0.986			7070	1.81	0.903			10500	1.79	0.894			9240	1.89	0.947		
Antimony	mg/kg	0.245	0.417	0.208	J	J	0.3	0.493	0.247	J	J	0.296	0.451	0.226	J	J	0.324	0.447	0.224	J	J	0.392	0.474	0.237	J	J
Arsenic	mg/kg	5.92	0.834	0.417			6.29	0.986	0.493			14.4	0.903	0.451			9.56	0.894	0.447			7.25	0.947	0.474		
Barium	mg/kg	51	0.167	0.0834			61.9	0.197	0.0986			54.1	0.181	0.0903			197	0.179	0.0894			89.3	0.189	0.0947		
Beryllium	mg/kg	5.58	0.167	0.0834			5.5	0.197	0.0986			8.44	0.181	0.0903			8.08	0.179	0.0894			7.48	0.189	0.0947		
Cadmium	mg/kg	0.23	0.417	0.208	J	J	0.2465	0.493	0.247	U	U	0.364	0.451	0.226	J	J	1.01	0.447	0.224			0.383	0.474	0.237	J	J
Calcium	mg/kg	42800	4.17	2.08			46300	4.93	2.47			17200	4.51	2.26			3710	4.47	2.24			42200	4.74	2.37		
Chromium	mg/kg	11.6	0.417	0.208			12.3	0.493	0.247			11.5	0.451	0.226			17.8	0.447	0.224			14.1	0.474	0.237		
Cobalt	mg/kg	8.09	0.167	0.0834			7.21	0.197	0.0986			6.38	0.181	0.0903			22.1	0.179	0.0894			10.4	0.189	0.0947		
Copper	mg/kg	25.8	0.417	0.208			24	0.493	0.247			24.5	0.451	0.226			28.4	0.447	0.224			29.4	0.474	0.237		
Iron	mg/kg	18400	1.67	0.834			17300	1.97	0.986			28000	3.61	1.81			28000	3.58	1.79			24600	1.89	0.947		
Lead	mg/kg	13	0.417	0.208			11.1	0.493	0.247			34.6	0.451	0.226			15.9	0.447	0.224			16	0.474	0.237		
Magnesium	mg/kg	16300	1.67	0.834			17800	1.97	0.986			4160	1.81	0.903			3850	1.79	0.894			13500	1.89	0.947		
Manganese	mg/kg	389	0.167	0.0834			368	0.197	0.0986			428	0.181	0.0903			2520	0.179	0.0894			696	0.189	0.0947		
Mercury	mg/kg	0.0177	0.0229	0.0114	J	J	0.0221	0.0232	0.0116	J	J	0.074	0.0206	0.0103			0.0223	0.0234	0.0117	J	J	0.0185	0.0208	0.0104	J	J
Nickel	mg/kg	21.3	0.25	0.125			20.8	0.296	0.148			17.5	0.271	0.135			57.1	0.268	0.134			30.9	0.284	0.142		
Potassium	mg/kg	813	20.8	10.4			829	24.7	12.3			422	22.6	11.3			735	22.4	11.2			860	23.7	11.8		
Selenium	mg/kg	0.436	0.834	0.417	J	J	0.493	0.986	0.493	U	U	0.695	0.903	0.451	J	J	0.447	0.894	0.447	U	U	0.4735	0.947	0.474	U	U
Silver	mg/kg	0.2085	0.417	0.208	U	U	0.2465	0.493	0.247	U	U	0.2255	0.451	0.226	U	U	0.2235	0.447	0.224	U	U	0.237	0.474	0.237	U	U
Sodium	mg/kg	97.3	8.34	4.17			103	9.86	4.93			47.7	9.03	4.51			48.9	8.94	4.47			88.8	9.47	4.74		
Thallium	mg/kg	0.216	0.417	0.208	J	J	0.2465	0.493	0.247	U	U	0.2255	0.451	0.226	U	U	0.292	0.447	0.224	J	J	0.281	0.474	0.237	J	J
Vanadium	mg/kg	19.3	0.167	0.0834			19.2	0.197	0.0986			18.3	0.181	0.0903			28.5	0.179	0.0894			23.2	0.189	0.0947		
Zinc	mg/kg	58.8	2.08	1.04			56.6	2.47	1.23			90.1	2.26	1.13			78.5	2.24	1.12			72.2	2.37	1.18		
PESTICIDES/PCBS																										
Aroclor 1016	mg/kg											1.22	0.0402	0.00804	P	J	0.1	0.0399	0.008		J					
Aroclor 1221	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
Aroclor 1232	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
Aroclor 1242	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
Aroclor 1248	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
Aroclor 1254	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
Aroclor 1260	mg/kg											0.0201	0.0402	0.00804	U	U	0.01995	0.0399	0.008	U	U					
SEMIVOLATILES																										
Acenaphthene	mg/kg	0.2	0.4	0.0072	U	U	0.202	0.404	0.00729	U	U	0.643	2	0.0361	J	J	0.0592	0.392	0.00706	J	J	0.201	0.402	0.00723	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB01					WWTP3-SB01					WWTP3-SB02					WWTP3-SB02					WWTP3-SB02				
SAMPLE_NO		WW0036					WW0037					WW0038					WW0039					WW0040				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08				
DEPTH		8 - 10 Ft					8 - 10 Ft					_5 - 1_5 Ft					5 - 5_5 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg	0.2	0.4	0.0048	U	U	0.202	0.404	0.00486	U	U	3.23	2	0.024			0.0788	0.392	0.0047	J	J	0.201	0.402	0.00482	U	U
ACETOPHENONE	mg/kg																									
Anthracene	mg/kg	0.2	0.4	0.00864	U	U	0.202	0.404	0.00874	U	U	4.53	2	0.0433			0.263	0.392	0.00847	J	J	0.201	0.402	0.00868	U	U
Atrazine	mg/kg																									
Benzaldehyde	mg/kg																									
Benzo(a)anthracene	mg/kg	0.2	0.4	0.0263	U	U	0.202	0.404	0.0266	U	U	11.9	2	0.132			0.309	0.392	0.0258	J	J	0.201	0.402	0.0264	U	U
Benzo(a)pyrene	mg/kg	0.2	0.4	0.0263	U	U	0.202	0.404	0.0266	U	U	10	2	0.132			0.306	0.392	0.0258	J	J	0.201	0.402	0.0264	U	U
Benzo(b)fluoranthene	mg/kg	0.2	0.4	0.0666	U	U	0.202	0.404	0.0674	U	U	13.9	2	0.334			0.409	0.392	0.0653			0.201	0.402	0.0669	U	U
Benzo(ghi)perylene	mg/kg	0.2	0.4	0.0975	U	U	0.202	0.404	0.0986	U	U	5.57	2	0.488			0.18	0.392	0.0955	J	J	0.201	0.402	0.0979	U	U
Benzo(k)fluoranthene	mg/kg	0.2	0.4	0.121	U	U	0.202	0.404	0.123	U	U	4.49	2	0.607			0.136	0.392	0.119	J	J	0.201	0.402	0.122	U	U
Benzoic acid	mg/kg	0.2	0.4	0.0975	U	U	0.202	0.404	0.0986	U	UJ	1	2	0.488	U	U	0.196	0.392	0.0955	U	U	0.201	0.402	0.0979	U	UJ
Benzyl alcohol	mg/kg	0.2	0.4	0.0975	U	U	0.202	0.404	0.0986	U	U	1	2	0.488	U	U	0.196	0.392	0.0955	U	U	0.201	0.402	0.0979	U	U
BIBENZENE	mg/kg																									
Bis(2-chloroethoxy)methane	mg/kg	0.2	0.4	0.0084	U	U	0.202	0.404	0.0085	U	U	1	2	0.0421	U	U	0.196	0.392	0.00823	U	U	0.201	0.402	0.00844	U	U
Bis(2-chloroethyl)ether	mg/kg	0.2	0.4	0.0102	U	U	0.202	0.404	0.0103	U	U	1	2	0.0511	U	U	0.196	0.392	0.01	U	U	0.201	0.402	0.0102	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.2	0.4	0.0174	U	U	0.202	0.404	0.0176	U	U	1	2	0.0871	U	U	0.196	0.392	0.0171	U	U	0.201	0.402	0.0175	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.2	0.4	0.037	U	U	0.202	0.404	0.0374	U	U	1	2	0.185	U	U	0.196	0.392	0.0362	U	U	0.201	0.402	0.0371	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.0143	U	U	0.202	0.404	0.0144	U	U	1	2	0.0715	U	U	0.196	0.392	0.014	U	U	0.201	0.402	0.0143	U	U
Butyl benzyl phthalate	mg/kg	0.2	0.4	0.0162	U	U	0.202	0.404	0.0164	U	U	1	2	0.0811	U	U	0.196	0.392	0.0159	U	U	0.201	0.402	0.0163	U	U
Caprolactam	mg/kg																									
Carbazole	mg/kg	0.2	0.4	0.04	U	U	0.202	0.404	0.0404	U	U	1.12	2	0.2	J	J	0.0443	0.392	0.0392	J	J	0.201	0.402	0.0402	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.2	0.4	0.00984	U	U	0.202	0.404	0.00996	U	U	1	2	0.0493	U	U	0.196	0.392	0.00964	U	U	0.201	0.402	0.00989	U	U
Chloroaniline, 4-	mg/kg	0.2	0.4	0.0347	U	UJ	0.202	0.404	0.0351	U	UJ	1	2	0.174	U	UJ	0.196	0.392	0.034	U	UJ	0.201	0.402	0.0348	U	UJ
Chloronaphthalene, 2-	mg/kg	0.2	0.4	0.00636	U	U	0.202	0.404	0.00644	U	U	1	2	0.0319	U	U	0.196	0.392	0.00623	U	U	0.201	0.402	0.00639	U	U
Chlorophenol, 2-	mg/kg	0.2	0.4	0.00492	U	U	0.202	0.404	0.00498	U	U	1	2	0.0246	U	U	0.196	0.392	0.00482	U	U	0.201	0.402	0.00494	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.0306	U	U	0.202	0.404	0.031	U	U	1	2	0.153	U	U	0.196	0.392	0.03	U	U	0.201	0.402	0.0307	U	U
Chrysene	mg/kg	0.2	0.4	0.0158	U	U	0.202	0.404	0.016	U	U	10.3	2	0.0793			0.276	0.392	0.0155	J	J	0.201	0.402	0.0159	U	U
Dibenz(a,h)anthracene	mg/kg	0.2	0.4	0.0904	U	U	0.202	0.404	0.0914	U	U	1.46	2	0.453	J	J	0.196	0.392	0.0885	U	U	0.201	0.402	0.0908	U	U
Dibenzofuran	mg/kg	0.2	0.4	0.00672	U	U	0.202	0.404	0.0068	U	U	1.35	2	0.0337	J	J	0.078	0.392	0.00659	J	J	0.201	0.402	0.00675	U	U
Dichlorobenzene, 1,2-	mg/kg	0.2	0.4	0.00924	U	U	0.202	0.404	0.00935	U	U	1	2	0.0463	U	U	0.196	0.392	0.00905	U	U	0.201	0.402	0.00928	U	U
Dichlorobenzene, 1,3-	mg/kg	0.2	0.4	0.0145	U	U	0.202	0.404	0.0147	U	U	1	2	0.0727	U	U	0.196	0.392	0.0142	U	U	0.201	0.402	0.0146	U	U
Dichlorobenzene, 1,4-	mg/kg	0.2	0.4	0.0078	U	U	0.202	0.404	0.00789	U	U	1	2	0.0391	U	U	0.196	0.392	0.00764	U	U	0.201	0.402	0.00784	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.2	0.4	0.0396	U	UJ	0.202	0.404	0.0401	U	UJ	1	2	0.198	U	UJ	0.196	0.392	0.0388	U	UJ	0.201	0.402	0.0398	U	UJ
Dichlorophenol, 2,4-	mg/kg	0.2	0.4	0.0143	U	U	0.202	0.404	0.0144	U	U	1	2	0.0715	U	U	0.196	0.392	0.014	U	U	0.201	0.402	0.0143	U	U
Diethyl phthalate	mg/kg	0.2	0.4	0.0162	U	U	0.202	0.404	0.0164	U	U	1	2	0.0811	U	U	0.196	0.392	0.0159	U	U	0.201	0.402	0.0163	U	U
Dimethyl phthalate	mg/kg	0.2	0.4	0.0122	U	U	0.202	0.404	0.0124	U	U	1	2	0.0613	U	U	0.196	0.392	0.012	U	U	0.201	0.402	0.0123	U	U
Dimethylphenol, 2,4-	mg/kg	0.2	0.4	0.0106	U	U	0.202	0.404	0.0107	U	U	1	2	0.0529	U	U	0.196	0.392	0.0103	U	U	0.201	0.402	0.0106	U	U
Di-n-butyl phthalate	mg/kg	0.2	0.4	0.00864	U	U	0.202	0.404	0.00874	U	U	1	2	0.0433	U	U	0.196	0.392	0.00847	U	U	0.201	0.402	0.00868	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.2	0.4	0.0402	U	U	0.202	0.404	0.0407	U	U	1	2	0.201	U	U	0.196	0.392	0.0394	U	U	0.201	0.402	0.0404	U	U
Dinitrophenol, 2,4-	mg/kg	0.2	0.4	0.0637	U	U	0.202	0.404	0.0645	U	UJ	1	2	0.319	U	U	0.196	0.392	0.0624	U	U	0.201	0.402	0.064	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.2	0.4	0.014	U	U	0.202	0.404	0.0142	U	U	1	2	0.0703	U	U	0.196	0.392	0.0138	U	U	0.201	0.402	0.0141	U	U
Dinitrotoluene, 2,6-	mg/kg	0.2	0.4	0.0096	U	U	0.202	0.404	0.00971	U	U	1	2	0.0481	U	U	0.196	0.392	0.00941	U	U	0.201	0.402	0.00965	U	U
Di-n-octyl phthalate	mg/kg	0.2	0.4	0.0753	U	U	0.202	0.404	0.0761	U	U	1	2	0.377	U	U	0.196	0.392	0.0737	U	U	0.201	0.402	0.0756	U	U
DIPHENYLAMINE	mg/kg	0.2	0.4	0.0396	U	U	0.202	0.404	0.0401	U	U	1	2	0.198	U	U	0.196	0.392	0.0388	U	U	0.201	0.402	0.0398	U	U
Fluoranthene	mg/kg	0.2	0.4	0.00864	U	U	0.202	0.404	0.00874	U	U	24.8	2	0.0433			0.816	0.392	0.00847			0.201	0.402	0.00868	U	U
Fluorene	mg/kg	0.2	0.4	0.0169	U	U	0.202	0.404	0.0171	U	U	1.78	2	0.0847	J	J	0.114	0.392	0.0166	J	J	0.201	0.402	0.017	U	U
Hexachlorobenzene	mg/kg	0.2	0.4	0.0248	U	U	0.202	0.404	0.0251	U	U	1	2	0.124	U	U	0.196	0.392	0.0243	U	U	0.201	0.402	0.025	U	U
Hexachlorobutadiene	mg/kg	0.2	0.4	0.0379	U	U	0.202	0.404	0.0384	U	U	1	2	0.19	U	U	0.196	0.392	0.0372	U	U	0.201	0.402	0.0381	U	U
Hexachlorocyclopentadiene	mg/kg	0.2	0.4	0.0127	U	UJ	0.202	0.404	0.0129	U	UJ	1	2	0.0637	U	UJ	0.196	0.392	0.0125	U	UJ	0.201	0.402	0.0128	U	UJ

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB01					WWTP3-SB01					WWTP3-SB02					WWTP3-SB02					WWTP3-SB02				
SAMPLE_NO		WW0036					WW0037					WW0038					WW0039					WW0040				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08				
DEPTH		8 - 10 Ft					8 - 10 Ft					_5 - 1_5 Ft					5 - 5_5 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg	0.2	0.4	0.0122	U	U	0.202	0.404	0.0124	U	U	1	2	0.0613	U	U	0.196	0.392	0.012	U	U	0.201	0.402	0.0123	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.2	0.4	0.13	U	U	0.202	0.404	0.131	U	U	8.1	2	0.649			0.436	0.392	0.127			0.201	0.402	0.13	U	U
Isophorone	mg/kg	0.2	0.4	0.0048	U	U	0.202	0.404	0.00486	U	U	1	2	0.024	U	U	0.196	0.392	0.0047	U	U	0.201	0.402	0.00482	U	U
Methylnaphthalene, 2-	mg/kg	0.2	0.4	0.105	U	U	0.202	0.404	0.106	U	U	1.57	2	0.525	J	J	0.196	0.392	0.103	U	U	0.201	0.402	0.105	U	U
Methylphenol, 2-	mg/kg	0.2	0.4	0.006	U	U	0.202	0.404	0.00607	U	U	1	2	0.03	U	U	0.196	0.392	0.00588	U	U	0.201	0.402	0.00603	U	U
Methylphenol, 4-	mg/kg	0.2	0.4	0.0125	U	U	0.202	0.404	0.0126	U	U	1	2	0.0625	U	U	0.196	0.392	0.0122	U	U	0.201	0.402	0.0125	U	U
Naphthalene	mg/kg	0.2	0.4	0.00948	U	U	0.202	0.404	0.00959	U	U	1.38	2	0.0475	J	J	0.196	0.392	0.00929	U	U	0.201	0.402	0.00953	U	U
Nitroaniline, 2-	mg/kg	0.2	0.4	0.0173	U	U	0.202	0.404	0.0175	U	U	1	2	0.0865	U	U	0.196	0.392	0.0169	U	U	0.201	0.402	0.0174	U	U
Nitroaniline, 3-	mg/kg	0.2	0.4	0.0136	U	U	0.202	0.404	0.0137	U	U	1	2	0.0679	U	U	0.196	0.392	0.0133	U	U	0.201	0.402	0.0136	U	U
Nitroaniline, 4-	mg/kg	0.2	0.4	0.142	U	U	0.202	0.404	0.143	U	U	1	2	0.709	U	U	0.196	0.392	0.139	U	U	0.201	0.402	0.142	U	U
Nitrobenzene	mg/kg	0.2	0.4	0.0131	U	U	0.202	0.404	0.0132	U	U	1	2	0.0655	U	U	0.196	0.392	0.0128	U	U	0.201	0.402	0.0131	U	U
Nitrophenol, 2-	mg/kg	0.2	0.4	0.0142	U	U	0.202	0.404	0.0143	U	U	1	2	0.0709	U	U	0.196	0.392	0.0139	U	U	0.201	0.402	0.0142	U	U
Nitrophenol, 4-	mg/kg	0.2	0.4	0.0324	U	U	0.202	0.404	0.0328	U	U	1	2	0.162	U	U	0.196	0.392	0.0318	U	U	0.201	0.402	0.0326	U	U
n-Nitrosodimethylamine	mg/kg	0.2	0.4	0.012	U	U	0.202	0.404	0.0121	U	U	1	2	0.0601	U	U	0.196	0.392	0.0118	U	U	0.201	0.402	0.0121	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.2	0.4	0.0143	U	U	0.202	0.404	0.0144	U	U	1	2	0.0715	U	U	0.196	0.392	0.014	U	U	0.201	0.402	0.0143	U	U
n-Nitrosodiphenylamine	mg/kg	0.2	0.4	0.00564	U	U	0.202	0.404	0.00571	U	U	1	2	0.0282	U	U	0.196	0.392	0.00553	U	U	0.201	0.402	0.00567	U	U
Pentachlorophenol	mg/kg	0.2	0.4	0.0359	U	U	0.202	0.404	0.0363	U	U	1	2	0.18	U	U	0.196	0.392	0.0352	U	U	0.201	0.402	0.0361	U	U
Phenanthrene	mg/kg	0.2	0.4	0.00972	U	U	0.202	0.404	0.00984	U	U	13.9	2	0.0487			0.845	0.392	0.00953			0.201	0.402	0.00977	U	U
Phenol	mg/kg	0.2	0.4	0.0048	U	U	0.202	0.404	0.00486	U	U	1	2	0.024	U	U	0.196	0.392	0.0047	U	U	0.201	0.402	0.00482	U	U
Pyrene	mg/kg	0.2	0.4	0.016	U	U	0.202	0.404	0.0161	U	U	18.1	2	0.0799			0.584	0.392	0.0156			0.201	0.402	0.016	U	U
Trichlorobenzene, 1,2,4-	mg/kg	0.2	0.4	0.00984	U	U	0.202	0.404	0.00996	U	U	1	2	0.0493	U	U	0.196	0.392	0.00964	U	U	0.201	0.402	0.00989	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.2	0.4	0.0343	U	U	0.202	0.404	0.0347	U	U	1	2	0.172	U	U	0.196	0.392	0.0336	U	U	0.201	0.402	0.0345	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.2	0.4	0.027	U	U	0.202	0.404	0.0273	U	U	1	2	0.135	U	U	0.196	0.392	0.0265	U	U	0.201	0.402	0.0271	U	U
VOLATILES																										
Benzene	mg/kg																									
Bromobenzene	mg/kg																									
Bromochloromethane	mg/kg																									
Bromodichloromethane	mg/kg																									
Bromoform	mg/kg																									
Bromomethane	mg/kg																									
Carbon tetrachloride	mg/kg																									
Chlorobenzene	mg/kg																									
Chloroethane	mg/kg																									
Chloroform	mg/kg																									
Chloromethane	mg/kg																									
Chlorotoluene, 2-	mg/kg																									
Chlorotoluene, 4-	mg/kg																									
Dibromo-3-chloropropane, 1,2-	mg/kg																									
Dibromochloromethane	mg/kg																									
Dibromoethane, 1,2-	mg/kg																									
Dibromomethane	mg/kg																									
Dichlorobenzene, 1,2-	mg/kg																									
Dichlorobenzene, 1,3-	mg/kg																									
Dichlorobenzene, 1,4-	mg/kg																									
Dichlorodifluoromethane	mg/kg																									
Dichloroethane, 1,1-	mg/kg																									
Dichloroethane, 1,2-	mg/kg																									
Dichloroethene, 1,1-	mg/kg																									
Dichloroethene, cis-1,2-	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB01					WWTP3-SB01					WWTP3-SB02					WWTP3-SB02					WWTP3-SB02				
SAMPLE_NO		WW0036					WW0037					WW0038					WW0039					WW0040				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08				
DEPTH		8 - 10 Ft					8 - 10 Ft					_5 - 1_5 Ft					5 - 5_5 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					FD					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg																									
Dichloropropane, 1,2-	mg/kg																									
Dichloropropane, 1,3-	mg/kg																									
Dichloropropane, 2,2-	mg/kg																									
Dichloropropene, 1,1-	mg/kg																									
Ethylbenzene	mg/kg																									
Hexachlorobutadiene	mg/kg																									
Isopropylbenzene	mg/kg																									
Methylene chloride	mg/kg																									
Naphthalene	mg/kg																									
n-Butylbenzene	mg/kg																									
n-Propylbenzene	mg/kg																									
p-Isopropyltoluene	mg/kg																									
sec-Butylbenzene	mg/kg																									
Styrene	mg/kg																									
tert-Butylbenzene	mg/kg																									
Tetrachloroethane, 1,1,1,2-	mg/kg																									
Tetrachloroethane, 1,1,2,2-	mg/kg																									
Tetrachloroethene	mg/kg																									
Toluene	mg/kg																									
Trichlorobenzene, 1,2,3-	mg/kg																									
Trichlorobenzene, 1,2,4-	mg/kg																									
Trichloroethane, 1,1,1-	mg/kg																									
Trichloroethane, 1,1,2-	mg/kg																									
Trichloroethene	mg/kg																									
Trichlorofluoromethane	mg/kg																									
Trichloropropane, 1,2,3-	mg/kg																									
Trimethylbenzene, 1,2,4-	mg/kg																									
Trimethylbenzene, 1,3,5-	mg/kg																									
Vinyl chloride	mg/kg																									
Xylenes, m,p-	mg/kg																									
Xylenes, total	mg/kg																									
WATER QUALITY																										
% moisture	Percent																									
% Solids	Percent																									
pH	pH_units																									
Total organic carbon	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB05				
SAMPLE_NO		WW0041					WW0042					WW0043					WW0044					WW0048				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					3 - 5 Ft					8 - 10 Ft					0 - 1 Ft				
SAMPLE PURPOSE		REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																										
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Dinitrobenzene, 1,3-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Dinitrotoluene, 2,6-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
HMX	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Nitrobenzene	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Nitrotoluene, 2-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Nitrotoluene, 3-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Nitrotoluene, 4-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
RDX	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Tetryl	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Trinitrobenzene, 1,3,5-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
Trinitrotoluene, 2,4,6-	mg/kg	0.1355	0.271	0.136	U	U	0.156	0.312	0.156	U	U	0.1435	0.287	0.144	U	U	0.1455	0.291	0.146	U	U	0.154	0.308	0.154	U	UJ
METALS (UNFILTERED)																										
Aluminum	mg/kg	7990	2	1			7740	1.94	0.97			7020	1.98	0.989			8680	2	1			6490	1.7	0.849		
Antimony	mg/kg	0.25	0.5	0.25	U	U	0.287	0.485	0.243	J	J	0.2475	0.495	0.247	U	U	0.436	0.501	0.25	J	J	0.413	0.424	0.212	J	J
Arsenic	mg/kg	4.64	1	0.5			6.32	0.97	0.485			4.51	0.989	0.495			15.6	1	0.501			6.29	0.849	0.424		
Barium	mg/kg	65.8	0.2	0.1			35.7	0.194	0.097			46.8	0.198	0.0989			70	0.2	0.1			48.4	0.339	0.17		
Beryllium	mg/kg	5.35	0.2	0.1			5.13	0.194	0.097			5.05	0.198	0.0989			7.5	0.2	0.1			4.59	0.17	0.0849		J
Cadmium	mg/kg	0.252	0.5	0.25	J	J	0.2425	0.485	0.243	U	U	0.2475	0.495	0.247	U	U	0.281	0.501	0.25	J	J	0.244	0.424	0.212	J	J
Calcium	mg/kg	3290	5	2.5			14000	4.85	2.43		J	37200	4.95	2.47		J	45500	5.01	2.5			28900	4.24	2.12		J
Chromium	mg/kg	11.1	0.5	0.25			9.22	0.485	0.243			10.2	0.495	0.247			14.2	0.501	0.25			9.68	0.424	0.212		
Cobalt	mg/kg	5.25	0.2	0.1			5.06	0.194	0.097			7.13	0.198	0.0989			11.9	0.2	0.1			6.31	0.17	0.0849		J
Copper	mg/kg	15.9	0.5	0.25			13.9	0.485	0.243			17.7	0.495	0.247			26.7	0.501	0.25			18.9	0.424	0.212		
Iron	mg/kg	14200	2	1			14400	1.94	0.97			15000	1.98	0.989			25100	2	1			13800	1.7	0.849		J
Lead	mg/kg	13	0.5	0.25			9.51	0.485	0.243			10.2	0.495	0.247			12.8	0.501	0.25			134	0.424	0.212		J
Magnesium	mg/kg	2010	2	1			5070	1.94	0.97		J	11700	1.98	0.989		J	16500	2	1			8750	3.39	1.7		J
Manganese	mg/kg	294	0.2	0.1			211	0.194	0.097		J	423	0.198	0.0989		J	495	0.2	0.1			322	0.339	0.17		J
Mercury	mg/kg	0.0511	0.0252	0.0126			0.0208	0.0246	0.0123	J	J	0.0331	0.0209	0.0105			0.0261	0.0222	0.0111			0.0698	0.0224	0.0112		J
Nickel	mg/kg	13.3	0.3	0.15			14.3	0.291	0.146			17.1	0.297	0.148			27.6	0.3	0.15			15.4	0.255	0.127		J
Potassium	mg/kg	522	25	12.5			371	24.3	12.1			448	24.7	12.4			919	25	12.5			642	21.2	10.6		
Selenium	mg/kg	0.602	1	0.5	J	J	0.485	0.97	0.485	U	U	0.4945	0.989	0.495	U	U	0.507	1	0.501	J	J	0.4245	0.849	0.424	U	UJ
Silver	mg/kg	0.25	0.5	0.25	U	U	0.2425	0.485	0.243	U	U	0.2475	0.495	0.247	U	U	0.2505	0.501	0.25	U	U	0.212	0.424	0.212	U	U
Sodium	mg/kg	25	10	5			40	9.7	4.85		J	69.8	9.89	4.95		J	130	10	5.01			64.6	8.49	4.24		
Thallium	mg/kg	0.25	0.5	0.25	U	U	0.2425	0.485	0.243	U	U	0.2475	0.495	0.247	U	U	0.259	0.501	0.25	J	J	0.212	0.424	0.212	U	U
Vanadium	mg/kg	17.7	0.2	0.1			17.7	0.194	0.097			18.6	0.198	0.0989			22.2	0.2	0.1			17.8	0.17	0.0849		
Zinc	mg/kg	51	2.5	1.25			44	2.43	1.21			43.7	2.47	1.24			66.8	2.5	1.25			75.9	2.12	1.06		
PESTICIDES/PCBS																										
Aroclor 1016	mg/kg	0.142	0.0429	0.0086	P	J	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1221	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1232	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1242	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1248	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1254	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.1015	0.203	0.0406	U	U
Aroclor 1260	mg/kg	0.02145	0.0429	0.0086	U	U	0.01985	0.0397	0.00794	U	U	0.02005	0.0401	0.00803	U	U						0.229	0.203	0.0406		
SEMIVOLATILES																										
Acenaphthene	mg/kg	0.2125	0.425	0.00766	U	U	0.199	0.398	0.00717	U	U	0.201	0.402	0.00725	U	U	0.2095	0.419	0.00755	U	U	0.2015	0.403	0.00726	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB05				
SAMPLE_NO		WW0041					WW0042					WW0043					WW0044					WW0048				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					3 - 5 Ft					8 - 10 Ft					0 - 1 Ft				
SAMPLE PURPOSE		REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg	0.2125	0.425	0.00511	U	U	0.199	0.398	0.00478	U	U	0.201	0.402	0.00483	U	U	0.2095	0.419	0.00503	U	U	0.0541	0.403	0.00484	J	J
ACETOPHENONE	mg/kg																									
Anthracene	mg/kg	0.2125	0.425	0.00919	U	U	0.199	0.398	0.0086	U	U	0.0902	0.402	0.0087	J	J	0.2095	0.419	0.00906	U	U	0.0504	0.403	0.00872	J	J
Atrazine	mg/kg																									
Benzaldehyde	mg/kg																									
Benzo(a)anthracene	mg/kg	0.2125	0.425	0.028	U	U	0.199	0.398	0.0262	U	U	0.254	0.402	0.0265	J	J	0.2095	0.419	0.0276	U	U	0.276	0.403	0.0265	J	J
Benzo(a)pyrene	mg/kg	0.2125	0.425	0.028	U	U	0.199	0.398	0.0262	U	U	0.193	0.402	0.0265	J	J	0.2095	0.419	0.0276	U	U	0.289	0.403	0.0265	J	J
Benzo(b)fluoranthene	mg/kg	0.2125	0.425	0.0709	U	U	0.199	0.398	0.0663	U	U	0.307	0.402	0.0671	J	J	0.2095	0.419	0.0698	U	U	0.438	0.403	0.0672		
Benzo(ghi)perylene	mg/kg	0.2125	0.425	0.104	U	U	0.199	0.398	0.097	U	U	0.108	0.402	0.0981	J	J	0.2095	0.419	0.102	U	U	0.178	0.403	0.0983	J	J
Benzo(k)fluoranthene	mg/kg	0.2125	0.425	0.129	U	U	0.199	0.398	0.121	U	U	0.201	0.402	0.122	U	U	0.2095	0.419	0.127	U	U	0.127	0.403	0.122	J	J
Benzoic acid	mg/kg	0.2125	0.425	0.104	U	U	0.199	0.398	0.097	U	U	0.201	0.402	0.0981	U	U	0.2095	0.419	0.102	U	UJ	0.2015	0.403	0.0983	U	UJ
Benzyl alcohol	mg/kg	0.2125	0.425	0.104	U	U	0.199	0.398	0.097	U	U	0.201	0.402	0.0981	U	U	0.2095	0.419	0.102	U	U	0.2015	0.403	0.0983	U	U
BIBENZENE	mg/kg																									
Bis(2-chloroethoxy)methane	mg/kg	0.2125	0.425	0.00894	U	U	0.199	0.398	0.00836	U	U	0.201	0.402	0.00846	U	U	0.2095	0.419	0.00881	U	U	0.2015	0.403	0.00848	U	U
Bis(2-chloroethyl)ether	mg/kg	0.2125	0.425	0.0109	U	U	0.199	0.398	0.0102	U	U	0.201	0.402	0.0103	U	U	0.2095	0.419	0.0107	U	U	0.2015	0.403	0.0103	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.2125	0.425	0.0185	U	U	0.199	0.398	0.0173	U	U	0.201	0.402	0.0175	U	U	0.2095	0.419	0.0182	U	U	0.2015	0.403	0.0176	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.2125	0.425	0.0393	U	U	0.041	0.398	0.0368	J	J	0.201	0.402	0.0372	U	U	0.2095	0.419	0.0388	U	U	0.2015	0.403	0.0373	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.2125	0.425	0.0152	U	U	0.199	0.398	0.0142	U	U	0.201	0.402	0.0144	U	U	0.2095	0.419	0.015	U	U	0.2015	0.403	0.0144	U	U
Butyl benzyl phthalate	mg/kg	0.2125	0.425	0.0172	U	U	0.199	0.398	0.0161	U	U	0.201	0.402	0.0163	U	U	0.2095	0.419	0.017	U	U	0.2015	0.403	0.0163	U	U
Caprolactam	mg/kg																									
Carbazole	mg/kg	0.2125	0.425	0.0425	U	U	0.199	0.398	0.0398	U	U	0.201	0.402	0.0402	U	U	0.2095	0.419	0.0419	U	U	0.2015	0.403	0.0403	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.2125	0.425	0.0105	U	U	0.199	0.398	0.0098	U	U	0.201	0.402	0.00991	U	U	0.2095	0.419	0.0103	U	U	0.2015	0.403	0.00993	U	U
Chloroaniline, 4-	mg/kg	0.2125	0.425	0.0369	U	UJ	0.199	0.398	0.0345	U	UJ	0.201	0.402	0.0349	U	UJ	0.2095	0.419	0.0364	U	UJ	0.2015	0.403	0.035	U	UJ
Chloronaphthalene, 2-	mg/kg	0.2125	0.425	0.00677	U	U	0.199	0.398	0.00633	U	U	0.201	0.402	0.0064	U	U	0.2095	0.419	0.00667	U	U	0.2015	0.403	0.00642	U	U
Chlorophenol, 2-	mg/kg	0.2125	0.425	0.00524	U	U	0.199	0.398	0.0049	U	U	0.201	0.402	0.00495	U	U	0.2095	0.419	0.00516	U	U	0.2015	0.403	0.00496	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.2125	0.425	0.0326	U	U	0.199	0.398	0.0305	U	U	0.201	0.402	0.0308	U	U	0.2095	0.419	0.0321	U	U	0.2015	0.403	0.0309	U	U
Chrysene	mg/kg	0.2125	0.425	0.0169	U	U	0.199	0.398	0.0158	U	U	0.243	0.402	0.016	J	J	0.2095	0.419	0.0166	U	U	0.282	0.403	0.016	J	J
Dibenz(a,h)anthracene	mg/kg	0.2125	0.425	0.0961	U	U	0.199	0.398	0.09	U	U	0.201	0.402	0.091	U	U	0.2095	0.419	0.0947	U	U	0.2015	0.403	0.0912	U	U
Dibenzofuran	mg/kg	0.2125	0.425	0.00715	U	U	0.199	0.398	0.00669	U	U	0.201	0.402	0.00677	U	U	0.2095	0.419	0.00705	U	U	0.2015	0.403	0.00678	U	U
Dichlorobenzene, 1,2-	mg/kg	0.2125	0.425	0.00983	U	U	0.199	0.398	0.0092	U	U	0.201	0.402	0.00931	U	U	0.2095	0.419	0.00969	U	U	0.2015	0.403	0.00932	U	U
Dichlorobenzene, 1,3-	mg/kg	0.2125	0.425	0.0155	U	U	0.199	0.398	0.0145	U	U	0.201	0.402	0.0146	U	U	0.2095	0.419	0.0152	U	U	0.2015	0.403	0.0147	U	U
Dichlorobenzene, 1,4-	mg/kg	0.2125	0.425	0.0083	U	U	0.199	0.398	0.00777	U	U	0.201	0.402	0.00786	U	U	0.2095	0.419	0.00818	U	U	0.2015	0.403	0.00787	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.2125	0.425	0.0421	U	UJ	0.199	0.398	0.0394	U	UJ	0.201	0.402	0.0399	U	UJ	0.2095	0.419	0.0415	U	UJ	0.2015	0.403	0.04	U	UJ
Dichlorophenol, 2,4-	mg/kg	0.2125	0.425	0.0152	U	U	0.199	0.398	0.0142	U	U	0.201	0.402	0.0144	U	U	0.2095	0.419	0.015	U	U	0.2015	0.403	0.0144	U	U
Diethyl phthalate	mg/kg	0.2125	0.425	0.0172	U	U	0.199	0.398	0.0161	U	U	0.201	0.402	0.0163	U	U	0.2095	0.419	0.017	U	U	0.2015	0.403	0.0163	U	U
Dimethyl phthalate	mg/kg	0.2125	0.425	0.013	U	U	0.199	0.398	0.0122	U	U	0.201	0.402	0.0123	U	U	0.2095	0.419	0.0128	U	U	0.2015	0.403	0.0123	U	U
Dimethylphenol, 2,4-	mg/kg	0.2125	0.425	0.0112	U	U	0.199	0.398	0.0105	U	U	0.201	0.402	0.0106	U	U	0.2095	0.419	0.0111	U	U	0.2015	0.403	0.0107	U	U
Di-n-butyl phthalate	mg/kg	0.2125	0.425	0.00919	U	U	0.199	0.398	0.0086	U	U	0.201	0.402	0.0087	U	U	0.2095	0.419	0.00906	U	U	0.2015	0.403	0.00872	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.2125	0.425	0.0428	U	U	0.199	0.398	0.04	U	U	0.201	0.402	0.0405	U	U	0.2095	0.419	0.0422	U	U	0.2015	0.403	0.0406	U	U
Dinitrophenol, 2,4-	mg/kg	0.2125	0.425	0.0678	U	U	0.199	0.398	0.0634	U	U	0.201	0.402	0.0642	U	U	0.2095	0.419	0.0668	U	UJ	0.2015	0.403	0.0643	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.2125	0.425	0.0149	U	U	0.199	0.398	0.014	U	U	0.201	0.402	0.0141	U	U	0.2095	0.419	0.0147	U	U	0.2015	0.403	0.0142	U	U
Dinitrotoluene, 2,6-	mg/kg	0.2125	0.425	0.0102	U	U	0.199	0.398	0.00956	U	U	0.201	0.402	0.00967	U	U	0.2095	0.419	0.0101	U	U	0.2015	0.403	0.00969	U	U
Di-n-octyl phthalate	mg/kg	0.2125	0.425	0.0801	U	U	0.199	0.398	0.0749	U	U	0.201	0.402	0.0758	U	U	0.2095	0.419	0.0789	U	U	0.2015	0.403	0.0759	U	U
DIPHENYLAMINE	mg/kg	0.2125	0.425	0.0421	U	U	0.199	0.398	0.0394	U	U	0.201	0.402	0.0399	U	U	0.2095	0.419	0.0415	U	U	0.2015	0.403	0.04	U	U
Fluoranthene	mg/kg	0.2125	0.425	0.00919	U	U	0.0402	0.398	0.0086	J	J	0.604	0.402	0.0087		J	0.2095	0.419	0.00906	U	U	0.4	0.403	0.00872	J	J
Fluorene	mg/kg	0.2125	0.425	0.018	U	U	0.199	0.398	0.0168	U	U	0.201	0.402	0.017	U	U	0.2095	0.419	0.0177	U	U	0.2015	0.403	0.0171	U	U
Hexachlorobenzene	mg/kg	0.2125	0.425	0.0264	U	U	0.199	0.398	0.0247	U	U	0.201	0.402	0.025	U	U	0.2095	0.419	0.026	U	U	0.2015	0.403	0.0251	U	U
Hexachlorobutadiene	mg/kg	0.2125	0.425	0.0403	U	U	0.199	0.398	0.0378	U	U	0.201	0.402	0.0382	U	U	0.2095	0.419	0.0398	U	U	0.2015	0.403	0.0383	U	U
Hexachlorocyclopentadiene	mg/kg	0.2125	0.425	0.0135	U	UJ	0.199	0.398	0.0127	U	UJ	0.201	0.402	0.0128	U	UJ	0.2095	0.419	0.0133	U	UJ	0.2015	0.403	0.0128	U	UJ

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB05				
SAMPLE_NO		WW0041					WW0042					WW0043					WW0044					WW0048				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					3 - 5 Ft					8 - 10 Ft					0 - 1 Ft				
SAMPLE PURPOSE		REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg	0.2125	0.425	0.013	U	U	0.199	0.398	0.0122	U	U	0.201	0.402	0.0123	U	U	0.2095	0.419	0.0128	U	U	0.2015	0.403	0.0123	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.2125	0.425	0.138	U	U	0.199	0.398	0.129	U	U	0.369	0.402	0.131	J	J	0.2095	0.419	0.136	U	U	0.45	0.403	0.131		
Isophorone	mg/kg	0.2125	0.425	0.00511	U	U	0.199	0.398	0.00478	U	U	0.201	0.402	0.00483	U	U	0.2095	0.419	0.00503	U	U	0.2015	0.403	0.00484	U	U
Methylnaphthalene, 2-	mg/kg	0.2125	0.425	0.112	U	U	0.199	0.398	0.104	U	U	0.201	0.402	0.106	U	U	0.2095	0.419	0.11	U	U	0.2015	0.403	0.106	U	U
Methylphenol, 2-	mg/kg	0.2125	0.425	0.00638	U	U	0.199	0.398	0.00597	U	U	0.201	0.402	0.00604	U	U	0.2095	0.419	0.00629	U	U	0.2015	0.403	0.00605	U	U
Methylphenol, 4-	mg/kg	0.2125	0.425	0.0133	U	U	0.199	0.398	0.0124	U	U	0.201	0.402	0.0126	U	U	0.2095	0.419	0.0131	U	U	0.2015	0.403	0.0126	U	U
Naphthalene	mg/kg	0.2125	0.425	0.0101	U	U	0.199	0.398	0.00944	U	U	0.201	0.402	0.00955	U	U	0.2095	0.419	0.00994	U	U	0.2015	0.403	0.00956	U	U
Nitroaniline, 2-	mg/kg	0.2125	0.425	0.0184	U	U	0.199	0.398	0.0172	U	U	0.201	0.402	0.0174	U	U	0.2095	0.419	0.0181	U	U	0.2015	0.403	0.0174	U	U
Nitroaniline, 3-	mg/kg	0.2125	0.425	0.0144	U	U	0.199	0.398	0.0135	U	U	0.201	0.402	0.0137	U	U	0.2095	0.419	0.0142	U	U	0.2015	0.403	0.0137	U	U
Nitroaniline, 4-	mg/kg	0.2125	0.425	0.151	U	U	0.199	0.398	0.141	U	U	0.201	0.402	0.143	U	U	0.2095	0.419	0.148	U	U	0.2015	0.403	0.143	U	U
Nitrobenzene	mg/kg	0.2125	0.425	0.0139	U	U	0.199	0.398	0.013	U	U	0.201	0.402	0.0132	U	U	0.2095	0.419	0.0137	U	U	0.2015	0.403	0.0132	U	U
Nitrophenol, 2-	mg/kg	0.2125	0.425	0.0151	U	U	0.199	0.398	0.0141	U	U	0.201	0.402	0.0143	U	U	0.2095	0.419	0.0148	U	U	0.2015	0.403	0.0143	U	U
Nitrophenol, 4-	mg/kg	0.2125	0.425	0.0345	U	U	0.199	0.398	0.0323	U	U	0.201	0.402	0.0326	U	U	0.2095	0.419	0.034	U	U	0.2015	0.403	0.0327	U	U
n-Nitrosodimethylamine	mg/kg	0.2125	0.425	0.0128	U	U	0.199	0.398	0.0119	U	U	0.201	0.402	0.0121	U	U	0.2095	0.419	0.0126	U	U	0.2015	0.403	0.0121	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.2125	0.425	0.0152	U	U	0.199	0.398	0.0142	U	U	0.201	0.402	0.0144	U	U	0.2095	0.419	0.015	U	U	0.2015	0.403	0.0144	U	U
n-Nitrosodiphenylamine	mg/kg	0.2125	0.425	0.006	U	U	0.199	0.398	0.00562	U	U	0.201	0.402	0.00568	U	U	0.2095	0.419	0.00591	U	U	0.2015	0.403	0.00569	U	U
Pentachlorophenol	mg/kg	0.2125	0.425	0.0382	U	U	0.199	0.398	0.0357	U	U	0.201	0.402	0.0361	U	U	0.2095	0.419	0.0376	U	U	0.2015	0.403	0.0362	U	U
Phenanthrene	mg/kg	0.2125	0.425	0.0103	U	U	0.199	0.398	0.00968	U	U	0.35	0.402	0.00979	J	J	0.2095	0.419	0.0102	U	U	0.0722	0.403	0.00981	J	J
Phenol	mg/kg	0.2125	0.425	0.00511	U	U	0.199	0.398	0.00478	U	U	0.201	0.402	0.00483	U	U	0.2095	0.419	0.00503	U	U	0.2015	0.403	0.00484	U	U
Pyrene	mg/kg	0.2125	0.425	0.017	U	U	0.199	0.398	0.0159	U	U	0.416	0.402	0.0161			0.2095	0.419	0.0167	U	U	0.35	0.403	0.0161	J	J
Trichlorobenzene, 1,2,4-	mg/kg	0.2125	0.425	0.0105	U	U	0.199	0.398	0.0098	U	U	0.201	0.402	0.00991	U	U	0.2095	0.419	0.0103	U	U	0.2015	0.403	0.00993	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.2125	0.425	0.0365	U	U	0.199	0.398	0.0342	U	U	0.201	0.402	0.0346	U	U	0.2095	0.419	0.036	U	U	0.2015	0.403	0.0346	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.2125	0.425	0.0287	U	U	0.199	0.398	0.0269	U	U	0.201	0.402	0.0272	U	U	0.2095	0.419	0.0283	U	U	0.2015	0.403	0.0272	U	U
VOLATILES																										
Benzene	mg/kg																									
Bromobenzene	mg/kg																									
Bromochloromethane	mg/kg																									
Bromodichloromethane	mg/kg																									
Bromoform	mg/kg																									
Bromomethane	mg/kg																									
Carbon tetrachloride	mg/kg																									
Chlorobenzene	mg/kg																									
Chloroethane	mg/kg																									
Chloroform	mg/kg																									
Chloromethane	mg/kg																									
Chlorotoluene, 2-	mg/kg																									
Chlorotoluene, 4-	mg/kg																									
Dibromo-3-chloropropane, 1,2-	mg/kg																									
Dibromochloromethane	mg/kg																									
Dibromoethane, 1,2-	mg/kg																									
Dibromomethane	mg/kg																									
Dichlorobenzene, 1,2-	mg/kg																									
Dichlorobenzene, 1,3-	mg/kg																									
Dichlorobenzene, 1,4-	mg/kg																									
Dichlorodifluoromethane	mg/kg																									
Dichloroethane, 1,1-	mg/kg																									
Dichloroethane, 1,2-	mg/kg																									
Dichloroethene, 1,1-	mg/kg																									
Dichloroethene, cis-1,2-	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB03					WWTP3-SB05				
SAMPLE_NO		WW0041					WW0042					WW0043					WW0044					WW0048				
SAMPLE DATE		10-Dec-08					10-Dec-08					10-Dec-08					10-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					3 - 5 Ft					8 - 10 Ft					0 - 1 Ft				
SAMPLE PURPOSE		REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg																									
Dichloropropane, 1,2-	mg/kg																									
Dichloropropane, 1,3-	mg/kg																									
Dichloropropane, 2,2-	mg/kg																									
Dichloropropene, 1,1-	mg/kg																									
Ethylbenzene	mg/kg																									
Hexachlorobutadiene	mg/kg																									
Isopropylbenzene	mg/kg																									
Methylene chloride	mg/kg																									
Naphthalene	mg/kg																									
n-Butylbenzene	mg/kg																									
n-Propylbenzene	mg/kg																									
p-Isopropyltoluene	mg/kg																									
sec-Butylbenzene	mg/kg																									
Styrene	mg/kg																									
tert-Butylbenzene	mg/kg																									
Tetrachloroethane, 1,1,1,2-	mg/kg																									
Tetrachloroethane, 1,1,2,2-	mg/kg																									
Tetrachloroethene	mg/kg																									
Toluene	mg/kg																									
Trichlorobenzene, 1,2,3-	mg/kg																									
Trichlorobenzene, 1,2,4-	mg/kg																									
Trichloroethane, 1,1,1-	mg/kg																									
Trichloroethane, 1,1,2-	mg/kg																									
Trichloroethene	mg/kg																									
Trichlorofluoromethane	mg/kg																									
Trichloropropane, 1,2,3-	mg/kg																									
Trimethylbenzene, 1,2,4-	mg/kg																									
Trimethylbenzene, 1,3,5-	mg/kg																									
Vinyl chloride	mg/kg																									
Xylenes, m,p-	mg/kg																									
Xylenes, total	mg/kg																									
WATER QUALITY																										
% moisture	Percent																									
% Solids	Percent																									
pH	pH_units																									
Total organic carbon	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB05					WWTP3-SB05					WWTP3-SB06					WWTP3-SB06					WWTP3-SB06				
SAMPLE_NO		WW0049					WW0050					WW0051					WW0052					WW0053				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		3 - 5 Ft					8 - 10 Ft					0 - 1 Ft					3 - 3_7 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																										
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.1465	0.293	0.146	U	UJ	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.1465	0.293	0.146	U	UJ	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Dinitrobenzene, 1,3-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Dinitrotoluene, 2,6-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
HMX	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Nitrobenzene	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Nitrotoluene, 2-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Nitrotoluene, 3-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Nitrotoluene, 4-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
RDX	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Tetryl	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Trinitrobenzene, 1,3,5-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
Trinitrotoluene, 2,4,6-	mg/kg	0.1465	0.293	0.146	U	U	0.138	0.276	0.138	U	UJ	0.142	0.284	0.142	U	U	0.157	0.314	0.157	U	U	0.1545	0.309	0.155	U	UJ
METALS (UNFILTERED)																										
Aluminum	mg/kg	6650	1.85	0.925			8370	2.05	1.02			4950	2	1			7230	1.81	0.904			7920	1.99	0.996		
Antimony	mg/kg	0.367	0.449	0.225	J	J	0.322	0.512	0.256	J	J	0.275	0.5	0.25	J	J	0.261	0.452	0.226	J	J	0.32	0.498	0.249	J	J
Arsenic	mg/kg	9.18	0.898	0.449			6.01	1.02	0.512			4.35	1	0.5			5.64	0.904	0.452			4.35	0.996	0.498		
Barium	mg/kg	42.5	0.37	0.185			54.7	0.41	0.205			32.1	0.4	0.2			56.7	0.362	0.181			53.3	0.398	0.199		
Beryllium	mg/kg	5.73	0.185	0.0925		J	6.17	0.205	0.102		J	3.88	0.2	0.1		J	4.72	0.181	0.0904		J	5.78	0.199	0.0996		J
Cadmium	mg/kg	0.317	0.449	0.225	J	J	0.256	0.512	0.256	U	U	0.25	0.5	0.25	U	U	0.252	0.452	0.226	J	J	0.283	0.498	0.249	J	J
Calcium	mg/kg	35200	4.63	2.31		J	46700	5.12	2.56		J	8960	5	2.5		J	12000	4.52	2.26		J	50800	4.98	2.49		J
Chromium	mg/kg	9.86	0.463	0.231			12.8	0.512	0.256			6.9	0.5	0.25			9.49	0.452	0.226			12.2	0.498	0.249		
Cobalt	mg/kg	8.44	0.185	0.0925		J	9.62	0.205	0.102		J	3.97	0.2	0.1		J	5.69	0.181	0.0904		J	8.93	0.199	0.0996		J
Copper	mg/kg	20.7	0.463	0.231			24.8	0.512	0.256			11.4	0.5	0.25			12.9	0.452	0.226			24.8	0.498	0.249		
Iron	mg/kg	18500	1.85	0.925		J	19900	2.05	1.02		J	10200	2	1		J	13000	1.81	0.904		J	18700	1.99	0.996		J
Lead	mg/kg	82.9	0.449	0.225		J	12.9	0.512	0.256		J	21.6	0.5	0.25		J	39.4	0.452	0.226		J	12.5	0.498	0.249		J
Magnesium	mg/kg	11800	3.7	1.85		J	16900	4.1	2.05		J	3190	4	2		J	4010	3.62	1.81		J	19000	3.98	1.99		J
Manganese	mg/kg	466	0.37	0.185		J	494	0.41	0.205		J	192	0.4	0.2		J	241	0.362	0.181		J	554	0.398	0.199		J
Mercury	mg/kg	0.18	0.0235	0.0117		J	0.0202	0.0251	0.0125	J	J	0.061	0.024	0.012		J	0.0305	0.0243	0.0121		J	0.0183	0.0248	0.0124	J	J
Nickel	mg/kg	23.9	0.278	0.139		J	24.9	0.307	0.154		J	9.37	0.3	0.15		J	13.5	0.271	0.136		J	23.5	0.299	0.149		J
Potassium	mg/kg	491	23.1	11.6			1080	25.6	12.8			363	25	12.5			321	22.6	11.3			1040	24.9	12.4		
Selenium	mg/kg	0.449	0.898	0.449	U	UJ	0.51	1.02	0.512	U	UJ	0.5	1	0.5	U	UJ	0.452	0.904	0.452	U	UJ	0.498	0.996	0.498	U	UJ
Silver	mg/kg	0.2315	0.463	0.231	U	U	0.256	0.512	0.256	U	U	0.25	0.5	0.25	U	U	0.226	0.452	0.226	U	U	0.249	0.498	0.249	U	U
Sodium	mg/kg	79.5	9.25	4.63			170	10.2	5.12			40.8	10	5			53.5	9.04	4.52			178	9.96	4.98		
Thallium	mg/kg	0.2245	0.449	0.225	U	U	0.268	0.512	0.256	J	J	0.25	0.5	0.25	U	U	0.226	0.452	0.226	U	U	0.282	0.498	0.249	J	J
Vanadium	mg/kg	20.3	0.185	0.0925			21.7	0.205	0.102			13.8	0.2	0.1			19	0.181	0.0904			21.1	0.199	0.0996		
Zinc	mg/kg	62	2.31	1.16			61.1	2.56	1.28			41.9	2.5	1.25			45	2.26	1.13			60.1	2.49	1.24		
PESTICIDES/PCBS																										
Aroclor 1016	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1221	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1232	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1242	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1248	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1254	mg/kg	0.102	0.204	0.0409	U	U						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
Aroclor 1260	mg/kg	0.0667	0.204	0.0409	P,J	J						0.1025	0.205	0.041	U	U	0.0995	0.199	0.04	U	U					
SEMIVOLATILES																										
Acenaphthene	mg/kg	0.205	0.41	0.00739	U	U	0.2065	0.413	0.00744	U	U	0.2055	0.411	0.0074	U	U	0.2	0.4	0.00721	U	U	0.208	0.416	0.0075	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB05					WWTP3-SB05					WWTP3-SB06					WWTP3-SB06					WWTP3-SB06				
SAMPLE_NO		WW0049					WW0050					WW0051					WW0052					WW0053				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		3 - 5 Ft					8 - 10 Ft					0 - 1 Ft					3 - 3_7 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg	0.205	0.41	0.00493	U	U	0.2065	0.413	0.00496	U	U	0.0942	0.411	0.00494	J	J	0.0577	0.4	0.00481	J	J	0.208	0.416	0.005	U	U
ACETOPHENONE	mg/kg																									
Anthracene	mg/kg	0.205	0.41	0.00887	U	U	0.2065	0.413	0.00893	U	U	0.183	0.411	0.00888	J	J	0.0617	0.4	0.00865	J	J	0.208	0.416	0.009	U	U
Atrazine	mg/kg																									
Benzaldehyde	mg/kg																									
Benzo(a)anthracene	mg/kg	0.0398	0.41	0.027	J	J	0.2065	0.413	0.0272	U	U	0.607	0.411	0.027			0.238	0.4	0.0263	J	J	0.208	0.416	0.0274	U	U
Benzo(a)pyrene	mg/kg	0.205	0.41	0.027	U	U	0.2065	0.413	0.0272	U	U	0.538	0.411	0.027			0.209	0.4	0.0263	J	J	0.208	0.416	0.0274	U	U
Benzo(b)fluoranthene	mg/kg	0.205	0.41	0.0684	U	U	0.2065	0.413	0.0688	U	U	0.756	0.411	0.0685			0.3	0.4	0.0667	J	J	0.208	0.416	0.0694	U	U
Benzo(ghi)perylene	mg/kg	0.205	0.41	0.1	U	U	0.2065	0.413	0.101	U	U	0.321	0.411	0.1	J	J	0.12	0.4	0.0976	J	J	0.208	0.416	0.102	U	U
Benzo(k)fluoranthene	mg/kg	0.205	0.41	0.124	U	U	0.2065	0.413	0.125	U	U	0.291	0.411	0.125	J	J	0.2	0.4	0.121	U	U	0.208	0.416	0.126	U	U
Benzoic acid	mg/kg	0.205	0.41	0.1	U	UJ	0.2065	0.413	0.101	U	U	0.2055	0.411	0.1	U	UJ	0.2	0.4	0.0976	U	UJ	0.208	0.416	0.102	U	U
Benzyl alcohol	mg/kg	0.205	0.41	0.1	U	UJ	0.2065	0.413	0.101	U	U	0.2055	0.411	0.1	U	U	0.2	0.4	0.0976	U	U	0.208	0.416	0.102	U	U
BIBENZENE	mg/kg																									
Bis(2-chloroethoxy)methane	mg/kg	0.205	0.41	0.00862	U	U	0.2065	0.413	0.00868	U	U	0.2055	0.411	0.00864	U	U	0.2	0.4	0.00841	U	U	0.208	0.416	0.00875	U	U
Bis(2-chloroethyl)ether	mg/kg	0.205	0.41	0.0105	U	U	0.2065	0.413	0.0105	U	U	0.2055	0.411	0.0105	U	U	0.2	0.4	0.0102	U	U	0.208	0.416	0.0106	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.205	0.41	0.0179	U	U	0.2065	0.413	0.018	U	U	0.2055	0.411	0.0179	U	U	0.2	0.4	0.0174	U	U	0.208	0.416	0.0181	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.205	0.41	0.0379	U	U	0.2065	0.413	0.0382	U	U	0.2055	0.411	0.038	U	U	0.2	0.4	0.037	U	U	0.208	0.416	0.0385	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.205	0.41	0.0147	U	U	0.2065	0.413	0.0148	U	U	0.2055	0.411	0.0147	U	U	0.2	0.4	0.0143	U	U	0.208	0.416	0.0149	U	U
Butyl benzyl phthalate	mg/kg	0.205	0.41	0.0166	U	U	0.2065	0.413	0.0167	U	U	0.2055	0.411	0.0167	U	U	0.2	0.4	0.0162	U	U	0.208	0.416	0.0169	U	U
Caprolactam	mg/kg																									
Carbazole	mg/kg	0.205	0.41	0.041	U	U	0.2065	0.413	0.0413	U	U	0.2055	0.411	0.0411	U	U	0.2	0.4	0.04	U	U	0.208	0.416	0.0416	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.205	0.41	0.0101	U	U	0.2065	0.413	0.0102	U	U	0.2055	0.411	0.0101	U	U	0.2	0.4	0.00986	U	U	0.208	0.416	0.0103	U	U
Chloroaniline, 4-	mg/kg	0.205	0.41	0.0356	U	UJ	0.2065	0.413	0.0358	U	UJ	0.2055	0.411	0.0357	U	UJ	0.2	0.4	0.0347	U	UJ	0.208	0.416	0.0361	U	UJ
Chloronaphthalene, 2-	mg/kg	0.205	0.41	0.00653	U	U	0.2065	0.413	0.00657	U	U	0.2055	0.411	0.00654	U	U	0.2	0.4	0.00637	U	U	0.208	0.416	0.00663	U	U
Chlorophenol, 2-	mg/kg	0.205	0.41	0.00505	U	U	0.2065	0.413	0.00508	U	U	0.2055	0.411	0.00506	U	U	0.2	0.4	0.00493	U	U	0.208	0.416	0.00513	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.205	0.41	0.0314	U	U	0.2065	0.413	0.0316	U	U	0.2055	0.411	0.0315	U	U	0.2	0.4	0.0307	U	U	0.208	0.416	0.0319	U	U
Chrysene	mg/kg	0.205	0.41	0.0163	U	U	0.2065	0.413	0.0164	U	U	0.556	0.411	0.0163			0.228	0.4	0.0159	J	J	0.208	0.416	0.0165	U	U
Dibenz(a,h)anthracene	mg/kg	0.205	0.41	0.0927	U	U	0.2065	0.413	0.0934	U	U	0.2055	0.411	0.0929	U	U	0.2	0.4	0.0905	U	U	0.208	0.416	0.0942	U	U
Dibenzofuran	mg/kg	0.205	0.41	0.0069	U	U	0.2065	0.413	0.00694	U	U	0.2055	0.411	0.00691	U	U	0.2	0.4	0.00673	U	U	0.208	0.416	0.007	U	U
Dichlorobenzene, 1,2-	mg/kg	0.205	0.41	0.00948	U	U	0.2065	0.413	0.00955	U	U	0.2055	0.411	0.0095	U	U	0.2	0.4	0.00926	U	U	0.208	0.416	0.00963	U	U
Dichlorobenzene, 1,3-	mg/kg	0.205	0.41	0.0149	U	U	0.2065	0.413	0.015	U	U	0.2055	0.411	0.0149	U	U	0.2	0.4	0.0145	U	U	0.208	0.416	0.0151	U	U
Dichlorobenzene, 1,4-	mg/kg	0.205	0.41	0.00801	U	U	0.2065	0.413	0.00806	U	U	0.2055	0.411	0.00802	U	U	0.2	0.4	0.00781	U	U	0.208	0.416	0.00813	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.205	0.41	0.0406	U	UJ	0.2065	0.413	0.0409	U	UJ	0.2055	0.411	0.0407	U	UJ	0.2	0.4	0.0397	U	UJ	0.208	0.416	0.0413	U	UJ
Dichlorophenol, 2,4-	mg/kg	0.205	0.41	0.0147	U	U	0.2065	0.413	0.0148	U	U	0.2055	0.411	0.0147	U	U	0.2	0.4	0.0143	U	U	0.208	0.416	0.0149	U	U
Diethyl phthalate	mg/kg	0.205	0.41	0.0166	U	U	0.2065	0.413	0.0167	U	U	0.2055	0.411	0.0167	U	U	0.2	0.4	0.0162	U	U	0.208	0.416	0.0169	U	U
Dimethyl phthalate	mg/kg	0.205	0.41	0.0126	U	U	0.2065	0.413	0.0126	U	U	0.2055	0.411	0.0126	U	U	0.2	0.4	0.0123	U	U	0.208	0.416	0.0128	U	U
Dimethylphenol, 2,4-	mg/kg	0.205	0.41	0.0108	U	U	0.2065	0.413	0.0109	U	U	0.2055	0.411	0.0109	U	U	0.2	0.4	0.0106	U	U	0.208	0.416	0.011	U	U
Di-n-butyl phthalate	mg/kg	0.205	0.41	0.00887	U	U	0.2065	0.413	0.00893	U	U	0.2055	0.411	0.00888	U	U	0.2	0.4	0.00865	U	U	0.208	0.416	0.009	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.205	0.41	0.0413	U	U	0.2065	0.413	0.0415	U	U	0.2055	0.411	0.0413	U	U	0.2	0.4	0.0403	U	U	0.208	0.416	0.0419	U	U
Dinitrophenol, 2,4-	mg/kg	0.205	0.41	0.0654	U	UJ	0.2065	0.413	0.0658	U	U	0.2055	0.411	0.0655	U	UJ	0.2	0.4	0.0638	U	UJ	0.208	0.416	0.0664	U	U
Dinitrotoluene, 2,4-	mg/kg	0.205	0.41	0.0144	U	U	0.2065	0.413	0.0145	U	U	0.2055	0.411	0.0144	U	U	0.2	0.4	0.0141	U	U	0.208	0.416	0.0146	U	U
Dinitrotoluene, 2,6-	mg/kg	0.205	0.41	0.00985	U	U	0.2065	0.413	0.00992	U	U	0.2055	0.411	0.00987	U	U	0.2	0.4	0.00962	U	U	0.208	0.416	0.01	U	U
Di-n-octyl phthalate	mg/kg	0.205	0.41	0.0772	U	U	0.2065	0.413	0.0777	U	U	0.2055	0.411	0.0774	U	U	0.2	0.4	0.0754	U	U	0.208	0.416	0.0784	U	U
DIPHENYLAMINE	mg/kg	0.205	0.41	0.0406	U	U	0.2065	0.413	0.0409	U	U	0.2055	0.411	0.0407	U	U	0.2	0.4	0.0397	U	U	0.208	0.416	0.0413	U	U
Fluoranthene	mg/kg	0.0505	0.41	0.00887	J	J	0.2065	0.413	0.00893	U	U	1.12	0.411	0.00888			0.464	0.4	0.00865			0.208	0.416	0.009	U	U
Fluorene	mg/kg	0.205	0.41	0.0174	U	U	0.2065	0.413	0.0175	U	U	0.2055	0.411	0.0174	U	U	0.2	0.4	0.0169	U	U	0.208	0.416	0.0176	U	U
Hexachlorobenzene	mg/kg	0.205	0.41	0.0255	U	U	0.2065	0.413	0.0257	U	U	0.2055	0.411	0.0255	U	U	0.2	0.4	0.0249	U	U	0.208	0.416	0.0259	U	U
Hexachlorobutadiene	mg/kg	0.205	0.41	0.0389	U	U	0.2065	0.413	0.0392	U	U	0.2055	0.411	0.039	U	U	0.2	0.4	0.038	U	U	0.208	0.416	0.0395	U	U
Hexachlorocyclopentadiene	mg/kg	0.205	0.41	0.0131	U	UJ	0.2065	0.413	0.0131	U	U	0.2055	0.411	0.0131	U	UJ	0.2	0.4	0.0127	U	UJ	0.208	0.416	0.0133	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB05					WWTP3-SB05					WWTP3-SB06					WWTP3-SB06					WWTP3-SB06				
SAMPLE_NO		WW0049					WW0050					WW0051					WW0052					WW0053				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		3 - 5 Ft					8 - 10 Ft					0 - 1 Ft					3 - 3_7 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg	0.205	0.41	0.0126	U	U	0.2065	0.413	0.0126	U	U	0.2055	0.411	0.0126	U	U	0.2	0.4	0.0123	U	U	0.208	0.416	0.0128	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.205	0.41	0.133	U	U	0.2065	0.413	0.134	U	U	0.62	0.411	0.133			0.388	0.4	0.13	J	J	0.208	0.416	0.135	U	U
Isophorone	mg/kg	0.205	0.41	0.00493	U	U	0.2065	0.413	0.00496	U	U	0.2055	0.411	0.00494	U	U	0.2	0.4	0.00481	U	U	0.208	0.416	0.005	U	U
Methylnaphthalene, 2-	mg/kg	0.205	0.41	0.108	U	U	0.2065	0.413	0.108	U	U	0.2055	0.411	0.108	U	U	0.2	0.4	0.105	U	U	0.208	0.416	0.109	U	U
Methylphenol, 2-	mg/kg	0.205	0.41	0.00616	U	U	0.2065	0.413	0.0062	U	U	0.2055	0.411	0.00617	U	U	0.2	0.4	0.00601	U	U	0.208	0.416	0.00625	U	U
Methylphenol, 4-	mg/kg	0.205	0.41	0.0128	U	U	0.2065	0.413	0.0129	U	U	0.2055	0.411	0.0128	U	U	0.2	0.4	0.0125	U	U	0.208	0.416	0.013	U	U
Naphthalene	mg/kg	0.205	0.41	0.00973	U	U	0.2065	0.413	0.0098	U	U	0.2055	0.411	0.00975	U	U	0.2	0.4	0.0095	U	U	0.208	0.416	0.00988	U	U
Nitroaniline, 2-	mg/kg	0.205	0.41	0.0177	U	U	0.2065	0.413	0.0179	U	U	0.2055	0.411	0.0178	U	U	0.2	0.4	0.0173	U	U	0.208	0.416	0.018	U	U
Nitroaniline, 3-	mg/kg	0.205	0.41	0.0139	U	UJ	0.2065	0.413	0.014	U	UJ	0.2055	0.411	0.0139	U	U	0.2	0.4	0.0136	U	U	0.208	0.416	0.0141	U	UJ
Nitroaniline, 4-	mg/kg	0.205	0.41	0.145	U	U	0.2065	0.413	0.146	U	U	0.2055	0.411	0.146	U	U	0.2	0.4	0.142	U	U	0.208	0.416	0.148	U	U
Nitrobenzene	mg/kg	0.205	0.41	0.0134	U	U	0.2065	0.413	0.0135	U	U	0.2055	0.411	0.0134	U	U	0.2	0.4	0.0131	U	U	0.208	0.416	0.0136	U	U
Nitrophenol, 2-	mg/kg	0.205	0.41	0.0145	U	U	0.2065	0.413	0.0146	U	U	0.2055	0.411	0.0146	U	U	0.2	0.4	0.0142	U	U	0.208	0.416	0.0148	U	U
Nitrophenol, 4-	mg/kg	0.205	0.41	0.0333	U	U	0.2065	0.413	0.0335	U	U	0.2055	0.411	0.0333	U	U	0.2	0.4	0.0325	U	U	0.208	0.416	0.0338	U	U
n-Nitrosodimethylamine	mg/kg	0.205	0.41	0.0123	U	U	0.2065	0.413	0.0124	U	U	0.2055	0.411	0.0123	U	U	0.2	0.4	0.012	U	U	0.208	0.416	0.0125	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.205	0.41	0.0147	U	U	0.2065	0.413	0.0148	U	U	0.2055	0.411	0.0147	U	U	0.2	0.4	0.0143	U	U	0.208	0.416	0.0149	U	U
n-Nitrosodiphenylamine	mg/kg	0.205	0.41	0.00579	U	U	0.2065	0.413	0.00583	U	U	0.2055	0.411	0.0058	U	U	0.2	0.4	0.00565	U	U	0.208	0.416	0.00588	U	U
Pentachlorophenol	mg/kg	0.205	0.41	0.0368	U	U	0.2065	0.413	0.0371	U	U	0.2055	0.411	0.0369	U	U	0.2	0.4	0.0359	U	U	0.208	0.416	0.0374	U	U
Phenanthrene	mg/kg	0.205	0.41	0.00998	U	U	0.2065	0.413	0.01	U	U	0.363	0.411	0.00999	J	J	0.293	0.4	0.00974	J	J	0.208	0.416	0.0101	U	U
Phenol	mg/kg	0.205	0.41	0.00493	U	U	0.2065	0.413	0.00496	U	U	0.2055	0.411	0.00494	U	U	0.2	0.4	0.00481	U	U	0.208	0.416	0.005	U	U
Pyrene	mg/kg	0.0406	0.41	0.0164	J	J	0.2065	0.413	0.0165	U	U	0.865	0.411	0.0164			0.337	0.4	0.016	J	J	0.208	0.416	0.0166	U	U
Trichlorobenzene, 1,2,4-	mg/kg	0.205	0.41	0.0101	U	U	0.2065	0.413	0.0102	U	U	0.2055	0.411	0.0101	U	U	0.2	0.4	0.00986	U	U	0.208	0.416	0.0103	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.205	0.41	0.0352	U	U	0.2065	0.413	0.0355	U	U	0.2055	0.411	0.0353	U	U	0.2	0.4	0.0344	U	U	0.208	0.416	0.0358	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.205	0.41	0.0277	U	U	0.2065	0.413	0.0279	U	U	0.2055	0.411	0.0278	U	U	0.2	0.4	0.027	U	U	0.208	0.416	0.0281	U	U
VOLATILES																										
Benzene	mg/kg																									
Bromobenzene	mg/kg																									
Bromochloromethane	mg/kg																									
Bromodichloromethane	mg/kg																									
Bromoform	mg/kg																									
Bromomethane	mg/kg																									
Carbon tetrachloride	mg/kg																									
Chlorobenzene	mg/kg																									
Chloroethane	mg/kg																									
Chloroform	mg/kg																									
Chloromethane	mg/kg																									
Chlorotoluene, 2-	mg/kg																									
Chlorotoluene, 4-	mg/kg																									
Dibromo-3-chloropropane, 1,2-	mg/kg																									
Dibromochloromethane	mg/kg																									
Dibromoethane, 1,2-	mg/kg																									
Dibromomethane	mg/kg																									
Dichlorobenzene, 1,2-	mg/kg																									
Dichlorobenzene, 1,3-	mg/kg																									
Dichlorobenzene, 1,4-	mg/kg																									
Dichlorodifluoromethane	mg/kg																									
Dichloroethane, 1,1-	mg/kg																									
Dichloroethane, 1,2-	mg/kg																									
Dichloroethene, 1,1-	mg/kg																									
Dichloroethene, cis-1,2-	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB05					WWTP3-SB05					WWTP3-SB06					WWTP3-SB06					WWTP3-SB06				
SAMPLE_NO		WW0049					WW0050					WW0051					WW0052					WW0053				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		3 - 5 Ft					8 - 10 Ft					0 - 1 Ft					3 - 3_7 Ft					8 - 10 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg																									
Dichloropropane, 1,2-	mg/kg																									
Dichloropropane, 1,3-	mg/kg																									
Dichloropropane, 2,2-	mg/kg																									
Dichloropropene, 1,1-	mg/kg																									
Ethylbenzene	mg/kg																									
Hexachlorobutadiene	mg/kg																									
Isopropylbenzene	mg/kg																									
Methylene chloride	mg/kg																									
Naphthalene	mg/kg																									
n-Butylbenzene	mg/kg																									
n-Propylbenzene	mg/kg																									
p-Isopropyltoluene	mg/kg																									
sec-Butylbenzene	mg/kg																									
Styrene	mg/kg																									
tert-Butylbenzene	mg/kg																									
Tetrachloroethane, 1,1,1,2-	mg/kg																									
Tetrachloroethane, 1,1,2,2-	mg/kg																									
Tetrachloroethene	mg/kg																									
Toluene	mg/kg																									
Trichlorobenzene, 1,2,3-	mg/kg																									
Trichlorobenzene, 1,2,4-	mg/kg																									
Trichloroethane, 1,1,1-	mg/kg																									
Trichloroethane, 1,1,2-	mg/kg																									
Trichloroethene	mg/kg																									
Trichlorofluoromethane	mg/kg																									
Trichloropropane, 1,2,3-	mg/kg																									
Trimethylbenzene, 1,2,4-	mg/kg																									
Trimethylbenzene, 1,3,5-	mg/kg																									
Vinyl chloride	mg/kg																									
Xylenes, m,p-	mg/kg																									
Xylenes, total	mg/kg																									
WATER QUALITY																										
% moisture	Percent																									
% Solids	Percent																									
pH	pH_units																									
Total organic carbon	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB07					WWTP3-SB07					WWTP3-SB07					WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0054					WW0055					WW0056					WW0060					WW0061				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					8 - 10 Ft					_2 - 1_6 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																										
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Dinitrobenzene, 1,3-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Dinitrotoluene, 2,6-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
HMX	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	U	0.1375	0.275	0.138	U	UJ
Nitrobenzene	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	U	0.1375	0.275	0.138	U	UJ
Nitrotoluene, 2-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Nitrotoluene, 3-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Nitrotoluene, 4-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
RDX	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Tetryl	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	U	0.1375	0.275	0.138	U	UJ
Trinitrobenzene, 1,3,5-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	UJ	0.1375	0.275	0.138	U	UJ
Trinitrotoluene, 2,4,6-	mg/kg	0.1315	0.263	0.132	U	UJ	0.1415	0.283	0.142	U	U	0.148	0.296	0.148	U	UJ	0.1515	0.303	0.152	U	U	0.1375	0.275	0.138	U	UJ
METALS (UNFILTERED)																										
Aluminum	mg/kg	5870	1.9	0.949			7800	1.76	0.879			7730	1.88	0.94			7780	1.95	0.973			8410	1.89	0.946		
Antimony	mg/kg	0.321	0.475	0.237	J	J	0.378	0.44	0.22	J	J	0.338	0.47	0.235	J	J	0.303	0.434	0.217	J	J	0.457	0.473	0.236	J	J
Arsenic	mg/kg	5.18	0.949	0.475			10.4	0.879	0.44			4.43	0.94	0.47			7.23	0.868	0.434			6.49	0.946	0.473		
Barium	mg/kg	35.9	0.38	0.19			56.6	0.352	0.176			48.1	0.376	0.188			52.6	0.195	0.0973			50.1	0.378	0.189		
Beryllium	mg/kg	4.25	0.19	0.0949		J	6.22	0.176	0.0879		J	5.42	0.188	0.094		J	5.75	0.195	0.0973		J	7.14	0.189	0.0946		J
Cadmium	mg/kg	0.2375	0.475	0.237	U	U	0.248	0.44	0.22	J	J	0.266	0.47	0.235	J	J	0.224	0.434	0.217	J	J	0.2365	0.473	0.236	U	U
Calcium	mg/kg	24700	4.75	2.37		J	16200	4.4	2.2		J	46200	4.7	2.35		J	29600	4.87	2.43		J	5270	4.73	2.36		J
Chromium	mg/kg	8.34	0.475	0.237			11.8	0.44	0.22			11.7	0.47	0.235			12	0.487	0.243			14.4	0.473	0.236		
Cobalt	mg/kg	5.14	0.19	0.0949		J	9.75	0.176	0.0879		J	8.57	0.188	0.094		J	7.21	0.195	0.0973			6.67	0.189	0.0946		J
Copper	mg/kg	13.8	0.475	0.237			23.2	0.44	0.22			24.2	0.47	0.235			20.5	0.487	0.243			19.8	0.473	0.236		
Iron	mg/kg	12100	1.9	0.949		J	19200	1.76	0.879		J	17500	1.88	0.94		J	17100	1.95	0.973		J	21600	1.89	0.946		J
Lead	mg/kg	19.2	0.475	0.237		J	12.4	0.44	0.22		J	12.4	0.47	0.235		J	13.3	0.434	0.217			11.7	0.473	0.236		J
Magnesium	mg/kg	5900	3.8	1.9		J	7450	3.52	1.76		J	17500	3.76	1.88		J	8750	1.95	0.973			3330	3.78	1.89		J
Manganese	mg/kg	287	0.38	0.19		J	485	0.352	0.176		J	511	0.376	0.188		J	377	0.195	0.0973			277	0.378	0.189		J
Mercury	mg/kg	0.12	0.0231	0.0116		J	0.0237	0.0237	0.0119		J	0.0212	0.0229	0.0114	J	J	0.02	0.0212	0.0106	J	J	0.0241	0.0214	0.0107		J
Nickel	mg/kg	12.4	0.285	0.142		J	22.1	0.264	0.132		J	22.6	0.282	0.141		J	19.6	0.292	0.146			21.4	0.284	0.142		J
Potassium	mg/kg	443	23.7	11.9			394	22	11			1020	23.5	11.8			567	24.3	12.2			414	23.6	11.8		
Selenium	mg/kg	0.483	0.949	0.475	J	J	0.4395	0.879	0.44	U	UJ	0.47	0.94	0.47	U	UJ	0.434	0.868	0.434	U	UJ	0.531	0.946	0.473	J	J
Silver	mg/kg	0.2375	0.475	0.237	U	U	0.22	0.44	0.22	U	U	0.235	0.47	0.235	U	U	0.2435	0.487	0.243	U	U	0.2365	0.473	0.236	U	U
Sodium	mg/kg	45.8	9.49	4.75			162	8.79	4.4			133	9.4	4.7			60.1	9.73	4.87			79	9.46	4.73		
Thallium	mg/kg	0.277	0.475	0.237	J	J	0.22	0.44	0.22	U	U	0.261	0.47	0.235	J	J	0.221	0.434	0.217	J	J	0.269	0.473	0.236	J	J
Vanadium	mg/kg	16.6	0.19	0.0949			23.5	0.176	0.0879			20.1	0.188	0.094			19.1	0.195	0.0973			25.5	0.189	0.0946		
Zinc	mg/kg	41.9	2.37	1.19			56.2	2.2	1.1			57.8	2.35	1.18			58.8	2.43	1.22			58.7	2.36	1.18		
PESTICIDES/PCBS																										
Aroclor 1016	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1221	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1232	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1242	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1248	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1254	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
Aroclor 1260	mg/kg	0.0985	0.197	0.0394	U	U	0.1005	0.201	0.0402	U	U						0.099	0.198	0.0397	U	U	0.1	0.2	0.04	U	U
SEMIVOLATILES																										
Acenaphthene	mg/kg	0.2	0.4	0.00721	U	U	0.2	0.4	0.00721	U	U	0.2075	0.415	0.00748	U	U	0.995	1.99	0.0359	U	U	0.201	0.402	0.00725	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB07					WWTP3-SB07					WWTP3-SB07					WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0054					WW0055					WW0056					WW0060					WW0061				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					8 - 10 Ft					_2 - 1_6 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg	0.2	0.4	0.00481	U	U	0.2	0.4	0.00481	U	U	0.2075	0.415	0.00499	U	U	0.995	1.99	0.0239	U	U	0.201	0.402	0.00483	U	U
ACETOPHENONE	mg/kg																									
Anthracene	mg/kg	0.2	0.4	0.00865	U	U	0.2	0.4	0.00865	U	U	0.2075	0.415	0.00897	U	U	0.995	1.99	0.043	U	U	0.201	0.402	0.0087	U	U
Atrazine	mg/kg																									
Benzaldehyde	mg/kg																									
Benzo(a)anthracene	mg/kg	0.101	0.4	0.0263	J	J	0.2	0.4	0.0263	U	U	0.2075	0.415	0.0273	U	U	0.995	1.99	0.131	U	U	0.201	0.402	0.0265	U	U
Benzo(a)pyrene	mg/kg	0.0909	0.4	0.0263	J	J	0.2	0.4	0.0263	U	U	0.2075	0.415	0.0273	U	U	0.995	1.99	0.131	U	U	0.201	0.402	0.0265	U	U
Benzo(b)fluoranthene	mg/kg	0.14	0.4	0.0667	J	J	0.2	0.4	0.0667	U	U	0.2075	0.415	0.0692	U	U	0.995	1.99	0.332	U	U	0.201	0.402	0.067	U	U
Benzo(ghi)perylene	mg/kg	0.2	0.4	0.0976	U	U	0.2	0.4	0.0976	U	U	0.2075	0.415	0.101	U	U	0.995	1.99	0.485	U	U	0.201	0.402	0.0981	U	U
Benzo(k)fluoranthene	mg/kg	0.2	0.4	0.121	U	U	0.2	0.4	0.121	U	U	0.2075	0.415	0.126	U	U	0.995	1.99	0.604	U	U	0.201	0.402	0.122	U	U
Benzoic acid	mg/kg	0.2	0.4	0.0976	U	UJ	0.2	0.4	0.0976	U	UJ	0.2075	0.415	0.101	U	U	0.995	1.99	0.485	U	UJ	0.201	0.402	0.0981	U	UJ
Benzyl alcohol	mg/kg	0.2	0.4	0.0976	U	U	0.2	0.4	0.0976	U	U	0.2075	0.415	0.101	U	U	0.995	1.99	0.485	U	U	0.201	0.402	0.0981	U	U
BIBENZENE	mg/kg																									
Bis(2-chloroethoxy)methane	mg/kg	0.2	0.4	0.00841	U	U	0.2	0.4	0.00841	U	U	0.2075	0.415	0.00872	U	U	0.995	1.99	0.0418	U	U	0.201	0.402	0.00846	U	U
Bis(2-chloroethyl)ether	mg/kg	0.2	0.4	0.0102	U	U	0.2	0.4	0.0102	U	U	0.2075	0.415	0.0106	U	U	0.995	1.99	0.0508	U	U	0.201	0.402	0.0103	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.2	0.4	0.0174	U	U	0.2	0.4	0.0174	U	U	0.2075	0.415	0.0181	U	U	0.995	1.99	0.0866	U	U	0.201	0.402	0.0175	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.2	0.4	0.037	U	U	0.2	0.4	0.037	U	U	0.2075	0.415	0.0384	U	U	0.995	1.99	0.184	U	U	0.201	0.402	0.0372	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.0143	U	U	0.2	0.4	0.0143	U	U	0.2075	0.415	0.0148	U	U	0.995	1.99	0.0711	U	U	0.201	0.402	0.0144	U	U
Butyl benzyl phthalate	mg/kg	0.2	0.4	0.0162	U	U	0.2	0.4	0.0162	U	U	0.2075	0.415	0.0168	U	U	0.995	1.99	0.0807	U	U	0.201	0.402	0.0163	U	U
Caprolactam	mg/kg																									
Carbazole	mg/kg	0.2	0.4	0.04	U	U	0.2	0.4	0.04	U	U	0.2075	0.415	0.0415	U	U	0.995	1.99	0.199	U	U	0.201	0.402	0.0402	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.2	0.4	0.00985	U	U	0.2	0.4	0.00986	U	U	0.2075	0.415	0.0102	U	U	0.995	1.99	0.049	U	U	0.201	0.402	0.0099	U	U
Chloroaniline, 4-	mg/kg	0.2	0.4	0.0347	U	UJ	0.2	0.4	0.0347	U	UJ	0.2075	0.415	0.036	U	UJ	0.995	1.99	0.173	U	UJ	0.201	0.402	0.0349	U	UJ
Chloronaphthalene, 2-	mg/kg	0.2	0.4	0.00637	U	U	0.2	0.4	0.00637	U	U	0.2075	0.415	0.00661	U	U	0.995	1.99	0.0317	U	U	0.201	0.402	0.0064	U	U
Chlorophenol, 2-	mg/kg	0.2	0.4	0.00493	U	U	0.2	0.4	0.00493	U	U	0.2075	0.415	0.00511	U	U	0.995	1.99	0.0245	U	U	0.201	0.402	0.00495	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.0306	U	U	0.2	0.4	0.0307	U	U	0.2075	0.415	0.0318	U	U	0.995	1.99	0.152	U	U	0.201	0.402	0.0308	U	U
Chrysene	mg/kg	0.0925	0.4	0.0159	J	J	0.2	0.4	0.0159	U	U	0.2075	0.415	0.0165	U	U	0.995	1.99	0.0789	U	U	0.201	0.402	0.0159	U	U
Dibenz(a,h)anthracene	mg/kg	0.2	0.4	0.0905	U	U	0.2	0.4	0.0905	U	U	0.2075	0.415	0.0938	U	U	0.995	1.99	0.45	U	U	0.201	0.402	0.091	U	U
Dibenzofuran	mg/kg	0.2	0.4	0.00673	U	U	0.2	0.4	0.00673	U	U	0.2075	0.415	0.00698	U	U	0.995	1.99	0.0335	U	U	0.201	0.402	0.00676	U	U
Dichlorobenzene, 1,2-	mg/kg	0.2	0.4	0.00925	U	U	0.2	0.4	0.00926	U	U	0.2075	0.415	0.0096	U	U	0.995	1.99	0.046	U	U	0.201	0.402	0.0093	U	U
Dichlorobenzene, 1,3-	mg/kg	0.2	0.4	0.0145	U	U	0.2	0.4	0.0145	U	U	0.2075	0.415	0.0151	U	U	0.995	1.99	0.0723	U	U	0.201	0.402	0.0146	U	U
Dichlorobenzene, 1,4-	mg/kg	0.2	0.4	0.00781	U	U	0.2	0.4	0.00781	U	U	0.2075	0.415	0.0081	U	U	0.995	1.99	0.0388	U	U	0.201	0.402	0.00785	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.2	0.4	0.0397	U	UJ	0.2	0.4	0.0397	U	UJ	0.2075	0.415	0.0411	U	UJ	0.995	1.99	0.197	U	UJ	0.201	0.402	0.0399	U	UJ
Dichlorophenol, 2,4-	mg/kg	0.2	0.4	0.0143	U	U	0.2	0.4	0.0143	U	U	0.2075	0.415	0.0148	U	U	0.995	1.99	0.0711	U	U	0.201	0.402	0.0144	U	U
Diethyl phthalate	mg/kg	0.2	0.4	0.0162	U	U	0.2	0.4	0.0162	U	U	0.2075	0.415	0.0168	U	U	0.995	1.99	0.0807	U	U	0.201	0.402	0.0163	U	U
Dimethyl phthalate	mg/kg	0.2	0.4	0.0123	U	U	0.2	0.4	0.0123	U	U	0.2075	0.415	0.0127	U	U	0.995	1.99	0.0609	U	U	0.201	0.402	0.0123	U	U
Dimethylphenol, 2,4-	mg/kg	0.2	0.4	0.0106	U	U	0.2	0.4	0.0106	U	U	0.2075	0.415	0.011	U	U	0.995	1.99	0.0526	U	U	0.201	0.402	0.0106	U	U
Di-n-butyl phthalate	mg/kg	0.2	0.4	0.00865	U	U	0.2	0.4	0.00865	U	U	0.2075	0.415	0.00897	U	U	0.995	1.99	0.043	U	U	0.201	0.402	0.0087	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.2	0.4	0.0403	U	U	0.2	0.4	0.0403	U	U	0.2075	0.415	0.0418	U	U	0.995	1.99	0.2	U	U	0.201	0.402	0.0405	U	U
Dinitrophenol, 2,4-	mg/kg	0.2	0.4	0.0638	U	UJ	0.2	0.4	0.0638	U	UJ	0.2075	0.415	0.0662	U	U	0.995	1.99	0.317	U	UJ	0.201	0.402	0.0641	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.2	0.4	0.0141	U	U	0.2	0.4	0.0141	U	U	0.2075	0.415	0.0146	U	U	0.995	1.99	0.0699	U	U	0.201	0.402	0.0141	U	U
Dinitrotoluene, 2,6-	mg/kg	0.2	0.4	0.00961	U	U	0.2	0.4	0.00962	U	U	0.2075	0.415	0.00997	U	U	0.995	1.99	0.0478	U	U	0.201	0.402	0.00966	U	U
Di-n-octyl phthalate	mg/kg	0.2	0.4	0.0753	U	U	0.2	0.4	0.0754	U	U	0.2075	0.415	0.0781	U	U	0.995	1.99	0.375	U	U	0.201	0.402	0.0757	U	U
DIPHENYLAMINE	mg/kg	0.2	0.4	0.0397	U	U	0.2	0.4	0.0397	U	U	0.2075	0.415	0.0411	U	U	0.995	1.99	0.197	U	U	0.201	0.402	0.0399	U	U
Fluoranthene	mg/kg	0.187	0.4	0.00865	J	J	0.2	0.4	0.00865	U	U	0.2075	0.415	0.00897	U	U	0.995	1.99	0.043	U	U	0.201	0.402	0.0087	U	U
Fluorene	mg/kg	0.2	0.4	0.0169	U	U	0.2	0.4	0.0169	U	U	0.2075	0.415	0.0176	U	U	0.995	1.99	0.0843	U	U	0.201	0.402	0.017	U	U
Hexachlorobenzene	mg/kg	0.2	0.4	0.0249	U	U	0.2	0.4	0.0249	U	U	0.2075	0.415	0.0258	U	U	0.995	1.99	0.124	U	U	0.201	0.402	0.025	U	U
Hexachlorobutadiene	mg/kg	0.2	0.4	0.038	U	U	0.2	0.4	0.038	U	U	0.2075	0.415	0.0394	U	U	0.995	1.99	0.189	U	U	0.201	0.402	0.0382	U	U
Hexachlorocyclopentadiene	mg/kg	0.2	0.4	0.0127	U	UJ	0.2	0.4	0.0127	U	UJ	0.2075	0.415	0.0132	U	U	0.995	1.99	0.0633	U	UJ	0.201	0.402	0.0128	U	UJ

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB07					WWTP3-SB07					WWTP3-SB07					WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0054					WW0055					WW0056					WW0060					WW0061				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					8 - 10 Ft					_2 - 1_6 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg	0.2	0.4	0.0123	U	U	0.2	0.4	0.0123	U	U	0.2075	0.415	0.0127	U	U	0.995	1.99	0.0609	U	U	0.201	0.402	0.0123	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.305	0.4	0.13	J	J	0.2	0.4	0.13	U	U	0.2075	0.415	0.135	U	U	0.995	1.99	0.645	U	U	0.201	0.402	0.13	U	U
Isophorone	mg/kg	0.2	0.4	0.00481	U	U	0.2	0.4	0.00481	U	U	0.2075	0.415	0.00499	U	U	0.995	1.99	0.0239	U	U	0.201	0.402	0.00483	U	U
Methylnaphthalene, 2-	mg/kg	0.2	0.4	0.105	U	U	0.2	0.4	0.105	U	U	0.2075	0.415	0.109	U	U	0.995	1.99	0.522	U	U	0.201	0.402	0.106	U	U
Methylphenol, 2-	mg/kg	0.2	0.4	0.00601	U	U	0.2	0.4	0.00601	U	U	0.2075	0.415	0.00623	U	U	0.995	1.99	0.0299	U	U	0.201	0.402	0.00604	U	U
Methylphenol, 4-	mg/kg	0.2	0.4	0.0125	U	U	0.2	0.4	0.0125	U	U	0.2075	0.415	0.013	U	U	0.995	1.99	0.0621	U	U	0.201	0.402	0.0126	U	U
Naphthalene	mg/kg	0.2	0.4	0.00949	U	U	0.2	0.4	0.0095	U	U	0.2075	0.415	0.00985	U	U	0.995	1.99	0.0472	U	U	0.201	0.402	0.00954	U	U
Nitroaniline, 2-	mg/kg	0.2	0.4	0.0173	U	U	0.2	0.4	0.0173	U	U	0.2075	0.415	0.0179	U	U	0.995	1.99	0.086	U	U	0.201	0.402	0.0174	U	U
Nitroaniline, 3-	mg/kg	0.2	0.4	0.0136	U	U	0.2	0.4	0.0136	U	U	0.2075	0.415	0.0141	U	UJ	0.995	1.99	0.0675	U	U	0.201	0.402	0.0136	U	U
Nitroaniline, 4-	mg/kg	0.2	0.4	0.142	U	U	0.2	0.4	0.142	U	U	0.2075	0.415	0.147	U	U	0.995	1.99	0.705	U	U	0.201	0.402	0.143	U	U
Nitrobenzene	mg/kg	0.2	0.4	0.0131	U	U	0.2	0.4	0.0131	U	U	0.2075	0.415	0.0136	U	U	0.995	1.99	0.0651	U	U	0.201	0.402	0.0132	U	U
Nitrophenol, 2-	mg/kg	0.2	0.4	0.0142	U	U	0.2	0.4	0.0142	U	U	0.2075	0.415	0.0147	U	U	0.995	1.99	0.0705	U	U	0.201	0.402	0.0143	U	U
Nitrophenol, 4-	mg/kg	0.2	0.4	0.0324	U	U	0.2	0.4	0.0325	U	U	0.2075	0.415	0.0337	U	U	0.995	1.99	0.161	U	U	0.201	0.402	0.0326	U	U
n-Nitrosodimethylamine	mg/kg	0.2	0.4	0.012	U	U	0.2	0.4	0.012	U	U	0.2075	0.415	0.0125	U	U	0.995	1.99	0.0598	U	U	0.201	0.402	0.0121	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.2	0.4	0.0143	U	U	0.2	0.4	0.0143	U	U	0.2075	0.415	0.0148	U	U	0.995	1.99	0.0711	U	U	0.201	0.402	0.0144	U	U
n-Nitrosodiphenylamine	mg/kg	0.2	0.4	0.00565	U	U	0.2	0.4	0.00565	U	U	0.2075	0.415	0.00586	U	U	0.995	1.99	0.0281	U	U	0.201	0.402	0.00568	U	U
Pentachlorophenol	mg/kg	0.2	0.4	0.0359	U	U	0.2	0.4	0.0359	U	U	0.2075	0.415	0.0373	U	U	0.995	1.99	0.179	U	U	0.201	0.402	0.0361	U	U
Phenanthrene	mg/kg	0.0677	0.4	0.00973	J	J	0.2	0.4	0.00974	U	U	0.2075	0.415	0.0101	U	U	0.995	1.99	0.0484	U	U	0.201	0.402	0.00978	U	U
Phenol	mg/kg	0.2	0.4	0.00481	U	U	0.2	0.4	0.00481	U	U	0.2075	0.415	0.00499	U	U	0.995	1.99	0.0239	U	U	0.201	0.402	0.00483	U	U
Pyrene	mg/kg	0.157	0.4	0.016	J	J	0.2	0.4	0.016	U	U	0.2075	0.415	0.0166	U	U	0.995	1.99	0.0795	U	U	0.201	0.402	0.0161	U	U
Trichlorobenzene, 1,2,4-	mg/kg	0.2	0.4	0.00985	U	U	0.2	0.4	0.00986	U	U	0.2075	0.415	0.0102	U	U	0.995	1.99	0.049	U	U	0.201	0.402	0.0099	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.2	0.4	0.0344	U	U	0.2	0.4	0.0344	U	U	0.2075	0.415	0.0356	U	U	0.995	1.99	0.171	U	U	0.201	0.402	0.0345	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.2	0.4	0.027	U	U	0.2	0.4	0.027	U	U	0.2075	0.415	0.028	U	U	0.995	1.99	0.134	U	U	0.201	0.402	0.0272	U	U
VOLATILES																										
Benzene	mg/kg																									
Bromobenzene	mg/kg																									
Bromochloromethane	mg/kg																									
Bromodichloromethane	mg/kg																									
Bromoform	mg/kg																									
Bromomethane	mg/kg																									
Carbon tetrachloride	mg/kg																									
Chlorobenzene	mg/kg																									
Chloroethane	mg/kg																									
Chloroform	mg/kg																									
Chloromethane	mg/kg																									
Chlorotoluene, 2-	mg/kg																									
Chlorotoluene, 4-	mg/kg																									
Dibromo-3-chloropropane, 1,2-	mg/kg																									
Dibromochloromethane	mg/kg																									
Dibromoethane, 1,2-	mg/kg																									
Dibromomethane	mg/kg																									
Dichlorobenzene, 1,2-	mg/kg																									
Dichlorobenzene, 1,3-	mg/kg																									
Dichlorobenzene, 1,4-	mg/kg																									
Dichlorodifluoromethane	mg/kg																									
Dichloroethane, 1,1-	mg/kg																									
Dichloroethane, 1,2-	mg/kg																									
Dichloroethene, 1,1-	mg/kg																									
Dichloroethene, cis-1,2-	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB07					WWTP3-SB07					WWTP3-SB07					WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0054					WW0055					WW0056					WW0060					WW0061				
SAMPLE DATE		11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08					11-Dec-08				
DEPTH		0 - 1 Ft					3 - 5 Ft					8 - 10 Ft					_2 - 1_6 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					REG					REG					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg																									
Dichloropropane, 1,2-	mg/kg																									
Dichloropropane, 1,3-	mg/kg																									
Dichloropropane, 2,2-	mg/kg																									
Dichloropropene, 1,1-	mg/kg																									
Ethylbenzene	mg/kg																									
Hexachlorobutadiene	mg/kg																									
Isopropylbenzene	mg/kg																									
Methylene chloride	mg/kg																									
Naphthalene	mg/kg																									
n-Butylbenzene	mg/kg																									
n-Propylbenzene	mg/kg																									
p-Isopropyltoluene	mg/kg																									
sec-Butylbenzene	mg/kg																									
Styrene	mg/kg																									
tert-Butylbenzene	mg/kg																									
Tetrachloroethane, 1,1,1,2-	mg/kg																									
Tetrachloroethane, 1,1,2,2-	mg/kg																									
Tetrachloroethene	mg/kg																									
Toluene	mg/kg																									
Trichlorobenzene, 1,2,3-	mg/kg																									
Trichlorobenzene, 1,2,4-	mg/kg																									
Trichloroethane, 1,1,1-	mg/kg																									
Trichloroethane, 1,1,2-	mg/kg																									
Trichloroethene	mg/kg																									
Trichlorofluoromethane	mg/kg																									
Trichloropropane, 1,2,3-	mg/kg																									
Trimethylbenzene, 1,2,4-	mg/kg																									
Trimethylbenzene, 1,3,5-	mg/kg																									
Vinyl chloride	mg/kg																									
Xylenes, m,p-	mg/kg																									
Xylenes, total	mg/kg																									
WATER QUALITY																										
% moisture	Percent																									
% Solids	Percent																									
pH	pH_units																									
Total organic carbon	mg/kg																									

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0062					WW0063				
SAMPLE DATE		11-Dec-08					11-Dec-08				
DEPTH		8 - 10 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					FD				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES											
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Dinitrobenzene, 1,3-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Dinitrotoluene, 2,4-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Dinitrotoluene, 2,6-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
HMX	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Nitrobenzene	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Nitrotoluene, 2-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Nitrotoluene, 3-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Nitrotoluene, 4-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
RDX	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Tetryl	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Trinitrobenzene, 1,3,5-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
Trinitrotoluene, 2,4,6-	mg/kg	0.1525	0.305	0.152	U	UJ	0.151	0.302	0.151	U	U
METALS (UNFILTERED)											
Aluminum	mg/kg	8440	1.85	0.927			9940	1.79	0.894		
Antimony	mg/kg	0.321	0.463	0.232	J	J	0.371	0.447	0.223	J	J
Arsenic	mg/kg	4.78	0.927	0.463			6.06	0.894	0.447		
Barium	mg/kg	51.2	0.371	0.185			59.7	0.357	0.179		
Beryllium	mg/kg	6.05	0.185	0.0927		J	6.45	0.179	0.0894		J
Cadmium	mg/kg	0.2315	0.463	0.232	U	U	0.2235	0.447	0.223	U	U
Calcium	mg/kg	45300	4.63	2.32		J	6090	4.47	2.23		J
Chromium	mg/kg	12.8	0.463	0.232			15.5	0.447	0.223		
Cobalt	mg/kg	9.32	0.185	0.0927		J	7.35	0.179	0.0894		J
Copper	mg/kg	25.3	0.463	0.232			19.3	0.447	0.223		
Iron	mg/kg	19800	1.85	0.927		J	19400	1.79	0.894		J
Lead	mg/kg	12	0.463	0.232		J	11.7	0.447	0.223		J
Magnesium	mg/kg	15900	3.71	1.85		J	3790	3.57	1.79		J
Manganese	mg/kg	473	0.371	0.185		J	430	0.357	0.179		J
Mercury	mg/kg	0.02	0.023	0.0115	J	J	0.0312	0.0236	0.0118		J
Nickel	mg/kg	24.7	0.278	0.139		J	23.3	0.268	0.134		J
Potassium	mg/kg	1090	23.2	11.6			463	22.3	11.2		
Selenium	mg/kg	0.4635	0.927	0.463	U	UJ	0.447	0.894	0.447	U	UJ
Silver	mg/kg	0.2315	0.463	0.232	U	U	0.2235	0.447	0.223	U	U
Sodium	mg/kg	148	9.27	4.63			78.5	8.94	4.47		
Thallium	mg/kg	0.252	0.463	0.232	J	J	0.2235	0.447	0.223	U	U
Vanadium	mg/kg	20.9	0.185	0.0927			23.2	0.179	0.0894		
Zinc	mg/kg	62	2.32	1.16			59.3	2.23	1.12		
PESTICIDES/PCBS											
Aroclor 1016	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1221	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1232	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1242	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1248	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1254	mg/kg						0.0995	0.199	0.0398	U	U
Aroclor 1260	mg/kg						0.0995	0.199	0.0398	U	U
SEMIVOLATILES											
Acenaphthene	mg/kg	0.21	0.42	0.00756	U	U	0.198	0.396	0.00714	U	U

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0062					WW0063				
SAMPLE DATE		11-Dec-08					11-Dec-08				
DEPTH		8 - 10 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					FD				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Acenaphthylene	mg/kg	0.21	0.42	0.00504	U	U	0.198	0.396	0.00476	U	U
ACETOPHENONE	mg/kg										
Anthracene	mg/kg	0.21	0.42	0.00907	U	U	0.198	0.396	0.00857	U	U
Atrazine	mg/kg										
Benzaldehyde	mg/kg										
Benzo(a)anthracene	mg/kg	0.21	0.42	0.0276	U	U	0.198	0.396	0.0261	U	U
Benzo(a)pyrene	mg/kg	0.21	0.42	0.0276	U	U	0.198	0.396	0.0261	U	U
Benzo(b)fluoranthene	mg/kg	0.21	0.42	0.0699	U	U	0.198	0.396	0.066	U	U
Benzo(ghi)perylene	mg/kg	0.21	0.42	0.102	U	U	0.198	0.396	0.0966	U	U
Benzo(k)fluoranthene	mg/kg	0.21	0.42	0.127	U	U	0.198	0.396	0.12	U	U
Benzoic acid	mg/kg	0.21	0.42	0.102	U	U	0.198	0.396	0.0966	U	UJ
Benzyl alcohol	mg/kg	0.21	0.42	0.102	U	U	0.198	0.396	0.0966	U	U
BIBENZENE	mg/kg										
Bis(2-chloroethoxy)methane	mg/kg	0.21	0.42	0.00882	U	U	0.198	0.396	0.00833	U	U
Bis(2-chloroethyl)ether	mg/kg	0.21	0.42	0.0107	U	U	0.198	0.396	0.0101	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.21	0.42	0.0183	U	U	0.198	0.396	0.0173	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.21	0.42	0.0388	U	U	0.198	0.396	0.0366	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.21	0.42	0.015	U	U	0.198	0.396	0.0142	U	U
Butyl benzyl phthalate	mg/kg	0.21	0.42	0.017	U	U	0.198	0.396	0.0161	U	U
Caprolactam	mg/kg										
Carbazole	mg/kg	0.21	0.42	0.042	U	U	0.198	0.396	0.0396	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.21	0.42	0.0103	U	U	0.198	0.396	0.00976	U	U
Chloroaniline, 4-	mg/kg	0.21	0.42	0.0364	U	UJ	0.198	0.396	0.0344	U	UJ
Chloronaphthalene, 2-	mg/kg	0.21	0.42	0.00668	U	U	0.198	0.396	0.00631	U	U
Chlorophenol, 2-	mg/kg	0.21	0.42	0.00517	U	U	0.198	0.396	0.00488	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.21	0.42	0.0321	U	U	0.198	0.396	0.0303	U	U
Chrysene	mg/kg	0.21	0.42	0.0166	U	U	0.198	0.396	0.0157	U	U
Dibenz(a,h)anthracene	mg/kg	0.21	0.42	0.0949	U	U	0.198	0.396	0.0896	U	U
Dibenzofuran	mg/kg	0.21	0.42	0.00706	U	U	0.198	0.396	0.00666	U	U
Dichlorobenzene, 1,2-	mg/kg	0.21	0.42	0.0097	U	U	0.198	0.396	0.00916	U	U
Dichlorobenzene, 1,3-	mg/kg	0.21	0.42	0.0152	U	U	0.198	0.396	0.0144	U	U
Dichlorobenzene, 1,4-	mg/kg	0.21	0.42	0.00819	U	U	0.198	0.396	0.00773	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.21	0.42	0.0416	U	UJ	0.198	0.396	0.0393	U	UJ
Dichlorophenol, 2,4-	mg/kg	0.21	0.42	0.015	U	U	0.198	0.396	0.0142	U	U
Diethyl phthalate	mg/kg	0.21	0.42	0.017	U	U	0.198	0.396	0.0161	U	U
Dimethyl phthalate	mg/kg	0.21	0.42	0.0129	U	U	0.198	0.396	0.0121	U	U
Dimethylphenol, 2,4-	mg/kg	0.21	0.42	0.0111	U	U	0.198	0.396	0.0105	U	U
Di-n-butyl phthalate	mg/kg	0.21	0.42	0.00907	U	U	0.198	0.396	0.00857	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.21	0.42	0.0422	U	U	0.198	0.396	0.0399	U	U
Dinitrophenol, 2,4-	mg/kg	0.21	0.42	0.0669	U	U	0.198	0.396	0.0632	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.21	0.42	0.0147	U	U	0.198	0.396	0.0139	U	U
Dinitrotoluene, 2,6-	mg/kg	0.21	0.42	0.0101	U	U	0.198	0.396	0.00952	U	U
Di-n-octyl phthalate	mg/kg	0.21	0.42	0.079	U	U	0.198	0.396	0.0746	U	U
DIPHENYLAMINE	mg/kg	0.21	0.42	0.0416	U	U	0.198	0.396	0.0393	U	U
Fluoranthene	mg/kg	0.21	0.42	0.00907	U	U	0.198	0.396	0.00857	U	U
Fluorene	mg/kg	0.21	0.42	0.0178	U	U	0.198	0.396	0.0168	U	U
Hexachlorobenzene	mg/kg	0.21	0.42	0.0261	U	U	0.198	0.396	0.0246	U	U
Hexachlorobutadiene	mg/kg	0.21	0.42	0.0398	U	U	0.198	0.396	0.0376	U	U
Hexachlorocyclopentadiene	mg/kg	0.21	0.42	0.0134	U	U	0.198	0.396	0.0126	U	UJ

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0062					WW0063				
SAMPLE DATE		11-Dec-08					11-Dec-08				
DEPTH		8 - 10 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					FD				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Hexachloroethane	mg/kg	0.21	0.42	0.0129	U	U	0.198	0.396	0.0121	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.21	0.42	0.136	U	U	0.198	0.396	0.128	U	U
Isophorone	mg/kg	0.21	0.42	0.00504	U	U	0.198	0.396	0.00476	U	U
Methylnaphthalene, 2-	mg/kg	0.21	0.42	0.11	U	U	0.198	0.396	0.104	U	U
Methylphenol, 2-	mg/kg	0.21	0.42	0.0063	U	U	0.198	0.396	0.00595	U	U
Methylphenol, 4-	mg/kg	0.21	0.42	0.0131	U	U	0.198	0.396	0.0124	U	U
Naphthalene	mg/kg	0.21	0.42	0.00995	U	U	0.198	0.396	0.0094	U	U
Nitroaniline, 2-	mg/kg	0.21	0.42	0.0181	U	U	0.198	0.396	0.0171	U	U
Nitroaniline, 3-	mg/kg	0.21	0.42	0.0142	U	UJ	0.198	0.396	0.0134	U	U
Nitroaniline, 4-	mg/kg	0.21	0.42	0.149	U	U	0.198	0.396	0.14	U	U
Nitrobenzene	mg/kg	0.21	0.42	0.0137	U	U	0.198	0.396	0.013	U	U
Nitrophenol, 2-	mg/kg	0.21	0.42	0.0149	U	U	0.198	0.396	0.014	U	U
Nitrophenol, 4-	mg/kg	0.21	0.42	0.034	U	U	0.198	0.396	0.0321	U	U
n-Nitrosodimethylamine	mg/kg	0.21	0.42	0.0126	U	U	0.198	0.396	0.0119	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.21	0.42	0.015	U	U	0.198	0.396	0.0142	U	U
n-Nitrosodiphenylamine	mg/kg	0.21	0.42	0.00592	U	U	0.198	0.396	0.00559	U	U
Pentachlorophenol	mg/kg	0.21	0.42	0.0377	U	U	0.198	0.396	0.0356	U	U
Phenanthrene	mg/kg	0.21	0.42	0.0102	U	U	0.198	0.396	0.00964	U	U
Phenol	mg/kg	0.21	0.42	0.00504	U	U	0.198	0.396	0.00476	U	U
Pyrene	mg/kg	0.21	0.42	0.0168	U	U	0.198	0.396	0.0158	U	U
Trichlorobenzene, 1,2,4-	mg/kg	0.21	0.42	0.0103	U	U	0.198	0.396	0.00976	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.21	0.42	0.036	U	U	0.198	0.396	0.034	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.21	0.42	0.0284	U	U	0.198	0.396	0.0268	U	U
VOLATILES											
Benzene	mg/kg										
Bromobenzene	mg/kg										
Bromochloromethane	mg/kg										
Bromodichloromethane	mg/kg										
Bromoform	mg/kg										
Bromomethane	mg/kg										
Carbon tetrachloride	mg/kg										
Chlorobenzene	mg/kg										
Chloroethane	mg/kg										
Chloroform	mg/kg										
Chloromethane	mg/kg										
Chlorotoluene, 2-	mg/kg										
Chlorotoluene, 4-	mg/kg										
Dibromo-3-chloropropane, 1,2-	mg/kg										
Dibromochloromethane	mg/kg										
Dibromoethane, 1,2-	mg/kg										
Dibromomethane	mg/kg										
Dichlorobenzene, 1,2-	mg/kg										
Dichlorobenzene, 1,3-	mg/kg										
Dichlorobenzene, 1,4-	mg/kg										
Dichlorodifluoromethane	mg/kg										
Dichloroethane, 1,1-	mg/kg										
Dichloroethane, 1,2-	mg/kg										
Dichloroethene, 1,1-	mg/kg										
Dichloroethene, cis-1,2-	mg/kg										

Table E-1

Soil Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		WWTP3-SB09					WWTP3-SB09				
SAMPLE_NO		WW0062					WW0063				
SAMPLE DATE		11-Dec-08					11-Dec-08				
DEPTH		8 - 10 Ft					3 - 5 Ft				
SAMPLE PURPOSE		REG					FD				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dichloroethene, trans-1,2-	mg/kg										
Dichloropropane, 1,2-	mg/kg										
Dichloropropane, 1,3-	mg/kg										
Dichloropropane, 2,2-	mg/kg										
Dichloropropene, 1,1-	mg/kg										
Ethylbenzene	mg/kg										
Hexachlorobutadiene	mg/kg										
Isopropylbenzene	mg/kg										
Methylene chloride	mg/kg										
Naphthalene	mg/kg										
n-Butylbenzene	mg/kg										
n-Propylbenzene	mg/kg										
p-Isopropyltoluene	mg/kg										
sec-Butylbenzene	mg/kg										
Styrene	mg/kg										
tert-Butylbenzene	mg/kg										
Tetrachloroethane, 1,1,1,2-	mg/kg										
Tetrachloroethane, 1,1,2,2-	mg/kg										
Tetrachloroethene	mg/kg										
Toluene	mg/kg										
Trichlorobenzene, 1,2,3-	mg/kg										
Trichlorobenzene, 1,2,4-	mg/kg										
Trichloroethane, 1,1,1-	mg/kg										
Trichloroethane, 1,1,2-	mg/kg										
Trichloroethene	mg/kg										
Trichlorofluoromethane	mg/kg										
Trichloropropane, 1,2,3-	mg/kg										
Trimethylbenzene, 1,2,4-	mg/kg										
Trimethylbenzene, 1,3,5-	mg/kg										
Vinyl chloride	mg/kg										
Xylenes, m,p-	mg/kg										
Xylenes, total	mg/kg										
WATER QUALITY											
% moisture	Percent										
% Solids	Percent										
pH	pH_units										
Total organic carbon	mg/kg										

FD - Field duplicate.
LQ - Laboratory qualifier.
MDL - Method detection limit.
mg/kg - Milligram(s) per kologram.
REG - Regular sample.
RL - Reporting limit.
VQ - Validation qualifier.

Validation Qualifiers:
U - Nondetect.
J - Estimated Concentration.
UJ - Nondetected; detection limit is estimated.
B - Analyte also found in blank.
R - Rejected.

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-001					WTP3-BEDGW-001					WTP3-BEDGW-002					WTP3-BEDGW-002					WTP3-BEDGW-003				
		SAMPLE NO	WW3024					WW3035					WW3025					WW3036					WW3026				
		SAMPLE DATE	22-May-09					13-Nov-09					23-May-09					13-Nov-09					22-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																											
Amino-2,6-dinitrotoluene, 4-	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	UJ	0.1	0.2	0.049	U	U	0.095	0.19	0.049	U	UJ
Amino-4,6-dinitrotoluene, 2-	N	µg/L	0.1	0.2	0.075	U	UJ	0.095	0.19	0.075	U	U	0.1	0.2	0.075	U	UJ	0.1	0.2	0.075	U	U	0.095	0.19	0.075	U	UJ
Dinitrobenzene, 1,3-	N	µg/L	0.1	0.2	0.05	U	UJ	0.095	0.19	0.05	U	U	0.1	0.2	0.05	U	UJ	0.1	0.2	0.05	U	U	0.095	0.19	0.05	U	UJ
Dinitrotoluene, 2,4-	N	µg/L	0.1	0.2	0.064	U	UJ	0.095	0.19	0.063	U	U	0.1	0.2	0.064	U	UJ	0.1	0.2	0.064	U	U	0.095	0.19	0.063	U	UJ
Dinitrotoluene, 2,6-	N	µg/L	0.1	0.2	0.091	U	UJ	0.095	0.19	0.09	U	U	0.1	0.2	0.091	U	UJ	0.1	0.2	0.091	U	U	0.095	0.19	0.09	U	UJ
HMX	N	µg/L	0.1	0.2	0.11	U	UJ	0.095	0.19	0.11	U	U	0.1	0.2	0.11	U	UJ	0.1	0.2	0.11	U	U	0.095	0.19	0.11	U	UJ
Nitrobenzene	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	UJ	0.1	0.2	0.049	U	U	0.095	0.19	0.049	U	UJ
Nitrotoluene, 2-	N	µg/L	0.1	0.2	0.063	U	UJ	0.095	0.19	0.062	U	U	0.1	0.2	0.063	U	UJ	0.1	0.2	0.063	U	U	0.095	0.19	0.062	U	UJ
Nitrotoluene, 3-	N	µg/L	0.1	0.2	0.095	U	UJ	0.095	0.19	0.094	U	U	0.1	0.2	0.095	U	UJ	0.1	0.2	0.095	U	U	0.095	0.19	0.094	U	UJ
Nitrotoluene, 4-	N	µg/L	0.1	0.2	0.075	U	UJ	0.095	0.19	0.074	U	U	0.1	0.2	0.075	U	UJ	0.1	0.2	0.075	U	U	0.095	0.19	0.074	U	UJ
RDX	N	µg/L	0.1	0.2	0.074	U	UJ	0.095	0.19	0.073	U	U	0.1	0.2	0.074	U	UJ	0.1	0.2	0.074	U	U	0.095	0.19	0.073	U	UJ
Tetryl	N	µg/L	0.1	0.2	0.076	U	UJ	0.095	0.19	0.076	U	U	0.1	0.2	0.076	U	UJ	0.1	0.2	0.076	U	U	0.095	0.19	0.076	U	UJ
Trinitrobenzene, 1,3,5-	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	UJ	0.1	0.2	0.049	U	U	0.095	0.19	0.049	U	UJ
Trinitrotoluene, 2,4,6-	N	µg/L	0.1	0.2	0.068	U	UJ	0.095	0.19	0.067	U	U	0.1	0.2	0.068	U	UJ	0.1	0.2	0.068	U	U	0.095	0.19	0.067	U	UJ
FIELD TESTS																											
Dissolved Oxygen	N	mg/L	4.72	0.3				5.28	0.3				10.8	0.3				5.91	0.3				10.22	0.3			
FERROUS IRON	N	mg/L	0	0.042				0	0.042				0	0.042				0	0.042				0	0.042			
Oxidation Reduction Potential	N	mV	-316.3	0.02				-25.4	0.02				-512.9	0.02				-14	0.02				-142.8	0.02			
pH	N	pH_units	6.39	0				7.08	0				6.25	0				6.87	0				6.41	0			
Specific Conductivity	N	mS/cm	2.387	0				2.323	0				2.148	0				2.498	0				2.505	0			
Temperature	N	C	13.34	0				10.43	0				13.34	0				10.63	0				13.64	0			
Turbidity	N	NTU	6.8	10				12.6	10				1	10				5.7	10				23.2	10			
METALS (UNFILTERED)																											
Aluminum	N	µg/L	97.4	200	11	B	J	125	200	11	B	J	73	200	11	B	J	23.4	200	11	B	B	28	200	11	B	J
Antimony	N	µg/L	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	N	µg/L	26.8	10	3.6			5	10	3.6	U	U	123	10	3.6			5	10	3.6	U	U	23.5	10	3.6		
Barium	N	µg/L	643	200	5			766	200	5			417	200	5			314	200	5			238	200	5		
Beryllium	N	µg/L	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U
Cadmium	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	N	µg/L	120000	1000	100			121000	1000	100		J	150000	1000	100			121000	1000	100		J	91700	1000	100		
Chromium	N	µg/L	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	N	µg/L	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U
Copper	N	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	N	µg/L	150	300	23	U	U	296	300	23	B	J	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U
Lead	N	µg/L	3.3	10	2	B	J	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U	2.3	10	2	B	J
Magnesium	N	µg/L	73600	5000	100			82100	5000	100			76200	5000	100			86400	5000	100			59800	5000	100		
Manganese	N	µg/L	186	15	0.5			43.1	15	0.5			663	15	0.5			15.9	15	0.5			106	15	0.5		
Mercury	N	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	N	µg/L	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U
Potassium	N	µg/L	35900	20000	100			46800	10000	100			24800	20000	100			42400	10000	100			45400	20000	100		
Selenium	N	µg/L	5	10	3.1	U	U	4.4	10	3.1	B	J	4.7	10	3.1	B	J	5	10	3.1	U	UJ	5	10	3.1	U	U
Silver	N	µg/L	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	N	µg/L	228000	50000	2500			243000	100000	5000			107000	50000	2500			211000	50000	2500			250000	100000	5000		
Thallium	N	µg/L	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	N	µg/L	1.9	50	0.66	B	J	1.7	50	0.66	B	J	1.6	50	0.66	B	J	1.9	50	0.66	B	J	1.2	50	0.66	B	J
Zinc	N	µg/L	9.7	20	3.8	B	B	8.9	20	3.8	B	J	12.2	20	3.8	B	B	10	20	3.8	U	U	8.2	20	3.8	B	B

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-001					WTP3-BEDGW-001					WTP3-BEDGW-002					WTP3-BEDGW-002					WTP3-BEDGW-003				
		SAMPLE NO	WW3024					WW3035					WW3025					WW3036					WW3026				
		SAMPLE DATE	22-May-09					13-Nov-09					23-May-09					13-Nov-09					22-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
METALS (FILTERED)																											
Aluminum	Y	µg/L	37.5	200	11	B	J	21.4	200	11	B	J	37.9	200	11	B	J	20.7	200	11	B	J	38.8	200	11	B	J
Antimony	Y	µg/L	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	Y	µg/L	24.1	10	3.6			5	10	3.6	U	U	132	10	3.6			5	10	3.6	U	U	6.3	10	3.6	B	J
Barium	Y	µg/L	674	200	5			726	200	5			405	200	5			340	200	5			238	200	5		
Beryllium	Y	µg/L	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U
Cadmium	Y	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	Y	µg/L	122000	1000	100			107000	1000	100		J	150000	1000	100			122000	1000	100		J	89600	1000	100		
Chromium	Y	µg/L	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	Y	µg/L	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U
Copper	Y	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	Y	µg/L	300	600	460	U	U	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U
Lead	Y	µg/L	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U
Magnesium	Y	µg/L	78300	5000	100			77800	5000	100			76000	5000	100			87700	5000	100			58600	5000	100		
Manganese	Y	µg/L	154	15	0.5			14.8	15	0.5	B	J	644	15	0.5			17	15	0.5			31.1	15	0.5		
Mercury	Y	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	Y	µg/L	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U	20	40	2.3	U	U
Potassium	Y	µg/L	38500	20000	100			45300	10000	100			24200	20000	100			43200	10000	100			44900	20000	100		
Selenium	Y	µg/L	3.8	10	3.1	B	J	54.9	10	3.1		J	6.1	10	3.1	B	J	5	10	3.1	U	UJ	5	10	3.1	U	U
Silver	Y	µg/L	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	Y	µg/L	224000	50000	2500			244000	100000	5000			110000	50000	2500			208000	50000	2500			244000	100000	5000		
Thallium	Y	µg/L	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	Y	µg/L	1.3	50	0.66	B	J	1.6	50	0.66	B	J	1.4	50	0.66	B	J	2.2	50	0.66	B	J	1.4	50	0.66	B	J
Zinc	Y	µg/L	10.2	20	3.8	B	B	10	20	3.8	U	U	10	20	3.8	U	U	10	20	3.8	U	U	10	20	3.8	U	U
SEMIVOLATILES																											
3-Methylphenol and 4-Methylphenol	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Acenaphthene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Acenaphthylene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
ACETOPHENONE	N	µg/L																									
Anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Atrazine	N	µg/L																									
Benzaldehyde	N	µg/L																									
Benzo(a)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Benzo(a)pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Benzo(b)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Benzo(ghi)perylene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Benzo(k)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Benzoic acid	N	µg/L	12	24	9.6	U	U	12.5	25	10	U	U	12	24	9.6	U	U	12	24	9.5	U	U	12	24	9.6	U	U
Benzyl alcohol	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
BIBENZENE	N	µg/L																									
Bis(2-chloroethoxy)methane	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Bis(2-chloroethyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Bis(2-chloroisopropyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Bis(2-ethylhexyl)phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.5	5	2	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Bromophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Butyl benzyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Caprolactam	N	µg/L																									
Carbazole	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-001					WTP3-BEDGW-001					WTP3-BEDGW-002					WTP3-BEDGW-002					WTP3-BEDGW-003				
		SAMPLE NO	WW3024					WW3035					WW3025					WW3036					WW3026				
		SAMPLE DATE	22-May-09					13-Nov-09					23-May-09					13-Nov-09					22-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Chloro-3-methylphenol, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Chloroaniline, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Chloronaphthalene, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Chlorophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.5	5	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.1	U	U	2.4	4.8	1.2	U	U
Chlorophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Chrysene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dibenz(a,h)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dibenzofuran	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,2-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,3-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dichlorobenzidine, 3,3'-	N	µg/L	4.8	9.6	1.9	U	U	5	10	2	U	U	4.8	9.6	1.9	U	U	4.75	9.5	1.9	U	U	4.8	9.6	1.9	U	U
Dichlorophenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.5	5	1.3	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Diethyl phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.5	5	2	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Dimethyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dimethylphenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.5	5	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.1	U	U	2.4	4.8	1.2	U	U
Di-n-butyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dinitro-2-methylphenol, 4,6-	N	µg/L	4.8	9.6	3.8	U	U	5	10	4	U	U	4.8	9.6	3.8	U	U	4.75	9.5	3.8	U	U	4.8	9.6	3.8	U	U
Dinitrophenol, 2,4-	N	µg/L	12	24	9.6	U	U	12.5	25	10	U	U	12	24	9.6	U	U	12	24	9.5	U	U	12	24	9.6	U	U
Dinitrotoluene, 2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Dinitrotoluene, 2,6-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Di-n-octyl phthalate	N	µg/L	2.4	4.8	1.4	U	U	2.5	5	1.5	U	U	2.4	4.8	1.4	U	U	2.4	4.8	1.4	U	U	2.4	4.8	1.4	U	U
Fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Fluorene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Hexachlorobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Hexachlorobutadiene	N	µg/L	2.4	4.8	2.4	U	U	2.5	5	2.5	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U
Hexachlorocyclopentadiene	N	µg/L	2.4	4.8	1.2	U	U	2.5	5	1.3	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Hexachloroethane	N	µg/L	2.4	4.8	2.4	U	U	2.5	5	2.5	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U
Indeno(1,2,3-cd)pyrene	N	µg/L	2.4	4.8	1.1	U	U	2.5	5	1.1	U	U	2.4	4.8	1.1	U	U	2.4	4.8	1	U	U	2.4	4.8	1.1	U	U
Isophorone	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Methylnaphthalene, 2-	N	µg/L	1.8	4.8	0.96	J	J	2.8	5	1	J	J	2.2	4.8	0.96	J	J	1.1	4.8	0.95	J	J	2.4	4.8	0.96	U	U
Methylphenol, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Methylphenol, 4-	N	µg/L																									
Naphthalene	N	µg/L	1.1	4.8	0.96	J	J	1.9	5	1	J	J	1.1	4.8	0.96	J	J	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Nitroaniline, 2-	N	µg/L	4.8	9.6	1.9	U	U	5	10	2	U	U	4.8	9.6	1.9	U	U	4.75	9.5	1.9	U	U	4.8	9.6	1.9	U	U
Nitroaniline, 3-	N	µg/L	4.8	9.6	1.9	U	U	5	10	2	U	U	4.8	9.6	1.9	U	U	4.75	9.5	1.9	U	U	4.8	9.6	1.9	U	U
Nitroaniline, 4-	N	µg/L	4.8	9.6	1.9	U	U	5	10	2	U	U	4.8	9.6	1.9	U	U	4.75	9.5	1.9	U	U	4.8	9.6	1.9	U	U
Nitrobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Nitrophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.5	5	1.3	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Nitrophenol, 4-	N	µg/L	12	24	9.6	U	U	12.5	25	10	U	U	12	24	9.6	U	U	12	24	9.5	U	U	12	24	9.6	U	U
n-Nitroso-di-n-propylamine	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
n-Nitrosodiphenylamine	N	µg/L	2.4	4.8	1.9	U	U	2.5	5	2	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Pentachlorophenol	N	µg/L	12	24	9.6	U	U	12.5	25	10	U	U	12	24	9.6	U	U	12	24	9.5	U	U	12	24	9.6	U	U
Phenanthrene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Phenol	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Trichlorobenzene, 1,2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.5	5	1	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.95	U	U	2.4	4.8	0.96	U	U
Trichlorophenol, 2,4,5-	N	µg/L	2.4	4.8	1.3	U	U	2.5	5	1.4	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U
Trichlorophenol, 2,4,6-	N	µg/L	2.4	4.8	1.3	U	U	2.5	5	1.4	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-001					WTP3-BEDGW-001					WTP3-BEDGW-002					WTP3-BEDGW-002					WTP3-BEDGW-003				
		SAMPLE NO	WW3024					WW3035					WW3025					WW3036					WW3026				
		SAMPLE DATE	22-May-09					13-Nov-09					23-May-09					13-Nov-09					22-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
VOLATILES																											
Acetone	N	µg/L	12.5	25	10	U	R	12.5	25	10	U	R	25	50	20	U	UJ	12.5	25	10	U	R	12.5	25	10	U	R
Benzene	N	µg/L	4.6	1	0.4			3.1	1	0.4			2.1	2	0.8			3.2	1	0.4			0.98	1	0.4	J	J
Bromodichloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	1	2	0.4	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Bromoform	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U	1	2	0.66	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Bromomethane	N	µg/L	1	2	0.78	U	U	1	2	0.78	U	U	2	4	1.6	U	U	1	2	0.78	U	U	1	2	0.78	U	U
Butanone, 2-	N	µg/L	9.2	5	2			10.7	5	2			5	10	4	U	U	14.4	5	2			2.5	5	2	U	U
Carbon disulfide	N	µg/L	1	2	0.4	U	U	1	2	0.4	U	U	2	4	0.8	U	U	1	2	0.4	U	U	1	2	0.4	U	U
Carbon tetrachloride	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	1	2	0.44	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chlorobenzene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	1	2	0.44	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chloroethane	N	µg/L	1	2	0.48	U	U	1	2	0.48	U	U	2	4	0.96	U	U	1	2	0.48	U	U	1	2	0.48	U	U
Chloroform	N	µg/L	0.5	1	0.28	U	U	0.5	1	0.28	U	U	1	2	0.56	U	U	0.5	1	0.28	U	U	0.5	1	0.28	U	U
Chloromethane	N	µg/L	23	46	46	U	U	1	2	0.61	U	U	2	4	1.2	U	U	1	2	0.61	U	U	10	20	20	U	U
Cyclohexane	N	µg/L																									
Dibromo-3-chloropropane, 1,2-	N	µg/L																									
Dibromochloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	1	2	0.4	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dibromoethane, 1,2-	N	µg/L																									
Dichlorobenzene, 1,2-	N	µg/L																									
Dichlorobenzene, 1,3-	N	µg/L																									
Dichlorobenzene, 1,4-	N	µg/L																									
Dichlorodifluoromethane	N	µg/L																									
Dichloroethane, 1,1-	N	µg/L	0.5	1	0.24	U	U	0.5	1	0.24	U	U	1	2	0.48	U	U	0.5	1	0.24	U	U	0.5	1	0.24	U	U
Dichloroethane, 1,2-	N	µg/L	0.5	1	0.34	U	U	0.5	1	0.34	U	U	1	2	0.68	U	U	0.5	1	0.34	U	U	0.5	1	0.34	U	U
Dichloroethene, 1,1-	N	µg/L	0.5	1	0.54	U	U	0.5	1	0.54	U	U	1	2	1.1	U	U	0.5	1	0.54	U	U	0.5	1	0.54	U	U
Dichloroethene, cis-1,2-	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	1	2	0.4	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dichloroethene, trans-1,2-	N	µg/L	0.5	1	0.45	U	U	0.5	1	0.45	U	U	1	2	0.9	U	U	0.5	1	0.45	U	U	0.5	1	0.45	U	U
Dichloropropane, 1,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	1	2	0.42	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, cis-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	1	2	0.42	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, trans-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	1	2	0.42	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Ethylbenzene	N	µg/L	3.8	1	0.43			4.6	1	0.43			1.4	2	0.86	J	J	1.2	1	0.43			0.75	1	0.43	J	J
Hexanone, 2-	N	µg/L	5	10	5	U	U	5	10	5	U	U	10	20	10	U	U	5	10	5	U	U	5	10	5	U	U
Isopropylbenzene	N	µg/L																									
METHYL ACETATE	N	µg/L																									
Methyl Tertiary Butyl Ether	N	µg/L																									
Methyl-2-pentanone, 4-	N	µg/L	2.5	5	2	U	U	2.5	5	2	U	U	5	10	4	U	U	2.5	5	2	U	U	2.5	5	2	U	U
Methylcyclohexane	N	µg/L																									
Methylene chloride	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	3.8	10	2	J	B	2.5	5	1	U	U	2.5	5	1	U	U
Styrene	N	µg/L	0.5	1	0.36	U	U	0.5	1	0.36	U	U	1	2	0.72	U	U	0.5	1	0.36	U	U	0.5	1	0.36	U	U
Tetrachloroethane, 1,1,2,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	1	2	0.42	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Tetrachloroethene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	1	2	0.44	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Toluene	N	µg/L	5.7	1	0.35			7.4	1	0.35			1.8	2	0.7	J	B	2.7	1	0.35			1.4	1	0.35		B
Trichlorobenzene, 1,2,4-	N	µg/L																									
Trichloroethane, 1,1,1-	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U	1	2	0.66	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Trichloroethane, 1,1,2-	N	µg/L	0.5	1	0.26	U	U	0.5	1	0.26	U	U	1	2	0.52	U	U	0.5	1	0.26	U	U	0.5	1	0.26	U	U
Trichloroethene	N	µg/L	0.5	1	0.32	U	U	0.5	1	0.32	U	U	1	2	0.64	U	U	0.5	1	0.32	U	U	0.5	1	0.32	U	U
Trichlorofluoromethane	N	µg/L																									
Trichlorotrifluoroethane	N	µg/L																									
Vinyl chloride	N	µg/L	0.5	1	0.3	U	U	0.5	1	0.3	U	U	1	2	0.6	U	U	0.5	1	0.3	U	U	0.5	1	0.3	U	U
Xylenes, total	N	µg/L	24.4	3	1.2			34.6	3	1.2			7.7	6	2.3			7.8	3	1.2			4.9	3	1.2		J

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-001					WTP3-BEDGW-001					WTP3-BEDGW-002					WTP3-BEDGW-002					WTP3-BEDGW-003				
		SAMPLE NO	WW3024					WW3035					WW3025					WW3036					WW3026				
		SAMPLE DATE	22-May-09					13-Nov-09					23-May-09					13-Nov-09					22-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
WATER QUALITY																											
Alkalinity	N	ppm																									
Alkalinity, Carbonate	N	µg/L	938000	25000	13000			1210000	25000	13000			785000	25000	13000			1190000	25000	13000			929000	5000	2500		
Chloride	N	ppm	136	20	10			148	10	5			163	4	2			23.8	2	1			147	20	10		
Cyanide, total	N	ppm	0.029	0.01	0.005			0.005	0.01	0.005	U	U	0.053	0.01	0.005			0.005	0.01	0.005	U	U	0.076	0.01	0.005		
Hardness	N	ppm																									
HARDNESS (as CaCO3)	N	ppm	603	4	4			639	4	4			691	4	4			656	4	4			475	4	4		
Nitrate-Nitrite	N	ppm	0.81	2	0.74	B	J	0.15	0.1	0.03			2	4	1.5	U	U	0.11	0.1	0.03			1	2	0.74	U	U
Sulfate	N	ppm	10	20	10	U	U	40.5	10	5			17.1	4	2			4.2	2	1		J	20.3	20	10		
Total dissolved solids	N	ppm	1350	100	10			1790	100	10			1160	100	10			1330	100	10			1290	100	10		
Total suspended solids	N	ppm	5	10	4	B	J	24	10	4			6	10	4	B	J	13	10	4			5	10	4	U	U
Turbidity	N	NTU	75.5	5	5			74.8	2	2			36.4	1	1			11.6	1	1			217	10	10		

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-003					WTP3-BEDGW-003				
		SAMPLE NO	WW3027					WW3037				
		SAMPLE DATE	22-May-09					12-Nov-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	FD					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES												
Amino-2,6-dinitrotoluene, 4-	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.048	U	UJ
Amino-4,6-dinitrotoluene, 2-	N	µg/L	0.1	0.2	0.075	U	UJ	0.095	0.19	0.073	U	UJ
Dinitrobenzene, 1,3-	N	µg/L	0.1	0.2	0.05	U	UJ	0.095	0.19	0.049	U	UJ
Dinitrotoluene, 2,4-	N	µg/L	0.1	0.2	0.064	U	UJ	0.095	0.19	0.062	U	UJ
Dinitrotoluene, 2,6-	N	µg/L	0.1	0.2	0.091	U	UJ	0.095	0.19	0.089	U	UJ
HMX	N	µg/L	0.1	0.2	0.11	U	UJ	0.095	0.19	0.1	U	UJ
Nitrobenzene	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.048	U	UJ
Nitrotoluene, 2-	N	µg/L	0.1	0.2	0.063	U	UJ	0.095	0.19	0.061	U	UJ
Nitrotoluene, 3-	N	µg/L	0.1	0.2	0.095	U	UJ	0.095	0.19	0.092	U	UJ
Nitrotoluene, 4-	N	µg/L	0.1	0.2	0.075	U	UJ	0.095	0.19	0.072	U	UJ
RDX	N	µg/L	0.1	0.2	0.074	U	UJ	0.095	0.19	0.071	U	UJ
Tetryl	N	µg/L	0.1	0.2	0.076	U	UJ	0.095	0.19	0.074	U	UJ
Trinitrobenzene, 1,3,5-	N	µg/L	0.1	0.2	0.049	U	UJ	0.095	0.19	0.048	U	UJ
Trinitrotoluene, 2,4,6-	N	µg/L	0.1	0.2	0.068	U	UJ	0.095	0.19	0.066	U	UJ
FIELD TESTS												
Dissolved Oxygen	N	mg/L	1.65	0.3				4.94	0.3			
FERROUS IRON	N	mg/L	0	0.042				0	0.042			
Oxidation Reduction Potential	N	mV	-32	0.02				-8.1	0.02			
pH	N	pH_units	7.54	0				6.76	0			
Specific Conductivity	N	mS/cm	0.721	0				2.182	0			
Temperature	N	C	15.94	0				9.53	0			
Turbidity	N	NTU	-0.3	10				0	10			
METALS (UNFILTERED)												
Aluminum	N	µg/L	35.8	200	11	B	J	24.7	200	11	B	B
Antimony	N	µg/L	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	N	µg/L	18	10	3.6			5	10	3.6	U	U
Barium	N	µg/L	241	200	5			245	200	5		
Beryllium	N	µg/L	2	4	1	U	U	2	4	1	U	U
Cadmium	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	N	µg/L	90600	1000	100			84600	1000	100		J
Chromium	N	µg/L	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	N	µg/L	25	50	0.83	U	U	25	50	0.83	U	U
Copper	N	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	N	µg/L	150	300	23	U	U	150	300	23	U	U
Lead	N	µg/L	5	10	2	U	U	5	10	2	U	U
Magnesium	N	µg/L	58800	5000	100			57100	5000	100		
Manganese	N	µg/L	88.8	15	0.5			13.5	15	0.5	B	J
Mercury	N	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	N	µg/L	20	40	2.3	U	U	20	40	2.3	U	U
Potassium	N	µg/L	44100	20000	100			47300	10000	100		
Selenium	N	µg/L	3.4	10	3.1	B	J	5	10	3.1	U	UJ
Silver	N	µg/L	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	N	µg/L	247000	100000	5000			270000	100000	5000		
Thallium	N	µg/L	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	N	µg/L	25	50	0.66	U	U	1.1	50	0.66	B	J
Zinc	N	µg/L	7.7	20	3.8	B	B	10	20	3.8	U	U

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-003					WTP3-BEDGW-003				
		SAMPLE NO	WW3027					WW3037				
		SAMPLE DATE	22-May-09					12-Nov-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	FD					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
METALS (FILTERED)												
Aluminum	Y	µg/L	26.1	200	11	B	J	16	200	11	B	J
Antimony	Y	µg/L	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	Y	µg/L	24	10	3.6			5	10	3.6	U	U
Barium	Y	µg/L	235	200	5			240	200	5		
Beryllium	Y	µg/L	2	4	1	U	U	2	4	1	U	U
Cadmium	Y	µg/L	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	Y	µg/L	87800	1000	100			82600	1000	100		J
Chromium	Y	µg/L	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	Y	µg/L	25	50	0.83	U	U	25	50	0.83	U	U
Copper	Y	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	Y	µg/L	150	300	23	U	U	150	300	23	U	U
Lead	Y	µg/L	5	10	2	U	U	2	10	2	B	B
Magnesium	Y	µg/L	57300	5000	100			55800	5000	100		
Manganese	Y	µg/L	98.2	15	0.5			10.3	15	0.5	B	J
Mercury	Y	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	Y	µg/L	20	40	2.3	U	U	20	40	2.3	U	U
Potassium	Y	µg/L	43200	20000	100			46200	10000	100		
Selenium	Y	µg/L	5	10	3.1	U	U	5	10	3.1	U	UJ
Silver	Y	µg/L	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	Y	µg/L	242000	100000	5000			256000	100000	5000		
Thallium	Y	µg/L	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	Y	µg/L	25	50	0.66	U	U	25	50	0.66	U	U
Zinc	Y	µg/L	8	20	3.8	B	B	10	20	3.8	U	U
SEMIVOLATILES												
3-Methylphenol and 4-Methylphenol	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Acenaphthene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Acenaphthylene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
ACETOPHENONE	N	µg/L										
Anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Atrazine	N	µg/L										
Benzaldehyde	N	µg/L										
Benzo(a)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Benzo(a)pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Benzo(b)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Benzo(ghi)perylene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Benzo(k)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Benzoic acid	N	µg/L	12	24	9.6	U	U	12	24	9.7	U	U
Benzyl alcohol	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
BIBENZENE	N	µg/L										
Bis(2-chloroethoxy)methane	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Bis(2-chloroethyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Bis(2-chloroisopropyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Bis(2-ethylhexyl)phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.45	4.9	1.9	U	U
Bromophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Butyl benzyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Caprolactam	N	µg/L										
Carbazole	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-003					WTP3-BEDGW-003				
		SAMPLE NO	WW3027					WW3037				
		SAMPLE DATE	22-May-09					12-Nov-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	FD					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Chloro-3-methylphenol, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Chloroaniline, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Chloronaphthalene, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Chlorophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.45	4.9	1.2	U	U
Chlorophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Chrysene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dibenz(a,h)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dibenzofuran	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dichlorobenzene, 1,2-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dichlorobenzene, 1,3-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dichlorobenzene, 1,4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dichlorobenzidine, 3,3'-	N	µg/L	4.8	9.6	1.9	U	U	4.85	9.7	1.9	U	U
Dichlorophenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U
Diethyl phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.45	4.9	1.9	U	U
Dimethyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dimethylphenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.45	4.9	1.2	U	U
Di-n-butyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dinitro-2-methylphenol, 4,6-	N	µg/L	4.8	9.6	3.8	U	U	4.85	9.7	3.9	U	U
Dinitrophenol, 2,4-	N	µg/L	12	24	9.6	U	U	12	24	9.7	U	U
Dinitrotoluene, 2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Dinitrotoluene, 2,6-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Di-n-octyl phthalate	N	µg/L	2.4	4.8	1.4	U	U	2.45	4.9	1.5	U	U
Fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Fluorene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Hexachlorobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Hexachlorobutadiene	N	µg/L	2.4	4.8	2.4	U	U	2.45	4.9	2.4	U	U
Hexachlorocyclopentadiene	N	µg/L	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U
Hexachloroethane	N	µg/L	2.4	4.8	2.4	U	U	2.45	4.9	2.4	U	U
Indeno(1,2,3-cd)pyrene	N	µg/L	2.4	4.8	1.1	U	U	2.45	4.9	1.1	U	U
Isophorone	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Methylnaphthalene, 2-	N	µg/L	1.3	4.8	0.96	J	J	2.45	4.9	0.97	U	U
Methylphenol, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Methylphenol, 4-	N	µg/L										
Naphthalene	N	µg/L	1.7	4.8	0.96	J	J	2.45	4.9	0.97	U	U
Nitroaniline, 2-	N	µg/L	4.8	9.6	1.9	U	U	4.85	9.7	1.9	U	U
Nitroaniline, 3-	N	µg/L	4.8	9.6	1.9	U	U	4.85	9.7	1.9	U	U
Nitroaniline, 4-	N	µg/L	4.8	9.6	1.9	U	U	4.85	9.7	1.9	U	U
Nitrobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Nitrophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U
Nitrophenol, 4-	N	µg/L	12	24	9.6	U	U	12	24	9.7	U	U
n-Nitroso-di-n-propylamine	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
n-Nitrosodiphenylamine	N	µg/L	2.4	4.8	1.9	U	U	2.45	4.9	1.9	U	U
Pentachlorophenol	N	µg/L	12	24	9.6	U	U	12	24	9.7	U	U
Phenanthrene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Phenol	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Trichlorobenzene, 1,2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.45	4.9	0.97	U	U
Trichlorophenol, 2,4,5-	N	µg/L	2.4	4.8	1.3	U	U	2.45	4.9	1.4	U	U
Trichlorophenol, 2,4,6-	N	µg/L	2.4	4.8	1.3	U	U	2.45	4.9	1.4	U	U

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-003					WTP3-BEDGW-003				
		SAMPLE NO	WW3027					WW3037				
		SAMPLE DATE	22-May-09					12-Nov-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	FD					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
VOLATILES												
Acetone	N	µg/L	12.5	25	10	U	R	12.5	25	10	U	R
Benzene	N	µg/L	16	1	0.4		J	15.4	1	0.4		
Bromodichloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Bromoform	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Bromomethane	N	µg/L	1	2	0.78	U	U	1	2	0.78	U	U
Butanone, 2-	N	µg/L	10.2	5	2			2.5	5	2	U	U
Carbon disulfide	N	µg/L	1	2	0.4	U	U	1	2	0.4	U	U
Carbon tetrachloride	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chlorobenzene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chloroethane	N	µg/L	1	2	0.48	U	U	1	2	0.48	U	U
Chloroform	N	µg/L	0.5	1	0.28	U	U	0.5	1	0.28	U	U
Chloromethane	N	µg/L	30	60	60	U	U	1	2	0.61	U	U
Cyclohexane	N	µg/L										
Dibromo-3-chloropropane, 1,2-	N	µg/L										
Dibromochloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dibromoethane, 1,2-	N	µg/L										
Dichlorobenzene, 1,2-	N	µg/L										
Dichlorobenzene, 1,3-	N	µg/L										
Dichlorobenzene, 1,4-	N	µg/L										
Dichlorodifluoromethane	N	µg/L										
Dichloroethane, 1,1-	N	µg/L	0.5	1	0.24	U	U	0.5	1	0.24	U	U
Dichloroethane, 1,2-	N	µg/L	0.5	1	0.34	U	U	0.5	1	0.34	U	U
Dichloroethene, 1,1-	N	µg/L	0.5	1	0.54	U	U	0.5	1	0.54	U	U
Dichloroethene, cis-1,2-	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dichloroethene, trans-1,2-	N	µg/L	0.5	1	0.45	U	U	0.5	1	0.45	U	U
Dichloropropane, 1,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, cis-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, trans-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Ethylbenzene	N	µg/L	6	1	0.43		J	3.4	1	0.43		
Hexanone, 2-	N	µg/L	5	10	5	U	U	5	10	5	U	U
Isopropylbenzene	N	µg/L										
METHYL ACETATE	N	µg/L										
Methyl Tertiary Butyl Ether	N	µg/L										
Methyl-2-pentanone, 4-	N	µg/L	2.5	5	2	U	U	2.5	5	2	U	U
Methylcyclohexane	N	µg/L										
Methylene chloride	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U
Styrene	N	µg/L	0.5	1	0.36	U	U	0.5	1	0.36	U	U
Tetrachloroethane, 1,1,2,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Tetrachloroethene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Toluene	N	µg/L	16.4	1	0.35		J	12.5	1	0.35		
Trichlorobenzene, 1,2,4-	N	µg/L										
Trichloroethane, 1,1,1-	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Trichloroethane, 1,1,2-	N	µg/L	0.5	1	0.26	U	U	0.5	1	0.26	U	U
Trichloroethene	N	µg/L	0.5	1	0.32	U	U	0.5	1	0.32	U	U
Trichlorofluoromethane	N	µg/L										
Trichlorotrifluoroethane	N	µg/L										
Vinyl chloride	N	µg/L	0.5	1	0.3	U	U	0.5	1	0.3	U	U
Xylenes, total	N	µg/L	46.2	3	1.2		J	24.7	3	1.2		

Table E-2

Bedrock Groundwater Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-BEDGW-003					WTP3-BEDGW-003				
		SAMPLE NO	WW3027					WW3037				
		SAMPLE DATE	22-May-09					12-Nov-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	FD					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
WATER QUALITY												
Alkalinity	N	ppm										
Alkalinity, Carbonate	N	µg/L	705000	25000	13000			1060000	25000	13000		
Chloride	N	ppm	148	20	10			141	10	5		
Cyanide, total	N	ppm	0.013	0.01	0.005			0.005	0.01	0.005	U	U
Hardness	N	ppm										
HARDNESS (as CaCO3)	N	ppm	468	4	4			447	4	4		
Nitrate-Nitrite	N	ppm	1	2	0.74	U	U	0.086	0.1	0.03	B	J
Sulfate	N	ppm	14.5	20	10	B	J	5	10	5	U	U
Total dissolved solids	N	ppm	1420	100	10			1280	100	10		
Total suspended solids	N	ppm	8	10	4	B	J	9	10	4	B	J
Turbidity	N	NTU	83.5	5	5			129	5	5		

C - Degrees Celcius.
FD - Field duplicate.
LQ - Laboratory qualifier.
MDL - Method detection limit.
µg/L - Microgram(s) per liter.
mS/cm - Millisiemen(s)/centimeter.
mV - Millivolts.
NTU - Nephalometric turbidity units.
REG - Regular sample.
RL - Reporting limit.
VQ - Validation qualifier.

Validation Qualifiers:
U - Nondetect.
J - Estimated Concentration.
UJ - Nondetected; detection limit is estimated.
B - Analyte also found in blank.
R - Rejected.

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-MW01					WTP3-MW01					WTP3-MW02					WTP3-MW02					WTP3-MW03				
		SAMPLE NO	WW3021					WW3032					WW3022					WW3033					WW3023				
		SAMPLE DATE	19-May-09					11-Nov-09					21-May-09					12-Nov-09					21-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																											
Amino-2,6-dinitrotoluene, 4-	N	µg/L	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	U	0.1	0.2	0.049	U	U
Amino-4,6-dinitrotoluene, 2-	N	µg/L	0.095	0.19	0.075	U	U	0.095	0.19	0.075	U	U	0.095	0.19	0.075	U	U	0.1	0.2	0.075	U	U	0.1	0.2	0.075	U	U
Dinitrobenzene, 1,3-	N	µg/L	0.095	0.19	0.05	U	U	0.095	0.19	0.05	U	U	0.095	0.19	0.05	U	U	0.1	0.2	0.05	U	U	0.15	0.2	0.05	J	J
Dinitrotoluene, 2,4-	N	µg/L	0.095	0.19	0.063	U	U	0.095	0.19	0.063	U	U	0.095	0.19	0.063	U	U	0.1	0.2	0.064	U	U	0.19	0.2	0.064	J	J
Dinitrotoluene, 2,6-	N	µg/L	0.095	0.19	0.09	U	U	0.095	0.19	0.09	U	U	0.095	0.19	0.09	U	U	0.1	0.2	0.091	U	U	0.1	0.2	0.091	U	U
HMX	N	µg/L	0.095	0.19	0.11	U	U	0.095	0.19	0.11	U	U	0.095	0.19	0.11	U	U	0.1	0.2	0.11	U	U	0.1	0.2	0.11	U	U
Nitrobenzene	N	µg/L	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	U	0.1	0.2	0.049	U	U
Nitrotoluene, 2-	N	µg/L	0.095	0.19	0.062	U	U	0.095	0.19	0.062	U	U	0.095	0.19	0.062	U	U	0.1	0.2	0.063	U	U	0.1	0.2	0.063	U	U
Nitrotoluene, 3-	N	µg/L	0.095	0.19	0.094	U	U	0.095	0.19	0.094	U	U	0.095	0.19	0.094	U	U	0.1	0.2	0.095	U	U	0.1	0.2	0.095	U	U
Nitrotoluene, 4-	N	µg/L	0.095	0.19	0.074	U	U	0.095	0.19	0.074	U	U	0.095	0.19	0.074	U	U	0.1	0.2	0.075	U	U	0.1	0.2	0.075	U	U
RDX	N	µg/L	0.095	0.19	0.073	U	U	0.095	0.19	0.073	U	U	0.095	0.19	0.073	U	U	0.1	0.2	0.074	U	U	0.1	0.2	0.074	U	U
Tetryl	N	µg/L	0.095	0.19	0.076	U	U	0.095	0.19	0.076	U	U	0.095	0.19	0.076	U	U	0.1	0.2	0.076	U	U	0.1	0.2	0.076	U	U
Trinitrobenzene, 1,3,5-	N	µg/L	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.1	0.2	0.049	U	U	0.29	0.2	0.049		
Trinitrotoluene, 2,4,6-	N	µg/L	0.095	0.19	0.067	U	U	0.095	0.19	0.067	U	U	0.095	0.19	0.067	U	U	0.1	0.2	0.068	U	U	0.1	0.2	0.068	U	U
FIELD TESTS																											
Dissolved Oxygen	N	mg/L	13.3	0.3				6.09	0.3				13.13	0.3				8.98	0.3				15.28	0.3			
FERROUS IRON	N	mg/L	0	0.042				0	0.042				0	0.042				0	0.042								
Oxidation Reduction Potential	N	mV	-234.8	0.02				-34.2	0.02				-4.018	0.02				-31.1	0.02				-507.2	0.02			
pH	N	pH_units	6.93	0				7.5	0				6.94	0				7.41	0				6.82	0			
Specific Conductivity	N	mS/cm	1.083	0				0.949	0				1.026	0				0.648	0				1.007	0			
Temperature	N	C	11.38	0				13.76	0				16.9	0				9.77	0				13.53	0			
Turbidity	N	NTU	3.1	10				67.6	10				5.8	10				6.1	10				0.9	10			
METALS (UNFILTERED)																											
Aluminum	N	µg/L	87.6	200	11	B	J	1190	200	11			109	200	11	B	J	95.3	200	11	B	J	91.9	200	11	B	J
Antimony	N	µg/L	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	N	µg/L	5	10	3.6	U	U	15.8	10	3.6			10.4	10	3.6			10.4	10	3.6			5	10	3.6	U	U
Barium	N	µg/L	165	200	5	B	J	411	200	5			203	200	5			264	200	5			162	200	5	B	J
Beryllium	N	µg/L	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U
Cadmium	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	N	µg/L	123000	1000	100			86900	1000	100		J	108000	1000	100			105000	1000	100		J	112000	1000	100		
Chromium	N	µg/L	5	10	1.6	U	U	2.9	10	1.6	B	J	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	N	µg/L	25	50	0.83	U	U	3	50	0.83	B	J	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U
Copper	N	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	N	µg/L	150	300	23	U	U	2870	300	23			59.9	300	23	B	J	130	300	23	B	J	150	300	23	U	U
Lead	N	µg/L	5	10	2	U	U	4.8	10	2	B	B	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U
Magnesium	N	µg/L	39000	5000	100			44500	5000	100			41800	5000	100			41600	5000	100			34400	5000	100		
Manganese	N	µg/L	30	15	0.5			482	15	0.5			125	15	0.5			181	15	0.5			521	15	0.5		
Mercury	N	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.21	1	0.14	B	J	0.5	1	0.14	U	U
Nickel	N	µg/L	2.4	40	2.3	B	J	4.5	40	2.3	B	J	2.3	40	2.3	B	J	20	40	2.3	U	U	3.3	40	2.3	B	J
Potassium	N	µg/L	2080	10000	100	B	J	4850	10000	100	B	J	2460	20000	100	B	J	3790	10000	100	B	J	1760	20000	100	B	J
Selenium	N	µg/L	5	10	3.1	U	U	5.2	10	3.1	B	J	5	10	3.1	U	U	3.4	10	3.1	B	J	5	10	3.1	U	U
Silver	N	µg/L	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	N	µg/L	17000	10000	500			24900	10000	500			23800	10000	500			28000	10000	500			19400	10000	500		
Thallium	N	µg/L	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	N	µg/L	0.94	50	0.66	B	J	2.5	50	0.66	B	J	0.9	50	0.66	B	J	25	50	0.66	U	U	25	50	0.66	U	U
Zinc	N	µg/L	10.9	20	3.8	B	B	13.1	20	3.8	B	J	7.4	20	3.8	B	B	10	20	3.8	U	U	10	20	3.8	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-MW01					WTP3-MW01					WTP3-MW02					WTP3-MW02					WTP3-MW03				
		SAMPLE NO	WW3021					WW3032					WW3022					WW3033					WW3023				
		SAMPLE DATE	19-May-09					11-Nov-09					21-May-09					12-Nov-09					21-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
METALS (FILTERED)																											
Aluminum	Y	µg/L	25.8	200	11	B	J	100	200	11	U	U	13.4	200	11	B	J	100	200	11	U	U	19.9	200	11	B	J
Antimony	Y	µg/L	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	Y	µg/L	5	10	3.6	U	U	5.9	10	3.6	B	J	11.7	10	3.6			7.7	10	3.6	B	J	5	10	3.6	U	U
Barium	Y	µg/L	136	200	5	B	J	372	200	5			197	200	5	B	J	262	200	5			186	200	5	B	J
Beryllium	Y	µg/L	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U
Cadmium	Y	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	Y	µg/L	123000	1000	100			76700	1000	100		J	108000	1000	100			104000	1000	100		J	114000	1000	100		
Chromium	Y	µg/L	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U	5	10	1.6	U	U
Cobalt	Y	µg/L	25	50	0.83	U	U	1.1	50	0.83	B	J	25	50	0.83	U	U	25	50	0.83	U	U	25	50	0.83	U	U
Copper	Y	µg/L	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U	12.5	25	2.1	U	U
Iron	Y	µg/L	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U	150	300	23	U	U
Lead	Y	µg/L	5	10	2	U	U	5	10	2	U	U	5	10	2	U	U	2.6	10	2	B	B	5	10	2	U	U
Magnesium	Y	µg/L	37700	5000	100			41700	5000	100			41700	5000	100			41700	5000	100			36400	5000	100		
Manganese	Y	µg/L	24.5	15	0.5			398	15	0.5			95.2	15	0.5			166	15	0.5			489	15	0.5		
Mercury	Y	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	Y	µg/L	2.9	40	2.3	B	J	20	40	2.3	U	U	2.5	40	2.3	B	J	20	40	2.3	U	U	3.3	40	2.3	B	J
Potassium	Y	µg/L	1870	10000	100	B	J	4240	10000	100	B	J	2430	20000	100	B	J	3800	10000	100	B	J	1950	20000	100	B	J
Selenium	Y	µg/L	5	10	3.1	U	U	5.2	10	3.1	B	J	5	10	3.1	U	U	5	10	3.1	U	UJ	3.7	10	3.1	B	J
Silver	Y	µg/L	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	Y	µg/L	16900	10000	500			23200	10000	500			23400	10000	500			28400	10000	500			20500	10000	500		
Thallium	Y	µg/L	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	Y	µg/L	0.92	50	0.66	B	J	25	50	0.66	U	U	25	50	0.66	U	U	25	50	0.66	U	U	25	50	0.66	U	U
Zinc	Y	µg/L	19.1	20	3.8	B	B	10	20	3.8	U	U	12.3	20	3.8	B	J	9.5	20	3.8	B	J	13.7	20	3.8	B	J
SEMIVOLATILES																											
3-Methylphenol and 4-Methylphenol	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Acenaphthene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Acenaphthylene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Anthracene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzo(a)anthracene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzo(a)pyrene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzo(b)fluoranthene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzo(ghi)perylene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzo(k)fluoranthene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Benzoic acid	N	µg/L	12.5	25	10	U	U	12	24	9.7	U	U	12	24	9.6	U	U	12.5	25	9.8	U	U	12.5	25	10	U	U
Benzyl alcohol	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Bis(2-chloroethoxy)methane	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Bis(2-chloroethyl)ether	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Bis(2-chloroisopropyl)ether	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Bis(2-ethylhexyl)phthalate	N	µg/L	2.5	5	2	U	U	2.45	4.9	1.9	U	U	2.4	4.8	1.9	U	U	2.45	4.9	2	U	U	2.5	5	2	U	U
Bromophenyl phenyl ether, 4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Butyl benzyl phthalate	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Carbazole	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Chloro-3-methylphenol, 4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Chloroaniline, 4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Chloronaphthalene, 2-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Chlorophenol, 2-	N	µg/L	2.5	5	1.2	U	U	2.45	4.9	1.2	U	U	2.4	4.8	1.2	U	U	2.45	4.9	1.2	U	U	2.5	5	1.2	U	U
Chlorophenyl phenyl ether, 4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Chrysene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-MW01					WTP3-MW01					WTP3-MW02					WTP3-MW02					WTP3-MW03				
		SAMPLE NO	WW3021					WW3032					WW3022					WW3033					WW3023				
		SAMPLE DATE	19-May-09					11-Nov-09					21-May-09					12-Nov-09					21-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Dibenz(a,h)anthracene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dibenzofuran	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dichlorobenzene, 1,2-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dichlorobenzene, 1,3-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dichlorobenzene, 1,4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dichlorobenzidine, 3,3'-	N	µg/L	5	10	2	U	U	4.85	9.7	1.9	U	U	4.8	9.6	1.9	U	U	4.9	9.8	2	U	U	5	10	2	U	U
Dichlorophenol, 2,4-	N	µg/L	2.5	5	1.3	U	U	2.45	4.9	1.3	U	U	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U	2.5	5	1.3	U	U
Diethyl phthalate	N	µg/L	2.5	5	2	U	U	2.45	4.9	1.9	U	U	2.4	4.8	1.9	U	U	2.45	4.9	2	U	U	2.5	5	2	U	U
Dimethyl phthalate	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dimethylphenol, 2,4-	N	µg/L	2.5	5	1.2	U	U	2.45	4.9	1.2	U	U	2.4	4.8	1.2	U	U	2.45	4.9	1.2	U	U	2.5	5	1.2	U	U
Di-n-butyl phthalate	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dinitro-2-methylphenol, 4,6-	N	µg/L	5	10	4	U	U	4.85	9.7	3.9	U	U	4.8	9.6	3.8	U	U	4.9	9.8	3.9	U	U	5	10	4	U	U
Dinitrophenol, 2,4-	N	µg/L	12.5	25	10	U	U	12	24	9.7	U	U	12	24	9.6	U	U	12.5	25	9.8	U	U	12.5	25	10	U	U
Dinitrotoluene, 2,4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Dinitrotoluene, 2,6-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Di-n-octyl phthalate	N	µg/L	2.5	5	1.5	U	U	2.45	4.9	1.5	U	U	2.4	4.8	1.4	U	U	2.45	4.9	1.5	U	U	2.5	5	1.5	U	U
Fluoranthene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Fluorene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Hexachlorobenzene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Hexachlorobutadiene	N	µg/L	2.5	5	2.5	U	U	2.45	4.9	2.4	U	U	2.4	4.8	2.4	U	U	2.45	4.9	2.5	U	U	2.5	5	2.5	U	U
Hexachlorocyclopentadiene	N	µg/L	2.5	5	1.3	U	U	2.45	4.9	1.3	U	U	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U	2.5	5	1.3	U	U
Hexachloroethane	N	µg/L	2.5	5	2.5	U	U	2.45	4.9	2.4	U	U	2.4	4.8	2.4	U	U	2.45	4.9	2.5	U	U	2.5	5	2.5	U	U
Indeno(1,2,3-cd)pyrene	N	µg/L	2.5	5	1.1	U	U	2.45	4.9	1.1	U	U	2.4	4.8	1.1	U	U	2.45	4.9	1.1	U	U	2.5	5	1.1	U	U
Isophorone	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Methylnaphthalene, 2-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Methylphenol, 2-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Naphthalene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Nitroaniline, 2-	N	µg/L	5	10	2	U	U	4.85	9.7	1.9	U	U	4.8	9.6	1.9	U	U	4.9	9.8	2	U	U	5	10	2	U	U
Nitroaniline, 3-	N	µg/L	5	10	2	U	U	4.85	9.7	1.9	U	U	4.8	9.6	1.9	U	U	4.9	9.8	2	U	U	5	10	2	U	U
Nitroaniline, 4-	N	µg/L	5	10	2	U	U	4.85	9.7	1.9	U	U	4.8	9.6	1.9	U	U	4.9	9.8	2	U	U	5	10	2	U	U
Nitrobenzene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Nitrophenol, 2-	N	µg/L	2.5	5	1.3	U	U	2.45	4.9	1.3	U	U	2.4	4.8	1.2	U	U	2.45	4.9	1.3	U	U	2.5	5	1.3	U	U
Nitrophenol, 4-	N	µg/L	12.5	25	10	U	U	12	24	9.7	U	U	12	24	9.6	U	U	12.5	25	9.8	U	U	12.5	25	10	U	U
n-Nitroso-di-n-propylamine	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
n-Nitrosodiphenylamine	N	µg/L	2.5	5	2	U	U	2.45	4.9	1.9	U	U	2.4	4.8	1.9	U	U	2.45	4.9	2	U	U	2.5	5	2	U	U
Pentachlorophenol	N	µg/L	12.5	25	10	U	U	12	24	9.7	U	U	12	24	9.6	U	U	12.5	25	9.8	U	U	12.5	25	10	U	U
Phenanthrene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Phenol	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Pyrene	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Trichlorobenzene, 1,2,4-	N	µg/L	2.5	5	1	U	U	2.45	4.9	0.97	U	U	2.4	4.8	0.96	U	U	2.45	4.9	0.98	U	U	2.5	5	1	U	U
Trichlorophenol, 2,4,5-	N	µg/L	2.5	5	1.4	U	U	2.45	4.9	1.4	U	U	2.4	4.8	1.3	U	U	2.45	4.9	1.4	U	U	2.5	5	1.4	U	U
Trichlorophenol, 2,4,6-	N	µg/L	2.5	5	1.4	U	U	2.45	4.9	1.4	U	U	2.4	4.8	1.3	U	U	2.45	4.9	1.4	U	U	2.5	5	1.4	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WTP3-MW01					WTP3-MW01					WTP3-MW02					WTP3-MW02					WTP3-MW03				
		SAMPLE NO	WW3021					WW3032					WW3022					WW3033					WW3023				
		SAMPLE DATE	19-May-09					11-Nov-09					21-May-09					12-Nov-09					21-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					REG					REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
VOLATILES																											
Acetone	N	µg/L	12.5	25	10	U	U	12.5	25	10	U	R	12.5	25	10	U	R	12.5	25	10	U	R	12.5	25	10	U	R
Benzene	N	µg/L	0.5	1	0.4	U	U	0.5	1	0.4	U	U	0.5	1	0.4	U	U	0.5	1	0.4	U	U	0.5	1	0.4	U	U
Bromodichloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Bromoform	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Bromomethane	N	µg/L	1	2	0.78	U	U	1	2	0.78	U	U	1	2	0.78	U	U	1	2	0.78	U	U	1	2	0.78	U	U
Butanone, 2-	N	µg/L	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U
Carbon disulfide	N	µg/L	1	2	0.4	U	U	1	2	0.4	U	U	1	2	0.4	U	U	1	2	0.4	U	U	1	2	0.4	U	U
Carbon tetrachloride	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chlorobenzene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Chloroethane	N	µg/L	1	2	0.48	U	U	1	2	0.48	U	U	1	2	0.48	U	U	1	2	0.48	U	U	1	2	0.48	U	U
Chloroform	N	µg/L	0.5	1	0.28	U	U	0.5	1	0.28	U	U	0.5	1	0.28	U	U	0.5	1	0.28	U	U	0.5	1	0.28	U	U
Chloromethane	N	µg/L	1	2	0.61	U	U	1	2	0.61	U	U	1	2	0.61	U	U	1	2	0.61	U	U	1	2	0.61	U	U
Dibromochloromethane	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dichloroethane, 1,1-	N	µg/L	0.5	1	0.24	U	U	0.5	1	0.24	U	U	0.5	1	0.24	U	U	0.5	1	0.24	U	U	0.5	1	0.24	U	U
Dichloroethane, 1,2-	N	µg/L	0.5	1	0.34	U	U	0.5	1	0.34	U	U	0.5	1	0.34	U	U	0.5	1	0.34	U	U	0.5	1	0.34	U	U
Dichloroethene, 1,1-	N	µg/L	0.5	1	0.54	U	U	0.5	1	0.54	U	U	0.5	1	0.54	U	U	0.5	1	0.54	U	U	0.5	1	0.54	U	U
Dichloroethene, cis-1,2-	N	µg/L	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U	0.5	1	0.2	U	U
Dichloroethene, trans-1,2-	N	µg/L	0.5	1	0.45	U	U	0.5	1	0.45	U	U	0.5	1	0.45	U	U	0.5	1	0.45	U	U	0.5	1	0.45	U	U
Dichloropropane, 1,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, cis-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Dichloropropene, trans-1,3-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Ethylbenzene	N	µg/L	0.5	1	0.43	U	U	0.5	1	0.43	U	U	0.5	1	0.43	U	U	0.5	1	0.43	U	U	0.5	1	0.43	U	U
Hexanone, 2-	N	µg/L	5	10	5	U	U	5	10	5	U	U	5	10	5	U	U	5	10	5	U	U	5	10	5	U	U
Methyl-2-pentanone, 4-	N	µg/L	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U	2.5	5	2	U	U
Methylene chloride	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Styrene	N	µg/L	0.5	1	0.36	U	U	0.5	1	0.36	U	U	0.5	1	0.36	U	U	0.5	1	0.36	U	U	0.5	1	0.36	U	U
Tetrachloroethane, 1,1,2,2-	N	µg/L	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U	0.5	1	0.21	U	U
Tetrachloroethene	N	µg/L	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U	0.5	1	0.22	U	U
Toluene	N	µg/L	0.5	1	0.35	U	U	0.5	1	0.35	U	U	0.5	1	0.35	U	U	0.5	1	0.35	U	U	0.5	1	0.35	U	U
Trichloroethane, 1,1,1-	N	µg/L	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U	0.5	1	0.33	U	U
Trichloroethane, 1,1,2-	N	µg/L	0.5	1	0.26	U	U	0.5	1	0.26	U	U	0.5	1	0.26	U	U	0.5	1	0.26	U	U	0.5	1	0.26	U	U
Trichloroethene	N	µg/L	0.5	1	0.32	U	U	0.5	1	0.32	U	U	0.5	1	0.32	U	U	0.5	1	0.32	U	U	0.5	1	0.32	U	U
Vinyl chloride	N	µg/L	0.5	1	0.3	U	U	0.5	1	0.3	U	U	0.5	1	0.3	U	U	0.5	1	0.3	U	U	0.5	1	0.3	U	U
Xylenes, total	N	µg/L	1.5	3	1.2	U	U	1.5	3	1.2	U	U	1.5	3	1.2	U	U	1.5	3	1.2	U	U	1.5	3	1.2	U	U
WATER QUALITY																											
Alkalinity, Carbonate	N	µg/L	431000	5000	2500			485000	25000	13000			438000	5000	2500			1060000	25000	13000			392000	5000	2500		
Chloride	N	ppm	11.2	2	1			8.4	2	1			8.3	2	1			7.2	2	1			20.6	2	1		
Cyanide, total	N	ppm	0.005	0.01	0.005	U	U	0.005	0.01	0.005	U	U	0.013	0.01	0.005			0.005	0.01	0.005	U	U	0.023	0.01	0.005		
HARDNESS (as CaCO3)	N	ppm	465	4	4			398	4	4			441	4	4			440	4	4			421	4	4		
Nitrate-Nitrite	N	ppm	0.05	0.1	0.037	U	U	0.35	0.1	0.03			0.05	0.1	0.037	U	U	0.24	0.1	0.03			1	2	0.74	U	U
Sulfate	N	ppm	41.1	2	1			37.3	2	1		J	60.9	2	1			83.6	2	1		J	72	2	1		
Total dissolved solids	N	ppm	615	100	10			494	100	10			488	100	10			721	100	10			606	100	10		
Total suspended solids	N	ppm	13	10	4			56	10	4			10	10	4			27	10	4			17	10	4		
Turbidity	N	NTU	3.2	1	1		J	36.5	1	1		J	3.8	1	1			6.5	1	1		J	5	1	1		

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

	LOCATION CODE		WTP3-MW03				
	SAMPLE NO		WW3034				
	SAMPLE DATE		12-Nov-09				
	DEPTH		0 - 0 Ft				
	SAMPLE PURPOSE		REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ
EXPLOSIVES							
Amino-2,6-dinitrotoluene, 4-	N	µg/L	0.095	0.19	0.049	U	U
Amino-4,6-dinitrotoluene, 2-	N	µg/L	0.095	0.19	0.075	U	U
Dinitrobenzene, 1,3-	N	µg/L	0.13	0.19	0.05	J	J
Dinitrotoluene, 2,4-	N	µg/L	0.16	0.19	0.063	J	J
Dinitrotoluene, 2,6-	N	µg/L	0.095	0.19	0.09	U	U
HMX	N	µg/L	0.095	0.19	0.11	U	U
Nitrobenzene	N	µg/L	0.095	0.19	0.049	U	U
Nitrotoluene, 2-	N	µg/L	0.095	0.19	0.062	U	U
Nitrotoluene, 3-	N	µg/L	0.095	0.19	0.094	U	U
Nitrotoluene, 4-	N	µg/L	0.095	0.19	0.074	U	U
RDX	N	µg/L	0.095	0.19	0.073	U	U
Tetryl	N	µg/L	0.095	0.19	0.076	U	U
Trinitrobenzene, 1,3,5-	N	µg/L	0.14	0.19	0.049	J	J
Trinitrotoluene, 2,4,6-	N	µg/L	0.095	0.19	0.067	U	U
FIELD TESTS							
Dissolved Oxygen	N	mg/L	9.59	0.3			
FERROUS IRON	N	mg/L	0	0.042			
Oxidation Reduction Potential	N	mV	157.4	0.02			
pH	N	pH_units	7.42	0			
Specific Conductivity	N	mS/cm	1.04	0			
Temperature	N	C	9.33	0			
Turbidity	N	NTU	11.9	10			
METALS (UNFILTERED)							
Aluminum	N	µg/L	96.2	200	11	B	J
Antimony	N	µg/L	3	6	4.5	U	U
Arsenic	N	µg/L	5	10	3.6	U	U
Barium	N	µg/L	249	200	5		
Beryllium	N	µg/L	2	4	1	U	U
Cadmium	N	µg/L	2.5	5	1	U	U
Calcium	N	µg/L	106000	1000	100		J
Chromium	N	µg/L	5	10	1.6	U	U
Cobalt	N	µg/L	1.4	50	0.83	B	J
Copper	N	µg/L	12.5	25	2.1	U	U
Iron	N	µg/L	150	300	23	U	U
Lead	N	µg/L	2.3	10	2	B	B
Magnesium	N	µg/L	35800	5000	100		
Manganese	N	µg/L	466	15	0.5		
Mercury	N	µg/L	0.5	1	0.14	U	U
Nickel	N	µg/L	3.1	40	2.3	B	J
Potassium	N	µg/L	3200	10000	100	B	J
Selenium	N	µg/L	4.5	10	3.1	B	J
Silver	N	µg/L	5	10	1.2	U	U
Sodium	N	µg/L	24600	10000	500		
Thallium	N	µg/L	5	10	3.4	U	U
Vanadium	N	µg/L	25	50	0.66	U	U
Zinc	N	µg/L	10	20	3.8	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

	LOCATION CODE		WTP3-MW03				
	SAMPLE NO		WW3034				
	SAMPLE DATE		12-Nov-09				
	DEPTH		0 - 0 Ft				
	SAMPLE PURPOSE		REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ
METALS (FILTERED)							
Aluminum	Y	µg/L	100	200	11	U	U
Antimony	Y	µg/L	3	6	4.5	U	U
Arsenic	Y	µg/L	5	10	3.6	U	U
Barium	Y	µg/L	242	200	5		
Beryllium	Y	µg/L	2	4	1	U	U
Cadmium	Y	µg/L	2.5	5	1	U	U
Calcium	Y	µg/L	112000	1000	100		J
Chromium	Y	µg/L	5	10	1.6	U	U
Cobalt	Y	µg/L	1.2	50	0.83	B	J
Copper	Y	µg/L	12.5	25	2.1	U	U
Iron	Y	µg/L	150	300	23	U	U
Lead	Y	µg/L	5	10	2	U	U
Magnesium	Y	µg/L	37400	5000	100		
Manganese	Y	µg/L	473	15	0.5		
Mercury	Y	µg/L	0.5	1	0.14	U	U
Nickel	Y	µg/L	3.1	40	2.3	B	J
Potassium	Y	µg/L	3270	10000	100	B	J
Selenium	Y	µg/L	5	10	3.1	U	UJ
Silver	Y	µg/L	5	10	1.2	U	U
Sodium	Y	µg/L	25800	10000	500		
Thallium	Y	µg/L	5	10	3.4	U	U
Vanadium	Y	µg/L	25	50	0.66	U	U
Zinc	Y	µg/L	12	20	3.8	B	J
SEMIVOLATILES							
3-Methylphenol and 4-Methylphenol	N	µg/L	2.45	4.9	0.98	U	U
Acenaphthene	N	µg/L	2.45	4.9	0.98	U	U
Acenaphthylene	N	µg/L	2.45	4.9	0.98	U	U
Anthracene	N	µg/L	2.45	4.9	0.98	U	U
Benzo(a)anthracene	N	µg/L	2.45	4.9	0.98	U	U
Benzo(a)pyrene	N	µg/L	2.45	4.9	0.98	U	U
Benzo(b)fluoranthene	N	µg/L	2.45	4.9	0.98	U	U
Benzo(ghi)perylene	N	µg/L	2.45	4.9	0.98	U	U
Benzo(k)fluoranthene	N	µg/L	2.45	4.9	0.98	U	U
Benzoic acid	N	µg/L	12.5	25	9.8	U	U
Benzyl alcohol	N	µg/L	2.45	4.9	0.98	U	U
Bis(2-chloroethoxy)methane	N	µg/L	2.45	4.9	0.98	U	U
Bis(2-chloroethyl)ether	N	µg/L	2.45	4.9	0.98	U	U
Bis(2-chloroisopropyl)ether	N	µg/L	2.45	4.9	0.98	U	U
Bis(2-ethylhexyl)phthalate	N	µg/L	2.45	4.9	2	U	U
Bromophenyl phenyl ether, 4-	N	µg/L	2.45	4.9	0.98	U	U
Butyl benzyl phthalate	N	µg/L	2.45	4.9	0.98	U	U
Carbazole	N	µg/L	2.45	4.9	0.98	U	U
Chloro-3-methylphenol, 4-	N	µg/L	2.45	4.9	0.98	U	U
Chloroaniline, 4-	N	µg/L	2.45	4.9	0.98	U	U
Chloronaphthalene, 2-	N	µg/L	2.45	4.9	0.98	U	U
Chlorophenol, 2-	N	µg/L	2.45	4.9	1.2	U	U
Chlorophenyl phenyl ether, 4-	N	µg/L	2.45	4.9	0.98	U	U
Chrysene	N	µg/L	2.45	4.9	0.98	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

	LOCATION CODE		WTP3-MW03				
	SAMPLE NO		WW3034				
	SAMPLE DATE		12-Nov-09				
	DEPTH		0 - 0 Ft				
	SAMPLE PURPOSE		REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ
Dibenz(a,h)anthracene	N	µg/L	2.45	4.9	0.98	U	U
Dibenzofuran	N	µg/L	2.45	4.9	0.98	U	U
Dichlorobenzene, 1,2-	N	µg/L	2.45	4.9	0.98	U	U
Dichlorobenzene, 1,3-	N	µg/L	2.45	4.9	0.98	U	U
Dichlorobenzene, 1,4-	N	µg/L	2.45	4.9	0.98	U	U
Dichlorobenzidine, 3,3'-	N	µg/L	4.9	9.8	2	U	U
Dichlorophenol, 2,4-	N	µg/L	2.45	4.9	1.3	U	U
Diethyl phthalate	N	µg/L	2.45	4.9	2	U	U
Dimethyl phthalate	N	µg/L	2.45	4.9	0.98	U	U
Dimethylphenol, 2,4-	N	µg/L	2.45	4.9	1.2	U	U
Di-n-butyl phthalate	N	µg/L	2.45	4.9	0.98	U	U
Dinitro-2-methylphenol, 4,6-	N	µg/L	4.9	9.8	3.9	U	U
Dinitrophenol, 2,4-	N	µg/L	12.5	25	9.8	U	U
Dinitrotoluene, 2,4-	N	µg/L	2.45	4.9	0.98	U	U
Dinitrotoluene, 2,6-	N	µg/L	2.45	4.9	0.98	U	U
Di-n-octyl phthalate	N	µg/L	2.45	4.9	1.5	U	U
Fluoranthene	N	µg/L	2.45	4.9	0.98	U	U
Fluorene	N	µg/L	2.45	4.9	0.98	U	U
Hexachlorobenzene	N	µg/L	2.45	4.9	0.98	U	U
Hexachlorobutadiene	N	µg/L	2.45	4.9	2.5	U	U
Hexachlorocyclopentadiene	N	µg/L	2.45	4.9	1.3	U	U
Hexachloroethane	N	µg/L	2.45	4.9	2.5	U	U
Indeno(1,2,3-cd)pyrene	N	µg/L	2.45	4.9	1.1	U	U
Isophorone	N	µg/L	2.45	4.9	0.98	U	U
Methylnaphthalene, 2-	N	µg/L	2.45	4.9	0.98	U	U
Methylphenol, 2-	N	µg/L	2.45	4.9	0.98	U	U
Naphthalene	N	µg/L	2.45	4.9	0.98	U	U
Nitroaniline, 2-	N	µg/L	4.9	9.8	2	U	U
Nitroaniline, 3-	N	µg/L	4.9	9.8	2	U	U
Nitroaniline, 4-	N	µg/L	4.9	9.8	2	U	U
Nitrobenzene	N	µg/L	2.45	4.9	0.98	U	U
Nitrophenol, 2-	N	µg/L	2.45	4.9	1.3	U	U
Nitrophenol, 4-	N	µg/L	12.5	25	9.8	U	U
n-Nitroso-di-n-propylamine	N	µg/L	2.45	4.9	0.98	U	U
n-Nitrosodiphenylamine	N	µg/L	2.45	4.9	2	U	U
Pentachlorophenol	N	µg/L	12.5	25	9.8	U	U
Phenanthrene	N	µg/L	2.45	4.9	0.98	U	U
Phenol	N	µg/L	2.45	4.9	0.98	U	U
Pyrene	N	µg/L	2.45	4.9	0.98	U	U
Trichlorobenzene, 1,2,4-	N	µg/L	2.45	4.9	0.98	U	U
Trichlorophenol, 2,4,5-	N	µg/L	2.45	4.9	1.4	U	U
Trichlorophenol, 2,4,6-	N	µg/L	2.45	4.9	1.4	U	U

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

	LOCATION CODE		WTP3-MW03				
	SAMPLE NO		WW3034				
	SAMPLE DATE		12-Nov-09				
	DEPTH		0 - 0 Ft				
	SAMPLE PURPOSE		REG				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ
VOLATILES							
Acetone	N	µg/L	12.5	25	10	U	R
Benzene	N	µg/L	0.5	1	0.4	U	U
Bromodichloromethane	N	µg/L	0.5	1	0.2	U	UJ
Bromoform	N	µg/L	0.5	1	0.33	U	U
Bromomethane	N	µg/L	1	2	0.78	U	U
Butanone, 2-	N	µg/L	2.5	5	2	U	U
Carbon disulfide	N	µg/L	1	2	0.4	U	U
Carbon tetrachloride	N	µg/L	0.5	1	0.22	U	U
Chlorobenzene	N	µg/L	0.5	1	0.22	U	U
Chloroethane	N	µg/L	1	2	0.48	U	U
Chloroform	N	µg/L	0.5	1	0.28	U	U
Chloromethane	N	µg/L	1	2	0.61	U	U
Dibromochloromethane	N	µg/L	0.5	1	0.2	U	U
Dichloroethane, 1,1-	N	µg/L	0.5	1	0.24	U	U
Dichloroethane, 1,2-	N	µg/L	0.5	1	0.34	U	U
Dichloroethene, 1,1-	N	µg/L	0.5	1	0.54	U	U
Dichloroethene, cis-1,2-	N	µg/L	0.5	1	0.2	U	U
Dichloroethene, trans-1,2-	N	µg/L	0.5	1	0.45	U	U
Dichloropropane, 1,2-	N	µg/L	0.5	1	0.21	U	U
Dichloropropene, cis-1,3-	N	µg/L	0.5	1	0.21	U	UJ
Dichloropropene, trans-1,3-	N	µg/L	0.5	1	0.21	U	U
Ethylbenzene	N	µg/L	0.5	1	0.43	U	U
Hexanone, 2-	N	µg/L	5	10	5	U	U
Methyl-2-pentanone, 4-	N	µg/L	2.5	5	2	U	U
Methylene chloride	N	µg/L	2.5	5	1	U	U
Styrene	N	µg/L	0.5	1	0.36	U	U
Tetrachloroethane, 1,1,2,2-	N	µg/L	0.5	1	0.21	U	U
Tetrachloroethene	N	µg/L	0.5	1	0.22	U	U
Toluene	N	µg/L	0.5	1	0.35	U	U
Trichloroethane, 1,1,1-	N	µg/L	0.5	1	0.33	U	U
Trichloroethane, 1,1,2-	N	µg/L	0.5	1	0.26	U	U
Trichloroethene	N	µg/L	0.5	1	0.32	U	U
Vinyl chloride	N	µg/L	0.5	1	0.3	U	U
Xylenes, total	N	µg/L	1.5	3	1.2	U	U
WATER QUALITY							
Alkalinity, Carbonate	N	µg/L	485000	25000	13000		
Chloride	N	ppm	20.3	2	1		
Cyanide, total	N	ppm	0.005	0.01	0.005	U	U
HARDNESS (as CaCO3)	N	ppm	413	4	4		
Nitrate-Nitrite	N	ppm	0.32	0.1	0.03		
Sulfate	N	ppm	81	2	1		
Total dissolved solids	N	ppm	539	100	10		
Total suspended solids	N	ppm	22	10	4		
Turbidity	N	NTU	5.8	1	1		J

Table E-3

Overburden Groundwater Monitoring Well Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

C - Degrees Celcius.
FD - Field duplicate.
LQ - Laboratory qualifier.
MDL - Method detection limit.
µg/L - Microgram(s) per liter.
mS/cm - Millisiemen(s)/centimeter.
mV - Millivolts.
NTU - Nephalometric turbidity units.
REG - Regular sample.
RL - Reporting limit.
VQ - Validation qualifier.

Validation Qualifiers:
U - Nondetect.
J - Estimated Concentration.
UJ - Nondetected; detection limit is estimated.
B - Analyte also found in blank.
R - Rejected.

Table E-4

Sediment Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SDW301					PBOW99-SDW302					WWTP3-SD01					WWTP3-SD01					WWTP3-SD02					WWTP3-SD03				
SAMPLE NO		PBOW99SDW301					PBOW99SDW302					WW1004					WW1005					WW1007					WW1008				
SAMPLE DATE		2-Sep-99					2-Sep-99					23-May-09					23-May-09					23-May-09					23-May-09				
DEPTH		_5 - 1 Ft					_5 - 1 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft				
SAMPLE PURPOSE		REG					REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																															
Amino-2,6-dinitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.05	U	U
Amino-4,6-dinitrotoluene, 2-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.11	U	U
Dinitrobenzene, 1,3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.053	U	U
Dinitrotoluene, 2,4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.06	U	U
Dinitrotoluene, 2,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.053	U	U
HMX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U																	0.1	0.2	0.086	U	U
Nitrobenzene	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.066	U	U
Nitrotoluene, 2-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.05	U	U
Nitrotoluene, 3-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.084	U	U
Nitrotoluene, 4-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.062	U	U
RDX	mg/kg	0.25	0.5	0.5	U		0.25	0.5	0.5	U																	0.1	0.2	0.085	U	U
Tetryl	mg/kg	0.325	0.65	0.65	U		0.325	0.65	0.65	U																	0.1	0.2	0.051	U	U
Trinitrobenzene, 1,3,5-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.05	U	U
Trinitrotoluene, 2,4,6-	mg/kg	0.125	0.25	0.25	U		0.125	0.25	0.25	U																	0.1	0.2	0.05	U	U
METALS (UNFILTERED)																															
Aluminum	mg/kg	8410	24.2	24.2			9580	25.4	25.4																		9000	21	1.2		
Antimony	mg/kg	3.65	7.3	7.3	U		3.8	7.6	7.6	U																	3.15	6.3	0.48	U	U
Arsenic	mg/kg	7.2	1.2	1.2			6.4	1.3	1.3																		6.8	0.85	0.38		
Barium	mg/kg	58.6	24.2	24.2			66.1	25.4	25.4																		82.5	21	0.53		
Beryllium	mg/kg	0.305	0.61	0.61	U		0.315	0.63	0.63	U																	0.64	0.53	0.11		
Cadmium	mg/kg	0.305	0.61	0.61	U		0.315	0.63	0.63	U																	0.86	0.42	0.11		
Calcium	mg/kg	33000	605	605			7240	635	635																		31300	530	11		
Chromium	mg/kg	14.1	1.2	1.2			14.3	1.3	1.3																		15.1	1.1	0.17		
Cobalt	mg/kg	8.2	6.1	6.1			7.1	6.3	6.3																		11.4	5.3	0.088		
Copper	mg/kg	17.9	3	3			18.9	3.2	3.2																		26.4	2.6	0.22		
Iron	mg/kg	18500	12.1	12.1			18300	12.7	12.7																		19300	11	2.4		
Lead	mg/kg	9.4	0.36	0.36			18.6	0.38	0.38																		16.1	11	0.21		
Magnesium	mg/kg	11000	605	605			3780	635	635																		10400	530	11		
Manganese	mg/kg	390	1.8	1.8			142	1.9	1.9																		1870	16	0.53		
Mercury	mg/kg	0.02	0.04	0.04	U		0.047	0.042	0.042																		0.058	0.18	0.025	B	J
Nickel	mg/kg	20.5	4.8	4.8			19.1	5.1	5.1																		23.7	4.2	0.24		
Potassium	mg/kg	998	605	605			877	635	635																		1180	2200	11	B	B
Selenium	mg/kg	0.71	0.61	0.61			0.99	0.63	0.63																		2.8	11	0.33	B	J
Silver	mg/kg	0.6	1.2	1.2	U		0.65	1.3	1.3	U																	0.55	1.1	0.13	U	U
Sodium	mg/kg	302.5	605	605	U		317.5	635	635	U																	172	2200	53	B	J
Thallium	mg/kg	1.2	1.2	1.2			0.65	1.3	1.3	U																	2.2	4.4	1.44	U	U
Vanadium	mg/kg	22	6.1	6.1			24.5	6.3	6.3																		24.3	5.3	0.07		
Zinc	mg/kg	52.6	2.4	2.4			65.2	2.5	2.5																		71.9	2.1	0.4		
PESTICIDES/PCBS																															
Aroclor 1016	mg/kg											0.0165	0.033	0.016	U	U	0.0175	0.035	0.017	U	U	0.0125	0.025	0.012	U	U	0.0175	0.035	0.018	U	U
Aroclor 1221	mg/kg											0.0165	0.033	0.026	U	U	0.0175	0.035	0.028	U	U	0.0125	0.025	0.02	U	U	0.0175	0.035	0.028	U	U
Aroclor 1232	mg/kg											0.0165	0.033	0.026	U	U	0.0175	0.035	0.028	U	U	0.0125	0.025	0.02	U	U	0.0175	0.035	0.028	U	U
Aroclor 1242	mg/kg											0.0165	0.033	0.016	U	U	0.0175	0.035	0.017	U	U	0.0125	0.025	0.012	U	U	0.0175	0.035	0.018	U	U
Aroclor 1248	mg/kg											0.0165	0.033	0.016	U	U	0.0175	0.035	0.017	U	U	0.0125	0.025	0.012	U	U	0.0175	0.035	0.018	U	U
Aroclor 1254	mg/kg											0.0165	0.033	0.016	U	U	0.0175	0.035	0.017	U	U	0.0125	0.025	0.012	U	U	0.0175	0.035	0.018	U	U
Aroclor 1260	mg/kg											0.0165	0.033	0.016	U	U	0.0175	0.035	0.017	U	U	0.0125	0.025	0.012	U	U	0.0175	0.035	0.018	U	U

Table E-4

Sediment Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SDW301					PBOW99-SDW302					WWTP3-SD01					WWTP3-SD01					WWTP3-SD02					WWTP3-SD03				
SAMPLE NO		PBOW99SDW301					PBOW99SDW302					WW1004					WW1005					WW1007					WW1008				
SAMPLE DATE		2-Sep-99					2-Sep-99					23-May-09					23-May-09					23-May-09					23-May-09				
DEPTH		_5 - 1 Ft					_5 - 1 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft				
SAMPLE PURPOSE		REG					REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
SEMIVOLATILES																															
3-Methylphenol and 4-Methylphenol	mg/kg																										0.175	0.35	0.07	U	U
Acenaphthene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Acenaphthylene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Anthracene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Benzo(a)anthracene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Benzo(a)pyrene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.12	0.35	0.07	J	J
Benzo(b)fluoranthene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.191	0.35	0.07	J	J
Benzo(ghi)perylene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.105	0.35	0.07	J	J
Benzo(k)fluoranthene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Benzoic acid	mg/kg																										0.9	1.8	0.7	U	U
Benzyl alcohol	mg/kg																										0.175	0.35	0.07	U	U
Bis(2-chloroethoxy)methane	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Bis(2-chloroethyl)ether	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Bis(2-chloroisopropyl)ether	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Bis(2-ethylhexyl)phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.35	U	U
Bromophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Butyl benzyl phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.14	U	U
Carbazole	mg/kg																										0.175	0.35	0.07	U	U
Chloro-3-methylphenol, 4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Chloroaniline, 4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.14	U	U
Chloronaphthalene, 2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Chlorophenol, 2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Chlorophenyl phenyl ether, 4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Chrysene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.103	0.35	0.07	J	J
Dibenz(a,h)anthracene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Dibenzofuran	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Dichlorobenzene, 1,2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.092	U	U
Dichlorobenzene, 1,3-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.092	U	U
Dichlorobenzene, 1,4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.085	U	U
Dichlorobenzidine, 3,3'-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.35	0.7	0.14	U	U
Dichlorophenol, 2,4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Diethyl phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.35	U	U
Dimethyl phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.14	U	U
Dimethylphenol, 2,4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Di-n-butyl phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.14	U	U
Dinitro-2-methylphenol, 4,6-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.35	0.7	0.23	U	U
Dinitrophenol, 2,4-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.9	1.8	0.7	U	UJ
Dinitrotoluene, 2,4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Dinitrotoluene, 2,6-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Di-n-octyl phthalate	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.35	0.7	0.14	U	U
Fluoranthene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.156	0.35	0.07	J	J
Fluorene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Hexachlorobenzene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Hexachlorobutadiene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Hexachlorocyclopentadiene	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.175	0.35	0.07	U	U
Hexachloroethane	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.085	U	U
Indeno(1,2,3-cd)pyrene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.11	0.35	0.07	J	J
Isophorone	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U

Table E-4

Sediment Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

LOCATION CODE		PBOW99-SDW301					PBOW99-SDW302					WWTP3-SD01					WWTP3-SD01					WWTP3-SD02					WWTP3-SD03				
SAMPLE NO		PBOW99SDW301					PBOW99SDW302					WW1004					WW1005					WW1007					WW1008				
SAMPLE DATE		2-Sep-99					2-Sep-99					23-May-09					23-May-09					23-May-09					23-May-09				
DEPTH		_5 - 1 Ft					_5 - 1 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft					0 - _5 Ft				
SAMPLE PURPOSE		REG					REG					REG					FD					REG					REG				
Parameter	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Methylnaphthalene, 2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Methylphenol, 2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Methylphenol, 4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																					
Naphthalene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Nitroaniline, 2-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.35	0.7	0.14	U	U
Nitroaniline, 3-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.35	0.7	0.14	U	U
Nitroaniline, 4-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.35	0.7	0.14	U	U
Nitrobenzene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Nitrophenol, 2-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Nitrophenol, 4-	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.9	1.8	0.7	U	U
n-Nitroso-di-n-propylamine	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
n-Nitrosodiphenylamine	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.14	U	U
Pentachlorophenol	mg/kg	0.95	1.9	1.9	U		1	2	2	U																	0.9	1.8	0.7	U	U
Phenanthrene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Phenol	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Pyrene	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.138	0.35	0.07	J	J
Trichlorobenzene, 1,2,4-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Trichlorophenol, 2,4,5-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
Trichlorophenol, 2,4,6-	mg/kg	0.2	0.4	0.4	U		0.21	0.42	0.42	U																	0.175	0.35	0.07	U	U
WATER QUALITY																															
% moisture	Percent	17.4	0.1	0.1			21.2	0.1	0.1																						
% Solids	Percent											49.7	0				48.1	0				68.8	0				47.3	0			
Total organic carbon	mg/kg																										2.2	0.32	0.32		

FD - Field duplicate.
LQ - Laboratory qualifier.
MDL - Method detection limit.
mg/kg - Milligram(s) per kologram.
REG - Regular sample.
RL - Reporting limit.
VQ - Validation qualifier.

Validation Qualifiers:
U - Nondetect.
J - Estimated Concentration.
UJ - Nondetected; detection limit is estimated.
B - Analyte also found in blank.
R - Rejected.

Table E-5

Surface Water Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WWTP3-SW01					WWTP3-SW02					WWTP3-SW03					WWTP3-SW03				
		SAMPLE NO	WW2004					WW2005					WW2006					WW2007				
		SAMPLE DATE	23-May-09					23-May-09					23-May-09					23-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					FD				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
EXPLOSIVES																						
Amino-2,6-dinitrotoluene, 4-	N	µg/L	0.095	0.19	0.048	U	U	0.095	0.19	0.048	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.048	U	U
Amino-4,6-dinitrotoluene, 2-	N	µg/L	0.095	0.19	0.074	U	U	0.095	0.19	0.074	U	U	0.095	0.19	0.075	U	U	0.095	0.19	0.073	U	U
Dinitrobenzene, 1,3-	N	µg/L	0.095	0.19	0.049	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.05	U	U	0.095	0.19	0.049	U	U
Dinitrotoluene, 2,4-	N	µg/L	0.095	0.19	0.062	U	U	0.095	0.19	0.062	U	U	0.095	0.19	0.063	U	U	0.095	0.19	0.062	U	U
Dinitrotoluene, 2,6-	N	µg/L	0.095	0.19	0.089	U	U	0.095	0.19	0.089	U	U	0.095	0.19	0.09	U	U	0.095	0.19	0.089	U	U
HMX	N	µg/L	0.095	0.19	0.1	U	U	0.095	0.19	0.1	U	U	0.095	0.19	0.11	U	U	0.095	0.19	0.1	U	U
Nitrobenzene	N	µg/L	0.095	0.19	0.048	U	U	0.095	0.19	0.048	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.048	U	U
Nitrotoluene, 2-	N	µg/L	0.095	0.19	0.062	U	U	0.095	0.19	0.062	U	U	0.095	0.19	0.062	U	U	0.095	0.19	0.061	U	U
Nitrotoluene, 3-	N	µg/L	0.095	0.19	0.093	U	U	0.095	0.19	0.093	U	U	0.095	0.19	0.094	U	U	0.095	0.19	0.092	U	U
Nitrotoluene, 4-	N	µg/L	0.095	0.19	0.073	U	U	0.095	0.19	0.073	U	U	0.095	0.19	0.074	U	U	0.095	0.19	0.072	U	U
RDX	N	µg/L	0.095	0.19	0.072	U	U	0.095	0.19	0.072	U	U	0.095	0.19	0.073	U	U	0.095	0.19	0.071	U	U
Tetryl	N	µg/L	0.095	0.19	0.075	U	U	0.095	0.19	0.075	U	U	0.095	0.19	0.076	U	U	0.095	0.19	0.074	U	U
Trinitrobenzene, 1,3,5-	N	µg/L	0.095	0.19	0.048	U	U	0.095	0.19	0.048	U	U	0.095	0.19	0.049	U	U	0.095	0.19	0.048	U	U
Trinitrotoluene, 2,4,6-	N	µg/L	0.095	0.19	0.066	U	U	0.095	0.19	0.066	U	U	0.095	0.19	0.067	U	U	0.095	0.19	0.066	U	U
FIELD TESTS																						
Dissolved Oxygen	N	mg/L	3.67	0.3				3.09	0.3									8.98	0.3			
Oxidation Reduction Potential	N	mV	70.7	0.02				61.4	0.02									124.1	0.02			
pH	N	pH_units	6.94	0				6.68	0									7.39	0			
Specific Conductivity	N	mS/cm	0.827	0				0.681	0									0.855	0			
Temperature	N	C	21.22	0				11.88	0									11.88	0			
Turbidity	N	NTU	199.7	10				12.4	10									9.9	10			
METALS (UNFILTERED)																						
Aluminum	N	µg/L	1420	200	11			1660	200	11			2940	200	11		J	4240	200	11		J
Antimony	N	µg/L	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U	3	6	4.5	U	U
Arsenic	N	µg/L	6.1	10	3.6	B	J	5	10	3.6	U	U	9.4	10	3.6	B	J	5	10	3.6	U	U
Barium	N	µg/L	65.4	200	5	B	J	47	200	5	B	J	106	200	5	B	J	104	200	5	B	J
Beryllium	N	µg/L	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U	2	4	1	U	U
Cadmium	N	µg/L	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U	2.5	5	1	U	U
Calcium	N	µg/L	110000	1000	100			91200	1000	100			123000	1000	100			116000	1000	100		
Chromium	N	µg/L	2.1	10	1.6	B	J	2.5	10	1.6	B	J	4.4	10	1.6	B	J	6.9	10	1.6	B	J
Cobalt	N	µg/L	2.1	50	0.83	B	J	1.6	50	0.83	B	J	6.2	50	0.83	B	J	5.7	50	0.83	B	J
Copper	N	µg/L	6.9	25	2.1	B	J	12.5	25	2.1	U	U	8.8	25	2.1	B	J	8	25	2.1	B	J
Iron	N	µg/L	2440	300	23			4190	300	23			10600	300	23			12000	300	23		
Lead	N	µg/L	4.5	5	2	B	J	2.2	5	2	B	J	7.4	5	2			7	5	2		
Magnesium	N	µg/L	24100	5000	100			23600	5000	100			29900	5000	100			28700	5000	100		
Manganese	N	µg/L	788	15	0.5			134	15	0.5			2030	15	0.5			1930	15	0.5		
Mercury	N	µg/L	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U	0.5	1	0.14	U	U
Nickel	N	µg/L	20	40	2.3	U	U	20	40	2.3	U	U	3.4	40	2.3	B	J	4.8	40	2.3	B	J
Potassium	N	µg/L	776	20000	100	B	J	703	20000	100	B	J	1300	20000	100	B	J	1630	20000	100	B	J
Selenium	N	µg/L	5	10	3.1	U	U	5	10	3.1	U	U	4.3	10	3.1	B	J	4.9	10	3.1	B	J
Silver	N	µg/L	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U	5	10	1.2	U	U
Sodium	N	µg/L	4480	20000	500	B	J	3850	20000	500	B	J	4810	20000	500	B	J	5100	20000	500	B	J
Thallium	N	µg/L	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U	5	10	3.4	U	U
Vanadium	N	µg/L	5	50	0.66	B	J	4.7	50	0.66	B	J	8.7	50	0.66	B	J	10.6	50	0.66	B	J
Zinc	N	µg/L	21.7	20	3.8		B	19.4	20	3.8	B	B	36.3	20	3.8		B	38.5	20	3.8		B

Table E-5

Surface Water Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WWTP3-SW01					WWTP3-SW02					WWTP3-SW03					WWTP3-SW03				
		SAMPLE NO	WW2004					WW2005					WW2006					WW2007				
		SAMPLE DATE	23-May-09					23-May-09					23-May-09					23-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					FD				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
SEMIVOLATILES																						
3-Methylphenol and 4-Methylphenol	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Acenaphthene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Acenaphthylene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
ACETOPHENONE	N	µg/L																				
Anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Atrazine	N	µg/L																				
Benzaldehyde	N	µg/L																				
Benzo(a)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Benzo(a)pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Benzo(b)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Benzo(ghi)perylene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Benzo(k)fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Benzoic acid	N	µg/L	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U
Benzyl alcohol	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
BIBENZENE	N	µg/L																				
Bis(2-chloroethoxy)methane	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Bis(2-chloroethyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Bis(2-chloroisopropyl)ether	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Bis(2-ethylhexyl)phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Bromophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Butyl benzyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Caprolactam	N	µg/L																				
Carbazole	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Chloro-3-methylphenol, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Chloroaniline, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Chloronaphthalene, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Chlorophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Chlorophenyl phenyl ether, 4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Chrysene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dibenz(a,h)anthracene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dibenzofuran	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,2-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,3-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dichlorobenzene, 1,4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dichlorobenzidine, 3,3'-	N	µg/L	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U
Dichlorophenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Diethyl phthalate	N	µg/L	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Dimethyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dimethylphenol, 2,4-	N	µg/L	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Di-n-butyl phthalate	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dinitro-2-methylphenol, 4,6-	N	µg/L	4.8	9.6	3.8	U	U	4.8	9.6	3.8	U	U	4.8	9.6	3.8	U	U	4.8	9.6	3.8	U	U
Dinitrophenol, 2,4-	N	µg/L	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U
Dinitrotoluene, 2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Dinitrotoluene, 2,6-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Di-n-octyl phthalate	N	µg/L	2.4	4.8	1.4	U	U	2.4	4.8	1.4	U	U	2.4	4.8	1.4	U	U	2.4	4.8	1.4	U	U

Table E-5

Surface Water Analytical Data Used in the WWTP3 Baseline Human Health Risk Assessment
Plum Brook Ordnance Works, Sandusky, Ohio

		LOCATION CODE	WWTP3-SW01					WWTP3-SW02					WWTP3-SW03					WWTP3-SW03				
		SAMPLE NO	WW2004					WW2005					WW2006					WW2007				
		SAMPLE DATE	23-May-09					23-May-09					23-May-09					23-May-09				
		DEPTH	0 - 0 Ft					0 - 0 Ft					0 - 0 Ft					0 - 0 Ft				
		SAMPLE PURPOSE	REG					REG					REG					FD				
Parameter	Filtered	Units	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ	Result	RL	MDL	LQ	VQ
Fluoranthene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Fluorene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Hexachlorobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Hexachlorobutadiene	N	µg/L	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U
Hexachlorocyclopentadiene	N	µg/L	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Hexachloroethane	N	µg/L	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U	2.4	4.8	2.4	U	U
Indeno(1,2,3-cd)pyrene	N	µg/L	2.4	4.8	1.1	U	U	2.4	4.8	1.1	U	U	2.4	4.8	1.1	U	U	2.4	4.8	1.1	U	U
Isophorone	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Methylnaphthalene, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Methylphenol, 2-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Methylphenol, 4-	N	µg/L																				
Naphthalene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Nitroaniline, 2-	N	µg/L	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U
Nitroaniline, 3-	N	µg/L	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U
Nitroaniline, 4-	N	µg/L	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U	4.8	9.6	1.9	U	U
Nitrobenzene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Nitrophenol, 2-	N	µg/L	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U	2.4	4.8	1.2	U	U
Nitrophenol, 4-	N	µg/L	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U
n-Nitroso-di-n-propylamine	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
n-Nitrosodiphenylamine	N	µg/L	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U	2.4	4.8	1.9	U	U
Pentachlorophenol	N	µg/L	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U	12	24	9.6	U	U
Phenanthrene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Phenol	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Pyrene	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Trichlorobenzene, 1,2,4-	N	µg/L	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U	2.4	4.8	0.96	U	U
Trichlorophenol, 2,4,5-	N	µg/L	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U
Trichlorophenol, 2,4,6-	N	µg/L	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U	2.4	4.8	1.3	U	U

C - Degrees Celcius.
FD - Field duplicate.
LQ - Laboratory qualifier.
MDL - Method detection limit.
µg/L - Microgram(s) per liter.
REG - Regular sample.
RL - Reporting limit.
VQ - Validation qualifier.

Validation Qualifiers:
U - Nondetect.
J - Estimated Concentration.
UJ - Nondetected; detection limit is estimated.
B - Analyte also found in blank.
R - Rejected.

APPENDIX F

EVALUATION OF CANCER RISKS EXCLUDING THE SAMPLES WITH THE THREE HIGHEST PAH CONCENTRATIONS

Table F-1

Summary of Surface Soil Samples Evaluated in the Baseline Human Health Risk Assessment
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Location	Sample Number	Sample Type	Sample Date	Depth (ft)	Analyses
PBOW99-SSW301	PBOW99SSW301	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW302	PBOW99SSW302	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals, PCB, SVOC, VOC
~~PBOW99-SSW303~~	~~PBOW99SSW303~~	~~REG~~	~~2-Sep-99~~	~~0 - 0~~	~~Explosives, Gen Chem, Metals, PCB, SVOC, VOC~~
PBOW99-SSW304	PBOW99SSW304	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW305	PBOW99SSW305	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW306	PBOW99SSW306	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW307	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW308	FD	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW309	PBOW99SSW309	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
PBOW99-SSW310	PBOW99SSW310	REG	2-Sep-99	0 - 0	Explosives, Gen Chem, Metals
WWTP3-SB03	WW0041	REG	10-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB05	WW0048	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB06	WW0051	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB07	WW0054	REG	11-Dec-08	0 - 1	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0060	REG	11-Dec-08	0.2 - 1.6	Explosives, Metals, PCB, SVOC
~~WWTP3-SB02~~	~~WW0038~~	~~REG~~	~~10-Dec-08~~	~~0.5 - 1.5~~	~~Explosives, Metals, PCB, SVOC~~
~~WWTP3-SB01~~	~~WW0034~~	~~REG~~	~~10-Dec-08~~	~~0.7 - 1.7~~	~~Explosives, Gen Chem, Metals, PCB, SVOC~~

ft - feet
FD - Field duplicate; averaged with the regular sample at the same location to create one result.
PAH - Polycyclic aromatic hydrocarbon
PCB - Polychlorinated biphenyls
REG - Regular sample
SVOC - Semivolatile organic compounds
VOC - Volatile organic compounds

Note: Strikethrough indicates the high-PAH samples that were excluded for the evaluation in this appendix.

Table F-2

Summary of Chemicals in Surface Soil
Excluding Samples with the Three Highest PAH Concetrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Inorganics															
Aluminum	16 / 16	100	3.11E+03		9.47E+03		1.70E+00	2.40E+01	7.11E+03	1.55E+04	7700		N (b)		---
Antimony	6 / 16	38	2.75E-01	J	4.13E-01	J	4.24E-01	7.20E+00	2.05E+00	9.30E+00	3.1		N (b)		---
Arsenic	16 / 16	100	3.90E+00		2.08E+01		8.49E-01	1.20E+00	7.48E+00	3.65E+01	0.39		N (b)		---
Barium	16 / 16	100	2.97E+01		7.47E+01		1.74E-01	2.40E+01	5.31E+01	8.26E+02	1500		N (b)		---
Beryllium	9 / 16	56	5.90E-01		8.44E+00		1.70E-01	6.00E-01	2.74E+00	1.00E+00	16		N (a)		---
Cadmium	5 / 16	31	2.24E-01	J	3.64E-01	J	4.24E-01	6.00E-01	2.73E-01	NA	7		N (a)		---
Calcium	16 / 16	100	3.29E+03		6.07E+04		4.24E+00	6.00E+02	1.97E+04	5.23E+04	Nutrient		N (c)		---
Chromium	16 / 16	100	6.90E+00		1.49E+01		4.24E-01	1.20E+00	1.17E+01	2.90E+01	0.29		N (b)		---
Cobalt	14 / 16	88	3.97E+00	J	9.78E+00		1.70E-01	6.00E+00	6.16E+00	1.16E+02	2.3		N (b)		---
Copper	16 / 16	100	7.10E+00		2.45E+01		4.24E-01	3.00E+00	1.54E+01	5.62E+01	310		N (b)		---
Iron	16 / 16	100	1.02E+04	J	2.90E+04		1.70E+00	1.20E+01	1.62E+04	2.34E+05	5500		N (b)		---
Lead	16 / 16	100	9.60E+00		1.34E+02	J	3.10E-01	5.00E-01	3.11E+01	4.86E+01	400		N (a)		---
Magnesium	16 / 16	100	2.01E+03		8.75E+03	J	1.74E+00	6.00E+02	5.08E+03	1.04E+04	Nutrient		N (c)		---
Manganese	16 / 16	100	1.70E+02		6.06E+02		1.74E-01	1.80E+00	3.27E+02	3.51E+03	180		N (b)		---
Mercury	14 / 16	88	2.00E-02	J	5.97E-01		2.06E-02	4.00E-02	9.50E-02	8.50E-02	2.3		N (a)		---
Nickel	16 / 16	100	8.40E+00		2.41E+01		2.55E-01	4.80E+00	1.56E+01	5.51E+01	150		N (b)		---
Potassium	15 / 16	94	3.63E+02		9.36E+02		2.12E+01	6.00E+02	6.17E+02	3.39E+03	Nutrient		N (c)		---
Selenium	12 / 16	75	4.83E-01	J	1.10E+00		5.20E-01	1.00E+00	6.66E-01	2.00E+00	39		N (b)		---
Sodium	7 / 16	44	2.50E+01		6.46E+01		8.49E+00	6.00E+02	1.80E+02	NA	Nutrient		N (c)		---
Thallium	7 / 16	44	2.21E-01	J	1.10E+00		4.24E-01	1.20E+00	5.59E-01	1.30E+00	0.51	g	N (b)		---
Vanadium	16 / 16	100	1.38E+01		2.32E+01		1.70E-01	6.00E+00	1.91E+01	4.09E+01	39		N (b)		---
Zinc	16 / 16	100	3.38E+01		1.05E+02		2.10E+00	2.50E+00	5.77E+01	3.22E+02	2300		N (b)		---
Polychlorinated biphenyls (PCB)															
Aroclor 1016	2 / 9	22	1.40E-01	J	1.22E+00	J	4.02E-02	2.05E-01	2.12E-01		0.39		Y	7.64E-01	7.64E-01
Aroclor 1254	2 / 9	22	2.50E-01		1.00E+00	J	4.02E-02	2.05E-01	1.90E-01		0.11		Y	5.40E-01	5.40E-01
Aroclor 1260	2 / 9	22	1.80E-01	J	2.29E-01		4.02E-02	4.60E-01	1.22E-01		0.22		Y	2.04E-01	2.04E-01
Nitroaromatics															
Amino-2,6-dinitrotoluene, 4-	1 / 16	6	2.60E-01		2.60E-01		2.50E-01	3.11E-01	1.42E-01		15		N (a)		---
Amino-4,6-dinitrotoluene, 2-	1 / 16	6	2.28E-01	/U	2.28E-01	/U	2.50E-01	3.11E-01	1.40E-01		15		N (a)		---
Trinitrotoluene, 2,4,6-	1 / 16	6	8.80E-01		8.80E-01		2.50E-01	3.11E-01	1.81E-01		3.6		N (a)		---
Semivolatile Organic Compounds															
Acenaphthene	2 / 9	22	4.78E-01		6.43E-01	J	3.60E-01	2.00E+00	3.68E-01		340		N (a)		---
Acenaphthylene	5 / 9	56	5.41E-02	J	3.23E+00		3.60E-01	2.00E+00	6.97E-01		340	h	N (a)		---
Anthracene	5 / 9	56	5.04E-02	J	4.53E+00		3.60E-01	2.00E+00	1.06E+00		1700		N (a)		---
Benzo(a)anthracene	4 / 6	67	1.01E-01	J	1.20E+00		3.60E-01	2.00E+00	2.56E+00		0.15		Y	8.97E-01	8.97E-01
Benzo(a)pyrene	4 / 6	67	9.09E-02	J	1.30E+00		3.60E-01	2.00E+00	2.23E+00		0.015		Y	9.40E-01	9.40E-01
Benzo(b)fluoranthene	4 / 6	67	1.40E-01	J	1.20E+00		3.60E-01	2.00E+00	2.84E+00		0.15		Y	9.54E-01	9.54E-01
Benzo(ghi)perylene	6 / 9	67	1.78E-01	J	5.57E+00		3.60E-01	2.00E+00	1.35E+00		170	i	N (a)		---
Benzo(k)fluoranthene	3 / 6	50	1.27E-01	J	1.10E+00		3.60E-01	2.00E+00	1.28E+00		1.5		N (a)	7.97E-01	7.97E-01
Carbazole	2 / 7	29	4.32E-01		1.12E+00	J	4.00E-01	2.00E+00	4.81E-01		24	j	N (a)		---
Chrysene	7 / 9	78	9.25E-02	J	1.03E+01		3.60E-01	2.00E+00	2.29E+00		15		N (a)		---
Dibenz(a,h)anthracene	0 / 6	0	0.00E+00	J	0.00E+00	J	3.60E-01	2.00E+00	5.08E-01		0.015		N (a)	0.00E+00	0.00E+00

Table F-2

Summary of Chemicals in Surface Soil
Excluding Samples with the Three Highest PAH Concetrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg	COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Dibenzofuran	2 / 9	22	4.36E-01		1.35E+00	J	3.60E-01	2.00E+00	4.42E-01		7.8	N (a)		---
Fluoranthene	7 / 9	78	1.87E-01	J	2.48E+01		3.60E-01	2.00E+00	5.06E+00		230	N (a)		---
Fluorene	3 / 9	33	5.81E-01		1.78E+00	J	3.60E-01	2.00E+00	5.52E-01		230	N (a)		---
Indeno(1,2,3-cd)pyrene	4 / 6	67	3.05E-01	J	8.70E-01		3.60E-01	2.00E+00	1.84E+00		0.15	Y	7.33E-01	7.33E-01
Methylnaphthalene, 2-	2 / 9	22	7.21E-01		1.57E+00	J	3.60E-01	2.00E+00	4.98E-01		31	N (a)		---
Naphthalene	2 / 9	22	6.77E-01		1.38E+00	J	3.60E-01	2.00E+00	4.72E-01		3.6	N (a)		---
Phenanthrene	7 / 9	78	6.77E-02	J	1.39E+01		3.60E-01	2.00E+00	2.79E+00		170 [i]	N (a)		---
Pyrene	7 / 9	78	1.57E-01	J	1.81E+01		3.60E-01	2.00E+00	3.93E+00		170	N (a)		---
Volatile Organic Compounds														
Methylene chloride	2 / 2	100	1.20E-02		1.30E-02		5.50E-03	6.00E-03	1.25E-02		11	N (a)		---

BSC - Background screening criterion;
COPC - Chemical of Potential Concern
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
mg/kg - milligrams per kilogram
PAH - Polycyclic aromatic hydrocarbon
RBSC - Risk based screening concentration
VQ - Validation qualifier.

Note: Shaded rows indicate the PAH COPCs that were re-evaluated excluding the samples with the three highest polycyclic aromatic (PAH) concentrations for this appendix.

[a] IT Corporation (IT), 1998, ***Site Investigation of Acid Areas***, Plum Brook Ordnance Works, Sandusky, Ohio, August.

[b] Risk-Based Screening Concentrations based on USEPA Regional Screening Level Table (April 2012) residential soil values (unless otherwise noted), and are based on a risk level of 1.0E-06 and a hazard index of 0.1.

[c] N = Chemical is not chosen as a COPC:
(a) = maximum detected concentration is less than the RBSC.
(b) = maximum detected concentration is less than the BSC.
(c) = essential nutrient.

[d] Y = Chemical is chosen as COPC.

[e] 95% UCL (Upper confidence limit) determined using ProUCL Version 4.1.01 U.S. Environmental Protection Agency (EPA), 2011, ProUCL Version 4.1.01, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.

[f] Concentration used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.

[g] RBSC based on thallium from IRIS, 2009.

[h] RBSC based on acenaphthene.

[i] RBSC based on pyrene.

[j] Because no RSL is available, the RBSC is based on the PRG (EPA, 2004). Note that the slope factor used for the PRG is the most current available.

Table F-3

Groundskeeper, Current Scenarios, Exposure to Surface Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	7.64E-01	2.67E-07	7.48E-07	1.87E-08	1.07E-02	2.14E-08	2.47E-07	6.91E-07	1.73E-08	9.87E-03
Aroclor 1254	5.40E-01	1.89E-07	5.28E-07	3.77E-07	2.64E-02	1.51E-08	1.74E-07	4.88E-07	3.49E-07	2.44E-02
Aroclor 1260	2.04E-01	7.13E-08	2.00E-07	1.43E-07	NA	5.71E-09	6.59E-08	1.84E-07	1.32E-07	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	8.97E-01	3.13E-07	8.78E-07	2.29E-07	NA	2.33E-08	2.69E-07	7.53E-07	1.96E-07	NA
Benzo(a)pyrene	9.40E-01	3.28E-07	9.20E-07	2.40E-06	NA	2.44E-08	2.82E-07	7.89E-07	2.06E-06	NA
Benzo(b)fluoranthene	9.54E-01	3.33E-07	9.33E-07	2.43E-07	NA	2.48E-08	2.86E-07	8.01E-07	2.09E-07	NA
Benzo(k)fluoranthene	7.97E-01	2.79E-07	7.80E-07	2.03E-08	NA	2.07E-08	2.39E-07	6.69E-07	1.74E-08	NA
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
Indeno(1,2,3-cd)pyrene	7.33E-01	2.56E-07	7.17E-07	1.87E-07	NA	1.91E-08	2.20E-07	6.15E-07	1.60E-07	NA
Total ILCR or HI				**3.62E-06**	**3.71E-02**				**3.14E-06**	**3.43E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter
PAH - Polycyclic aromatic hydrocarbon

Table F-3

Groundskeeper, Current Scenarios, Exposure to Surface Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	Inhalation ILCR	Inhalation HQ	**All Pathways Total ILCR**	**All Pathways Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	7.64E-08	5.34E-09	1.50E-08	3.74E-10	NA	**3.63E-08**	**2.05E-02**
Aroclor 1254	5.40E-08	3.77E-09	1.06E-08	7.55E-09	NA	**7.34E-07**	**5.08E-02**
Aroclor 1260	2.04E-08	1.43E-09	3.99E-09	2.85E-09	NA	**2.77E-07**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	8.97E-08	6.27E-09	1.76E-08	1.94E-09	NA	**4.27E-07**	**NA**
Benzo(a)pyrene	9.40E-08	6.57E-09	1.84E-08	2.04E-08	NA	**4.48E-06**	**NA**
Benzo(b)fluoranthene	9.54E-08	6.67E-09	1.87E-08	2.07E-09	NA	**4.54E-07**	**NA**
Benzo(k)fluoranthene	7.97E-08	5.57E-09	1.56E-08	1.73E-10	NA	**3.79E-08**	**NA**
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	**NA**	**NA**
Indeno(1,2,3-cd)pyrene	7.33E-08	5.12E-09	1.43E-08	1.59E-09	NA	**3.49E-07**	**NA**
Total ILCR or HI				**3.69E-08**	**NA**	**6.79E-06**	**7.14E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter
PAH - Polycyclic aromatic hydrocarbon

Table F-4

Indoor Worker, Future Scenario, Exposure to Surface Soil
Exluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion					
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	**Total ILCR**	**Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	7.64E-01	1.33E-07	3.74E-07	9.34E-09	5.34E-03	**9.34E-09**	**5.34E-03**
Aroclor 1254	5.40E-01	9.44E-08	2.64E-07	1.89E-07	1.32E-02	**1.89E-07**	**1.32E-02**
Aroclor 1260	2.04E-01	3.56E-08	9.98E-08	7.13E-08	NA	**7.13E-08**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	8.97E-01	1.57E-07	4.39E-07	1.14E-07	NA	**1.14E-07**	**NA**
Benzo(a)pyrene	9.40E-01	1.64E-07	4.60E-07	1.20E-06	NA	**1.20E-06**	**NA**
Benzo(b)fluoranthene	9.54E-01	1.67E-07	4.67E-07	1.22E-07	NA	**1.22E-07**	**NA**
Benzo(k)fluoranthene	7.97E-01	1.39E-07	3.90E-07	1.02E-08	NA	**1.02E-08**	**NA**
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	**0.00E+00**	**NA**
Indeno(1,2,3-cd)pyrene	7.33E-01	1.28E-07	3.59E-07	9.35E-08	NA	**9.35E-08**	**NA**
Total ILCR or HI						**1.81E-06**	**1.85E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
PAH - Polycyclic aromatic hydrocarbon

Table F-5

Adult Hunter, Future Scenario, Exposure to Surface Soil
Excluding Samples with the Three Highest PAH Concentrtaions
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
	EPC	Cancer Dose	Noncancer Dose	Adult Hunter	Adult Hunter	Dose Absorbed	Cancer Dose	Noncancer Dose	Adult Hunter	Adult Hunter
Chemicals of Potential Concern	mg/kg	mg/kg-day	mg/kg-day	ILCR	HQ	mg/cm^2-day	mg/kg-day	mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	7.64E-01	1.79E-08	4.19E-08	1.26E-09	5.98E-04	2.14E-08	1.66E-08	3.87E-08	1.16E-09	5.53E-04
Aroclor 1254	5.40E-01	1.27E-08	2.96E-08	2.54E-08	1.48E-03	1.51E-08	1.17E-08	2.73E-08	2.34E-08	1.37E-03
Aroclor 1260	2.04E-01	4.79E-09	1.12E-08	9.58E-09	NA	5.71E-09	4.43E-09	1.03E-08	8.85E-09	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	8.97E-01	2.11E-08	4.92E-08	1.54E-08	NA	2.33E-08	1.81E-08	4.22E-08	1.32E-08	NA
Benzo(a)pyrene	9.40E-01	2.21E-08	5.15E-08	1.61E-07	NA	2.44E-08	1.89E-08	4.42E-08	1.38E-07	NA
Benzo(b)fluoranthene	9.54E-01	2.24E-08	5.23E-08	1.64E-08	NA	2.48E-08	1.92E-08	4.49E-08	1.40E-08	NA
Benzo(k)fluoranthene	7.97E-01	1.87E-08	4.37E-08	1.37E-09	NA	2.07E-08	1.61E-08	3.75E-08	1.17E-09	NA
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
Indeno(1,2,3-cd)pyrene	7.33E-01	1.72E-08	4.02E-08	1.26E-08	NA	1.91E-08	1.48E-08	3.45E-08	1.08E-08	NA
Total ILCR and HI				**2.43E-07**	**2.08E-03**				**2.11E-07**	**1.92E-03**

EPC - Exposure Point Concentration
HQ - Hazard Quotient; HI - Hazard Index
ILCR - Incremental Lifetime Cancer Risk
mg/kg - milligram per kilogram
mg/cm^2 - milligram per square meter
PAH - Polycyclic aromatic hydrocarbon

Table F-5

Adult Hunter, Future Scenario, Exposure to Surface Soil
Excluding Samples with the Three Highest PAH Concentrtaions
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

	Concentration in Forage C_p	Concentration in Venison C_v	Consumption of Venison				**All Pathways**	
			Cancer Dose	Noncancer Dose			**Total**	**Total**
Chemicals of Potential Concern	mg/kg	mg/kg	mg/kg-day	mg/kg-day	ILCR	HQ	**ILCR**	**HI**
Polychlorinated biphenyls (PCB)								
Aroclor 1016	2.14E-02	1.12E-06	8.52E-11	1.99E-10	5.97E-12	2.84E-06	**2.42E-09**	**1.15E-03**
Aroclor 1254	4.58E-03	1.90E-06	1.45E-10	3.38E-10	2.90E-10	1.69E-05	**4.91E-08**	**2.86E-03**
Aroclor 1260	1.16E-03	9.57E-07	7.30E-11	1.70E-10	1.46E-10	NA	**1.86E-08**	**NA**
Semivolatile Organic Compounds								
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA	**2.86E-08**	**NA**
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	**2.99E-07**	**NA**
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	**3.04E-08**	**NA**
Benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	**2.54E-09**	**NA**
Dibenz(a,h)anthracene	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA	NA	**2.33E-08**	**NA**
Total ILCR and HI					**4.42E-10**	**1.97E-05**	**4.54E-07**	**4.02E-03**

EPC - Exposure Point Concentration
HQ - Hazard Quotient; HI - Hazard Index
ILCR - Incremental Lifetime Cancer Risk
mg/kg - milligram per kilogram
mg/cm^2 - milligram per square meter
PAH - Polycyclic aromatic hydrocarbon

Table F-6

Hunter's Child, Future Scenario, Exposure to Surface Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Concentration	Concentration	Consumption of Venison					
	EPC	in Forage C_p	in Venison C_v	Cancer Dose	Noncancer Dose			**Total**	**Total**
Chemicals of Potential Concern	mg/kg	mg/kg	mg/kg	mg/kg-day	mg/kg-day	ILCR	HQ	**ILCR**	**HI**
Polychlorinated biphenyls (PCB)									
Aroclor 1016	7.64E-01	2.14E-02	1.12E-06	3.06E-11	3.57E-10	2.14E-12	5.10E-06	**2.14E-12**	**5.10E-06**
Aroclor 1254	5.40E-01	4.58E-03	1.90E-06	5.20E-11	6.06E-10	1.04E-10	3.03E-05	**1.04E-10**	**3.03E-05**
Aroclor 1260	2.04E-01	1.16E-03	9.57E-07	2.62E-11	3.06E-10	5.24E-11	NA	**5.24E-11**	**NA**
Semivolatile Organic Compounds									
Benzo(a)anthracene	8.97E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(a)pyrene	9.40E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(b)fluoranthene	9.54E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Benzo(k)fluoranthene	7.97E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Dibenz(a,h)anthracene	0.00E+00	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Indeno(1,2,3-cd)pyrene	7.33E-01	NA	NA	NA	NA	NA	NA	**NA**	**NA**
Total ILCR and HI						**1.59E-10**	**3.54E-05**	**1.59E-10**	**3.54E-05**

EPC - Exposure Point Concentration
HQ - Hazard Quotient; HI - Hazard Index
ILCR - Incremental Lifetime Cancer Risk
mg/kg - milligram per kilogram
PAH - Polycyclic aromatic hydrocarbon

Table F-7

Total Soil Samples Evaluated in Baseline Human Health Risk Assessment
Excluding Samples with Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Location	Sample Number	Sample Type	Sample Date	Depth (ft)			Analyses
PBOW99-SSW301	PBOW99SSW301	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW302	PBOW99SSW302	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals, PCB, SVOC, VOC
~~PBOW99-SSW303~~	~~PBOW99SSW303~~	~~REG~~	~~2-Sep-99~~	~~0~~	~~-~~	~~0~~	~~Explosives, Gen Chem, Metals, PCB, SVOC, VOC~~
PBOW99-SSW304	PBOW99SSW304	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW305	PBOW99SSW305	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW306	PBOW99SSW306	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW307	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW307	PBOW99SSW308	FD	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW309	PBOW99SSW309	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
PBOW99-SSW310	PBOW99SSW310	REG	2-Sep-99	0	-	0	Explosives, Gen Chem, Metals
WWTP3-SB03	WW0041	REG	10-Dec-08	0	-	1	Explosives, Metals, PCB, SVOC
WWTP3-SB05	WW0048	REG	11-Dec-08	0	-	1	Explosives, Metals, PCB, SVOC
WWTP3-SB06	WW0051	REG	11-Dec-08	0	-	1	Explosives, Metals, PCB, SVOC
WWTP3-SB07	WW0054	REG	11-Dec-08	0	-	1	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0060	REG	11-Dec-08	0.2	-	1.6	Explosives, Metals, PCB, SVOC
~~WWTP3-SB02~~	~~WW0038~~	~~REG~~	~~10-Dec-08~~	~~0.5~~	~~-~~	~~1.5~~	~~Explosives, Metals, PCB, SVOC~~
~~WWTP3-SB01~~	~~WW0034~~	~~REG~~	~~10-Dec-08~~	~~0.7~~	~~-~~	~~1.7~~	~~Explosives, Gen Chem, Metals, PCB, SVOC~~
WWTP3-SB06	WW0052	REG	11-Dec-08	3	-	3.7	Explosives, Metals, PCB, SVOC
WWTP3-SB03	WW0042	REG	10-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB03	WW0043	FD	10-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB05	WW0049	REG	11-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB07	WW0055	REG	11-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0061	REG	11-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB09	WW0063	FD	11-Dec-08	3	-	5	Explosives, Metals, PCB, SVOC
WWTP3-SB02	WW0039	REG	10-Dec-08	5	-	5.5	Explosives, Metals, PCB, SVOC
WWTP3-SB01	WW0035	REG	10-Dec-08	5	-	5.7	Explosives, Metals, PCB, SVOC
WWTP3-SB01	WW0036	REG	10-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB01	WW0037	FD	10-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB02	WW0040	REG	10-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB03	WW0044	REG	10-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB05	WW0050	REG	11-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB06	WW0053	REG	11-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB07	WW0056	REG	11-Dec-08	8	-	10	Explosives, Metals, SVOC
WWTP3-SB09	WW0062	REG	11-Dec-08	8	-	10	Explosives, Metals, SVOC

ft - feet

FD - Field duplicate; averaged with the regular sample at the same location to create one result.

Table F-7

Total Soil Samples Evaluated in Baseline Human Health Risk Assessment
Excluding Samples with Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

PCB - Polychlorinated biphenyls
REG - regular sample
SVOC - Semivolatile organic compounds
VOC - Volatile organic compounds

Table F-8

Summary of Chemicals in Total Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg		COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Inorganics															
Aluminum	30 / 30	100	3.11E+03		1.05E+04		1.70E+00	2.40E+01	7.62E+03	1.55E+04	7700		N (b)		---
Antimony	20 / 30	67	2.61E-01	J	4.36E-01	J	4.24E-01	7.20E+00	1.25E+00	9.30E+00	3.1		N (b)		---
Arsenic	30 / 30	100	3.90E+00		2.08E+01		8.49E-01	1.20E+00	7.32E+00	3.65E+01	0.39		N (b)		---
Barium	30 / 30	100	2.97E+01		1.97E+02		1.74E-01	2.40E+01	5.90E+01	8.26E+02	1500		N (b)		---
Beryllium	23 / 30	77	5.90E-01		8.44E+00		1.70E-01	6.00E-01	4.33E+00	1.00E+00	16		N (a)		---
Cadmium	14 / 30	47	2.24E-01	J	1.01E+00		4.24E-01	6.00E-01	2.94E-01	NA	7		N (a)		---
Calcium	30 / 30	100	3.29E+03		6.07E+04		4.24E+00	6.00E+02	2.53E+04	5.23E+04	Nutrient		N (c)		---
Chromium	30 / 30	100	6.90E+00		1.78E+01		4.24E-01	1.20E+00	1.21E+01	2.90E+01	0.29		N (b)		---
Cobalt	28 / 30	93	3.97E+00	J	2.21E+01		1.70E-01	6.00E+00	7.67E+00	1.16E+02	2.3		N (b)		---
Copper	30 / 30	100	7.10E+00		2.94E+01		4.24E-01	3.00E+00	1.89E+01	5.62E+01	310		N (b)		---
Iron	30 / 30	100	1.02E+04	J	2.90E+04		1.70E+00	1.20E+01	1.78E+04	2.34E+05	5500		N (b)		---
Lead	30 / 30	100	9.60E+00		1.34E+02	J	3.10E-01	5.12E-01	2.57E+01	4.86E+01	400		N (a)		---
Magnesium	30 / 30	100	2.01E+03		1.90E+04	J	1.74E+00	6.00E+02	8.17E+03	1.04E+04	Nutrient		N (c)		---
Manganese	30 / 30	100	1.70E+02		2.52E+03		1.74E-01	1.80E+00	4.49E+02	3.51E+03	180		N (b)		---
Mercury	28 / 30	93	1.63E-02	J	5.97E-01		2.06E-02	4.00E-02	6.64E-02	8.50E-02	2.3		N (a)		---
Nickel	30 / 30	100	8.40E+00		5.71E+01		2.55E-01	4.80E+00	1.99E+01	5.51E+01	150		N (a)		---
Potassium	29 / 30	97	3.21E+02		1.09E+03		2.12E+01	6.00E+02	6.65E+02	3.39E+03	Nutrient		N (c)		---
Selenium	15 / 30	50	4.65E-01	U/J	1.10E+00		5.20E-01	1.02E+00	5.75E-01	2.00E+00	39		N (b)		---
Sodium	21 / 30	70	2.50E+01		1.78E+02		8.49E+00	6.00E+02	1.46E+02	NA	Nutrient		N (c)		---
Thallium	16 / 30	53	2.21E-01	J	1.10E+00		4.24E-01	1.20E+00	4.15E-01	1.30E+00	0.51	g	N (b)		---
Vanadium	30 / 30	100	1.38E+01		2.85E+01		1.70E-01	6.00E+00	2.02E+01	4.09E+01	39		N (b)		---
Zinc	30 / 30	100	3.38E+01		1.05E+02		2.10E+00	2.56E+00	5.85E+01	3.22E+02	2300		N (b)		---
Polychlorinated biphenyls (PCB)															
Aroclor 1016	3 / 16	19	1.00E-01	J	1.22E+00	J	3.99E-02	2.05E-01	1.53E-01		0.39		Y	3.21E-01	3.21E-01
Aroclor 1254	2 / 16	13	2.50E-01		1.00E+00	J	3.99E-02	2.05E-01	1.36E-01		0.11		Y	4.09E-01	4.09E-01
Aroclor 1260	3 / 16	19	6.67E-02	J	2.29E-01		3.99E-02	4.60E-01	9.52E-02		0.22		Y	1.30E-01	1.30E-01
Nitroaromatics															
Amino-2,6-dinitrotoluene, 4-	1 / 30	3	2.60E-01		2.60E-01		2.50E-01	3.14E-01	1.44E-01		15		N (a)		---
Amino-4,6-dinitrotoluene, 2-	1 / 30	3	2.28E-01	/U	2.28E-01	/U	2.50E-01	3.14E-01	1.43E-01		15		N (a)		---
Trinitrotoluene, 2,4,6-	1 / 30	3	8.80E-01		8.80E-01		2.50E-01	3.14E-01	1.65E-01		3.6		N (a)		---
Semivolatile Organic Compounds															
Acenaphthene	3 / 23	13	5.92E-02	J	6.43E-01	J	3.60E-01	2.00E+00	2.62E-01		340		N (a)		---
Acenaphthylene	7 / 23	30	5.41E-02	J	3.23E+00		3.60E-01	2.00E+00	3.86E-01		340	h	N (a)		---
Anthracene	8 / 23	35	5.04E-02	J	4.53E+00		3.60E-01	2.00E+00	5.34E-01		1700		N (a)		---
Benzo(a)anthracene	8 / 20	40	3.98E-02	J	1.20E+00		3.60E-01	2.00E+00	1.13E+00		0.15		Y	3.92E-01	3.92E-01
Benzo(a)pyrene	7 / 20	35	9.09E-02	J	1.30E+00		3.60E-01	2.00E+00	1.00E+00		0.015		Y	4.13E-01	4.13E-01
Benzo(b)fluoranthene	7 / 20	35	1.40E-01	J	1.20E+00		3.60E-01	2.00E+00	1.25E+00		0.15		Y	4.66E-01	4.66E-01
Benzo(ghi)perylene	9 / 23	39	1.20E-01	J	5.57E+00		3.60E-01	2.00E+00	6.44E-01		170	i	N (a)		---
Benzo(k)fluoranthene	4 / 20	20	1.27E-01	J	1.10E+00		3.60E-01	2.00E+00	6.21E-01		1.5		N (a)	3.57E-01	3.57E-01
Bis(2-ethylhexyl)phthalate	1 / 23	4	1.21E-01	U/J	1.21E-01	U/J	3.60E-01	2.00E+00	2.68E-01		35		N (a)		---
Carbazole	3 / 21	14	4.43E-02	J	1.12E+00	J	3.92E-01	2.00E+00	2.89E-01		24	j	N (a)		---
Chrysene	10 / 23	43	9.25E-02	J	1.03E+01		3.60E-01	2.00E+00	1.03E+00		15		N (a)		---

Table F-8

Summary of Chemicals in Total Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemical	Detection Frequency	Percent Detection	Range of Values, mg/kg: Detected Concentrations Minimum	VQ	Maximum	VQ	Reporting Limits Minimum	Maximum	Mean mg/kg	BSC [a] mg/kg	RBSC [b] mg/kg	COPC? [c,d]	95% UCL [e] mg/kg	EPC [f] mg/kg
Dibenz(a,h)anthracene	0 / 20	0	0.00E+00	J	0.00E+00	J	3.60E-01	2.00E+00	3.23E-01		0.015	N (a)	0.00E+00	0.00E+00
Dibenzofuran	3 / 23	13	7.80E-02	J	1.35E+00	J	3.60E-01	2.00E+00	2.92E-01		7.8	N (a)		---
Fluoranthene	11 / 23	48	5.05E-02	J	2.48E+01		3.60E-01	2.00E+00	2.14E+00		230	N (a)		---
Fluorene	4 / 23	17	1.14E-01	J	1.78E+00	J	3.60E-01	2.00E+00	3.36E-01		230	N (a)		---
Indeno(1,2,3-cd)pyrene	7 / 20	35	2.84E-01	JU	8.10E+00		3.60E-01	2.00E+00	8.68E-01		0.15	Y	4.62E-01	4.62E-01
Methylnaphthalene, 2-	2 / 23	9	7.21E-01		1.57E+00	J	3.60E-01	2.00E+00	3.19E-01		31	N (a)		---
Naphthalene	2 / 25	8	6.77E-01		1.38E+00	J	5.50E-03	2.00E+00	2.84E-01		3.6	N (a)		---
Phenanthrene	10 / 23	43	6.77E-02	J	1.39E+01		3.60E-01	2.00E+00	1.25E+00		170 [i]	N (a)		---
Pyrene	11 / 23	48	4.06E-02	J	1.81E+01		3.60E-01	2.00E+00	1.68E+00		170	N (a)		---
Volatile Organic Compounds														
Methylene chloride	2 / 2	100	1.20E-02		1.30E-02		5.50E-03	6.00E-03	1.25E-02		11	N (a)		---

BSC - Background screening criterion;
COPC - Chemical of Potential Concern
J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
mg/kg - milligrams per kilogram
PAH - Polycyclic aromatic hydrocarbon
RBSC - Risk based screening concentration
VQ - Validation qualifier.

Note: Shaded rows indicate the PAH COPCs that were re-evaluated excluding the samples with the three highest PAH concentrations for this appendix.

[a] IT Corporation (IT), 1998, ***Site Investigation of Acid Areas***, Plum Brook Ordnance Works, Sandusky, Ohio, August.
[b] Risk-Based Screening Concentrations based on USEPA Regional Screening Level Table (April 2012) residential soil values (unless otherwise noted), and are based on a risk level of 1.0E-06 and a hazard index of 0.1.
[c] N = Chemical is not chosen as a COPC:
(a) = maximum detected concentration is less than the RBSC.
(b) = maximum detected concentration is less than the BSC.
(c) = essential nutrient.
[d] Y = Chemical is chosen as COPC.
[e] 95% UCL (Upper confidence limit) determined using ProUCL Version 4.1.01 U.S. Environmental Protection Agency (EPA), 2011, ProUCL Version 4.1.01, Office of Research and Development, Las Vegas, Nevada, and Technology Support Center, Atlanta, GA, May, on line at http://www.epa.gov/esd/tsc/TSC_form.htm.
[f] Concentration used in risk assessment equal to 95% UCL or maximum detected concentration, whichever is lower.
[g] RBSC based on thallium from IRIS, 2009.
[h] RBSC based on acenaphthene.
[i] RBSC based on pyrene.
[j] Because no RSL is available, the RBSC is based on the PRG (EPA, 2004). Note that the slope factor used for the PRG is the most current available.

Table F-9

Groundskeeper, Future Scenario, Exposure to Total Soil
Excluding Samples with the Three Highest PAH Concetrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	1.12E-07	3.14E-07	7.85E-09	4.49E-03	8.99E-09	1.04E-07	2.90E-07	7.26E-09	4.15E-03
Aroclor 1254	4.09E-01	1.43E-07	4.00E-07	2.86E-07	2.00E-02	1.15E-08	1.32E-07	3.70E-07	2.64E-07	1.85E-02
Aroclor 1260	1.30E-01	4.54E-08	1.27E-07	9.09E-08	NA	3.64E-09	4.20E-08	1.18E-07	8.40E-08	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	3.92E-01	1.37E-07	3.84E-07	1.00E-07	NA	1.02E-08	1.18E-07	3.29E-07	8.58E-08	NA
Benzo(a)pyrene	4.13E-01	1.44E-07	4.04E-07	1.05E-06	NA	1.07E-08	1.24E-07	3.47E-07	9.04E-07	NA
Benzo(b)fluoranthene	4.66E-01	1.63E-07	4.56E-07	1.19E-07	NA	1.21E-08	1.40E-07	3.91E-07	1.02E-07	NA
Benzo(k)fluoranthene	3.57E-01	1.25E-07	3.49E-07	9.11E-09	NA	9.28E-09	1.07E-07	3.00E-07	7.81E-09	NA
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
Indeno(1,2,3-cd)pyrene	4.62E-01	1.61E-07	4.52E-07	1.18E-07	NA	1.20E-08	1.39E-07	3.88E-07	1.01E-07	NA
Total ILCR or HI				**1.78E-06**	**2.45E-02**				**1.56E-06**	**2.26E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter

Table F-9

Groundskeeper, Future Scenario, Exposure to Total Soil
Excluding Samples with the Three Highest PAH Concetrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	Inhalation ILCR	Inhalation HQ	**All Pathways Total ILCR**	**All Pathways Total HI**
Polychlorinated biphenyls (PCB)							
Aroclor 1016	3.21E-08	2.24E-09	6.28E-09	1.57E-10	NA	**1.53E-08**	**8.63E-03**
Aroclor 1254	4.09E-08	2.86E-09	8.00E-09	5.72E-09	NA	**5.56E-07**	**3.85E-02**
Aroclor 1260	1.30E-08	9.09E-10	2.54E-09	1.82E-09	NA	**1.77E-07**	**NA**
Semivolatile Organic Compounds							
Benzo(a)anthracene	3.92E-08	2.74E-09	7.67E-09	8.49E-10	NA	**1.87E-07**	**NA**
Benzo(a)pyrene	4.13E-08	2.89E-09	8.08E-09	8.95E-09	NA	**1.97E-06**	**NA**
Benzo(b)fluoranthene	4.66E-08	3.26E-09	9.12E-09	1.01E-09	NA	**2.22E-07**	**NA**
Benzo(k)fluoranthene	3.57E-08	2.50E-09	6.99E-09	7.73E-11	NA	**1.70E-08**	**NA**
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	**NA**	**NA**
Indeno(1,2,3-cd)pyrene	4.62E-08	3.23E-09	9.04E-09	1.00E-09	NA	**2.20E-07**	**NA**
Total ILCR or HI				**1.96E-08**	**NA**	**3.36E-06**	**4.71E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter

Table F-10

Construction Worker, Future Scenario, Exposure to Total Soil
Excluding Samples with Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion				Dermal Contact				
Chemicals of Potential Concern	EPC mg/kg	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ	Dose Absorbed mg/cm^2-day	Cancer Dose mg/kg-day	Noncancer Dose mg/kg-day	ILCR	HQ
Polychlorinated biphenyls (PCB)										
Aroclor 1016	3.21E-01	7.40E-09	1.03E-06	5.18E-10	1.48E-02	1.35E-08	3.11E-09	4.34E-07	2.18E-10	6.20E-03
Aroclor 1254	4.09E-01	9.43E-09	1.32E-06	1.89E-08	6.59E-02	1.72E-08	3.96E-09	5.53E-07	7.92E-09	2.77E-02
Aroclor 1260	1.30E-01	3.00E-09	4.19E-07	6.00E-09	NA	5.46E-09	1.26E-09	1.76E-07	2.52E-09	NA
Semivolatile Organic Compounds										
Benzo(a)anthracene	3.92E-01	9.04E-09	1.26E-06	6.60E-09	NA	1.53E-08	3.53E-09	4.92E-07	2.57E-09	NA
Benzo(a)pyrene	4.13E-01	9.53E-09	1.33E-06	6.95E-08	NA	1.61E-08	3.71E-09	5.19E-07	2.71E-08	NA
Benzo(b)fluoranthene	4.66E-01	1.07E-08	1.50E-06	7.85E-09	NA	1.82E-08	4.19E-09	5.85E-07	3.06E-09	NA
Benzo(k)fluoranthene	3.57E-01	8.23E-09	1.15E-06	6.01E-10	NA	1.39E-08	3.21E-09	4.48E-07	2.34E-10	NA
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
Indeno(1,2,3-cd)pyrene	4.62E-01	1.07E-08	1.49E-06	7.78E-09	NA	1.80E-08	4.16E-09	5.80E-07	3.03E-09	NA
Total ILCR or HI				**1.18E-07**	**8.06E-02**				**4.67E-08**	**3.39E-02**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter

Table F-10

Construction Worker, Future Scenario, Exposure to Total Soil
Excluding Samples with Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Cancer Dose mg/kg-day	Inhalation Noncancer Dose mg/kg-day	ILCR
Polychlorinated biphenyls (PCB)				
Aroclor 1016	1.12E-07	1.57E-10	2.19E-08	1.10E-11
Aroclor 1254	1.43E-07	2.00E-10	2.79E-08	4.00E-10
Aroclor 1260	4.55E-08	6.36E-11	8.88E-09	1.27E-10
Semivolatile Organic Compounds				
Benzo(a)anthracene	1.37E-07	1.92E-10	2.68E-08	5.95E-11
Benzo(a)pyrene	1.45E-07	2.02E-10	2.82E-08	6.26E-10
Benzo(b)fluoranthene	1.63E-07	2.28E-10	3.18E-08	7.07E-11
Benzo(k)fluoranthene	1.25E-07	1.75E-10	2.44E-08	5.41E-12
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno(1,2,3-cd)pyrene	1.62E-07	2.26E-10	3.16E-08	7.01E-11
Total ILCR or HI				**1.37E-09**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
HQ - Hazard Quotient; HI - Hazard Index
mg/kg - milligram per kilogram
mg/m^3 - milligram per cubic meter

Table F-11

Resident, Cancer, Future Scenario, Exposure to Total Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

		Incidental Ingestion			Dermal Contact				
	EPC	Adult Dose	Child Dose	Resident	Adult Dose Absorbed	Adult Dose	Child Dose Absorbed	Child Dose	Resident
Chemicals of Potential Concern	mg/kg	mg/kg-day	mg/kg-day	ILCR	mg/cm^2-day	mg/kg-day	mg/cm^2-day	mg/kg-day	ILCR
Polychlorinated biphenyls (PCB)									
Aroclor 1016	3.21E-01	1.36E-07	3.17E-07	3.17E-08	3.15E-09	8.42E-08	8.99E-09	1.38E-07	1.55E-08
Aroclor 1254	4.09E-01	1.73E-07	4.03E-07	1.15E-06	4.01E-09	1.07E-07	1.15E-08	1.76E-07	5.66E-07
Aroclor 1260	1.30E-01	5.50E-08	1.28E-07	3.66E-07	1.27E-09	3.41E-08	3.64E-09	5.58E-08	1.80E-07
Semivolatile Organic Compounds									
Benzo(a)anthracene	3.92E-01	1.66E-07	3.87E-07	4.03E-07	3.57E-09	9.55E-08	1.02E-08	1.56E-07	1.84E-07
Benzo(a)pyrene	4.13E-01	1.75E-07	4.07E-07	4.25E-06	3.76E-09	1.01E-07	1.07E-08	1.65E-07	1.94E-06
Benzo(b)fluoranthene	4.66E-01	1.97E-07	4.60E-07	4.79E-07	4.24E-09	1.14E-07	1.21E-08	1.86E-07	2.19E-07
Benzo(k)fluoranthene	3.57E-01	1.51E-07	3.52E-07	3.67E-08	3.25E-09	8.70E-08	9.28E-09	1.42E-07	1.67E-08
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno(1,2,3-cd)pyrene	4.62E-01	1.95E-07	4.56E-07	4.75E-07	4.20E-09	1.13E-07	1.20E-08	1.84E-07	2.17E-07
Total ILCR				**7.19E-06**					**3.33E-06**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
mg/kg - milligram per kilogram
mg/cm^2 - milligram per square meter
mg/m^3 - milligram per cubic meter

Table F-11

Resident, Cancer, Future Scenario, Exposure to Total Soil
Excluding Samples with the Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works
Sandusky, Ohio

Chemicals of Potential Concern	Concentration in Air C_a mg/m^3	Inhalation Adult Dose mg/kg-day	Inhalation Child Dose mg/kg-day	Inhalation Resident ILCR	**All Pathways Total ILCR**
Polychlorinated biphenyls (PCB)					
Aroclor 1016	6.32E-10	5.94E-11	3.46E-11	6.58E-12	**4.72E-08**
Aroclor 1254	8.06E-10	7.57E-11	4.41E-11	2.40E-10	**1.72E-06**
Aroclor 1260	2.56E-10	2.41E-11	1.40E-11	7.62E-11	**5.46E-07**
Semivolatile Organic Compounds					
Benzo(a)anthracene	7.72E-10	7.25E-11	4.23E-11	3.56E-11	**5.87E-07**
Benzo(a)pyrene	8.13E-10	7.64E-11	4.46E-11	3.75E-10	**6.19E-06**
Benzo(b)fluoranthene	9.18E-10	8.62E-11	5.03E-11	4.23E-11	**6.98E-07**
Benzo(k)fluoranthene	7.03E-10	6.61E-11	3.85E-11	3.24E-12	**5.35E-08**
Dibenz(a,h)anthracene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**NA**
Indeno(1,2,3-cd)pyrene	9.10E-10	8.55E-11	4.99E-11	4.20E-11	**6.92E-07**
Total ILCR				**8.21E-10**	**1.05E-05**

EPC - Exposure Point Concentration
ILCR - Incremental Lifetime Cancer Risk
mg/kg - milligram per kilogram
mg/cm^2 - milligram per square meter
mg/m^3 - milligram per cubic meter

ATTACHMENT F-1

ProUCL INPUT AND OUTPUT FOR SURFACE SOIL EXCLUDING SAMPLES WITH THE THREE HIGHEST PAH CONCENTRATIONS

Input for ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

(Page 1 of 2)

		Benzo(a)anthracene	D_Benzo(a)anthracene	Benzo(a)pyrene	D_Benzo(a)pyrene	Benzo(b)fluoranthene	D_Benzo(b)fluoranthene
PBOW99-SSW302	PBOW99SSW302	1.2	1	1.3	1	1.2	1
WWTP3-SB03	WW0041	0.425	0	0.425	0	0.425	0
WWTP3-SB05	WW0048	0.276	1	0.289	1	0.438	1
WWTP3-SB06	WW0051	0.607	1	0.538	1	0.756	1
WWTP3-SB07	WW0054	0.101	1	0.0909	1	0.14	1
WWTP3-SB09	WW0060	1.99	0	1.99	0	1.99	0

Input for ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Benzo(k)fluoranthene	D_Benzo(k)fluoranthene	Dibenz(a,h)anthracene	D_Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	D_Indeno(1,2,3-cd)pyrene
1.1	1	0.36	0	0.87	1
0.425	0	0.425	0	0.425	0
0.127	1	0.403	0	0.45	1
0.291	1	0.411	0	0.62	1
0.4	0	0.4	0	0.305	1
1.99	0	1.99	0	1.99	0

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Minus 3 highest Surface Soil	**General UCL Statistics for Data Sets with Non-Detects**
User Selected Options	
From File	ss run 1.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Benzo(a)anthracene

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.101	Minimum Detected	-2.293
Maximum Detected	1.2	Maximum Detected	0.182
Mean of Detected	0.546	Mean of Detected	-0.974
SD of Detected	0.484	SD of Detected	1.064
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.936	Shapiro Wilk Test Statistic	0.988
5% Shapiro Wilk Critical Value	0.748	5% Shapiro Wilk Critical Value	0.748
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.565	Mean	-0.908
SD	0.45	SD	0.964
95% DL/2 (t) UCL	0.936	95% H-Stat (DL/2) UCL	3.579
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.144
		SD in Log Scale	0.888
		Mean in Original Scale	0.443
		SD in Original Scale	0.41
		95% t UCL	0.78
		95% Percentile Bootstrap UCL	0.706
		95% BCA Bootstrap UCL	0.805
		95% H-UCL	2.085

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	0.542
Theta Star	1.008
nu star	4.332
A-D Test Statistic	0.199
5% A-D Critical Value	0.662
K-S Test Statistic	0.662
5% K-S Critical Value	0.399
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	0.101
Maximum	1.2
Mean	0.453
Median	0.33
SD	0.409
k star	0.93
Theta star	0.487
Nu star	11.16
AppChi2	4.68
95% Gamma Approximate UCL	1.079
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only	
Data appear Normal at 5% Significance Level	
Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.475
SD	0.403
SE of Mean	0.21
95% KM (t) UCL	0.897
95% KM (z) UCL	0.819
95% KM (jackknife) UCL	0.899
95% KM (bootstrap t) UCL	1.127
95% KM (BCA) UCL	0.904
95% KM (Percentile Bootstrap) UCL	0.862
95% KM (Chebyshev) UCL	1.388
97.5% KM (Chebyshev) UCL	1.783
99% KM (Chebyshev) UCL	2.56
Potential UCLs to Use	
95% KM (t) UCL	0.897
95% KM (Percentile Bootstrap) UCL	0.862

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(a)pyrene

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0909	Minimum Detected	-2.398
Maximum Detected	1.3	Maximum Detected	0.262
Mean of Detected	0.554	Mean of Detected	-0.999
SD of Detected	0.53	SD of Detected	1.118
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.905
5% Shapiro Wilk Critical Value	0.748

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

DL/2 Substitution Method	
Mean	0.571
SD	0.48
95% DL/2 (t) UCL	0.966
Maximum Likelihood Estimate(MLE) Method	N/A

MLE method failed to converge properly

Lognormal Distribution Test with Detected Values Only

Shapiro Wilk Test Statistic	0.996
5% Shapiro Wilk Critical Value	0.748

Data appear Lognormal at 5% Significance Level

Assuming Lognormal Distribution

DL/2 Substitution Method	
Mean	-0.925
SD	1.001
95% H-Stat (DL/2) UCL	4.154
Log ROS Method	
Mean in Log Scale	-1.176
SD in Log Scale	0.932
Mean in Original Scale	0.446
SD in Original Scale	0.446
95% t UCL	0.813
95% Percentile Bootstrap UCL	0.741
95% BCA Bootstrap UCL	0.844
95% H-UCL	2.395

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.508
Theta Star	1.092
nu star	4.061
A-D Test Statistic	0.197
5% A-D Critical Value	0.664
K-S Test Statistic	0.664
5% K-S Critical Value	0.4

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data	
Minimum	0.0909
Maximum	1.3
Mean	0.454
Median	0.331
SD	0.446
k star	0.843
Theta star	0.538
Nu star	10.12
AppChi2	4.015
95% Gamma Approximate UCL	1.143
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method	
Mean	0.482
SD	0.438
SE of Mean	0.228
95% KM (t) UCL	0.94
95% KM (z) UCL	0.856
95% KM (jackknife) UCL	0.943
95% KM (bootstrap t) UCL	1.224
95% KM (BCA) UCL	0.919
95% KM (Percentile Bootstrap) UCL	0.897
95% KM (Chebyshev) UCL	1.474
97.5% KM (Chebyshev) UCL	1.904
99% KM (Chebyshev) UCL	2.747

Potential UCLs to Use

95% KM (t) UCL	0.94
95% KM (Percentile Bootstrap) UCL	0.897

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Benzo(b)fluoranthene

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.14	Minimum Detected	-1.966
Maximum Detected	1.2	Maximum Detected	0.182
Mean of Detected	0.634	Mean of Detected	-0.722
SD of Detected	0.454	SD of Detected	0.926
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.989	Shapiro Wilk Test Statistic	0.956
5% Shapiro Wilk Critical Value	0.748	5% Shapiro Wilk Critical Value	0.748
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.624	Mean	-0.74
SD	0.43	SD	0.868
95% DL/2 (t) UCL	0.977	95% H-Stat (DL/2) UCL	2.897
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-0.967
		SD in Log Scale	0.868
		Mean in Original Scale	0.509
		SD in Original Scale	0.408
		95% t UCL	0.845
		95% Percentile Bootstrap UCL	0.767
		95% BCA Bootstrap UCL	0.813
		95% H-UCL	2.313

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.675
Theta Star	0.939
nu star	5.398
A-D Test Statistic	0.214
5% A-D Critical Value	0.661
K-S Test Statistic	0.661
5% K-S Critical Value	0.398

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.0669
Maximum	1.2
Mean	0.51
Median	0.45
SD	0.419
k star	0.826
Theta star	0.618
Nu star	9.916
AppChi2	3.889
95% Gamma Approximate UCL	1.301
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.535
SD	0.403
SE of Mean	0.208
95% KM (t) UCL	0.954
95% KM (z) UCL	0.877
95% KM (jackknife) UCL	0.96
95% KM (bootstrap t) UCL	1.007
95% KM (BCA) UCL	1.022
95% KM (Percentile Bootstrap) UCL	0.934
95% KM (Chebyshev) UCL	1.442
97.5% KM (Chebyshev) UCL	1.835
99% KM (Chebyshev) UCL	2.606

Potential UCLs to Use

95% KM (t) UCL	0.954
95% KM (Percentile Bootstrap) UCL	0.934

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(k)fluoranthene

General Statistics

Number of Valid Data	6	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	3
		Percent Non-Detects	50.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.127	Minimum Detected	-2.064
Maximum Detected	1.1	Maximum Detected	0.0953
Mean of Detected	0.506	Mean of Detected	-1.068
SD of Detected	0.521	SD of Detected	1.089
Minimum Non-Detect	0.4	Minimum Non-Detect	-0.916
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.872
5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level	
Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	0.488
SD	0.438
95% DL/2 (t) UCL	0.848
Maximum Likelihood Estimate(MLE) Method	N/A
MLE method failed to converge properly	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.982
5% Shapiro Wilk Critical Value	0.767
Data appear Lognormal at 5% Significance Level	
Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	-1.061
SD	0.897
95% H-Stat (DL/2) UCL	2.342
Log ROS Method	
Mean in Log Scale	-1.303
SD in Log Scale	0.743
Mean in Original Scale	0.361
SD in Original Scale	0.366
95% t UCL	0.663
95% Percentile Bootstrap UCL	0.647
95% BCA Bootstrap UCL	0.68
95% H-UCL	1.072

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A
Data not Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Data Distribution Test with Detected Values Only
Data appear Normal at 5% Significance Level

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.387
SD	0.364
SE of Mean	0.203
95% KM (t) UCL	0.797
95% KM (z) UCL	0.722
95% KM (jackknife) UCL	0.787
95% KM (bootstrap t) UCL	1.474
95% KM (BCA) UCL	1.1
95% KM (Percentile Bootstrap) UCL	1.1
95% KM (Chebyshev) UCL	1.273
97.5% KM (Chebyshev) UCL	1.657
99% KM (Chebyshev) UCL	2.41
Potential UCLs to Use	
95% KM (t) UCL	0.797
95% KM (Percentile Bootstrap) UCL	1.1

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Dibenz(a,h)anthracene

General Statistics

Number of Valid Data	6	Number of Detected Data	0
Number of Distinct Detected Data	0	Number of Non-Detect Data	6
		Percent Non-Detects	100.00%

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Dibenz(a,h)anthracene was not processed!

Indeno(1,2,3-cd)pyrene

General Statistics

Number of Valid Data	6	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	2
		Percent Non-Detects	33.33%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.305	Minimum Detected	-1.187
Maximum Detected	0.87	Maximum Detected	-0.139
Mean of Detected	0.561	Mean of Detected	-0.651
SD of Detected	0.243	SD of Detected	0.448
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.982	Shapiro Wilk Test Statistic	0.996
5% Shapiro Wilk Critical Value	0.748	5% Shapiro Wilk Critical Value	0.748
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.575	Mean	-0.693
SD	0.312	SD	0.602
95% DL/2 (t) UCL	0.832	95% H-Stat (DL/2) UCL	1.309
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-0.768
		SD in Log Scale	0.418
		Mean in Original Scale	0.5
		SD in Original Scale	0.218
		95% t UCL	0.679
		95% Percentile Bootstrap UCL	0.64
		95% BCA Bootstrap UCL	0.651
		95% H-UCL	0.802

Output from ProUCL
Surface Soil Excluding Three Highest PAH Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	1.914
Theta Star	0.293
nu star	15.32
A-D Test Statistic	0.195
5% A-D Critical Value	0.658
K-S Test Statistic	0.658
5% K-S Critical Value	0.396

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.252
Maximum	0.87
Mean	0.502
Median	0.484
SD	0.225
k star	3.128
Theta star	0.161
Nu star	37.54
AppChi2	24.51
95% Gamma Approximate UCL	0.769
95% Adjusted Gamma UCL	N/A

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only

Data appear Normal at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.51
SD	0.214
SE of Mean	0.111
95% KM (t) UCL	0.733
95% KM (z) UCL	0.692
95% KM (jackknife) UCL	0.734
95% KM (bootstrap t) UCL	0.763
95% KM (BCA) UCL	0.745
95% KM (Percentile Bootstrap) UCL	0.703
95% KM (Chebyshev) UCL	0.992
97.5% KM (Chebyshev) UCL	1.201
99% KM (Chebyshev) UCL	1.61

Potential UCLs to Use

95% KM (t) UCL	0.733
95% KM (Percentile Bootstrap) UCL	0.703

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

ATTACHMENT F-2

ProUCL INPUT AND OUTPUT FOR TOTAL SOIL EXCLUDING SAMPLES WITH THE THREE HIGHEST PAH CONCENTRATIONS

Input for ProUCL
Total Soil Excluding Three Highest PAH Concentrations
Plum Brook Ordnance Works, Sandusky, Ohio

(Page 1 of 2)

		Benzo(a)anthracene	D_Benzo(a)anthracene	Benzo(a)pyrene	D_Benzo(a)pyrene	Benzo(b)fluoranthene	D_Benzo(b)fluoranthene
PBOW99-SSW302	PBOW99SSW302	1.2	1	1.3	1	1.2	1
WWTP3-SB01	WW0035	0.417	0	0.417	0	0.417	0
WWTP3-SB01	WW0037WW0036	0.402	0	0.402	0	0.402	0
WWTP3-SB02	WW0039	0.309	1	0.306	1	0.409	1
WWTP3-SB02	WW0040	0.402	0	0.402	0	0.402	0
WWTP3-SB03	WW0041	0.425	0	0.425	0	0.425	0
WWTP3-SB03	WW0043WW0042	0.2265	1	0.196	1	0.253	1
WWTP3-SB03	WW0044	0.419	0	0.419	0	0.419	0
WWTP3-SB05	WW0048	0.276	1	0.289	1	0.438	1
WWTP3-SB05	WW0049	0.0398	1	0.41	0	0.41	0
WWTP3-SB05	WW0050	0.413	0	0.413	0	0.413	0
WWTP3-SB06	WW0051	0.607	1	0.538	1	0.756	1
WWTP3-SB06	WW0052	0.238	1	0.209	1	0.3	1
WWTP3-SB06	WW0053	0.416	0	0.416	0	0.416	0
WWTP3-SB07	WW0054	0.101	1	0.0909	1	0.14	1
WWTP3-SB07	WW0055	0.4	0	0.4	0	0.4	0
WWTP3-SB07	WW0056	0.415	0	0.415	0	0.415	0
WWTP3-SB09	WW0060	1.99	0	1.99	0	1.99	0
WWTP3-SB09	WW0062	0.42	0	0.42	0	0.42	0
WWTP3-SB09	WW0063WW0061	0.399	0	0.399	0	0.399	0

Input for ProUCL
Total Soil Excluding Three Highest PAH Concentrations
Plum Brook Ordnance Works, Sandusky, Ohio

Benzo(k)fluoranthene	D_Benzo(k)fluoranthene	Dibenz(a,h)anthracene	D_Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	D_Indeno(1,2,3-cd)pyrene
1.1	1	0.36	0	0.87	1
0.417	0	0.417	0	0.417	0
0.402	0	0.402	0	0.402	0
0.136	1	0.392	0	0.436	1
0.402	0	0.402	0	0.402	0
0.425	0	0.425	0	0.425	0
0.4	0	0.4	0	0.284	1
0.419	0	0.419	0	0.419	0
0.127	1	0.403	0	0.45	1
0.41	0	0.41	0	0.41	0
0.413	0	0.413	0	0.413	0
0.291	1	0.411	0	0.62	1
0.4	0	0.4	0	0.388	1
0.416	0	0.416	0	0.416	0
0.4	0	0.4	0	0.305	1
0.4	0	0.4	0	0.4	0
0.415	0	0.415	0	0.415	0
1.99	0	1.99	0	1.99	0
0.42	0	0.42	0	0.42	0
0.399	0	0.399	0	0.399	0

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

User Selected Options

From File	ts run 1.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Benzo(a)anthracene

General Statistics

Number of Valid Data	20	Number of Detected Data	8
Number of Distinct Detected Data	8	Number of Non-Detect Data	12
		Percent Non-Detects	60.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.0398	Minimum Detected	-3.224
Maximum Detected	1.2	Maximum Detected	0.182
Mean of Detected	0.375	Mean of Detected	-1.402
SD of Detected	0.374	SD of Detected	1.036
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 8 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.791	Shapiro Wilk Test Statistic	0.964
5% Shapiro Wilk Critical Value	0.818	5% Shapiro Wilk Critical Value	0.818
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.313	Mean	-1.431
SD	0.29	SD	0.718
95% DL/2 (t) UCL	0.425	95% H-Stat (DL/2) UCL	0.449
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.643
		SD in Log Scale	0.672
		Mean in Original Scale	0.25
		SD in Original Scale	0.251
		95% t UCL	0.347
		95% Percentile Bootstrap UCL	0.349
		95% BCA Bootstrap UCL	0.41
		95% H-UCL	0.341

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Gamma Distribution Test with Detected Values Only

k star (bias corrected)	0.916
Theta Star	0.409
nu star	14.65
A-D Test Statistic	0.29
5% A-D Critical Value	0.731
K-S Test Statistic	0.731
5% K-S Critical Value	0.3

Data appear Gamma Distributed at 5% Significance Level

Assuming Gamma Distribution

Gamma ROS Statistics using Extrapolated Data

Minimum	0.0398
Maximum	1.2
Mean	0.297
Median	0.24
SD	0.241
k star	2.151
Theta star	0.138
Nu star	86.05
AppChi2	65.66
95% Gamma Approximate UCL	0.389
95% Adjusted Gamma UCL	0.398

Data Distribution Test with Detected Values Only

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics

Kaplan-Meier (KM) Method

Mean	0.273
SD	0.254
SE of Mean	0.0691
95% KM (t) UCL	0.392
95% KM (z) UCL	0.386
95% KM (jackknife) UCL	0.392
95% KM (bootstrap t) UCL	0.449
95% KM (BCA) UCL	0.395
95% KM (Percentile Bootstrap) UCL	0.387
95% KM (Chebyshev) UCL	0.574
97.5% KM (Chebyshev) UCL	0.704
99% KM (Chebyshev) UCL	0.96

Potential UCLs to Use

95% KM (t) UCL	0.392

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(a)pyrene

General Statistics

Number of Valid Data	20	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	13
		Percent Non-Detects	65.00%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.0909	Minimum Detected	-2.398
Maximum Detected	1.3	Maximum Detected	0.262
Mean of Detected	0.418	Mean of Detected	-1.197
SD of Detected	0.413	SD of Detected	0.84
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.742	Shapiro Wilk Test Statistic	0.962
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.32	Mean	-1.368
SD	0.299	SD	0.6
95% DL/2 (t) UCL	0.435	95% H-Stat (DL/2) UCL	0.408
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.439
		SD in Log Scale	0.516
		Mean in Original Scale	0.283
		SD in Original Scale	0.254
		95% t UCL	0.381
		95% Percentile Bootstrap UCL	0.381
		95% BCA Bootstrap UCL	0.443
		95% H-UCL	0.345

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	1.058	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	0.396		
nu star	14.81		
A-D Test Statistic	0.413	**Nonparametric Statistics**	
5% A-D Critical Value	0.719	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.719	Mean	0.292
5% K-S Critical Value	0.316	SD	0.258
Data appear Gamma Distributed at 5% Significance Level		SE of Mean	0.0699
		95% KM (t) UCL	0.413
Assuming Gamma Distribution		95% KM (z) UCL	0.407
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	0.412
Minimum	0.0909	95% KM (bootstrap t) UCL	0.485
Maximum	1.3	95% KM (BCA) UCL	0.419
Mean	0.328	95% KM (Percentile Bootstrap) UCL	0.413
Median	0.275	95% KM (Chebyshev) UCL	0.596
SD	0.247	97.5% KM (Chebyshev) UCL	0.728
k star	2.958	99% KM (Chebyshev) UCL	0.987
Theta star	0.111		
Nu star	118.3	**Potential UCLs to Use**	
AppChi2	94.2	95% KM (t) UCL	0.413
95% Gamma Approximate UCL	0.412		
95% Adjusted Gamma UCL	0.419		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Benzo(b)fluoranthene

General Statistics

Number of Valid Data	20	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	13
		Percent Non-Detects	65.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.14	Minimum Detected	-1.966
Maximum Detected	1.2	Maximum Detected	0.182
Mean of Detected	0.499	Mean of Detected	-0.909
SD of Detected	0.365	SD of Detected	0.709
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.986
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.348	Mean	-1.267
SD	0.292	SD	0.594
95% DL/2 (t) UCL	0.461	95% H-Stat (DL/2) UCL	0.448
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.275
		SD in Log Scale	0.493
		Mean in Original Scale	0.325
		SD in Original Scale	0.244
		95% t UCL	0.419
		95% Percentile Bootstrap UCL	0.424
		95% BCA Bootstrap UCL	0.464
		95% H-UCL	0.396

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	1.515
Theta Star	0.33
nu star	21.21
A-D Test Statistic	0.236
5% A-D Critical Value	0.714
K-S Test Statistic	0.714
5% K-S Critical Value	0.314
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	0.107
Maximum	1.2
Mean	0.357
Median	0.292
SD	0.237
k star	3.269
Theta star	0.109
Nu star	130.8
AppChi2	105.4
95% Gamma Approximate UCL	0.444
95% Adjusted Gamma UCL	0.451

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only	
Data appear Normal at 5% Significance Level	
Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.339
SD	0.247
SE of Mean	0.0684
95% KM (t) UCL	0.458
95% KM (z) UCL	0.452
95% KM (jackknife) UCL	0.462
95% KM (bootstrap t) UCL	0.498
95% KM (BCA) UCL	0.482
95% KM (Percentile Bootstrap) UCL	0.466
95% KM (Chebyshev) UCL	0.637
97.5% KM (Chebyshev) UCL	0.766
99% KM (Chebyshev) UCL	1.02
Potential UCLs to Use	
95% KM (t) UCL	0.458
95% KM (Percentile Bootstrap) UCL	0.466

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(k)fluoranthene

General Statistics

Number of Valid Data	20	Number of Detected Data	4
Number of Distinct Detected Data	4	Number of Non-Detect Data	16
		Percent Non-Detects	80.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.127	Minimum Detected	-2.064
Maximum Detected	1.1	Maximum Detected	0.0953
Mean of Detected	0.414	Mean of Detected	-1.299
SD of Detected	0.464	SD of Detected	1.003
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 4 Distinct Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions
It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.748
5% Shapiro Wilk Critical Value	0.748
Data not Normal at 5% Significance Level	
Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	0.286
SD	0.263
95% DL/2 (t) UCL	0.388
Maximum Likelihood Estimate(MLE) Method	N/A
MLE method failed to converge properly	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.86
5% Shapiro Wilk Critical Value	0.748
Data appear Lognormal at 5% Significance Level	
Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	-1.45
SD	0.537
95% H-Stat (DL/2) UCL	0.349
Log ROS Method	
Mean in Log Scale	-1.641
SD in Log Scale	0.507
Mean in Original Scale	0.231
SD in Original Scale	0.213
95% t UCL	0.313
95% Percentile Bootstrap UCL	0.32
95% BCA Bootstrap UCL	0.373
95% H-UCL	0.279

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	0.502
Theta Star	0.823
nu star	4.02
A-D Test Statistic	0.501
5% A-D Critical Value	0.664
K-S Test Statistic	0.664
5% K-S Critical Value	0.4
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	0.000001
Maximum	1.1
Mean	0.242
Median	0.18
SD	0.235
k star	0.666
Theta star	0.364
Nu star	26.66
AppChi2	15.89
95% Gamma Approximate UCL	0.407
95% Adjusted Gamma UCL	N/A

Data Distribution Test with Detected Values Only	
Data appear Gamma Distributed at 5% Significance Level	
Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.233
SD	0.217
SE of Mean	0.0721
95% KM (t) UCL	0.357
95% KM (z) UCL	0.351
95% KM (jackknife) UCL	0.366
95% KM (bootstrap t) UCL	0.391
95% KM (BCA) UCL	0.386
95% KM (Percentile Bootstrap) UCL	0.381
95% KM (Chebyshev) UCL	0.547
97.5% KM (Chebyshev) UCL	0.683
99% KM (Chebyshev) UCL	0.95
Potential UCLs to Use	
95% KM (t) UCL	0.357

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Dibenz(a,h)anthracene

General Statistics

Number of Valid Data	20	Number of Detected Data	0
Number of Distinct Detected Data	0	Number of Non-Detect Data	20
		Percent Non-Detects	100.00%

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Dibenz(a,h)anthracene was not processed!

Indeno(1,2,3-cd)pyrene

General Statistics

Number of Valid Data	20	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	13
		Percent Non-Detects	65.00%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	0.284	Minimum Detected	-1.259
Maximum Detected	0.87	Maximum Detected	-0.139
Mean of Detected	0.479	Mean of Detected	-0.806
SD of Detected	0.205	SD of Detected	0.392
Minimum Non-Detect	0.399	Minimum Non-Detect	-0.919
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	20
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.874	Shapiro Wilk Test Statistic	0.944
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.341	Mean	-1.231
SD	0.233	SD	0.522
95% DL/2 (t) UCL	0.431	95% H-Stat (DL/2) UCL	0.427
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.023
		SD in Log Scale	0.279
		Mean in Original Scale	0.376
		SD in Original Scale	0.14
		95% t UCL	0.43
		95% Percentile Bootstrap UCL	0.43
		95% BCA Bootstrap UCL	0.454
		95% H-UCL	0.42

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	4.299
Theta Star	0.111
nu star	60.19
A-D Test Statistic	0.318
5% A-D Critical Value	0.709
K-S Test Statistic	0.709
5% K-S Critical Value	0.313
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	0.262
Maximum	0.87
Mean	0.399
Median	0.353
SD	0.133
k star	11.29
Theta star	0.0353
Nu star	451.6
AppChi2	403.3
95% Gamma Approximate UCL	0.447
95% Adjusted Gamma UCL	0.451

Data Distribution Test with Detected Values Only	
Data appear Normal at 5% Significance Level	
Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.382
SD	0.141
SE of Mean	0.0402
95% KM (t) UCL	0.452
95% KM (z) UCL	0.448
95% KM (jackknife) UCL	0.457
95% KM (bootstrap t) UCL	0.497
95% KM (BCA) UCL	0.462
95% KM (Percentile Bootstrap) UCL	0.462
95% KM (Chebyshev) UCL	0.558
97.5% KM (Chebyshev) UCL	0.633
99% KM (Chebyshev) UCL	0.783
Potential UCLs to Use	
95% KM (t) UCL	0.452
95% KM (Percentile Bootstrap) UCL	0.462

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.723
5% Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level	
Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	2.836
SD	4.407
95% DL/2 (t) UCL	5.568
Maximum Likelihood Estimate(MLE) Method	N/A
MLE yields a negative mean	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.986
5% Shapiro Wilk Critical Value	0.803
Data appear Lognormal at 5% Significance Level	
Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	0.103
SD	1.485
95% H-Stat (DL/2) UCL	33.72
Log ROS Method	
Mean in Log Scale	-0.055
SD in Log Scale	1.601
Mean in Original Scale	2.762
SD in Original Scale	4.448
95% t UCL	5.519
95% Percentile Bootstrap UCL	5.373
95% BCA Bootstrap UCL	6.769

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	0.484
Theta Star	7.173
nu star	6.779
A-D Test Statistic	0.258
5% A-D Critical Value	0.74
K-S Test Statistic	0.74
5% K-S Critical Value	0.324
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	1E-12
Maximum	13.9
Mean	2.869
Median	1.2
SD	4.401
k star	0.204
Theta star	14.09
Nu star	3.666
AppChi2	0.594
95% Gamma Approximate UCL	17.7
95% Adjusted Gamma UCL	27.09

Data Distribution Test with Detected Values Only
Data appear Gamma Distributed at 5% Significance Level

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	2.777
SD	4.188
SE of Mean	1.509
95% KM (t) UCL	5.582
95% KM (z) UCL	5.258
95% KM (jackknife) UCL	5.51
95% KM (bootstrap t) UCL	10.26
95% KM (BCA) UCL	5.413
95% KM (Percentile Bootstrap) UCL	5.524
95% KM (Chebyshev) UCL	9.353
97.5% KM (Chebyshev) UCL	12.2
99% KM (Chebyshev) UCL	17.79
Potential UCLs to Use	
95% KM (Chebyshev) UCL	9.353

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Benzo(k)fluoranthene

General Statistics

Number of Valid Data	9	Number of Detected Data	6
Number of Distinct Detected Data	6	Number of Non-Detect Data	3
		Percent Non-Detects	33.33%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.127	Minimum Detected	-2.064
Maximum Detected	4.49	Maximum Detected	1.502
Mean of Detected	1.681	Mean of Detected	-0.0875
SD of Detected	1.713	SD of Detected	1.357
Minimum Non-Detect	0.4	Minimum Non-Detect	-0.916
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	7
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	2
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	77.78%

Warning: There are only 6 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.867
5% Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level	

Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.944
5% Shapiro Wilk Critical Value	0.788
Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution	
DL/2 Substitution Method	
Mean	1.277
SD	1.501
95% DL/2 (t) UCL	2.208
Maximum Likelihood Estimate(MLE) Method	N/A
MLE method failed to converge properly	

Assuming Lognormal Distribution	
DL/2 Substitution Method	
Mean	-0.41
SD	1.262
95% H-Stat (DL/2) UCL	8.191
Log ROS Method	
Mean in Log Scale	-0.516
SD in Log Scale	1.261
Mean in Original Scale	1.209
SD in Original Scale	1.53
95% t UCL	2.157
95% Percentile Bootstrap UCL	2.118
95% BCA Bootstrap UCL	2.287

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	0.589
Theta Star	2.854
nu star	7.068
A-D Test Statistic	0.253
5% A-D Critical Value	0.716
K-S Test Statistic	0.716
5% K-S Critical Value	0.341
Data appear Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	0.127
Maximum	4.49
Mean	1.422
Median	1.08
SD	1.428
k star	0.874
Theta star	1.627
Nu star	15.74
AppChi2	7.778
95% Gamma Approximate UCL	2.878
95% Adjusted Gamma UCL	3.375

Note: DL/2 is not a recommended method.

Data Distribution Test with Detected Values Only
Data appear Normal at 5% Significance Level

Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	1.223
SD	1.442
SE of Mean	0.53
95% KM (t) UCL	2.208
95% KM (z) UCL	2.095
95% KM (jackknife) UCL	2.182
95% KM (bootstrap t) UCL	3.456
95% KM (BCA) UCL	2.223
95% KM (Percentile Bootstrap) UCL	2.171
95% KM (Chebyshev) UCL	3.532
97.5% KM (Chebyshev) UCL	4.532
99% KM (Chebyshev) UCL	6.494
Potential UCLs to Use	
95% KM (t) UCL	2.208
95% KM (Percentile Bootstrap) UCL	2.171

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

Dibenz(a,h)anthracene

General Statistics

Number of Valid Data	9	Number of Detected Data	3
Number of Distinct Detected Data	3	Number of Non-Detect Data	6
		Percent Non-Detects	66.67%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.397	Minimum Detected	-0.924
Maximum Detected	1.46	Maximum Detected	0.378
Mean of Detected	0.859	Mean of Detected	-0.291
SD of Detected	0.545	SD of Detected	0.652
Minimum Non-Detect	0.36	Minimum Non-Detect	-1.022
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	9
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	0
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	100.00%

Warning: There are only 3 Distinct Detected Values in this data set
The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.951	Shapiro Wilk Test Statistic	0.998
5% Shapiro Wilk Critical Value	0.767	5% Shapiro Wilk Critical Value	0.767
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.508	Mean	-0.993
SD	0.458	SD	0.809
95% DL/2 (t) UCL	0.792	95% H-Stat (DL/2) UCL	1.154
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	-1.103
		SD in Log Scale	0.728
		Mean in Original Scale	0.439
		SD in Original Scale	0.419
		95% t UCL	0.699
		95% Percentile Bootstrap UCL	0.674
		95% BCA Bootstrap UCL	0.776

Gamma Distribution Test with Detected Values Only	
k star (bias corrected)	N/A
Theta Star	N/A
nu star	N/A
A-D Test Statistic	N/A
5% A-D Critical Value	N/A
K-S Test Statistic	N/A
5% K-S Critical Value	N/A
Data not Gamma Distributed at 5% Significance Level	
Assuming Gamma Distribution	
Gamma ROS Statistics using Extrapolated Data	
Minimum	N/A
Maximum	N/A
Mean	N/A
Median	N/A
SD	N/A
k star	N/A
Theta star	N/A
Nu star	N/A
AppChi2	N/A
95% Gamma Approximate UCL	N/A
95% Adjusted Gamma UCL	N/A

Data Distribution Test with Detected Values Only	
Data appear Normal at 5% Significance Level	
Nonparametric Statistics	
Kaplan-Meier (KM) Method	
Mean	0.57
SD	0.353
SE of Mean	0.153
95% KM (t) UCL	0.854
95% KM (z) UCL	0.821
95% KM (jackknife) UCL	0.858
95% KM (bootstrap t) UCL	0.87
95% KM (BCA) UCL	1.46
95% KM (Percentile Bootstrap) UCL	N/A
95% KM (Chebyshev) UCL	1.236
97.5% KM (Chebyshev) UCL	1.524
99% KM (Chebyshev) UCL	2.089
Potential UCLs to Use	
95% KM (t) UCL	0.854
95% KM (Percentile Bootstrap) UCL	N/A

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Indeno(1,2,3-cd)pyrene

General Statistics

Number of Valid Data	9	Number of Detected Data	7
Number of Distinct Detected Data	7	Number of Non-Detect Data	2
		Percent Non-Detects	22.22%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.305	Minimum Detected	-1.187
Maximum Detected	8.1	Maximum Detected	2.092
Mean of Detected	2.198	Mean of Detected	0.188
SD of Detected	2.776	SD of Detected	1.165
Minimum Non-Detect	0.425	Minimum Non-Detect	-0.856
Maximum Non-Detect	1.99	Maximum Non-Detect	0.688

Note: Data have multiple DLs - Use of KM Method is recommended	Number treated as Non-Detect	6
For all methods (except KM, DL/2, and ROS Methods),	Number treated as Detected	3
Observations < Largest ND are treated as NDs	Single DL Non-Detect Percentage	66.67%

Warning: There are only 7 Detected Values in this data
Note: It should be noted that even though bootstrap may be performed on this data set
the resulting calculations may not be reliable enough to draw conclusions

It is recommended to have 10-15 or more distinct observations for accurate and meaningful results.

Output from ProUCL
Total Soil Excluding Three Highest Concentrations
Waste Water Treatment Plant 3
Plum Brook Ordnance Works, Sandusky, Ohio

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.731	Shapiro Wilk Test Statistic	0.951
5% Shapiro Wilk Critical Value	0.803	5% Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	1.844	Mean	-0.0266
SD	2.512	SD	1.161
95% DL/2 (t) UCL	3.401	95% H-Stat (DL/2) UCL	8.387
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	0.0112	Mean in Log Scale	-0.111
SD	4.178	SD in Log Scale	1.192
95% MLE (t) UCL	2.601	Mean in Original Scale	1.787
95% MLE (Tiku) UCL	4.217	SD in Original Scale	2.539
		95% t UCL	3.361
		95% Percentile Bootstrap UCL	3.275
		95% BCA Bootstrap UCL	3.841
Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	0.647	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	3.395		
nu star	9.064		
A-D Test Statistic	0.386	**Nonparametric Statistics**	
5% A-D Critical Value	0.729	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.729	Mean	1.8
5% K-S Critical Value	0.32	SD	2.387
Data appear Gamma Distributed at 5% Significance Level		SE of Mean	0.86
		95% KM (t) UCL	3.399
Assuming Gamma Distribution		95% KM (z) UCL	3.214
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	3.359
Minimum	1E-12	95% KM (bootstrap t) UCL	6.468
Maximum	8.1	95% KM (BCA) UCL	3.351
Mean	1.855	95% KM (Percentile Bootstrap) UCL	3.289
Median	0.87	95% KM (Chebyshev) UCL	5.548
SD	2.52	97.5% KM (Chebyshev) UCL	7.17
k star	0.213	99% KM (Chebyshev) UCL	10.36
Theta star	8.712		
Nu star	3.832	**Potential UCLs to Use**	
AppChi2	0.656	95% KM (Chebyshev) UCL	5.548
95% Gamma Approximate UCL	10.83		
95% Adjusted Gamma UCL	16.4		

Note: DL/2 is not a recommended method.

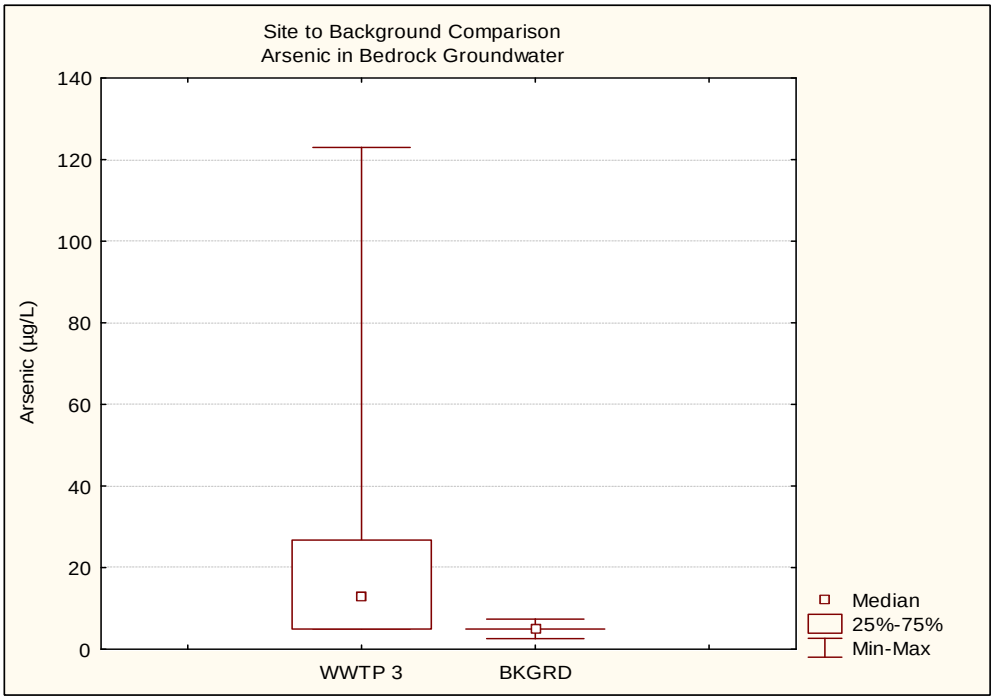
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

APPENDIX G

WILCOXON RANK SUM TEST STATISTICAL OUTPUT

Wilcoxon Rank-Sum Statistical Output

	Rank Sum	Rank Sum	U	Z	p-level	Z	p-level	Valid N	Valid N	2*1sided	
Arsenic	147.0000	448.0000	42.00000	1.897367	0.057780	2.443895	0.014530	6	28	0.059558	
Manganese	113.0000	482.0000	76.00000	0.361403	0.717798	0.361431	0.717778	6	28	0.741231	Passed



RESPONSE TO COMMENTS

Response to Ohio Environmental Protection Agency Comments
Draft Baseline Human Health Risk Assessment and
Draft Screening Level Ecological Risk Assessment
Waste Water Treatment Plant No. 3
Plum Brook Ordnance Works, Sandusky, Ohio,
Dated August 10, 2012
FUDS Project No. G05OH001817

Comments by Janusz Byczkowski, Ph.D., Ohio Environmental Protection Agency (OEPA) Toxicologist, received January 30, 2013.

Comment 1: **Baseline Human Health Risk Assessment (BHHRA), ES. P. ES-2 L#13, Section. 2.4.3.1, P. 2-7 L# 26 and Screening Level Ecological Risk Assessment Section (SLERA) . 2.2.3.3 P. 2-12 L# 21, Section 2.2.1 P.2-9, L# 14. <u>This document states:</u> In BHHRA: "…*This background screening protocol, which is based on PBOW Project Delivery Team agreement, differs somewhat from the current Ohio environmental Protection Agency guidance*…" In both, BHHRA and SLERA: "…*This PBOW team agreement, which has been used for all PBOW risk assessments to date, takes precedence over OEPA (2009) guidance*…" and also in SLERA: "…*Potential source of background information include data from previous and current investigations as well as monitoring wells in areas unaffected by site activities*…"**

The issue of determining background and the "agreement" was already discussed in previous reviews. Please note that no legally binding agreement has been made with ACE or Shaw Environmental Inc., regarding risk assessment at the NASA Plum Brook Site. Recommendation: Please provide justification for not applying in BHHRA and SLERA the recommended OEPA-DERR (2009) methodology.

Response 1: A statement consistent with the following will be added to the first paragraph of Section 2.4.3.1 of the BHHRA and to the second paragraph of Section 2.2.3.3 of the SLERA: "*Use of this method for the development of BSCs and as part of the COPC screening process ensures consistency between all of the PBOW FUDS project sites.*"

The sentence referenced by the reviewer on Page 2-9 (beginning, "Potential sources of background…") will be deleted.

Comment 2: **BHHRA S. 9.0 P. 8-1 L# 6; S.9.0, P. 8-4 L# 27; S.9.0 P. 8-4 L#30 Table 3-2 P. 4, L# 11. This document states: "… http://www.oehha.co.gov/risk/ChemicalDB/index.asp …" Also "… http://www.epa.gov/superfund/programs/lead/products.htm …" and "… http://www.epa.gov/region09/waste/sfund/prg/files/04usersguide.pdf …" Some Internet links do not work. Recommendation: Please check and correct/update URLs.**

Response 2: The URLs will be updated as requested. Correct URLs are as follows:
http://oehha.ca.gov/risk/chemicaldb/index.asp
http://www.epa.gov/superfund/lead/pbrisk.htm
http://www.epa.gov/region9/superfund/prg/files/04usersguide.pdf