PAH Background Study and Calculation of Background Threshold Values (DE-1348)

New Castle, Kent, and Sussex Counties, Delaware

Prepared for:

Delaware Department of Natural Resources and Environmental Control
Site Investigation and Restoration Section
391 Lukens Drive
New Castle, Delaware 19720

Prepared by:

EA Engineering, Science, and Technology, Inc., PBC
1311 Continental Drive, Suite K
Abingdon, Maryland 21009

January 2016
Version: FINAL Revision 1
EA Project No. 1482626

This page intentionally left blank

TABLE OF CONTENTS

Page

LIST OF TABLES iii
LIST OF FIGURES iii
ACRONYMS AND ABBREVIATIONS iv

1. INTRODUCTION 1

2. DEVELOPMENT AND IMPLEMENTATION OF PAH BACKGROUND THRESHOLD VALUES BY OTHER REGULATORY AGENCIES 3

2.1 PROCESS, CIRCUMSTANCES, AND CRITERIA FOR CONDUCTING SITE-SPECIFIC BACKGROUND STUDY, SAMPLE DESIGN, AND STATISTICS 3
2.2 SUMMARY OF STATE-SPECIFIC PAH BACKGROUND CONCENTRATIONS 4

2.2.1 California 4
2.2.2 Illinois 5
2.2.3 Massachusetts 5
2.2.4 Maine 5
2.2.5 Washington State 6

2.3 SUMMARY 6

3. EVALUATION OF AVAILABLE BACKGROUND DATA FOR PAHS IN DELAWARE 7

3.1 COMPARABILITY OF THE 2011 AND 2014 DATA SETS 7

3.1.1 Study Design Comparability 7
3.1.2 Data Comparability 8

3.2 SUMMARY OF BACKGROUND AREAS 8

4. CALCULATION OF BACKGROUND STATISTICS 11

4.1 SUMMARY STATISTICS AND OUTLIER EVALUATION 11
4.2 STATISTCIAL METHODS FOR POTENTIAL BACKGROUND THRESHOLD VALUES 15
4.3 STATISTICAL RESULTS 18

5. IMPLEMENTATION OF THE BACKGROUND STATISTICS 21

5.1 COMPARISONS TO BACKGROUND THRESHOLD VALUES 21

5.2 HYPOTHESIS TESTING 21

6. CONCLUSIONS..... 23

7. REFERENCES 25

APPENDIX A: LOGNORMAL Q-Q PLOTS OF DETECTED PAHS FOR THE 2012 AND 2014 SOIL BACKGROUND STUDIES

APPENDIX B LOGNORMAL Q-Q PLOTS OF DETECTED PAHS OF THE COMBINED 2012 AND 2014 SOIL BACKGROUND STUDIES

APPENDIX C: BACKGROUND SITES AND SAMPLE LOCATIONS: 2014 STUDY

APPENDIX D: PAH BACKGROUND STUDY RAW AND REDUCED DATASETS (PROVIDED AS AN EXCEL FILE)

APPENDIX E: PROUCL OUTPUTS

APPENDIX F: PAH BACKGROUND STUDY DATASET APPROPRIATE FOR DISTRIBUTION (PROVIDED AS AN EXCEL FILE)

LIST OF TABLES

Number	Title
1	Background Areas and Study Site Numbers
2	General Statistics of PAH Concentrations in Soil Samples
3	Computed Background Threshold Values for Detected PAH Concentrations in Soil
4	Proposed Background Threshold Values for PAHs in Soil

LIST OF FIGURES

Number	Title
1	Geologic Provinces and Reference Area Locations
2	Box Plot Analysis of Detected High Molecular Weight PAHs
3	Box Plot Analysis of Detected Low Molecular Weight PAHs
4	Decision Tree for Determining 95% Upper Simultaneous Limit (USL) from PAH Monitoring Data Containing Both Detected and Nondetected Results.

ACRONYMS AND ABBREVIATIONS

BTV	Background threshold value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CV	Coefficient of variation
DNREC	Delaware Department of Natural Resources and Environmental Control
EA	EA Engineering, Science, and Technology, Inc., PBC
EPA	United States Environmental Protection Agency
H_o	Null hypothesis
H_a	Alternative hypothesis
HSCA	Hazardous Substance Cleanup Act
KM	Kaplan-Meier
mg/kg	Milligrams per kilograms
MDL	Method detection limit
MVT	Multivariate trimming
PAH	Polycyclic aromatic hydrocarbon
Q-Q Plot	Quantile-quantile plot
RL	Reporting limit
SIRS	Site Investigation and Restoration Section
SWFPR	Site-wide false positive error rate
TACO	Tiered Approach to Corrective Action Objectives
TCL	Target compound list
UCL	Upper confidence level
UPL	Upper prediction limit
USL	Upper simultaneous limit
UTL	Upper tolerance level
UTL95-95	95% upper tolerance level with 95% confidence
VSP	Visual Sample Plan

1. INTRODUCTION

EA Engineering, Science, and Technology Inc., PBC (EA) has been tasked by the Delaware Department of Natural Resources and Environmental Control (DNREC) Site Investigation and Restoration Section (SIRS) to conduct an evaluation of background polycyclic aromatic hydrocarbon (PAH) concentrations found throughout Delaware (DE-1348) and to calculate background statistics. This work is a continuation of the effort completed by EA in 2014 (EA 2014). In addition to the evaluation of background PAH concentrations and calculation of background statistics, this document includes a summary of how other regulatory agencies identify and use PAH background statistics.

DNREC-SIRS administers site cleanup programs for the State of Delaware under the Hazardous Substance Cleanup Act (HSCA). Some chemicals regulated by the program are present in soil as a natural condition or as the result of human activities. PAHs are widely present in soils due to industrial activities resulting in releases, as defined by HSCA. However, PAHs are also believed to be present in soil where no specific release has occurred due to natural causes (e.g., fire) or due to ubiquitous, anthropogenic impacts. Ubiquitous, anthropogenic impacts result in an ambient condition and are the result of deposition of PAH particles originating from sources such as asphalt. These impacts can be considered background. DNREC-SIRS has developed the following definition of background as it relates to efforts at sites regulated under HSCA (DNREC 2015).

> *The concentration of substances widely present in the soil, sediment, air, surface water or groundwater in the vicinity of a facility, or at a comparable reference area, due to natural causes or human activities other than releases from, or activities on, the facility, as determined by the Department.*

In the context of DNREC-SIRS' efforts under HSCA, the identification of background levels of PAHs would be used to assist in the determination of whether or not no further investigation or cleanup actions for these constituents would be required at a HSCA site.

This page intentionally left blank

2. DEVELOPMENT AND IMPLEMENTATION OF PAH BACKGROUND THRESHOLD VALUES BY OTHER REGULATORY AGENCIES

All other state environmental departments have been examined to characterize the following with respect to the determination of background values or providing general state background values, specifically for PAHs:

- The process, circumstances, and criteria (quantitative and qualitative) for conducting a site-specific background study
- Sample designs used to generate data
- Calculation of Background Threshold Values (BTVs) for PAHs
- Calculation of site-specific background values.

2.1 PROCESS, CIRCUMSTANCES, AND CRITERIA FOR CONDUCTING SITE-SPECIFIC BACKGROUND STUDY, SAMPLE DESIGN, AND STATISTICS

Most state agencies acknowledge that background or reference concentrations can play a role in state decisions (typically for Brownfield Sites). However, most states did not provide specific guidance on how to conduct a site-specific background study or how to develop state- or area-specific background values. An exception is Missouri, which has a short document that describes how to conduct a background study (Appendix M to their Risk-Based Corrective Action Technical Guidance [MODNR 2015]). This document notes that background samples should be collected from an area with a soil type similar to that found at the site, but the document does not provide guidance with respect to numbers of samples or appropriate statistical analyses. Approval of the study by the state is required.

Similarly, in 1994 the Michigan Department of Natural Resources published a guidance document for how to conduct a background study (MIDNR 1994). The document offers some advice for establishing random grids for sampling purposes; however, because it is an older document, it only offers the now outdated “background plus three standard deviations” approach as the recommendation for BTVs. In 2005, Michigan published a background soil survey for metals, but has not addressed PAHs (MIDNR 2005).

In summary the guidance offered by states for conducting background studies is limited. Most states indicate that consideration of background data is acceptable for decision-making, but offer little guidance for how to generate such data, establish sampling designs, or calculate BTVs. In addition, because the statistical assessment of background data has advanced considerably since the 1990s, recommended statistical treatments vary widely, from three times the standard deviation, and the 90th or the 95th percentile upper confidence limit (UCL), to the more recently promoted upper prediction limit (UPL) and upper tolerance limit (UTL).

While state-specific guidance on the development of background studies is limited, the United States Environmental Protection Agency (EPA) has published a guidance document specifically discussing the characterization of background concentrations in soil and how to evaluate background datasets in comparison to site-specific data (EPA 2002). This document was prepared to support efforts at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, and the concepts and statistical tools described in the guidance can be applied to HSCA sites as well. The EPA (2002) guidance document discusses in detail the following aspects of a background study:

- Selection of background areas that take into account soil types, the physical and chemical nature of the contaminants of concern, and potential anthropogenic impacts (if any) at selected background sample locations

- Sample sizes necessary to derive background concentrations (a minimum of 5, 20 or greater preferred) and statistical tests that can be used to estimate the necessary number of background samples

- Data quality objectives appropriate to a background study including discussions about sample depths, proximity to potential anthropogenic sources, and appropriate if-then decision statements

- Preliminary data analysis tools such as tests for normality, graphical displays of data (like the quantile plots shown in Appendixes A and B of this document), and the identification of outliers (Section 4.1 of this document)

- Statistical tools for the comparison of background and site data including parametric and nonparametric (e.g. Wilcoxon Rank Sum) tests and hypothesis testing.

The background study presented herein for PAHs in Delaware, and the statistical tools employed for the calculation of candidate BTVs, are consistent with the EPA guidance.

2.2 SUMMARY OF STATE-SPECIFIC PAH BACKGROUND CONCENTRATIONS

Five states provided some kind of PAH background data, which are summarized below.

2.2.1 California

In 2009, the California Department of Toxic Substances Control published benzo(a)pyrene equivalents background values for northern and southern California (Cal DTSC 2009). California Toxicity Equivalency Factors were used in the assessment. The guidance is geared to the assessment of historic manufactured gas sites (which are notorious for their PAH contamination). Large numbers of samples were involved (86 for northern California and 185 for southern California), and 95% UCLs and UTLs were reported for benzo(a)pyrene equivalents to assist in the determination of nature and extent of contamination. UTLs for northern and southern California for benzo(a)pyrene equivalents were 1.5 and 0.9 milligrams per kilograms

(mg/kg) respectively. Raw data (in Excel format) from these data-sets are available for download for statistical comparisons to site data.

2.2.2 Illinois

Illinois has established Tiered Approach to Corrective Action Objectives (TACO) values for use in their voluntary cleanup program (ILEPA 2015). Many TACO screening values are based on risk; however, TACO screening values for PAHs (specifically benzo(a)pyrene) have been established based on background concentrations. Four separate benzo(a)pyrene values have been established:

- Within the Chicago corporate limits, 1.3 mg/kg
- A populated area within a Metropolitan Statistical Area excluding Chicago, 2.1 mg/kg
- A populated area not in a Metropolitan Statistical Area, 0.98 mg/kg
- Outside a populated area, 0.09 mg/kg.

These concentrations have been tied to the Illinois Administrative Code (35 IAC 742 Appendix A, Table H); which provides background values for PAHs in Chicago, metropolitan areas other than Chicago, and non-metropolitan areas. It is not clear how these background PAH concentrations have been derived, and raw data have not been provided; consequently, statistical hypothesis testing cannot be performed. TACO guidance in the Administrative Code (35 IAC 742) offers very generic guidance on how to establish background, relying on concurrence with the regulators.

2.2.3 Massachusetts

Massachusetts established background values for PAHs based on existing data sets (MADEP 2002). Background levels were established at the 90th percentile of all background values for "natural" soil and soils containing coal or wood ash as "fill material." From the documentation, it does not appear as though any outlier tests were performed on these data. The raw data have not been made available to the public; thus statistical hypothesis testing cannot be performed.

2.2.4 Maine

In 2012, Maine published background concentrations of PAHs in soils (MEDEP 2012). Data were generated from Brownfield sites and studies performed by the State. Two sets of results were produced, urban and rural, the former based on areas designated by the Maine Department of Transportation to be Urban Compact Areas or "built-up" sections of road where structures along the highway are nearer than 200 feet apart for a distance of 1/4 of a mile. One observation made was that the urban soil dataset had two separate distributions, one associated with urban fill and the other with urban soil. Urban fill was handled separately from urban soil. These data were examined for outliers (box and whisker plots followed by interquartile range testing), and then by tests for single/multiple populations. Once the outliers were removed, 90% UPLs were calculated for urban and rural PAHs using ProUCL. Finally, the raw data are available for statistical testing purposes.

2.2.5 Washington State

Washington State has published a background study of arsenic, PAHs, and dioxin/furans for rural state parks (WSDOE 2011). The study was based on 41 6-point composite samples from 31 rural parks and 1 undeveloped area. Sample areas were remote by design; none were within city or town boundaries, they were miles from major roads, and were in areas with population densities less than 500 people per square mile. The only study area description noted was whether the samples were from a forested or open area. Outlier testing was completed, with box and whisker plots followed by Principal Component Analysis and other robust outlier testing techniques. For PAHs, the carcinogenic toxic equivalents relative to benzo(a)pyrene were calculated for each sample. Statistics presented include percentiles and other data; however, UCLs, UPLs, or UTLs were not presented. Separate values were presented for forested and open areas. These data show very low PAH concentrations due to the sample design focusing on rural State parks.

2.3 SUMMARY

Most states accept background as an appropriate consideration for decision-making, although few offer specific guidance for how to design, conduct, and analyze these types of data. Five states were found to have published some type of PAH background values. Of all the states included in this list, the state of Maine has the most recent and robust assessment. EPA has published a detailed guidance document for the characterization of background concentrations in soil and the evaluation of background datasets in comparison to site-specific data. The background study discussed herein for Delaware, and the statistical tools employed for the calculation of candidate BTVs, are consistent with the EPA (2002) guidance.

3. EVALUATION OF AVAILABLE BACKGROUND DATA FOR PAHS IN DELAWARE

In 2012, DNREC-SIRS completed a statewide background soil study of PAHs and metals in an attempt to establish background levels to compare to levels at HSCA sites (DNREC 2012). This study focused on rural/suburban areas with no history of industrial use, development, or suspected contamination. The background study was later expanded to include the collection of samples in urban areas as well as rural/residential areas (EA 2014). A total of eight rural/suburban background areas were included in the 2012 effort and 12 areas (six urban and six rural/suburban) were included in the expanded (2014) effort. The same rural/suburban areas were sampled as part of both efforts; although, the specific sampling sites may have changed. Background areas were dispersed among two geologic provinces and the three counties of the State. The selection of the background areas for the 2012 effort is detailed in DNREC 2012 and the selection of background areas for the expanded effort is detailed in EA 2013a, 2013b, and 2014.

3.1 COMPARABILITY OF THE 2011 AND 2014 DATA SETS

The two available datasets were evaluated for comparability to determine whether or not they could be combined into a single dataset for statistical evaluation. The evaluation included a qualitative assessment of the study designs and methods and a quantitative assessment of the datasets.

3.1.1 Study Design Comparability

The 2012 study identified eight rural/suburban areas that did not have any prior commercial or industrial uses or recent agricultural uses (as confirmed through interviews with Wildlife Managers and Park Managers). Six of these background areas were selected by DNREC-SIRS for re-evaluation in the expanded (2014) background study. Six urban background areas were also identified for evaluation in the expanded study after completion of a brief site history search, which confirmed that none of them had been part of a current or past state or federal cleanup, and that there were no other reasons to believe the area might contain PAHs from a historic, on-site release (EA 2013a).

For both efforts, DNREC-SIRS identified two-acre plots within each background area to be sampled. The two-acre plots were referred to as “background study sites.” The two-acre plots identified for the 2014 study were randomly selected through the use of Visual Sample Plan (VSP) software (VSP Development Team 2013) with some restrictions to avoid large areas where sampling would not be possible (e.g., impervious areas and ponds) (EA 2013b). The method employed for the selection of the two-acre plots sampled as part of the 2012 effort is not detailed in DNREC (2012).

For the 2012 study, 20 sample locations were fixed at each two-acre background study site on a systematic rectangular grid with a random start. For the 2014 study, the 20 sample locations were identified with VSP using a triangular systematic grid with a random start. For both

studies, surface soil samples were collected from the top 6-inches of soil in accordance with the DNREC-SIRS Standard Operating Procedure for soil sampling. Samples were analyzed by DNREC-SIRS contracted laboratories for target compound list PAHs via method SW846 Method 8270.

The methods used to select background areas and sampling locations, and the sample collection and analytical methods employed for both the 2012 and the 2014 background studies were similar. Therefore, the two studies would be expected to yield comparable data.

3.1.2 Data Comparability

Lognormal quantile-quantile plots (Q-Q plots) of detected PAHs were prepared to evaluate the comparability of the 2012 dataset and the 2014 dataset. The Q-Q plots are presented in Appendix A for each PAH with at least one detected sample result; values for non-detects (i.e., "U" qualified) were set to the method detection limit (MDL). The Q-Q plots show that a portion of the 2012 dataset is confounded by non-detect results having an erroneously high MDL due to laboratory error. Therefore, non-detect results in the 2012 study that had a MDL exceeding the maximum MDL of the 2014 study were treated as rejected data and were not included in any further analysis. Lognormal Q-Q plots of the combined 2012/2014 datasets were then developed in order to investigate the distribution of detected results and to identify potential outliers. The Q-Q plots of the combined datasets are presented in Appendix B, and are further discussed in Section 4.

3.2 SUMMARY OF BACKGROUND AREAS

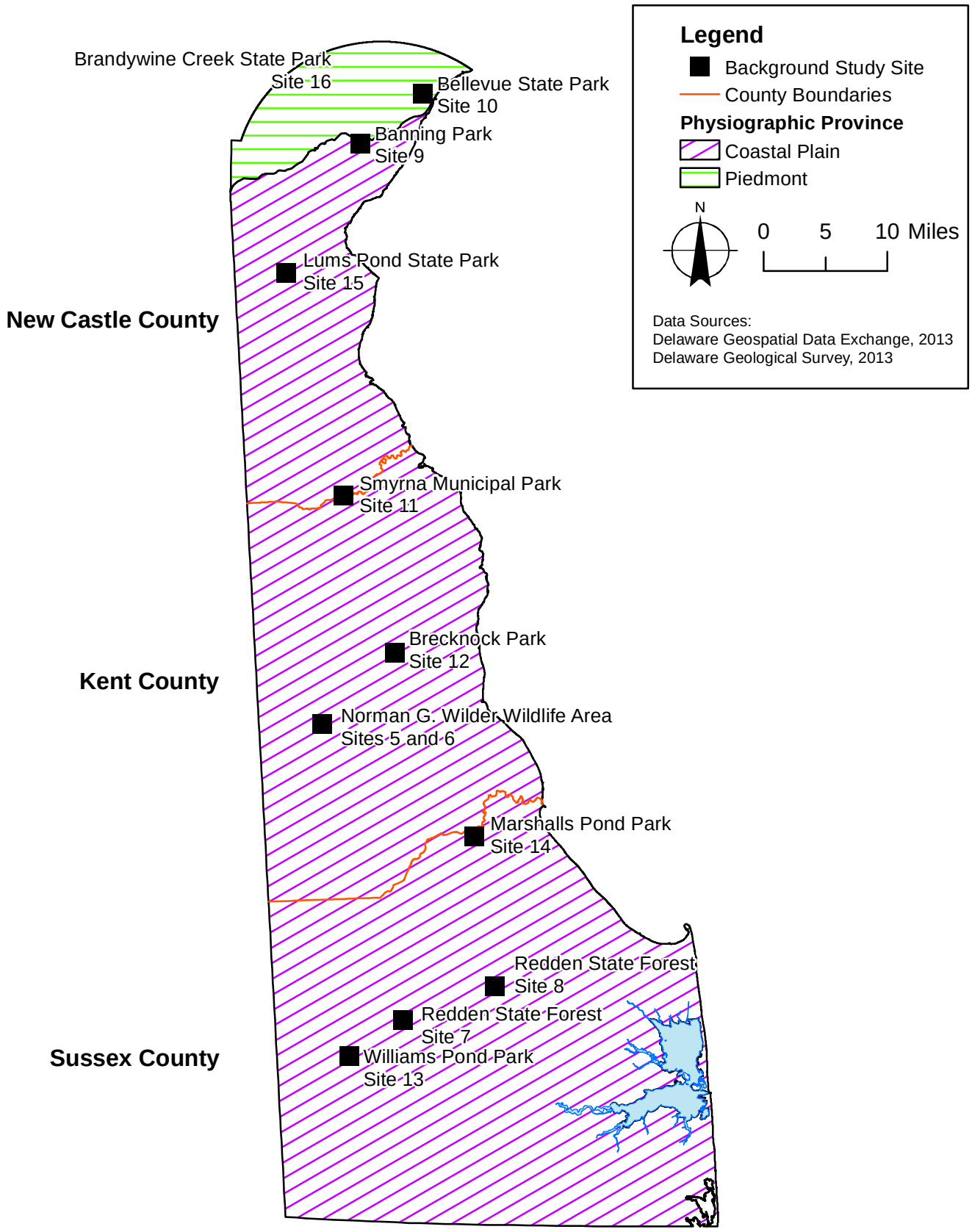
The selection of the background areas and background study sites for the 2014 study is summarized in Section 3.1.1. The specific background areas and background study sites sampled as part of the 2014 study, and therefore contributing to the dataset used to generate BTVs, are identified below. Twelve background areas were included in the 2014 effort. Four areas were located in each of Delaware's counties; two rural/suburban areas and two urban areas were selected for each county. The background areas are identified in Table 1 and their locations are presented in Figure 1. Appendix C includes sampling coordinates and sample location figures for each of the background study sites.

Table 1. Background Areas and Study Site Numbers

County	Study Site Number*	Background Area	Area Category
New Castle	16	Brandywine Creek State Park	Rural/Suburban
New Castle	15	Lums Pond State Park	Rural/Suburban
New Castle	9	Banning Park	Urban
New Castle	10	Bellevue State Park	Urban
Kent	5	Norman Wilder Wildlife Area	Rural/Suburban
Kent	6	Norman Wilder Wildlife Area	Rural/Suburban
Kent	11	Smyrna Municipal Park	Urban
Kent	12	Brecknock Park	Urban
Sussex	7	Redden State Forest	Rural/Suburban

County	Study Site Number*	Background Area	Area Category
Sussex	8	Redden State Forest	Rural/Suburban
Sussex	13	Williams Pond Park	Urban
Sussex	14	Marshall's Pond Park	Urban

*Study site numbers for the rural/suburban sites are the same as were used in the 2012 background study with the exception of Brandywine Creek State Park and Lums Pond State Park. The specific sampling grids at these two parks were changed for the expanded effort; therefore, they were assigned new study site numbers.



PAH Background Study
New Castle, Kent, and
Sussex Counties, Delaware

Figure 1
Geologic Provinces and
Reference Area Locations

EA Engineering, Science, and Technology, Inc., PBC

\\abingdon\projects\Universal GIS\DNREC\MXD\PAH Study\1_Site Locations.mxd

4. CALCULATION OF BACKGROUND STATISTICS

EPA guidance (EPA 1989, 2002, 2013) specifies that upper limits such as the UPL, UTL, or upper simultaneous limit (USL) be used for calculating the BTV. These upper limits represent a high estimate of background concentrations, such that PAH concentrations from natural or ubiquitous anthropogenic sources are unlikely to exceed them (i.e., a low rate of false positives is expected). BTVs would most likely be used for screening individual data points that are part of small sampling populations (e.g., a soil sample's data from a given source area). Hypothesis testing may be conducted as an alternative for larger datasets (e.g., soil sampling data from an entire site), as discussed in Chapter 5.

4.1 SUMMARY STATISTICS AND OUTLIER EVALUATION

In general, the frequency of detection of PAHs was low. PAHs were detected with greater frequency at four sites, Smyrna Municipal Park, Norman Wilder Wildlife Area Site 5, Williams Pond Park, and Marshall's Pond Park. In addition, high molecular weight PAHs tended to have higher frequencies of detection than low molecular weight PAHs (acenaphthene, acenaphthylene, anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, and phenanthrene).

Table 2 presents summary statistics for the surface soil dataset. The full, raw dataset is provided in Appendix D. The following general statistics were computed using ProUCL:

- Number of samples
- Number of detected samples
- Minimum and maximum non-detect result
- Minimum and maximum detected result
- Kaplan-Meier mean and standard deviation assuming a normal distribution.

Box-and-whisker plots (Figures 2 and 3) were prepared and present the 25th percentile, median, and 75th percentile of the full, raw dataset for each PAH with at least one detected sample result, and non-detects set to the MDL. The whiskers indicate the 5th and 95th percentiles, and detected sample results exceeding the 95th percentile are identified.

Table 2. General Statistics of PAH Concentrations in Soil Samples

PAH	Units	MDL	RL	No. of Samples	No. of Samples Detected Above MDL	Minimum Value of Dataset	Maximum Value of Dataset	Minimum Detected Value[1]	Maximum Detected Value	KM Mean[2]	KM Std. Dev. [2]
2-chloronaphthalene	µg/kg	41	370	240	0	< 38	< 54	NC	NC	NC	NC
2-methylnaphthalene	µg/kg	47	370	240	0	< 44	< 63	NC	NC	NC	NC
Acenaphthene	µg/kg	54	370	246	2	< 3	1,500	75	1,500	< 9.38	95.3
Acenaphthylene	µg/kg	43	370	246	3	< 1	510	79	510	< 4.4	36.3
Anthracene	µg/kg	45	370	253	7	< 1	2400	67	2400	< 16.1	158
Benzo[a]anthracene	µg/kg	2.6	37	262	55	< 2	720	5	720	27.1	88.4
Benzo[a]pyrene	µg/kg	2.6	37	258	83	< 2	210	4	210	19.3	39.5
Benzo[b]fluoranthene	µg/kg	2.3	37	238	79	< 2.2	240	6	240	24	48.5
Benzo[g,h,i]perylene	µg/kg	27	370	259	38	< 2	2100	37	2100	47.9	214
Benzo[k]fluoranthene	µg/kg	2.8	37	256	49	< 2.8	700	4	700	22.4	76.8
Chrysene	µg/kg	43	370	262	39	< 43	990	58	990	< 35.2	124
Dibenz[a,h]anthracene	µg/kg	4.6	37	253	30	< 2	2700	8	2700	24.3	181
Fluoranthene	µg/kg	49	370	267	36	< 2	1200	76	1200	< 41.7	149
Fluorene	µg/kg	47	370	245	2	< 5	490	74	490	< 7.26	31.2
Indeno[1,2,3-c,d]pyrene	µg/kg	6.8	37	258	54	< 2	2200	10	2200	48.4	209
Naphthalene	µg/kg	43	370	255	2	< 2	210	190	210	<43	17.5
Phenanthrene	µg/kg	47	370	257	18	< 47	430	63	430	< 12	48.1
Pyrene	µg/kg	31	370	269	56	< 31	1200	42	1200	47.2	156

1. Minimum detected value that is greater than the MDL presented in this table.
2. Computed using Kaplan-Meier (KM) estimator.
KM = Kaplan-Meier
MDL = Minimum detection limit
NC = Not calculated; analyte was not detected in any samples
< = Value is less than the MDL
PAH = Polycyclic aromatic hydrocarbon
RL = Reporting limit
Std. Dev. = Standard deviation
µg/kg = Micrograms per kilogram

Figure 2. Box plot analysis of detected high molecular weight PAHs.
Boxes show 25th percentile, median, and 75th percentile of the data. The whiskers indicate the 5th and 95th percentiles. Detected sample results exceeding the 95th percentile are shown as symbols (•).

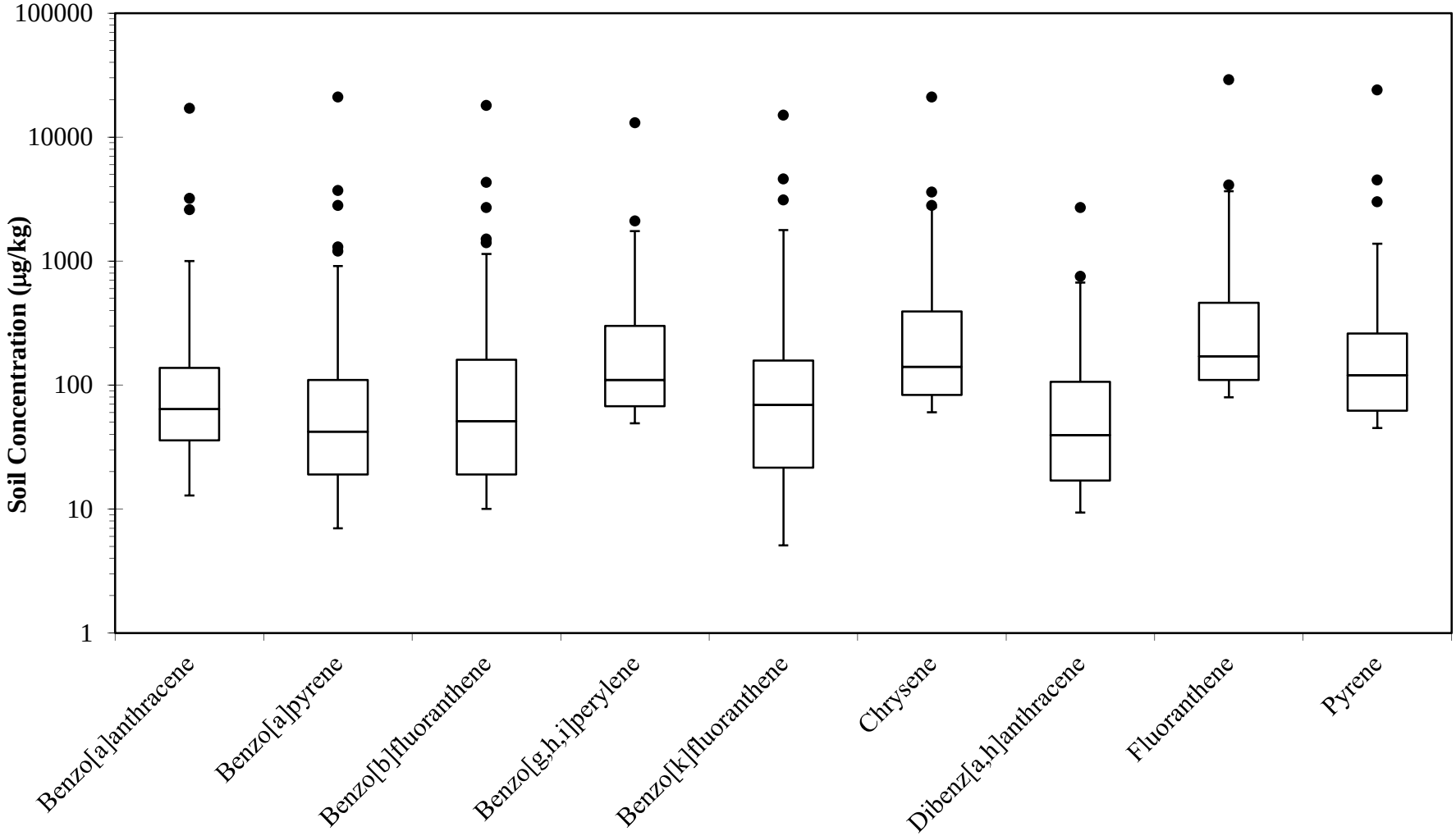
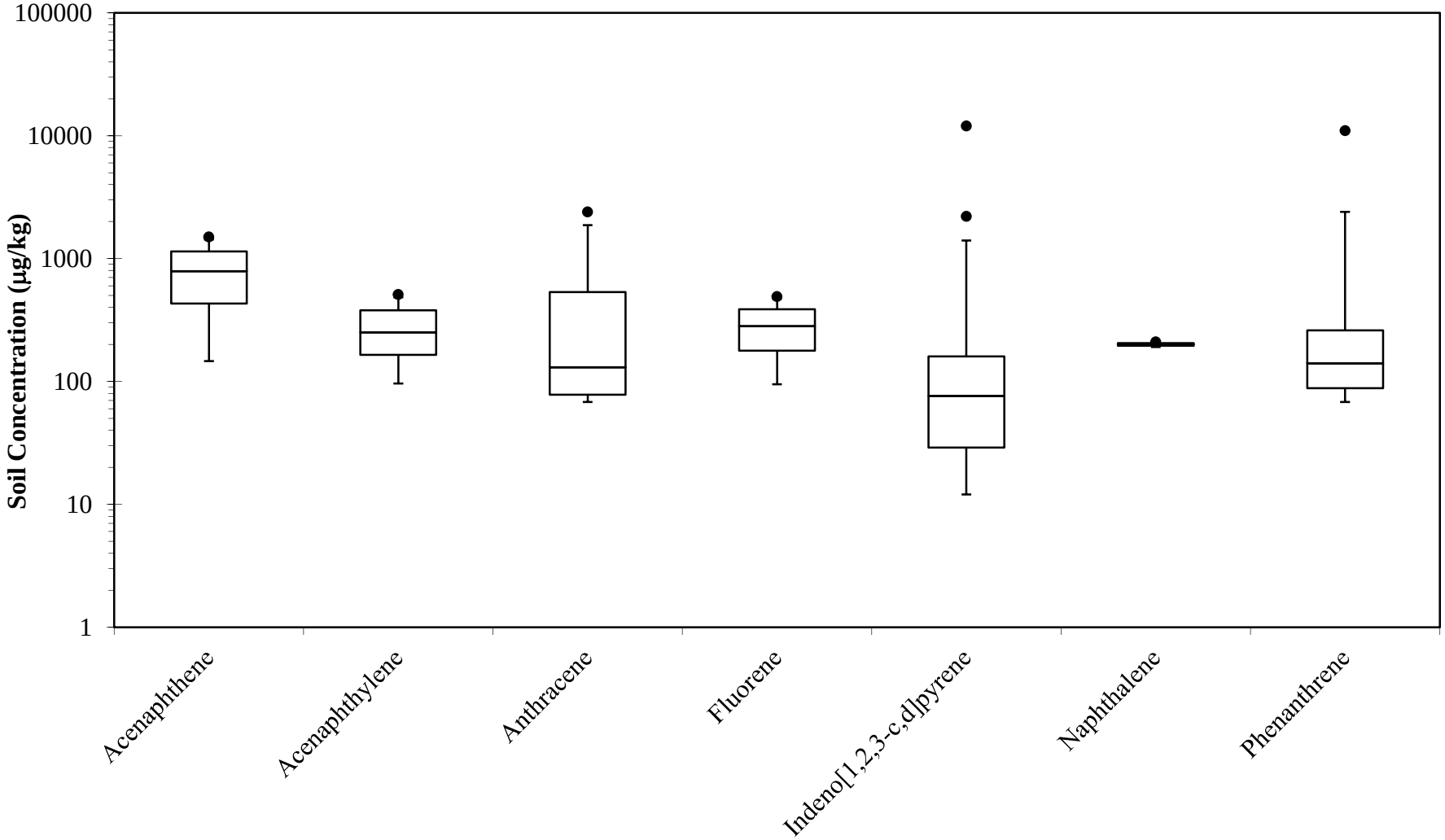


Figure 3. Box plot analysis of detected low molecular weight PAHs.
Boxes show 25th percentile, median, and 75th percentile of the data. The whiskers indicate the 5th and 95th percentiles. Detected sample results exceeding the 95th percentile are shown as symbols (•).



Q-Q plots were also prepared for each detected PAH. The Q-Q plots are presented in Appendix B. The box-and-whisker and Q-Q plots show that the distributions of PAH concentrations are positively skewed, indicting the presence of potential outliers or mixed-population data sets that are not representative of background. Therefore, an outlier evaluation was conducted to identify and remove potential outliers prior to computing USLs. Outliers were identified using multivariate trimming (MVT), which is a robust outlier test suitable for identifying multiple outliers in a dataset containing multiple outliers or sample data from more than one population (EPA 2009). The MVT outlier analysis was conducted using the Scout 2008 version 1.0 software package (EPA 2009). Sample data exceeding the final squared Mahalanobis distance at the 99% significance level were treated as statistical outliers, and removed from the background dataset prior to computing USLs. Q-Q plots of the final background dataset are presented in Appendix B. These Q-Q plots show the distribution of detected sample data plotted against the quantiles of a theoretical lognormal distribution. The Q-Q plots also show the values and theoretical quantiles of the outliers identified from the MVT outlier test. The final, reduced dataset that was used for computing USLs is provided in Appendix D.

4.2 STATISTCIAL METHODS FOR POTENTIAL BACKGROUND THRESHOLD VALUES

The following statistics were considered as potential BTV candidates: the 95% UPL, the 95% UTL with 95% coverage, and the 95% USL.

- A UPL represents the upper end of a range that is calculated to include one or more independent observation from the same population with a specified confidence. For example, a UPL with 95% confidence for background benzo(a)pyrene concentrations in soil represents the concentration that a benzo(a)pyrene concentration from an independent background sample will fall below that value with 95% confidence. UPLs are commonly used as BTVs, but it should be noted that false positive error rate α applies to each comparison made to the UPL in a given study. Therefore, the site-wide false positive error rate (SWFPR) for a given study increases with each comparison (k: $SWFPR = 1 - (1 - \alpha)^k$). Therefore, using the UPL as a BTV can yield an unacceptably high SWFPR for studies requiring many comparisons to the UPL.

- A UTL is a statistical upper limit designed to contain a specified proportion of the population with a specified confidence. For example, a 95% UTL with 95% (UTL95-95) confidence represents the concentration at which there is 95% confidence that 95% of all background benzo(a)pyrene concentrations will be below the value. The UTL95-95 exceeds the 95% UPL, but converges toward the 95% UPL as the number of samples in the background data set increases. By definition the UTL95-95 can classify 5% of background observations as not coming from the background population with a confidence of 95%. Therefore, when comparing data to the UTL, the number of false positive errors will increase with the number of comparisons made.

- A USL is statistical upper limit designed to contain all of the population with a specified confidence. The 95% USL represents a statistic such that all observations from the background dataset will be less than or equal to the 95% USL with a confidence of 95%. Therefore, assuming that the background data set is free of outliers, the computed 95% USL will always be greater than or equal to the maximum value in the background dataset. The false positive error rate does not change with the number of comparisons to the USL; therefore, the USL is suitable for performing many comparisons simultaneously. A potential disadvantage to using the USL as a BTV is that the USL can yield a high *false negative* error rate if outliers are present in the background data set.

If a future observation exceeds the UPL, UTL, or USL, then there is statistical evidence that the analyzed sample does not fit in the population of natural background concentrations, and likely represents a sample from an impacted area. Because it is expected that the computed BTVs will be compared to many individual sample concentrations from many future projects, the 95% USL was chosen as the upper limit to be used for the BTV.

Technical guidance (EPA 2013) recommends that a minimum of 8 to 10 sample concentrations be used to derive a BTV or conduct hypothesis tests with site data. The background dataset evaluated for this study consisted of approximately 250 samples after removal of statistical outliers as described in Section 4.1. The number of detected concentrations for individual PAHs ranged from 0 to 83 (Table 2). For PAHs with at least 5 detected sample results, the 95% USL was computed using the ProUCL software version 5.0 (EPA 2013). Because all of the PAH datasets contained non-detect results, estimates of the mean and standard deviation were also computed using the Kaplan-Meier method, which estimates the population mean and standard deviation using a distribution function adjusted for censoring. The distribution of detected results was characterized as normally distributed, gamma distributed, lognormally distributed, or nonparametric. As summarized in Figure 4, upper limits were then computed using the Kaplan-Meier method with an assumed data distribution consistent with the distribution of detected results. Details of the numerical procedure used to compute upper limits using the Kaplan-Meier method can be found in the ProUCL Technical Guide (EPA 2013). For detected PAHs with less than 5 detected sample results, the maximum detected value was selected as a nonparametric 95% USL.

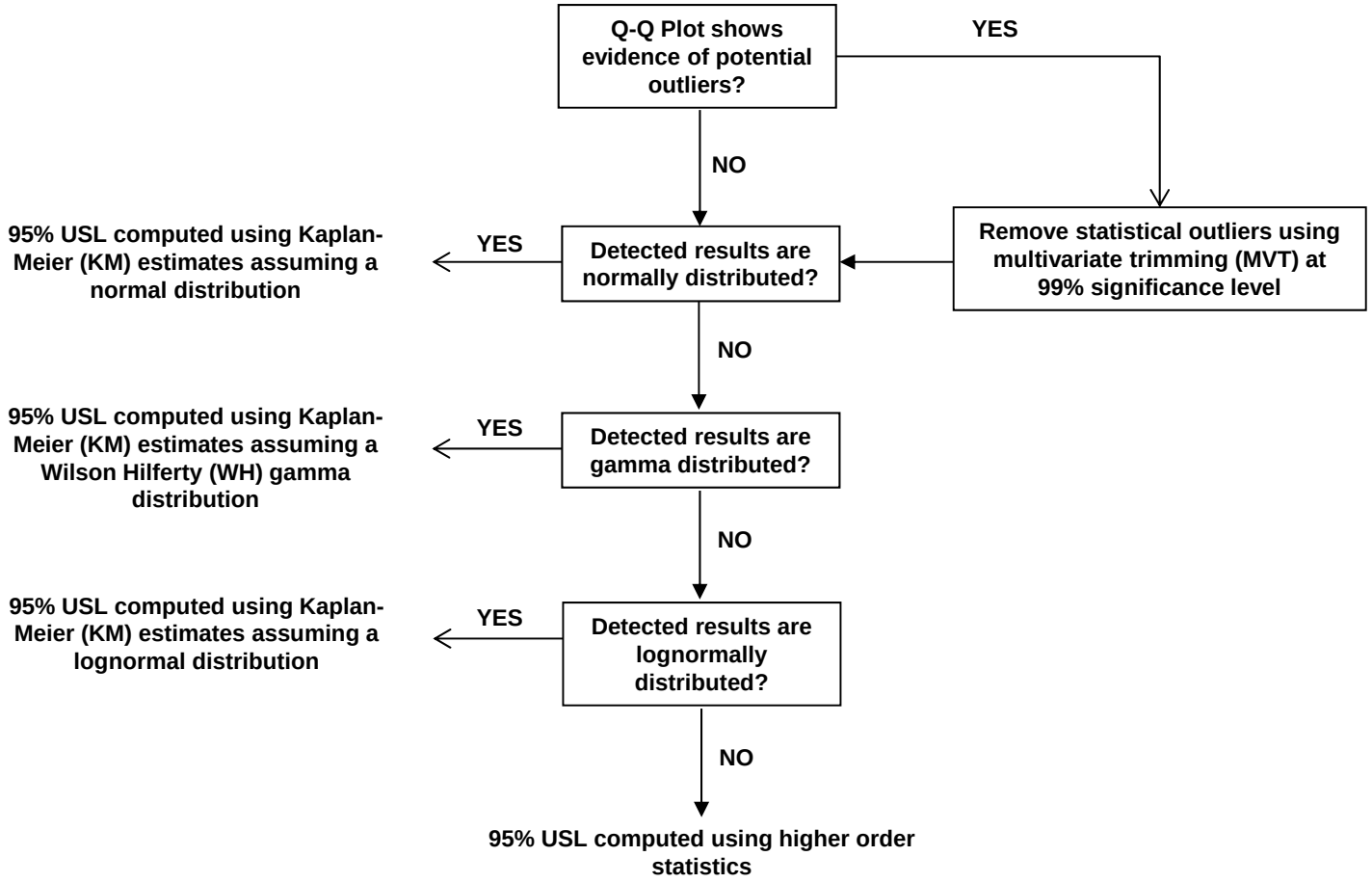


Figure 4. Decision tree for determining 95% upper simultaneous limit (USL) from PAH monitoring data containing both detected and nondetected results.

4.3 STATISTICAL RESULTS

The ProUCL outputs are presented in Appendix E. The outputs contain a variety of upper limit statistics, including USLs, computed under different distribution assumptions. Table 3 summarizes the ProUCL outputs for each PAH and includes an appropriate 95% USL for each PAH with at least 5 detected results. For statistical calculations, all detected results that were less than the MDL presented in Table 2 were treated as non-detects. Table 4 presents a summary of the computed BTVs, the target cancer risk and hazard quotient for each value, and the proposed BTV. For those detected PAHs without sufficient detected results to compute statistically based USLs, the maximum detected result was used as the BTV.

Most of the proposed BTVs are less than the EPA Region 3 human health residential soil screening level with the exception of the following:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Dibenz(a,h)anthracene
- Indeno(1,2,3-c,d)pyrene.

Table 3. Computed Background Threshold Values for Detected PAH Concentrations in Soil

PAH	Units	MDL	RL	No. of Samples	No. of Samples Detected Above MDL	Max Detected	USL Computed with ProUCL	
							ProUCL Method [1]	95% USL
Acenaphthene	µg/kg	54	370	246	2	1,500	NC	NC
Acenaphthylene	µg/kg	43	370	246	3	510	NC	NC
Anthracene	µg/kg	45	370	253	7	2,400	KM-Normal	570
Benzo[a]anthracene	µg/kg	2.6	37	262	55	720	KM-Lognormal	819
Benzo[a]pyrene	µg/kg	2.6	37	258	83	210	KM-Gamma(WH)	242
Benzo[b]fluoranthene	µg/kg	2.3	37	238	79	240	KM-Gamma(WH)	1,106
Benzo[g,h,i]perylene	µg/kg	27	370	259	38	2,100	Nonparametric	2,100
Benzo[k]fluoranthene	µg/kg	2.8	37	256	49	700	KM-Gamma(WH)	345
Chrysene	µg/kg	43	370	262	39	990	Nonparametric	990
Dibenz[a,h]anthracene	µg/kg	4.6	37	253	30	2,700	KM-Logormal	166
Fluoranthene	µg/kg	49	370	267	36	1,200	KM-Logormal	1,045
Fluorene	µg/kg	47	370	245	2	490	NC	NC
Indeno[1,2,3-c,d]pyrene	µg/kg	6.8	37	258	54	2,200	KM-Lognormal	1,304
Naphthalene	µg/kg	43	370	255	2	210	NC	NC
Phenanthrene	µg/kg	47	370	257	18	430	KM-Gamma(WH)	138
Pyrene	µg/kg	31	370	269	56	1,200	KM-Gamma(WH)	3,505

BTV = Background threshold value
CV = Coefficient of variation
KM = Kaplan-Meier
MDL = Minimum detection limit
NC = Not calculated; insufficient detected sample results
PAH = Polycyclic aromatic hydrocarbon
RL = Reporting limit
USL = Upper simultaneous limit
µg/kg = micrograms per kilogram

1. Statistical method for computing upper limits as recommended by ProUCL 5.0. Note that for statistical calculations, all detected results that were less than the MDL presented in Table 2 were treated as non-detects.

- KM-Normal = Kaplan-Meier estimates assuming normal distribution
- KM-Lognormal = Kaplan-Meier estimates assuming lognormal distribution
- KM-Gamma(WH) = Kaplan-Meier estimates assuming Wilson Hilferty (WH) gamma distribution
- KM-Normal = Kaplan-Meier estimates assuming normal distribution

Table 4. Proposed Background Threshold Values for PAHs in Soil

PAH	Units	MDL	RL	RSL[1]		Max Detected	95% USL		Proposed BTV[3]	
				SL	C/N		mg/kg	TR/HQ[2]	mg/kg	TR/HQ[2]
Acenaphthene	mg/kg	0.054	0.37	3600	N	1.50	NC	NC	**1.50**	**0.0004**
Acenaphthylene	mg/kg	0.043	0.37	3600	N	0.51	NC	NC	**0.51**	**0.00014**
Anthracene	mg/kg	0.045	0.37	18000	N	2.4	0.57	0.00003	**0.57**	**0.000032**
Benzo[a]anthracene	mg/kg	0.0026	0.037	0.16	C	0.72	0.82	5.1E-06	**0.82**	**5.1E-06**
Benzo[a]pyrene	mg/kg	0.0026	0.037	0.016	C	0.21	0.24	1.5E-05	**0.24**	**1.5E-05**
Benzo[b]fluoranthene	mg/kg	0.0023	0.037	0.16	C	0.24	1.11	6.9E-06	**1.11**	**6.9E-06**
Benzo[g,h,i]perylene	mg/kg	0.027	0.37	1800	N	2.1	2.1	0.001	**2.1**	**0.00117**
Benzo[k]fluoranthene	mg/kg	0.0028	0.037	1.6	C	0.7	0.35	2.2E-07	**0.35**	**2.2E-07**
Chrysene	mg/kg	0.043	0.37	16	C	0.99	0.99	6.2E-08	**0.99**	**6.2E-08**
Dibenz[a,h]anthracene	mg/kg	0.0046	0.037	0.016	C	2.7	0.17	1.1E-05	**0.17**	**1.1E-05**
Fluoranthene	mg/kg	0.049	0.37	2400	N	1.2	1.05	0.0004	**1.05**	**0.00044**
Fluorene	mg/kg	0.047	0.37	2400	N	0.49	NC	NC	**0.49**	**0.0002**
Indeno[1,2,3-c,d]pyrene	mg/kg	0.0068	0.037	0.16	C	2.2	1.3	8.1E-06	**1.3**	**8.1E-06**
Naphthalene	mg/kg	0.043	0.37	3.8	C	0.21	NC	NC	**0.21**	**5.5E-08**
Phenanthrene	mg/kg	0.047	0.37	1800	N	0.43	0.14	NC	**0.14**	**0.00008**
Pyrene	mg/kg	0.031	0.37	1800	N	1.2	3.51	0.002	**3.51**	**0.00195**

1. EPA Region 3 human health RSL for residential soil. For carcinogens, the SL is based on a TR of 10^{-6}. For noncarcinogens, the SL is based on a HQ of 1.0.
2. Cancer risk based on EPA Region III human health RSL for residential soil.
   - For carcinogens, the TR is computed as 10^{-6}*BTV/SL.
   - For noncarcinogens, the HQ is computed as BTV/SL.
3. For PAHs without USLs, the proposed BTV is the maximum detected value or RL.

BTV = Background threshold value
C = Carcinogen
HQ = Hazard quotient
MDL = Method detection limit
mg/kg = Miligrams per kilogram
N = Noncarcinogen
NC = Not calculated; insufficient detected sample results
PAH = Polycyclic aromatic hydrocarbon
RL = Reporting limit
RSL = Regional screening level
SL = Screening level
TR = Target cancer risk
USL = Upper simultaneous limit

5. IMPLEMENTATION OF THE BACKGROUND STATISTICS

5.1 COMPARISONS TO BACKGROUND THRESHOLD VALUES

As discussed in Chapter 4, BTVs are upper limits that represent a high estimate of background concentrations such that PAH concentrations from non site-related sources (i.e., natural sources or ubiquitous anthropogenic sources) are unlikely to exceed them (i.e., a low rate of false positives is expected). BTVs are most appropriately used for screening individual data points that are part of small sampling populations (e.g., a soil sample's data from a given source area). BTVs were calculated and discussed in Chapter 4.

5.2 HYPOTHESIS TESTING

While the USL is designed to be compared to any number of site samples, it is recommended that hypothesis testing be considered as an alternative for larger datasets (e.g., soil sampling data from an entire site). For datasets containing eight or more samples/detected results, tests for means comparison between the background and site data, such as the t-test or Wilcox Rank Sum test, are more appropriate than comparison to BTVs, which are designed for comparison with individual site samples. With hypothesis testing, data from potentially contaminated parts of a site are compared to the background data using statistical tests that compare the entire background dataset to another population of data (e.g., soil samples from a given source area). Hypothesis testing should be performed in accordance with guidance such as EPA 2002 and 2013.

For hypothesis testing, the null hypothesis (H_0) and alternative hypotheses (H_a) must be defined. There are two forms of the statistical hypothesis test that can be used for background comparisons.

Background Test Form 1:

$$\mathrm{H}_0 : \mu_{site} \leq \mu_{bkgd}$$
$$\mathrm{H}_\mathrm{a} : \mu_{site} > \mu_{bkgd}$$

where μ_{site} is the true mean of the site data, and μ_{bkgd} is the true mean of the background data.

This form of the test assumes that site concentrations are less than or equal to background. A t-test or Wilcox Rank Sum test is then used in an attempt to disprove the hypothesis. Background Test Form 1 is most appropriate for sites that are believed to be clean.

Background Test Form 2:

$$\mathrm{H}_0 : \mu_{site} > \mu_{bkgd} + S$$
$$\mathrm{H}_\mathrm{a} : \mu_{site} \leq \mu_{bkgd} + S$$

where μ_{site} is the true mean of the site data, μ_{bkgd} is the true mean of the background data, and S is the value of substantial difference representing the allowed increase of site data over the background. This form of the test assumes that site concentrations are contaminated by a substantial amount S. A t-test or Wilcox Rank Sum test is then used in an attempt to demonstrate that the site is not contaminated. Background Test Form 2 is most appropriate for sites that are believed to be contaminated. The acceptable level of S would be determined on a site-by-site basis and with input from DNREC.

In order to conduct hypothesis testing, the Type I (α) and Type II (β) error rates that can be tolerated must be specified. The substantial difference S must also be specified. Once the values for α, β, and S have been chosen, the number of samples that need to be collected can be determined. Below are the values for α, β, and S that EPA recommends (EPA 2002):

Background Test Form		Type I Error	Type II Error	Examples of Substantial Difference Values (S)
Form 1:	$H_0 : \mu_{site} \le \mu_{bkgd}$ $H_a : \mu_{site} > \mu_{bkgd}$	80–95% confidence (α = 0.2 to 0.05) [More conservative: α = 0.05]	Power ≥ 90% (β ≤ 0.10)	$S = 1 \times s_{bkgd}$ $S = 1 \times \overline{x}_{bkgd}$ $S = Q_{80_{bkgd}} - \overline{x}_{bkgd}$
Form 2:	$H_0 : \mu_{site} > \mu_{bkgd} + S$ $H_a : \mu_{site} \le \mu_{bkgd} + S$	80–95% confidence (α = 0.2 to 0.05) [More conservative: α = 0.05]	Power ≥ 80% (β ≤ 0.20)	

$\overline{x}_{bkgd}$ = mean of background sample data

s_{bkgd} = standard deviation of background sample data

$Q_{80_{bkgd}}$ = 80th percentile of background sample data

For future data users to complete hypothesis testing, it is recommended that the background dataset (with outliers excluded) be available in an electronic format (e.g., Excel). A version of the background dataset appropriate for distribution is included in Appendix F.

6. CONCLUSIONS

Background concentrations of a number of PAHs have been determined based on data from over 200 surface soil samples taken in 2012 and 2014 from parks located in Delaware. Appropriate graphical and statistical methods have been employed to these data to remove potential outliers (data not consistent with the rest of the data set) and the USL calculated. The USL was chosen as the most appropriate statistic for the BTV. Data contained in this document can be used for a sample-by-sample comparison to the BTVs shown in Table 4 to determine if a site's PAH concentration likely exceeds Delaware background concentrations of that PAH. It is important to note that these BTVs have a 5% probability that a site concentration will be found to be higher than background when in reality it is not. Consequently when large datasets are used, hypothesis testing of site data and the background chemical data are recommended for determining if site data statistically exceed these State background levels.

This page intentionally left blank.

7. REFERENCES

California Department of Toxic Substances Control (Cal DTSC). 2009. *Use of the Northern and Southern California Polynuclear Aromatic Hydrocarbon (PAH) Studies in the Manufactured Gas Plant Site Cleanup Process*. January.

Delaware Department of Natural Resources and Environmental Control (DNREC). 2015. *Delaware Regulations Governing Hazardous Substance Cleanup*. July.

———. 2012. *Statewide Soil Background Study: Report of Findings*. Final. July.

EA Engineering, Science, and Technology, Inc. (EA). 2013a. *Final Urban Background Reference Site Historic Research Letter Report.* Final. Prepared for DNREC-SIRS, New Castle Delaware. 23 October.

———. 2013b. *Final Sampling Analysis Plan for the PAH Background Study (DE-1348), New Castle, Kent, and Sussex Counties, Delaware*. October.

———. 2014. *Report of Findings, PAH Background Study (DE-1348) New Castle, Kent, and Sussex Counties, Delaware*. Final. Prepared for DNREC-SIRS, New Castle Delaware. November.

Illinois Environmental Protection Agency (ILEPA). 2015. *Tiered Approach to Corrective Action Objectives*. http://www.epa.illinois.gov/topics/cleanup-programs/taco/index. Accessed on 14 July 2015.

Maine Department of Environmental Protection (MEDEP). 2012. *Summary Report for Evaluation of Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) and Metals in Background Soils in Maine*. Prepared by AMEC Environment & Infrastructure, Inc. November.

Massachusetts Department of Environmental Protection (MADEP). 2002. *Technical Update Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil*. May.

Michigan Department of Natural Resources (MIDNR). 1994. *Guidance Document, Verification of Soil Remediation*. April.

———. 2005. *Michigan Background Soil Survey*.

Missouri Department of Natural Resources (MODNR). 2015. *Missouri Risk-Based Corrective Action*. http://dnr.mo.gov/env/hwp/mrbca/mrbca.htm. Accessed on 14 July 2015.

U.S. Environmental Protection Agency (EPA). 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities* EPA 530-SW-89-026.

———. 2002. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. EPA 540-R-01-003; OSWER 9285.7-41. Office of Emergency and Remedial Response. Washington, DC. September.

———. 2009. Scout 2008 – *A Robust Statistical Package, Office of Research and Development*. February.

———. 2013. *ProUCL Version 5.0.00, Technical Guide, Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*. Office of Research and Development, EPA/600/R-07/041. September.

VSP Development Team. 2013. *Visual Sample Plan: A Tool for Design and Analysis of Environmental Sampling*. Version 6.5. Pacific Northwest National Laboratory. Richland, WA. http://vsp.pnnl.gov.

Washington State Department of Ecology (WSDOE). 2011. *Draft Washington State Background Concentration Study Rural State Parks Washington State*. June.

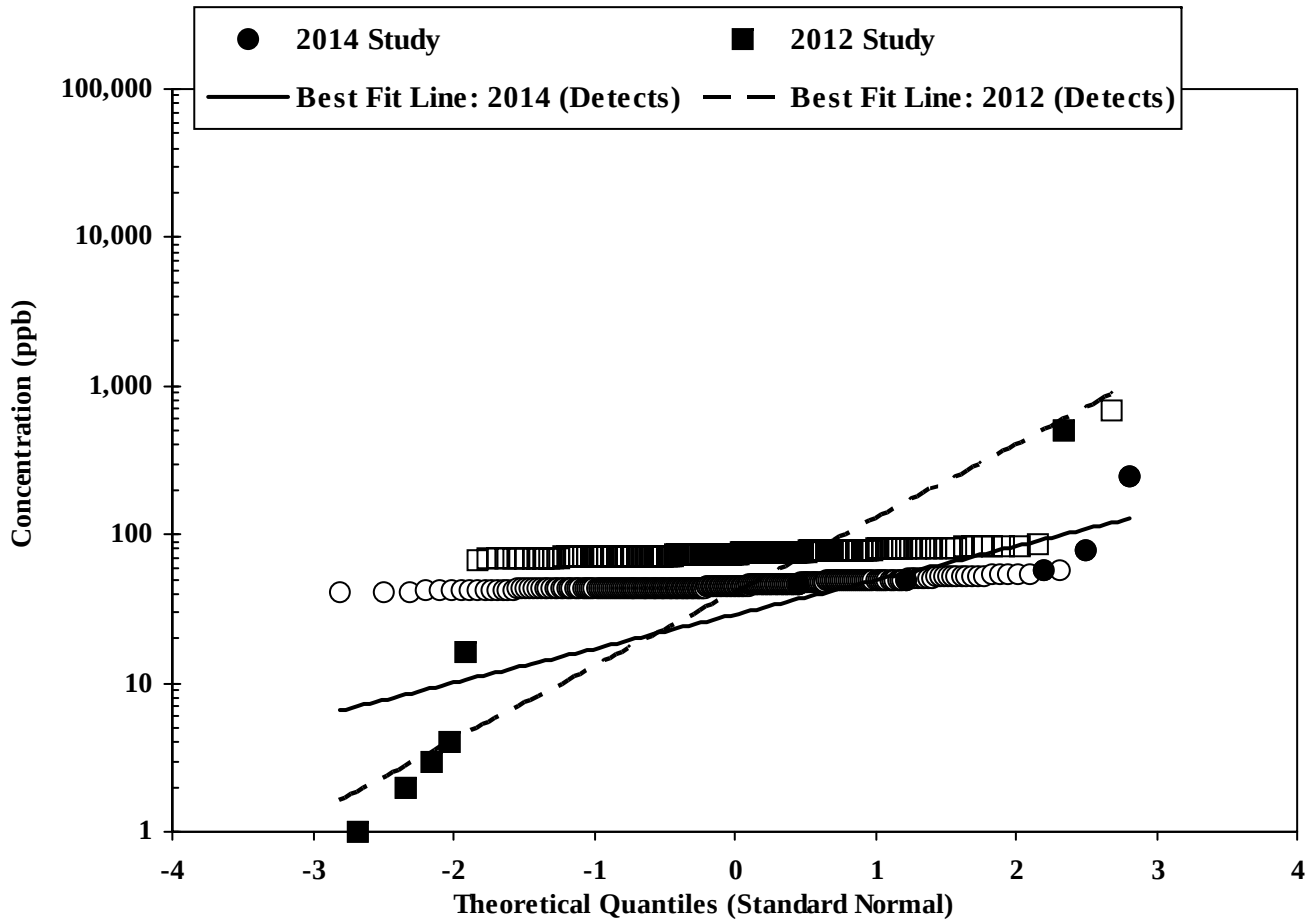
Appendix A

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

This page intentionally left blank.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Acenaphthylene**



2014 Study

No. of Samples =	256
No. of Detects =	5
Mean =	47.1
CV (%) =	28.3
KM Mean =	42.1
KM CV (%) =	31.6
Slope (Detects) =	0.5298
Intercept (Detects) =	28.98
R-Square (Detects)	0.5576

2012 Study

No. of Samples =	168
No. of Detects =	6
Mean =	79.4
CV (%) =	74.9
KM Mean =	8.22
KM CV (%) =	478
Slope (Detects) =	1.146
Intercept (Detects) =	40.73
R-Square (Detects)	0.9149

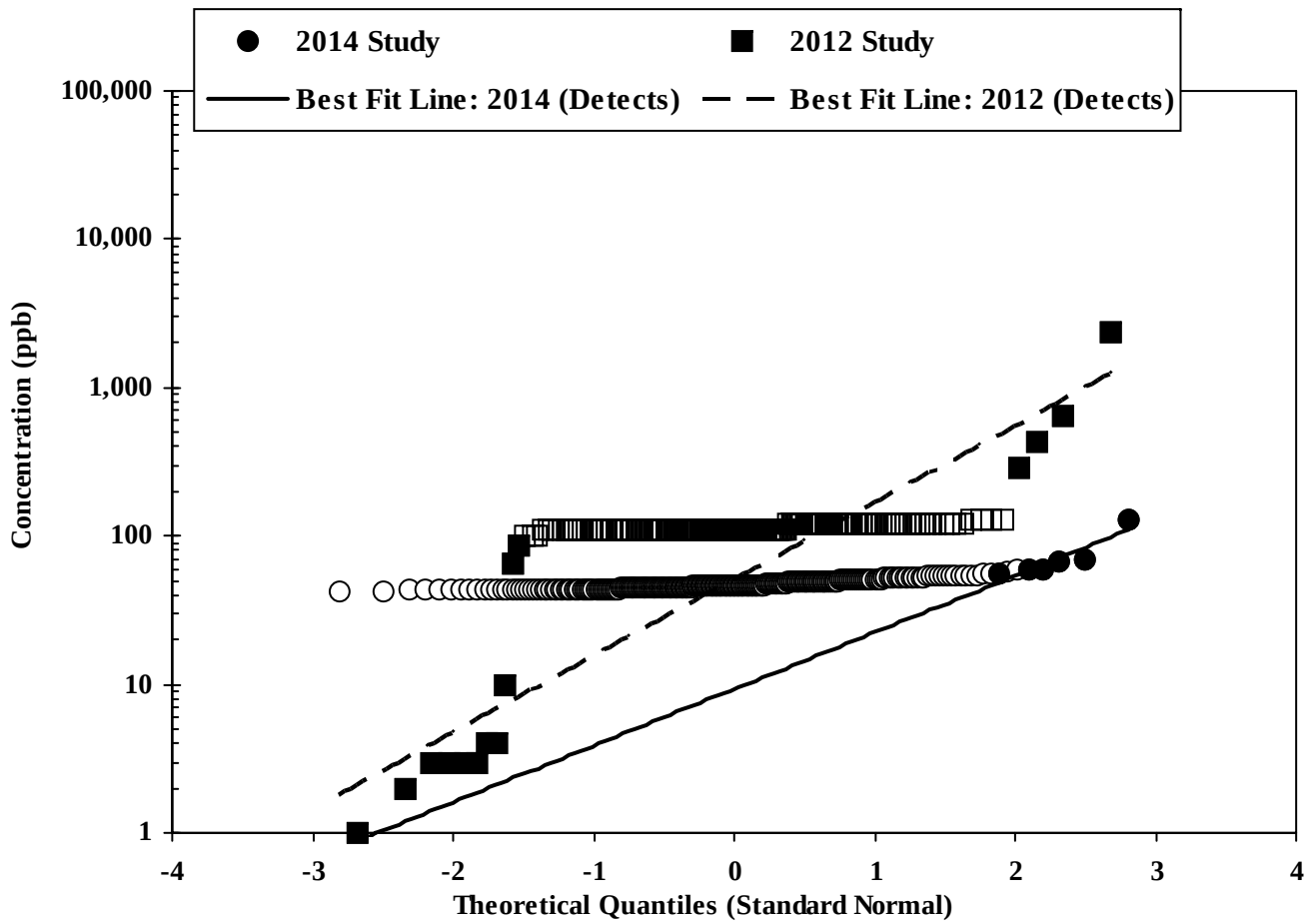
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Anthracene**



2014 Study

No. of Samples =	256
No. of Detects =	6
Mean =	48
CV (%) =	13.5
KM Mean =	42.7
KM CV (%) =	14.5
Slope (Detects) =	0.878
Intercept (Detects) =	9.309
R-Square (Detects)	0.8257

2012 Study

No. of Samples =	168
No. of Detects =	15
Mean =	127
CV (%) =	145.8
KM Mean =	38.8
KM CV (%) =	502
Slope (Detects) =	1.188
Intercept (Detects) =	50.99
R-Square (Detects)	0.8487

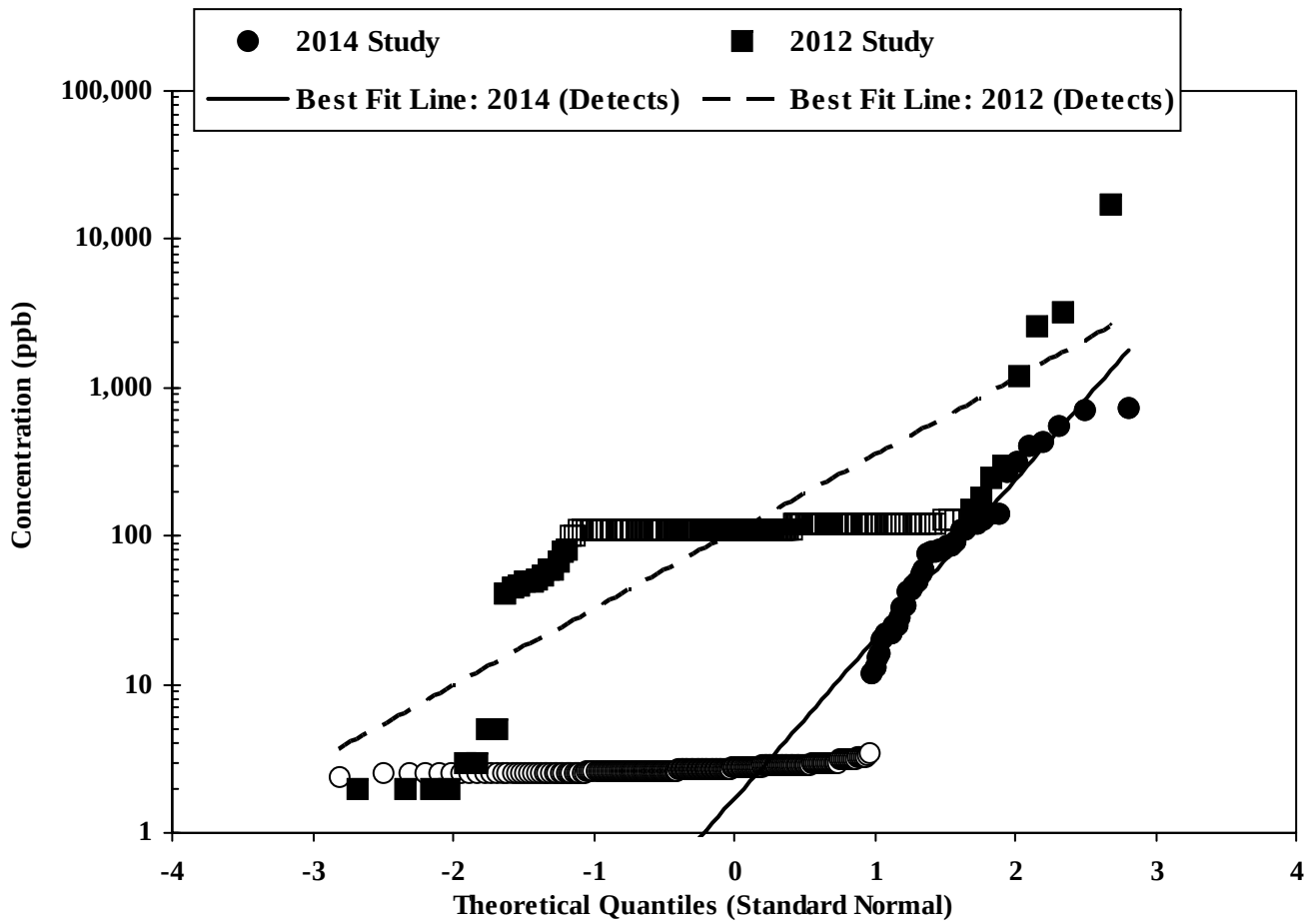
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Benzo[a]anthracene**



2014 Study

No. of Samples =	256
No. of Detects =	42
Mean =	24
CV (%) =	360.1
KM Mean =	23.7
KM CV (%) =	364
Slope (Detects) =	2.476
Intercept (Detects) =	1.689
R-Square (Detects)	0.9463

2012 Study

No. of Samples =	168
No. of Detects =	28
Mean =	247
CV (%) =	541.9
KM Mean =	182
KM CV (%) =	738
Slope (Detects) =	1.192
Intercept (Detects) =	105.8
R-Square (Detects)	0.7583

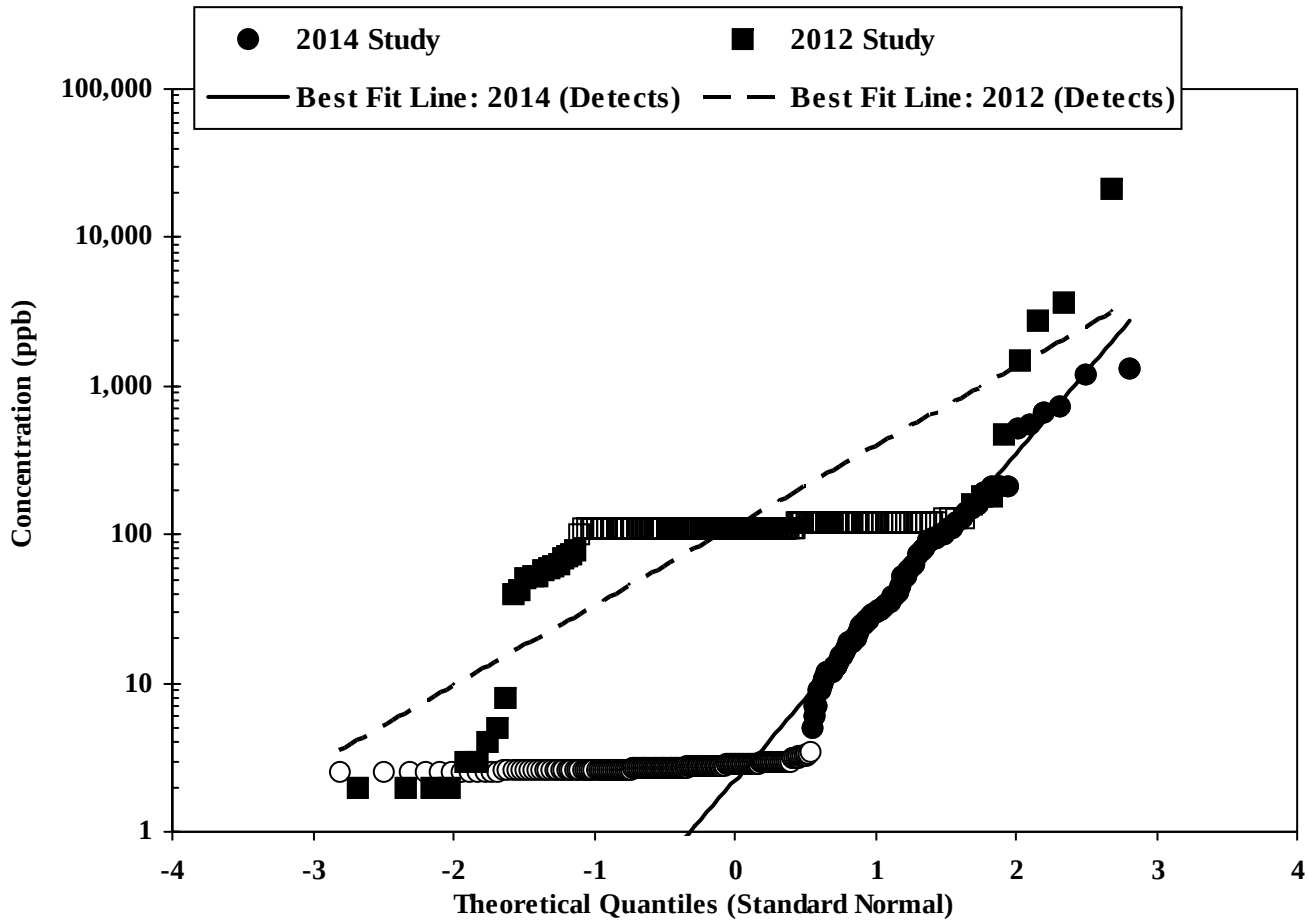
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Benzo[a]pyrene**



2014 Study

No. of Samples =	256
No. of Detects =	75
Mean =	35.7
CV (%) =	382.2
KM Mean =	35.5
KM CV (%) =	384
Slope (Detects) =	2.531
Intercept (Detects) =	2.212
R-Square (Detects)	0.982

2012 Study

No. of Samples =	168
No. of Detects =	31
Mean =	277
CV (%) =	595.8
KM Mean =	214
KM CV (%) =	771
Slope (Detects) =	1.235
Intercept (Detects) =	113.6
R-Square (Detects)	0.7606

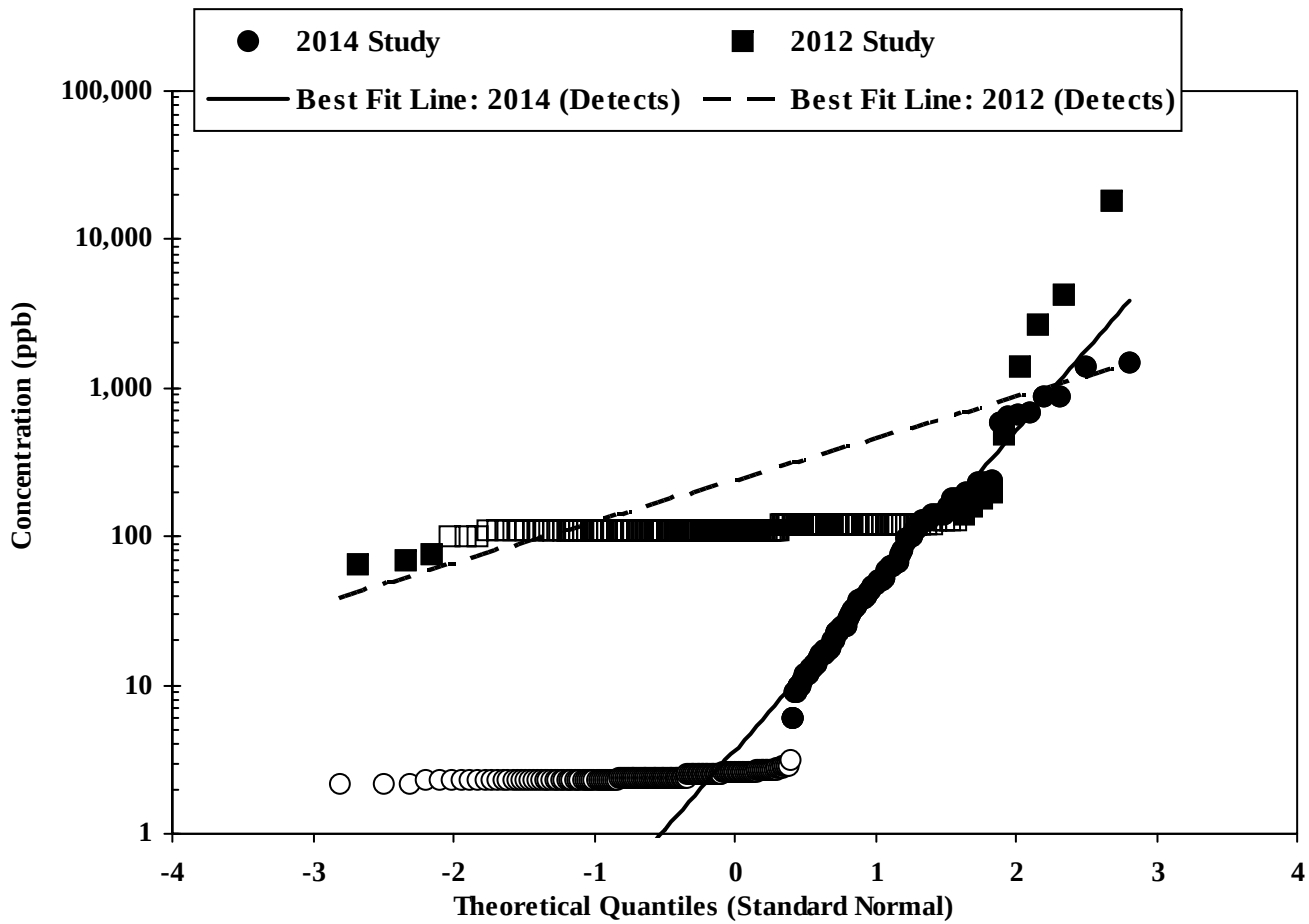
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Benzo[b]fluoranthene**



2014 Study

No. of Samples =	256
No. of Detects =	88
Mean =	49.4
CV (%) =	344.8
KM Mean =	49.3
KM CV (%) =	345
Slope (Detects) =	2.479
Intercept (Detects) =	3.634
R-Square (Detects)	0.9793

2012 Study

No. of Samples =	168
No. of Detects =	12
Mean =	271
CV (%) =	528.4
KM Mean =	230
KM CV (%) =	622
Slope (Detects) =	0.6443
Intercept (Detects) =	239.5
R-Square (Detects)	0.4915

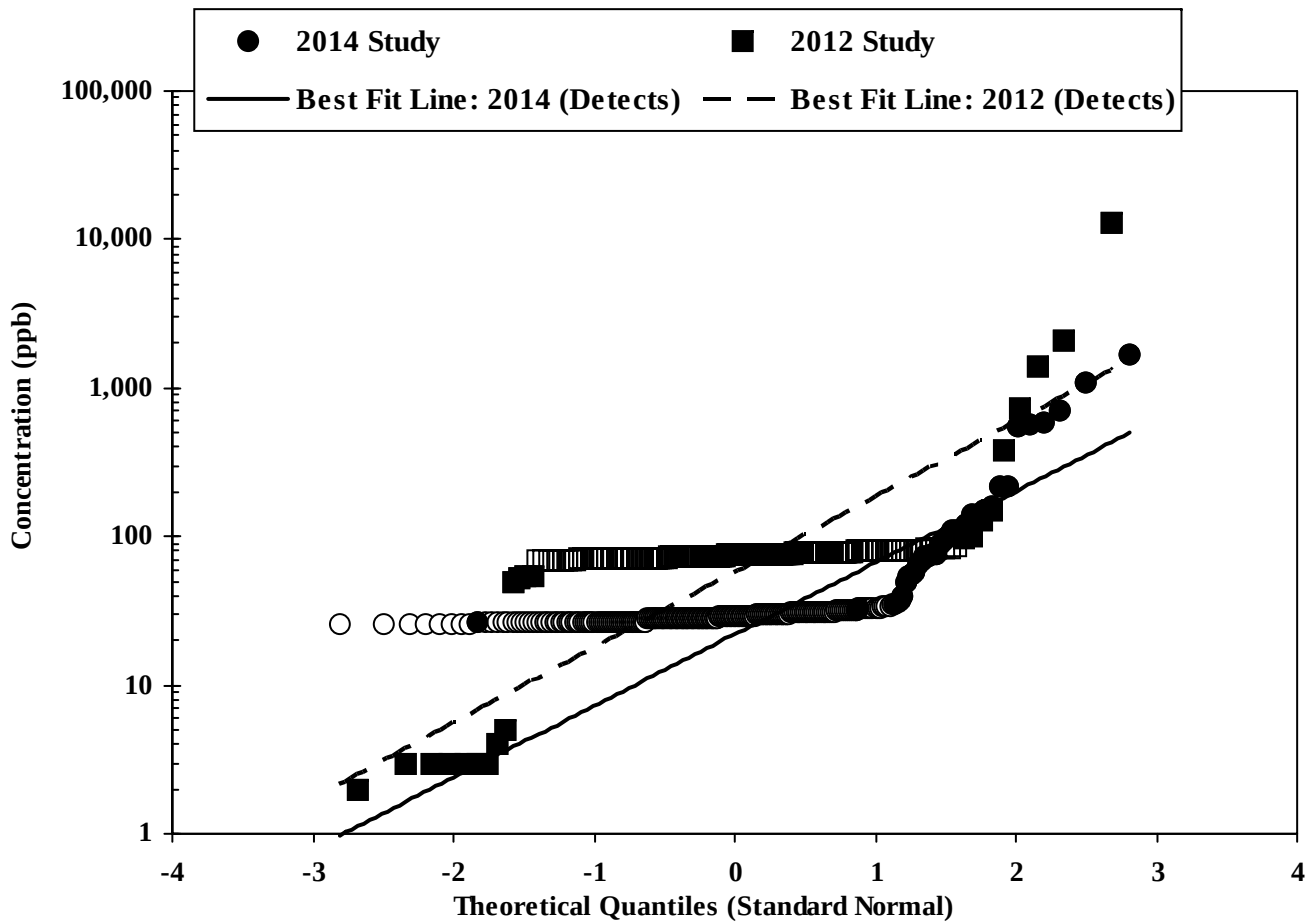
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Benzo[g,h,i]perylene**



2014 Study

No. of Samples =	256
No. of Detects =	35
Mean =	55.6
CV (%) =	258.7
KM Mean =	53.1
KM CV (%) =	272
Slope (Detects) =	1.109
Intercept (Detects) =	21.99
R-Square (Detects)	0.5845

2012 Study

No. of Samples =	168
No. of Detects =	22
Mean =	175
CV (%) =	580.4
KM Mean =	125
KM CV (%) =	812
Slope (Detects) =	1.168
Intercept (Detects) =	57.56
R-Square (Detects)	0.7986

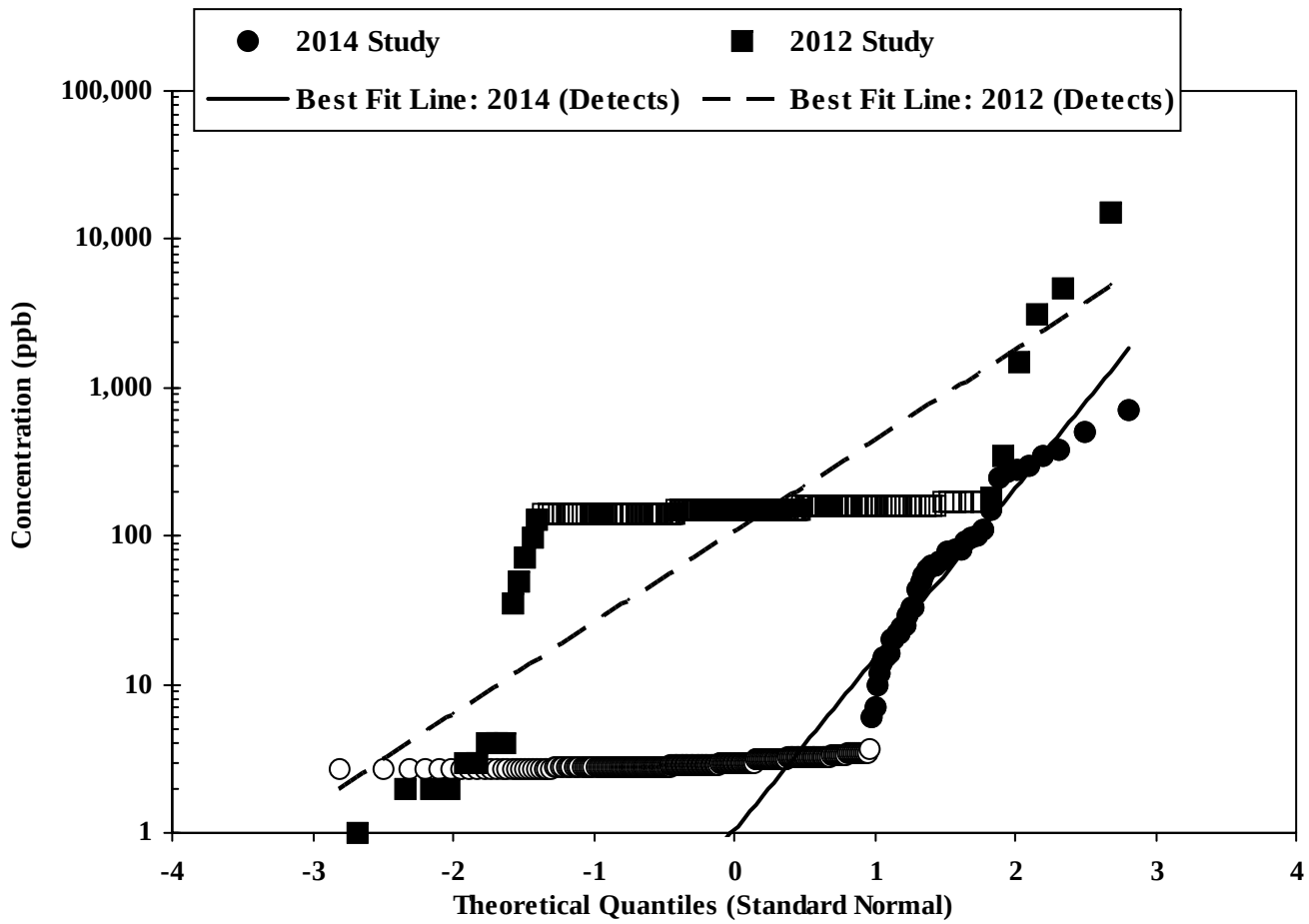
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Benzo[k]fluoranthene**



2014 Study

No. of Samples =	256
No. of Detects =	42
Mean =	20.9
CV (%) =	346.8
KM Mean =	20.6
KM CV (%) =	350
Slope (Detects) =	2.65
Intercept (Detects) =	1.049
R-Square (Detects)	0.9241

2012 Study

No. of Samples =	168
No. of Detects =	21
Mean =	282
CV (%) =	431.7
KM Mean =	177
KM CV (%) =	693
Slope (Detects) =	1.415
Intercept (Detects) =	106.5
R-Square (Detects)	0.8071

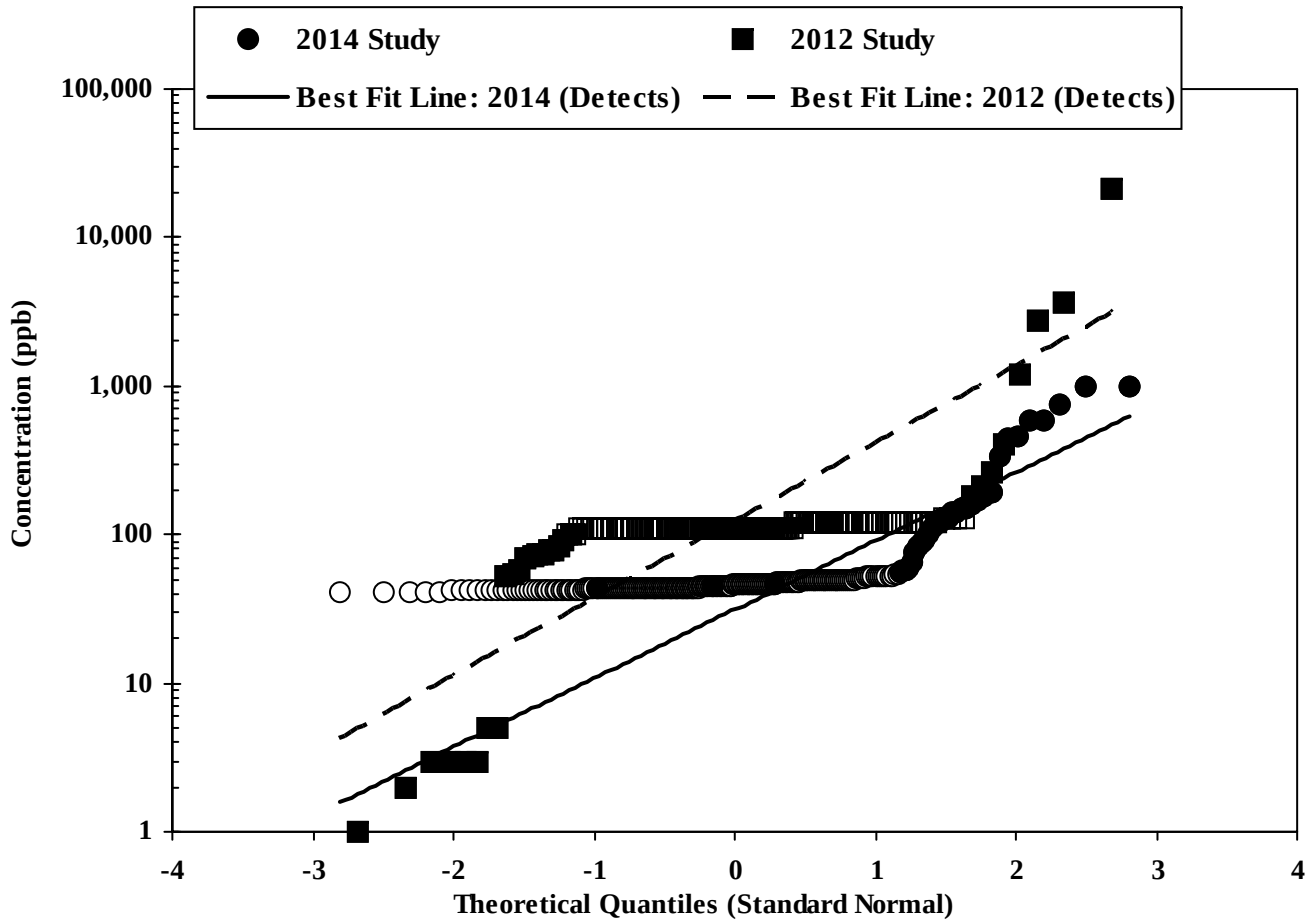
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Chrysene**



2014 Study

No. of Samples =	256
No. of Detects =	33
Mean =	70.5
CV (%) =	160.6
KM Mean =	66.4
KM CV (%) =	171
Slope (Detects) =	1.064
Intercept (Detects) =	31.31
R-Square (Detects)	0.6939

2012 Study

No. of Samples =	168
No. of Detects =	28
Mean =	277
CV (%) =	595.0
KM Mean =	220
KM CV (%) =	750
Slope (Detects) =	1.2
Intercept (Detects) =	124
R-Square (Detects)	0.7362

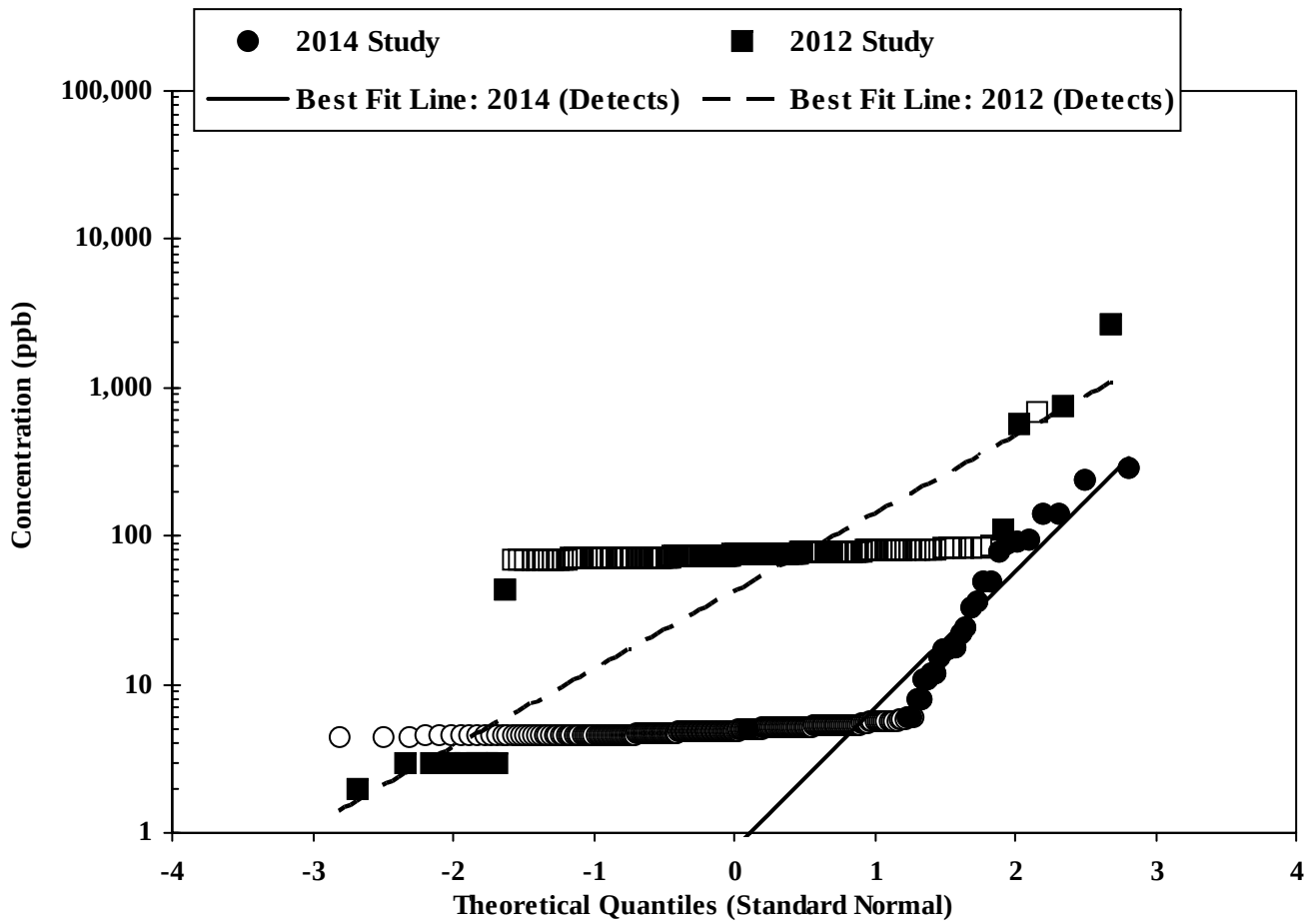
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Dibenz[a,h]anthracene**



2014 Study

No. of Samples =	256
No. of Detects =	28
Mean =	10.4
CV (%) =	269.2
KM Mean =	9.94
KM CV (%) =	283
Slope (Detects) =	2.146
Intercept (Detects) =	0.7998
R-Square (Detects)	0.8346

2012 Study

No. of Samples =	168
No. of Detects =	13
Mean =	98.2
CV (%) =	221.9
KM Mean =	31.8
KM CV (%) =	689
Slope (Detects) =	1.208
Intercept (Detects) =	42.25
R-Square (Detects)	0.9061

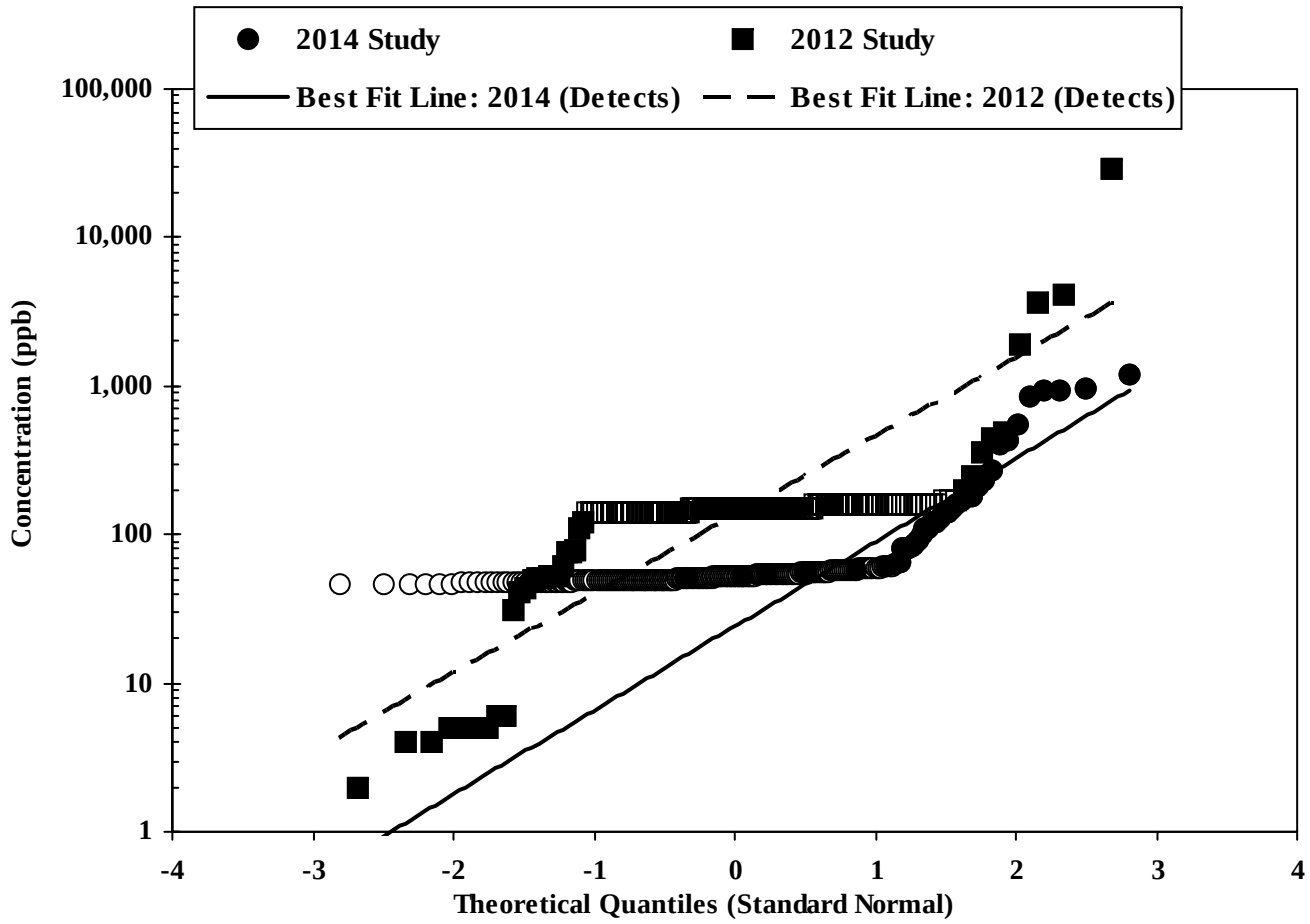
***KM = Kaplan-Meier estimate**

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Fluoranthene**



2014 Study

No. of Samples =	256
No. of Detects =	39
Mean =	82.6
CV (%) =	166.5
KM Mean =	78.2
KM CV (%) =	177
Slope (Detects) =	1.301
Intercept (Detects) =	24.15
R-Square (Detects)	0.7845

2012 Study

No. of Samples =	168
No. of Detects =	33
Mean =	367
CV (%) =	617.1
KM Mean =	279
KM CV (%) =	812
Slope (Detects) =	1.222
Intercept (Detects) =	135.1
R-Square (Detects)	0.8086

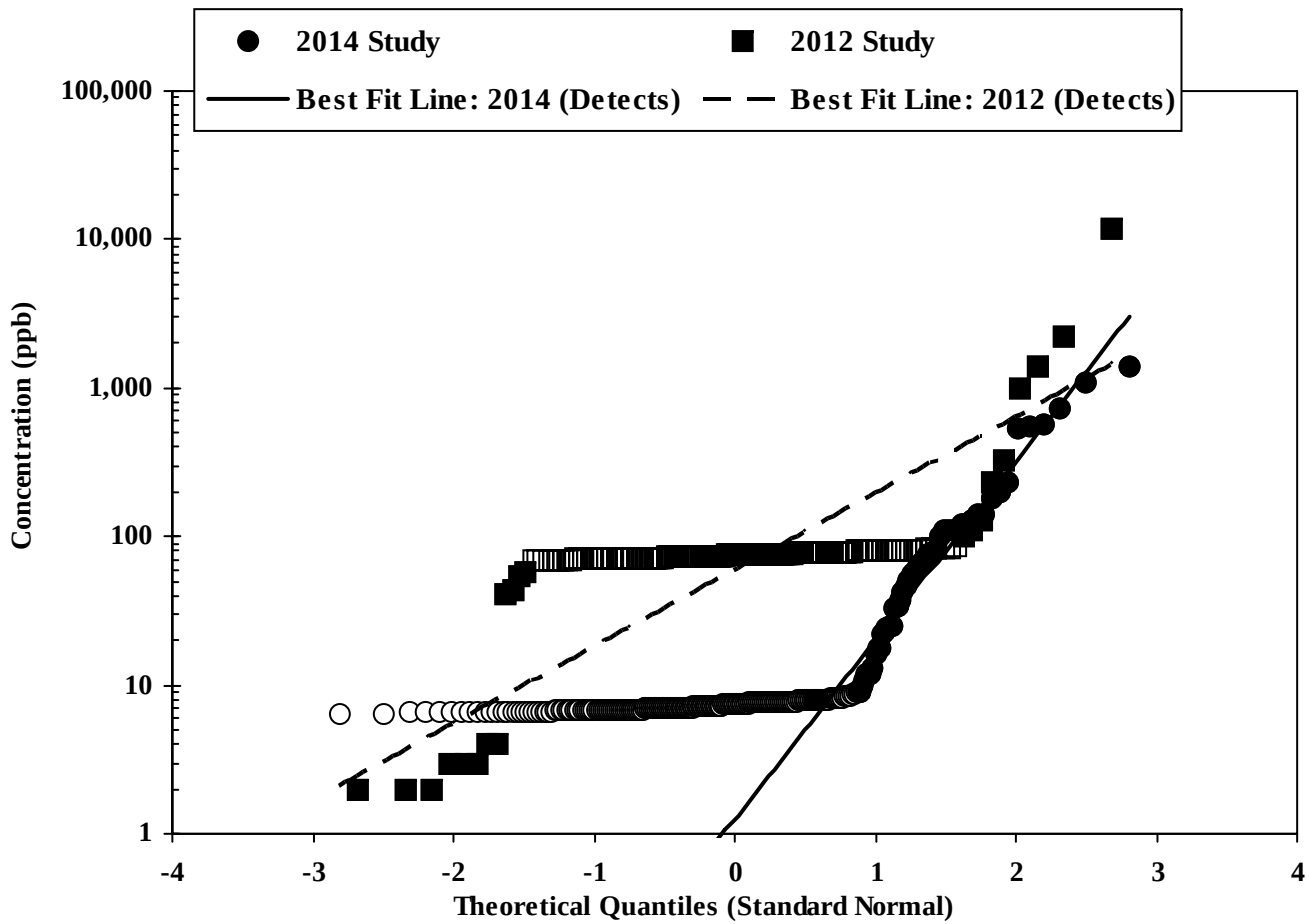
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Indeno[1,2,3-c,d]pyrene**



2014 Study

No. of Samples =	256
No. of Detects =	52
Mean =	36.1
CV (%) =	372.2
KM Mean =	35.5
KM CV (%) =	379
Slope (Detects) =	2.77
Intercept (Detects) =	1.258
R-Square (Detects)	0.9577

2012 Study

No. of Samples =	168
No. of Detects =	21
Mean =	172
CV (%) =	548.6
KM Mean =	122
KM CV (%) =	776
Slope (Detects) =	1.188
Intercept (Detects) =	59.53
R-Square (Detects)	0.808

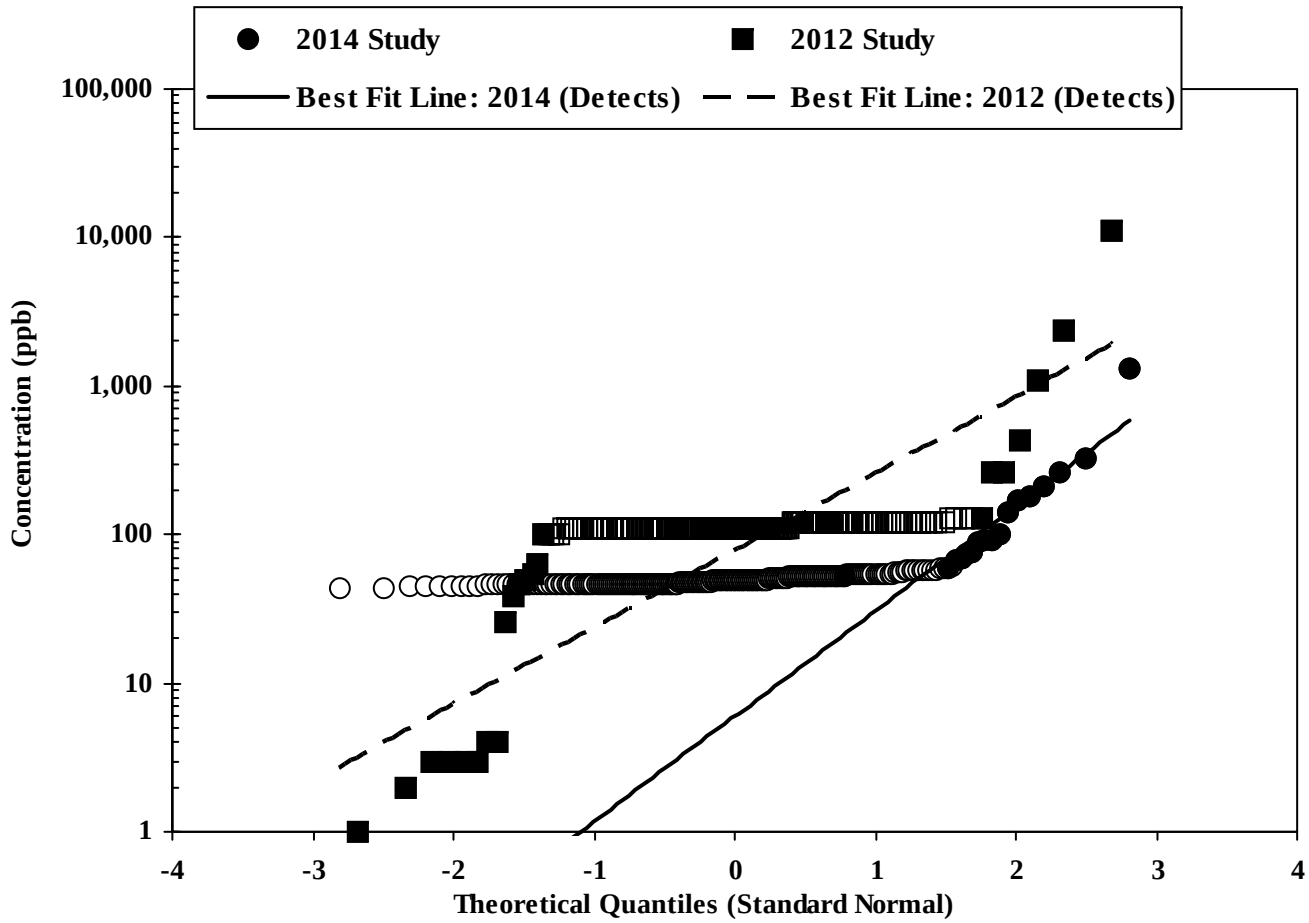
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Phenanthrene**



2014 Study

No. of Samples =	256
No. of Detects =	17
Mean =	59.5
CV (%) =	138.7
KM Mean =	54.2
KM CV (%) =	153
Slope (Detects) =	1.628
Intercept (Detects) =	5.99
R-Square (Detects)	0.8269

2012 Study

No. of Samples =	168
No. of Detects =	22
Mean =	194
CV (%) =	444.4
KM Mean =	118
KM CV (%) =	738
Slope (Detects) =	1.191
Intercept (Detects) =	77.94
R-Square (Detects)	0.7869

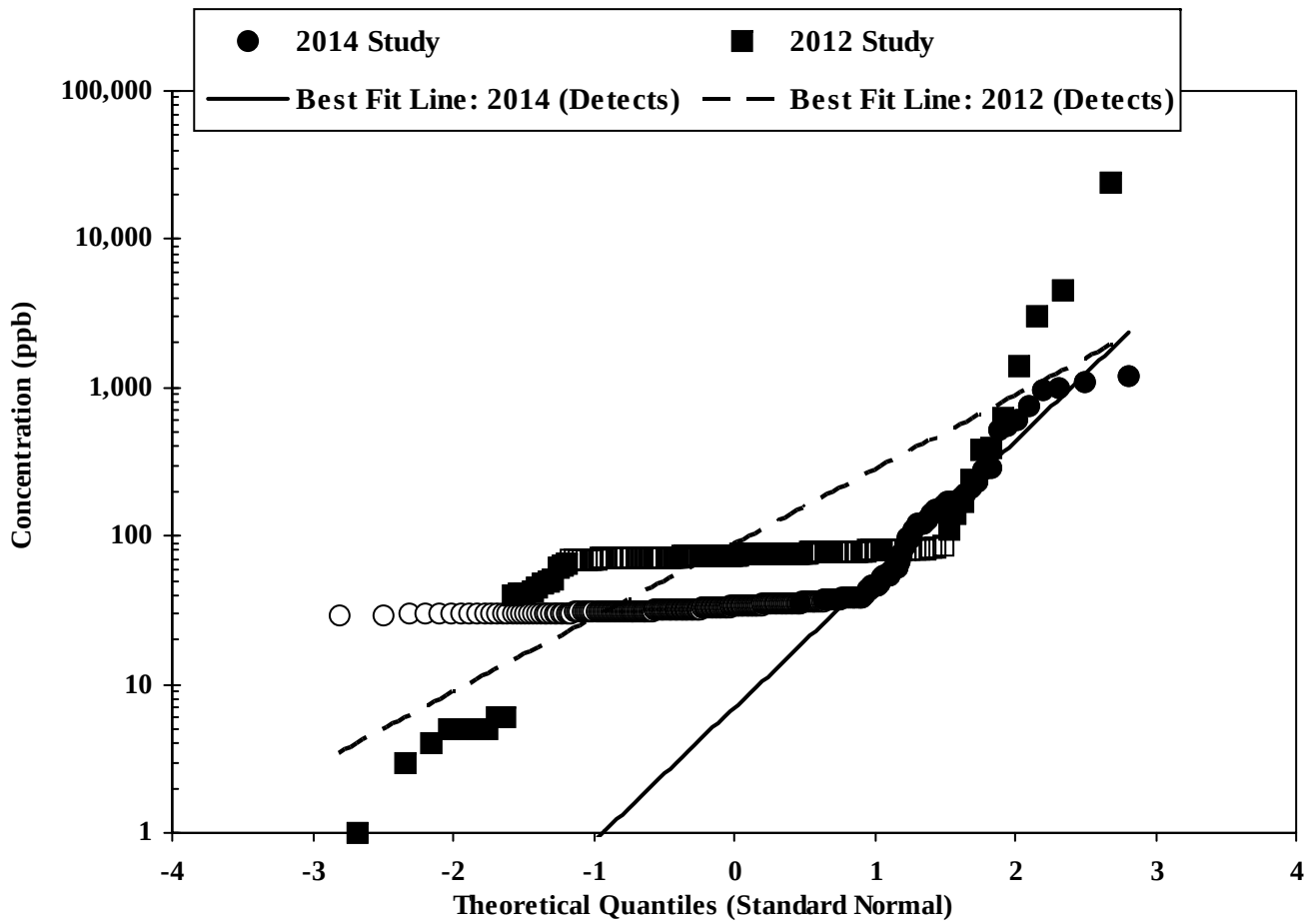
*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

Lognormal Q-Q Plots of Detected PAHs for the 2012 and 2014 Soil Background Studies

PAH: **Pyrene**



2014 Study

No. of Samples =	256
No. of Detects =	52
Mean =	69.9
CV (%) =	214.2
KM Mean =	66.8
KM CV (%) =	225
Slope (Detects) =	2.07
Intercept (Detects) =	6.94
R-Square (Detects)	0.9541

2012 Study

No. of Samples =	168
No. of Detects =	35
Mean =	273
CV (%) =	692.3
KM Mean =	237
KM CV (%) =	796
Slope (Detects) =	1.15
Intercept (Detects) =	88.47
R-Square (Detects)	0.7836

*KM = Kaplan-Meier estimate

Notes:

1) Open symbols denote non-detects.

This page intentionally left blank

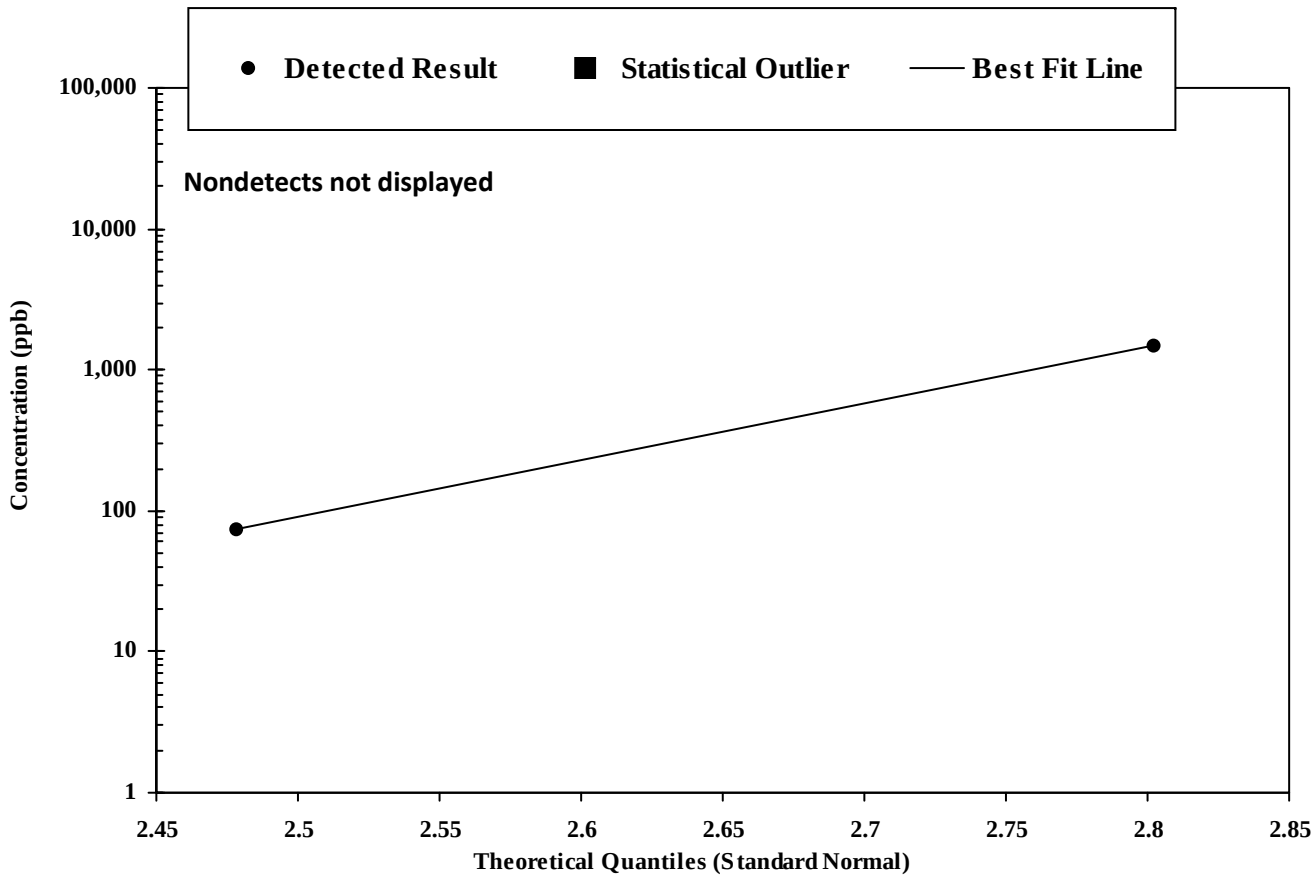
Appendix B

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

This page intentionally left blank.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Acenaphthene**



Summary of Outlier Free Data

No. of Samples =	246
No. of Detects =	2
Mean =	62.1
CV (%) =	148.6
KM Mean =	9.38
KM CV (%) =	1020
Slope (Detects) =	9.252
Intercept (Detects) =	8.25E-09
R-Square (Detects)	1

*KM = Kaplan-Meier estimate

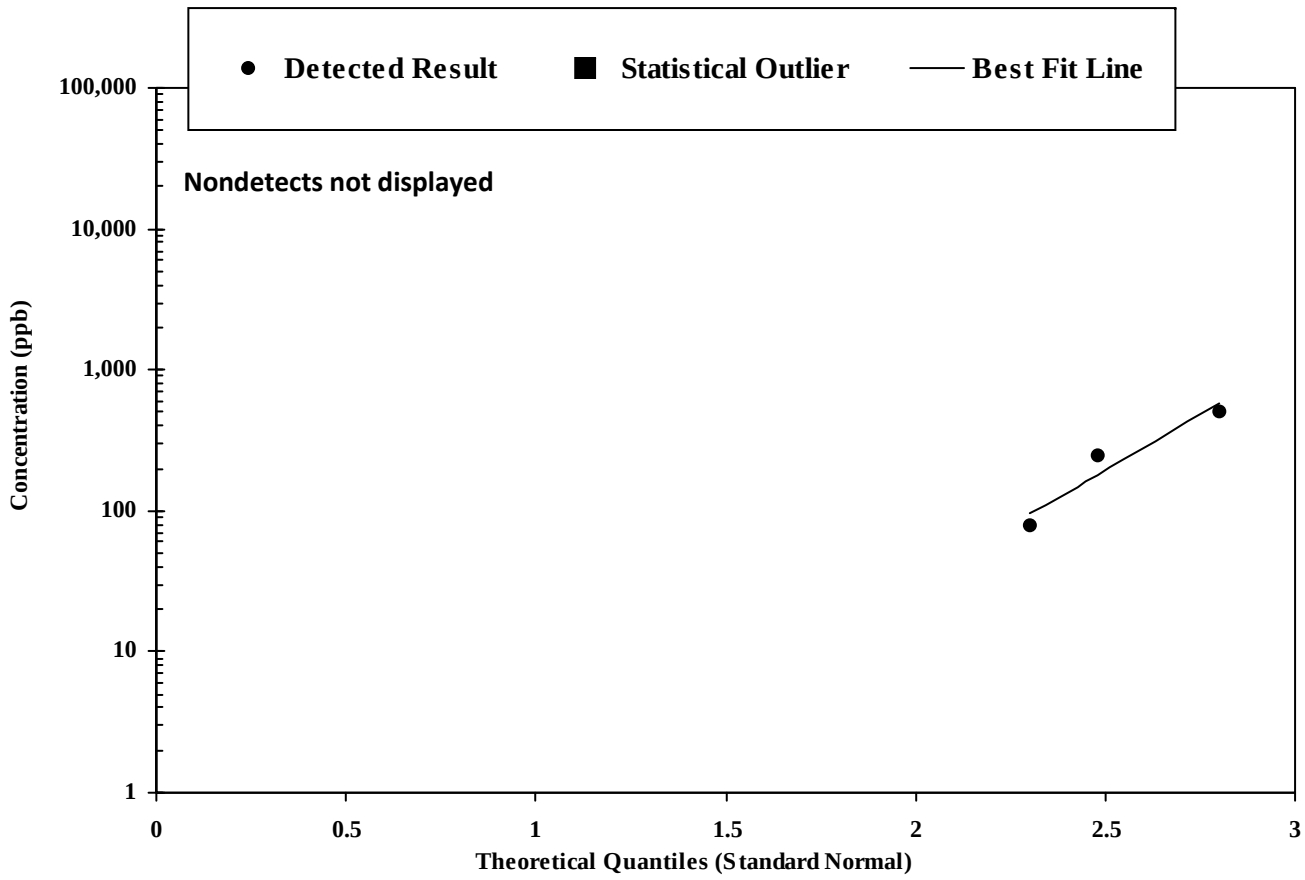
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Acenaphthylene**



Summary of Outlier Free Data

No. of Samples =	246
No. of Detects =	3
Mean =	48.2
CV (%) =	68.6
KM Mean =	4.4
KM CV (%) =	826
Slope (Detects) =	3.541
Intercept (Detects) =	0.02799
R-Square (Detects)	0.9104

*KM = Kaplan-Meier estimate

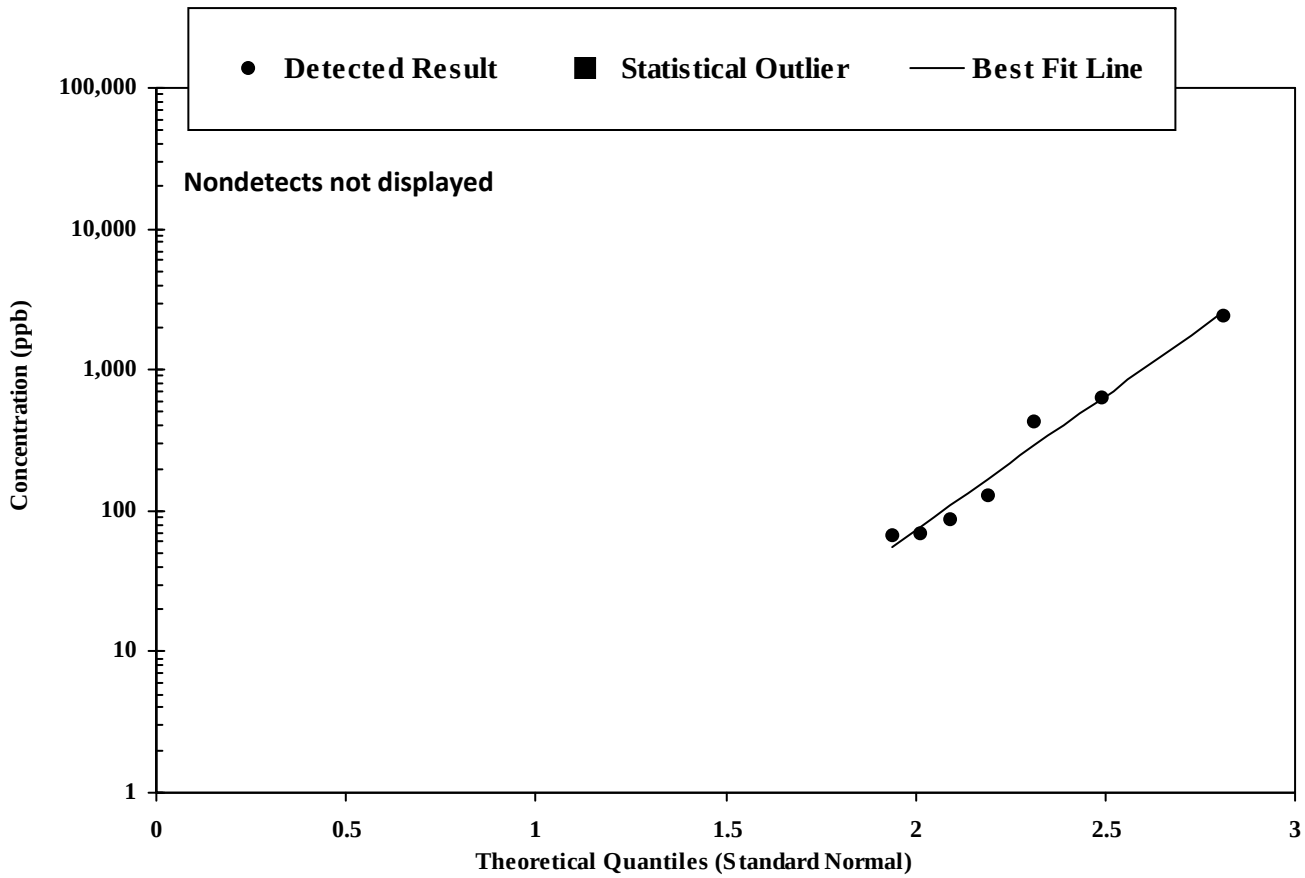
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Anthracene**



Summary of Outlier Free Data

No. of Samples =	253
No. of Detects =	7
Mean =	59.8
CV (%) =	258.3
KM Mean =	16.1
KM CV (%) =	983
Slope (Detects) =	4.413
Intercept (Detects) =	0.01059
R-Square (Detects)	0.9712

*KM = Kaplan-Meier estimate

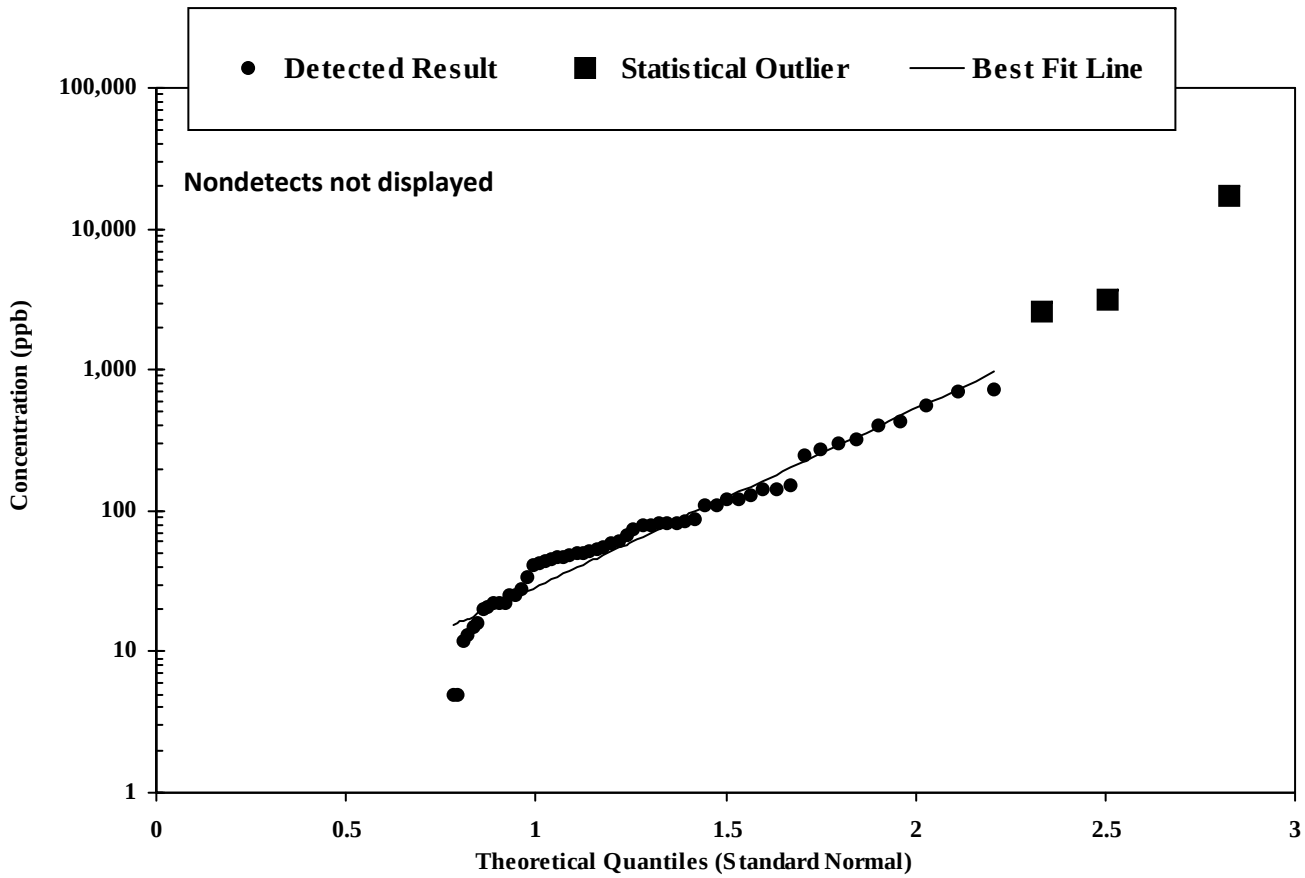
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Benzo[a]anthracene**



Summary of Outlier Free Data

No. of Samples =	262
No. of Detects =	55
Mean =	27.6
CV (%) =	319.9
KM Mean =	27.1
KM CV (%) =	327
Slope (Detects) =	2.906
Intercept (Detects) =	1.58
R-Square (Detects)	0.9374

*KM = Kaplan-Meier estimate

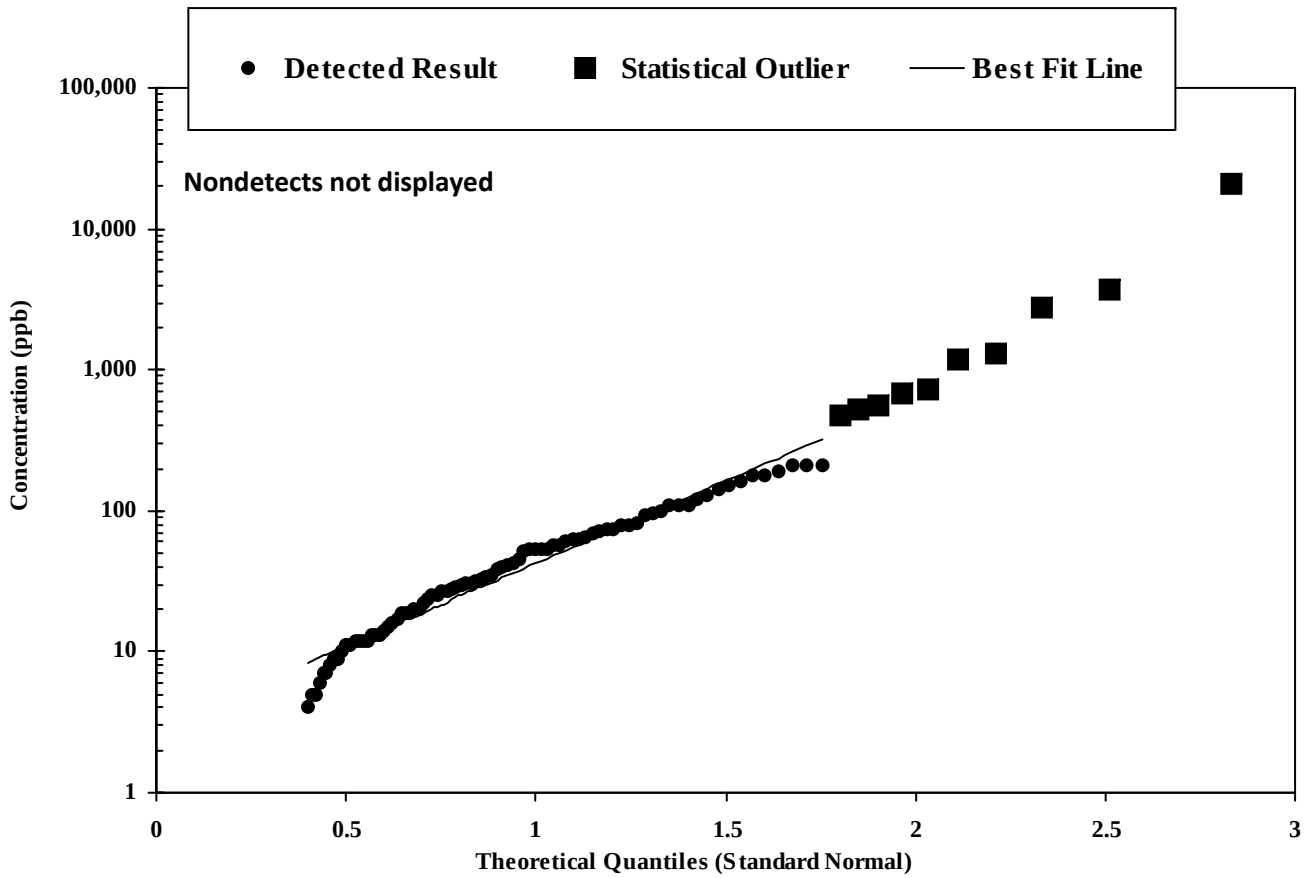
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Benzo[a]pyrene**



Summary of Outlier Free Data

No. of Samples =	258
No. of Detects =	83
Mean =	19.8
CV (%) =	198.6
KM Mean =	19.3
KM CV (%) =	205
Slope (Detects) =	2.691
Intercept (Detects) =	2.878
R-Square (Detects)	0.9628

*KM = Kaplan-Meier estimate

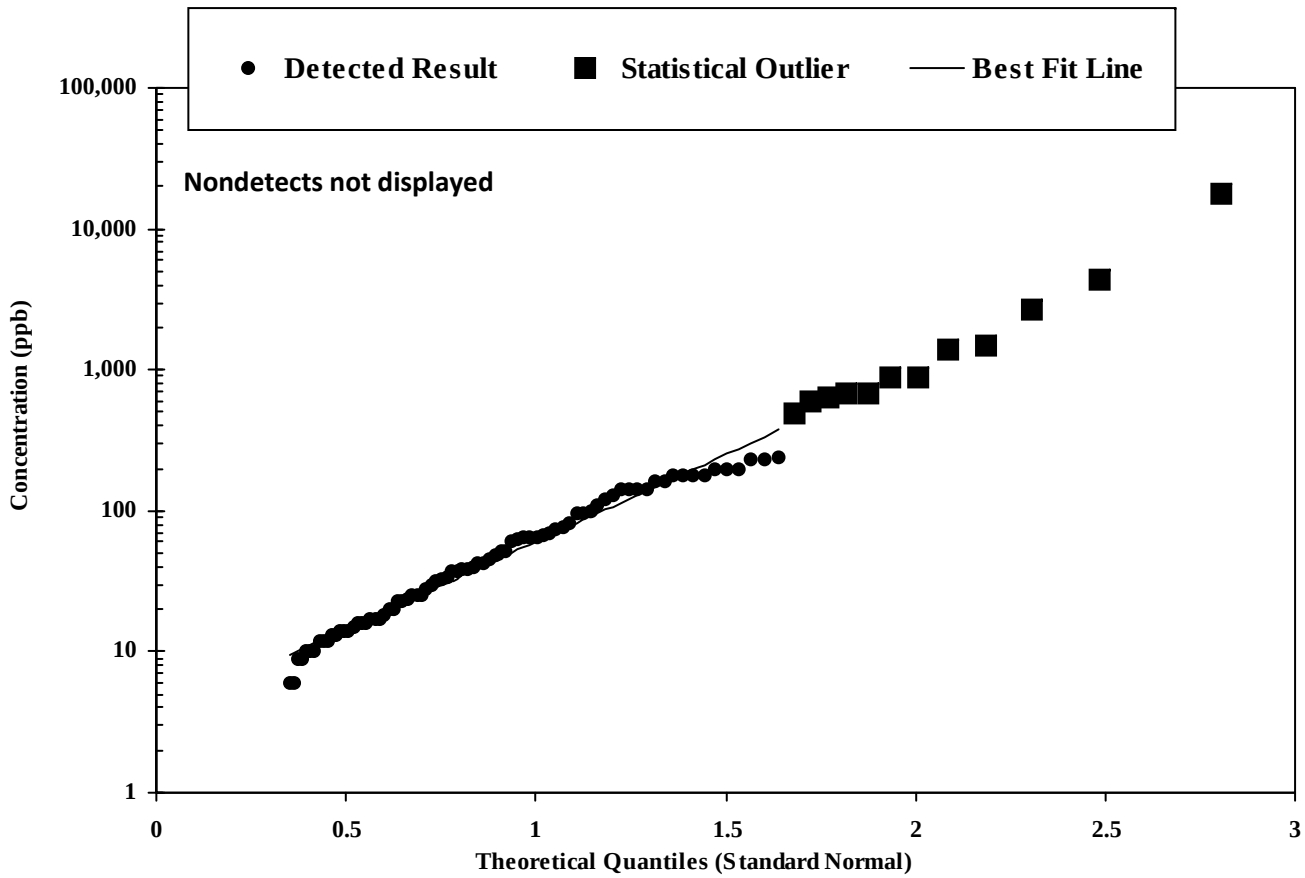
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Benzo[b]fluoranthene**



Summary of Outlier Free Data

No. of Samples =	238
No. of Detects =	79
Mean =	24.1
CV (%) =	201.2
KM Mean =	24
KM CV (%) =	203
Slope (Detects) =	2.846
Intercept (Detects) =	3.494
R-Square (Detects)	0.9796

*KM = Kaplan-Meier estimate

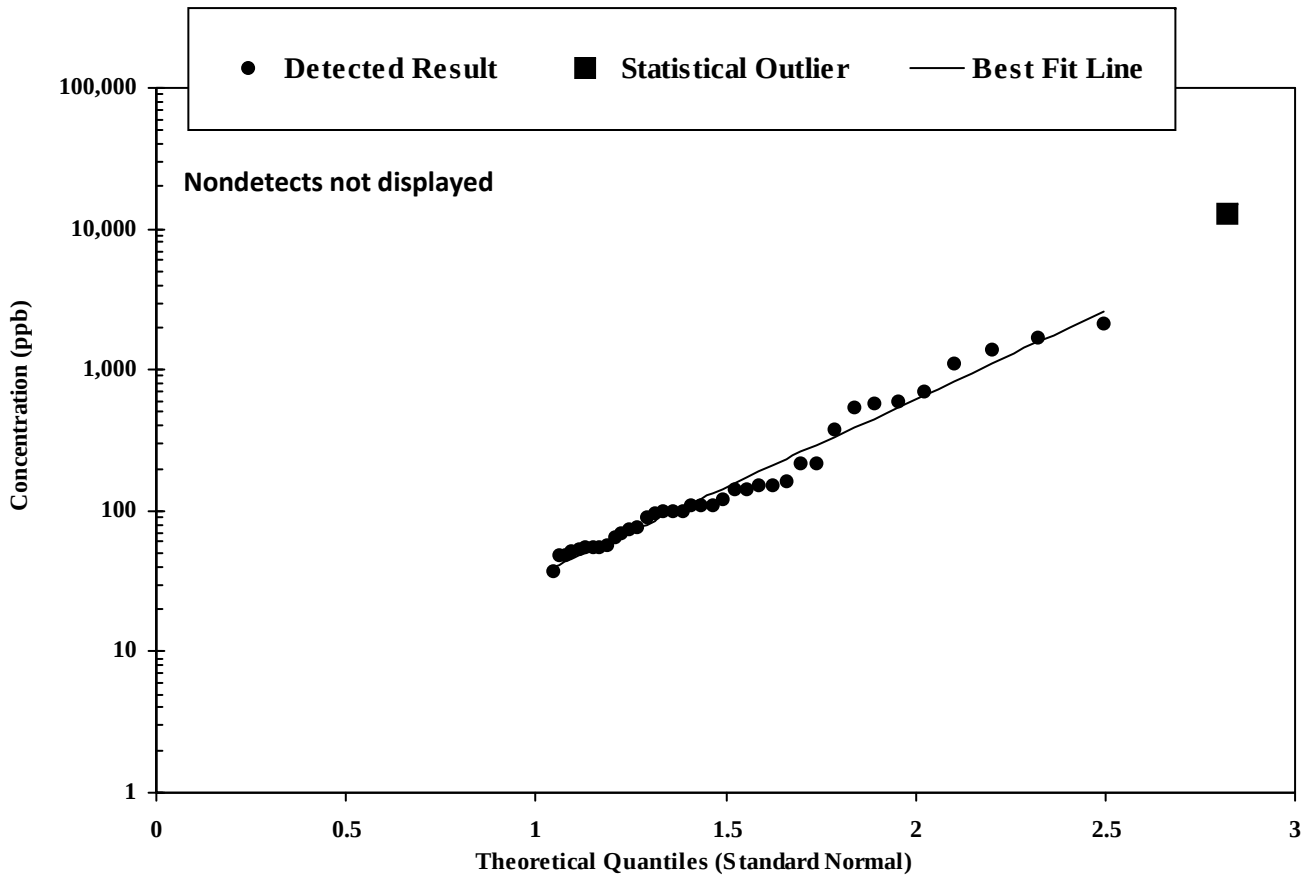
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Benzo[g,h,i]perylene**



Summary of Outlier Free Data

No. of Samples =	259
No. of Detects =	38
Mean =	70.1
CV (%) =	299.2
KM Mean =	47.9
KM CV (%) =	447
Slope (Detects) =	2.875
Intercept (Detects) =	1.966
R-Square (Detects)	0.9762

*KM = Kaplan-Meier estimate

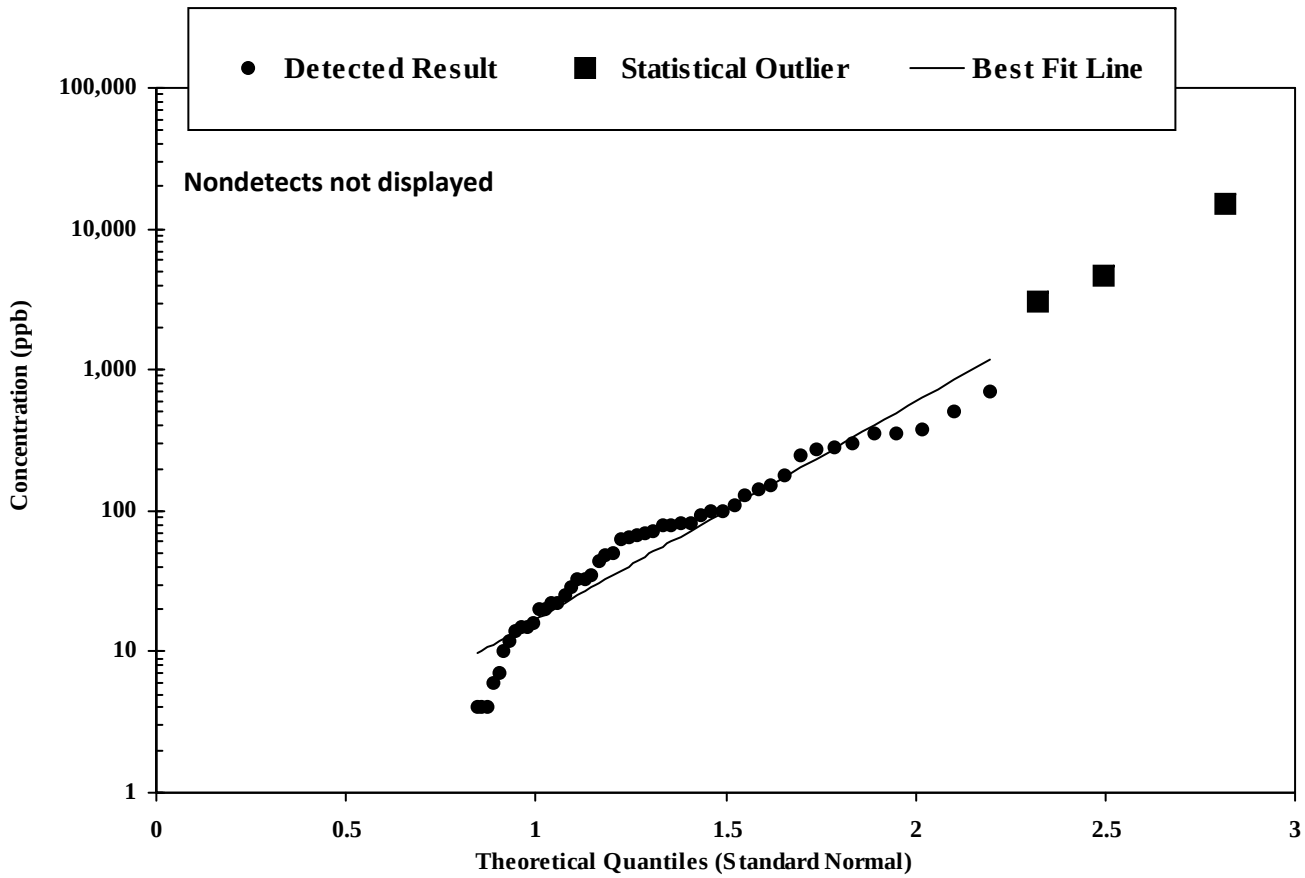
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Benzo[k]fluoranthene**



Summary of Outlier Free Data

No. of Samples =	256
No. of Detects =	49
Mean =	24
CV (%) =	318.7
KM Mean =	22.4
KM CV (%) =	342
Slope (Detects) =	3.558
Intercept (Detects) =	0.481
R-Square (Detects)	0.9259

*KM = Kaplan-Meier estimate

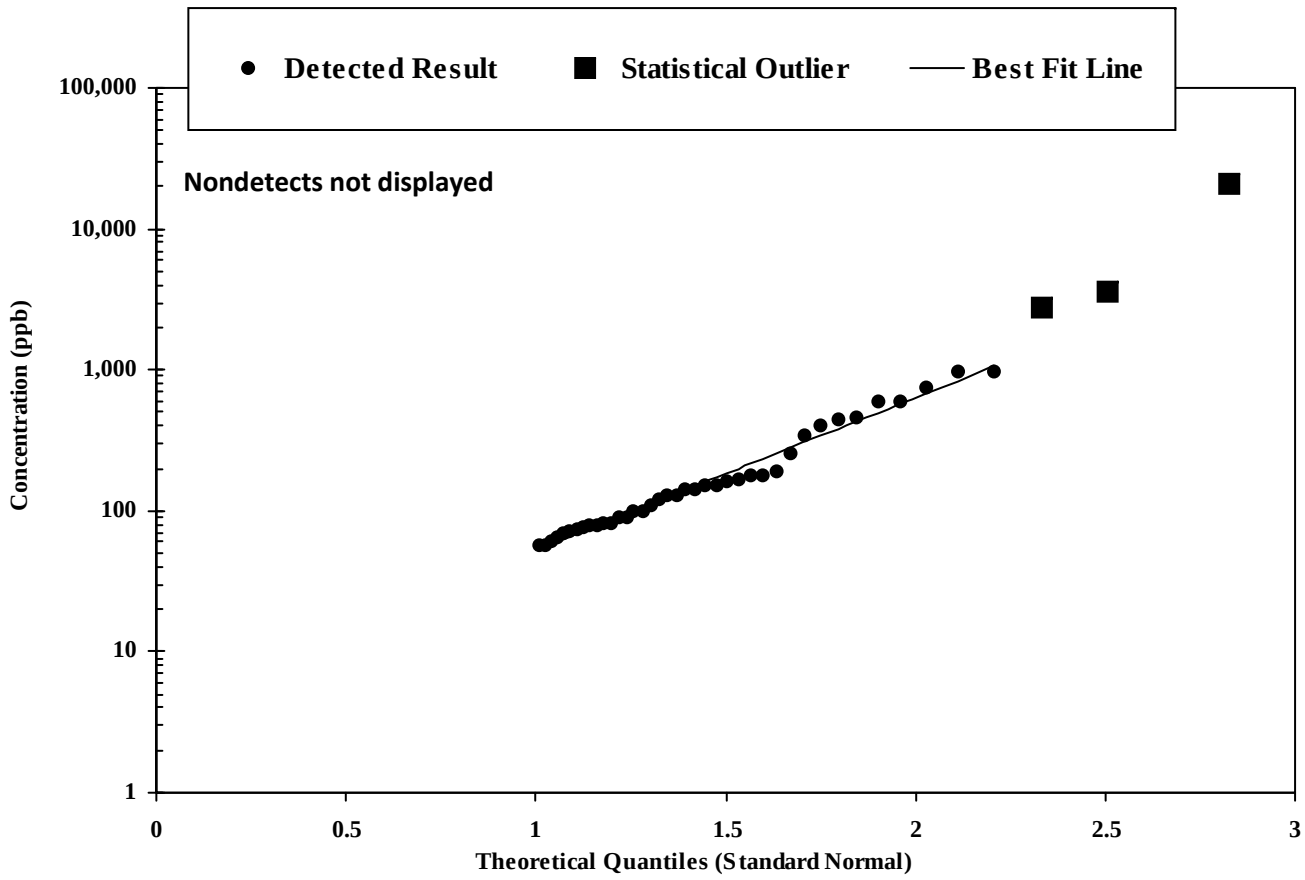
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Chrysene**



Summary of Outlier Free Data

No. of Samples =	262
No. of Detects =	39
Mean =	72.2
CV (%) =	159.5
KM Mean =	35.2
KM CV (%) =	353
Slope (Detects) =	2.494
Intercept (Detects) =	4.343
R-Square (Detects)	0.9827

*KM = Kaplan-Meier estimate

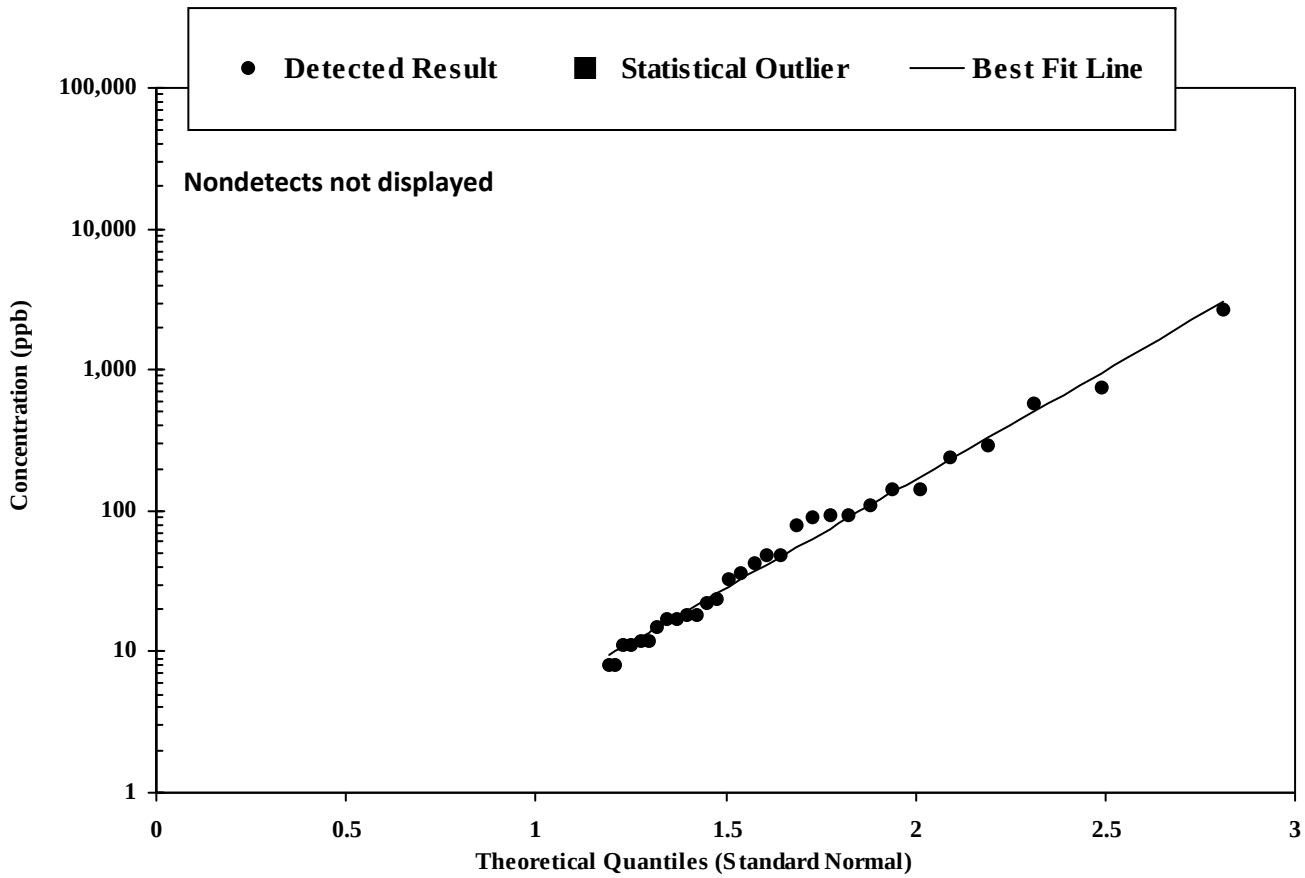
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Dibenz[a,h]anthracene**



Summary of Outlier Free Data

No. of Samples =	253
No. of Detects =	30
Mean =	26.8
CV (%) =	673.9
KM Mean =	24.3
KM CV (%) =	744
Slope (Detects) =	3.561
Intercept (Detects) =	0.1352
R-Square (Detects)	0.9891

*KM = Kaplan-Meier estimate

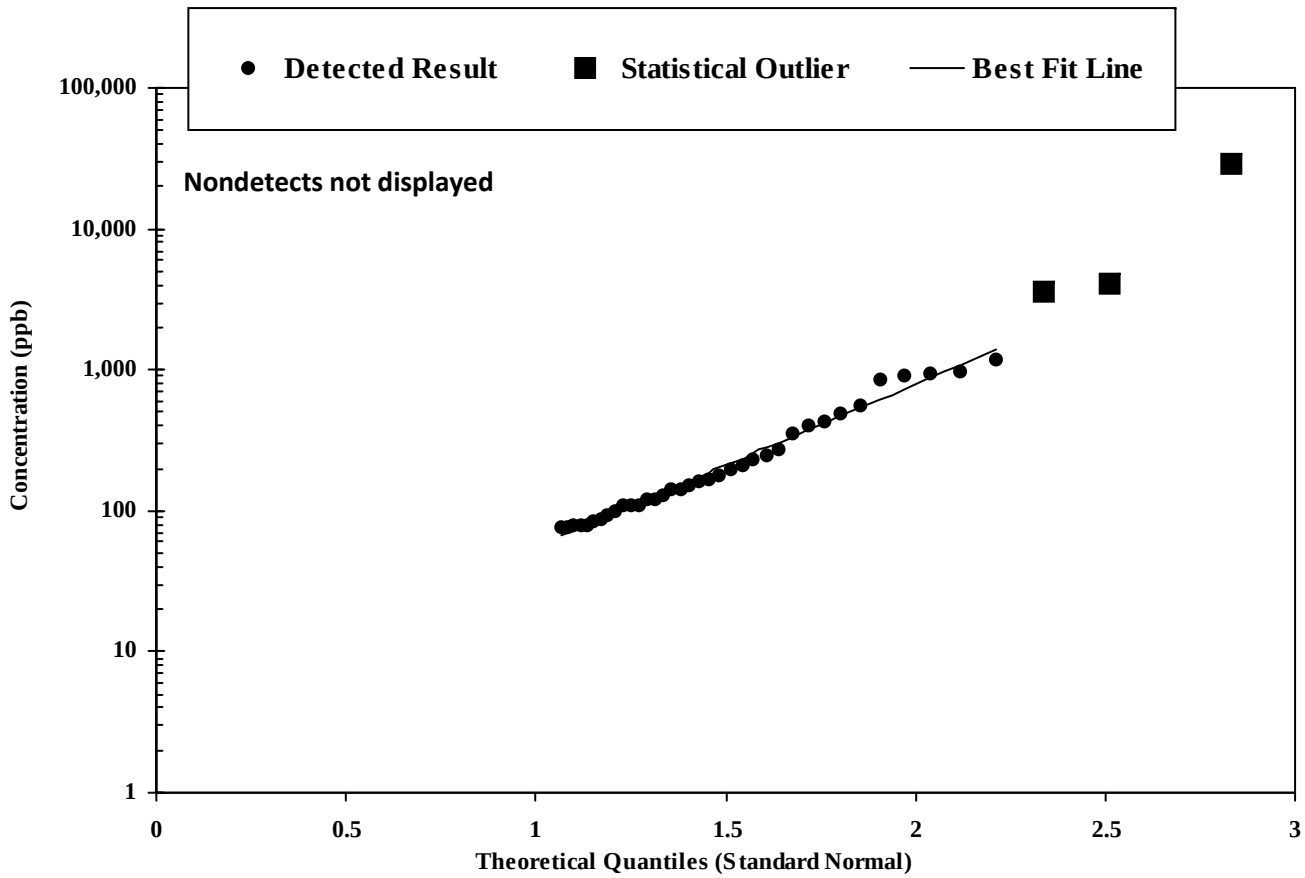
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Fluoranthene**



Summary of Outlier Free Data

No. of Samples =	267
No. of Detects =	36
Mean =	83.7
CV (%) =	166.3
KM Mean =	41.7
KM CV (%) =	358
Slope (Detects) =	2.652
Intercept (Detects) =	3.924
R-Square (Detects)	0.9857

*KM = Kaplan-Meier estimate

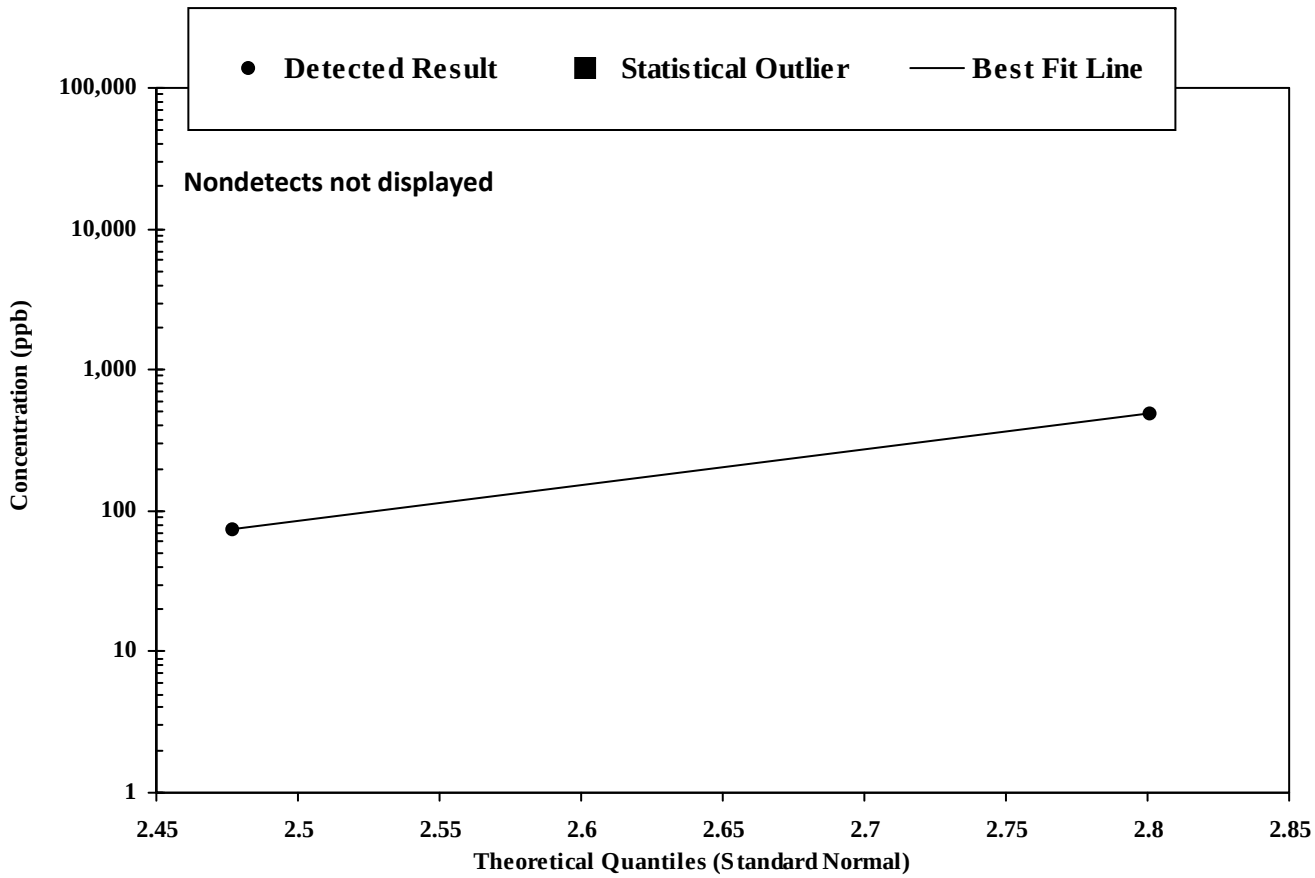
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Fluorene**



Summary of Outlier Free Data

No. of Samples =	245
No. of Detects =	2
Mean =	51.4
CV (%) =	55.8
KM Mean =	7.26
KM CV (%) =	430
Slope (Detects) =	5.836
Intercept (Detects) =	3.90E-05
R-Square (Detects)	1

*KM = Kaplan-Meier estimate

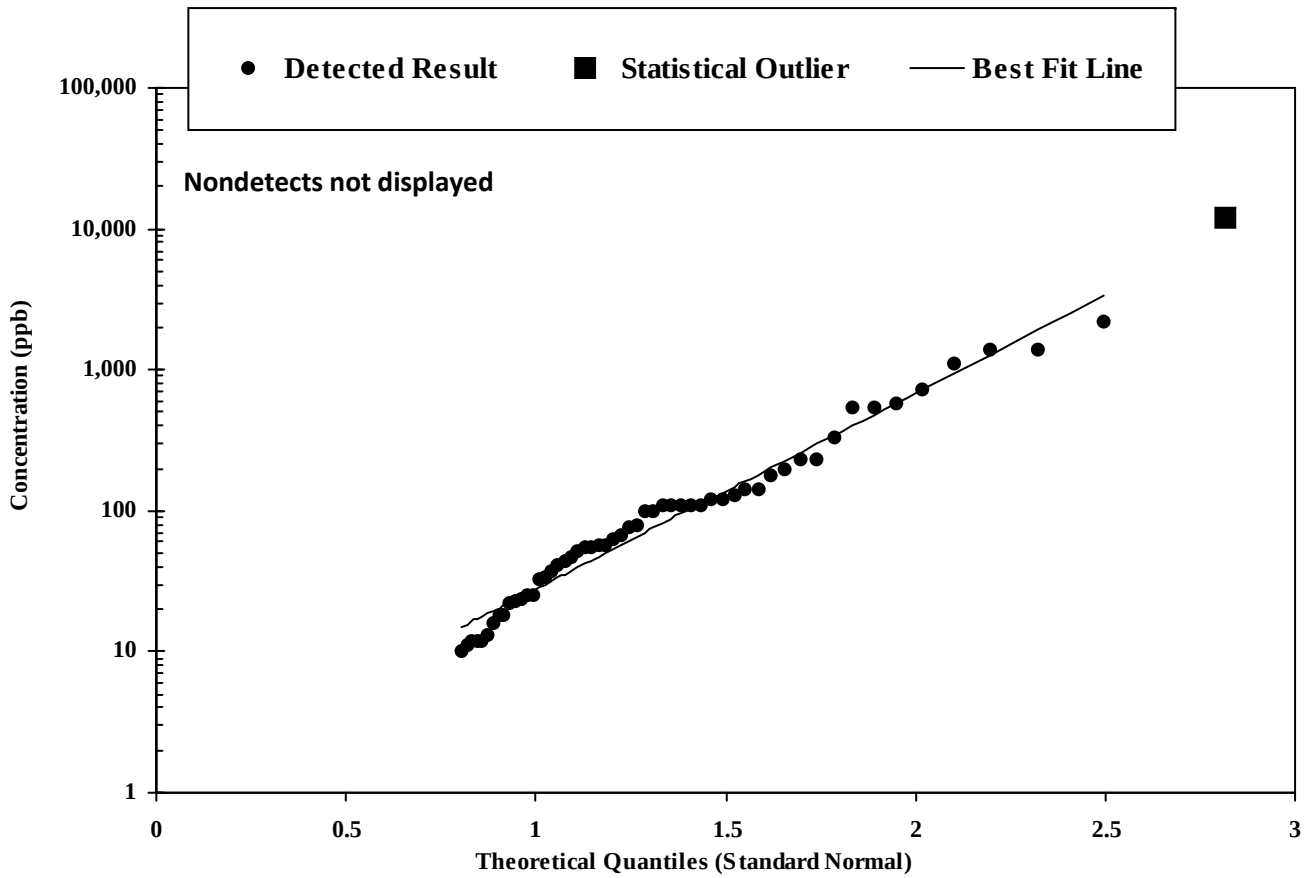
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Indeno[1,2,3-c,d]pyrene**



Summary of Outlier Free Data

No. of Samples =	258
No. of Detects =	54
Mean =	52.5
CV (%) =	397.6
KM Mean =	48.4
KM CV (%) =	432
Slope (Detects) =	3.195
Intercept (Detects) =	1.143
R-Square (Detects)	0.9751

*KM = Kaplan-Meier estimate

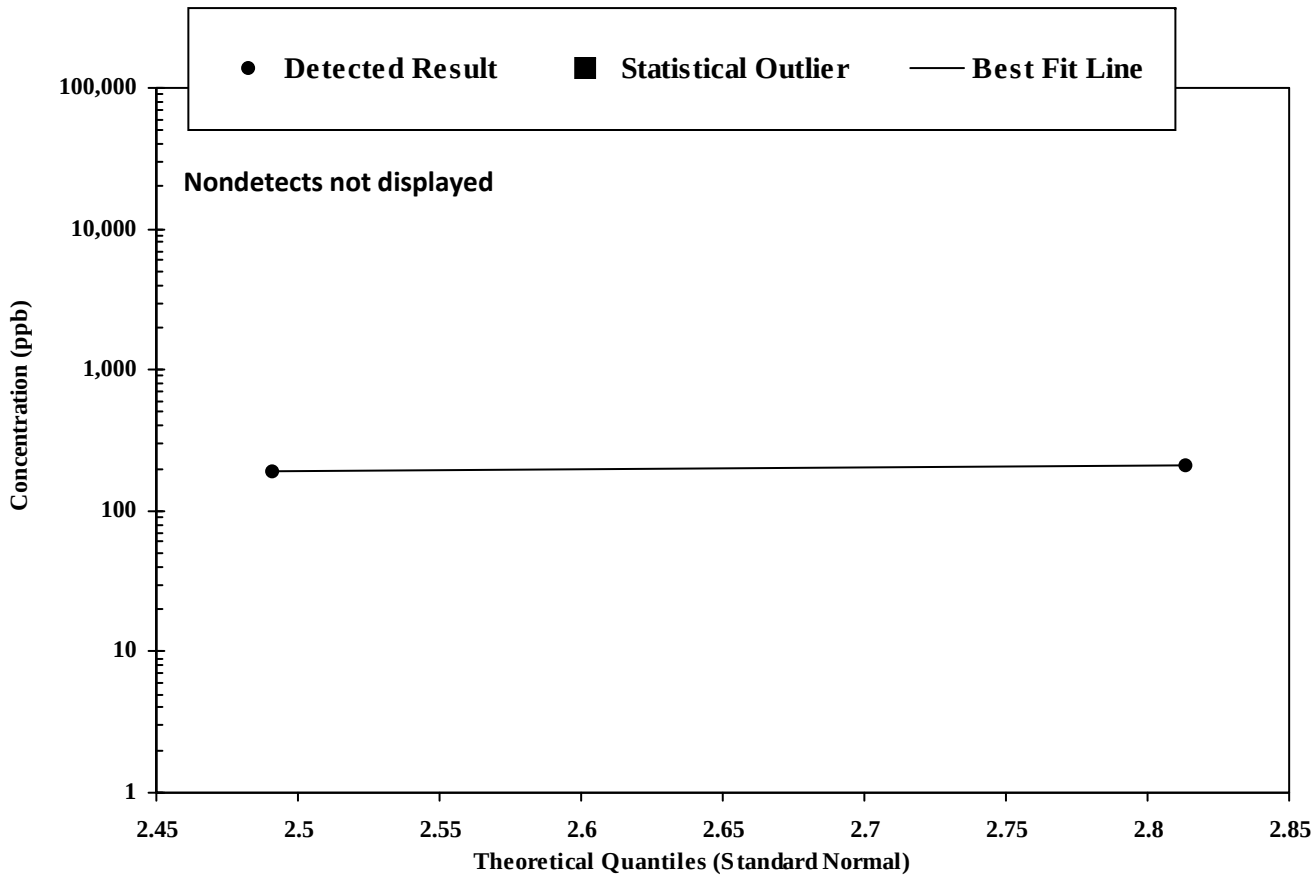
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Naphthalene**



Summary of Outlier Free Data

No. of Samples =	255
No. of Detects =	2
Mean =	44.5
CV (%) =	37.2
KM Mean =	3.55
KM CV (%) =	492
Slope (Detects) =	0.3103
Intercept (Detects) =	87.71
R-Square (Detects)	1

*KM = Kaplan-Meier estimate

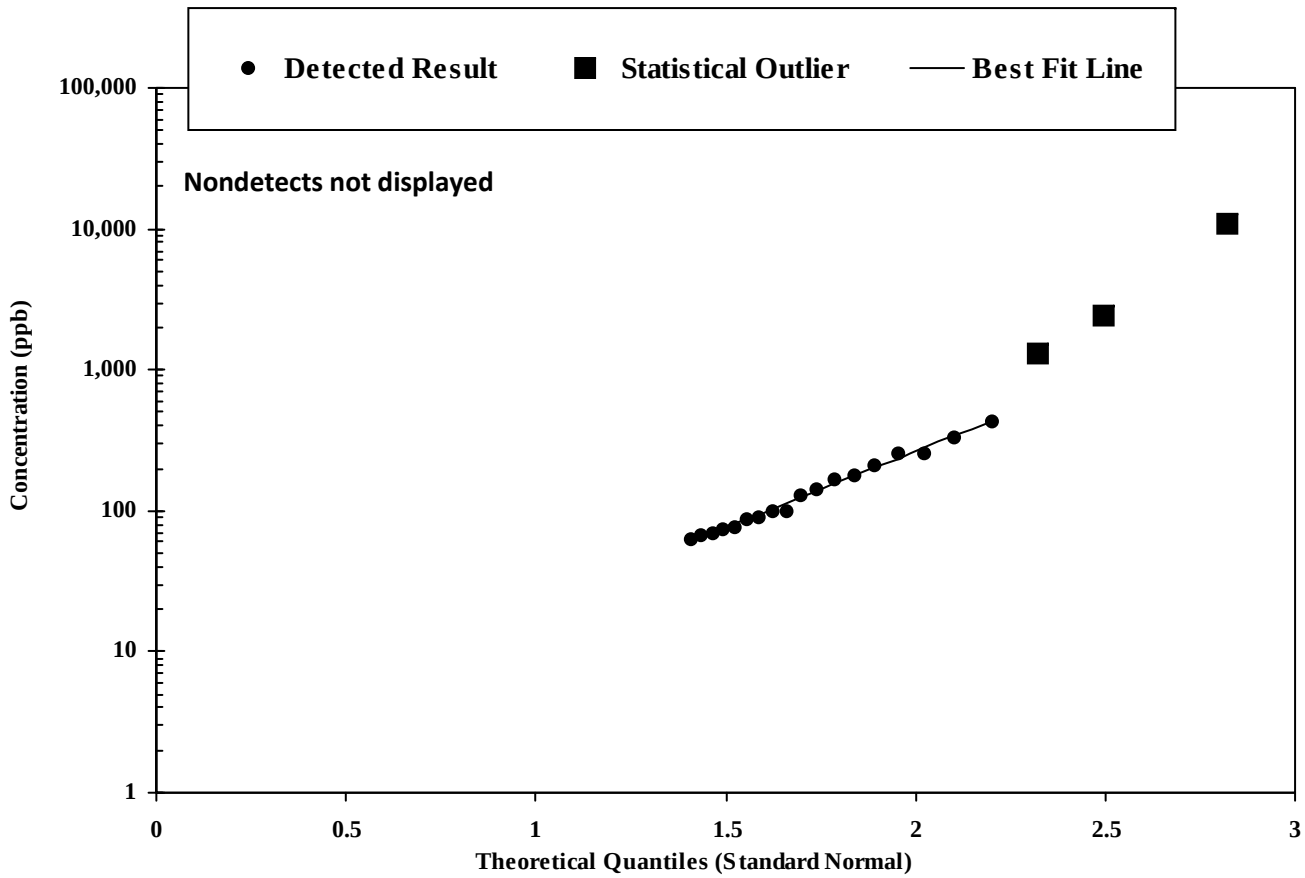
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Phenanthrene**



Summary of Outlier Free Data

No. of Samples =	257
No. of Detects =	18
Mean =	55.8
CV (%) =	71.3
KM Mean =	12
KM CV (%) =	402
Slope (Detects) =	2.498
Intercept (Detects) =	1.793
R-Square (Detects)	0.9912

*KM = Kaplan-Meier estimate

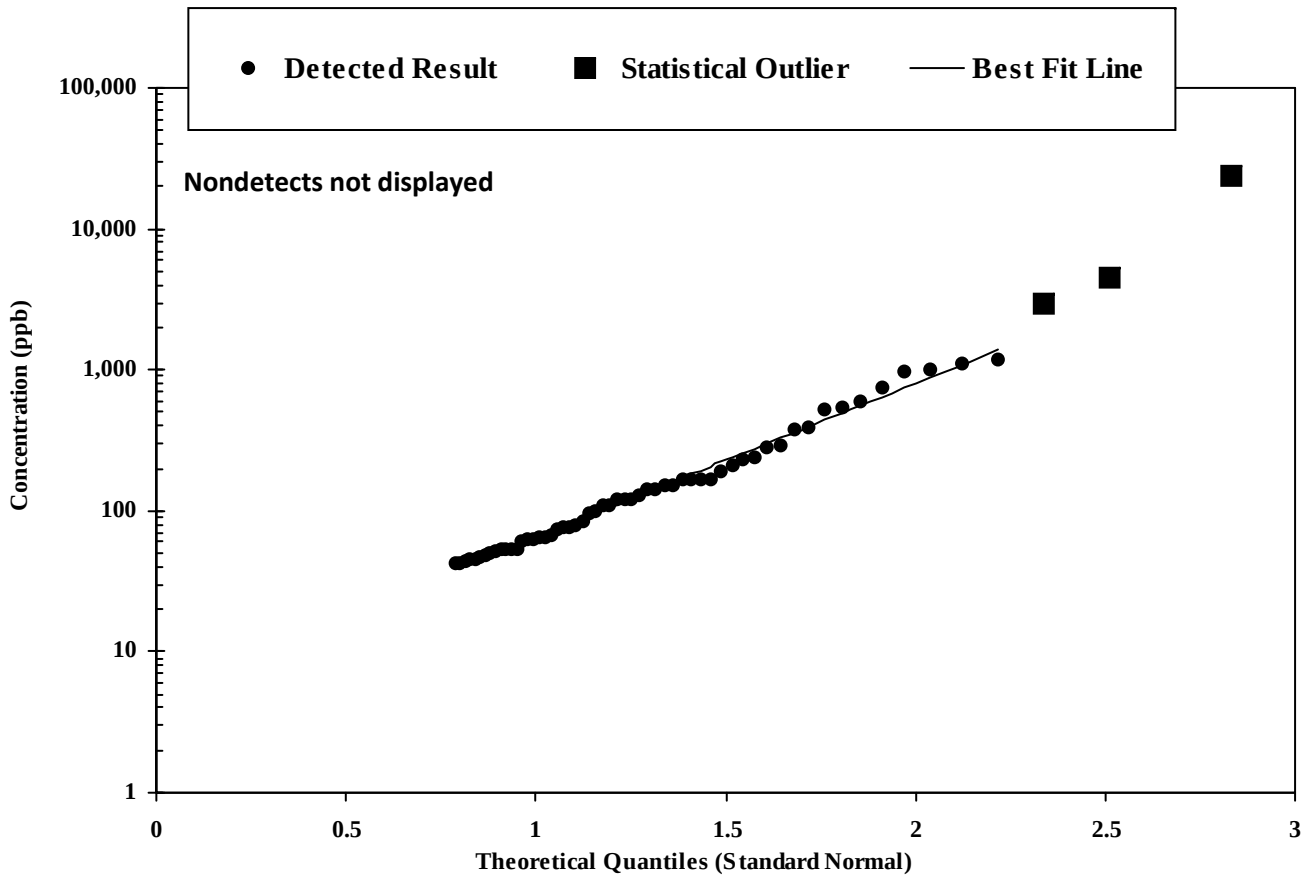
Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Lognormal Q-Q Plots of Detected PAHs of the Combined 2012 and 2014 Soil Background Studies

PAH: **Pyrene**



Summary of Outlier Free Data

No. of Samples =	269
No. of Detects =	56
Mean =	71.8
CV (%) =	207.9
KM Mean =	47.2
KM CV (%) =	330
Slope (Detects) =	2.51
Intercept (Detects) =	5.289
R-Square (Detects)	0.9917

*KM = Kaplan-Meier estimate

Notes:

1) Plotting positions only displayed for detect sample results. Plotting positions for detected data incorporate nondetects censored to the method detection limit.

2) Outliers identified using multivariate trimming (MTV) at the 99% significance level.

Appendix C

Background Sites and Sample Locations: 2014 Study

This page intentionally left blank

Table 1. Sample Coordinates: 2014 Study

NEW CASTLE COUNTY					
Brandywine Creek State Park, Site 16					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF16-SO01	185880.70	200520.02	REF16-SO11	185937.77	200524.12
REF16-SO02	185895.99	200535.31	REF16-SO12	185953.06	200539.41
REF16-SO03	185911.28	200550.60	REF16-SO13	185912.78	200472.64
REF16-SO04	185926.57	200565.89	REF16-SO14	185928.07	200487.94
REF16-SO05	185886.29	200499.13	REF16-SO15	185943.36	200503.23
REF16-SO06	185901.59	200514.42	REF16-SO16	185958.65	200518.52
REF16-SO07	185916.88	200529.71	REF16-SO17	185933.67	200467.05
REF16-SO08	185932.17	200545.00	REF16-SO18	185948.96	200482.34
REF16-SO09	185907.18	200493.53	REF16-SO19	185964.25	200497.63
REF16-SO10	185922.47	200508.82	REF16-SO20	185979.54	200512.92
Lums Pond State Park, Site 15					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF15-SO01	174070.21	173446.67	REF15-SO11	174113.54	173409.14
REF15-SO02	174091.69	173450.44	REF15-SO12	174131.62	173409.14
REF15-SO03	174113.54	173446.67	REF15-SO13	174056.36	173388.31
REF15-SO04	174140.11	173446.86	REF15-SO14	174081.04	173390.38
REF15-SO05	174059.38	173427.90	REF15-SO15	174102.71	173390.38
REF15-SO06	174081.04	173427.90	REF15-SO16	174124.37	173390.38
REF15-SO07	174110.63	173428.09	REF15-SO17	174070.21	173371.62
REF15-SO08	174124.37	173427.90	REF15-SO18	174091.88	173371.62
REF15-SO09	174070.21	173409.14	REF15-SO19	174113.54	173371.62
REF15-SO10	174091.88	173409.14	REF15-SO20	174131.81	173371.62
Banning Park, Site 9					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF09-SO01	184989.45	190936.37	REF09-SO11	185032.70	190898.91
REF09-SO02	185011.07	190936.37	REF09-SO12	185054.32	190898.91
REF09-SO03	185032.70	190936.37	REF09-SO13	184978.64	190880.19
REF09-SO04	185054.32	190936.37	REF09-SO14	185000.26	190880.19
REF09-SO05	184978.64	190917.64	REF09-SO15	185021.89	190880.19
REF09-SO06	185000.26	190917.64	REF09-SO16	185043.51	190880.19
REF09-SO07	185021.89	190917.64	REF09-SO17	184989.45	190861.46
REF09-SO08	185043.51	190917.64	REF09-SO18	185011.07	190861.46
REF09-SO09	184989.45	190898.91	REF09-SO19	185032.70	190861.46
REF09-SO10	185011.07	190898.91	REF09-SO20	185054.32	190861.46

Table 1. Sample Coordinates: 2014 Study

Bellevue State Park, Site 10					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF10-SO01	194161.61	197077.32	REF10-SO11	194204.86	197039.87
REF10-SO02	194183.23	197077.32	REF10-SO12	194226.48	197039.87
REF10-SO03	194204.86	197077.32	REF10-SO13	194150.79	197021.14
REF10-SO04	194226.48	197077.32	REF10-SO14	194172.42	197021.14
REF10-SO05	194150.79	197058.60	REF10-SO15	194194.04	197021.14
REF10-SO06	194172.42	197058.60	REF10-SO16	194215.67	197021.14
REF10-SO07	194194.04	197058.60	REF10-SO17	194161.61	197002.41
REF10-SO08	194215.67	197058.60	REF10-SO18	194183.23	197002.41
REF10-SO09	194161.61	197039.87	REF10-SO19	194204.86	197002.41
REF10-SO10	194183.23	197039.87	REF10-SO20	194226.48	197002.41
KENT COUNTY					
Norman Wilder Wildlife Area, Site 5					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF05-SO01	180655.48	115298.87	REF05-SO11	180623.05	115242.71
REF05-SO02	180601.43	115280.15	REF05-SO12	180644.67	115242.71
REF05-SO03	180623.05	115280.15	REF05-SO13	180666.29	115242.71
REF05-SO04	180644.67	115280.15	REF05-SO14	180687.90	115242.71
REF05-SO05	180666.29	115280.15	REF05-SO15	180612.24	115223.98
REF05-SO06	180612.24	115261.43	REF05-SO16	180633.86	115223.98
REF05-SO07	180633.86	115261.43	REF05-SO17	180655.48	115223.98
REF05-SO08	180655.48	115261.43	REF05-SO18	180677.09	115223.98
REF05-SO09	180677.09	115261.43	REF05-SO19	180623.05	115205.26
REF05-SO10	180601.43	115242.71	REF05-SO20	180644.67	115205.26
Norman Wilder Wildlife Area, Site 6					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF06-SO01	180013.67	115702.62	REF06-SO11	180057.02	115665.07
REF06-SO02	180035.34	115702.62	REF06-SO12	180078.69	115665.07
REF06-SO03	180057.02	115702.62	REF06-SO13	180002.83	115646.30
REF06-SO04	180078.69	115702.62	REF06-SO14	180024.50	115646.30
REF06-SO05	180002.83	115683.85	REF06-SO15	180046.18	115646.30
REF06-SO06	180024.50	115683.85	REF06-SO16	180067.85	115646.30
REF06-SO07	180046.18	115683.85	REF06-SO17	180013.67	115627.53
REF06-SO08	180067.85	115683.85	REF06-SO18	180035.34	115627.53
REF06-SO09	180013.67	115665.07	REF06-SO19	180057.02	115627.53
REF06-SO10	180035.34	115665.07	REF06-SO20	180078.69	115627.53

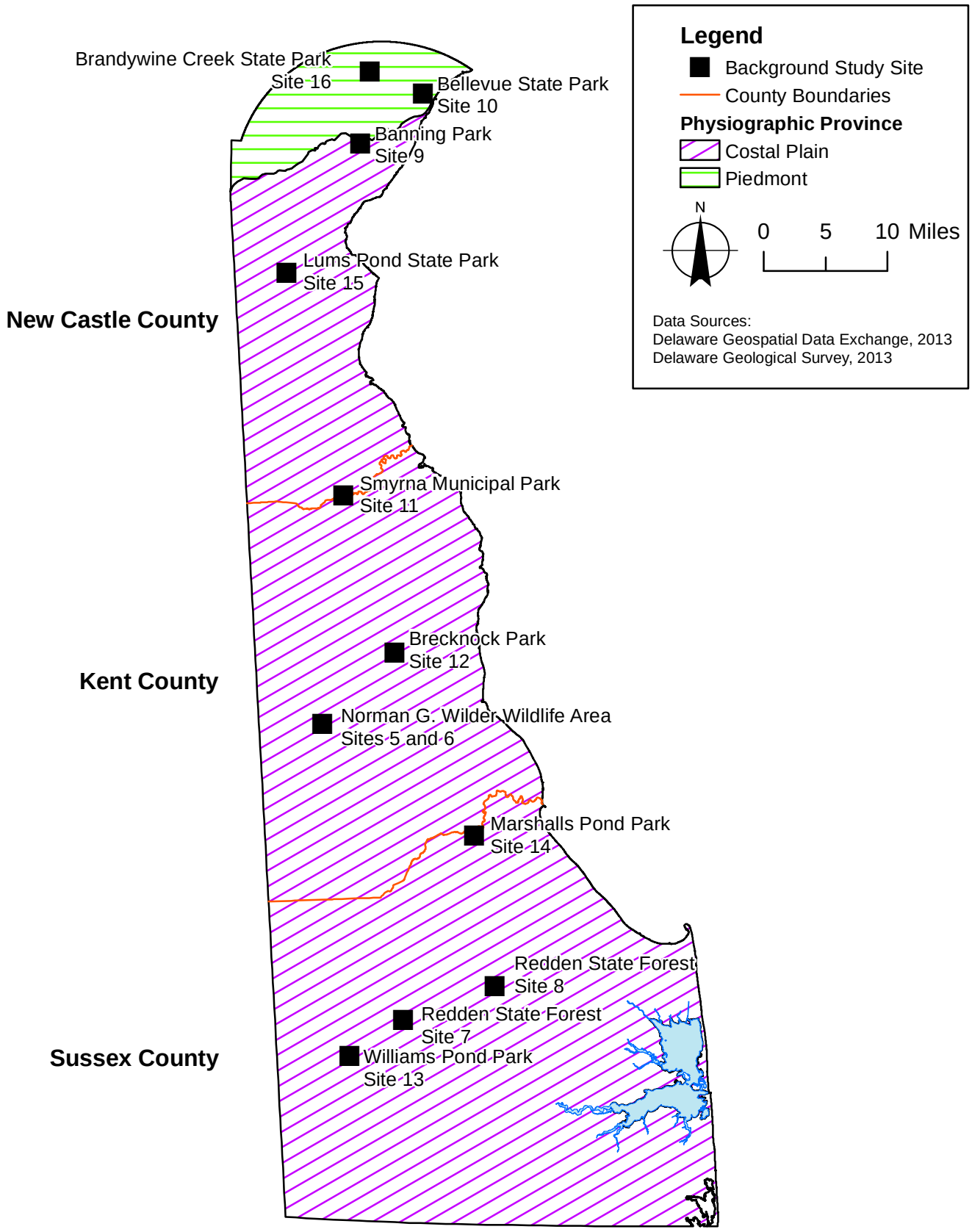
Table 1. Sample Coordinates: 2014 Study

Smyrna Municipal Park, Site 11					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF11-SO01	182955.25	145075.15	REF11-SO11	182995.87	145039.97
REF11-SO02	182975.56	145075.15	REF11-SO12	182945.09	145022.38
REF11-SO03	182995.87	145075.15	REF11-SO13	182965.40	145022.38
REF11-SO04	182945.09	145057.56	REF11-SO14	182985.72	145022.38
REF11-SO05	182965.40	145057.56	REF11-SO15	183006.03	145022.38
REF11-SO06	182985.72	145057.56	REF11-SO16	182934.93	145004.79
REF11-SO07	183006.03	145057.56	REF11-SO17	182955.25	145004.79
REF11-SO08	182934.93	145039.97	REF11-SO18	182975.56	145004.79
REF11-SO09	182955.25	145039.97	REF11-SO19	182995.87	145004.79
REF11-SO10	182975.56	145039.97	REF11-SO20	182985.72	144987.19
Brecknock Park, Site 12					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF12-SO01	189410.76	124674.93	REF12-SO11	189454.01	124637.47
REF12-SO02	189432.39	124674.93	REF12-SO12	189475.64	124637.47
REF12-SO03	189454.01	124674.93	REF12-SO13	189421.57	124618.74
REF12-SO04	189475.64	124674.93	REF12-SO14	189443.20	124618.74
REF12-SO05	189421.57	124656.20	REF12-SO15	189464.83	124618.74
REF12-SO06	189443.20	124656.20	REF12-SO16	189486.45	124618.74
REF12-SO07	189464.83	124656.20	REF12-SO17	189410.76	124600.02
REF12-SO08	189486.45	124656.20	REF12-SO18	189432.39	124600.02
REF12-SO09	189410.76	124637.47	REF12-SO19	189454.01	124600.02
REF12-SO10	189432.39	124637.47	REF12-SO20	189475.64	124600.02
SUSSEX COUNTY					
Redden State Forest, Site 7					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF07-SO01	190996.25	76930.02	REF07-SO11	190952.94	76817.49
REF07-SO02	190985.42	76911.26	REF07-SO12	190974.59	76817.49
REF07-SO03	191007.08	76911.26	REF07-SO13	190942.11	76798.74
REF07-SO04	190974.59	76892.51	REF07-SO14	190963.77	76798.74
REF07-SO05	190996.25	76892.51	REF07-SO15	190952.94	76779.98
REF07-SO06	190985.42	76873.75	REF07-SO16	190974.59	76779.98
REF07-SO07	190974.59	76855.00	REF07-SO17	190942.11	76761.23
REF07-SO08	190996.25	76855.00	REF07-SO18	190963.77	76761.23
REF07-SO09	190963.77	76836.25	REF07-SO19	190931.28	76742.47
REF07-SO10	190985.42	76836.25	REF07-SO20	190952.94	76742.47

Table 1. Sample Coordinates: 2014 Study

Redden State Forest, Site 8					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF08-SO01	202889.15	81364.58	REF08-SO11	202932.46	81327.07
REF08-SO02	202910.80	81364.58	REF08-SO12	202954.12	81327.07
REF08-SO03	202932.46	81364.58	REF08-SO13	202878.32	81308.32
REF08-SO04	202954.12	81364.58	REF08-SO14	202899.97	81308.32
REF08-SO05	202878.32	81345.83	REF08-SO15	202921.63	81308.32
REF08-SO06	202899.97	81345.83	REF08-SO16	202943.29	81308.32
REF08-SO07	202921.63	81345.83	REF08-SO17	202889.15	81289.56
REF08-SO08	202943.29	81345.83	REF08-SO18	202910.80	81289.56
REF08-SO09	202889.15	81327.07	REF08-SO19	202932.46	81289.56
REF08-SO10	202910.80	81327.07	REF08-SO20	202954.12	81289.56
Williams Pond Park, Site 13					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF13-SO01	184012.15	72149.84	REF13-SO11	184044.27	72094.20
REF13-SO02	183980.02	72131.29	REF13-SO12	184065.69	72094.20
REF13-SO03	184001.44	72131.29	REF13-SO13	184012.15	72075.65
REF13-SO04	184022.86	72131.29	REF13-SO14	184033.56	72075.65
REF13-SO05	183972.02	72115.90	REF13-SO15	184054.98	72075.65
REF13-SO06	183990.73	72112.74	REF13-SO16	184073.02	72078.80
REF13-SO07	184012.15	72112.74	REF13-SO17	184022.86	72057.10
REF13-SO08	184033.56	72112.74	REF13-SO18	184044.27	72057.10
REF13-SO09	184001.44	72094.20	REF13-SO19	184065.69	72057.10
REF13-SO10	184022.86	72094.20	REF13-SO20	184033.56	72038.55
Marshall's Pond Park, Site 14					
Location	X-Coordinate	Y-Coordinate	Location	X-Coordinate	Y-Coordinate
REF14-SO01	200162.46	100771.27	REF14-SO11	200240.99	100712.97
REF14-SO02	200184.90	100771.27	REF14-SO12	200207.34	100693.54
REF14-SO03	200155.82	100751.84	REF14-SO13	200229.77	100693.54
REF14-SO04	200173.68	100751.84	REF14-SO14	200218.56	100674.11
REF14-SO05	200196.12	100751.84	REF14-SO15	200235.46	100674.11
REF14-SO06	200184.90	100732.41	REF14-SO16	200207.34	100654.68
REF14-SO07	200207.34	100732.41	REF14-SO17	200229.77	100654.68
REF14-SO08	200227.49	100732.21	REF14-SO18	200199.17	100637.54
REF14-SO09	200196.12	100712.97	REF14-SO19	200218.56	100635.25
REF14-SO10	200218.56	100712.97	REF14-SO20	200234.51	100636.01

Projected Coordinate System: NAD_1983_StatePlane_Delaware_FIPS_0700, meters.

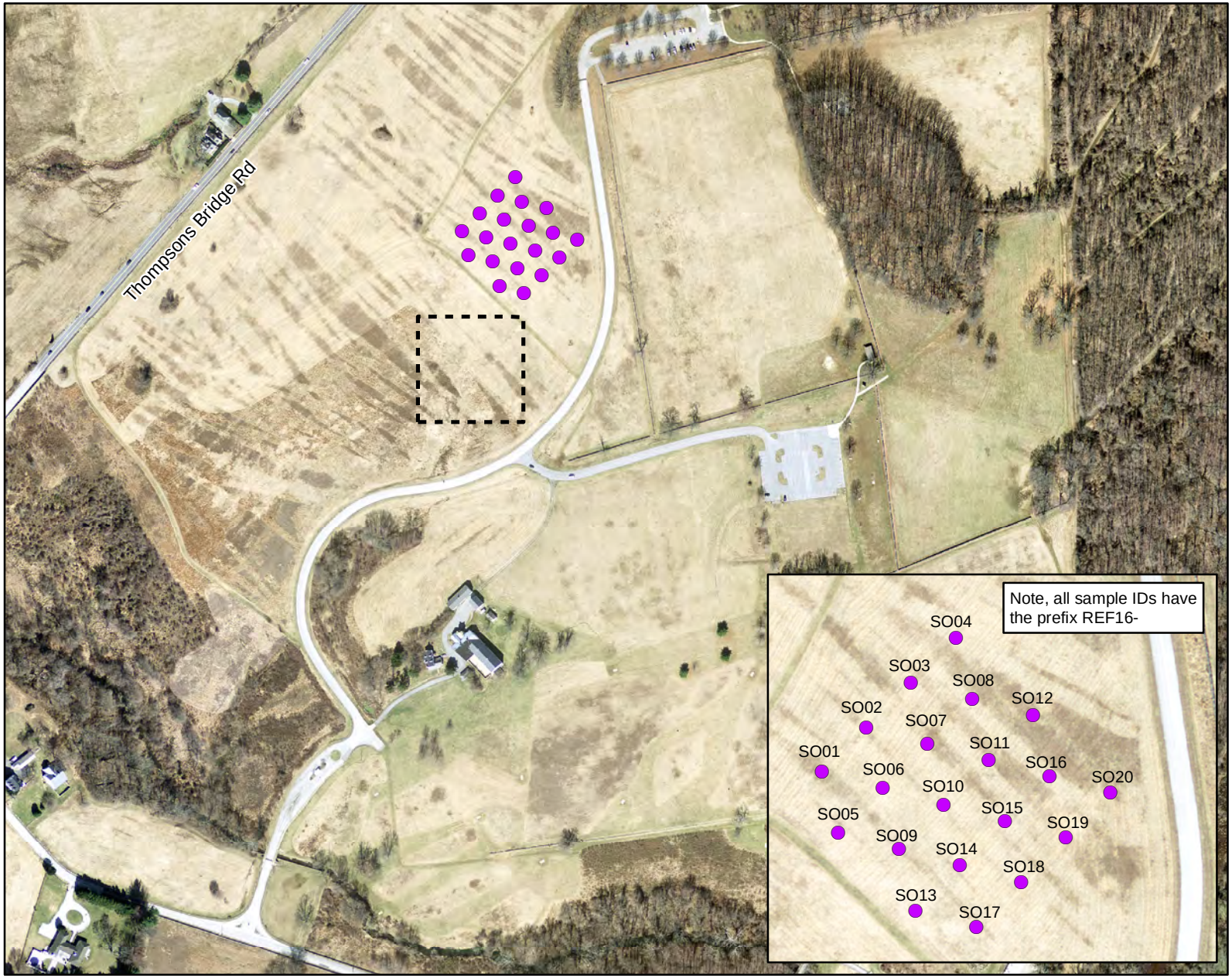


PAH Background Study
New Castle, Kent, and
Sussex Counties, Delaware

Figure 1
Geologic Provinces and
Reference Area Locations

EA Engineering, Science, and Technology, Inc.

\\abingdon\projects\Universal GIS\DNREC\MXD\PAH Study\1_Site Locations.mxd



Legend

- 2013 Sample Location
- Sampling Grid from 2012 Background Study

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500
Feet

Scale for sample name detail:

0 100 200
Feet

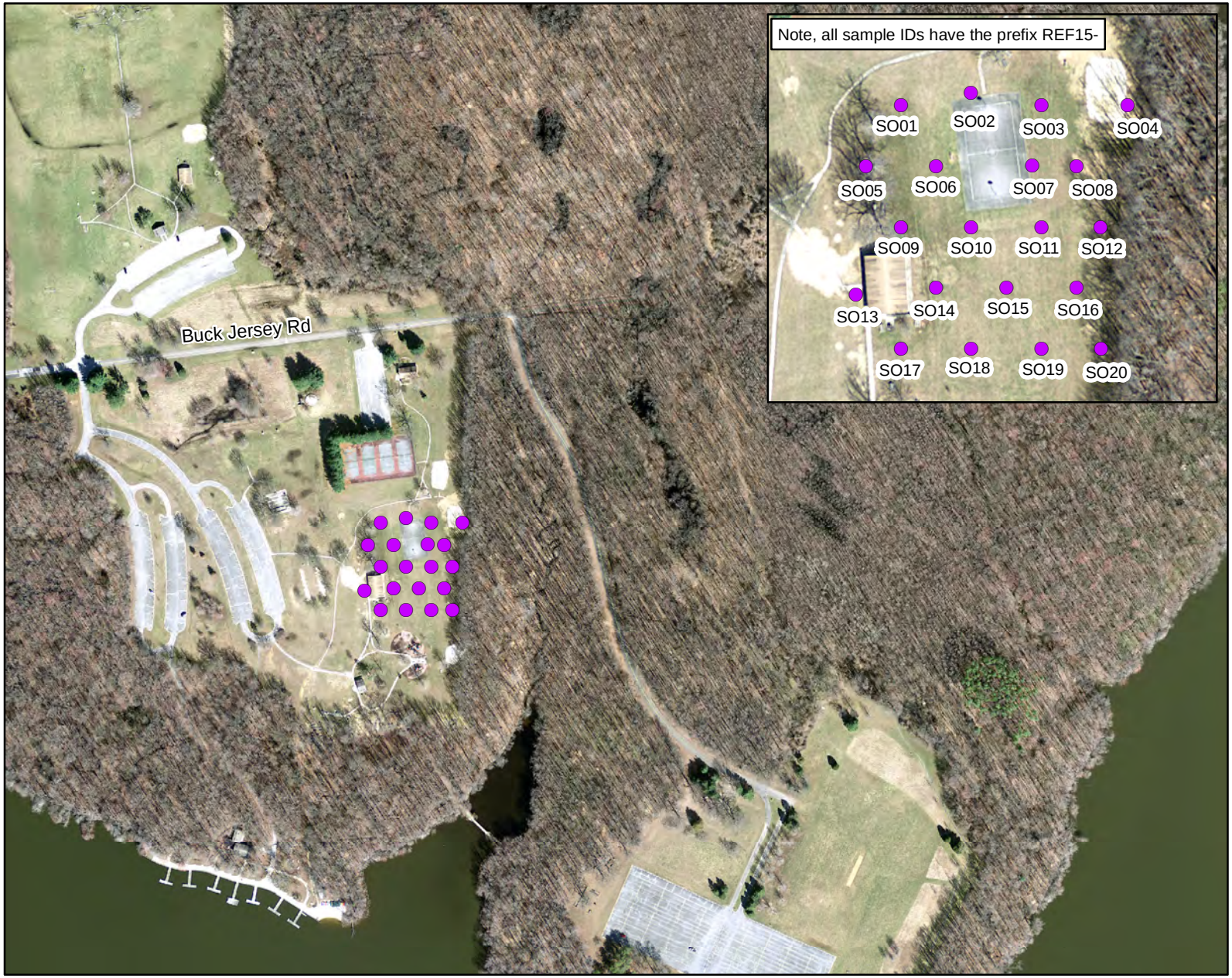
EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 2
Sample Locations in Brandywine Creek State Park, Site 16

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_2-Brandywine.mxd



Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500

Feet

Scale for sample name detail:

0 100 200

Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 3
Sample Locations in Lums Pond State Park, Site 15

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_3-Lums.mxd

Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500

Feet

Scale for sample name detail:

0 100 200

Feet

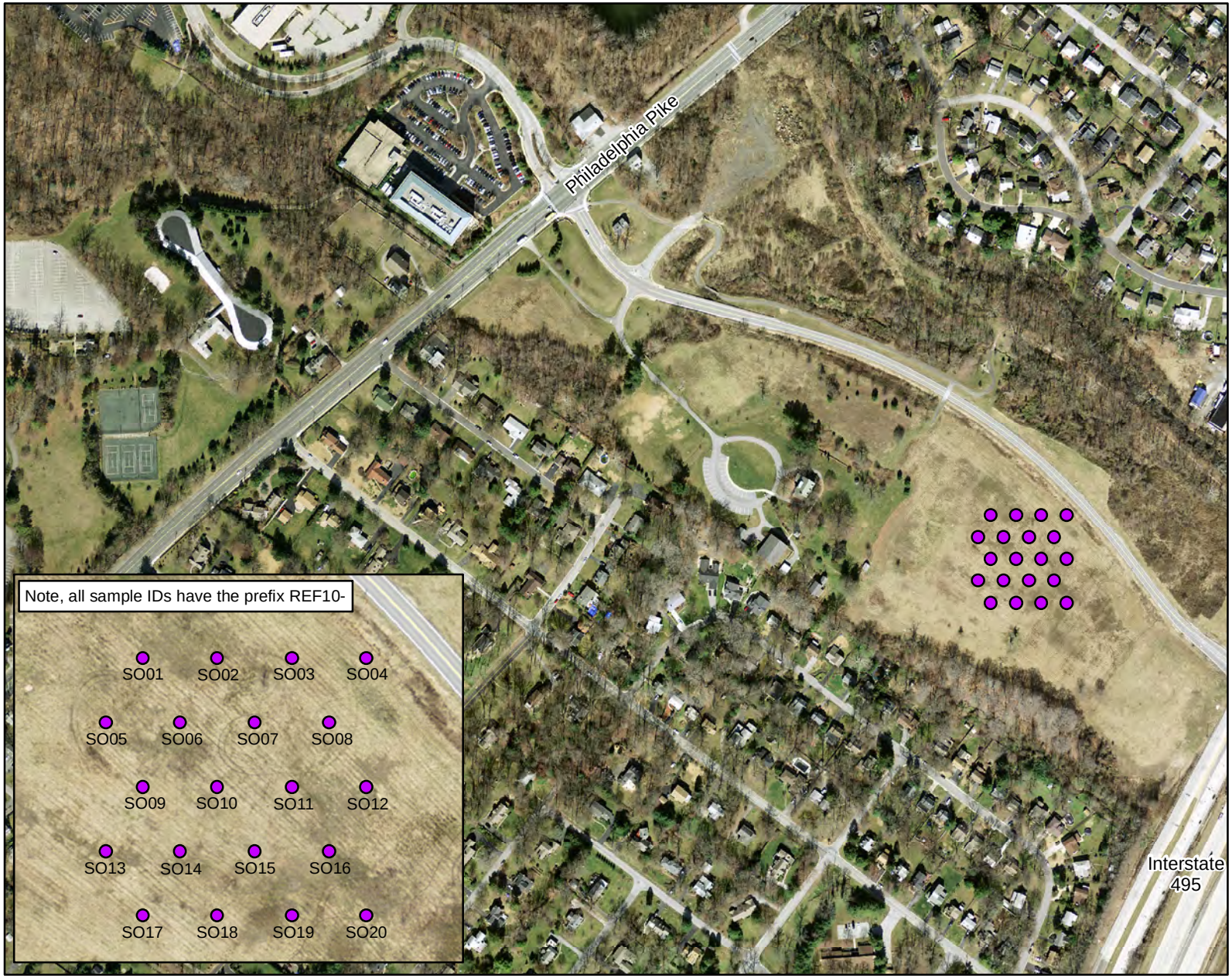
EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 4
Sample Locations in Banning Park, Site 9

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_4-Banning.mxd



Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500

Feet

Scale for sample name detail:

0 100 200

Feet

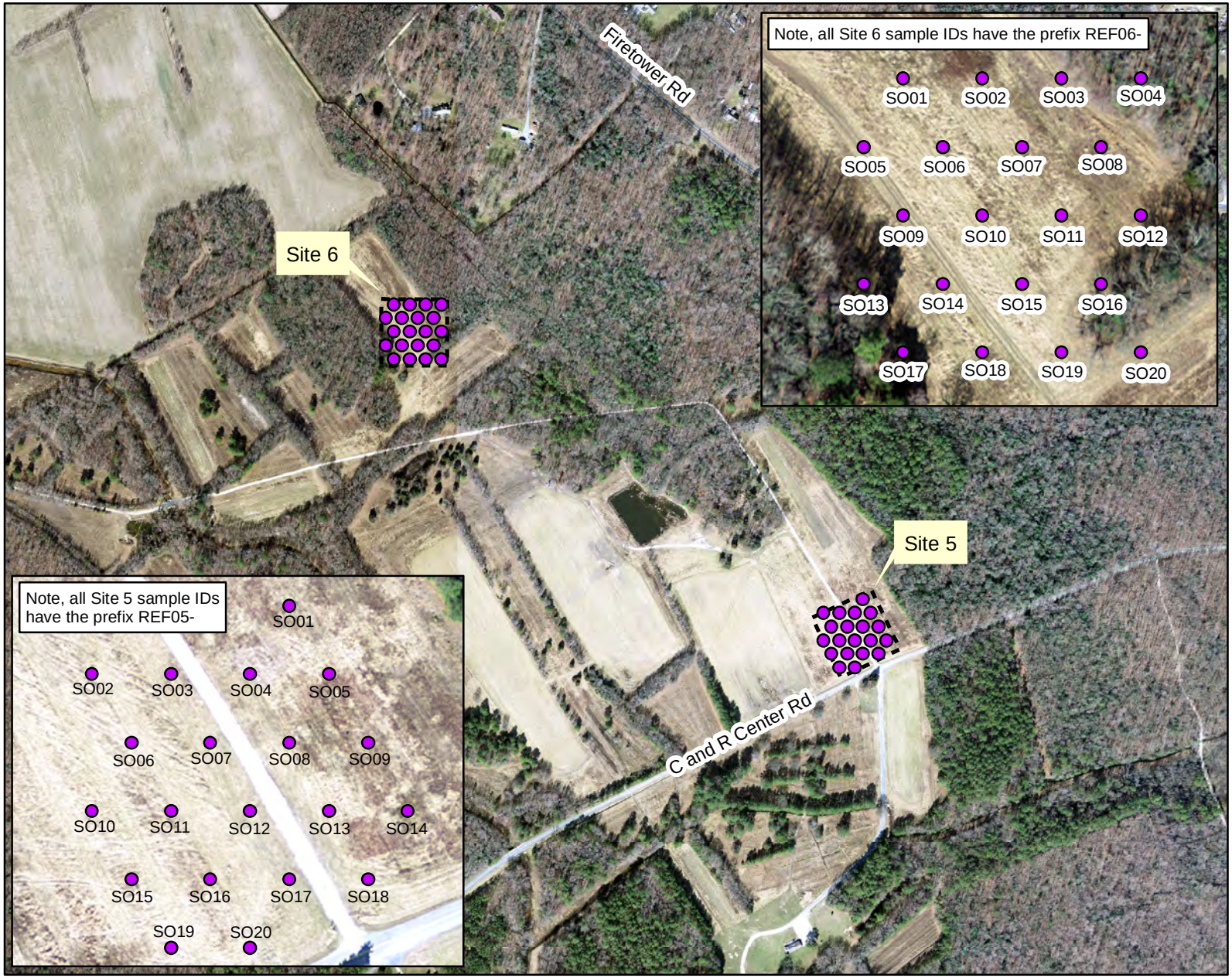
EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 5
Sample Locations in Bellevue State Park, Site 10

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_5-Bellevue.mxd



Legend

- 2013 Sample Location
- Sampling Grid from 2012 Background Study

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 400 800

Feet

Scale for sample name detail maps:

0 100 200

Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 6
Sample Locations at Norman G. Wilder Wildlife Area, Sites 5 and 6

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_6-Wilder.mxd

Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500

Feet

Scale for sample name detail:

0 75 150

Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 7
Sample Locations in Smyrna Municipal Park, Site 11

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_7-Smyrna.mxd

Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500
Feet

Scale for sample name detail:

0 75 150
Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 8
Sample Locations in Brecknock Park, Site 12

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_8-Brecknock.mxd

Legend

- 2013 Sample Location
- Sampling Grid from 2012 Background Study

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500
Feet

Scale for sample name detail:

0 100 200
Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 9
Sample Locations in Redden State Forest, Site 7

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_9-Redden7.mxd

Legend

- 2013 Sample Location
- Sampling Grid from 2012 Background Study

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500
Feet

Scale for sample name detail:

0 100 200
Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 10
Sampling Locations in Redden State Forest, Site 8

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_10-Redden8.mxd

Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500

Feet

Scale for sample name detail:

0 100 200

Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 11
Sample Locations in Williams Pond Park, Site 13

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_11-Williams.mxd

Legend

2013 Sample Location

Aerial Image: USGS, 2012

N

Scale for Main Map:

0 250 500
Feet

Scale for sample name detail:

0 100 200
Feet

EA Engineering, Science, and Technology, Inc.

PAH Background Study

New Castle, Kent, and Sussex Counties, Delaware

Figure 12
Sample Locations in Marshalls Pond Park, Site 14

\\abingdon\projects\Universal GIS\DNREC\MXDs\PAH Study\Rpt_of_Findings_12-Marshalls.mxd

Appendix D

PAH Background Study Raw and Reduced Datasets (provided as an Excel file)

This page intentionally left blank

Appendix E

ProUCL Outputs

This page intentionally left blank

Background Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	12/15/2015 10:21:09 PM
From File	proucl_data.xls
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
Different or Future K Observations	1
Number of Bootstrap Operations	2000

Result (2-chloronaphthalene)

General Statistics

Total Number of Observations	240	Number of Missing Observations	0
Number of Distinct Observations	16		
Number of Detects	0	Number of Non-Detects	240
Number of Distinct Detects	0	Number of Distinct Non-Detects	16
Minimum Detect	N/A	Minimum Non-Detect	38
Maximum Detect	N/A	Maximum Non-Detect	54
Variance Detected	N/A	Percent Non-Detects	100%
Mean Detected	N/A	SD Detected	N/A
Mean of Detected Logged Data	N/A	SD of Detected Logged Data	N/A

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 Result (2-chloronaphthalene) was not processed!

Result (2-methylnaphthalene)

General Statistics

Total Number of Observations	240	Number of Missing Observations	0
Number of Distinct Observations	18		
Number of Detects	0	Number of Non-Detects	240
Number of Distinct Detects	0	Number of Distinct Non-Detects	18
Minimum Detect	N/A	Minimum Non-Detect	44
Maximum Detect	N/A	Maximum Non-Detect	63
Variance Detected	N/A	Percent Non-Detects	100%
Mean Detected	N/A	SD Detected	N/A
Mean of Detected Logged Data	N/A	SD of Detected Logged Data	N/A

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 Result (2-methylnaphthalene) was not processed!

Result (acenaphthene)

General Statistics

Total Number of Observations	246	Number of Missing Observations	0
Number of Distinct Observations	25		
Number of Detects	2	Number of Non-Detects	244
Number of Distinct Detects	2	Number of Distinct Non-Detects	23
Minimum Detect	75	Minimum Non-Detect	3
Maximum Detect	1500	Maximum Non-Detect	71
Variance Detected	1015313	Percent Non-Detects	99.19%
Mean Detected	787.5	SD Detected	1008
Mean of Detected Logged Data	5.815	SD of Detected Logged Data	2.118

Warning: Data set has only 2 Detected Values.

This is not enough to compute meaningful or reliable statistics and estimates.

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.816	d2max (for USL)	3.495

Normal GOF Test on Detects Only

Not Enough Data to Perform GOF Test

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	9.378	SD	95.34
95% UTL95% Coverage	182.5	95% KM UPL (t)	167.1
90% KM Percentile (z)	131.6	95% KM Percentile (z)	166.2
99% KM Percentile (z)	231.2	95% KM USL	342.6

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	34.27	SD	93.94
95% UTL95% Coverage	204.9	95% UPL (t)	189.7
90% Percentile (z)	154.7	95% Percentile (z)	188.8
99% Percentile (z)	252.8	95% USL	362.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

Not Enough Data to Perform GOF Test

Gamma Statistics on Detected Data Only

k hat (MLE)	0.707	k star (bias corrected MLE)	N/A
Theta hat (MLE)	1114	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	2.828	nu star (bias corrected)	N/A
MLE Mean (bias corrected)	N/A		
MLE Sd (bias corrected)	N/A	95% Percentile of Chisquare (2k)	N/A

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.00968		nu hat (KM)	4.76
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	19.52	14.14	95% Approx. Gamma UPL	17.2	12.66
95% Gamma USL	54.89	38.49			

Lognormal GOF Test on Detected Observations Only

Not Enough Data to Perform GOF Test

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	6.403	Mean in Log Scale	-28.17
SD in Original Scale	95.74	SD in Log Scale	10.72
95% UTL95% Coverage	1.6422E-4	95% BCA UTL95% Coverage	6.5291E-5
95% Bootstrap (%) UTL95% Coverage	1.7887E-4	95% UPL (t)	2.9162E-5
90% Percentile (z)	5.3632E-7	95% Percentile (z)	2.6313E-5
99% Percentile (z)	0.0391	95% USL	10669

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	34.27	Mean in Log Scale	3.334
SD in Original Scale	93.94	SD in Log Scale	0.393
95% UTL95% Coverage	57.24	95% UPL (t)	53.72
90% Percentile (z)	46.4	95% Percentile (z)	53.52
99% Percentile (z)	69.95	95% USL	110.7

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	239	95% UTL with95% Coverage	66
Approximate f	1.572	Confidence Coefficient (CC) achieved by UTL	0.928
95% UPL	65	95% USL	1500
95% KM Chebyshev UPL	425.8		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (acenaphthylene)

General Statistics

Total Number of Observations	246	Number of Missing Observations	0
Number of Distinct Observations	25		
Number of Detects	3	Number of Non-Detects	243
Number of Distinct Detects	3	Number of Distinct Non-Detects	22
Minimum Detect	79	Minimum Non-Detect	1
Maximum Detect	510	Maximum Non-Detect	58
Variance Detected	47100	Percent Non-Detects	98.78%
Mean Detected	279.7	SD Detected	217
Mean of Detected Logged Data	5.375	SD of Detected Logged Data	0.941

Warning: Data set has only 3 Detected Values.

This is not enough to compute meaningful or reliable statistics and estimates.

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.816	d2max (for USL)	3.495

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.986	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.767	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.221	Lilliefors GOF Test
5% Lilliefors Critical Value	0.512	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	4.398	SD	36.31
95% UTL95% Coverage	70.33	95% KM UPL (t)	64.47
90% KM Percentile (z)	50.93	95% KM Percentile (z)	64.12
99% KM Percentile (z)	88.87	95% KM USL	131.3

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	25.82	SD	34.56
95% UTL95% Coverage	88.57	95% UPL (t)	83
90% Percentile (z)	70.11	95% Percentile (z)	82.67
99% Percentile (z)	106.2	95% USL	146.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

Not Enough Data to Perform GOF Test

Gamma Statistics on Detected Data Only

k hat (MLE)	2.086	k star (bias corrected MLE)	N/A
Theta hat (MLE)	134.1	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	12.51	nu star (bias corrected)	N/A
MLE Mean (bias corrected)	N/A		
MLE Sd (bias corrected)	N/A	95% Percentile of Chisquare (2k)	N/A

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	3.42
Maximum	510	Median	0.01
SD	36.48	CV	10.66
k hat (MLE)	0.136	k star (bias corrected MLE)	0.137
Theta hat (MLE)	25.08	Theta star (bias corrected MLE)	24.89
nu hat (MLE)	67.1	nu star (bias corrected)	67.61
MLE Mean (bias corrected)	3.42	MLE Sd (bias corrected)	9.227
95% Percentile of Chisquare (2k)	1.537	90% Percentile	9.999
95% Percentile	19.13	99% Percentile	46.12

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	3.513	1.416	95% Approx. Gamma UPL	2.8	1.108
95% Gamma USL	18.8	9.744			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0147	nu hat (KM)		7.219
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	9.825	7.093	95% Approx. Gamma UPL	8.5	6.216
95% Gamma USL	30.93	22.73			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.982	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.767	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.228	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.512	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	3.587	Mean in Log Scale	-6.504
SD in Original Scale	36.47	SD in Log Scale	4.112
95% UTL95% Coverage	2.62	95% BCA UTL95% Coverage	2.093
95% Bootstrap (%) UTL95% Coverage	2.093	95% UPL (t)	1.349
90% Percentile (z)	0.291	95% Percentile (z)	1.297
99% Percentile (z)	21.39	95% USL	2609

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	0.0656	95% KM UTL (Lognormal)95% Coverage	3.151
KM SD of Logged Data	0.596	95% KM UPL (Lognormal)	2.862
95% KM Percentile Lognormal (z)	2.846	95% KM USL (Lognormal)	8.571

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	25.82	Mean in Log Scale	3.111
SD in Original Scale	34.56	SD in Log Scale	0.482
95% UTL95% Coverage	53.83	95% UPL (t)	49.81
90% Percentile (z)	41.62	95% Percentile (z)	49.58
99% Percentile (z)	68.84	95% USL	120.9

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	239	95% UTL with95% Coverage	54
Approximate f	1.572	Confidence Coefficient (CC) achieved by UTL	0.928
95% UPL	53	95% USL	510
95% KM Chebyshev UPL	163		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (anthracene)

General Statistics

Total Number of Observations	253	Number of Missing Observations	0
Number of Distinct Observations	29		
Number of Detects	7	Number of Non-Detects	246
Number of Distinct Detects	7	Number of Distinct Non-Detects	22
Minimum Detect	67	Minimum Non-Detect	1
Maximum Detect	2400	Maximum Non-Detect	59
Variance Detected	716713	Percent Non-Detects	97.23%
Mean Detected	546.1	SD Detected	846.6
Mean of Detected Logged Data	5.441	SD of Detected Logged Data	1.364

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.813	d2max (for USL)	3.503

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.653	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.803	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.313	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.335	Detected Data appear Normal at 5% Significance Level

Detected Data appear Approximate Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	16.08	SD	158.1
95% UTL95% Coverage	302.7	95% KM UPL (t)	277.6
90% KM Percentile (z)	218.7	95% KM Percentile (z)	276.1
99% KM Percentile (z)	383.9	95% KM USL	569.8

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	37.48	SD	156.4
95% UTL95% Coverage	321.2	95% UPL (t)	296.3
90% Percentile (z)	238	95% Percentile (z)	294.8
99% Percentile (z)	401.4	95% USL	585.5

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.609	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.739	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.278	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.324	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.701	k star (bias corrected MLE)	0.496
Theta hat (MLE)	779.4	Theta star (bias corrected MLE)	1102
nu hat (MLE)	9.81	nu star (bias corrected)	6.939
MLE Mean (bias corrected)	546.1		
MLE Sd (bias corrected)	775.8	95% Percentile of Chisquare (2k)	3.82

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	15.12
Maximum	2400	Median	0.01
SD	158.5	CV	10.48
k hat (MLE)	0.113	k star (bias corrected MLE)	0.115
Theta hat (MLE)	133.3	Theta star (bias corrected MLE)	131.8
nu hat (MLE)	57.4	nu star (bias corrected)	58.05
MLE Mean (bias corrected)	15.12	MLE Sd (bias corrected)	44.64
95% Percentile of Chisquare (2k)	1.316	90% Percentile	42.28
95% Percentile	86.74	99% Percentile	224

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	16.89	7.056	95% Approx. Gamma UPL	13.4	5.392
95% Gamma USL	96.55	57.7			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0103	nu hat (KM)		5.237
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	30.31	19.62	95% Approx. Gamma UPL	25.5	16.5
95% Gamma USL	120.8	86.99			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.875	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.234	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.335	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	15.35	Mean in Log Scale	-6.354
SD in Original Scale	158.5	SD in Log Scale	4.636
95% UTL95% Coverage	7.792	95% BCA UTL95% Coverage	8.864
95% Bootstrap (%) UTL95% Coverage	8.864	95% UPL (t)	3.728
90% Percentile (z)	0.662	95% Percentile (z)	3.57
99% Percentile (z)	84.12	95% USL	19668

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	0.151	95% KM UTL (Lognormal)95% Coverage	6.127
KM SD of Logged Data	0.917	95% KM UPL (Lognormal)	5.296
95% KM Percentile Lognormal (z)	5.251	95% KM USL (Lognormal)	28.84

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	37.48	Mean in Log Scale	3.133
SD in Original Scale	156.4	SD in Log Scale	0.685
95% UTL95% Coverage	79.51	95% UPL (t)	71.3
90% Percentile (z)	55.23	95% Percentile (z)	70.85
99% Percentile (z)	113	95% USL	253.2

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	245	95% UTL with95% Coverage	59
Approximate f	1.433	Confidence Coefficient (CC) achieved by UTL	0.889
95% UPL	56	95% USL	2400
95% KM Chebyshev UPL	706.5		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (benzo[a]anthracene)

General Statistics

Total Number of Observations	262	Number of Missing Observations	0
Number of Distinct Observations	56		
Number of Detects	55	Number of Non-Detects	207
Number of Distinct Detects	44	Number of Distinct Non-Detects	12
Minimum Detect	5	Minimum Non-Detect	2
Maximum Detect	720	Maximum Non-Detect	3.4
Variance Detected	26456	Percent Non-Detects	79.01%
Mean Detected	121.4	SD Detected	162.7
Mean of Detected Logged Data	4.166	SD of Detected Logged Data	1.13

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.81	d2max (for USL)	3.513

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.649	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	3.331E-16	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.119	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	27.06	SD	88.41
95% UTL95% Coverage	187.1	95% KM UPL (t)	173.3
90% KM Percentile (z)	140.4	95% KM Percentile (z)	172.5
99% KM Percentile (z)	232.7	95% KM USL	337.6

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	26.56	SD	88.72
95% UTL95% Coverage	187.1	95% UPL (t)	173.3

90% Percentile (z)	140.3	95% Percentile (z)	172.5
99% Percentile (z)	232.9	95% USL	338.2

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	1.71	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.784	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.168	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.124	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.922	k star (bias corrected MLE)	0.883
Theta hat (MLE)	131.7	Theta star (bias corrected MLE)	137.4
nu hat (MLE)	101.4	nu star (bias corrected)	97.18
MLE Mean (bias corrected)	121.4		
MLE Sd (bias corrected)	129.1	95% Percentile of Chisquare (2k)	5.532

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	25.49
Maximum	720	Median	0.01
SD	89.03	CV	3.493
k hat (MLE)	0.131	k star (bias corrected MLE)	0.132
Theta hat (MLE)	195.1	Theta star (bias corrected MLE)	193.6
nu hat (MLE)	68.44	nu star (bias corrected)	68.99
MLE Mean (bias corrected)	25.49	MLE Sd (bias corrected)	70.24
95% Percentile of Chisquare (2k)	1.483	90% Percentile	73.86
95% Percentile	143.5	99% Percentile	351.5

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	85.21	74.43	95% Approx. Gamma UPL	69.[illegible]	57.91
95% Gamma USL	427	568.6			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0937		nu hat (KM)	49.08
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	93.61	84.82	95% Approx. Gamma UPL	80.[illegible]	71.44
95% Gamma USL	346.9	382.9			

Lognormal GOF Test on Detected Observations Only

Lilliefors Test Statistic	0.0863	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.119	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	27.63	Mean in Log Scale	0.876
SD in Original Scale	88.47	SD in Log Scale	2.314
95% UTL95% Coverage	158.2	95% BCA UTL95% Coverage	150
95% Bootstrap (%) UTL95% Coverage	245	95% UPL (t)	110.2
90% Percentile (z)	46.56	95% Percentile (z)	107.9
99% Percentile (z)	522.2	95% USL	8133

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.422	95% KM UTL (Lognormal)95% Coverage	63.16
KM SD of Logged Data	1.505	95% KM UPL (Lognormal)	49.93
95% KM Percentile Lognormal (z)	49.25	95% KM USL (Lognormal)	818.8

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	26.56	Mean in Log Scale	1.119
SD in Original Scale	88.72	SD in Log Scale	1.657
95% UTL95% Coverage	61.47	95% UPL (t)	47.45
90% Percentile (z)	25.6	95% Percentile (z)	46.75
99% Percentile (z)	144.6	95% USL	1033

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	254	95% UTL with95% Coverage	250
Approximate f	1.485	Confidence Coefficient (CC) achieved by UTL	0.91
95% UPL	128.5	95% USL	720
95% KM Chebyshev UPL	413.2		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (benzo[a]pyrene)

General Statistics

Total Number of Observations	258	Number of Missing Observations	0
Number of Distinct Observations	69		
Number of Detects	83	Number of Non-Detects	175
Number of Distinct Detects	58	Number of Distinct Non-Detects	11
Minimum Detect	4	Minimum Non-Detect	2
Maximum Detect	210	Maximum Non-Detect	3.4
Variance Detected	2922	Percent Non-Detects	67.83%
Mean Detected	55.73	SD Detected	54.06
Mean of Detected Logged Data	3.554	SD of Detected Logged Data	1.017

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.811	d2max (for USL)	3.509

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.802	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	4.441E-16	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.169	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0973	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	19.29	SD	39.48
95% UTL95% Coverage	90.81	95% KM UPL (t)	84.59
90% KM Percentile (z)	69.88	95% KM Percentile (z)	84.23
99% KM Percentile (z)	111.1	95% KM USL	157.8

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	18.87	SD	39.74
95% UTL95% Coverage	90.86	95% UPL (t)	84.6
90% Percentile (z)	69.8	95% Percentile (z)	84.24
99% Percentile (z)	111.3	95% USL	158.3

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.833	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.777	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0813	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.101	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.21	k star (bias corrected MLE)	1.175
Theta hat (MLE)	46.05	Theta star (bias corrected MLE)	47.45
nu hat (MLE)	200.9	nu star (bias corrected)	195
MLE Mean (bias corrected)	55.73		
MLE Sd (bias corrected)	51.43	95% Percentile of Chisquare (2k)	6.651

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	17.94
Maximum	210	Median	0.01
SD	40.16	CV	2.239
k hat (MLE)	0.157	k star (bias corrected MLE)	0.158
Theta hat (MLE)	114.3	Theta star (bias corrected MLE)	113.8
nu hat (MLE)	80.95	nu star (bias corrected)	81.34
MLE Mean (bias corrected)	17.94	MLE Sd (bias corrected)	45.18
95% Percentile of Chisquare (2k)	1.718	90% Percentile	53.52
95% Percentile	97.74	99% Percentile	224.8

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	76.78	79.95	95% Approx. Gamma UPL	63.5	63.16
95% Gamma USL	350.9	546.2			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.239	nu hat (KM)		123.1
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	72.46	71.1	95% Approx. Gamma UPL	62.9	60.74
95% Gamma USL	242.1	286			

Lognormal GOF Test on Detected Observations Only

Lilliefors Test Statistic	0.0686	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0973	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	19.75	Mean in Log Scale	1.45
SD in Original Scale	39.41	SD in Log Scale	1.839
95% UTL95% Coverage	119.3	95% BCA UTL95% Coverage	134.5
95% Bootstrap (%) UTL95% Coverage	141.5	95% UPL (t)	89.29
90% Percentile (z)	45.01	95% Percentile (z)	87.8
99% Percentile (z)	307.5	95% USL	2704

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.613	95% KM UTL (Lognormal)95% Coverage	69.92
KM SD of Logged Data	1.454	95% KM UPL (Lognormal)	55.61
95% KM Percentile Lognormal (z)	54.87	95% KM USL (Lognormal)	824.6

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	18.87	Mean in Log Scale	1.361
SD in Original Scale	39.74	SD in Log Scale	1.62
95% UTL95% Coverage	73.35	95% UPL (t)	56.83
90% Percentile (z)	31.09	95% Percentile (z)	56
99% Percentile (z)	168.9	95% USL	1147

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	250	95% UTL with95% Coverage	140
Approximate f	1.462	Confidence Coefficient (CC) achieved by UTL	0.901
95% UPL	110	95% USL	210
95% KM Chebyshev UPL	191.7		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (benzo[b]fluoranthene)

General Statistics

Total Number of Observations	238	Number of Missing Observations	0
Number of Distinct Observations	57		
Number of Detects	79	Number of Non-Detects	159
Number of Distinct Detects	48	Number of Distinct Non-Detects	9
Minimum Detect	6	Minimum Non-Detect	2.2
Maximum Detect	240	Maximum Non-Detect	3.1
Variance Detected	4279	Percent Non-Detects	66.81%
Mean Detected	67.73	SD Detected	65.42
Mean of Detected Logged Data	3.731	SD of Detected Logged Data	1.026

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.819	d2max (for USL)	3.485

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.804	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	8.882E-15	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.196	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0997	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	23.95	SD	48.53
95% UTL95% Coverage	112.2	95% KM UPL (t)	104.3
90% KM Percentile (z)	86.14	95% KM Percentile (z)	103.8
99% KM Percentile (z)	136.8	95% KM USL	193.1

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	23.31	SD	48.92
95% UTL95% Coverage	112.3	95% UPL (t)	104.3
90% Percentile (z)	86	95% Percentile (z)	103.8
99% Percentile (z)	137.1	95% USL	193.8

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	1.714	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.778	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.117	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.103	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.169	k star (bias corrected MLE)	1.133
Theta hat (MLE)	57.92	Theta star (bias corrected MLE)	59.76
nu hat (MLE)	184.8	nu star (bias corrected)	179.1
MLE Mean (bias corrected)	67.73		
MLE Sd (bias corrected)	63.62	95% Percentile of Chisquare (2k)	6.499

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	22.49
Maximum	240	Median	0.01
SD	49.29	CV	2.192
k hat (MLE)	0.155	k star (bias corrected MLE)	0.155
Theta hat (MLE)	145.5	Theta star (bias corrected MLE)	144.7
nu hat (MLE)	73.57	nu star (bias corrected)	73.97
MLE Mean (bias corrected)	22.49	MLE Sd (bias corrected)	57.05
95% Percentile of Chisquare (2k)	1.699	90% Percentile	67
95% Percentile	122.9	99% Percentile	284

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	97.87	103	95% Approx. Gamma UPL	80.[illegible]	80.59
95% Gamma USL	435.7	683.1			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.244		nu hat (KM)	116
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	91.49	90.04	95% Approx. Gamma UPL	78.[illegible]	76.2
95% Gamma USL	303.5	360.9			

Lognormal GOF Test on Detected Observations Only

Lilliefors Test Statistic	0.0877	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0997	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Approximate Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	24.61	Mean in Log Scale	1.651
SD in Original Scale	48.39	SD in Log Scale	1.858
95% UTL95% Coverage	152.9	95% BCA UTL95% Coverage	180
95% Bootstrap (%) UTL95% Coverage	180	95% UPL (t)	112.8
90% Percentile (z)	56.36	95% Percentile (z)	110.7
99% Percentile (z)	392.7	95% USL	3379

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.765	95% KM UTL (Lognormal)95% Coverage	90.18
KM SD of Logged Data	1.505	95% KM UPL (Lognormal)	70.46
95% KM Percentile Lognormal (z)	69.41	95% KM USL (Lognormal)	1106

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	23.31	Mean in Log Scale	1.378
SD in Original Scale	48.92	SD in Log Scale	1.764
95% UTL95% Coverage	98.08	95% UPL (t)	73.44
90% Percentile (z)	38.03	95% Percentile (z)	72.17
99% Percentile (z)	240.1	95% USL	1852

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	231	95% UTL with95% Coverage	180
Approximate f	1.52	Confidence Coefficient (CC) achieved by UTL	0.912
95% UPL	160	95% USL	240
95% KM Chebyshev UPL	235.9		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (benzo[g,h,i]perylene)

General Statistics

Total Number of Observations	259	Number of Missing Observations	0
Number of Distinct Observations	45		
Number of Detects	38	Number of Non-Detects	221
Number of Distinct Detects	30	Number of Distinct Non-Detects	15
Minimum Detect	37	Minimum Non-Detect	2
Maximum Detect	2100	Maximum Non-Detect	36
Variance Detected	234489	Percent Non-Detects	85.33%
Mean Detected	314.8	SD Detected	484.2
Mean of Detected Logged Data	5.023	SD of Detected Logged Data	1.1

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.811	d2max (for USL)	3.51

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.599	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.938	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.341	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.144	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	47.9	SD	213.9
95% UTL95% Coverage	435.3	95% KM UPL (t)	401.7
90% KM Percentile (z)	322	95% KM Percentile (z)	399.7
99% KM Percentile (z)	545.5	95% KM USL	798.6

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	58.15	SD	212.2
95% UTL95% Coverage	442.4	95% UPL (t)	409
90% Percentile (z)	330	95% Percentile (z)	407.1
99% Percentile (z)	551.7	95% USL	802.7

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	3.271	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.786	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.274	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.148	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.813	k star (bias corrected MLE)	0.766
Theta hat (MLE)	387.4	Theta star (bias corrected MLE)	410.9
nu hat (MLE)	61.77	nu star (bias corrected)	58.23
MLE Mean (bias corrected)	314.8		
MLE Sd (bias corrected)	359.7	95% Percentile of Chisquare (2k)	5.049

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	46.2
Maximum	2100	Median	0.01
SD	214.7	CV	4.646
k hat (MLE)	0.114	k star (bias corrected MLE)	0.115
Theta hat (MLE)	406.4	Theta star (bias corrected MLE)	401.9
nu hat (MLE)	58.89	nu star (bias corrected)	59.55
MLE Mean (bias corrected)	46.2	MLE Sd (bias corrected)	136.3
95% Percentile of Chisquare (2k)	1.319	90% Percentile	129.3
95% Percentile	265	99% Percentile	683.8

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	122.2	90.95	95% Approx. Gamma UPL	98.6	69.77
95% Gamma USL	648.1	747.3			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0501		nu hat (KM)	25.98
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	145.2	120.6	95% Approx. Gamma UPL	122.5	99.82
95% Gamma USL	589.8	608.7			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.871	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.938	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.192	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.144	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	50.02	Mean in Log Scale	0.878
SD in Original Scale	213.9	SD in Log Scale	2.524
95% UTL95% Coverage	232.5	95% BCA UTL95% Coverage	253
95% Bootstrap (%) UTL95% Coverage	397	95% UPL (t)	156.4
90% Percentile (z)	61.09	95% Percentile (z)	152.8
99% Percentile (z)	853.5	95% USL	16913

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	58.15	Mean in Log Scale	2.942
SD in Original Scale	212.2	SD in Log Scale	1.046
95% UTL95% Coverage	125.9	95% UPL (t)	106.8
90% Percentile (z)	72.37	95% Percentile (z)	105.8
99% Percentile (z)	215.8	95% USL	743.7

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	251	95% UTL with95% Coverage	380
Approximate f	1.468	Confidence Coefficient (CC) achieved by UTL	0.904
95% UPL	150	95% USL	2100
95% KM Chebyshev UPL	982		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (benzo[k]fluoranthene)

General Statistics

Total Number of Observations	256	Number of Missing Observations	0
Number of Distinct Observations	53		
Number of Detects	49	Number of Non-Detects	207
Number of Distinct Detects	41	Number of Distinct Non-Detects	12
Minimum Detect	4	Minimum Non-Detect	1
Maximum Detect	700	Maximum Non-Detect	3.7
Variance Detected	21097	Percent Non-Detects	80.86%
Mean Detected	113	SD Detected	145.2
Mean of Detected Logged Data	3.965	SD of Detected Logged Data	1.337

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.812	d2max (for USL)	3.506

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.725	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.947	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.25	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.127	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	22.43	SD	76.78
95% UTL95% Coverage	161.6	95% KM UPL (t)	149.4
90% KM Percentile (z)	120.8	95% KM Percentile (z)	148.7
99% KM Percentile (z)	201.1	95% KM USL	291.7

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	22.81	SD	76.83
95% UTL95% Coverage	162	95% UPL (t)	149.9
90% Percentile (z)	121.3	95% Percentile (z)	149.2
99% Percentile (z)	201.5	95% USL	292.2

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.681	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.791	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.109	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.132	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.781	k star (bias corrected MLE)	0.747
Theta hat (MLE)	144.6	Theta star (bias corrected MLE)	151.2
nu hat (MLE)	76.58	nu star (bias corrected)	73.22
MLE Mean (bias corrected)	113		
MLE Sd (bias corrected)	130.7	95% Percentile of Chisquare (2k)	4.968

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	21.63
Maximum	700	Median	0.01
SD	77.16	CV	3.567
k hat (MLE)	0.13	k star (bias corrected MLE)	0.131
Theta hat (MLE)	166.5	Theta star (bias corrected MLE)	165.1
nu hat (MLE)	66.51	nu star (bias corrected)	67.06
MLE Mean (bias corrected)	21.63	MLE Sd (bias corrected)	59.76
95% Percentile of Chisquare (2k)	1.477	90% Percentile	62.62
95% Percentile	121.9	99% Percentile	299.1

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	68.42	57.06	95% Approx. Gamma UPL	55.6	44.2
95% Gamma USL	345	436.2			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0853		nu hat (KM)	43.69
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	75.77	66.64	95% Approx. Gamma UPL	64.0	55.21
95% Gamma USL	300	330.4			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.947	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0836	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.127	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	22.72	Mean in Log Scale	-0.115
SD in Original Scale	76.87	SD in Log Scale	2.759
95% UTL95% Coverage	132.2	95% BCA UTL95% Coverage	250
95% Bootstrap (%) UTL95% Coverage	255	95% UPL (t)	85.47
90% Percentile (z)	30.58	95% Percentile (z)	83.32
99% Percentile (z)	546.1	95% USL	14154

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	0.759	95% KM UTL (Lognormal)95% Coverage	43.56
KM SD of Logged Data	1.664	95% KM UPL (Lognormal)	33.49
95% KM Percentile Lognormal (z)	32.98	95% KM USL (Lognormal)	730

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	22.81	Mean in Log Scale	1.069
SD in Original Scale	76.83	SD in Log Scale	1.53
95% UTL95% Coverage	46.57	95% UPL (t)	36.57
90% Percentile (z)	20.68	95% Percentile (z)	36.05
99% Percentile (z)	102.3	95% USL	621.7

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	248	95% UTL with95% Coverage	250
Approximate f	1.45	Confidence Coefficient (CC) achieved by UTL	0.897
95% UPL	131.5	95% USL	700
95% KM Chebyshev UPL	357.8		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (chrysene)

General Statistics

Total Number of Observations	262	Number of Missing Observations	0
Number of Distinct Observations	50		
Number of Detects	39	Number of Non-Detects	223
Number of Distinct Detects	30	Number of Distinct Non-Detects	20
Minimum Detect	58	Minimum Non-Detect	1
Maximum Detect	990	Maximum Non-Detect	57
Variance Detected	60236	Percent Non-Detects	85.11%
Mean Detected	230.9	SD Detected	245.4
Mean of Detected Logged Data	5.054	SD of Detected Logged Data	0.826

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.81	d2max (for USL)	3.513

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.69	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.31	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.142	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	35.23	SD	124.2
95% UTL95% Coverage	260.1	95% KM UPL (t)	240.7
90% KM Percentile (z)	194.4	95% KM Percentile (z)	239.6
99% KM Percentile (z)	324.3	95% KM USL	471.7

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	53.28	SD	119.7
95% UTL95% Coverage	269.9	95% UPL (t)	251.2
90% Percentile (z)	206.7	95% Percentile (z)	250.2
99% Percentile (z)	331.7	95% USL	473.8

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	2.421	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.768	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.22	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.144	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.432	k star (bias corrected MLE)	1.339
Theta hat (MLE)	161.3	Theta star (bias corrected MLE)	172.5
nu hat (MLE)	111.7	nu star (bias corrected)	104.4
MLE Mean (bias corrected)	230.9		
MLE Sd (bias corrected)	199.6	95% Percentile of Chisquare (2k)	7.248

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	34.39
Maximum	990	Median	0.01
SD	124.7	CV	3.627
k hat (MLE)	0.118	k star (bias corrected MLE)	0.12
Theta hat (MLE)	290.2	Theta star (bias corrected MLE)	287.4
nu hat (MLE)	62.08	nu star (bias corrected)	62.7
MLE Mean (bias corrected)	34.39	MLE Sd (bias corrected)	99.4
95% Percentile of Chisquare (2k)	1.366	90% Percentile	97.35
95% Percentile	196.3	99% Percentile	498.5

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	103.6	82.11	95% Approx. Gamma UPL	84.(	63.25
95% Gamma USL	543	667.3			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

k hat (KM)	0.0804		nu hat (KM)	42.13	
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	116.5	100.4	95% Approx. Gamma UPL	97.8	82.32
95% Gamma USL	491.6	547.1			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.886	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.939	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.151	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.142	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	42.14	Mean in Log Scale	1.974
SD in Original Scale	123	SD in Log Scale	1.854
95% UTL95% Coverage	206.5	95% BCA UTL95% Coverage	336
95% Bootstrap (%) UTL95% Coverage	340	95% UPL (t)	154.6
90% Percentile (z)	77.52	95% Percentile (z)	152
99% Percentile (z)	537.9	95% USL	4856

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	53.28	Mean in Log Scale	3.333
SD in Original Scale	119.7	SD in Log Scale	0.928
95% UTL95% Coverage	150.2	95% UPL (t)	129.9
90% Percentile (z)	91.98	95% Percentile (z)	128.8
99% Percentile (z)	242.4	95% USL	728.8

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	254	95% UTL with95% Coverage	340
Approximate f	1.485	Confidence Coefficient (CC) achieved by UTL	0.91
95% UPL	178.5	95% USL	990
95% KM Chebyshev UPL	577.8		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (dibenz[a,h]anthracene)

General Statistics

Total Number of Observations	253	Number of Missing Observations	0
Number of Distinct Observations	43		
Number of Detects	30	Number of Non-Detects	223
Number of Distinct Detects	23	Number of Distinct Non-Detects	20
Minimum Detect	8	Minimum Non-Detect	2
Maximum Detect	2700	Maximum Non-Detect	6.1
Variance Detected	252828	Percent Non-Detects	88.14%
Mean Detected	189.9	SD Detected	502.8
Mean of Detected Logged Data	3.917	SD of Detected Logged Data	1.457

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.813	d2max (for USL)	3.503

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.384	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.927	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.373	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.162	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	24.28	SD	180.8
95% UTL95% Coverage	352	95% KM UPL (t)	323.3
90% KM Percentile (z)	255.9	95% KM Percentile (z)	321.6
99% KM Percentile (z)	444.8	95% KM USL	657.4

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	24.67	SD	181.1
95% UTL95% Coverage	353	95% UPL (t)	324.2
90% Percentile (z)	256.7	95% Percentile (z)	322.5
99% Percentile (z)	445.9	95% USL	658.9

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	2.398	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.813	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.219	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.17	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.481	k star (bias corrected MLE)	0.455
Theta hat (MLE)	395.2	Theta star (bias corrected MLE)	417.6
nu hat (MLE)	28.84	nu star (bias corrected)	27.29
MLE Mean (bias corrected)	189.9		
MLE Sd (bias corrected)	281.6	95% Percentile of Chisquare (2k)	3.614

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	22.53
Maximum	2700	Median	0.01
SD	181.3	CV	8.048
k hat (MLE)	0.118	k star (bias corrected MLE)	0.12
Theta hat (MLE)	190.3	Theta star (bias corrected MLE)	188.3
nu hat (MLE)	59.91	nu star (bias corrected)	60.54
MLE Mean (bias corrected)	22.53	MLE Sd (bias corrected)	65.14
95% Percentile of Chisquare (2k)	1.366	90% Percentile	63.78
95% Percentile	128.6	99% Percentile	326.7

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	43.42	27.63	95% Approx. Gamma UPL	34.8	21.2
95% Gamma USL	232.5	220.5			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0181	nu hat (KM)		9.134
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	61.54	47.46	95% Approx. Gamma UPL	52.4	40.08
95% Gamma USL	230.1	203.7			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.923	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.927	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.127	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.162	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Approximate Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	22.92	Mean in Log Scale	-2.316
SD in Original Scale	181.3	SD in Log Scale	3.466
95% UTL95% Coverage	52.9	95% BCA UTL95% Coverage	93.4
95% Bootstrap (%) UTL95% Coverage	100.4	95% UPL (t)	30.48
90% Percentile (z)	8.379	95% Percentile (z)	29.51
99% Percentile (z)	313.2	95% USL	18479

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.075	95% KM UTL (Lognormal)95% Coverage	23.71
KM SD of Logged Data	1.153	95% KM UPL (Lognormal)	19.74
95% KM Percentile Lognormal (z)	19.53	95% KM USL (Lognormal)	166.4

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	24.67	Mean in Log Scale	1.245
SD in Original Scale	181.1	SD in Log Scale	1.106
95% UTL95% Coverage	25.79	95% UPL (t)	21.63
90% Percentile (z)	14.33	95% Percentile (z)	21.41
99% Percentile (z)	45.49	95% USL	167

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	245	95% UTL with95% Coverage	94
Approximate f	1.433	Confidence Coefficient (CC) achieved by UTL	0.889
95% UPL	58	95% USL	2700
95% KM Chebyshev UPL	813.7		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (fluoranthene)

General Statistics

Total Number of Observations	267	Number of Missing Observations	0
Number of Distinct Observations	54		
Number of Detects	36	Number of Non-Detects	231
Number of Distinct Detects	29	Number of Distinct Non-Detects	25
Minimum Detect	76	Minimum Non-Detect	2
Maximum Detect	1200	Maximum Non-Detect	65
Variance Detected	92864	Percent Non-Detects	86.52%
Mean Detected	296.3	SD Detected	304.7
Mean of Detected Logged Data	5.298	SD of Detected Logged Data	0.846

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.808	d2max (for USL)	3.519

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.716	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.935	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.257	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.148	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	41.67	SD	149.2
95% UTL95% Coverage	311.6	95% KM UPL (t)	288.5
90% KM Percentile (z)	232.9	95% KM Percentile (z)	287.2
99% KM Percentile (z)	388.9	95% KM USL	566.8

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	61.82	SD	144.4
95% UTL95% Coverage	322.9	95% UPL (t)	300.5
90% Percentile (z)	246.8	95% Percentile (z)	299.3
99% Percentile (z)	397.6	95% USL	569.7

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	2.123	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.768	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.184	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.15	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.414	k star (bias corrected MLE)	1.314
Theta hat (MLE)	209.6	Theta star (bias corrected MLE)	225.4
nu hat (MLE)	101.8	nu star (bias corrected)	94.63
MLE Mean (bias corrected)	296.3		
MLE Sd (bias corrected)	258.4	95% Percentile of Chisquare (2k)	7.16

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	39.95
Maximum	1200	Median	0.01
SD	150	CV	3.754
k hat (MLE)	0.115	k star (bias corrected MLE)	0.116
Theta hat (MLE)	348.4	Theta star (bias corrected MLE)	344.8
nu hat (MLE)	61.24	nu star (bias corrected)	61.88
MLE Mean (bias corrected)	39.95	MLE Sd (bias corrected)	117.4
95% Percentile of Chisquare (2k)	1.328	90% Percentile	112.1
95% Percentile	228.9	99% Percentile	588.9

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	114	86.66	95% Approx. Gamma UPL	92.3	66.7
95% Gamma USL	610.2	723.9			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.078		nu hat (KM)	41.64
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	135.9	116.6	95% Approx. Gamma UPL	115.2	96.87
95% Gamma USL	550.7	590.7			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.884	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.935	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.135	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.148	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Approximate Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	48.56	Mean in Log Scale	1.975
SD in Original Scale	148.1	SD in Log Scale	1.914
95% UTL95% Coverage	229.8	95% BCA UTL95% Coverage	361
95% Bootstrap (%) UTL95% Coverage	388	95% UPL (t)	170.9
90% Percentile (z)	83.82	95% Percentile (z)	168
99% Percentile (z)	619.4	95% USL	6070

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.314	95% KM UTL (Lognormal)95% Coverage	67.45
KM SD of Logged Data	1.602	95% KM UPL (Lognormal)	52.64
95% KM Percentile Lognormal (z)	51.9	95% KM USL (Lognormal)	1045

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	61.82	Mean in Log Scale	3.454
SD in Original Scale	144.4	SD in Log Scale	0.912
95% UTL95% Coverage	164.5	95% UPL (t)	142.9
90% Percentile (z)	101.8	95% Percentile (z)	141.7
99% Percentile (z)	263.8	95% USL	782

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	259	95% UTL with95% Coverage	400
Approximate f	1.515	Confidence Coefficient (CC) achieved by UTL	0.921
95% UPL	222	95% USL	1200
95% KM Chebyshev UPL	693.4		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (fluorene)

General Statistics

Total Number of Observations	245	Number of Missing Observations	0
Number of Distinct Observations	23		
Number of Detects	2	Number of Non-Detects	243
Number of Distinct Detects	2	Number of Distinct Non-Detects	21
Minimum Detect	74	Minimum Non-Detect	5
Maximum Detect	490	Maximum Non-Detect	62
Variance Detected	86528	Percent Non-Detects	99.18%
Mean Detected	282	SD Detected	294.2
Mean of Detected Logged Data	5.249	SD of Detected Logged Data	1.337

Warning: Data set has only 2 Detected Values.

This is not enough to compute meaningful or reliable statistics and estimates.

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.816	d2max (for USL)	3.493

Normal GOF Test on Detects Only

Not Enough Data to Perform GOF Test

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	7.261	SD	31.22
95% UTL95% Coverage	63.95	95% KM UPL (t)	58.91
90% KM Percentile (z)	47.27	95% KM Percentile (z)	58.61
99% KM Percentile (z)	79.88	95% KM USL	116.3

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	26.84	SD	29.99
95% UTL95% Coverage	81.3	95% UPL (t)	76.46
90% Percentile (z)	65.27	95% Percentile (z)	76.17
99% Percentile (z)	96.61	95% USL	131.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

Not Enough Data to Perform GOF Test

Gamma Statistics on Detected Data Only

k hat (MLE)	1.417	k star (bias corrected MLE)	N/A
Theta hat (MLE)	199	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	5.668	nu star (bias corrected)	N/A
MLE Mean (bias corrected)	N/A		
MLE Sd (bias corrected)	N/A	95% Percentile of Chisquare (2k)	N/A

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0541		nu hat (KM)	26.51
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	15.91	13.62	95% Approx. Gamma UPL	14.6	12.62
95% Gamma USL	33.57	27.81			

Lognormal GOF Test on Detected Observations Only

Not Enough Data to Perform GOF Test

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	2.305	Mean in Log Scale	-16.29
SD in Original Scale	31.64	SD in Log Scale	7.067
95% UTL95% Coverage	0.0316	95% BCA UTL95% Coverage	0.0279
95% Bootstrap (%) UTL95% Coverage	0.0246	95% UPL (t)	0.0101
90% Percentile (z)	7.2288E-4	95% Percentile (z)	0.00942
99% Percentile (z)	1.163	95% USL	4435

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	26.84	Mean in Log Scale	3.214
SD in Original Scale	29.99	SD in Log Scale	0.278
95% UTL95% Coverage	41.2	95% UPL (t)	39.39
90% Percentile (z)	35.51	95% Percentile (z)	39.29
99% Percentile (z)	47.47	95% USL	65.65

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	238	95% UTL with95% Coverage	58
Approximate f	1.566	Confidence Coefficient (CC) achieved by UTL	0.926
95% UPL	57	95% USL	490
95% KM Chebyshev UPL	143.6		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (indeno[1,2,3-c,d]pyrene)

General Statistics

Total Number of Observations	258	Number of Missing Observations	0
Number of Distinct Observations	68		
Number of Detects	54	Number of Non-Detects	204
Number of Distinct Detects	41	Number of Distinct Non-Detects	27
Minimum Detect	10	Minimum Non-Detect	2
Maximum Detect	2200	Maximum Non-Detect	9
Variance Detected	173654	Percent Non-Detects	79.07%
Mean Detected	223.9	SD Detected	416.7
Mean of Detected Logged Data	4.391	SD of Detected Logged Data	1.364

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.811	d2max (for USL)	3.509

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.544	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.339	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.121	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	48.43	SD	209.3
95% UTL95% Coverage	427.6	95% KM UPL (t)	394.7
90% KM Percentile (z)	316.7	95% KM Percentile (z)	392.7
99% KM Percentile (z)	535.4	95% KM USL	782.9

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	49.69	SD	209.5
95% UTL95% Coverage	429.1	95% UPL (t)	396.1
90% Percentile (z)	318.1	95% Percentile (z)	394.2
99% Percentile (z)	537	95% USL	784.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	2.909	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.806	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.217	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.127	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.605	k star (bias corrected MLE)	0.584
Theta hat (MLE)	370	Theta star (bias corrected MLE)	383.4
nu hat (MLE)	65.35	nu star (bias corrected)	63.05
MLE Mean (bias corrected)	223.9		
MLE Sd (bias corrected)	293	95% Percentile of Chisquare (2k)	4.243

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	46.86
Maximum	2200	Median	0.01
SD	210.1	CV	4.483
k hat (MLE)	0.121	k star (bias corrected MLE)	0.122
Theta hat (MLE)	388.5	Theta star (bias corrected MLE)	384.7
nu hat (MLE)	62.24	nu star (bias corrected)	62.85
MLE Mean (bias corrected)	46.86	MLE Sd (bias corrected)	134.3
95% Percentile of Chisquare (2k)	1.388	90% Percentile	133.3
95% Percentile	266.9	99% Percentile	673.1

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	136.9	111.9	95% Approx. Gamma UPL	111.[illegible]	86.43
95% Gamma USL	699.5	876			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	k hat (KM)	0.0535		nu hat (KM)	27.62
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	152	129.8	95% Approx. Gamma UPL	128.[illegible]	107.8
95% Gamma USL	605.3	641.7			

Lognormal GOF Test on Detected Observations Only

Lilliefors Test Statistic	0.102	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.121	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Approximate Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	48.16	Mean in Log Scale	0.339
SD in Original Scale	209.8	SD in Log Scale	2.738
95% UTL95% Coverage	200.1	95% BCA UTL95% Coverage	330
95% Bootstrap (%) UTL95% Coverage	361.5	95% UPL (t)	130
90% Percentile (z)	46.9	95% Percentile (z)	126.8
99% Percentile (z)	819.8	95% USL	20876

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.467	95% KM UTL (Lognormal)95% Coverage	82.54
KM SD of Logged Data	1.626	95% KM UPL (Lognormal)	63.89
95% KM Percentile Lognormal (z)	62.95	95% KM USL (Lognormal)	1304

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	49.69	Mean in Log Scale	1.915
SD in Original Scale	209.5	SD in Log Scale	1.431
95% UTL95% Coverage	90.65	95% UPL (t)	72.36
90% Percentile (z)	42.47	95% Percentile (z)	71.42
99% Percentile (z)	189.4	95% USL	1028

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	250	95% UTL with95% Coverage	330
Approximate f	1.462	Confidence Coefficient (CC) achieved by UTL	0.901
95% UPL	181	95% USL	2200
95% KM Chebyshev UPL	962.6		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (naphthalene)

General Statistics

Total Number of Observations	255	Number of Missing Observations	0
Number of Distinct Observations	26		
Number of Detects	2	Number of Non-Detects	253
Number of Distinct Detects	2	Number of Distinct Non-Detects	24
Minimum Detect	190	Minimum Non-Detect	2
Maximum Detect	210	Maximum Non-Detect	56
Variance Detected	200	Percent Non-Detects	99.22%
Mean Detected	200	SD Detected	14.14
Mean of Detected Logged Data	5.297	SD of Detected Logged Data	0.0708

Warning: Data set has only 2 Detected Values.

This is not enough to compute meaningful or reliable statistics and estimates.

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.813	d2max (for USL)	3.505

Normal GOF Test on Detects Only

Not Enough Data to Perform GOF Test

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	3.553	SD	17.49
95% UTL95% Coverage	35.25	95% KM UPL (t)	32.48
90% KM Percentile (z)	25.97	95% KM Percentile (z)	32.32
99% KM Percentile (z)	44.24	95% KM USL	64.85

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	23.02	SD	16.42
95% UTL95% Coverage	52.77	95% UPL (t)	50.17
90% Percentile (z)	44.05	95% Percentile (z)	50.02
99% Percentile (z)	61.21	95% USL	80.56

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

Not Enough Data to Perform GOF Test

Gamma Statistics on Detected Data Only

k hat (MLE)	399.7	k star (bias corrected MLE)	N/A
Theta hat (MLE)	0.5	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	1599	nu star (bias corrected)	N/A
MLE Mean (bias corrected)	N/A		
MLE Sd (bias corrected)	N/A	95% Percentile of Chisquare (2k)	N/A

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

k hat (KM)	0.0413		nu hat (KM)	21.05	
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	8.358	6.895	95% Approx. Gamma UPL	7.5	6.303
95% Gamma USL	20	16.14			

Lognormal GOF Test on Detected Observations Only

Not Enough Data to Perform GOF Test

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	67.81	Mean in Log Scale	4.146
SD in Original Scale	26.84	SD in Log Scale	0.374
95% UTL95% Coverage	124.4	95% BCA UTL95% Coverage	125.5
95% Bootstrap (%) UTL95% Coverage	125.5	95% UPL (t)	117.2
90% Percentile (z)	102	95% Percentile (z)	116.8
99% Percentile (z)	150.7	95% USL	234.1

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	23.02	Mean in Log Scale	3.027
SD in Original Scale	16.42	SD in Log Scale	0.527
95% UTL95% Coverage	53.59	95% UPL (t)	49.3
90% Percentile (z)	40.52	95% Percentile (z)	49.06
99% Percentile (z)	70.25	95% USL	130.7

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	247	95% UTL with95% Coverage	52
Approximate f	1.444	Confidence Coefficient (CC) achieved by UTL	0.894
95% UPL	52	95% USL	210
95% KM Chebyshev UPL	79.93		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations. The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (phenanthrene)

General Statistics

Total Number of Observations	257	Number of Missing Observations	0
Number of Distinct Observations	40		
Number of Detects	18	Number of Non-Detects	239
Number of Distinct Detects	16	Number of Distinct Non-Detects	24
Minimum Detect	63	Minimum Non-Detect	1
Maximum Detect	430	Maximum Non-Detect	62
Variance Detected	10809	Percent Non-Detects	93%
Mean Detected	157.7	SD Detected	104
Mean of Detected Logged Data	4.883	SD of Detected Logged Data	0.596

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.812	d2max (for USL)	3.507

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.838	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.897	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.211	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.209	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	11.98	SD	48.11
95% UTL95% Coverage	99.15	95% KM UPL (t)	91.56
90% KM Percentile (z)	73.64	95% KM Percentile (z)	91.11
99% KM Percentile (z)	123.9	95% KM USL	180.7

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	33.44	SD	43.65
95% UTL95% Coverage	112.5	95% UPL (t)	105.6
90% Percentile (z)	89.39	95% Percentile (z)	105.2
99% Percentile (z)	135	95% USL	186.6

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.635	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.746	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.202	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.205	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	2.973	k star (bias corrected MLE)	2.514
Theta hat (MLE)	53.06	Theta star (bias corrected MLE)	62.73
nu hat (MLE)	107	nu star (bias corrected)	90.51
MLE Mean (bias corrected)	157.7		
MLE Sd (bias corrected)	99.47	95% Percentile of Chisquare (2k)	11.11

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	11.06
Maximum	430	Median	0.01
SD	48.42	CV	4.379
k hat (MLE)	0.124	k star (bias corrected MLE)	0.126
Theta hat (MLE)	88.87	Theta star (bias corrected MLE)	88.07
nu hat (MLE)	63.94	nu star (bias corrected)	64.53
MLE Mean (bias corrected)	11.06	MLE Sd (bias corrected)	31.2
95% Percentile of Chisquare (2k)	1.424	90% Percentile	31.69
95% Percentile	62.71	99% Percentile	156.3

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	24.98	15.87	95% Approx. Gamma UPL	20.(	12.19
95% Gamma USL	135.1	128.1			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

k hat (KM)	0.062		nu hat (KM)	31.85	
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	35.78	28.9	95% Approx. Gamma UPL	30.4	24.22
95% Gamma USL	138.1	132.6			

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.927	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.897	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.18	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.209	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	18.38	Mean in Log Scale	1.57
SD in Original Scale	47.67	SD in Log Scale	1.581
95% UTL95% Coverage	84.3	95% BCA UTL95% Coverage	132
95% Bootstrap (%) UTL95% Coverage	130	95% UPL (t)	65.69
90% Percentile (z)	36.45	95% Percentile (z)	64.74
99% Percentile (z)	190.2	95% USL	1231

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	0.342	95% KM UTL (Lognormal)95% Coverage	13.7
KM SD of Logged Data	1.256	95% KM UPL (Lognormal)	11.23
95% KM Percentile Lognormal (z)	11.11	95% KM USL (Lognormal)	115.1

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	33.44	Mean in Log Scale	3.236
SD in Original Scale	43.65	SD in Log Scale	0.706
95% UTL95% Coverage	91.4	95% UPL (t)	81.76
90% Percentile (z)	62.86	95% Percentile (z)	81.24
99% Percentile (z)	131.4	95% USL	302.5

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	249	95% UTL with95% Coverage	130
Approximate f	1.456	Confidence Coefficient (CC) achieved by UTL	0.899
95% UPL	88.3	95% USL	430
95% KM Chebyshev UPL	222.1		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.

The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Result (pyrene)

General Statistics

Total Number of Observations	269	Number of Missing Observations	0
Number of Distinct Observations	63		
Number of Detects	56	Number of Non-Detects	213
Number of Distinct Detects	45	Number of Distinct Non-Detects	18
Minimum Detect	42	Minimum Non-Detect	1
Maximum Detect	1200	Maximum Non-Detect	41
Variance Detected	78980	Percent Non-Detects	79.18%
Mean Detected	222.7	SD Detected	281
Mean of Detected Logged Data	4.885	SD of Detected Logged Data	0.949

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.808	d2max (for USL)	3.521

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.647	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	1.110E-16	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.289	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.118	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Kaplan Meier (KM) Background Statistics Assuming Normal Distribution

Mean	47.15	SD	155.7
95% UTL95% Coverage	328.7	95% KM UPL (t)	304.7
90% KM Percentile (z)	246.7	95% KM Percentile (z)	303.3
99% KM Percentile (z)	409.4	95% KM USL	595.4

DL/2 Substitution Background Statistics Assuming Normal Distribution

Mean	59.06	SD	152.6
95% UTL95% Coverage	334.9	95% UPL (t)	311.4
90% Percentile (z)	254.6	95% Percentile (z)	310
99% Percentile (z)	414	95% USL	596.3

DL/2 is not a recommended method. DL/2 provided for comparisons and historical reasons

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	3.215	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.777	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.191	**Kolmogrov-Smirnoff GOF**
5% K-S Critical Value	0.122	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.097	k star (bias corrected MLE)	1.05
Theta hat (MLE)	203	Theta star (bias corrected MLE)	212
nu hat (MLE)	122.9	nu star (bias corrected)	117.6
MLE Mean (bias corrected)	222.7		
MLE Sd (bias corrected)	217.3	95% Percentile of Chisquare (2k)	6.185

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detected data is small such as < 0.1

For such situations, GROS method tends to yield inflated values of UCLs and BTVs

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	46.37
Maximum	1200	Median	0.01
SD	156.2	CV	3.37
k hat (MLE)	0.122	k star (bias corrected MLE)	0.123
Theta hat (MLE)	379.1	Theta star (bias corrected MLE)	375.6
nu hat (MLE)	65.81	nu star (bias corrected)	66.41
MLE Mean (bias corrected)	46.37	MLE Sd (bias corrected)	132
95% Percentile of Chisquare (2k)	1.404	90% Percentile	132.4
95% Percentile	263.6	99% Percentile	661.4

The following statistics are computed using Gamma ROS Statistics on Imputed Data

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	157.1	138.3	95% Approx. Gamma UPL	128.!	107.5
95% Gamma USL	801.1	1095			

The following statistics are computed using gamma distribution and KM estimates

Upper Limits using Wilson Hilferty (WH) and Hawkins Wixley (HW) Methods

k hat (KM)	0.0917		nu hat (KM)	49.33	
	WH	HW		WH	HW
95% Approx. Gamma UTL with 95% Coverage	165	149	95% Approx. Gamma UPL	139	122.3
95% Gamma USL	698.1	828.5			

Lognormal GOF Test on Detected Observations Only

Lilliefors Test Statistic	0.113	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.118	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Approximate Lognormal at 5% Significance Level

Background Lognormal ROS Statistics Assuming Lognormal Distribution Using Imputed Non-Detects

Mean in Original Scale	52.34	Mean in Log Scale	2.017
SD in Original Scale	154.7	SD in Log Scale	1.983
95% UTL95% Coverage	270.8	95% BCA UTL95% Coverage	386
95% Bootstrap (%) UTL95% Coverage	390	95% UPL (t)	199.5
90% Percentile (z)	95.41	95% Percentile (z)	196.1
99% Percentile (z)	757.2	95% USL	8084

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean of Logged Data	1.017	95% KM UTL (Lognormal)95% Coverage	108.4
KM SD of Logged Data	2.029	95% KM UPL (Lognormal)	79.26
95% KM Percentile Lognormal (z)	77.86	95% KM USL (Lognormal)	3505

Background DL/2 Statistics Assuming Lognormal Distribution

Mean in Original Scale	59.06	Mean in Log Scale	3.17
SD in Original Scale	152.6	SD in Log Scale	1.058
95% UTL95% Coverage	161.1	95% UPL (t)	136.9
90% Percentile (z)	92.36	95% Percentile (z)	135.6
99% Percentile (z)	278.8	95% USL	986.1

DL/2 is not a Recommended Method. DL/2 provided for comparisons and historical reasons.

Nonparametric Distribution Free Background Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Upper Limits for BTVs(no distinction made between detects and nondetects)

Order of Statistic, r	261	95% UTL with95% Coverage	390
Approximate f	1.526	Confidence Coefficient (CC) achieved by UTL	0.924
95% UPL	235	95% USL	1200
95% KM Chebyshev UPL	727.2		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Appendix F

PAH Background Study
Dataset Appropriate for Distribution
(provided as an Excel file)

This page intentionally left blank