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CNC CHARLESTON
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EVALUATION OF BACKGROUND OR REFERENCE VALUE FOR POLYCYCLIC AROMATIC HYDROCARBONS IN SOILS CNC CHARLESTON SC

11/29/2000

CH2MHILL

Background PaH Determination
CNC

1. Memo Edits.
2. Remove samples within SWMUs.

TECHNICAL MEMORANDUM – Draft Revision 1 **CH2MHILL**

Evaluation of Background or Reference Value for PAHs in Soils at CNC

3. RR–add more samples.
4. Maybe eliminate Zone K.

PREPARED FOR:	CNC Team
PREPARED BY:	CH2M HILL- Jones
DATE:	November 29, 2000

This revised Technical Memorandum [TM] incorporates suggestions provided by SCDHEC after review of the original TM at the November 2000 BCT meeting.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are detected in environmental media at the CNC, including areas that did not have site-specific operations involving PAHs. Grid soil samples collected from un-impacted industrial and non-industrial areas also had detectable levels of PAHs. Since human health and ecological protection based criteria (e.g., RBC values) for several PAHs are below typical detection limits, any detection of these PAHs indicates an exceedence of an RBC value. Because PAHs are detected across the CNC, with similar distribution at sites (i.e., SWMU/AOCs) and non-sites, remediation of the PAHs strictly based on RBCs is not technically feasible or defensible.

The RCRA Facility Investigations (RFIs) conducted to date for CNC did not include an evaluation of or establish a "background" or reference PAH concentration. This technical memorandum presents an approach for estimating a reference or base-specific background value for PAHs in soils at the CNC. This approach follows the EPA Region IV guidance for evaluating background values for risk management decisions (EPA, 1998). The approach that is proposed in this paper provides a reference PAH value that may be used as a guide during site-specific risk management decision making by the BCT. The PAH reference value is not proposed as an absolute number to determine when active remediation must be implemented.

PAH Occurrence in the Environment

PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco, and charbroiled meat. PAHs are ubiquitous in the urban environment and generally occur as complex mixtures, not as single compounds. There are more than 100 different PAHs. Table 1 provides typical representative PAH concentrations reported by ATSDR in rural, agricultural and urban soil types.

Calculation of BEQ Values

About 15 PAHs are typically included in analytical list at hazardous waste sites, due to their relatively higher toxicity, and are, hence, part of the EPA's Target Compound List (TCL). Of these, 7 are identified as carcinogenic PAHs. Table 2 presents the TCL PAHs and identifies the seven carcinogenic PAHs. Each of these carcinogenic PAHs is assigned a toxicity equivalency factor (TEF) relative to benzo(a)pyrene. To calculate a benzo(a) pyrene equivalent (BEQ) value for a sample, the value for each of these seven PAHs is first multiplied by its respective TEF. The sum of the seven resulting values is the BEQ value for that sample.

PAH Sources at CNC

A variety of sources are likely to have contributed PAHs to the environment at CNC. At sites where petroleum products or waste oil handling operations were performed, PAHs in soils could have originated from these site operations. However, a variety of other PAH sources could also have contributed PAHs to the soils. These other potential sources include:

- coal-tar/creosote used in asphalt roads, and railroad ties,
- oil leaks from motor vehicles (automobiles, train engines, buses, tractor trailers),
- exhaust air emissions from motor vehicles,
- air emissions from coal burning facilities (steam plant, steam engines, incinerators)
- air emissions from Naval ships,
- spraying of used oils mixed with pesticide formulations.

The precise source of PAHs detected within CNC can not be established due to ubiquitous occurrence and high variation in the detected concentration levels, age of the source, and varied rates of weathering of the source material in surface and subsurface environments in which it is incorporated.

The relative proportion of the PAHs in various petroleum hydrocarbons, creosote/coal tar materials were reported by several authors. Some of these references are listed here: 1) Millner, James, and Nye, 1992; 2) Heath, Koblis, and Sager, 1993; 3) ATSDR, 1995; 4) ATSDR, 1994- Toxicological Profile for Creosote; and 5) EPA 1982. Table 4 summarizes the PAH content of some representative petroleum, diesel, heating oils, creosote, and coal tar products. When oils are burnt or partially burnt (e.g., crank case oil) the PAH content increases, thus waste oils are reported with higher PAHs (see Table 4).

Additionally, some of the older base maintenance practices may have included use of the waste motor oils in the pesticide formulations leading to widespread distribution of PAHs. This particular practice is not reported for CNC in existing documentation, however it is one that has occurred historically at many similar DOD facilities. Also, areas that are free of industrial activities at the present time may have been impacted by PAH-containing source material, such as asphalt pavements or railroad lines, that are currently not present. All these potential source materials are likely to have contributed to the PAHs detected at the CNC.

Degradation Rates for PAH in Different Media

PAHs originating from different sources tend to degrade with time. The degradation half-life estimates for individual PAH constituents are reported in Howard, et. al., 1991. The lighter PAHs (e.g., naphthalene) degrade faster than heavier (e.g., BaP) PAHs. Aerobic environment (e.g., surface soil) degrades PAHs faster than anaerobic (e.g., sediments) and subsurface environment. Typically, PAHs released into air are likely to degrade within a very short period of time. Table 3 include the estimated half-lives for individual PAH constituents. The half-lives are estimated for individual chemicals, and these rates are much slower when PAHs are incorporated into matrix of hardened asphaltic material.

Degradation rates of PAHs can be affected by a variety of factors, including the number of aromatic rings, adsorption onto clays, presence of other PAHs, oxygen concentrations, temperature, nutrients, and degradable organic matter. There is extensive technical literature available on this subject that should be consulted for more detail.

PAHs in Grid-based soil samples

PAHs have been analyzed in a significant number of surface and subsurface soils collected at grid locations. The documentation and justification for grid sampling locations were previously discussed in reports prepared by Ensafe.

Approximately 212 surface soil samples, and 153 subsurface soil samples with several duplicate samples were collected from soils across CNC and analyzed for all PAH constituents. A qualitative DQO process has been performed for CNC. Much of the complex has asphalt streets and railroad tracks that contribute to the general PAH background. There are a small number of sites with PAH concentrations arising from site-specific waste operations. PAH concentrations at sites with potential sources, and sites with elevated PAHs will be identified. The chances of both Type 1 errors (false negatives) and Type II errors (false positives) are minimal because of two factors: ~~(1) the obvious distinction between PAH sites and non-PAH sites during evaluation process; and~~ (2) the large sample size of the background data set.

Figures 1a and 1b (previously presented in the initial version of this TM) show grid sample locations and station identification numbers included for the development of a reference value for PAHs at CNC. These grid samples were collected systematically from areas outside of known SWMUs/AOC of CNC. Appendix A (previously provided to BCT members electronically) includes the analytical data for the PAH constituents from these samples. BEQ values were calculated for these samples. Figures 2a and 2b (previously presented in the initial version of this TM) presents the distribution of BEQ concentrations across the CNC at background sample locations.

The BEQ data from these samples were evaluated to determine the nature of the sample concentration distribution. Figures 3a through 3f illustrate different graphing techniques (referred to as descriptive statistics) to assess the nature of the concentration distribution. Figure 3a (surface soil) and 3b (subsurface soil) presents the simple concentration plot of all the samples within background data set. The PAH concentration for non-detect samples was estimated at half the detection limit, which is EPA's preferred method for addressing non-detect values.

Figures 3c through 3f present probability plots for normal and log-transformed data. A straight-line through the XY coordinates would indicate a normal distribution. None of the plots indicates a normal or log-normal distribution.

Because of a large variation in the concentration levels within the data set, an upper confidence limit (UCL) at 95% on the mean could not be established using parametric methods (H-statistic by Land's method). This is because the data did not fit a normal distribution for either normal or log-transformed data, which is essential in estimating a

UCL95% concentration. Because of the high variability, further attempts were not made to fit the data to a particular type of distribution. To keep this reference value assessment simple and avoid extensive statistical exploratory work required to implement an acceptable non-parametric method, a decision was made to proceed following EPA Region IV guidance that is in common practice (and SCDHEC's preferred method) and use a value of 2 times the mean concentration as an estimated reference value for BEQs in surface and subsurface soils.

Development of Reference BEQ Value

Two sets of mean concentrations were estimated using the grid PAH soil data: 1) the mean of detected concentrations only, and 2) a combined mean of the detects and non-detects, using a value of half the detection limit for non-detects. This value is referred to as the adjusted mean value. Table 5 presents the summary statistics of the grid sample data sets for surface and subsurface soils, along with the 2xMean concentration for detect concentrations only, and for detects and non-detects using half the detection limit value. The more conservative (lower) of the two values is proposed as the CNC reference value. Thus, a value of 2 x mean calculated using the adjusted mean value is the proposed PAH reference value. All duplicate sample results were removed from the data set before calculating these values.

Data Evaluation Summary

This section presents several conclusions that can be reached after a review of the data sets for the grid and non-grid (AOC and SMWU related) PAH results.

Variability of Sample Detection Limits

The sample detection limits varied in a similar manner across the data sets (both background and site-related) (See Appendix A for values). The samples from site and background data sets identified with a 'U' qualifier flag were similar in the variability of their reporting limits. The range of 'U' values was between 340 ug/kg and 4000 ug/kg. The highest 'U' value is lower than the maximum detected concentration.

Variability of Sample Results

A review of the data quality indicates that analytical methods were the same for background and onsite data and the techniques and reporting limits met the required data quality. Thus, it can be concluded that the observed high variability in results for both site and background samples is innate to the soil sample PAHs, and is independent of sample location and sampling event.

Discussion of Additional Factors Suggested by SCDHEC

SCDHEC provided recommendations for evaluating the PAH data with regard to its spatial variability at the CNC. This section presents a summary of these data subsets evaluated. The data were separated into several subgroups as per DHEC's suggestion and BEQs were estimated for each subgroup. These subgroups are described below.

Background BEQs per zone

Table 6 presents surface soil grid-sample BEQ results per zone and for all zones. Table 7 presents subsurface soil grid-sample BEQ results per zone and for all zones (last data set) for comparison. As can be noted from these two tables, there is no particular pattern to the distribution of the PAHs across different zones. Zones A and B have higher levels than all other zones. Zone F, which has a highly industrial area and is adjacent to Zone E, has one of the lowest BEQs reported in the background samples.

One problem in attempting to develop a zone-specific BEQ value is the wide variability in the number of grid samples collected in different zones. For example, in Zone F only 5 grid samples were collected and analyzed for PAHs. Five samples provides a poor statistical data set for this zone and increases the uncertainty regarding decision errors. By contrast, Zone H had 96 surface soil grid samples analyzed for PAHs. Typically, for effectively applying environmental statistics for developing average site concentrations, at least 12 samples is preferred. It can be seen that in addition to Zone F, Zones D and G had fewer than 12 grid samples analyzed for PAHs.

For this reason, CH2M HILL believes that a basewide calculation approach to determining background PAH concentrations is a technically more defensible approach compared to a zone-by-zone calculation.

Background PAH Concentrations Related to Site Features

Background BEQs in surface soil along railroad (RR), roadways, asphalt-paved areas, and all other areas combined are summarized in Table 8. This table includes BEQs estimated for data identified to be within a RR and 10 ft buffer zones, roadways and within 10 ft from roadways, and asphalt paved parking areas and 10 ft buffer zones. There are 2 samples identified within railroad tracks, 20 samples were identified within or near roadways and 50 samples were identified within asphalt paved areas. As can be noted from the table, there is not a significant variability in the calculated values between these different groups.

While the highest calculated values are for the samples collected within 10 ft of railroads, there is a limited number of samples (2) in this set, raising questions about the representativeness of this value.

Impact on BEQ Calculation from Removing 10 Highest Samples

The background BEQs estimated by removing the top 10 highest values are presented in Table 9. As can be noted, removal of the highest concentrations only slighted decreased the overall estimated BEQs. Table 10 includes the individual sample IDs and the associated BEQ concentrations for these top 10 samples.

Summary

Overall BEQ levels do not appear to differ significantly between different ways of looking at the data. Where a difference can be observed, there is no particular readily identified association/reason for the variability observed. For the reasons previously presented, CH2M HILL believes that a basewide value for PAH background will provide the most defensible approach and a consistent basis for remedial decision-making and planning. The values presented in Table 5, calculated using twice the adjusted mean value, are recommended as the surface soil and subsurface soil background BEQ values for CNC.

The proposed reference values could be used for screening evaluations at sites that are being investigated, recommended for no further actions, limited removal action or a CMS study. It should be noted that a single value estimate does not fully describe the internal variability of the data distributions and the occurrence of values well above the 2 x mean values within the reference data sets. Therefore, for sites where the reference value is exceeded, further evaluation may be considered following EPA Region IV guidance for background evaluations (EPA, 1998).

References:

ATSDR, 1994. –Toxicological Profile for Creosote. Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, A Public Health Service, Atlanta, Georgia, August 1994.

ATSDR, 1995. –Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs) (Update). Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, A Public Health Service, Atlanta, Georgia, August 1994.

Heath, Jenifer S., Kristin Koblis, and Shawn L. Sager, 1993. Review of Chemical, Physical, and Toxicologic Properties of Components of Total Petroleum Hydrocarbons. Journal of Soil Contamination, 2(1): 1-25, 1993.

Millner, C., Glenn, Robert C. James, and Alan C. Nye., 1992. Human Health-Based Soil Cleanup Guidelines for Diesel Fuel No. 2. Journal of Soil Contamination, 1(2): 103-157 (1992).

EPA, 1982. , An Exposure and Risk Assessment for Benzo(a)pyrene and Other Polycyclic Aromatic Hydrocarbons. Volume IV. EPA-440/4-85-020.

Howard, P.H., Robert S. Boethling, William F. Jarvis, William M. Meylan, and Edward M. Michalenko. 1991. *Handbook of Environmental Degradation Rates*. Heather Taub Printup, ed. Lewis Publishers.

EPA, 1998. Statistical Tests for Background Comparison at Hazardous Waste Sites. Data Collection and Evaluation, Human Health Risk Assessment, Supplemental Guidance to RAGs: Region 4 Bulletins – Addition #1Background comparison statistical guidance, draft, November, 1998.

TABLE 1:BACKGROUND SOIL PAH CONCENTRATIONS IN UNITED STATES

Chemical	Concentration (ug/kg)		
	Rural Soil	Agricultural Soil	Urban Soil
Acenapththene	1.7	6	-
Acenapththylene	-	5	-
Anthracene	-	11-13	-
Benzo(a)athracene	5-20	56-110	169-59,000
Benzo(a)pyrene	2-1,300	4.6-900	165-220
Benzo(b)fluoranthene	20-30	58-220	1,500-62,000
Benzo(g,h,I)perylene	10-70	66	900-47,000
Benzo(k)fluoranthene	10-110	58-250	300-26,000
Chrysene	38.3	78-120	251-640
Fluoranthene	0.3-40	120-210	200-166,000
Fluorene	-	9.7	-
Indeno(1,2,3-c,d)pyrene	10-15	63-100	8,000-61,000
Phenanthrene	30	48-140	-
Pyrene	1-19.7	99-150	145-147,000

Note: This table is adapted from Table 5-3 from ATSDR's Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), August 1995.

TABLE 2: LIST OF PAHS COMMONLY REPORTED IN SOIL SAMPLES

PAH	Carcinogen?	TEF for BEQ
Acenaphthene	No	
Anthracene	No	
Benz(a)anthracene	Yes	0.1
Benzo(b)fluoranthene	Yes	0.1
Benzo(k)fluoranthene	Yes	0.01
Benzo(a)pyrene	Yes	1.0
Carbazole*	Yes	
Chrysene	Yes	0.001
Dibenz(a,h)anthracene	Yes	1.0
Dibenzofuran	No	
Fluoranthene	No	
Fluorene	No	
Indeno(1,2,3-c,d)pyrene	Yes	0.1
2-methylnaphthalene	No	
Naphthalene	No	
Pyrene	No	

- Carbazole is included in risk assessment separately; TEF = Toxicity equivalency factor; BEQ = benzo(a)pyrene equivalent concentration.

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TABLE 3
Half-Life Estimates for PAHs (in days)

Media	Naphthalene	Anthracene	Benzo(a)pyrene
Soil (aerobic)	17	50	57
Groundwater	1	100	114
Sediments(anaerobic)	25	200	228
Surface Water	<0.5	<0.1	<0.1
Air	<0.12	<0.1	<0.1

Notes:
Biodegradation half-life estimates in days for surface and subsurface media. Values are the low-end estimates selected for comparison between different PAH constituents.
Surface water attenuation primarily attributed to volatilization and photolysis in the water column. Does not consider sediment partitioning (Howard, 1991).

TABLE 4: PAH CONTENT OF DIFFERENT POTENTIAL SOURCE MATERIAL AT CNC

Potential Source	PAH Content (mg/kg)
Gasoline	7.0
Diesel	>8000*
Fuel Oil No. 2	0.07 – BaP
Used Motor Oil**	BaP – <0.1 to 405
Coal-tar/Creosote	163,000 – 750,000 / (300 to 3600 ppm BaP)
European asphalt cements	10
US asphalt cements (average of 12)	24
European Coaltar	152,647
US Low temperature Coal tar	63,160

- Diesel has mostly di- and trimethyl naphthalenes, with negligible <1 mg/kg of BaP content

**_ From ATSDR, 1995

TABLE 5: PROPOSED PAH REFERENCE VALUES USING 'U' VALUES FOR ADJUSTED MEAN ESTIMATES

Parameter Name	Number of Analysis	Number of Detects	Min Detect	Max Detect	Mean Detect	Adjusted Mean Value*	2X Mean of Detects	2X Adjusted Mean Value*
Surface Soil								
BENZO(a)ANTHRACENE	212	53	34	2100	342	299	683	597
BENZO(a)PYRENE	212	51	45	1500	341	296	681	593
BENZO(b)FLUORANTHENE	212	44	49	1800	383	304	765	607
BENZO(k)FLUORANTHENE	212	48	42	1700	348	295	697	590
CHRYSENE	212	57	40	3000	377	302	754	603
DIBENZ(a,h)ANTHRACENE	212	15	64	440	175	258	351	515
INDENO(1,2,3-c,d)PYRENE	212	36	42	670	215	258	431	516
						BEQ	**1213**	**1258**
Subsurface Soil								
BENZO(a)ANTHRACENE	153	19	55	3400	444	309	888	618
BENZO(a)PYRENE	153	17	52	2600	403	305	805	610
BENZO(b)FLUORANTHENE	153	14	57	2600	384	307	768	613
BENZO(k)FLUORANTHENE	153	13	92	2300	448	303	896	606
CHRYSENE	153	21	57	3400	421	304	841	608
DIBENZ(a,h)ANTHRACENE	153	4	160	780	348	285	695	569
INDENO(1,2,3-c,d)PYRENE	153	10	54	1600	341	289	681	578
						BEQ	**1744**	**1367**

Note: * - Includes non-detects at half of the reported detection limit value
All values in ug/kg

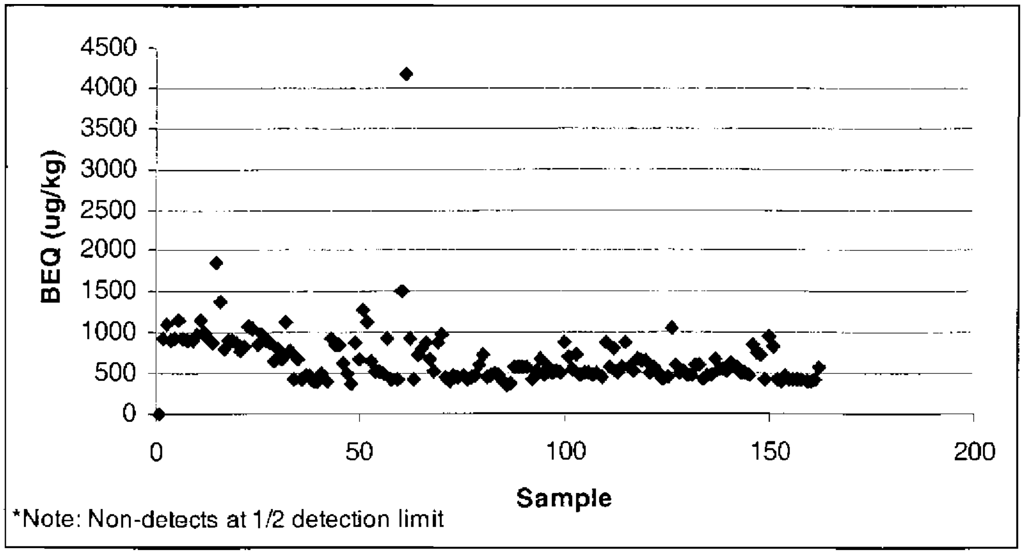

FIGURE 3B
Background **Subsurface Soil** BEQ concentrations plotted against samples
Charleston Navy Complex

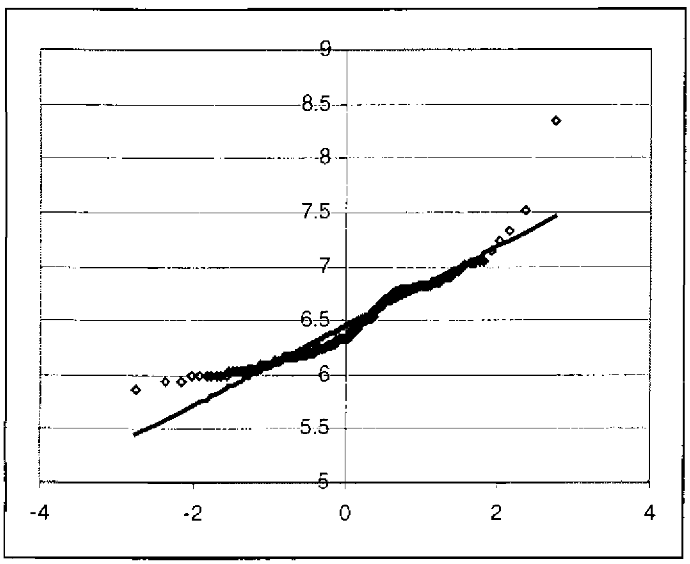

FIGURE 3E
Probability Plot of Background **Subsurface Soil** BEQ concentrations for lognormal transformed data
Charleston Navy Complex

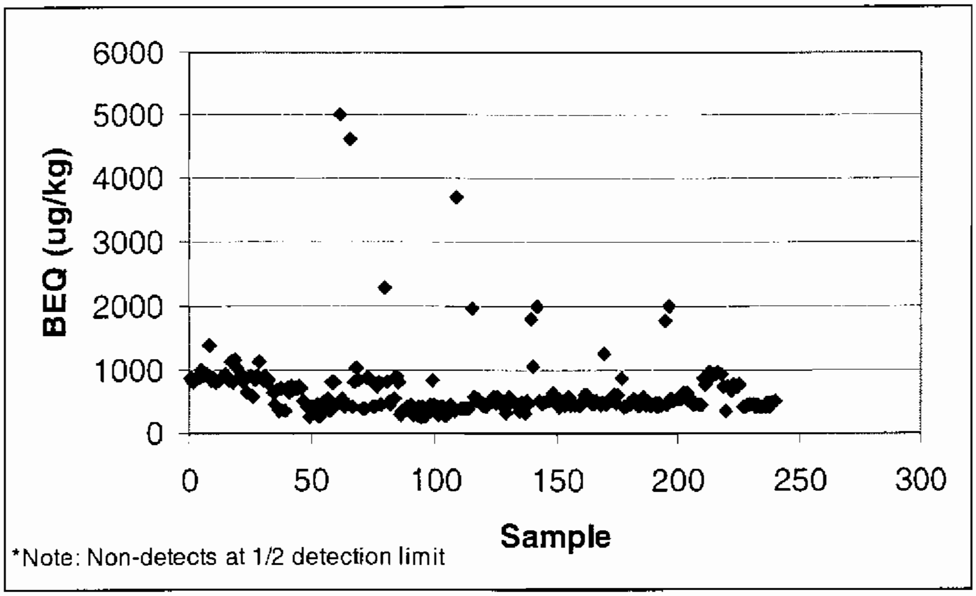

FIGURE 3A
Background **Surface Soil** BEQ concentrations plotted against samples
Charleston Navy Complex

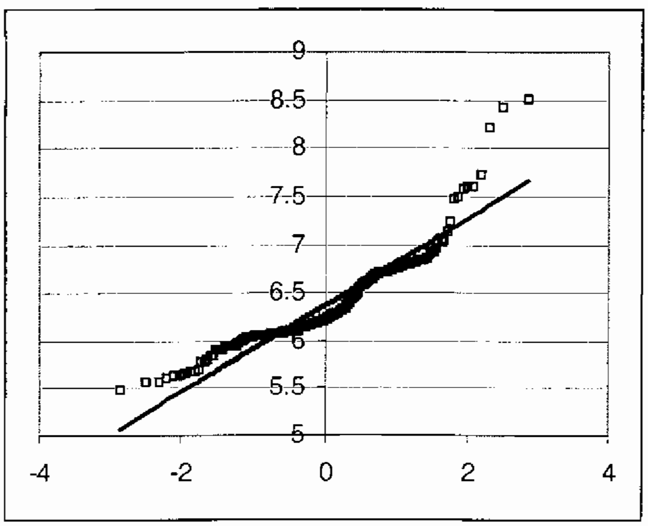

FIGURE 3C
Probability Plot of Background **Surface Soil** BEQ concentrations for lognormal transformed data
Charleston Navy Complex

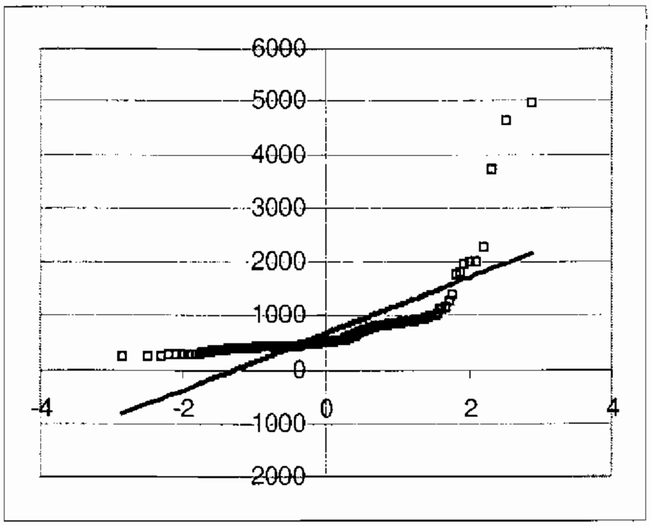

FIGURE 3D
Probability Plot of Background **Surface Soil** BEQ Concentrations of **normal data**.
Charleston Navy Complex

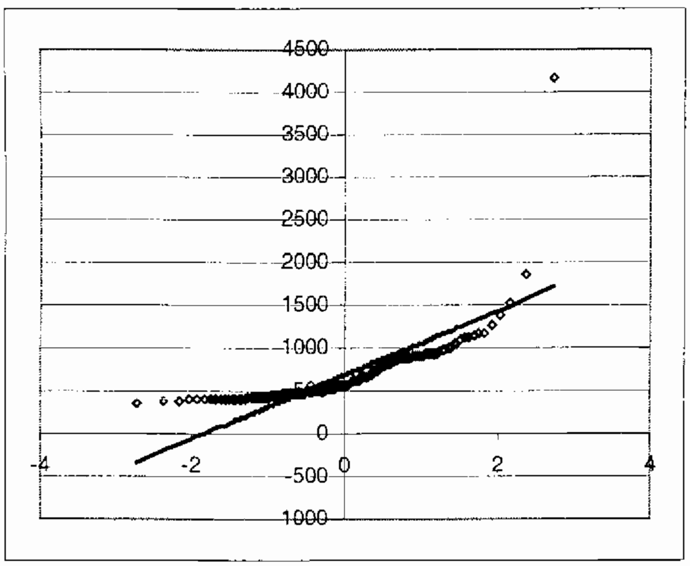

FIGURE 3F
Probability Plot of Background **Subsurface Soil** BEQs assuming a **normal data distribution**
Charleston Navy Complex

Table 6 : Surface soil background BEQs per zone and combined for all zones

Zone-Medium	Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detecs	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
A-SS	BENZO(a)ANTHRACENE	UG/KG	13	4	250	660	423	397	720	860	845	793	85	79
A-SS	BENZO(a)PYRENE	UG/KG	13	4	340	830	490	417	720	860	980	835	980	835
A-SS	BENZO(b)FLUORANTHENE	UG/KG	13	4	390	1800	763	501	720	860	1525	1002	153	100
A-SS	BENZO(k)FLUORANTHENE	UG/KG	13	4	390	1100	598	450	720	860	1195	901	12	9
A-SS	CHRYSENE	UG/KG	13	5	190	980	456	412	720	860	912	825	1	1
A-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	13	1	230	230	230	372	720	860	460	744	460	744
A-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	13	4	210	670	333	369	720	860	665	738	67	74
												BEQ	**1756**	**1842**
B-SS	BENZO(a)ANTHRACENE	UG/KG	15	2	160	260	210	372	690	1000	420	743	42	74
B-SS	BENZO(a)PYRENE	UG/KG	15	2	150	210	180	368	690	1000	360	735	360	735
B-SS	BENZO(b)FLUORANTHENE	UG/KG	15	1	220	220	220	382	690	1000	440	764	44	76
B-SS	BENZO(k)FLUORANTHENE	UG/KG	15					391	690	1000		783	0	8
B-SS	CHRYSENE	UG/KG	15	2	160	280	220	373	690	1000	440	746	0	1
B-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	15					391	690	1000		783	0	783
B-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	15	2	130	140	135	362	690	1000	270	723	27	72
												BEQ	**473**	**1750**
C-SS	BENZO(a)ANTHRACENE	UG/KG	12	4	50	260	131	292	720	780	262	585	26	58
C-SS	BENZO(a)PYRENE	UG/KG	12	5	66	330	158	282	720	770	316	564	316	564
C-SS	BENZO(b)FLUORANTHENE	UG/KG	12	5	49	340	192	332	840	900	384	665	38	66
C-SS	BENZO(k)FLUORANTHENE	UG/KG	12	5	52	360	200	287	670	730	401	574	4	6
C-SS	CHRYSENE	UG/KG	12	4	76	200	124	245	590	640	248	490	0	0
C-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	12					242	470	510		483	0	483
C-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	12	2	110	120	115	235	500	540	230	471	23	47
												BEQ	**408**	**1226**
D-SS	BENZO(a)ANTHRACENE	UG/KG	6	2	34	38	36	136	350	400	72	272	7	27
D-SS	BENZO(a)PYRENE	UG/KG	6	1	45	45	45	162	350	400	90	323	90	323
D-SS	BENZO(b)FLUORANTHENE	UG/KG	6	2	57	58	58	143	350	400	115	287	12	29
D-SS	BENZO(k)FLUORANTHENE	UG/KG	6	2	71	77	74	149	350	400	148	298	1	3
D-SS	CHRYSENE	UG/KG	6	2	54	57	56	143	350	400	111	285	0	0
D-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	6					183	340	400		365	0	365
D-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	6					183	340	400		365	0	37
												BEQ	**110**	**784**
E-SS	BENZO(a)ANTHRACENE	UG/KG	28	11	62	2100	463	407	350	4000	926	813	93	81
E-SS	BENZO(a)PYRENE	UG/KG	28	12	82	1500	379	374	350	4000	757	748	757	748
E-SS	BENZO(b)FLUORANTHENE	UG/KG	28	8	69	700	317	333	350	4000	634	667	63	67
E-SS	BENZO(k)FLUORANTHENE	UG/KG	28	12	85	950	398	383	350	4000	797	766	8	8
E-SS	CHRYSENE	UG/KG	28	13	64	3000	540	456	350	4000	1079	912	1	1
E-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	28	5	68	440	190	309	350	4000	379	617	379	617
E-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	28	11	58	450	191	300	350	4000	382	600	38	60
												BEQ	**1339**	**1582**
F-SS	BENZO(a)ANTHRACENE	UG/KG	5	4	58	78	70	93	370	370	140	186	14	19
F-SS	BENZO(a)PYRENE	UG/KG	5	4	72	90	82	103	370	370	165	206	165	206
F-SS	BENZO(b)FLUORANTHENE	UG/KG	5	3	84	110	94	146	370	530	188	293	19	29
F-SS	BENZO(k)FLUORANTHENE	UG/KG	5	4	82	110	97	114	370	370	194	229	2	2
F-SS	CHRYSENE	UG/KG	5	4	91	130	111	126	370	370	222	251	0	0
F-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	5					197	340	530		394	0	394
F-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	5	3	42	69	59	126	370	530	119	251	12	25

Table 6 : Surface soil background BEQs per zone and combined for all zones

Zone-Medium	Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detecs	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
												BEQ	**211**	**675**
G-SS	BENZO(a)ANTHRACENE	UG/KG	9	6	49	470	183	186	370	400	366	373	37	37
G-SS	BENZO(a)PYRENE	UG/KG	9	6	48	500	185	188	370	400	371	376	371	376
G-SS	BENZO(b)FLUORANTHENE	UG/KG	9	5	64	710	273	238	370	400	546	476	55	48
G-SS	BENZO(k)FLUORANTHENE	UG/KG	9	6	42	390	171	179	370	400	343	357	3	4
G-SS	CHRYSENE	UG/KG	9	6	59	680	243	226	370	400	486	453	0	0
G-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	9	3	64	180	106	169	370	440	212	338	212	338
G-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	9	3	95	300	185	196	370	440	370	391	37	39
												BEQ	**715**	**842**
H-SS	BENZO(a)ANTHRACENE	UG/KG	96	17	48	1900	513	277	340	1700	1025	553	103	55
H-SS	BENZO(a)PYRENE	UG/KG	96	16	81	1400	511	273	340	1700	1023	546	1023	546
H-SS	BENZO(b)FLUORANTHENE	UG/KG	96	12	68	1700	662	280	340	1700	1325	559	132	56
H-SS	BENZO(k)FLUORANTHENE	UG/KG	96	10	88	1700	637	274	340	1700	1274	548	13	5
H-SS	CHRYSENE	UG/KG	96	18	50	1700	503	278	340	1700	1006	556	1	1
H-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	96	6	84	270	189	230	360	1800	378	460	378	460
H-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	96	11	80	650	281	238	340	1700	562	475	56	48
												BEQ	**1706**	**1171**
I-SS	BENZO(a)ANTHRACENE	UG/KG	15	2	43	59	51	381	710	1000	102	762	10	76
I-SS	BENZO(a)PYRENE	UG/KG	15	1	50	50	50	404	710	1000	100	809	100	809
I-SS	BENZO(b)FLUORANTHENE	UG/KG	15	4	81	97	90	381	830	1100	179	761	18	76
I-SS	BENZO(k)FLUORANTHENE	UG/KG	15	4	97	120	104	317	670	920	207	633	2	6
I-SS	CHRYSENE	UG/KG	15	2	40	49	45	312	580	830	89	624	0	1
I-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	15					279	460	660		557	0	557
I-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	15					298	500	700		596	0	60
												BEQ	**130**	**1585**
K-SS	BENZO(a)ANTHRACENE	UG/KG	13	1	110	110	110	187	360	450	220	374	22	37
K-SS	BENZO(a)PYRENE	UG/KG	13					195	360	450		391	0	391
K-SS	BENZO(b)FLUORANTHENE	UG/KG	13					195	360	450		391	0	39
K-SS	BENZO(k)FLUORANTHENE	UG/KG	13	1	200	200	200	194	360	450	400	388	4	4
K-SS	CHRYSENE	UG/KG	13	1	96	96	96	186	360	450	192	372	0	0
K-SS	DIBENZ(a,h)ANTHRACENE	UG/KG	13					195	360	450		391	0	391
K-SS	INDENO(1,2,3-c,d)PYRENE	UG/KG	13					195	360	450		391	0	39
												BEQ	**26**	**901**
SS-BACKG	BENZO(a)ANTHRACENE	UG/KG	212	53	34	2100	342	299	340	4000	683	597	68	60
SS-BACKG	BENZO(a)PYRENE	UG/KG	212	51	45	1500	341	296	340	4000	681	593	681	593
SS-BACKG	BENZO(b)FLUORANTHENE	UG/KG	212	44	49	1800	383	304	340	4000	765	607	77	61
SS-BACKG	BENZO(k)FLUORANTHENE	UG/KG	212	48	42	1700	348	295	340	4000	697	590	7	6
SS-BACKG	CHRYSENE	UG/KG	212	57	40	3000	377	302	340	4000	754	603	1	1
SS-BACKG	DIBENZ(a,h)ANTHRACENE	UG/KG	212	15	64	440	175	258	340	4000	351	515	351	515
SS-BACKG	INDENO(1,2,3-c,d)PYRENE	UG/KG	212	36	42	670	215	258	340	4000	431	516	43	52
												BEQ	**1228**	**1287**

Table 7 : Subsurface soil background BEQs per zone and combined for all zones

Zone-Medium	Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detecs	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
A-SB	BENZO(a)ANTHRACENE	UG/KG	12					425	770	1000		850	0	85
A-SB	BENZO(a)PYRENE	UG/KG	12					425	770	1000		850	0	850
A-SB	BENZO(b)FLUORANTHENE	UG/KG	12					425	770	1000		850	0	85
A-SB	BENZO(k)FLUORANTHENE	UG/KG	12					425	770	1000		850	0	9
A-SB	CHRYSENE	UG/KG	12	1	160	160	160	406	780	1000	320	813	0	1
A-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	12					425	770	1000		850	0	850
A-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	12					425	770	1000		850	0	85
												BEQ	**0**	**1964**
B-SB	BENZO(a)ANTHRACENE	UG/KG	14	1	190	190	190	419	680	1600	380	838	38	84
B-SB	BENZO(a)PYRENE	UG/KG	14					437	680	1600		874	0	874
B-SB	BENZO(b)FLUORANTHENE	UG/KG	14					437	680	1600		874	0	87
B-SB	BENZO(k)FLUORANTHENE	UG/KG	14					437	680	1600		874	0	9
B-SB	CHRYSENE	UG/KG	14	1	230	230	230	422	680	1600	460	844	0	1
B-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	14					437	680	1600		874	0	874
B-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	14					437	680	1600		874	0	87
												BEQ	**38**	**2015**
C-SB	BENZO(a)ANTHRACENE	UG/KG	6	3	130	180	150	258	690	800	300	515	30	52
C-SB	BENZO(a)PYRENE	UG/KG	6	2	120	150	135	328	690	1200	270	655	270	655
C-SB	BENZO(b)FLUORANTHENE	UG/KG	6	2	180	240	210	399	800	1400	420	798	42	80
C-SB	BENZO(k)FLUORANTHENE	UG/KG	6	2	96	200	148	320	640	1200	296	640	3	6
C-SB	CHRYSENE	UG/KG	6	3	96	190	149	224	560	660	297	447	0	0
C-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	6					265	450	800		530	0	530
C-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	6	1	82	82	82	255	480	860	164	511	16	51
												BEQ	**362**	**1374**
D-SB	BENZO(a)ANTHRACENE	UG/KG	6					192	350	430		383	0	38
D-SB	BENZO(a)PYRENE	UG/KG	6					192	350	430		383	0	383
D-SB	BENZO(b)FLUORANTHENE	UG/KG	6					192	350	430		383	0	38
D-SB	BENZO(k)FLUORANTHENE	UG/KG	6					192	350	430		383	0	4
D-SB	CHRYSENE	UG/KG	6					192	350	430		383	0	0
D-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	6					192	350	430		383	0	383
D-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	6					192	350	430		383	0	38
												BEQ	**0**	**886**
E-SB	BENZO(a)ANTHRACENE	UG/KG	29	8	130	3400	798	434	350	1100	1595	868	160	87
E-SB	BENZO(a)PYRENE	UG/KG	29	9	120	2600	609	394	350	1100	1218	788	1218	788
E-SB	BENZO(b)FLUORANTHENE	UG/KG	29	7	120	2600	617	380	350	1100	1234	760	123	76
E-SB	BENZO(k)FLUORANTHENE	UG/KG	29	8	92	2300	646	386	350	1100	1292	772	13	8
E-SB	CHRYSENE	UG/KG	29	9	58	3400	731	434	350	1100	1462	867	1	1
E-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	29	4	160	780	348	307	350	1100	695	614	695	614
E-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	29	6	83	1600	498	342	350	1100	995	685	100	68
												BEQ	**2310**	**1642**
F-SB	BENZO(a)ANTHRACENE	UG/KG	5					215	380	530		430	0	43
F-SB	BENZO(a)PYRENE	UG/KG	5					215	380	530		430	0	430
F-SB	BENZO(b)FLUORANTHENE	UG/KG	5					215	380	530		430	0	43
F-SB	BENZO(k)FLUORANTHENE	UG/KG	5					215	380	530		430	0	4
F-SB	CHRYSENE	UG/KG	5					215	380	530		430	0	0
F-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	5					215	380	530		430	0	430
F-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	5					215	380	530		430	0	43
												BEQ	**0**	**994**

Table 7 : Subsurface soil background BEQs per zone and combined for all zones

Zone-Medium	Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detects	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
G-SB	BENZO(a)ANTHRACENE	UG/KG	7	3	55	180	112	181	400	630	223	363	22	36
G-SB	BENZO(a)PYRENE	UG/KG	7	2	93	150	122	200	400	630	243	399	243	399
G-SB	BENZO(b)FLUORANTHENE	UG/KG	7	3	57	130	82	169	400	630	165	338	16	34
G-SB	BENZO(k)FLUORANTHENE	UG/KG	7	2	110	120	115	198	400	630	230	396	2	4
G-SB	CHRYSENE	UG/KG	7	3	57	200	119	185	400	630	238	369	0	0
G-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	7					231	400	630		461	0	461
G-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	7	2	54	65	60	182	400	630	119	364	12	36
												BEQ	**296**	**972**
H-SB	BENZO(a)ANTHRACENE	UG/KG	58	3	120	640	317	251	360	910	633	501	63	50
H-SB	BENZO(a)PYRENE	UG/KG	58	3	140	480	267	248	360	910	533	496	533	496
H-SB	BENZO(b)FLUORANTHENE	UG/KG	58	1	270	270	270	249	360	910	540	498	54	50
H-SB	BENZO(k)FLUORANTHENE	UG/KG	58					248	360	910		496	0	5
H-SB	CHRYSENE	UG/KG	58	3	140	580	307	250	360	910	613	500	1	1
H-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	58					249	380	910		498	0	498
H-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	58	1	220	220	220	247	360	910	440	494	44	49
												BEQ	**695**	**1148**
I-SB	BENZO(a)ANTHRACENE	UG/KG	6	1	130	130	130	372	750	980	260	743	26	74
I-SB	BENZO(a)PYRENE	UG/KG	6	1	52	52	52	359	750	980	104	717	104	717
I-SB	BENZO(b)FLUORANTHENE	UG/KG	6	1	120	120	120	423	870	1100	240	847	24	85
I-SB	BENZO(k)FLUORANTHENE	UG/KG	6	1	130	130	130	351	700	920	260	702	3	7
I-SB	CHRYSENE	UG/KG	6	1	140	140	140	309	610	800	280	618	0	1
I-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	6					280	490	640		560	0	560
I-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	6					298	520	680		595	0	60
												BEQ	**157**	**1503**
K-SB	BENZO(a)ANTHRACENE	UG/KG	10					191	350	490		381	0	38
K-SB	BENZO(a)PYRENE	UG/KG	10					191	350	490		381	0	381
K-SB	BENZO(b)FLUORANTHENE	UG/KG	10					191	350	490		381	0	38
K-SB	BENZO(k)FLUORANTHENE	UG/KG	10					191	350	490		381	0	4
K-SB	CHRYSENE	UG/KG	10					191	350	490		381	0	0
K-SB	DIBENZ(a,h)ANTHRACENE	UG/KG	10					191	350	490		381	0	381
K-SB	INDENO(1,2,3-c,d)PYRENE	UG/KG	10					191	350	490		381	0	38
												BEQ	**0**	**880**
SB-BACKG	BENZO(a)ANTHRACENE	UG/KG	153	19	55	3400	444	309	350	1600	888	618	89	62
SB-BACKG	BENZO(a)PYRENE	UG/KG	153	17	52	2600	403	305	350	1600	805	610	805	610
SB-BACKG	BENZO(b)FLUORANTHENE	UG/KG	153	14	57	2600	384	307	350	1600	768	613	77	61
SB-BACKG	BENZO(k)FLUORANTHENE	UG/KG	153	13	92	2300	448	303	350	1600	896	606	9	6
SB-BACKG	CHRYSENE	UG/KG	153	21	57	3400	421	304	350	1600	841	608	1	1
SB-BACKG	DIBENZ(a,h)ANTHRACENE	UG/KG	153	4	160	780	348	285	350	1600	695	569	695	569
SB-BACKG	INDENO(1,2,3-c,d)PYRENE	UG/KG	153	10	54	1600	341	289	350	1600	681	578	68	58
												BEQ	**1744**	**1367**

Table 8 : Surface soil background BEQs Near and Away from Potential Anthropogenic Source Areas

Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detecs	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
Samples within and near (10ft) Railroad Tracks													
BENZO(a)ANTHRACENE	UG/KG	2	1	530	530	530	360	380	380	1060	720	106	72
BENZO(a)PYRENE	UG/KG	2	1	560	560	560	375	380	380	1120	750	1120	750
BENZO(b)FLUORANTHENE	UG/KG	2					200	380	420		400	0	40
BENZO(k)FLUORANTHENE	UG/KG	2	1	760	760	760	475	380	380	1520	950	15	10
CHRYSENE	UG/KG	2	1	650	650	650	420	380	380	1300	840	1	1
DIBENZ(a,h)ANTHRACENE	UG/KG	2	1	130	130	130	160	380	380	260	320	260	320
INDENO(1,2,3-c,d)PYRENE	UG/KG	2	1	310	310	310	250	380	380	620	500	62	50
												1565	**1242**
Samples within and near (10ft) Apshalt Paved Areas													
BENZO(a)ANTHRACENE	UG/KG	50	8	34	380	179	253	360	860	359	506	36	51
BENZO(a)PYRENE	UG/KG	50	7	45	1400	357	278	360	860	715	556	715	556
BENZO(b)FLUORANTHENE	UG/KG	50	8	57	1700	384	294	360	930	768	589	77	59
BENZO(k)FLUORANTHENE	UG/KG	50	9	71	1200	317	270	360	860	634	540	6	5
CHRYSENE	UG/KG	50	9	54	810	267	254	360	860	534	507	1	1
DIBENZ(a,h)ANTHRACENE	UG/KG	50	2	68	270	169	240	340	860	338	480	338	480
INDENO(1,2,3-c,d)PYRENE	UG/KG	50	6	42	650	214	239	340	860	427	478	43	48
												1215	**1199**
Samples within and near (10ft) Roadways													
BENZO(a)ANTHRACENE	UG/KG	20	7	48	1900	564	389	360	1000	1128	778	113	78
BENZO(a)PYRENE	UG/KG	20	6	82	1200	502	352	360	1000	1004	704	1004	704
BENZO(b)FLUORANTHENE	UG/KG	20	4	68	1400	570	352	360	1100	1139	704	114	70
BENZO(k)FLUORANTHENE	UG/KG	20	4	88	1100	690	356	360	1000	1379	712	14	7
CHRYSENE	UG/KG	20	7	50	1700	561	372	360	1000	1123	745	1	1
DIBENZ(a,h)ANTHRACENE	UG/KG	20	3	130	210	167	229	360	1000	333	459	333	459
INDENO(1,2,3-c,d)PYRENE	UG/KG	20	5	94	380	251	248	360	1000	502	496	50	50
												1629	**1368**
Surface Soil Samples from Other Areas													
BENZO(a)ANTHRACENE	UG/KG	140	38	43	2100	335	301	340	4000	669	602	67	60
BENZO(a)PYRENE	UG/KG	140	38	48	1500	312	294	340	4000	624	588	624	588
BENZO(b)FLUORANTHENE	UG/KG	140	32	49	1800	359	299	340	4000	718	599	72	60
BENZO(k)FLUORANTHENE	UG/KG	140	35	42	1700	317	294	340	4000	635	589	6	6
CHRYSENE	UG/KG	140	41	40	3000	370	308	340	4000	739	616	1	1
DIBENZ(a,h)ANTHRACENE	UG/KG	140	10	64	440	179	267	350	4000	358	535	358	535
INDENO(1,2,3-c,d)PYRENE	UG/KG	140	25	58	670	209	266	340	4000	418	532	42	53
												1170	**1303**
All Surface Soil Background Samples Across CNC													
BENZO(a)ANTHRACENE	UG/KG	212	53	34	2100	342	299	340	4000	683	597	68	60
BENZO(a)PYRENE	UG/KG	212	51	45	1500	341	296	340	4000	681	593	681	593
BENZO(b)FLUORANTHENE	UG/KG	212	44	49	1800	383	304	340	4000	765	607	77	61
BENZO(k)FLUORANTHENE	UG/KG	212	48	42	1700	348	295	340	4000	697	590	7	6
CHRYSENE	UG/KG	212	57	40	3000	377	302	340	4000	754	603	1	1
DIBENZ(a,h)ANTHRACENE	UG/KG	212	15	64	440	175	258	340	4000	351	515	351	515
INDENO(1,2,3-c,d)PYRENE	UG/KG	212	36	42	670	215	258	340	4000	431	516	43	52
											BEQ	**1228**	**1287**

Table 9 : Surface and Subsurface background BEQs after removing top 10 samples

Chemical Name	Units	No. Analysis	No. Detects	Minimum of Detects	Max. of Detects	Mean of Detect	Adjusted Mean	Minimum of Non-Detecs	Maximum of Non-Detects	2x Mean of Detects	2x Adjusted Mean	BEQ (2x Mean Value)	BEQ (2x Adj Mean Value)
Surface Soil													
BENZO(a)ANTHRACENE	UG/KG	202	46	34	860	214	256	340	1000	428	512	43	51
BENZO(a)PYRENE	UG/KG	202	44	45	710	217	256	340	1000	435	511	435	511
BENZO(b)FLUORANTHENE	UG/KG	202	37	49	710	224	260	340	1100	448	520	45	52
BENZO(k)FLUORANTHENE	UG/KG	202	42	42	950	235	255	340	980	470	510	5	5
CHRYSENE	UG/KG	202	50	40	1200	238	253	340	980	476	505	0	1
DIBENZ(a,h)ANTHRACENE	UG/KG	202	9	64	200	119	241	340	980	238	483	238	483
INDENO(1,2,3-c,d)PYRENE	UG/KG	202	30	42	370	154	235	340	980	308	469	31	47
											BEQ	**796**	**1150**
Subsurface Soil													
BENZO(a)ANTHRACENE	UG/KG	143	16	55	640	228	270	350	980	457	539	46	54
BENZO(a)PYRENE	UG/KG	143	15	52	610	217	270	350	980	434	539	434	539
BENZO(b)FLUORANTHENE	UG/KG	143	13	57	620	214	274	350	1100	427	548	43	55
BENZO(k)FLUORANTHENE	UG/KG	143	11	92	440	184	266	350	940	368	532	4	5
CHRYSENE	UG/KG	143	18	57	630	226	264	350	940	452	529	0	1
DIBENZ(a,h)ANTHRACENE	UG/KG	143	2	160	160	160	267	350	940	320	534	320	534
INDENO(1,2,3-c,d)PYRENE	UG/KG	143	8	54	360	157	264	350	940	314	527	31	53
											BEQ	**878**	**1241**

Table 10: Top BEQ Concentrations Removed			
Matrix	SumOfBEQ	SampleID	Rank
SB	4166.4	GDESB01502	1
SB	1848.8	GDBSB00102	2
SB	1519.7	GDESB01402	3
SB	1386.6	GDBSB00202	4
SB	1271.05	GDESB00602	5
SB	1155.5	GDASB00502	6
SB	1155.5	GDASB01102	6
SB	1137.16	GDCSB00402a	8
SB	1120.835	GDESB00702	9
SB	1109.28	GDASB00102	10
SS	4622	GDESB00401	1
SS	2277.5	GDESB01801	2
SS	2014.35	GDHSB08301	3
SS	2006.7	GDHSB02801	4
SS	1955.81	GDHSB00101	5
SS	1790.7	GDHSB02601	6
SS	1761.06	GDHSB08101	6
SS	1384.98	GDASB00601	8
SS	1257.73	GDHSB05601	9
SS	1155.5	GDBSB00101	10