Statewide Soil Background Study:

Report of Findings

DE-1348

July 2012

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Acknowledgements

The authors would like to thank the following individuals for their help.

For allowing access to State Parks and Wildlife Areas and interviews-

Dwight Antilla- Brandywine Creek State Park

Mike Moyer-Lums Pond State Park

Craig Rhodes- Cedar Swamp Wildlife Area (WLA)

Wayne Lehman-Norman G. Wilder WLA

For reviewing and providing comments on the Work Plan-

Dr. Qazi Salahuddin-DNREC-SIRS

Scott Andres- Delaware Geological Survey

Dr. David Wunsch- Delaware Geological Survey

Dr. Mingxin Guo- Delaware State University

Jason Sunde-BrightFields, Inc.

For providing technical support-

Kelly Black, Matt Pocernich and Mark Fitzgerald -Neptune and Company, Inc.

For field sampling support-

Karissa Hendershot- DNREC-SIRS

Krystal Stanley- DNREC-SIRS

Lindsay Hall- DNREC-SIRS

Randy Wolfe- DNREC-SIRS

Diane Shields- United States Department of Agriculture Natural Resources Conservation Service (USDA/NCRS)

For GIS support-

Karissa Hendershot- DNREC-SIRS

Krystal Stanley- DNREC-SIRS

For EQUIS/database management support-

Stephanie Scholl- DNREC-SIRS

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Section 1.0-Introduction

The Department of Natural Resources and Environmental Control-Site Investigation and Restoration Section (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. DNREC-SIRS performed a study of the background concentrations of metals and polycyclic aromatic hydrocarbons (PAHs) in soil for the purpose of establishing background conditions. Results at or below these background levels at a HSCA site would be used to determine if no further investigation or cleanup actions for these constituents would be required. Since the study involved an extensive field effort to collect soil samples, the opportunity was also taken to evaluate alternative methods of soil sampling. This study reports the results obtained through two different analytical methods and two different sampling methods.
Field work was performed during the summer and autumn of 2011 by DNREC-SIRS staff following the Background Study Work Plan (DNREC, 2011).

Section 2.0-Objectives

The Work Plan stated the following objectives:

1) To collect representative soil samples from both geologic provinces (Piedmont and Coastal Plain) and predominant soil types in the three counties of the state to represent a wide range of natural conditions.

2) To generate reference data sets of results obtained by two different soil sampling methods- discrete soil samples taken according to the HSCA Standard Operating Procedures (SOPs) and soil samples collected by the Incremental Sample Method (ISM), an emerging sampling technique.

3) To develop a database of background concentrations of metals in soil based on analysis using X-ray fluorescence (XRF) in a screening application. This methodology is routinely used by DNREC-SIRS.

4) To evaluate the presence of PAHs in surface soil due to aerial deposition or naturally occurring phenomena such as brush fires.

The purpose of this report is to present the results of the study. Official guidance for using the results in site investigation and remediation performed under the HSCA will be presented in a separate SIRS document.

Section 3.0-Methods

Site selection, data collection, analytical procedures, and statistical methods are discussed. The study used methods and procedures developed by DNREC-SIRS, the USEPA and other industry standards so that the results would be directly comparable to the results of sampling and analysis at HSCA jurisdiction sites under investigation for suspected contamination.

Section 3.1- Site Selection

Eight sites representing natural background conditions were selected for the study. DNREC-SIRS confirmed, through interviews with Wildlife Managers and Park Managers, that the sites did not have any prior commercial or industrial uses or recent agricultural uses and thus represent background conditions. Some minor human impacts were present at Sites 3 and 4, which is discussed in the sections below.

The sites were dispersed among two geologic provinces and the three counties of the state. The Piedmont province occurs in northern New Castle County and occupies less than 5% of Delaware's total land area. Piedmont rocks are composed of structurally complex bodies of metamorphic and igneous rocks. The Piedmont dips southeastward under the sediments of the Atlantic Coastal Plain in the area known as the Fall Zone (Ramsey, 2005). The Fall Zone extends from north of Newark to north of the Christina River in Wilmington. The Coastal Plain province occurs in the southern portions of New Castle County (northern Coastal Plain) and all of Kent and Sussex Counties (southern Coastal Plain). The Coastal Plain sediments are composed of seaward dipping strata of mostly unconsolidated sand, silt, and clay. Figure 1 shows the geologic provinces of Delaware and locations of the eight sites.

USDA Natural Resource Conservation Service (NRCS) personnel performed a detailed description and functional classification of the soil. Table 1 summarizes the characteristics of the background site locations. Appendices 1 through 8 include a location map of each site and the full NRCS soil description.

Based on the typical surface area of properties in the DNREC-SIRS cleanup program, a rectangular area of two-acres was selected as the approximate shape and size of the eight background sites (DNREC, 2011). Field conditions required modifications of the area and aspect of Sites 3 and 7. Departures from the Work Plan are discussed in Appendices 3 and 7.

Section 3.2-Soil Sampling

At each two-acre site, 20 sample locations were fixed on a systematic rectangular grid with a random start. At each of the locations, two discrete samples were taken: one from surface soil (0-6" below ground surface [BGS]) and one from shallow soil (0-24" BGS). In addition to the discrete samples, two soil "increments" from surface and shallow soils were taken at each location and composited in accordance with procedures for the ISM. A description of the ISM including its theory and methodology is found in the Work Plan Appendix C.
Sampling was performed by experienced field personnel in accordance with the Work Plan and DNREC Standard Operating Procedures (SOPs) (SIRS, Revision 2010). Two field duplicate samples were obtained at each of the eight sites for Quality Assurance/Quality Control (QA/QC). Routine chain-of-custody procedures were followed.

Table 1-Background Reference Site Information

Site	Physio-graphic Province	Surficial Geologic Formation	Soil Series	Soil Texture Class	Location	County
1	Piedmont	Wissahickon*	Glenelg	clay loam	Brandywine Creek State Park	New Castle
2	Piedmont	Wissahickon*	Neshaminy	silt loam	Brandywine Creek State Park	New Castle
3	Coastal Plain	Columbia	Sassafras	sandy loam	Lums Pond State Park	New Castle
4	Coastal Plain	Scotts Corner	Leipsic	silt loam	Cedar Swamp Wildlife Area	New Castle
5	Coastal Plain	Beaverdam	Hambrook	loam	Norman Wilder Wildlife Area	Kent
6	Coastal Plain	Beaverdam	Woodstown	sandy loam	Norman Wilder Wildlife Area	Kent
7	Coastal Plain	Beaverdam	Pepperbox	loamy sand	Redden State Forest	Sussex
8	Coastal Plain	Beaverdam	Cedartown	loamy sand	Redden State Forest	Sussex

* Wissahickon Formation is the bedrock underlying the saprolite and regolith.

Section 3.3-Chemical Analysis

Section 3.3.1-Analytical Laboratories

Analysis of soil samples involved three different laboratories employing methods described below:

1. The DNREC Division of Water Laboratory (DWL), certified by the USEPA, used industry standard methods consistent with the USEPA's "Contract Lab Program" (CLP) and DNREC's Standard Operating Procedures for Chemical Analytical Programs (SOPCAP) to analyze the discrete samples. These results shall be referred to in this report as the discrete data.

2. The DNREC-SIRS laboratory used a bench XRF instrument to produce "screening" level results for metals in discrete soil samples. These results shall be referred to as XRF data.

3. The private laboratory TestAmerica Laboratories, Inc. (TestAmerica) performed the specialized preparation of the ISM samples and provided analysis using methods consistent with the CLP and SOPCAP. These results shall be referred to as ISM data.

Section 3.3.2- PAH Analysis

The discrete surface soil samples (168 samples) and the ISM surface composite samples (seven samples) were analyzed for PAHs by USEPA SW-846 Analytical Method 8270. The ISM PAH

and metal samples for inadvertently misplaced and were therefore not analyzed (see Table 6-2 and Table 6-4). Table 4 (page 14) lists the 16 PAH analytes. The DNREC DWL detection limit for individual PAHs was 0.33 milligrams per kilogram (mg/kg). The TestAmerica Lab detection limit was 0.33 mg/kg for compounds except benzo (a) pyrene and dibenz (a,h) anthracene, for which the detection limit was 0.033 mg/kg.

Section 3.3.3-Metals Analysis

The 168 shallow discrete samples were screened in the DNREC-SIRS laboratory by DNREC personnel using a bench XRF instrument and were also submitted to the DNREC Water Resources Laboratory for analysis by USEPA SW-846 Analytical Method 6010B. The list of analytes is not identical for the two methods. Table 2 presents the typical detection limits of the two methods and indicates which analytes are addressed by the two methods.

Section 3.3.4-Data Quality and Management

DNREC-SIRS performed data verification and an independent contractor conducted data validation on 20% of the laboratory analytical results. Data were qualified as necessary. The results of field duplicates were examined and the Relative % Difference (RPD) generally fell within the acceptable range of + or – 20%. Therefore, the original sample result was retained and the duplicate result was eliminated from the data base.
Results of the XRF analysis were validated by the DNREC-SIRS laboratory and qualified as appropriate.

The nearly 8,000 separate results produced by this study were managed in the EQuIS© system except for the 16 ISM results which were maintained manually in a spreadsheet.

Section 3.3.5-Statistical Methods

The utility of this data set to DNREC-SIRS is in establishing appropriate data sets of background metals and PAHs to aid in determining whether a subject site is contaminated above the expected background concentrations. Separate data sets of results were compiled for conventional lab analysis and for screening analysis by XRF. Direct comparison of the analytical and sampling methods is not part of this report.

Statistical tables and graphs were produced using the NCSS 2007 statistical package (Version 07.1.2.1, Hintze, J.) or ProUCL (Version 4.1.00, USEPA).

This report uses basic summary statistics. Chart 1 consists of violin plots created by NCSS 2007. The violin plot is a hybrid of the box plot and a vertical density trace which facilitates the side by side comparison of ranges and distributions of analytes at the eight background sites.

Data tables in this report (Appendices 1 to 8) include columns indicating the frequency of detection when relevant. For some data tables, summary statistics are based on detected values only and this is noted in the column heading. When there were no detections, “NA” (not applicable) appears in the table rather than a statistic. In keeping with current practice for managing censored data (data containing non-detects expressed as inequalities), no substitutions for non-detects have been used for this study (USEPA 2009).

Table 2 Metals Detection Limits

	Discrete and ISM CLP DLs (mg/kg)	XRF DLs (mg/kg)
Analytes		
Aluminum	40	--
Antimony	12	20
Arsenic	2	4
Barium	40	12
Beryllium	1	--
Cadmium	1	2
Calcium	1,000	180
Chromium	2	80
Cobalt	10	310
Copper	5	9
Iron	20	82
Lead	1	3
Magnesium	1,000	--
Manganese	3	200
Mercury	0.04	7
Nickel	8	25
Potassium	1,000	--
Selenium	7	4
Silver	2	3
Sodium	1,000	--
Thallium	5	5
Titanium	--	No DL
Vanadium	10	60
Zinc	4	9

CLP RLs= Contract Laboratory Program Required Detection Limits. The lowest detection level for analytes required under SIRs contract with HSCA labs.

-- = Analyte not analyzed by the analytical method.

DL= Detection Limit

ND= Not Detected

Section 4.0-Findings

This section discusses the soil characteristics, geology and analytical results obtained from the eight background sites. Appendices 1 through 8 include tables of summary data by site. The first table of each appendix (Table 1-1, Table 2-1, etc.) is a soil description of the background site. The second table of each appendix (Table 1-2, Table 2-2, etc.) summarizes descriptive statistics of 20 discrete samples and the ISM result for each analyte. The third table of each appendix summarizes the XRF results for each site (Table 1-3, Table 2-3, etc.) and the fourth table of each appendix (Table 1-4, Table 2-4, etc.) summarizes the PAH results for each site. While the summary tables included in the appendices are complete for all analytical results, discussion of findings is limited to a subset of those analytes having significance in the HSCA cleanup program due to their frequency of detection and toxicity: aluminum, arsenic, barium, chromium, cobalt, copper, iron, manganese, mercury, nickel, vanadium, and zinc.

Section 4.1-Site Characteristics

Section 4.1.1- Site 1& 2

Section 4.1.1.1 Geology

Sites 1 and 2 are located in the Piedmont province. The Piedmont rocks are composed of mafic silicate minerals that contain high concentrations of magnesium and iron as well as other metals, and relatively low concentrations of silica (Plank, 2001).

The bedrock beneath Site 1 is the pre-Cambrian age Wissahickon Formation, which is an amphibolite gneiss (Ramsey, 2005). The main mineral assemblage is biotite mica, plagioclase, quartz, garnet and sillimanite. Small grains of mica were observed in the soil as described in Table 1-1. The metal fraction of these minerals is mainly magnesium, iron and aluminum.

The bedrock beneath Site 2 is Ordovician age Wilmington Complex Montchanin Metagabbro (Ramsey, 2005). The main mineral assemblage is olivine, pyroxene and plagioclase. The metal fraction of these minerals is mainly calcium, sodium, magnesium, iron and aluminum, with the highest concentration components being aluminum, iron and magnesium. Mica was again observed in the soil as noted in Table 2-1. The mica may be from the Wissahickon Formation rocks, which are upslope of Site 2. Pieces of gneiss saprolite were also observed during sample collection. Based on the presences of the mica and saprolite, the detrital material was likely from the Wissahickon Formation bedrock carried downslope to be incorporated into the soil in Site 2.

Section 4.1.1.2 Soil

Site 1 soil is a Glenelg loam, which is a moderately well-drained clayey loam. Site 2 soil is a Neshaminy loam, which is a well-drained silty loam. Loam is a soil with relatively equal amounts of sand, silt and clay. The clayey and silty designation indicates that there is slightly more clay and silt than sand. The major minerals in the mafic rock weather into clay and silt-sized particles, or dissolve while the silica weathers into sand sized particles (Pidwirny, 2006).

Since the proportion of clay/silt size particles is higher than the sand content, and clay/silt size particles have a higher level of metals, the soils with higher clay/silt proportion should have

higher metals concentrations. And in fact, Site 1 and 2 silty and clayey loams are higher in magnesium, iron and aluminum than Sites 3 through 8, which are predominately sandy loams or loamy sands. The reverse is also true, where the proportion of sand is higher than clay/silt, the metals concentrations are lower.

Section 4.1.2-Sites 3 to 8

Section 4.1.2.1 Geology

The soils of the Coastal Plain of Delaware are sandy and silty and were deposited in fluvial, estuarine and shallow brackish water environments (Ramsey, 2005). Sites 3 and 4 are in the Coastal Plain yet soil descriptions and analytical results suggest that they are transitional to the marine deposits of southern Delaware. Site 3 consists of soil from the Columbia Formation, which is fluvial in origin (Groot and Jordan, 1999). Site 4 consists of soil from the Scotts Corner Formation, which was deposited during sea level transgressions and regressions (Groot and Jordan, 1999). Sites 5 and 6 are located in the Coastal Plain in Kent County. Sites 7 and 8 are located in the Coastal Plain in Sussex County. Sites 5 through 8 are located within the Beaverdam Formation, which is fluvial and estuarine in origin (Groot and Jordan, 1999).

Section 4.1.2.2 Soil

Both weathering and depositional environment influenced particle size in the soil. During transport, sand is the first particle size to be deposited due to the size and shape, while clay and silt sized particles are last to be deposited due to their smaller size and flat shape (Pidwirny, 2006). Weathering and erosion continues to occur to the deposited particles to re-sort and re-size them as the soil develops. Site 3 soil is Sassafras sandy loam while Site 4 is a Leipsic silt loam. The higher sand content at Site 3 with correspondingly lower silt and clay sized particles content reflects the high energy fluvial environmental in which the soil was deposited (Pidwirny, 2006). The higher silt content at Site 4 is indicative of the lower energy of sea level transgression/regression deposition. The lower energy depositional environment of sea level transgression/regression would be expected to be similar to the low energy in an estuarine environment.

Site 5 soil is classified as the Hambrook loam. Site 6 is classified as the Woodstown sandy loam while Sites 7 and 8 are classified as the Pepperbox and Cedartown loamy sand, respectively. Site 5 is representative of lower energy estuarine environment while Sites 6, 7, 8 are representative of the fluvial environment.

Section 4.2-Analytical Results for Metals

Section 4.2.1-Discrete Metal Results

This section compares the laboratory results of discrete samples taken from the 8 background sites and relates those findings to soil class and geologic province.

Table 3 shows the percent samples at each site which were “non-detect” for specific analytes. The study results show that three metals (antimony, , selenium, and thallium) are not present above detection levels in natural Delaware soils. Beryllium, cadmium, and silver were only detected once in 160 samples. Table 3 shows that the number of metals not detected increases from Sites 5 to 8, specifically arsenic, barium, and vanadium.

Table 3- Percent Non-Detects by Site (Greater than 50% non-detects are highlighted in red)

Variable	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Aluminum	0%	0%	0%	0%	0%	0%	0%	0%
Antimony	100%	100%	100%	100%	100%	100%	100%	100%
Arsenic	0%	35%	0%	5%	60%	70%	60%	100%
Barium	0%	0%	45%	20%	45%	85%	95%	100%
Beryllium	100%	95%	100%	100%	100%	100%	100%	100%
Cadmium	100%	100%	100%	100%	100%	95%	100%	100%
Calcium	0%	0%	0%	0%	0%	0%	5%	20%
Total Chromium	0%	0%	0%	0%	0%	0%	0%	0%
Cobalt	30%	0%	100%	100%	100%	100%	100%	100%
Copper	0%	0%	0%	0%	0%	15%	0%	0%
Iron	0%	0%	0%	0%	0%	0%	0%	0%
Lead	0%	0%	0%	0%	0%	0%	0%	0%
Magnesium	0%	0%	0%	0%	0%	0%	0%	10%
Manganese	0%	0%	0%	0%	0%	0%	0%	0%
Mercury	90%	55%	100%	100%	100%	100%	100%	100%
Nickel	0%	0%	35%	80%	100%	100%	100%	100%
Potassium	0%	0%	0%	0%	5%	5%	0%	50%
Selenium	100%	100%	100%	100%	100%	100%	100%	100%
Silver	100%	95%	100%	100%	100%	100%	100%	100%
Sodium	100%	100%	70%	100%	100%	95%	100%	100%
Thallium	100%	100%	100%	100%	100%	100%	100%	100%
Vanadium	0%	0%	0%	0%	10%	25%	55%	85%
Zinc	0%	0%	0%	0%	0%	0%	0%	0%

Chart 1 is a set of violin plots showing metals concentrations according to site from north (Sites 1 and 2) to south (Site 8). The varying width of the violin plot represents the relative distribution of concentrations. The y-axis is the metal concentration in mg/kg.

The concentrations of all metals in soil generally exhibit a decreasing trend from north to south. Note that Sites 1 and 2 are located less than one half mile apart.

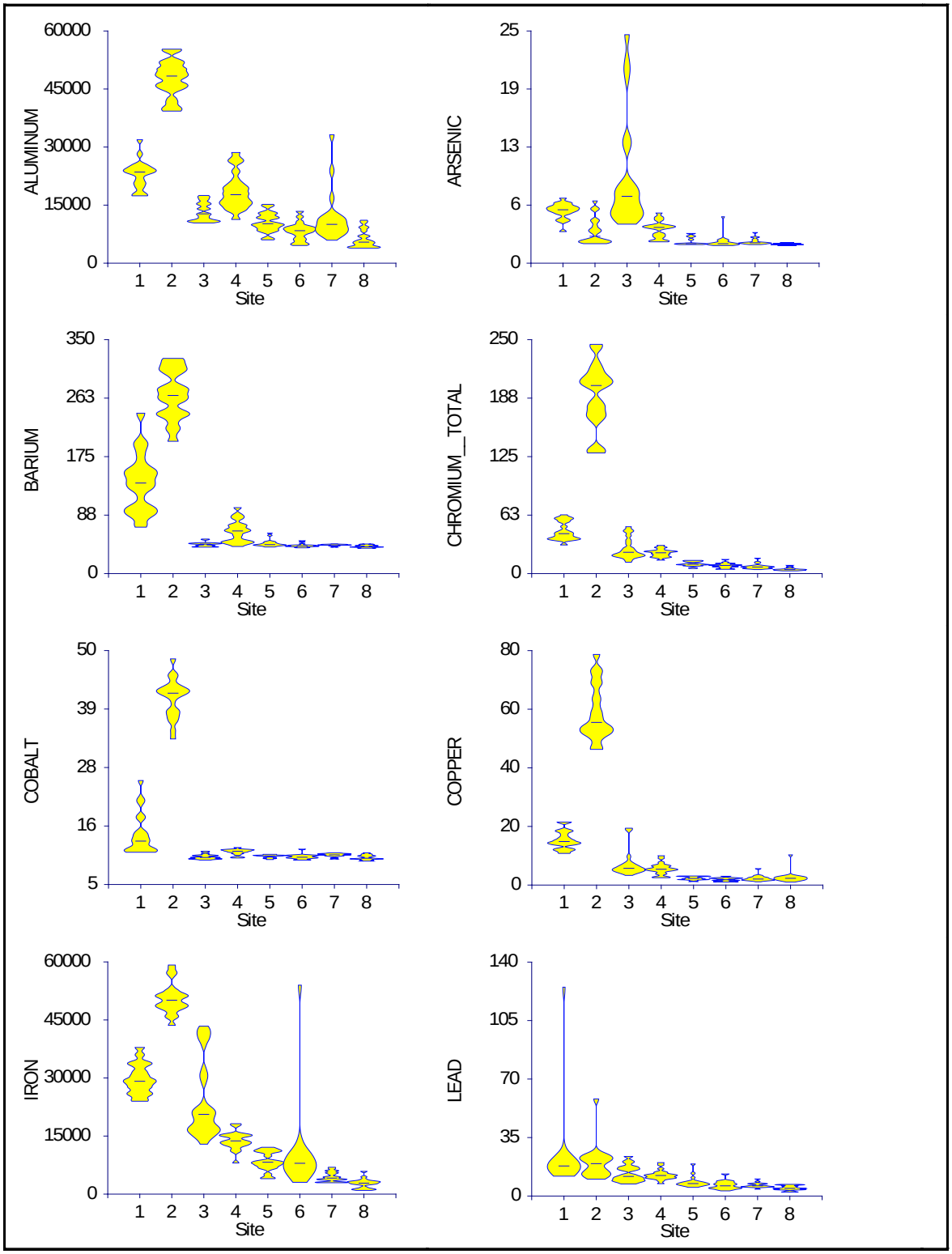

Chart 1. Distribution of concentrations (mg/kg) of metals at eight background sites

(Note: The y-axis represents the analyte concentration in mg/kg; the x-axis indicates Sites 1 to 8; the width of the violin plot represents the distribution of the analyte concentration and the horizontal line within each violin marks the mean concentration of the analyte.)

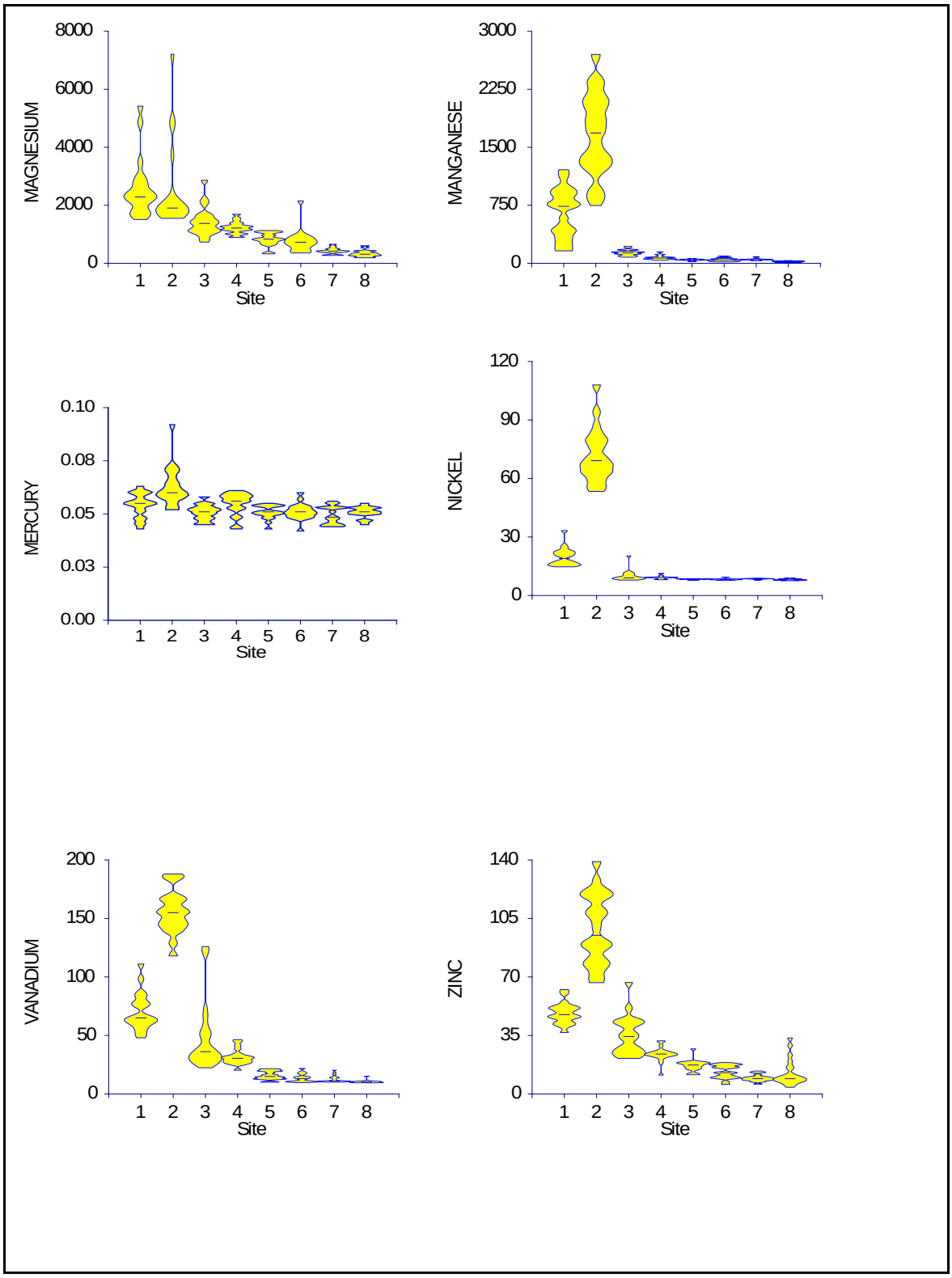

Chart 1 *(continued)*

Section 4.2.1.1 Sites 1 & 2

The soil of Sites 1 and 2 is weathered from bedrock with silicate minerals that contain high concentrations of magnesium and iron (mafic). Material generated from this weathering would result in a clayey silty soil with high concentrations of magnesium, and iron. As shown on Chart 1, Sites 1 and 2 have significant concentrations of aluminum, iron and magnesium as predicted based on the bedrock composition. Site 2 has higher concentrations of aluminum, iron, barium, chromium, cobalt, copper, manganese, nickel, vanadium and zinc than Site 1 which may be due to the relatively higher metal concentrations in the Metagabbro parent rock.

The Piedmont soil texture is generally clayey/silty with less sand (Glenelg clay loam and Neshaminy silt loam) (Table 1).

Site 2 had the highest average concentrations of aluminum (47,595 mg/kg), barium (266 mg/kg), chromium (190 mg/kg) cobalt (41 mg/kg), copper (59 mg/kg), iron (50,500 mg/kg), lead (20 mg/kg), magnesium (2,500 mg/kg), manganese (1,663 mg/kg), nickel (72 mg/kg), vanadium (155 mg/kg) and zinc (99 mg/kg) of any of the background sites. Site 1 had the highest average magnesium at 2,587 mg/kg.

Section 4.2.1.2 Sites 3 to 8

The soil texture changes from the Sites located in the Piedmont (Sites 1 and 2) to the Sites located on the Coastal Plain (Sites 3 to 8). The northern Coastal Plain soil has textures characteristic of both Piedmont and southern Coastal Plain. For example, the Site 3 Sassafras sandy loam is similar in texture to the soil textures in the southern Coastal Plain e.g. sandy loam or loamy sand but the Site 4 Leipsic silt loam is similar to the Piedmont silt and clay loams. The southern Coastal Plain texture is generally sandy with less clay and silt (Groot and Jordan, 1999). Soil descriptions and analytical results for the northern Coastal Plain suggest that it is a transitional zone between the Piedmont and the southern Coastal Plain. Sites 3 and 4 are located in the northern Coastal Plain and Sites 5 to 8 are located in the southern Coastal Plain. This division appears on some geological maps, although it is not recognized by all authorities, and the nomenclature among those who do identify this transition is not consistent.
Since metals tend to adsorb to clay and silt sized particles, the slightly higher clay and silt content in Sites 3 and Site 4 is reflected in the slightly higher metals concentrations than Sites 5 through 8.

The highest concentrations of arsenic found in this study were at Site 3. The average arsenic concentration was 9.3 mg/kg and the 20 discrete sample results ranged from 4.2 to 24.6 mg/kg.

The strong trend of higher clay/silt content and lower sand content soils in the north to higher sand and lower clay/silt in the south (Groot and Jordan, 1999) continues within the southern Coastal Plan. Sites 5 and 6 have slightly higher clay/silt content than Sites 7 and 8 and this is reflected in the higher metals concentration in Sites 5 and 6.

Section 4.2.2- ISM Results

ISM results are presented in the 2nd table of each Appendix. Note that in these tables, the ISM results and discrete data averages are arranged for convenient comparison. The mean of the

discrete data is the mean of the detections only. Like the discrete sample results, the ISM results show the same north to south trend of decreasing metals concentrations. The results suggest that the eight background sites represent two populations corresponding to the Piedmont and the Coastal Plain in Delaware with a transitional zone in the northern Coastal Plain.

Section 4.3-Analytical Results for PAHs

In contrast to the findings for inorganic analytes, the distribution of PAHs in soil is not related to soil class or geological province. There were too few samples with positive detections of PAHs to warrant statistical analysis or comparison between results obtained from discrete and ISM samples.

The distribution of PAHs was markedly uneven both among the eight sites and within individual sites. As shown in Table 4, PAHs were detected in at least one sample at seven of the eight sites. None of the sites, however, were contaminated consistently across 20 sample locations. Four of the sites (2, 3, 5 and 6) had a significant number of detections considering that the reference sites were selected to be minimally impacted by human activity.

The most common PAHs detected were pyrene, fluoranthene, benzo(a)pyrene, benzo(a)-anthracene, chrysene , and benzo (g,h,i) perylene. Benzo (a) pyrene was present in 45% of the samples taken at Sites 5 and 6 and in 20 to 25% of samples taken at Sites 2 and 3. The presence of PAHs on Sites 2, 5, and 6 remains unexplained after interviews with Wildlife Managers and Park Managers. Site 3 is used as a youth camping area for Lums Pond State Park. During field sampling, fire rings were observed within the sampling grid. Several sample locations were adjusted to avoid sampling areas with obvious signs of campfires. At Site 4, the Wildlife Manager reported that the area had been burned for weed control approximately two years previous to the sampling event. The silty soil would be expected to retain residual PAHs if present; however, this is the only site where no PAHs were reported above the detection limit.

Table 4- Number of PAH Detections by Site

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	All Sites
				Number of Detections					
Analyte									
Acenaphthene	0	0	0	0	4	2	0	0	6
Acenaphthylene	0	0	1	0	3	2	0	0	6
Anthracene	0	0	2	0	3	8	0	0	13
Benzo (a) anthracene	0	4	4	0	8	8	0	1	25
Benzo (a) pyrene	0	5	4	0	9	9	0	1	28
Benzo(b)fluoranthene	0	1	2	0	6	0	0	1	10
Benzo (g,h,i)perylene	0	0	3	0	7	9	0	1	20
Benzo(k)fluoranthene	0	1	2	0	6	9	0	1	19
Chrysene	0	4	4	0	8	8	0	1	25
Dibenz(a,h)anthracene	0	0	1	0	4	8	0	0	13
Fluoranthene	0	8	5	0	7	9	0	1	30
Fluorene	0	0	1	0	3	1	0	0	5
Indeno(1,2,3-c,d)pyrene	0	0	2	0	8	8	0	1	19
Naphthalene	0	0	0	0	2	9	4	0	15
Phenanthrene	0	4	2	0	5	8	0	1	20
Pyrene	1	8	6	0	7	9	0	1	32
Total Number of Detections	1	35	39	0	90	107	4	10	286

Note that Table 4 includes “J” qualified data as detections.

The PAHs do not appear to be aerially deposited in surface soil at concentrations above the detection limit of 0.33 mg/kg. If PAHs were aerially deposited, one would expect that PAHs detections and concentrations would be higher in northern Delaware due to the greater number of historical industrial sources. However, Sites 5 and 6 in Kent County have the greatest number of PAH detections and Site 5 has the highest individual PAH concentrations.

Proximity to roads does not appear to impact frequency or concentration of PAHs. Sites 1 and 2 both located in Brandywine Creek State Park are equidistant from a park road but Site 2 has significantly more detections than Site 1. In addition, Sites 1, 2 and 3 are located in suburban areas while Sites 4 to 8 are located in rural areas with less traffic.

The sampling results indicate that PAH concentrations are site specific and can be generated by minimal human activity.

Section 5.0-Conclusions

DNREC-SIRS conducted soil sampling to determine statewide background levels of metals and PAHs. The sampling was conducted on eight background sites located on public lands across the three counties and two geological provinces of the state. The background sites were

approximately two-acres in size, typical of sites in the HSCA cleanup program. Soil samples were collected from surface and shallow soil. For each sample area, 20 discrete samples were collected for PAHs analysis (surface), 20 discrete samples were collected for metals analysis (shallow), one ISM sample was collected for PAHs analysis (surface), one ISM sample was collected for metals analysis (shallow) and 20 discrete samples were collected for metal analysis by XRF (shallow).

Based on the data and findings discussed above, DNREC-SIRS has developed the following conclusions:

1) Metals concentrations are higher in the Piedmont than the northern Coastal Plain of New Castle County and decrease further in the Coastal Plain of Kent and Sussex Counties.

2) The concentration of metals in soil is strongly associated both with smaller particle size and the mineral content of parent rock, but neither of those characteristics is consistently predominant for all analytes.

3) Antimony, selenium, and thallium are not present as background conditions in Delaware soils.

4) PAHs are present in Delaware soils even when historic land use does not suggest their presence. PAHs were detected at seven of the eight reference sites.

5) Within the limits imposed by the detection levels used in this study, PAHs in Delaware soils are not attributable to aerial deposition from regional sources. The detection limits were typically 0.33 mg/kg for individual PAHs in soil.

6) PAH concentrations in soil appear to have been caused by casual human activities, such as camp fires and burning for weed control, which are not associated with the release of hazardous substances.

Section 6.0-References

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Figure

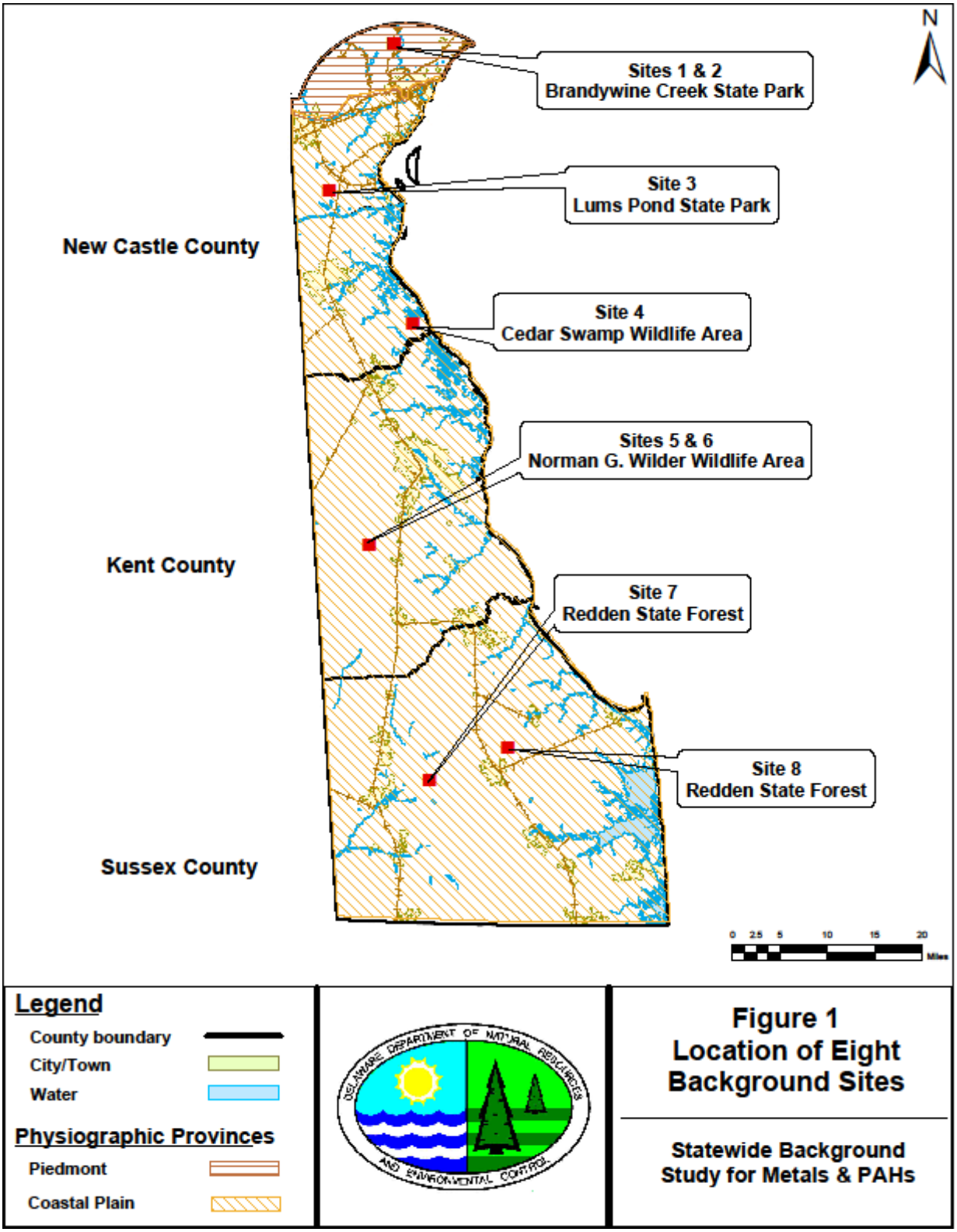
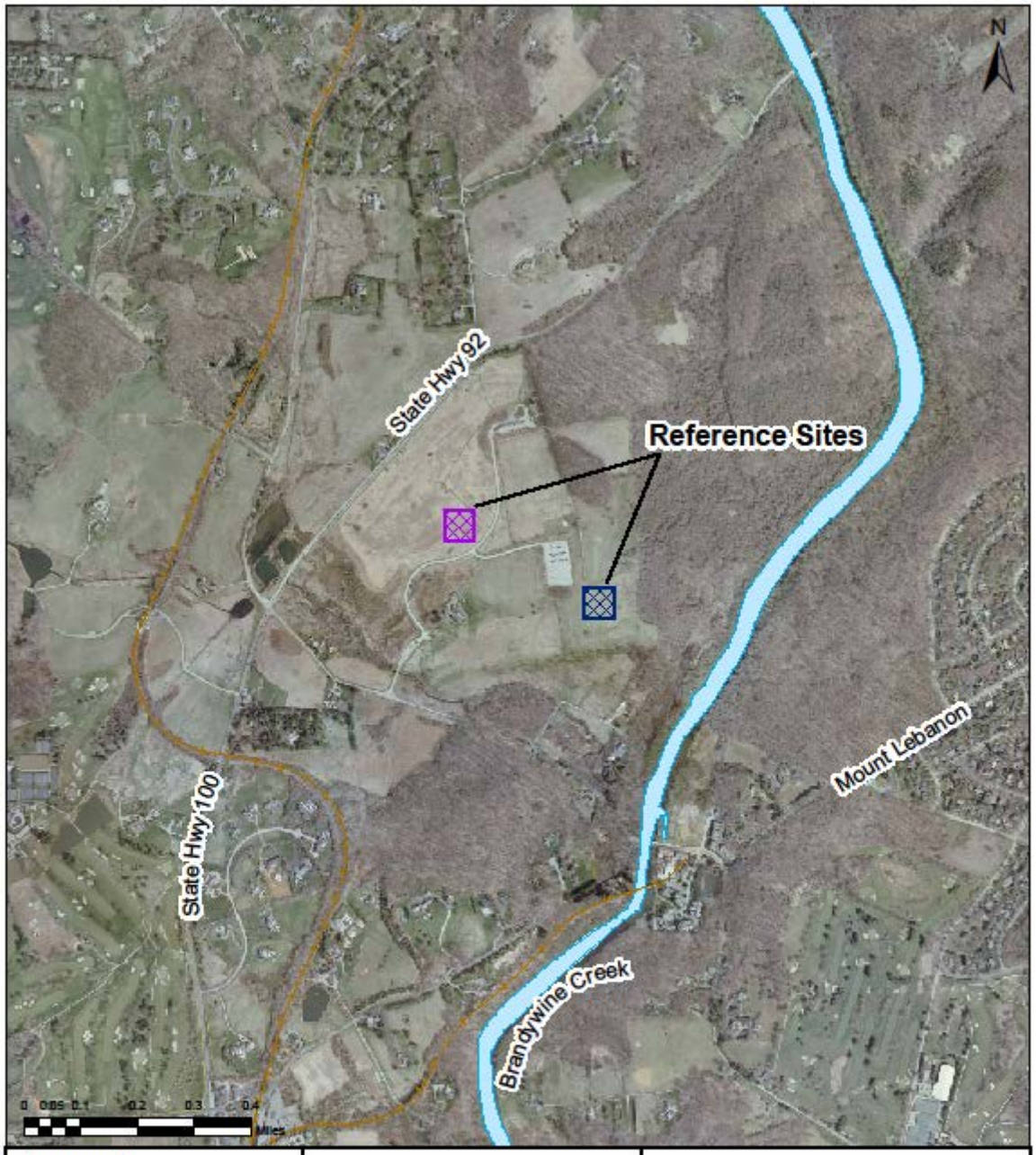


Figure 1
Location of Eight Background Sites

Statewide Background Study for Metals & PAHs

Appendicies

Appendix 1-Background Site 1



Legend

Site1
Glenelg Soil

Site 2
Neshaminy Soil

Figure 2
Background Reference Sites 1 and 2
New Castle County
Brandywine Creek State Park

Statewide Background
Study for Metals & PAHs

Table 1-1 Site 1: Summary Table

Description Date:	6/8/2011
Soil Survey Area:	DE003 -- New Castle County, Delaware
Location Description:	Brandywine State Park
Latitude:	39 degrees 48 minutes 19.80 seconds north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 34 minutes 56.30 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Glenelg Taxadjunct
Classification:	Fine-loamy, mixed, semi active, mesic Aquic Hapludults
Map Unit:	GeB -- Glenelg loam, 3 to 8 % slopes
Bedrock Kind:	mica schist
Slope:	5.0%
Elevation:	83 m
Drainage class:	moderately well drained
Soil Description:	
Ap1	0 to 6 centimeters; dark brown (10YR 3/3) silt loam; 15 % clay; weak fine granular structure; very friable, nonsticky, slightly plastic; many fine roots throughout and many medium roots throughout; common fine interstitial pores; slightly acid, pH 6.2.
Ap2	6 to 28 centimeters; dark yellowish brown (10YR 3/4) silt loam; weak medium platy parts to moderate medium subangular blocky structure; friable, nonsticky, slightly plastic; common fine roots throughout and common very fine roots throughout; common fine moderate-continuity tubular pores; moderately acid, pH 5.8.
Bt1	28 to 50 centimeters; dark yellowish brown (10YR 4/6) silt loam; 25 % clay; moderate medium subangular blocky structure; friable, nonsticky, moderately plastic; few fine roots throughout and few very fine roots throughout; few fine moderate-continuity tubular and few fine moderate- continuity vesicular pores; 25 % faint clay films on all faces of peds; 3 % fine iron-manganese concretions; 10 % fine mica flakes, unspecified throughout; 7 % nonflat angular weakly cemented 5- to 15-millimeter gneiss fragments; slightly acid, pH 6.5.
Bt2	50 to 90 centimeters; dark yellowish brown (10YR 4/6) silty clay loam; 30 % clay; moderate medium subangular blocky structure; firm, nonsticky, moderately plastic; few fine roots throughout and few very fine roots throughout; few fine moderate-continuity tubular and few fine moderate- continuity vesicular pores; 30 % distinct clay films on all faces of peds; 1 % fine distinct yellowish red (5YR 4/6), moist, masses of oxidized iron and 3 % fine iron-manganese concretions and 10 % medium distinct grayish brown (10YR 5/2), moist, iron depletions; 10 % fine mica flakes, unspecified throughout; 7 % nonflat angular weakly cemented 5- to 15-millimeter gneiss fragments; neutral, pH 6.8.
BC	90 to 115 centimeters; brown (7.5YR 4/4); 12 % clay; weak medium subangular blocky structure; very friable, nonsticky, slightly plastic; 30 % fine mica flakes, unspecified throughout; slightly acid, pH 6.5.
CB	115 to 200 centimeters; 65 % brown (7.5YR 4/4) and 20 % light yellowish brown (10YR 6/4) and 15 % very dark gray (7.5YR 3/1) sandy loam; 10 % clay; very friable, nonsticky, slightly plastic; 50 % fine mica flakes, unspecified throughout; 10 % nonflat angular weakly cemented 5- to 15-millimeter gneiss fragments; moderately acid, pH 6.0.

Table 1-2 Site 1: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	23,100.00	22,925.0	0%	17,400.0	31,900.0	23,550.0	0.16
Antimony	<1.5	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	4.90	5.7	0%	3.4	7.0	5.8	0.15
Barium	115.00	135.8	0%	69.5	240.0	135.5	0.32
Beryllium	0.81	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	0.11	N/A	100%	N/A	N/A	N/A	N/A
Calcium	850.00	1,918.0	0%	1,600.0	2,270.0	1,890.0	0.09
Chromium, Total	44.30	45.6	0%	30.6	62.8	42.7	0.22
Cobalt	12.60	16.0	30%	11.5	25.0	14.7	0.25
Copper	20.90	15.3	0%	10.8	21.5	14.9	0.20
Iron	29,300.00	29,780.0	0%	24,000.0	37,900.0	29,150.0	0.13
Lead	14.60	23.2	0%	11.9	125.0	18.0	1.05
Magnesium	2,280.00	2,587.0	0%	1,510.0	5,420.0	2,290.0	0.39
Manganese	522.00	656.0	0%	161.0	1,210.0	736.0	0.48
Mercury	0.0391	0.054	90%	0.045	0.063	0.054	0.24
Nickel	24.00	19.8	0%	14.7	33.3	19.0	0.23
Potassium	1,080.00	1,588.0	0%	725.0	5,690.0	1,165.0	0.78
Selenium	1.20	N/A	100%	N/A	N/A	N/A	N/A
Silver	<1	N/A	100%	N/A	N/A	N/A	N/A
Sodium	<516	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<1.2	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	68.20	70.2	0%	48.0	111.0	65.0	0.23
Zinc	45.80	48.3	0%	36.8	62.4	47.5	0.13

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 1-3 Site 1: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	100%	N/A	N/A	N/A	N/A	N/A
Arsenic	85%	7.1	9.2	8.1	8.1	0.127
Barium	0%	560.0	972.4	714.2	706.0	0.127
Cadmium	90%	2.9	3.1	3.0	3.0	0.0517
Calcium	0%	3,064.0	4,090.0	3,507.0	3,422.0	0.0904
Chromium, Total	0%	49.9	155.8	103.2	105.3	0.357
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	5%	13.1	37.4	24.5	23.2	0.238
Iron	0%	28,247.0	48,231.0	38,671.0	37,779.0	0.145
Lead	5%	10.4	59.9	38.4	40.6	0.297
Manganese	80%	139.0	432.0	276.4	267.3	0.47
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	0%	50.4	93.9	70.5	63.9	0.216
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	90%	3.3	4.0	3.7	3.7	0.136
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	593.5	707.0	651.7	645.4	0.0448
Vanadium	25%	53.0	126.0	82.9	79.0	0.314
Zinc	0%	47.5	105.7	75.7	73.1	0.174

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

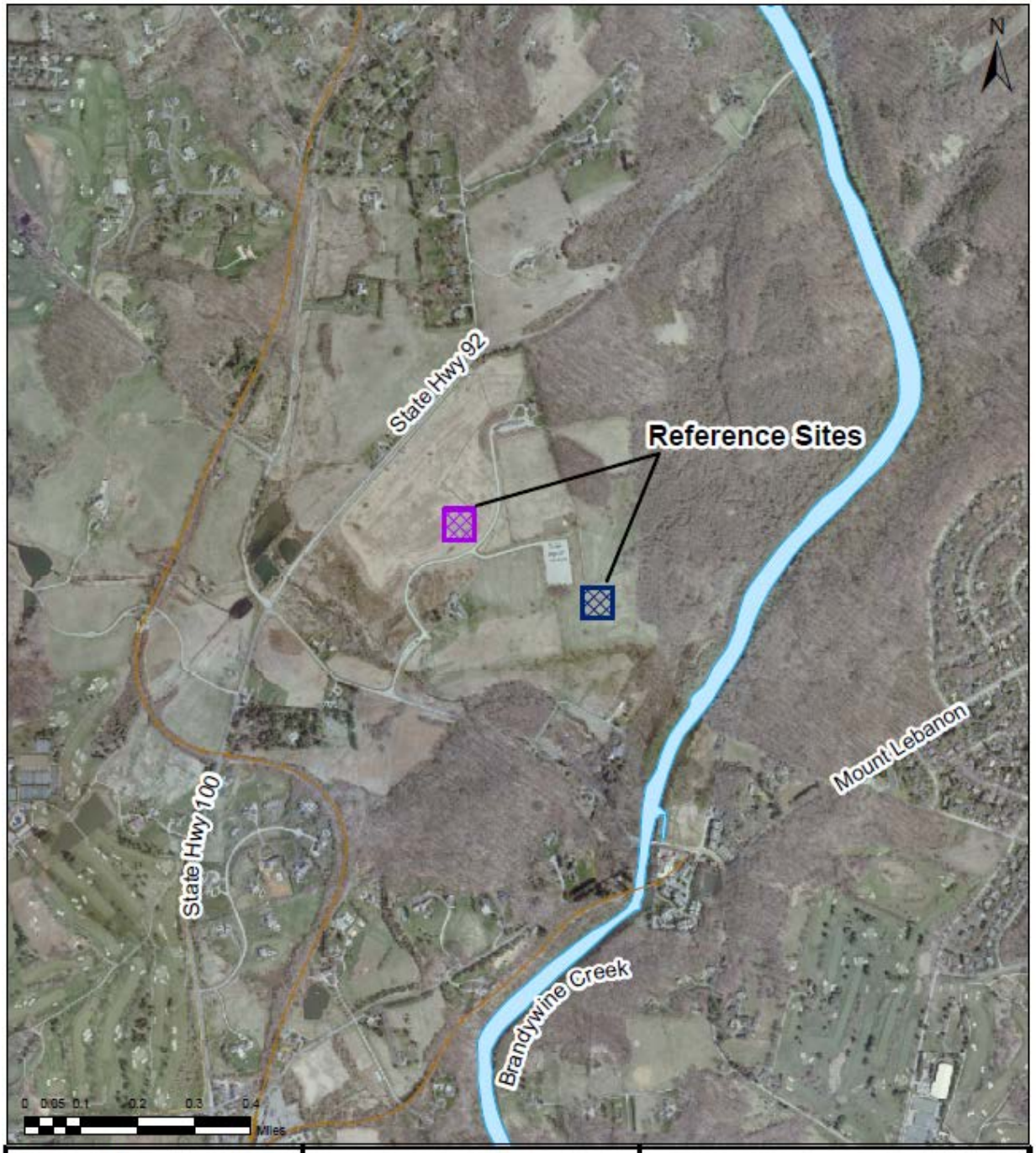
Analytical results are in mg/kg.

Table 1-4 Site 1: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Anthracene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) anthracene	0.02	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) pyrene	0.01	N/A	100%	N/A	N/A	N/A	N/A
Benzo (b) fluoranthene	0.02	N/A	100%	N/A	N/A	N/A	N/A
Benzo (g,h,i) perylene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Benzo (k) fluoranthene	0.01	N/A	100%	N/A	N/A	N/A	N/A
Chrysene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Dibenz (a,h) anthracene	< 0.034	N/A	100%	N/A	N/A	N/A	N/A
Fluoranthene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Fluorene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Indeno (1,2,3-c,d) pyrene	0.01	N/A	100%	N/A	N/A	N/A	N/A
Naphthalene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Phenanthrene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Pyrene	< 0.34	0.1	95%	0.1	0.1	0.1	N/A

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 2-Background Site 2



Legend

Site1
Glenelg Soil

Site 2
Neshaminy Soil

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

Figure 2
Background Reference Sites 1 and 2
New Castle County
Brandywine Creek State Park

Statewide Background
Study for Metals & PAHs

Table 2-1 Site 2: Summary Table

Description Date:	6/8/2011
Soil Survey Area:	DE003 – New Castle County, Delaware
Location Description:	Brandywine State Park
Latitude:	39 degrees 48 minutes 11.00 seconds north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 34 minutes 36.10 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Neshaminy
Classification:	Fine-loamy, superactive, mesic Ultic Hapludalfs
Map Unit:	NtC – Neshaminy silt loam, 8 to 15 percent slopes
Slope:	11.0%
Elevation:	79 m
Drainage class:	well drained
Soil Description:	
Ap1	0 to 10 centimeters; dark brown (7.5YR 3/2) channery loam, brown (7.5YR 5/3), dry; 10 percent clay; moderate fine granular structure; very friable, loose, non-sticky, non-plastic; fine roots and medium roots and coarse roots and very fine roots; fine tubular pores; 25 percent flat subangular indurated 2- to 75-millimeter unspecified fragments; moderately acid, pH 5.8.
Ap2	10 to 26 centimeters; dark brown (7.5YR 3/2) channery loam; 10 percent clay; weak coarse subangular blocky parts to moderate fine granular structure; friable, slightly hard, non-sticky, non-plastic; fine roots and very fine roots; fine tubular pores; 30 percent flat subangular indurated 2- to 75-millimeter unspecified fragments; moderately acid, pH 5.8.
BA	26 to 40 centimeters; dark reddish brown (5YR ¾) channery loam; 15 percent clay; friable, non-sticky, non-plastic; 30 percent flat subangular indurated 2- to 75-millimeter unspecified fragments; slightly acid, pH 6.2.
Bt	40 to 50 centimeters; reddish brown (5YR 4/4) channery clay loam; 28 percent clay; friable, non-sticky, slightly plastic; 10 percent fine mica flakes, mixed; 30 percent flat subangular indurated 2- to 75-millimeter unspecified fragments; moderately acid, pH 6.0.

Table 2-2 Site 2: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	58,600.00	47,595.0	0%	39,300.0	55,300.0	48,350.0	0.10
Antimony	<15.3	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	<20.5	4.1	35%	2.5	6.7	3.7	0.33
Barium	335.00	266.7	0%	198.0	322.0	266.5	0.14
Beryllium	1.20	1.4	95%	1.4	1.4	1.4	N/A
Cadmium	<5.1	N/A	100%	N/A	N/A	N/A	N/A
Calcium	1,660.00	2,858.0	0%	2,440.0	3,240.0	2,840.0	0.08
Chromium, Total	230.00	190.4	0%	129.0	245.0	201.0	0.18
Cobalt	48.20	40.8	0%	33.0	48.4	41.8	0.09
Copper	80.00	58.9	0%	46.3	78.7	55.5	0.16
Iron	74,100.00	50,505.0	0%	43,600.0	59,200.0	50,100.0	0.08
Lead	22.10	20.1	0%	10.1	58.1	19.4	0.51
Magnesium	3,400.00	2,509.0	0%	1,550.0	7,210.0	1,905.0	0.59
Manganese	2,020.00	1,663.0	0%	747.0	2,700.0	1,685.0	0.32
Mercury	0.0518	0.068	55%	0.057	0.092	0.065	0.15
Nickel	94.20	71.8	0%	53.4	108.0	69.2	0.19
Potassium	1,990.00	2,206.0	0%	1,050.0	8,900.0	1,210.0	0.94
Selenium	<13.3	N/A	100%	N/A	N/A	N/A	N/A
Silver	<10.2	3.3	95%	3.3	3.3	3.3	N/A
Sodium	<5120	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<12.3	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	176.00	155.4	0%	118.0	188.0	155.0	0.12
Zinc	126.00	98.7	0%	66.6	139.0	95.0	0.21

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicabl
CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 2-3 Site 2: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	90%	1.6	2.3	2.0	2.0	0.241
Arsenic	100%	N/A	N/A	N/A	N/A	N/A
Barium	0%	735.0	1,594.0	1,142.0	1,132.0	0.157
Cadmium	90%	3.3	4.6	4.0	4.0	0.233
Calcium	0%	2,594.0	7,644.0	4,043.0	3,811.0	0.301
Chromium, Total	0%	226.5	440.6	332.1	343.4	0.184
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	0%	78.2	157.0	106.5	108.3	0.181
Iron	0%	67,436.0	117,614.0	86,507.0	88,004.0	0.139
Lead	0%	19.9	72.5	44.3	43.0	0.362
Manganese	35%	155.0	2,384.0	957.3	902.0	0.726
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	0%	165.5	383.7	236.1	235.9	0.202
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	556.1	768.0	639.4	643.4	0.0861
Vanadium	20%	43.0	187.0	99.2	85.0	0.458
Zinc	0%	136.0	291.9	205.6	194.4	0.217

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

Analytical results are in mg/kg.

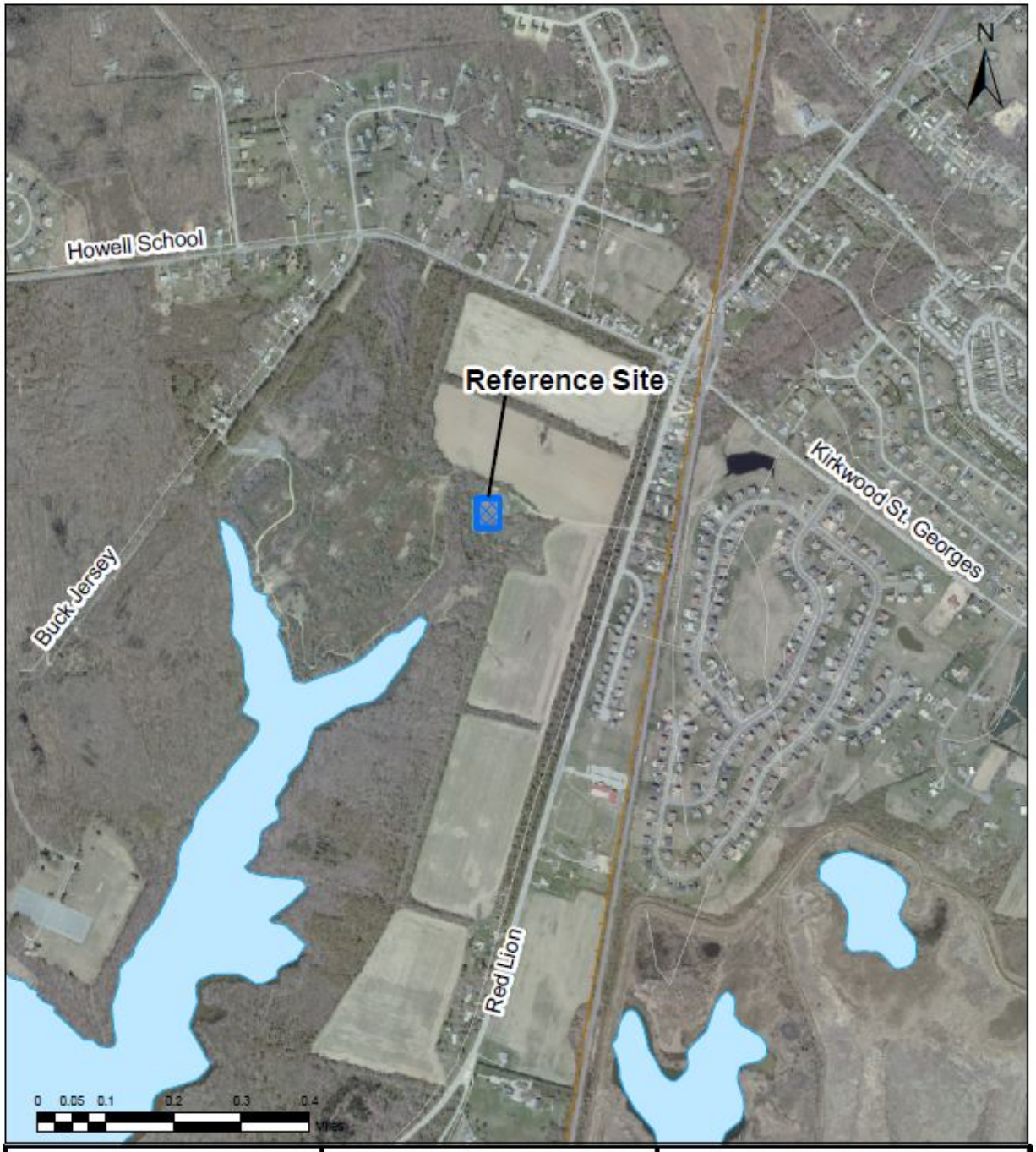
Table 2-4 Site 2: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Anthracene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Benzo(a)anthracene	0.13	0.1	80%	0.1	0.1	0.1	0.19
Benzo (a) pyrene	0.10	0.1	75%	0.1	0.1	0.1	0.20
Benzo (b) fluoranthene	0.11	0.1	95%	0.1	0.1	0.1	N/A
Benzo (g,h,i) perylene	0.07	N/A	100%	N/A	N/A	N/A	N/A
Benzo (k) fluoranthene	0.06	0.1	95%	0.1	0.1	0.1	N/A
Chrysene	0.13	0.1	80%	0.1	0.1	0.1	0.17
Dibenz (a,h) anthracene	0.01	N/A	100%	N/A	N/A	N/A	N/A
Fluoranthene	0.34	0.1	60%	0.0	0.2	0.1	0.66
Fluorene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Indeno (1,2,3-c,d) pyrene	0.06	N/A	100%	N/A	N/A	N/A	N/A
Naphthalene	< 0.34	N/A	100%	N/A	N/A	N/A	N/A
Phenanthrene	0.24	0.1	80%	0.0	0.1	0.1	0.52
Pyrene	0.26	0.1	60%	0.0	0.2	0.1	0.53

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable;

CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 3-Background Site 3



Legend

Site 3
Sassafras Soil

Figure 3
Background Reference Site 3
New Castle County
Lums Pond State Park

Statewide Background
Study for Metals & PAHs

Table 3-1 Site 3 Summary Table

Description Date:	6/14/2011
Soil Survey Area:	DE003 -- New Castle County, Delaware
Location Description:	Lum's Pond State Park
Latitude:	39 degrees 34 minutes 2.60 seconds north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 42 minutes 11.40 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	series not determined
Classification:	Coarse-loamy, siliceous, mesic Typic Udorthents
Map Unit:	SaD -- Sassafras sandy loam, 10 to 15 percent slopes
Slope:	1.0%
Elevation:	20 m
Drainage class:	well drained
Soil Description:	
A	0 to 3 centimeters; brown (10YR 4/3) gravelly loam; 20 percent nonflat rounded indurated 2- to 75-millimeter quartzite fragments.
C1	3 to 8 centimeters; yellowish brown (10YR 5/4) sandy loam, gravelly loam; 25 percent non-flat rounded indurated 2- to 75-millimeter quartzite fragments.
C2	8 to 20 centimeters; reddish yellow (7.5YR 6/6) sandy loam; 10 percent non-flat rounded very strongly cemented 2- to 75-millimeter quartzite fragments.
Ab	20 to 28 centimeters; dark grayish brown (10YR 4/2) loam; 10 percent nonflat rounded very strongly cemented 2- to 75-millimeter quartzite fragments.
C’	28 to 50 centimeters; yellowish brown (10YR 5/4) sandy loam; 10 percent non-flat rounded very strongly cemented 2- to 75-millimeter quartzite fragments.

Note on Site 3:

At Site 3, twenty sample locations were evenly distributed over an area of approximately one acre instead of the 2-acres used at the majority of the sites due to unanticipated field conditions.

Table 3-2 Site 3: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	17,000.00	13,340.0	0%	10,400.0	17,500.0	12,750.0	0.18
Antimony	<2	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	12.60	9.3	0%	4.2	24.6	7.2	0.65
Barium	61.90	45.5	45%	41.1	51.7	44.8	0.07
Beryllium	0.83	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	0.09	N/A	100%	N/A	N/A	N/A	N/A
Calcium	1,040.00	1,491.0	0%	939.0	2,400.0	1,400.0	0.31
Chromium, Total	52.90	26.7	0%	12.2	50.1	22.8	0.42
Cobalt	7.00	N/A	100%	N/A	N/A	N/A	N/A
Copper	12.20	7.0	0%	3.3	19.4	5.7	0.62
Iron	31,500.00	23,955.0	0%	12,900.0	43,400.0	20,600.0	0.42
Lead	16.70	13.4	0%	7.2	23.7	11.8	0.36
Magnesium	1,890.00	1,428.0	0%	732.0	2,860.0	1,375.0	0.35
Manganese	222.00	136.2	0%	78.9	219.0	133.5	0.28
Mercury	0.04	N/A	100%	N/A	N/A	N/A	N/A
Nickel	25.70	10.9	35%	8.4	20.3	10.0	0.28
Potassium	2,310.00	2,276.0	0%	980.0	9,420.0	1,775.0	0.80
Selenium	<1.7	N/A	100%	N/A	N/A	N/A	N/A
Silver	<1.3	N/A	100%	N/A	N/A	N/A	N/A
Sodium	98.10	355.5	70%	272.0	486.0	345.0	0.24
Thallium	<1.6	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	61.50	47.2	0%	22.4	126.0	36.2	0.62
Zinc	47.00	35.2	0%	21.3	66.7	34.4	0.33

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 3-3 Site 3: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	100%	N/A	N/A	N/A	N/A	N/A
Arsenic	20%	1.6	22.7	5.7	3.7	0.915
Barium	0%	515.7	1,129.0	847.8	875.3	0.154
Cadmium	100%	N/A	N/A	N/A	N/A	N/A
Calcium	0%	1,955.0	4,211.0	3,331.0	3,458.0	0.189
Chromium, Total	0%	28.1	66.7	48.8	47.7	0.203
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	40%	9.0	46.1	17.5	12.8	0.641
Iron	0%	23,690.0	68,695.0	36,282.0	32,407.0	0.311
Lead	10%	17.6	54.7	36.8	37.2	0.316
Manganese	90%	203.8	228.5	216.2	216.2	0.0808
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	5%	7.5	131.6	55.1	48.3	0.482
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	325.4	924.2	578.1	570.9	0.203
Vanadium	30%	54.0	268.0	107.4	94.3	0.548
Zinc	0%	38.1	109.6	59.3	54.8	0.31

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

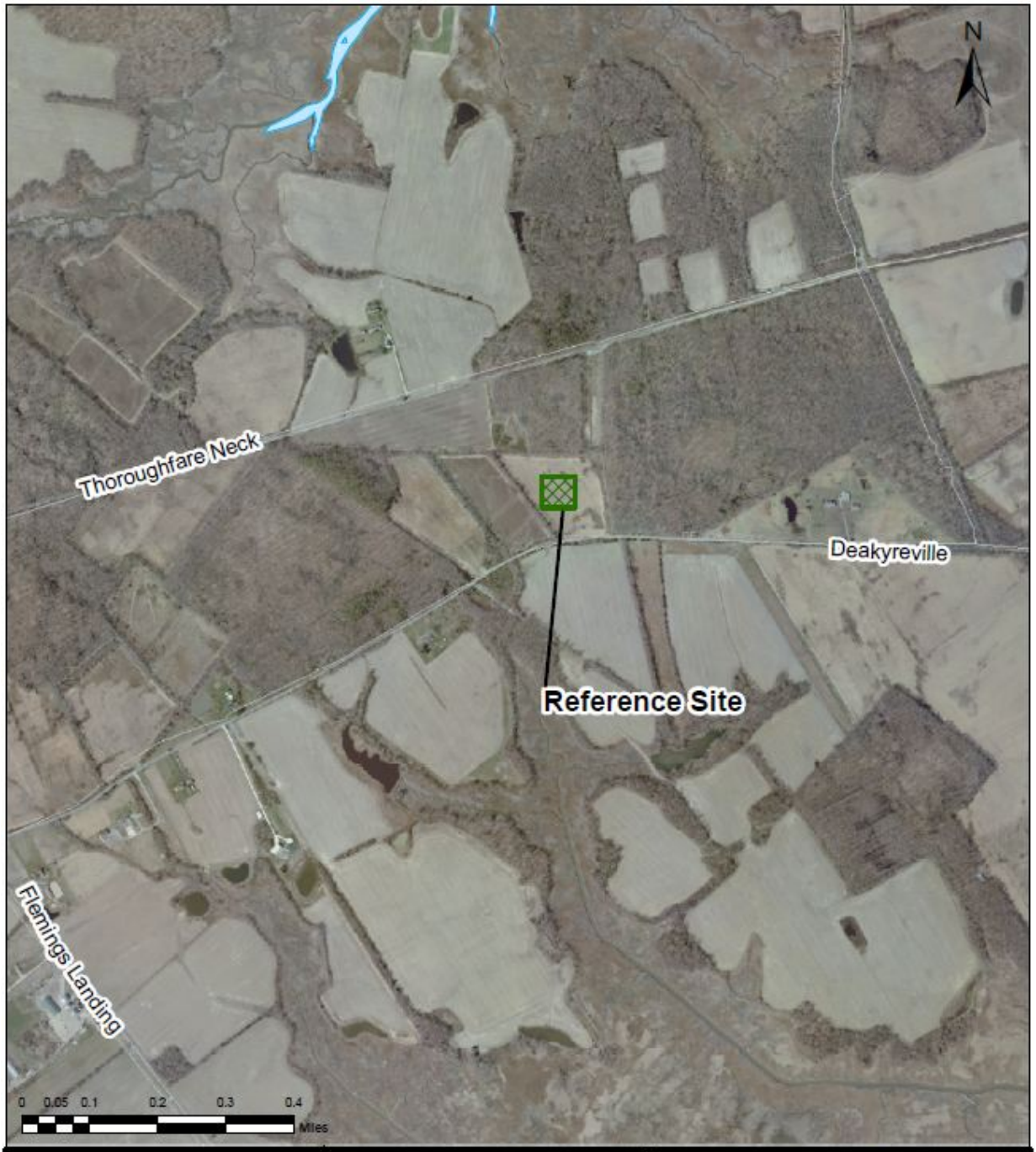
Analytical results are in mg/kg.

Table 3-4 Site 3: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.45	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.45	0.5	95%	0.5	0.5	0.5	N/A
Anthracene	< 0.45	0.3	90%	0.1	0.4	0.3	0.94
Benzo (a) anthracene	0.16	0.9	80%	0.0	3.2	0.2	1.74
Benzo (a) pyrene	0.12	1.0	80%	0.0	3.7	0.1	1.82
Benzo (b) fluoranthene	0.15	2.3	90%	0.2	4.3	2.3	1.29
Benzo (g,h,i) perylene	0.06	0.8	85%	0.1	2.1	0.1	1.56
Benzo (k) fluoranthene	0.08	2.4	90%	0.2	4.6	2.4	1.31
Chrysene	0.17	1.0	80%	0.1	3.6	0.2	1.72
Dibenz (a,h) anthracene	< 0.045	0.8	95%	0.8	0.8	0.8	N/A
Fluoranthene	0.28	0.9	75%	0.0	4.1	0.1	1.88
Fluorene	< 0.45	0.0	95%	0.0	0.0	0.0	N/A
Indeno (1,2,3-c,d) pyrene	0.07	1.2	90%	0.1	2.2	1.2	1.28
Naphthalene	< 0.45	N/A	100%	N/A	N/A	N/A	N/A
Phenanthrene	0.31	0.3	90%	0.3	0.4	0.3	0.35
Pyrene	0.24	0.9	70%	0.0	4.5	0.1	2.11

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 4-Background Site 4



Legend

Site 4
Leipsic Soil

Figure 4
Background Reference Site 4
New Castle County
Cedar Swamp Wildlife Area

Statewide Background
Study for Metals & PAHs

Table 4-1 Site 4: Summary Table

Description Date:	6/14/2011
Soil Survey Area:	DE003 -- New Castle County, Delaware
Location Description:	Cedar Swamp Wildlife Area
Latitude:	39 degrees 22 minutes 15.60 seconds (NAD83, UTM Zone: 18)
Longitude:	75 degrees 32 minutes 29.80 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Tent
Classification:	Fine-silty, mixed, active, mesic Typic Endoaquults
Map Unit:	LeA -- Leipsic silt loam, 0 to 2 percent slopes
Slope:	0.0%
Elevation:	6 m
Drainage class:	poorly drained
Soil Description:	
A	0 to 13 centimeters; grayish brown (2.5Y 5/2) silt loam; weak fine granular structure; friable; 2 percent fine prominent masses of oxidized iron.
ABg	13 to 31 centimeters; light brownish gray (2.5Y 6/2) silt loam; weak fine subangular blocky structure; friable; 5 percent fine prominent masses of oxidized iron.
Btg1	31 to 50 centimeters; gray (5Y 6/1) silty clay loam; weak medium subangular blocky structure; firm; 20 percent fine and medium prominent masses of oxidized iron.
Btg2	50 to 76 centimeters; gray (5Y 5/1) silty clay; weak medium subangular blocky structure; firm; 25 percent fine and medium prominent masses of oxidized iron.
BCg	76 to 114 centimeters; gray (5Y 5/1) silty clay loam; weak coarse subangular blocky structure; firm; 30 percent fine to coarse prominent masses of oxidized iron.
CBg1	114 to 147 centimeters; grayish brown (2.5Y 5/2) silty clay loam; weak medium platy structure; firm; 10 percent fine and medium prominent masses of oxidized iron.
CBg2	147 to 180 centimeters; grayish brown (2.5Y 5/2) silt loam; weak fine platy structure; friable; 5 percent fine and medium prominent masses of oxidized iron.

Table 4-2 Site 4: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	15,900.00	18,650.0	0%	11,300.0	28,600.0	17,700.0	0.25
Antimony	<1.4	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	3.10	3.7	5%	2.3	5.4	3.9	0.24
Barium	61.70	68.2	20%	47.0	98.7	66.1	0.22
Beryllium	0.33	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	<0.46	N/A	100%	N/A	N/A	N/A	N/A
Calcium	841.00	1,286.0	0%	758.0	1,770.0	1,250.0	0.20
Chromium, Total	18.60	22.1	0%	14.4	30.1	22.3	0.19
Cobalt	2.40	N/A	100%	N/A	N/A	N/A	N/A
Copper	6.50	5.5	0%	2.5	10.0	5.4	0.36
Iron	11,900.00	13,802.0	0%	8,040.0	18,200.0	13,750.0	0.17
Lead	12.00	12.6	0%	7.4	20.0	12.3	0.24
Magnesium	918.00	1,223.0	0%	890.0	1,690.0	1,215.0	0.17
Manganese	91.70	72.3	0%	37.6	147.0	67.4	0.38
Mercury	0.02	N/A	100%	N/A	N/A	N/A	N/A
Nickel	9.10	10.3	80%	9.5	11.3	10.1	0.08
Potassium	464.00	847.3	0%	478.0	1,210.0	824.5	0.22
Selenium	<1.2	N/A	100%	N/A	N/A	N/A	N/A
Silver	<0.93	N/A	100%	N/A	N/A	N/A	N/A
Sodium	79.80	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<1.1	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	25.10	31.7	0%	20.3	46.4	30.5	0.21
Zinc	22.10	23.9	0%	11.3	31.8	23.9	0.18

Notes: < indicates that the result < the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 4-3 Site 4: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	95%	1.5	1.5	1.5	1.5	N/A
Arsenic	80%	2.2	7.2	4.2	3.7	0.512
Barium	0%	407.1	621.1	530.1	544.4	0.115
Cadmium	100%	N/A	N/A	N/A	N/A	N/A
Calcium	0%	2,532.0	4,263.0	3,428.0	3,468.0	0.137
Chromium, Total	0%	29.9	54.4	36.8	35.2	0.164
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	45%	7.6	19.3	12.1	11.2	0.325
Iron	0%	12,516.0	20,521.0	16,193.0	15,900.0	0.132
Lead	10%	17.6	38.8	28.1	28.6	0.214
Manganese	100%	N/A	N/A	N/A	N/A	N/A
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	0%	17.7	35.2	27.1	26.9	0.181
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	85%	3.0	4.7	3.6	3.0	0.275
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	524.9	598.7	564.6	568.8	0.0335
Vanadium	50%	29.0	67.0	53.1	54.0	0.21
Zinc	0%	21.8	43.5	34.8	34.5	0.168

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

Analytical results are in mg/kg.

Table 4-4 Site 4: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Anthracene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) anthracene	< 0.036	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) pyrene	< 0.036	N/A	100%	N/A	N/A	N/A	N/A
Benzo (b) fluoranthene	< 0.036	N/A	100%	N/A	N/A	N/A	N/A
Benzo (g,h,i) perylene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Benzo (k) fluoranthene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Chrysene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Dibenz (a,h) anthracene	< 0.036	N/A	100%	N/A	N/A	N/A	N/A
Fluoranthene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Fluorene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Indeno (1,2,3-c,d) pyrene	< 0.036	N/A	100%	N/A	N/A	N/A	N/A
Naphthalene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Phenanthrene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A
Pyrene	< 0.36	N/A	100%	N/A	N/A	N/A	N/A

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 5-Background Site 5

Legend

Site 5
Hambrook Soil

Site 6
Woodstown Soil

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

Figure 5
Background Reference Sites 5 and 6
Kent County
Norman G. Wilder Wildlife Area

Statewide Background
Study for Metals & PAHs

Table 5-1 Site 5: Summary Table

Description Date:	6/16/2011
Soil Survey Area:	DE001 – Kent County, Delaware
Location Description:	Norman G. Wilder Wildlife Area
Latitude:	39 degrees 2 minutes 27.80 seconds (NAD83, UTM Zone: 18)
Longitude:	75 degrees 38 minutes 50.10 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Hambrook
Classification:	Fine-loamy, siliceous, semiactive, mesic Typic Hapludults
Map Unit:	HbB – Hambrook sandy loam, 2 to 5 percent slopes
Parent Material:	coastal plain sediments
Slope:	0.5%
Elevation:	17 m
Drainage class:	well drained, wet substratum
Soil Description:	
Ap	0 to 23 centimeters; very dark grayish brown (10YR 3/2) sandy loam; weak fine granular structure; very friable; slightly acid, pH 6.5.
Bt1	23 to 36 centimeters; dark yellowish brown (10YR 4/6) loam; weak medium platy structure; friable; moderately acid, pH 6.0.
Bt2	36 to 61 centimeters; yellowish brown (10YR 5/6) loam; moderate medium platy structure; firm, moderately cemented; strongly acid, pH 5.5.
Bt3	61 to 81 centimeters; yellowish brown (10YR 5/4) sandy loam; weak medium subangular blocky structure; friable, loose; strongly acid, pH 5.5.
BC	81 to 122 centimeters; 60 percent yellowish brown (10YR 5/4) and 40 percent pale brown (10YR 6/3) sand; structureless single grain; very friable, loose; slightly acid, pH 6.5.
C1	122 to 140 centimeters; 90 percent yellowish brown (10YR 5/4) and 10 percent pale brown (10YR 6/3) loamy sand; very friable; slightly acid, pH 6.5.
C2	140 to 180 centimeters; 60 percent yellowish brown (10YR 5/6) and 20 percent strong brown (7.5YR 4/6) and 20 percent gray (2.5Y 6/1) loamy sand, sandy loam; very friable; strongly acid, pH 5.5.

Table 5-2 Site 5: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	9,810.00	10,488.0	0%	6,030.0	15,200.0	10,200.0	0.24
Antimony	<1.8	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	3.40	2.9	60%	2.5	3.2	2.9	0.09
Barium	54.00	47.9	45%	43.2	60.6	45.8	0.12
Beryllium	0.43	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	0.07	N/A	100%	N/A	N/A	N/A	N/A
Calcium	528.00	581.5	0%	360.0	851.0	576.0	0.22
Chromium, Total	13.50	10.5	0%	5.5	14.1	10.0	0.24
Cobalt	2.00	N/A	100%	N/A	N/A	N/A	N/A
Copper	4.20	2.3	0%	1.2	3.1	2.3	0.25
Iron	7,250.00	8,414.0	0%	3,990.0	12,100.0	8,240.0	0.29
Lead	17.90	8.3	0%	5.2	19.2	7.5	0.39
Magnesium	695.00	825.0	0%	325.0	1,130.0	831.5	0.27
Manganese	47.30	43.4	0%	22.4	59.8	43.7	0.21
Mercury	0.03	N/A	100%	N/A	N/A	N/A	N/A
Nickel	7.30	N/A	100%	N/A	N/A	N/A	N/A
Potassium	345.00	438.8	5%	219.0	609.0	420.0	0.22
Selenium	<1.6	N/A	100%	N/A	N/A	N/A	N/A
Silver	<1.2	N/A	100%	N/A	N/A	N/A	N/A
Sodium	88.20	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<1.5	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	15.00	16.5	10%	12.6	21.6	15.7	0.19
Zinc	26.40	17.0	0%	11.5	27.0	17.3	0.20

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV=Coefficient of Variation; Analytical results are in mg/kg.

Table 5-3 Site 5: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	95%	2.6	2.6	2.6	2.6	N/A
Arsenic	80%	3.1	5.7	4.3	4.1	0.251
Barium	0%	716.9	931.7	787.5	776.6	0.0811
Cadmium	95%	3.8	3.8	3.8	3.8	N/A
Calcium	0%	2,471.0	3,509.0	2,822.0	2,766.0	0.0996
Chromium, Total	0%	21.0	30.2	26.0	26.3	0.105
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	75%	8.3	13.8	9.8	8.8	0.231
Iron	0%	8,454.0	19,556.0	14,019.0	13,681.0	0.212
Lead	10%	9.2	32.8	21.7	21.6	0.21
Manganese	100%	N/A	N/A	N/A	N/A	N/A
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	0%	12.1	36.4	20.3	19.2	0.33
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	488.2	589.3	548.0	550.6	0.0473
Vanadium	90%	38.0	38.0	38.0	38.0	0
Zinc	0%	17.3	40.3	28.5	28.6	0.187

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation
Analytical results are in mg/kg.

Table 5-4 Site 5: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	0.18	0.4	80%	0.0	1.5	0.1	1.79
Acenaphthylene	< 0.42	0.0	85%	0.0	0.0	0.0	0.94
Anthracene	1.30	1.0	85%	0.0	2.4	0.6	1.22
Benzo (a) anthracene	3.70	2.5	60%	0.0	17.0	0.1	2.33
Benzo (a) pyrene	3.70	2.8	55%	0.0	21.0	0.1	2.50
Benzo (b) fluoranthene	3.90	3.6	70%	0.1	18.0	0.3	1.98
Benzo (g,h,i) perylene	2.10	2.2	65%	0.0	13.0	0.2	2.22
Benzo (k) fluoranthene	1.90	3.1	70%	0.0	15.0	0.2	1.90
Chrysene	3.80	3.1	60%	0.1	21.0	0.1	2.36
Dibenz (a,h) anthracene	0.39	0.9	80%	0.0	2.7	0.3	1.46
Fluoranthene	5.70	4.8	65%	0.1	29.0	0.3	2.26
Fluorene	0.26	0.2	85%	0.0	0.5	0.1	1.38
Indeno (1,2,3-c,d) pyrene	2.10	1.8	60%	0.0	12.0	0.2	2.34
Naphthalene	0.07	0.1	90%	0.0	0.2	0.1	1.32
Phenanthrene	4.90	2.7	75%	0.0	11.0	0.1	1.74
Pyrene	6.00	4.0	65%	0.0	24.0	0.2	2.24

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 6-Background Site 6

Legend

Site 5
Hambrook Soil

Site 6
Woodstown Soil

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

Figure 5
Background Reference Sites 5 and 6
Kent County
Norman G. Wilder Wildlife Area

Statewide Background
Study for Metals & PAHs

Table 6-1 Site 6: Summary Table

Description Date:	6/16/2011
Soil Survey Area:	DE001 – Kent County, Delaware
Location Description:	Norman G. Wilder Wildlife Area
Latitude:	39 degrees 2 minutes 29.60 seconds north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 38 minutes 49.90 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Woodstown
Classification:	Fine-loamy, mixed, active, mesic Aquic Hapludults
Map Unit:	WdA – Woodstown sandy loam, 0 to2 percent slopes
Parent Material:	coastal plain sediments
Slope:	0.5%
Elevation:	17 m
Drainage class:	moderately well drained
Soil Description:	
Ap	0 to 20 centimeters; brown (10YR 4/3) loam; 12 percent clay; weak medium granular structure; very friable; slightly acid, pH 6.5.
Bt1	20 to 46 centimeters; yellowish brown (10YR 5/4) loam; 18 percent clay; weak medium subangular blocky structure; friable; moderately acid, pH 6.0.
Bt2	46 to 66 centimeters; yellowish brown (10YR 5/6) loam; 20 percent clay; moderate medium subangular blocky structure; friable; strongly acid, pH 5.5.
Bt3	66 to 79 centimeters; yellowish brown (10YR 5/6) sandy loam; 16 percent clay; weak medium subangular blocky structure; friable; 1 percent medium prominent iron depletions and 1 percent medium faint masses of oxidized iron; strongly acid, pH 5.5.
BC	79 to 90 centimeters; light yellowish brown (10YR 6/4) sand; structureless single grain; loose; 15 percent medium distinct iron depletions; strongly acid, pH 5.5.
Cg1	90 to 152 centimeters; light brownish gray (10YR 6/2) sand; structureless single grain; loose; strongly acid, pH 5.5.
Cg2	152 to 180 centimeters; light gray (10YR 7/1) sand; structureless single grain; loose; 20 percent medium prominent masses of oxidized iron; slightly acid, pH 6.5.

Table 6-2 Site 6: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	NA	8,279.0	0%	4,570.0	13,400.0	8,395.0	0.28
Antimony	NA	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	NA	2.9	70%	2.4	5.0	2.5	0.36
Barium	NA	44.8	85%	41.0	49.1	44.4	0.09
Beryllium	NA	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	NA	3.3	95%	3.3	3.3	3.3	N/A
Calcium	NA	721.5	0%	200.0	3,730.0	515.0	1.15
Chromium, Total	NA	8.6	0%	4.6	15.1	8.8	0.31
Cobalt	NA	N/A	100%	N/A	N/A	N/A	N/A
Copper	NA	2.0	15%	1.1	3.0	2.1	0.26
Iron	NA	9,983.0	0%	3,050.0	54,000.0	7,965.0	1.07
Lead	NA	6.5	0%	3.1	13.2	6.1	0.37
Magnesium	NA	758.0	0%	355.0	2,150.0	722.5	0.51
Manganese	NA	44.7	0%	17.9	92.8	40.5	0.46
Mercury	NA	N/A	100%	N/A	N/A	N/A	N/A
Nickel	NA	N/A	100%	N/A	N/A	N/A	N/A
Potassium	NA	377.6	5%	217.0	663.0	379.0	0.29
Selenium	NA	N/A	100%	N/A	N/A	N/A	N/A
Silver	NA	N/A	100%	N/A	N/A	N/A	N/A
Sodium	NA	715.0	95%	715.0	715.0	715.0	N/A
Thallium	NA	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	NA	14.8	25%	10.4	21.8	14.3	0.22
Zinc	NA	13.3	0%	5.8	18.8	12.8	0.30

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg. NA =ISM results not available.

Table 6-3 Site 6: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	85%	1.4	2.7	2.0	1.9	0.305
Arsenic	85%	1.7	3.3	2.3	1.9	0.378
Barium	0%	749.4	971.4	857.5	852.4	0.079
Cadmium	80%	2.7	3.5	3.0	2.9	0.127
Calcium	0%	1,975.0	7,965.0	2,915.0	2,727.0	0.417
Chromium, Total	5%	15.3	34.5	24.9	25.0	0.235
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	80%	7.9	11.0	9.3	9.1	0.158
Iron	0%	7,454.0	110,234.0	19,035.0	14,363.0	1.144
Lead	5%	7.2	46.5	21.4	20.6	0.404
Manganese	100%	N/A	N/A	N/A	N/A	N/A
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	5%	8.2	29.4	18.5	20.2	0.283
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	334.5	595.8	513.9	529.5	0.132
Vanadium	75%	27.0	52.0	36.7	28.5	0.333
Zinc	0%	5.6	31.3	21.7	23.1	0.314

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation; Analytical Results are in mg/kg.

Table 6-4 Site 6: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	N/R	0.003	90%	0.0030	0.0030	0.0030	0.00
Acenaphthylene	N/R	0.002	90%	0.0010	0.0020	0.0015	0.47
Anthracene	N/R	0.003	60%	0.0010	0.0040	0.0030	0.35
Benzo (a) antracene	N/R	0.003	60%	0.0020	0.0050	0.0025	0.44
Benzo (a) pyrene	N/R	0.003	55%	0.0020	0.0080	0.0030	0.58
Benzo (b) fluoranthene	N/R	N/A	100%	N/A	N/A	N/A	N/A
Benzo (g,h,i) perylene	N/R	0.003	55%	0.0020	0.0050	0.0030	0.26
Benzo (k) fluoranthene	N/R	0.003	55%	0.0010	0.0040	0.0030	0.39
Chrysene	N/R	0.003	60%	0.0010	0.0050	0.0030	0.43
Dibenz (a,h) anthracene	N/R	0.003	60%	0.0020	0.0030	0.0030	0.12
Fluoranthene	N/R	0.005	55%	0.0020	0.0060	0.0050	0.26
Fluorene	N/R	0.011	95%	0.0110	0.0110	0.0110	N/A
Indeno (1,2,3-c,d) pyrene	N/R	0.003	60%	0.0020	0.0040	0.0030	0.29
Naphthalene	N/R	0.004	55%	0.0020	0.0070	0.0040	0.35
Phenanthrene	N/R	0.003	60%	0.0010	0.0040	0.0030	0.35
Pyrene	N/R	0.004	55%	0.0010	0.0060	0.0050	0.36

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg. N/R = No Result

Appendix 7-Background Site 7

Legend

Site 7
Pepperbox Soil

Figure 6
Background Reference Site 7
Sussex County
Redden State Forest

Statewide Background
Study for Metals & PAHs

Table 7-1 Site 7: Summary Table

Description Date:	10/28/2011
Soil Survey Area:	DE005 -- Sussex County, Delaware
Location Description:	Redden State Forest
Latitude:	38 degrees 41 minutes 30.70 north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 31 minutes 14.40 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Pepperbox
Classification:	Loamy, mixed, semiactive, mesic Aquic Arenic Hapludults
Map Unit:	RoA -- Rosedale loamy sand, 0 to 2 percent slopes
Parent Material:	coastal plain sediments
Slope:	0.5%
Elevation:	10 m
Drainage class:	moderately well drained
Soil Description:	
Ap	0 to 23 centimeters; dark grayish brown (10YR 4/2) loamy sand; weak medium granular structure; 2 percent rounded fine quartzite fragments.
E	23 to 53 centimeters; yellowish brown(10YR 5/4)loamy sand; weak medium subangular blocky structure; 2 percent rounded fine quartzite fragments.
Bt1	53 to 74 centimeters; yellowish brown (10YR 5/6) sandy clay loam; 1 percent fine distinct yellowish red (5YR 5/8) masses of oxidized iron; moderate medium subangular blocky structure.
Bt2	74 to 99 centimeters; yellowish brown (10YR 5/6) sandy clay loam; moderate coarse subangular blocky structure; 2 percent fine distinct gray (10YR 6/1) iron depletions and 5 percent fine prominent yellowish red (5YR 5/8) masses of oxidized iron.
BC	99 to 127 centimeters; brownish yellow (10YR 6/6) loamy sand with strata of sandy loam; single grain.
C1	127 to 167 centimeters; yellow (10YR 7/6) loamy sand; single grain; 5 percent rounded fine quartzite fragments.
C2	167 to 183 centimeters; light yellowish brown (10YR 6/4) loamy sand with strata of silt loam; massive; 10 percent medium prominent reddish yellow (7.5YR 6/8) masses of oxidized iron and 15 percent medium distinct light gray (10YR 7/2) iron depletions.

Note on Site 7 :

Twenty samples were distributed over an elongated rectangle of approximately 2 acres in area in response to field conditions. The shape of the grid is shown on Figure 6.

Table 7-2 Site 7: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	4,590.00	11,753.0	0%	5,930.0	33,200.0	10,035.0	0.55
Antimony	<2	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	1.90	2.6	60%	2.1	3.3	2.6	0.14
Barium	26.50	43.1	95%	43.1	43.1	43.1	N/A
Beryllium	<0.41	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	<1	N/A	100%	N/A	N/A	N/A	N/A
Calcium	278.00	335.4	5%	207.0	509.0	306.0	0.27
Chromium, Total	3.90	7.6	0%	4.3	16.5	7.1	0.38
Cobalt	<10.2	N/A	100%	N/A	N/A	N/A	N/A
Copper	1.60	2.3	0%	1.1	5.6	2.1	0.42
Iron	2,680.00	4,458.0	0%	2,940.0	6,940.0	4,140.0	0.28
Lead	6.10	6.4	0%	4.1	10.2	6.1	0.22
Magnesium	237.00	425.0	0%	270.0	656.0	414.0	0.25
Manganese	35.30	50.3	0%	33.2	85.7	47.6	0.26
Mercury	<0.037	N/A	100%	N/A	N/A	N/A	N/A
Nickel	1.90	N/A	100%	N/A	N/A	N/A	N/A
Potassium	161.00	407.5	0%	228.0	853.0	359.5	0.40
Selenium	<2	N/A	100%	N/A	N/A	N/A	N/A
Silver	<2	N/A	100%	N/A	N/A	N/A	N/A
Sodium	<1020	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<2	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	6.10	15.1	55%	11.7	20.3	14.2	0.18
Zinc	4.70	9.5	0%	5.9	13.7	9.2	0.21

Notes: < indicates that the result is < the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 7-3 Site 7: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	100%	N/A	N/A	N/A	N/A	N/A
Arsenic	100%	N/A	N/A	N/A	N/A	N/A
Barium	0%	529.0	755.0	632.0	623.0	0.0888
Cadmium	100%	N/A	N/A	N/A	N/A	N/A
Calcium	0%	1,070.0	2,545.0	1,603.0	1,474.0	0.238
Chromium, Total	0%	14.0	45.2	24.0	22.6	0.329
Cobalt	100%	N/A	N/A	N/A	N/A	N/A
Copper	40%	5.9	13.8	10.1	10.4	0.232
Iron	0%	5,085.0	11,119.0	7,298.0	7,229.0	0.203
Lead	0%	6.1	17.9	11.5	11.7	0.26
Manganese	0%	85.1	676.0	173.3	124.3	0.96
Mercury	100%	N/A	N/A	N/A	N/A	N/A
Nickel	95%	18.5	18.5	18.5	18.5	N/A
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	476.7	6,277.0	4,058.0	4,289.0	0.346
Vanadium	100%	N/A	N/A	N/A	N/A	N/A
Zinc	0%	10.2	27.0	17.0	15.9	0.274

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

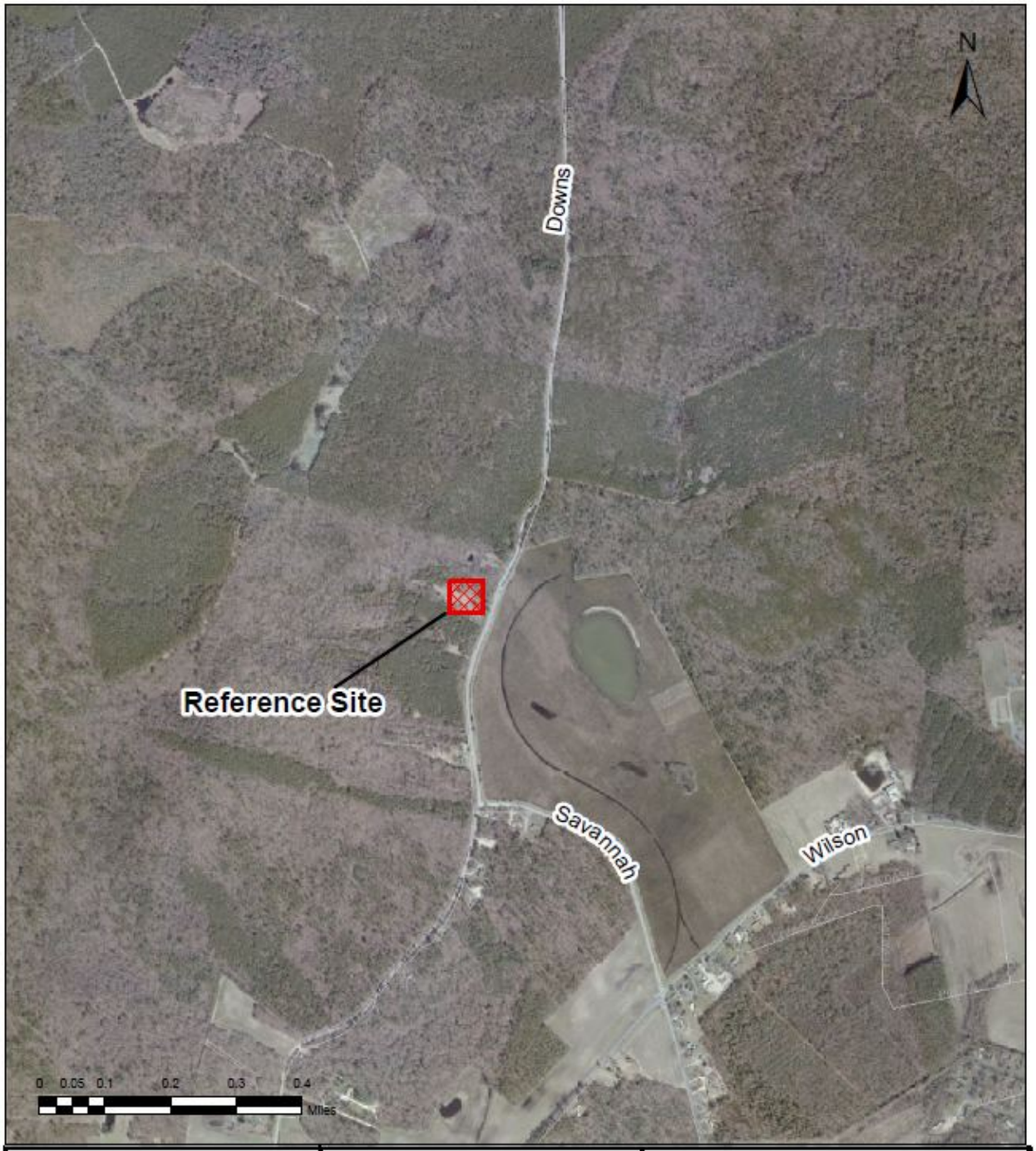
Analytical results are in mg/kg.

Table 7-4 Site 7: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Anthracene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) anthracene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) pyrene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Benzo (b) fluoranthene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Benzo (g,h,i) perylene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Benzo (k) fluoranthene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Chrysene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Dibenz (a,h) anthracene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Fluoranthene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Fluorene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Indeno (1,2,3-c,d) pyrene	< 0.039	N/A	100%	N/A	N/A	N/A	N/A
Naphthalene	< 0.39	0.1	80%	0.01	0.19	0.02	1.43
Phenanthrene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A
Pyrene	< 0.39	N/A	100%	N/A	N/A	N/A	N/A

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Appendix 8-Background Site 8



Legend

Site 8
Cedartown Soil

Figure 7
Background Reference Site 8
Sussex County
Redden State Forest

State Wide Background
Study for Metals & PAHs

Table 8-1 Site 8: Summary Table

Description Date:	10/28/2011
Soil Survey Area:	DE005 -- Sussex County, Delaware
Location Description:	Redden State Forest
Latitude:	38 degrees 43 minutes 58.10 seconds north (NAD83, UTM Zone: 18)
Longitude:	75 degrees 22 minutes 59.50 seconds west (NAD83, UTM Zone: 18)
Soil Name as Described/Sampled:	Cedartown
Classification:	Siliceous, mesic Psammentic Hapludults
Map Unit:	KsA -- Klej loamy sand, 0 to 2 percent slopes
Parent Material:	coastal plain sediments
Slope:	0%
Elevation:	14 m
Drainage class:	somewhat excessively drained
Soil Description:	
Ap	0 to 30 centimeters; dark brown (7.5YR 3/2) sand; weak fine granular structure.
Bt	30 to 86 centimeters; yellowish brown (10YR 5/6) loamy sand; single grain.
C1	86 to 140 centimeters; brownish yellow (10YR 6/6) loamy sand; single grain.
C2	140 to 183 centimeters; light yellowish brown (10YR 6/4) loamy sand; single grain; thin strata of sandy loam; 2 percent fine prominent strong brown (7.5YR 5/8) masses of oxidized iron and 5 percent medium distinct light gray (10YR 7/1) iron depletions primarily in sandy loam strata.

Table 8-2 Site 8: Laboratory Analytical Data Summary for Metals

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Aluminum	3,440.00	6,217.0	0%	3,850.0	11,100.0	5,440.0	0.37
Antimony	<2	N/A	100%	N/A	N/A	N/A	N/A
Arsenic	0.74	N/A	100%	N/A	N/A	N/A	N/A
Barium	20.10	N/A	100%	N/A	N/A	N/A	N/A
Beryllium	<0.39	N/A	100%	N/A	N/A	N/A	N/A
Cadmium	<0.99	N/A	100%	N/A	N/A	N/A	N/A
Calcium	906.00	461.7	20%	226.0	842.0	416.5	0.37
Chromium, Total	2.40	4.7	0%	2.9	8.8	4.3	0.32
Cobalt	<9.9	N/A	100%	N/A	N/A	N/A	N/A
Copper	4.60	2.6	0%	1.0	10.3	2.3	0.72
Iron	2,200.00	2,742.0	0%	963.0	5,880.0	2,830.0	0.45
Lead	9.80	4.8	0%	2.3	7.0	4.6	0.30
Magnesium	195.00	350.0	10%	207.0	605.0	330.0	0.30
Manganese	37.60	21.1	0%	10.0	33.9	22.9	0.33
Mercury	0.03	N/A	100%	N/A	N/A	N/A	N/A
Nickel	1.50	N/A	100%	N/A	N/A	N/A	N/A
Potassium	114.00	285.8	50%	211.0	390.0	262.0	0.25
Selenium	<2	N/A	100%	N/A	N/A	N/A	N/A
Silver	0.27	N/A	100%	N/A	N/A	N/A	N/A
Sodium	<986	N/A	100%	N/A	N/A	N/A	N/A
Thallium	<2	N/A	100%	N/A	N/A	N/A	N/A
Vanadium	4.00	12.5	85%	10.8	15.2	11.4	0.19
Zinc	37.70	12.6	0%	4.0	33.5	9.1	0.64

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.

Table 8-3 Site 8: XRF Analytical Data Summary for Metals

		Discrete Samples (detected results)				
Analyte	**%ND**	**Minimum**	**Maximum**	**Mean**	**Median**	**CV**
Antimony	100%	N/A	N/A	N/A	N/A	N/A
Arsenic	75%	1.0	1.9	1.5	1.6	0.232
Barium	0%	515.0	791.0	669.0	676.0	0.122
Cadmium	100%	N/A	N/A	N/A	N/A	N/A
Calcium	0%	1,293.0	4,772.0	2,802.0	3,002.0	0.348
Chromium, Total	55%	17.0	80.6	34.1	25.4	0.598
Cobalt	95%	13.1	13.1	13.1	13.1	N/A
Copper	50%	7.8	22.3	11.2	9.9	0.377
Iron	0%	3,201.0	10,001.0	5,861.0	5,466.0	0.327
Lead	10%	7.0	18.6	11.7	10.7	0.288
Manganese	0%	51.9	209.8	93.6	77.2	0.401
Mercury	95%	1.8	1.8	1.8	1.8	N/A
Nickel	85%	10.0	17.6	12.7	10.6	0.332
Selenium	100%	N/A	N/A	N/A	N/A	N/A
Silver	100%	N/A	N/A	N/A	N/A	N/A
Thallium	100%	N/A	N/A	N/A	N/A	N/A
Titanium	0%	2,229.0	5,569.0	3,799.0	3,515.0	0.295
Vanadium	100%	N/A	N/A	N/A	N/A	N/A
Zinc	5%	8.1	67.8	23.1	15.7	0.742

Notes: ND = Not Detected; N/A = Not Applicable; CV = Coefficient of Variation

Analytical results are in mg/kg.

Table 8-4 Site 8: Laboratory Analytical Data Summary for PAHs

	ISM Sample	Discrete Samples (detected results)					
Analyte	**Result**	**Mean**	**% ND**	**Minimum**	**Maximum**	**Median**	**CV**
Acenaphthene	< 0.35	N/A	100%	N/A	N/A	N/A	N/A
Acenaphthylene	< 0.35	N/A	100%	N/A	N/A	N/A	N/A
Anthracene	< 0.35	N/A	100%	N/A	N/A	N/A	N/A
Benzo (a) antracene	< 0.035	0.051	95%	0.051	0.051	0.051	N/A
Benzo (a) pyrene	< 0.035	0.069	95%	0.069	0.069	0.069	N/A
Benzo (b) fluoranthene	< 0.035	0.069	95%	0.069	0.069	0.069	N/A
Benzo (g,h,i) perylene	< 0.35	0.055	95%	0.055	0.055	0.055	N/A
Benzo (k) fluoranthene	< 0.035	0.049	95%	0.049	0.049	0.049	N/A
Chrysene	< 0.35	0.054	95%	0.054	0.054	0.054	N/A
Dibenz (a,h) anthracene	< 0.035	N/A	100%	N/A	N/A	N/A	N/A
Fluoranthene	< 0.35	0.076	95%	0.076	0.076	0.076	N/A
Fluorene	< 0.35	N/A	100%	N/A	N/A	N/A	N/A
Indeno (1,2,3-c,d) pyrene	< 0.035	0.044	95%	0.044	0.044	0.044	N/A
Naphthalene	< 0.35	N/A	100%	N/A	N/A	N/A	N/A
Phenanthrene	< 0.35	0.054	95%	0.054	0.054	0.054	N/A
Pyrene	< 0.35		95%	0.076	0.076	0.076	N/A

Notes: < indicates that the result is less than the given Detection Limit; ND = Not Detected; N/A = Not Applicable; CV= Coefficient of Variation; Analytical results are in mg/kg.