FINAL

AREA I SOIL
REMEDIAL INVESTIGATION/RISK ASSESSMENT REPORT

FORMER FRANKFORD ARSENAL
FUDS SITE ID: C03PA004201
PHILADELPHIA, PENNSYLVANIA

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Prepared for

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LIST OF ACRONYMS AND ABBREVIATIONS

Atm-m^3/mol	atmosphere-cubic meter/moles
ALM	Adult Lead Model
AOC	Area of Concern
AOI	Area of Interest
Army	U.S. Army
AST	above-ground storage tank
atm-m^3/mol	atmosphere-cubic meters per mole
bgs	below ground surface
BRA	baseline risk assessment
Cabrera	Cabrera Services Inc.
K_{OC}	organic carbon/water partition coefficient
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
^{60}Co	Cobalt-60
COC	contaminants of concern
COPC	constituents of potential concern
COPIACS	chemicals of potential indoor air concern
cm^2	square centimeters
^{137}Cs	Cesium-137
CSM	conceptual site model
DoD	Department of Defense
DNT	Dinitrotoluene
dpm	disintegrations per minute
DPT	direct push technology
DQO	data quality objective
EE/CA	Engineering Evaluation / Cost Analysis
Eh	redox potential
EPC	exposure point concentration
ESA	environmental site assessment
^{o}F	degrees Fahrenheit
FFA	Former Frankford Arsenal
FSP	field sampling plan
FS	feasibility study
ft bgs	feet below ground surface
ft	foot or feet
ft^2	square feet
ft/ft	feet per feet
ft/day	feet per day
FUDS	Formerly Used Defense Site
g/L	grams per liter
GM	Geiger Mueller (detector)
GWS	gamma walkover survey
^{3}H	Tritium
t$^{1/2}$	Half-life
HHRA	Human Health Risk Assessment
HI	hazard index
HSA	historical site assessment
ILCR	incremental lifetime cancer risks
IRA	Interim Removal Action
I-95	Interstate 95
JMA	John Milner Associates

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

K_d	distribution coefficient
Koc	soil organic carbon-water partitioning coefficient
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
Langan	Langan Engineering and Environmental Services, Inc.
mm	millimeters
MEC	munitions and explosives of concern
MDA	minimum detectable activity
MOA	Memorandum of Agreement
$\mu g/m^3$	micrograms per cubic meter
µg/dL	micrograms per deciliter
µg/kg	micrograms per kilogram
MB	method blank
mg/kg	milligrams per kilogram
MSC	(PADEP) medium specific concentration
MS/MSD	matrix spike/matrix spike duplicate
m^3	cubic meter
NAD	normalized absolute difference
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRC	Nuclear Regulatory Commission
%	percent
^{40}K	Potassium-40
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene, tetrachloroethylene
pCi/g	picocuries per gram
PDPH	Philadelphia Department of Public Works
PFBC	Pennsylvania Fish & Boat Commission
PID	photoionization detector
^{234m}Pa	Protactinium-234m
PSI	Property Solutions, Inc.
PWD	Philadelphia Water Department
QA/QC	quality assurance / quality control
RA	risk assessment
RCOPC	radiological constituent of potential concern
RI	remedial investigation
RME	reasonable maximum exposure
RSL	regional screening level
SLERA	screening level ecological risk assessment
SPL	separate phase liquid
SSI	supplemental site investigation
SVOC	semivolatile organic compound
TCE	trichloroethene
TNT	trinitrotoluene
TSCA	Toxic Substances Control Act
^{234}U	Uranium-234

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

^{235}U	Uranium-235
^{238}U	Uranium-238
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	underground storage tank
UXO	unexploded ordnance
VOC	volatile organic compound

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE) has completed a remedial investigation (RI) of soil in the eastern half (Area I) of the Former Frankford Arsenal (FFA) in Philadelphia, Pennsylvania (PA). The purpose of the RI was to characterize the environmental conditions and define the nature and extent of soil contamination. Separate RIs will be conducted for the western half of the FFA (designated Area II), the land occupying the PA Fish and Boat Commission launch and a portion of the Dietz and Watson facility (designated as Area III), and groundwater at the FFA (designated as Area IV). The following report relates the description and background of the site and discusses analytical results of investigations and Interim Removal Actions (IRAs) conducted between 1999 and 2013.This report also provides results of the post-remedial risk assessment (RA), including both a human health risk assessment and an ecological risk evaluation.

USACE is conducting environmental restoration at the FFA under the Formerly Used Defense Sites (FUDS) program. USACE is mandated to remediate FUDS sites using guidelines established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

FFA consists of some 109 acres and 53 existing buildings, plus 159 locations where buildings formerly existed. Between 1816 and its decommissioning in 1977, the facility was used for military ordnance research, testing, production, and storage. Most of the Site is currently used as a commercial business park, while 17 acres to the east have been transferred to the Commonwealth of PA Fish and Boat Commission and five acres to Dietz & Watson. Area I consists of a total of 46 acres.

The unconsolidated soil beneath the Site forms a wedge shape that thickens and slopes southward toward the Delaware River. Fill material and debris occur from ground surface to depths of between 10 to 20 feet (ft) below ground surface (bgs). The alluvial sands and gravels of the Trenton Formation underlie the fill material to depths of approximately 50 ft, below which is fractured gneiss bedrock. The depth to groundwater varies from four to 14 ft bgs.

Three historical site assessments have been conducted for the federal government: one focused on historical and archeological aspects, one focused on munitions and explosives of concern and one on potential radiological contamination. The site-related constituents identified in those assessments include explosives, metals, chlorinated solvents, and polychlorinated biphenyls (PCBs). Additionally, 14 separate environmental investigations and six different removal actions have been undertaken in Area I. Those investigations resulted in the following removal activities:

- Surveys for radionuclides inside and outside of buildings and sewers, followed by removal of contamination from building surfaces and sewers, and excavation of uranium-contaminated soil from several locations;
- Surveys and removal of munitions, consisting of solid-shot cannon balls;
- Survey and remediation of buildings and sewers for heavy-metal and explosives residues;
- Removal of above-ground storage tanks and excavation and removal of underground storage tanks and associated contaminated soils; and
- Removal of lead batteries and PCB-containing transformers.
- Well closures

The present site owners have conducted a number of site investigations, culminating in a Draft RI report produced by Langan Engineering and Environmental Services that was written in 2005 (but not submitted to PADEP). The evaluation of that data identified several areas of soil contaminated with metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and PCBs. Areas of groundwater contamination were also identified. USACE contracted Cabrera Services Inc. (Cabrera) to conduct a Supplemental Site Investigation (SSI) in 2007 and a Data Gap Investigation in 2008. The SSI identified several Areas of Interest where certain constituents exceeded PADEP Medium Specific-Screening Concentrations (MSCs). The SSI also investigated several areas not previously characterized. Based on the results of these investigations, 16 Areas of Interest (AOIs) were identified of which 11 were later designated Areas of Concern (AOCs) as source areas for soil contamination. These AOCs were designated AOC 1 through AOC 11. Between 2009 and 2013, six Interim Removal Actions (IRAs) have been conducted to remove VOC, metal, and PCB contaminated soil from Area I.

Several MSC values were revised from 2009 to 2012. These MSC revisions were made by regulators to incorporate: additional toxicological information; changes in the Maximum Contaminant Levels for drinking water; and new risk assessment methodologies adopted by the United States Environmental Protection Agency (USEPA).

In total, over 400 soil samples have been collected from Area I and analyzed for metals, VOCs, SVOCs, PCBs, explosives, and radionuclides. The results were summarized and compared to the site-specific soil screening limits established under various regulatory authorities. With the exception of PCBs, the site-specific soil screening limits for chemicals were based on the guidelines provided in the PADEP Act 2 non-residential MSC standards. The MSCs established under Act 2 are risk-based cleanup goals. For PCBs, the site-specific soil screening limit was based on the Toxic Substances Control Act (TSCA) level for high-occupancy areas with unrestricted future use, which is more restrictive than Act 2 standards. USACE selected the "high-occupancy" level in discussions with the site owner, who was required to use this level as a result of a separate mandate from the USEPA. These standards were used to guide the six IRAs.

Arsenic and lead are the most prevalent metals remaining at concentrations exceeding their respective soil screening limits. To a lesser extent, chromium, and mercury also remain above the site-specific screening limits. It should be noted the MSC for arsenic was modified by PADEP after 2009. Therefore, the 2009 IRA remediation was performed relative to the standard in place at the time (arsenic MSC of 53 mg/kg surface soil/150 mg/kg subsurface soil). All of the arsenic exceedances presented in this RI/RA are relative to the updated standard of 29 mg/kg for both surface and subsurface soil.

Trichloroethene (TCE) is the most prevalent VOC remaining in the Area I soil above the MSC. Tetrachloroethene (PCE), benzene, and carbon tetrachloride also remain at concentrations exceeding their MSCs. Methylene chloride remains in one location beneath the southeast corner of Building 58 however, methylene chloride has not been identified as a constituent of potential concern for any AOCs within Area I.

Aroclor 1248, 1254 and 1260 are the PCB compounds remaining above the TSCA level. Concentrations of PCBs remain in the Tank Pit 44/47, AOC 9, AOC 14, and the Building 58 leaking sump locations. Concentrations ranged from 1.1 to 7.6 milligrams per kilogram.

In general, soil impacts remain in deeper soils, with limited impacts in shallow soils (zero to two ft depth). A human health risk assessment was conducted to evaluate potential cancer risks and noncancer health hazards for exposure to contamination in Area I soils. Both carcinogenic risks and non-carcinogenic hazards were estimated for industrial/commercial, construction, maintenance, and utility worker receptors. The results were compared against the CERCLA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$ (one in ten thousand to one in one million). The results showed that the carcinogenic risks for each receptor did not exceedd the CERCLA acceptable risk range. Additionally, for non-cancer hazards, the hazard indices also did not exceed the CERCLA acceptable limit.

A screening-level ecological risk evaluation (SLERA) was performed for Area I soils to evaluate whether releases of chemicals to onsite soils may adversely affect ecological receptors. The current and probable future land use for Area I is commercial/industrial. The Site currently has and is expected in the future to continue to have physical features that would limit potential exposure to Area I soil. As a result, no ecological habitats or associated ecological receptors are considered to be associated with the current and future land use for Area I. Since the soil exposure pathway, ecological habitats and associated receptors are not present, no additional ecological evaluation is necessary for soils at Area I. Based on the results of the SLERA, an ecological risk assessment is not required for Area I.

Based on the soil analysis results and the post-remedial risk assessment it is recommended that no further remedial action be taken at Area I.

The CERCLA processes will be completed, including the preparation of a Proposed Plan and Decision Document. Any submissions required under PADEP Act 2 will be completed by current property owner.

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1.0 INTRODUCTION

1.1 Purpose

The U.S. Army Corps of Engineers (USACE) has tasked Cabrera Services Inc. (Cabrera) under contract number DACA31-01-D-0033 Delivery Order 0011 to conduct a remedial investigation (RI) and risk assessment (RA) of the soils in Area I (the Site) at the Former Frankford Arsenal (FFA) located in Philadelphia, Pennsylvania (PA). The purpose of the RI/RA was to characterize the environmental conditions and define the nature and extent of soil contamination in Area I at the FFA. Cabrera conducted a Supplemental Site Investigation (SSI) in 2007 (Cabrera, 2009), a Data Gap Investigation in 2008, and a total of six Interim Removal Actions (IRAs) between 2009 and 2013. In addition, Langan Engineering and Environmental Services, Inc. (Langan) performed a Phase 1 Environmental Site Assessment (ESA) on eastern portions of the FFA in 1999. This RI Report summarizes the analytical results of all nine investigations/IRAs and describes the methods employed during the Data Gap Investigation.

As a part of this RI/RA, a risk assessment was conducted using data collected from the most recent IRAs. The risk assessment was performed to determine the current and potential future risks to human and ecological receptors from exposure to site constituents present in the soil within Area I.

The project objectives are as follows:

- Identify the nature, extent, and source of contamination in soil.
- Develop conceptual site models (CSMs) to establish the relationship between the sources of contamination, potential receptors, and migration of contamination from sources to receptors.
- Prioritize locations for further investigation and/or remediation.
- Establish Pennsylvania Department of Environmental Protection (PADEP) Medium Specific Concentration (MSC) screening levels.
- Collect data of sufficient quality and quantity to allow for the evaluation of remedial alternatives if a Feasibility Study (FS) is to be conducted.

1.2 Regulatory Drivers

The FFA was a Department of Defense (DoD) research, testing, manufacturing, and storage facility for military ordnance, including artillery and small arms ammunition, dating back to the early 1800s. These historical activities led to the contamination of soils and groundwater by heavy metals, chlorinated solvents, PCBs, radionuclides, and explosives. Due to the size of the FFA, the plans for future redevelopment and the Formerly Used Defense Site (FUDS) program funding constraints, environmental remediation efforts have been undertaken in a phased approach.

USACE is conducting environmental restoration at the FFA under the FUDS program. Remedial activities must comply with the Defense Environmental Restoration Program statute (10 USC 2701 et seq.); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC § 9601 et seq.; Executive Orders 12580 and 13016; the National Oil and

Hazardous Substances Pollution Contingency Plan (NCP); and applicable DoD and U.S. Army policies for managing and executing the FUDS program.

USACE is seeking to address the contamination at the Site using the standards of the Land Recycling and Environmental Remediation Standards Act ("Act 2") of the Commonwealth of PA, which is codified at 35 Pa. P.S. §§ 6026.101 et seq. While Act 2 standards do not waive or supersede federal law, Act 2 standards are considered applicable standards for remediation conducted at CERCLA sites in PA.

The USACE is using the Toxic Substances Control Act (TSCA) cleanup level for "high occupancy" areas for addressing PCB contamination at the Site. The TSCA level is more stringent than Act 2 standards. USACE selected the "high-occupancy" level in discussions with the site owner, who was required to use this level due to a separate mandate from the USEPA. The surface soil screening values in Table 6.91 of the Residual Radioactive Contamination from Decommissioning, Nuclear Regulation (NUREG/CR 5512, Volume 3), were selected as the site-specific soil screening values for radionuclides (NRC 1999).

1.3 Site Description and History

1.3.1 Site Description

The FFA is a 109.4-acre facility located in northeast Philadelphia (Figure 1-1). The facility currently consists of 53 remaining buildings of various sizes, age, and condition, as shown in Figure 1-2. Two hundred and twelve buildings were present when FFA was decommissioned (USATHAMA, 1977); therefore 159 buildings have been demolished, creating some open spaces between buildings. A network of utility tunnels exists at FFA, as shown in Figure 1-3. Within Area I, these tunnels have been taken out of service and backfilled. Since its decommissioning from military use, Area I is now primarily used as a commercial business park, while 17 acres to the east have been transferred to the Commonwealth of PA Fish and Boat Commission (PFBC) and approximately five acres transferred to Dietz and Watson. Area I consists of a total of 46 acres.

The FFA is located in an urban, mixed-use area of northeast Philadelphia. The facility is bounded to the north by Tacony Street and Interstate 95 (I-95); by the Dietz and Watson industrial properties to the east; by Frankford Creek and the Delaware River to the south; and to the west by Bridge Street and several industrial properties. Beyond the Frankford Creek is the Rohm and Haas Refinery. Beyond I-95 to the north are more industrial properties, and further north is a residential area.

The Site, referred to as Area I, consists of that part of the FFA occupying the eastern half of the facility between Baird Street and Sanger Street. Figure 1-2 is a site layout map showing Areas I and II. The present and future land uses for Area I have been determined to be industrial/commercial.

1.3.2 Site History

The FFA was commissioned in 1816 for military use. Previously, the area was farmland and undeveloped wetlands. The wetlands areas were entirely filled in over the years. Between 1816 and the decommissioning in 1977, the facility was used for a variety of military activities as its mission was adjusted to fit the military's changing needs. Activities at the FFA during its years of operation included military ordnance production, testing and storage, and munitions research. Figure 1-4 provides a historic timeline of site-related events for the period between 1816 and 2013.

In 1976, the FFA was declared excess by the U.S. Army (Army), and on 30 September 1977, the Arsenal was closed. Subsequently, a number of cleanups were conducted at the Arsenal by the Army Toxic and Hazardous Materials Agency (USATHAMA) prior to transferring the property to the General Services Administration for subsequent disposition. Decontamination efforts were primarily focused on the removal of munitions and radiological wastes. Some chemical-waste cleanup was also conducted to allow for the commercial redevelopment of the Site. This RI/RA was developed to complete the evaluation of chemical contamination in the Area I soils and was used as the basis for the final phase of site cleanup and for regulatory closure.

1.4 Report Organization

The remedial investigation follows PADEP Act 2 policy as well as CERCLA guidance as required by FUDS policy. This investigation only addresses the nature and extent of constituents in Area I soil. A detailed discussion of the removal activities associated with the six IRAs is presented in the *Interim Removal Action Completion Report* (Cabrera, 2013).

Table 1-1 presents a crosswalk between Act 2 requirements and the format of this RI/RA report, which has been organized according to the *Guidance for Conducting Remedial Investigation and Feasibility Study under CERCLA* (USEPA, 1988).

Table 1-1: CERCLA/PADEP Act 2 Requirements Crosswalk

PADEP Suggested Outline for an RI Report under the Site-Specific Standard	Analogous Section of This RI Report
I. Summary	Executive Summary Section 1 – Introduction
II. Site Description	Section 2 - Physical Characteristics of the Study Area Section 3 - Previous Investigations -Summarizes the results of previous investigations
III. Site Characterization	Section 4 - Investigation Methods -Sampling methods for the final phase of the investigation [the Data Gap investigation] are discussed. Section 5 - Data Quality Assessment -Data quality assessment for the Data Gap Investigation Section 6 - Investigation Results -Discusses current conditions based on results of IRAs.
IV. Fate and Transport Analysis	Section 7 - Constituent Fate and Transport

Table 1-1: CERCLA/PADEP Act 2 Requirements Crosswalk (Continued)

PADEP Suggested Outline for an RI Report under the Site-Specific Standard	Analogous Section of This RI Report
V. Other Information Required under the Site-Specific Standard -Provide the results of ecological receptor evaluation. -Identify complete exposure pathways.	Section 8 - Risk Assessment -discusses which exposure pathways are complete and which are not. -ecological receptor evaluation is summarized in this section and in Appendix F.
VI. Conclusions and Recommendations -Draw conclusions regarding the existence of exposure pathways and the potential effectiveness of institutional or engineering controls for pathway elimination. -Identify the appropriate remedial technology options.	Section 9 - Summary and Conclusions -Addresses exposure pathways -Institutional controls, engineering controls, and/or remedial options will be addressed in a future document.
VII. References	Section 10 - References
VIII. Attachments	Appendices
IX. Public Comments	Not included in this RI Report
X. Signatures	To be submitted in a PADEP Cleanup Liability Protection letter.

2.0 PHYSICAL CHARACTERISTICS OF THE FORMER FRANKFORD ARSENAL

2.1 Climate and Topography

The climate of the FFA is moderately humid, with a mean temperature of 55 degrees Fahrenheit (°F); mean annual precipitation of 41 inches evenly distributed throughout the year, and a relative humidity of 58 percent (%). The average growing season is 168 days, with prevailing winds blowing from the west at an average speed of 7.5 miles per hour (city-data.com, 2009).

The FFA is located in the Coastal Plains physiographic province and is characterized by broad areas of low relief. Surface elevations on the Site range from four to 20 feet (ft) above mean sea level. The Site slopes down from northwest to the southeast.

2.2 Regional and Site Geology

The FFA is underlain by unconsolidated sediments of the Coastal Plain province. These unconsolidated materials sit on older crystalline rocks of the Piedmont. The Site is located about one-half mile southeast of the fall line between the Coastal Plain and the Piedmont provinces. The Site is underlain by the Trenton gravel, a Pleistocene unit of Wisconsin-age, described as a pale or reddish-brown, gravelly sand with a wide range of grain sizes, inter-bedded with cross-bedded sands and clayey-silt layers (USGS, 1991). Locally, this gravel layer has areas of Holocene alluvium and swamp deposits with small amounts of clay. The average thickness of this unit is about 40 ft, but can be as great as 80 ft (Langan, 2005).

The basement beneath the unconsolidated deposits is made up of crystalline rocks of Wissahickon Formation, believed to be of early Paleozoic-age, and is mapped in the Philadelphia area as Oligoclase-mica schist with some gneissic, quartz-rich, and feldspar-rich members. The Trenton gravel and the bedrock are both used as aquifers in the Philadelphia area (USGS, 1991).

Descriptions of the subsurface conditions at the Site are based on the numerous soil borings advanced within Area I. Graphical presentation of the subsurface is presented on Figures 2-1 through 2-4. The surface deposits at the Site are fill materials consisting of reworked native soil mixed with bricks, wood, coal, concrete, gravel, slag, and ash. This fill material was encountered from surface to a depth of nine ft below ground surface (bgs). Demolition debris was encountered at specific and localized areas, at depths of up to 20 ft bgs. Native soils, consistent with the published descriptions of the Trenton gravel, and consisting of reddish-brown gravelly sands, were encountered from surface to about 15 ft bgs. Organic silts and peat-matching published descriptions of Holocene alluvium and swamp deposits were present in several borings across the Site. Figure 2-1 is an east-west cross-section of the northern portion of the Site, parallel to Tacony Boulevard. The cross-section can be divided approximately into three segments: (1) fill material and silts from ground surface to 10 ft bgs; (2) fining-upward alluvial sand and gravel encountered from 10 to 45 ft bgs; and (3) below that, bedrock consisting of schist. A five-ft thick clay layer separates the gravel from the bedrock occurring from 40 to 45 ft bgs.

Figure 2-2 is a north-south cross-section near Sanger Street, on the eastern side of the Site. Ground surface slopes down toward Frankford Creek and the Delaware River at a gradient of 10%. The surface fill layer is encountered across the Site, with thickness ranging from five to 15 ft, generally thickening toward the river. Marsh deposits overlie the Trenton gravel in the southern quarter of the Area I. The thickness of this unit ranges up to about 15 ft in some areas beneath the Site. Fill and dredge spoils cover most of the southern third of the Site. The Trenton gravel is persistent across the Site, but the basal clay unit of the Trenton gravel does not appear to persist to the south.

Figure 2-3 is a north-south cross-section parallel to Baird Street, which forms the western edge of Area I. The land surface slopes down to the Frankford Creek at a gradient of approximately 7%. In the center of the transect, several different sand units and a silt unit are present, indicating the paleochannel of a small stream or creek. These stream sediments overlie the Trenton gravel. A clay unit is at the southern end of this transect and may be indicative of marsh deposits.

Figure 2-4 is a generally east-west cross-section of the southern border of Area I. There are no deep wells drilled to bedrock in this area, so the section presents only the soil above the Trenton gravel. Ten to 20 ft of fill material covers the Trenton gravel in this area. To the west near Frankford Creek, the fill is underlain by peat and clay layers, indicative of marsh deposits.

2.3 Surface Water Hydrology

There are no wetlands, streams, or other surface watercourses located on the FFA property at the present time. Historically, a surface water feature named Hellfire Creek existed in the area of Baird Street until sometime in the 1800s. The creek drained to a marsh that existed along the Delaware River. This low-lying area has since been filled in by expansion of the Arsenal (USA Environmental, 2004). Regional drainage surrounding the FFA is controlled by Frankford Creek and the Delaware River, which border the FFA to the south/southeast. Both the frontage on Frankford Creek and the Delaware River are entirely bounded by sea walls.

Surface water at the FFA site is controlled by a system of catch basins and storm water pipes. The storm water is conveyed by this system to a pumping or “lift station” located adjacent to Frankford Creek. The storm water is discharged to Frankford Creek at this point. Frankford Creek flows in a southeasterly direction towards its confluence with Delaware River (Langan, 2005).

2.4 Hydrogeology

The saturated soil underlying the FFA is the Quaternary-aged Trenton gravel. Most of the gravel and sands of the Coastal Plain yield large supplies of water that are used for industrial and other non-domestic purposes. These soils form the principal aquifers in the Philadelphia area. The Trenton gravel consists of gray or pale reddish-brown gravelly sand interstratified with cross-bedded sand and silty-clay beds. The thickness of the Trenton gravel locally can be as much as 80 ft, but it averages approximately 40 ft on the Site (Langan, 2005).

Groundwater occurs under unconfined conditions in the unconsolidated overburden in the northern part of the Site and is encountered at depths ranging from 4.5 to 13.3 ft bgs. In the southern part of the Site, the Trenton gravel aquifer is partially confined by overlying fine-grained, saturated soil. Groundwater flow is generally from northwest to south-southeast toward the Delaware River, or locally toward Frankford Creek. The hydraulic gradient was estimated at 0.001 to 0.003 ft per ft (ft/ft), with a downward vertical gradient observed in shallow and deep well pairs. Wells set in the Trenton gravel have lower hydraulic heads than nearby wells screened in the overlying fill material, indicating that a confining (or partially confining) layer is present.

2.5 Underground Utilities

The FFA has a network of underground utilities including tunnels for steam transmission, electrical, natural gas, and storm/sanitary sewer systems. These underground structures may locally influence groundwater flow directions. Only the storm/sanitary sewers have connections and/or outfalls outside of the boundaries of the FFA as shown on Figure 1-3. A brief analysis of the site-wide utility system indicates that:

- A network of tunnels is used to distribute steam, telephone, compressed air, fire protection alarm system, and power cables to buildings. According to facility records, there are about 15,592 linear ft of tunnels, ranging from three to 6.5 ft in diameter, and constructed of reinforced concrete. Numerous access points via manholes, located at regular intervals along the tunnels, are visible at the surface (Langan, 2005).
- Electrical power is delivered via conduit constructed of asbestos-cement and encased in a reinforced, watertight concrete envelope. Numerous substations and secondary distribution systems are located at critical points to provide the required transformations needed.
- Natural gas is provided to the FFA by the Philadelphia Gas Works Co. through a network of about 13,000 ft of seamless steel pipes, with the primary supply connection a 20-inch main tapped into the main supply line on Tacony Street. According to historical information, the locations of Buildings 120 and 121 previously housed a manufactured gas plant between 1883 and 1900 (JMA, 1979).
- In Area I, the storm and sanitary sewer collects in an eight-by-nine ft main on Sanger Street. This flow combines with the larger (10 by 11 ft) Delaware Connector via an interceptor chamber east of Building 307. The flow then continues south, under Frankford Creek, to the city publicly-owned treatment works. In the event of heavy rains, excess flow can bypass the interceptor into the lower segment of the Sanger Street sewer and discharge to the Delaware River.

It should be noted that the utility tunnels within Area I were demolished in place and reportedly backfilled with soil by the site owner. Utility services to the west of Area I are still provided through the tunnel system.

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3.0 PREVIOUS INVESTIGATIONS

Samples from soils, groundwater, drains, sumps, pits and buildings were collected during the various investigations conducted at the Site. Samples were analyzed for site-related constituents, including metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), explosive compounds, and radionuclides. The scope and results of the site investigations and IRAs that occurred following decommissioning of the FFA are summarized below. The site investigation performed between 1999 and 2008 and the results of the IRA soil excavation activities between 2009 and 2013 form the basis for this Area I Soils RI/RA.

3.1 Site Investigations 1999-2004

3.1.1 Inventory and Hazmat Removal, U.S. Army, 1973 to 1976

The Army inventoried and removed hazardous materials from the FFA, starting in 1973 and concluding shortly after FFA was decommissioned in 1976 (Rockwell, 1977). The Army removed commercial quantities of acids, bases, solvents and paints from the plating shop (Building 45). Laboratory reagents were removed from the Pitman-Dunn Laboratory (Building 64). Approximately one ton of mercury and six tons of depleted uranium were removed from the Site, as well as other radionuclides in smaller quantities.

3.1.2 Installation Assessment, USATHAMA, 1977

USATHAMA conducted a records and historical data search of the facility during the summer and early fall of 1977. The purpose of this assessment was to "…uncover indications of possible contamination at the Installation by chemical, biological, and radiological materials resulting from past manufacturing, testing, storage, and disposal operations; and to assess the possibility of contaminant migration beyond the installation boundaries" (Rockwell, 1977).

After the records search, interviews with former managers and employees, and a review of routine manufacturing and handling practices at the FFA, USATHAMA determined that several areas on the installation were potentially contaminated with explosives, pyrotechnics, propellants or propellant wastes. There were two disposal areas at FFA: a sanitary disposal area operated during the civil war period, and a demolition debris disposal area in the southeast portion of Area I (approximately 160 to 250 ft east of Building 308).

Unexploded ordnance (UXO) was suspected at several locations. Additionally, indoor target ranges in Buildings 521 and 150 were used for ammunition testing. Quantities of chemicals used for the production and plating of munitions were stored on the Site, including cyanide and acid baths in Building 45. A catch basin was located on the banks of the Delaware River, which received effluent from the former lead styphnate production area (Rockwell, 1977).

Based on the factors outlined above, USATHAMA concluded that "Areas of potential explosive/pyrotechnic, radiological, chemical, and UXO contamination were identified and, in addition, other areas of potential contamination were documented." USATHAMA recommended that "…findings of the Records Research Team be reviewed by personnel responsible for the decontamination program at FFA and, where applicable, be incorporated into the program." (Rockwell, 1977)

3.1.3 Detailed Survey and Alternatives Assessment for FFA, Battelle, 1978

Battelle conducted a survey in 1978 that included the property, buildings, vents, sewers, sumps, surface water, sediments, groundwater, soil, ambient air and biota of the FFA. Approximately 120 shallow (zero to one ft deep) soil samples were collected and analyzed for metals, explosives, and radionuclides. The results confirmed that there were low levels of heavy metal residues, explosive residues, and radiological contamination. Four separate sub-studies were conducted, including:

- A safety examination for physical, radiological, and explosive/toxic gas hazards;
- A soil-sampling investigation of the real property of FFA;
- A survey of the areas in which radiological contamination was found; and
- A series of tests to determine the effectiveness of various methods of decontamination.

The survey results were summarized as follows:

- The exposures from radiological contaminants were minimal, in limited areas, and tended to be in low areas such as sumps and cracks. Four areas were identified as spill areas.
- There were a small number of sites where exposure to vapors and/or explosives was also a concern. These areas were identified to the FFA staff.
- Heavy metal contamination, principally lead, was common on many building surfaces. It ranged from 40 to 30,000 micrograms per square centimeter. The major source of the lead was lead-based paint. However, additional areas had cadmium, chromium, and mercury.

The survey results constituted the basis for the design and execution of the facility decontamination conducted by USATHAMA in 1980 and 1981 (Rockwell, 1981), after which USATHAMA issued a statement of clearance for the unrestricted use of the facility.

3.1.4 Historic and Archeological Survey, John Milner Associates, Inc., 1979

In May 1979, the Department of the Army awarded a contract to John Milner Associates Inc. (JMA) to conduct a historic and archeological survey of the FFA, as the facility was listed in the National Register of Historic Places. The focus of the survey was the future use of site buildings and other facilities and whether or not future plans could be combined with national preservation objectives. In addition to documenting the historic evolution of the facility from its inception in 1816 to its role as a principal depot, the report discusses the archeological, architectural, and industrial significance of the installation, and the preservation guidelines to be used in future planning and development (JMA, 1979).

3.1.5 Frankford Arsenal Decontamination/Cleanup Report, Rockwell, 1981

The 1981 Rockwell International survey for USATHAMA concluded that numerous buildings with their associated sumps, sewers, and vents were contaminated with low levels of heavy metal, explosive, and radiological residues and required cleanup (Rockwell, 1981). The major elements of this cleanup are discussed below.

The Building 329 Platform area was determined to contain several hundred cannonballs, some of which were lodged beneath the platform (Figure 3-1). The Building 329 platform was used as a loading/unloading dock at FFA. During the post-closure assessment, several hundred cannonballs were removed from the vicinity of the platform, but some were lodged beneath the platform and required excavation, necessitating that the platform first be removed. Once the Building 329 Platform was removed, a Navy explosive ordnance disposal team furnished by the Army recovered seven cannonballs, all of which were certified as inert. The rubble and other debris generated from the removal of the platform were buried in the excavation created during removal of the cannonballs.

Heavy metal residues (lead, cadmium, chromium, and mercury) were primarily associated with the use of lead-based paints used on interior surfaces of buildings; as well as the operation of electroplating and metallurgical laboratories. Based on the contamination survey, the surfaces of 135 buildings and the structures in the "400 Area," and associated sumps and vents were determined to be contaminated with heavy metal residues and required decontamination (Figure 3-1). Twenty-three buildings contained sumps, and 32 had vents.

Remediation of building surfaces included the removal of loose and flaking paint from walls, preparation of the surfaces, and repainting of the buildings to meet the Surgeon General's bioavailability requirements. This work was completed in November 1980 (Rockwell, 1981).

The sumps were decontaminated by pumping out any liquids (mostly water), analyzing the liquids, and arranging for appropriate disposal of hazardous; or discharging the liquids to the sanitary sewer if determined to be non-hazardous. Similarly, any sludge (mostly soil) present in the sumps was removed, analyzed to determine whether it was hazardous, and disposed appropriately. The sumps were then flushed out using high-pressure water. Post cleaning sampling of the sumps indicated that sumps associated with Buildings 46 (five sumps), 119 (three sumps), and 219 (one sump) were still contaminated. These sumps were taken out of service by filling them in place with concrete, rendering them inoperable.

Thirty-two buildings were identified as containing vents with heavy metal residues. Surface testing of the walls of these buildings showed very low levels of contamination, which prompted the surface sampling of the vents. Results of the vent sampling indicated no heavy metal residue contamination (Rockwell, 1981).

Explosives residues were a result of the manufacturing of small arms munitions; the storage, supplying, and maintenance of munitions; and the use of the FFA as the national center for the development of cartridges and propellants devices.

Explosives residue decontamination was accomplished by high-temperature flaming. This process involved the use of charcoal and supplied air to generate high-temperature flames that caused the explosives to burn off the surfaces. The surfaces and/or sumps were covered with charcoal, and aerators were installed to supply compressed air to the ensuing fire. This caused the fire to generate temperatures in excess of 2,000ºF which in turn caused the explosives to burn (Rockwell, 1981).

Fourteen buildings, (Buildings 64, 68, 69, 149,151, 151A, 201, 214, 214A, 222, 235, 305, 307 and 521), were identified as having explosive residues on the floor and wall surfaces (Figure 3-1). Remote and hand-flaming were used to destroy these residues. Remote flaming was used to clean the easily accessible surfaces, and hand-flaming was used to clean hard-to-reach surfaces.

The sumps associated with the buildings in the "400 Area" and Buildings 58, 68, 122, 213, and 244A contained explosive residues. These sumps were cleaned by installing aerator lines to each sump, filling the sump with charcoal and igniting the coal using remote detonator. As the coal burned, the fire was supplied with compressed air, causing the explosive residues to burn off.

Several vents in Buildings 240, 305, and 316 were flamed to remove surface explosives residues. Because the vents also contained radiological contamination, they were then removed and disposed of at the Barnwell, South Carolina, radioactive waste burial site (Rockwell, 1981, p. 38).

Radiological contamination resulted from the use of depleted uranium in the development of armor piercing projectiles, and the use of other radioactive materials (e.g., radium) for fire control instruments.

Radiological contamination was detected in 12 buildings: Buildings 46, 64, 108, 121, 149, 150, 201, 210, 227B, 316, 518 and 521, as shown in Figure 3-1 (Rockwell, 1981). The decontamination of these buildings consisted of the removal of contaminated building surfaces, drains, and vents. The wastes generated were packaged and transported to Barnwell, South Carolina, and Beatty, Nevada, for proper disposal. Post-decontamination sampling was conducted to verify and document cleanup.

Forty-two buildings contained sumps. Radiological surveys indicated none of the sumps contained radiological contamination at levels requiring cleanup; therefore, no radiological decontamination of the sewers was necessary.

A total of seven vents in Buildings 149, 150, 201, 316 and 521 were contaminated with radiological wastes. Since they were also contaminated with explosives residues, these vents were treated by flaming to remove explosive residues prior to their removal, transport, and disposal at the Barnwell burial facility in South Carolina. In addition, contaminated soil from outside of Buildings 149/150, 227B, and 316 was excavated and disposed at the low-level radioactive waste disposal facility.

The FFA decontamination was conducted using Army-approved standard operating procedures; and post-cleanup data indicated that the approved release criteria for the identified contaminants were satisfied. Decontamination and cleanup activities were completed by November 1980 (Rockwell, 1981).

3.1.6 Remedial Action Decision Document, USATHAMA, 1988

USATHAMA prepared a Decision Document providing a description of the selected remedy based upon the decontamination/cleanup work documented in the Battelle (1978) and Rockwell (1981) reports.

3.1.7 Phase 1 Site Assessment, PSI, 1996

In March 1996, a Phase I Site Assessment of the FFA was conducted by Property Solutions, Inc. (PSI) for Arsenal Associates (PSI, 1996). This study involved the review of several environmental assessment reports previously prepared by various consultants including a 1993 report by Consulting Services, Inc. of Exton, PA; an October 1994 update of the 1993 report by ORBIS Environmental Group, Inc.; and a January 1981 report by Rockwell (Rockwell, 1981). Information reviewed under the Phase I Site Assessment included historical ownership records, aerial photographs, and U.S. Geological Survey (USGS) topographic maps. The review was supplemented by a historical records search, site visit, and interviews of current and former employees. The review included a Dames & Moore report entitled "Final Design Analysis Report for Removal of Tanks and Appurtenances," conducted for the USACE, in 1994. The report describes the removal of 10 aboveground storage tanks (ASTs) from the area of Building 301, along with the removal and disposal of asbestos insulation materials, the removal of a generator, and the excavation of petroleum-contaminated soils.

PSI summarized these multiple environmental assessment reports as follows:

- Probable leaks and/or spills from a tank field of 10 ASTs near Building 301 resulted in elevated levels of hydrocarbons in soil samples collected in the area. Similarly, two heating oil ASTs in the basement of Building 238 and one diesel AST outside Buildings 108/109 contributed to soil staining and contamination. Some soil samples contained up to 170,000 milligrams per kilogram (mg/kg) of total petroleum hydrocarbons.
- The possibility that several underground storage tanks (USTs) existed on the Site: three located on the eastern wall of Building 128 along Eakin Street; one on the north side of Buildings 47/48, and one in the basement of Building 58. There were no visible fill ports for these tanks, except for Building 58. However, metal pipes along walls close to these locations were suspected to be vent pipes for the USTs.
- As a result of observed leaks in transformers and storage containers at bulk storage locations for chemicals and hazardous materials, there was suspected PCB contamination at several tenant storage locations.
- From historical photographs, there seem to have been an acid neutralization pit and an underground neutralization tank located between Buildings 55 and 58, on the eastern side of Building 235. The pit and tank were used as a process wastewater pre-treatment system.

PSI concluded that there were 15 areas of potential environmental concern including spray painting areas, ASTs, USTs, PCB-containing equipment, asbestos-containing materials, potential lead-based paints in many buildings, bulk storage of chemicals, hazardous materials and other raw materials storage, visual staining of floors and drains in buildings, and waste piles of demolition debris and other wastes (PSI, 1996).

3.1.8 Site Inspection and Evaluation, USEPA, 1996

The USEPA organized a team of scientists from its TSCA, Resource Conservation and Recovery Act, and Clean Air Act divisions to inspect and evaluate the general environmental conditions at the FFA, and to identify potential issues of non-compliance at the facility. The inspection identified non-compliance issues related to:

- The discharge of wastewater to the sewers from Buildings 124 and 238. A dye test was conducted as part of the evaluation and indicated that some drains from these buildings discharge to Frankford Creek. One of the drains was diverted to the sanitary sewer system to correct the problem.
- Potential PCB contamination, including storage drums containing PCBs at Building 301A, storage of out-of-service transformers near Building 235, and a drum of PCB wastes at Building 128, visually stained soils at substation 27 near Building 250.
- A PCB cleanup effort that was conducted at Buildings 128, 149, 150 and 250 (Langan, 2005).

3.1.9 Phase 1 Environmental Site Assessment (ESA), Langan Environmental & Engineering Services, 1999

In June 1999, Langan performed a Phase 1 Environmental Site Assessment (ESA) on eastern portions of the FFA. The ESA consisted of groundwater-monitoring well installation, groundwater sampling, surface soil sampling, subsurface soil investigation (soil borings and test pits), and sump, pit, and drain sampling in existing buildings. The soil investigation included the collection of 42 soil samples from 48 soil borings; the collection of 17 soil samples from 42 test pits; and the collection of 48 surface soil samples. Selection of the sample point locations was based on the historical use of the buildings, site inspections and a records review. Surface samples were collected where stained soil or stressed vegetation were observed. Test pits and soil borings were completed in areas that currently or historically housed chemicals or where storage tanks were located. Soil borings were installed adjacent to areas that had sumps, drains, USTs and pits. Test pits were located in areas of suspected dumping/landfilling. Test pit samples were also tested for asbestos containing materials.

The results of the Phase 1 ESA showed the presence of inorganic and organic contamination in both soil and groundwater at the Site exceeding the PADEP non-residential cleanup standards for soil and groundwater; primarily heavy metals (arsenic and lead), VOCs (trichloroethene [TCE] and carbon tetrachloride), SVOCs (naphthalene), and PCBs. Based on the results, Langan recommended a supplemental investigation to further delineate the presence of contamination within soil and groundwater.

3.1.10 Radiological Historical Site Assessment, Cabrera Services, 2001

In 1989, the U.S. General Accounting Office raised concerns about the decommissioning of sites formerly licensed by the Atomic Energy Commission and the Nuclear Regulatory Commission (NRC). NRC agreed to reexamine the files of the terminated license sites to verify that the sites had been properly decommissioned. Sites were identified for additional review based on file information indicating that, while licensed material may have been used, no adequate final survey records existed. The FFA was among those sites identified.

Cabrera was contracted by the USACE to perform a Radiological Historical Site Assessment (HSA). Over 150 documents were reviewed with an emphasis on radiological material use and storage and building release survey documentation. A database was developed that contained a master building list, along with supporting references associated with each building, to assist in the investigation. Based on the document review, 106 buildings were selected and evaluated to determine if they were potentially affected by radiological operations at the FFA. Fifty-six of the buildings were determined to be impacted, indicating that radiological surveys would have been necessary to ensure that the buildings had been properly released. Of the 56 buildings, 14 had survey documentation showing verification and release granted by the NRC. Verification of final release surveys could not be located for the remaining 42 buildings. Nineteen of these buildings had been demolished and 23 remained.

During the HSA, the use of radioactive material at the FFA was researched. The various radioactive material licenses granted to the Army (during both operational and decontamination activities) were reviewed, taking into consideration material form and radioactive decay through January 1, 2002. The Radiological Constituents of Potential Concern (RCOPCs) were then identified from constituents listed on the various licenses. Depleted uranium was identified as the primary radionuclide of concern at the FFA. In addition to depleted uranium, radium was used in research and development and production of watch dials, fire control system dials, and other applications. Radium laboratory and production work was spread out over a number of buildings, with activities and storage first documented in Building 23 (Cabrera, 2001). Radium was also utilized in Buildings 23, 46, 64, 109, 112, 150, 201, 202, 230, and 519 and in smoke detectors located in the Building 109 computer area. Additional RCOPCs included Tritium (^{3}H), Cesium-137 (^{137}Cs), and Cobalt-60 (^{60}Co).

3.1.11 Radiological Scoping Survey, Cabrera Services, July 2003

The objective of the radiological scoping survey was to determine if residual concentrations of the RCOPCs in buildings and land areas at the FFA supported the prior license termination action to release the Site for unrestricted use. The data produced by the radiological scoping surveys were combined with the information obtained from the 2001 HSA to determine whether current residual concentrations of RCOPCs exceed designated NRC criteria for residual radioactive contamination on building surfaces or in surface soils.

Cabrera identified eight areas of "High Priority," four areas of "Medium Priority," and 29 areas of "Low Priority," for a total of 41 buildings and land areas. The survey coverage varied depending on the classification and media type.

Cabrera collected a combination of beta-gamma scans of building surfaces and systems, swipes for removable alpha-beta contamination, fixed contamination measurements at selected locations, gamma walkover scans of land areas, and samples of surface soils. Samples were analyzed for gross alpha, gross beta, and gamma radiation; removable alpha and beta particles; ^{3}H; isotopic uranium (^{238}U, ^{235}U, ^{234}U); ^{137}Cs; and ^{60}Co.

A total (fixed plus removable) depleted uranium screening value of 100 disintegrations per minute (dpm) per 100 square centimeters (cm^2) and a removable screening value of 10 dpm/100cm^2 were used for comparison of results. The DU screening value selected was the most conservative limit for the site alpha-emitting RCOPCs.

A total of 342 fixed-point measurements were performed on building surfaces. Of these measurements, one exceeded the 100 dpm/100cm^2 alpha, and no measurements exceeded the 7.0E+3 dpm/100cm^2 beta screening values. There was no significant difference between High Priority, Medium Priority, or Reference building results. The four highest fixed-point measurement results were in buildings that were classified as Low Priority.

Soil samples were collected at locations with the highest gamma walkover survey (GWS) results, and submitted for off-site laboratory analysis for gamma spectroscopy and isotopic uranium. Results of GWS were within 20% of those from the background reference area. All results were less than the surface soil screening values, even without correcting for the background concentrations of naturally occurring radionuclides.

Of the 385 removable contamination measurements collected from building surfaces, only five were greater than 10 dpm/100cm^2 alpha and no measurements exceeded the beta removable screening values. The maximum removable alpha and beta values were 11 and 127 dpm/100cm^2, respectively. Results for removable ^{3}H contamination were less than the laboratory detection limit of 115 dpm/100cm^2. The levels were considerably less than 10% of the screening value for ^{3}H.

With the exception of five results for removable alpha contamination from building surfaces, the results were below the screening criteria. Furthermore, all results, including the five cited above, were below the regulatory limits for unrestricted release.

Cabrera determined that there were no RCOPCs present above the screening criteria. Based on these results, it was concluded that there was no indication of residual radioactive contamination at concentrations of concern at FFA. NRC concurred and, thus, released FFA for unrestricted use (with respect to radioactivity) in 2003 (NRC, 2003).

3.1.12 Engineering Evaluation/Cost Analysis for MEC, USA Environmental, 2005

Due to the historical uses of the FFA and the potential existence of munitions and explosives of concern (MEC), DoD commissioned an Engineering Evaluation/Cost Analysis (EE/CA) to investigate and characterize the presence of MEC, evaluate associated risk, if any, and develop appropriate measures to mitigate such risk. The EE/CA concluded that buried munitions were a potential hazard; however, their presence was considered to be unlikely. The report recommended institutional controls to protect workers during future intrusive investigations and/or development activities (USA Environmental, 2005).

3.2 Site Investigations 2005-2013

Between 2005 and 2013, a total of two RIs, an SSI, groundwater monitoring, and six IRAs were conducted for Area I. Based on the results of these investigations, several potential source areas were identified for soil and groundwater contamination and are depicted on Figure 3-2. The following subsections provide summary conclusions for each investigation.

3.2.1 Draft Act 2 Remedial Investigation Report, Langan, 2005

In December 2005, Langan completed a RI with the following objectives:

- Delineation of PCB contamination near the transformers between Buildings 128 and 129 and the circuit breaker debris pile at Building 236;
- Investigation of suspected VOC impact on soil and groundwater around the location of Monitoring Well MW-9; and
- Determination of the nature and extent of non-aqueous phase liquids detected at Monitoring Well MW-3.

The 2005 investigation involved the installation and sampling of soil borings and groundwater monitoring wells. Investigation results confirmed the presence of PCBs in the area adjacent to Building 128.

The RI incorporated the results of the 1999 Phase 1 ESA (see Section 3.1.9) into the investigation summary. A total of 123 soil samples were analyzed for site-related constituents. The combined data evaluation identified several areas of soil contaminated with heavy metals, VOCs, SVOCs, PCBs, and radionuclides. The report also identified limited areas of groundwater contamination and concluded that groundwater contamination was contained onsite. Results of the 2005 groundwater investigation will be documented in a future Groundwater RI for Area I.

3.2.2 Supplemental Site Investigation, Cabrera Services, 2007

Cabrera conducted a Supplemental Site Investigation (SSI) in the summer of 2007 to verify the nature and extent of contamination within Area I at locations identified as potential source areas during previous investigations (Cabrera, 2007b). Because the SSI was designed to fill data gaps identified after the evaluation of the Langan 1999 ESA and 2005 Act 2 RI, the effort also encompassed areas not previously investigated. The SSI consisted of the installation of 35 soil borings, 24 temporary and 14 permanent groundwater monitoring wells, and the excavation of eight test pits. In total, 11 Areas of Interest (AOIs) were identified, based on constituent concentrations that exceeded MSCs.

Constituents that exceeded the screening values included lead and VOCs (benzene; carbon tetrachloride; PCE, and TCE). No concentrations of SVOCs, PCBs, or explosives exceeded the screening limits.

Although the results of the 2007 SSI did verify and document contamination at both previously identified and new areas of concern, the extent of contamination was not fully determined. Based on the results evaluated from the 1995 through 2007 investigations, 16 AOIs were identified as potential source areas of soil and groundwater contamination and are depicted on Figure 3-2. These AOIs were further investigated in the Area I Data Gap Investigation, as presented in Section 3.2.3.

3.2.3 Area I Data Gap Investigation, Cabrera Services, 2008

The investigation conducted in February and March 2008 by Cabrera was a data gap investigation to determine the lateral and vertical extent of soil contamination at the 16 potential source areas (AOI 1 through AOI 16) identified at the conclusion of the SSI. Locations of the AOIs are presented on Figure 3-2. The fieldwork conducted in 2008 consisted of advancing 30 soil borings at the 16 AOIs and collecting approximately 90 soil samples for onsite field and off-site laboratory analysis for metals, VOCs, SVOCs, PCBs, and radionuclides. Based on the results of these investigations, 11 of the AOIs were later designated Areas of Concern (AOCs) as source areas for soil contamination. Table 3-1 presents a summary of the AOIs/AOCs, associated buildings and site constituents, as well as the final status for each.

A brief description of the analysis results from the data gap field investigation is presented below. Data results were compared to the MSC values used at the time.

Metals

Two of the ten soil samples submitted for metals analysis contained constituents which exceeded their respective MSCs. Arsenic exceeded its MSC of 50 mg/kg in one sample collected in AOI 4 with a concentration of 65 mg/kg. The MSC for mercury (10 mg/kg) was exceeded in a single surface soil collected within AOI 5(19.8 mg/kg).

VOCs

A total of 75 soil samples collected from 49 locations were submitted to the onsite laboratory for VOC analysis. An additional 10 samples were submitted to the off-site laboratory for QA purposes. Carbon tetrachloride was reported above the MSC (500 µg/kg) in AOI/AOC1 in a single soil sample at a concentration of 720 µg/kg. The TCE concentrations in a total of 14 soil samples exceeded the MSC of 500 µg/kg in AOIs 1, 3 and 10. In AOI/AOC 1, the nine sample exceedances ranged from 510 µg/kg to 12,000 µg/kg. The three sample exceedances in AOI/AOC 3 ranged from 980 µg/kg to 3,100 µg/kg. In AOI/AOC 10, the three sample exceedances ranged from 460 µg/kg to 2,800 µg/kg.

Eighteen locations within AOI/AOC 9 contain methylene chloride in excess of the MSC of 500 µg/kg. Concentrations range from 600 µg/kg to 6,400 µg/kg, with depths between the ground surface and 16 ft bgs. Quality control samples associated with the AOI/AOC 9 sampling event included two method blanks (MB), two laboratory control samples (LCS), two laboratory control sample duplicates (LCSD) and two matrix spike/ matrix spike duplicates (MS/MSD). Methylene chloride was detected in the MB samples, resulting in a positive bias for all soil sample results associated with that analytical batch. Therefore, the lab assigned an X+ qualifier for the sampling results. In the laboratory narrative, it was stated that the carry-over contamination biased the elevated results.

As both the percent recovery results (≥300%) for LCS and MS samples exceeded 150%, the elevated methylene chloride sampling results with the X+ qualifier were rejected. Therefore, methylene chloride has not been identified as a constituent of potential concern for any AOCs within FFA Area I.

SVOCs

A total of eight soil samples were submitted for SVOC analysis, One constituent, benzo(a)pyrene exceeded the MSC of 11,000 µg/kg in one soil sample collected from AOI/AOC 9 (11,400 µg/kg).

Polychlorinated Biphenyls

Twenty-five of 75 soil samples analyzed for PCBs contained concentrations in excess of the TSCA level of 1.0 mg/kg. The exceedances were detected in samples from five AOI/AOCs: 4, 5, 6, 8, and 9. The PCB concentration ranges were as follows:

- AOI/AOC 4 – three samples- 6.9 mg/kg to 16 mg/kg
- AOI/AOC 5 – 16 samples - 1.1 mg/kg to 8,600 mg/kg
- AOI/AOC 6 – three samples 2.2 mg/kg to 10 mg/kg
- AOI/AOC 8 – two samples - 2.4 mg/kg to 14 mg/kg
- AOI/AOC 9 – one sample - 3.01 mg/kg

Radionuclides

Uranium, natural-thorium (^{232}Th), radium-226 (^{226}Ra), ^{137}Cs, ^{60}Co and americium-241 (^{241}Am) were identified as RCOPCs during the 2001 Historical Site Assessment and 2003 Radiological Scoping Survey. Gamma spec analysis was performed during the 2008 Data Gap Investigation to provide analytical results for all RCOPCs. Gamma spec analysis was also performed for potassium-40 (^{40}K).

Analytical results for actinium-228 (daughter product of natural-thorium), thorium-234 (daughter product of ^{238}U), and bismuth-214 and lead-214 (daughter products of ^{226}Ra) were utilized to represent the analytical results for ^{232}Th, ^{238}U and ^{226}Ra, respectively.

In the absence of PADEP MSCs, the RCOPC results were compared to NRC soil screening values. Analytical results for the RCOPCs did not exceed their corresponding NRC soil screening values. However, the analytical results for ^{40}K did exceed the corresponding NRC soil screening value of 3.6 pCi/g. Therefore, an evaluation was performed to identify whether ^{40}K should be an RCOPC for the Site.

Potassium-40 represents 0.012% of naturally occurring potassium and its concentration in the earth's crust is about 13 picocurie per gram (pCi/g). Potassium binds preferentially to soil, with the concentration associated with sandy soil particles estimated to be 15 times higher than in the interstitial water. Potassium binds more tightly to loam and clay soil, so those concentration ratios are higher (above 50). (Human Health Fact Sheet, ANL 2001). The onsite maximum and average concentrations for ^{40}K are 10.4 and 8.4 pCi/g, respectively. Onsite maximum and average concentrations for ^{40}K are less than its natural background of 13 pCi/g. Therefore, it was determined that ^{40}K was not an RCOPC for the Site.

Protactinum-234m is a very short-lived (1.17 minutes half- life) daughter product of ^{238}U. Similarly, Actinium-228 is a short-lived (6.13 hour half-life) is a daughter product of the thorium-232 decay chain. The sampling results for the parents did not exceed the corresponding NRC screening values. Therefore, both short-lived radionuclides were not considered as RCOPCs for the Site.

Similarly, sampling results for both daughter products (Bismuth-214 and Lead-214) of ^{226}Ra did not exceed the screening value for radium-226.

3.2.4 Project Close-Out Report, EA Engineering, 2008

EA Engineering, Technology, and Science performed the removal of USTs and batteries, as well as the abandonment of groundwater monitoring wells. Additionally, EA focused on the determination of the presence or absence of soil and groundwater contamination associated surrounding the removal areas. A total of 10 USTs were investigated following PA Act 32 underground storage tank regulations; however, only seven USTs were found at four locations. The four locations included Building 128, Buildings 44/47, Building 48, and Buildings 55/58.

Adjacent to Building 128, two USTs were removed and confirmatory sampling indicated that PA Act 32 standards had been met. Three waste oil flow-through process USTs at Buildings 44/47 were closed in place due to live utilities immediately adjacent to the USTs. The tanks were cleaned and filled with flowable material consisting primary of sand. Confirmatory samples results met the PA Act 32 standards; however, PA Act 2 standards were exceeded for VOCs and SVOCs. A single waste oil tank at Building 48 was closed in place due to its proximity to live utilities. The tank was cleaned and filled with flowable material consisting primary of sand. All confirmatory samples but one SVOC met the PA Act 2 standard. One former neutralization UST located at Building 55/58 was determined to be connected to the sewer system and was left in place without being removed.

In April 2008 1,870 nickel-cadmium batteries were collected from 24 separate substations across the FFA. The batteries were taken to a central staging area where they were bundled and shipped to an off-site disposal facility.

A total of 16 groundwater monitoring wells were scheduled for abandonment in accordance with the PADEP Ground Water Monitoring Guidance Manual. Only eight of the 16 wells could be located. Each well was tremie grouted and the surface casing cut to the ground surface.

3.2.5 Area I Groundwater Monitoring and Sampling, 2007–2009

A total of five groundwater monitoring events were conducted at Area I between 2007 and 2009. Up to as many as 26 permanent monitoring wells and seven piezometers were sampled via low flow techniques for VOCs, SVOCs, metals, PCBs, explosives and radiological parameters. Sample results were compared to the PA Act 2 MSCs.

Consistent between sampling events was the exceedance of the VOCs PCE and TCE along with the SVOCs (bis(2-ethylhexl)phthalate) and (bis(2-chloroethyl) ether). Antimony, lead, thallium, and zinc were reported to exceed their respective MSCs. There were no reported exceedances of PCBs, radionuclides, or explosive compounds during any of the five events.

3.2.6 Area I Interim Removal Actions, Cabrera Services, 2009-2013

A total of six IRAs were conducted by Cabrera between September 2009 and August 2013. Locations of the areas addressed during the six IRAs are presented on Figure 3-3. The purpose of the IRAs was to remove certain soil contamination and USTs remaining from historic DoD activities to allow for redevelopment of the site. Each IRA is summarized in the following subsections. Detailed descriptions can be found in the *Interim Removal Action Completion Report* (Cabrera, 2013), which is included in Appendix C. Results of these final soil removal activities have been used to determine current site conditions, as presented in Section 6.0. The cleanup criteria used were the TSCA residential high occupancy level for PCBs and the PADEP Act 2 non-residential standards for metals and VOCs/SVOCs.

The remedial action conducted during the 2009 IRA was performed relative to the cleanup standard established in the Area I EE/CA (Cabrera, 2009). As described in the EE/CA, the surface and subsurface soil cleanup standards for arsenic were 53 mg/kg and 150 mg/kg, respectively. Those cleanup standards were based on PADEP MSCs. However, PADEP issued revised statewide health standards during January, 2011 in the PA Bulletin (PADEP, 2011). The revised MSCs for arsenic were changed to 29 mg/kg for both surface and subsurface soil. USACE adopted the revised health standard for arsenic as the cleanup standard for subsequent IRAs. Based on this revision, some AOCs remediated for arsenic in 2009 contain arsenic concentrations in excess of the current arsenic standard.

The scope of work for the IRAs was limited to excavation of contaminated soil to the groundwater table. No excavation dewatering/water treatment activities were initiated, therefore, no additional soil removal was attempted once groundwater was reached. Any soil contamination remaining at depths below the groundwater table will be addressed during a subsequent Groundwater RI.

3.2.6.1 Area I Interim Removal Action, Cabrera Services, 2009-2010

The initial IRA encompassed soil removal at a total of 10 locations: Building 44/47 Tank Pit; Building 141 through 143; the Compound Area; Building 149; and AOCs 3 through 8. Four USTs that had previously been closed in place were also removed and disposed of off-site.

Building 44/47 Tank Pit

For the Building 44/47 Tank Pit excavation, a total of 15 confirmation soil samples (nine floor and six wall samples) were obtained for PCB and metals analysis. As shown on Figure 3-4, the analytical results for two floor samples (TP44-SO-07; 5.5 mg/kg and TP44-SO-08; 7.6 mg/kg) exceeded the TSCA PCB level (1.0 mg/kg) and one floor sample (TP44-SO-11; 1,810 mg/kg) exceeded the cleanup criteria for lead (450 mg/kg). These locations were below the water table

(12 to 15 feet bgs), therefore no further excavation was conducted. Analytical results for the remaining confirmation samples were below the PADEP cleanup standards.

Building 141 through 143

For the Building 141 through 143 (AOI/AOC 11) excavation, a total of 15 floor confirmation soil samples were obtained at a depth of 1.0 foot bgs for metals analysis. As shown on Figure 3-5, the analytical results were below the cleanup standards.

Compound Area

For the Compound Area excavation, a total of 16 confirmation soil samples obtained at 1.5 feet bgs (eight floor and eight wall samples) were obtained for metals analysis. As shown on Figure 3-6, the analytical results were below the cleanup standards.

Building 149

For the Building 149 (AOI/AOC 7) excavation, a total of eight confirmation soil samples obtained at 1.5 feet bgs (five floor and three wall samples) were obtained for metals analysis. As shown on Figure 3-7, the analytical results were below the cleanup standards.

AOI/AOCs 3 through 8

In the AOI/AOC 3 excavation, a total of 12 confirmation samples were obtained for VOC, SVOC and metals analysis at depths between six and 12 feet bgs (seven floor samples and five wall samples). All confirmation samples met the respective cleanup criteria, as shown on Figure 3-8.

In the AOI/AOC 4 excavation, a total of eight confirmation samples were obtained for PCBs and metals analysis at depth of two feet bgs (six floor samples and two wall samples). All confirmation samples met the respective cleanup criteria, as shown on Figure 3-9.

As shown on Figure 3-10, the analytical results for two floor samples in AOI/AOC 5 exceeded the cleanup criteria for lead (450 mg/kg); mercury (10 mg/kg) and chromium (190 mg/kg). Sample AOC5-SO-03 (4 ft bgs) contained lead at concentration of 770 mg/kg, and mercury at a concentration of 18.7 mg/kg. Chromium (235 mg/kg) was detected at a depth of six ft bgs in sample AOC5-SO-07. Due to the risk for undermining the building foundation, benching that had been used for construction excavation safety was left in place and the remaining soil contamination adjacent to the foundation was not removed.

In the AOI/AOC 6 excavation, a total of eight confirmation samples were obtained for PCBs and metals analysis at depths between two and eight feet bgs (five floor samples and three wall samples). All confirmation samples met the respective cleanup criteria, as shown on Figure 3-11.

In the AOI/AOC 7 excavation, a total of eight confirmation samples were obtained for VOC, SVOC and metals analysis at a depth of two feet bgs. All confirmation samples met the respective cleanup criteria, as shown on Figure 3-12.

In the AOI/AOC 8 excavation, a total of seven confirmation samples were obtained for PCBs and metals analysis at depths between two and four feet bgs. Two sample locations (AOC8-SO-02; 609 mg/kg and AOC8-SO-03c; 518 mg/kg) exceeded the cleanup criteria for lead at a depth of 3.0 feet bgs, as shown on Figure 3-13. All remaining samples were below the PADEP cleanup criteria or the TSCA PCB level. Due to the presence of concrete foundations, contamination could not be removed and was left in place.

Following confirmatory sampling, the excavations for each area were backfilled with tested-clean, off-site fill. In total, 726 cubic yards of PCB-contaminated soil and 1,648 cubic yards of hazardous and non-hazardous waste soil were excavated and transported to licensed landfills.

3.2.6.2 Area I Interim Removal Action, Cabrera Services, May-June 2012

The IRA conducted between May 2012 and June 2012 encompassed soil removal within the footprint of the following four locations: Building 47; Building 58; Building 128 Transformer Pad; and Building 231.

Building 47

For the Building 47 AOI/AOC 1 and 2) excavation, a total of 114 floor confirmation soil samples were obtained for VOC analysis. As shown on Figures 3-14 and 3-15, the analytical results for eight samples exceeded the cleanup criteria for VOCs (500 mg/kg) at depths of 1.0 to 4.0 feet bgs. These contaminated soil areas were subsequently addressed during the October 2012 mobilization (Section 3.2.6.3). The remaining 106 soil samples were below the cleanup criteria.

Building 58

A total of 34 floor confirmation soil samples were obtained for PCB, metals and/or VOC analysis in the Building 58 (AOI/AOC 14) excavation, as shown on Figure 3-16. The 10 VOC samples were obtained at a depth of 5-10 feet bgs. The six metals samples were obtained at a depth of 3 feet bgs and the 18 PCB samples were obtained at a depth of 1.0 foot bgs.

Analytical results indicated that confirmation samples for VOCs and metals were below the respective cleanup criteria. Five PCB samples exceeded the TSCA PCB level and were further addressed in the October 2012 mobilization (Section 3.2.6.3).

Building 128 Transformer Pad

A total of four floor confirmation soil samples were obtained at a depth of 1.0 foot bgs and analyzed for PCBs. As shown on Figure 3-17, the analytical results were below the TSCA PCB level.

Building 231

For the Building 231 (AOI/AOC 12) excavation, a total of eight floor soil confirmation samples (Figure 3-18) were obtained between three and five ft bgs and analyzed for VOCs, PCBs and metals. All VOC and SVOC constituents were either reported as a non-detect or at concentrations below the cleanup criteria. No PCBs were detected in the confirmation samples. Four samples contained antimony, lead, and/or mercury at concentrations exceeding the cleanup criteria. These contaminated soil areas were subsequently addressed during the October 2012 mobilization (Section 3.2.6.3)

In total, 1,484 cubic yards of hazardous and non-hazardous waste soil were excavated and transported to licensed landfills during the May-June 2012 IRA.

3.2.6.3 Area I Interim Removal Action, Cabrera Services, October 2012 to January 2013

The IRA conducted between October 2012 and January 2013 encompassed soil removal within the footprint of the following three locations: Building 47; Building 58 (AOI/AOC 14); and Building 231 (AOI/AOC 12). An oil-water separator adjacent to Building 47 was removed and soil beneath the structure was excavated. Three USTs at Building 48 were also addressed.

Building 47

A total of 17 floor confirmation soil samples (Figure 3-19) were obtained from the excavation at depth of three to six feet bgs. The samples were analyzed for VOCs. All confirmation sample results were below the cleanup criteria.

Building 47 Oil-Water Separator

Once the oil-water separator structure and surrounding soils were removed, confirmation soil sampling was conducted for each wall and the floor of the excavation and analyzed for VOCs and PCBs. A total of 40 samples were collected (20 floor and 20 wall samples), as shown on Figure 3-20. All confirmation sample VOC and PCB results were non-detect.

Building 58

A total of 13 floor confirmation soil samples (Figure 3-21) were obtained from the excavation at depth of seven to eight feet bgs. The samples were analyzed for PCBs and metals. Two confirmation samples (58-CS-47-P-8; 4-4 mg/kg and 58-CS-38-P-8; 1.4 mg/kg) exceeded the TSCA PCB level and one sample exceeded the cleanup criteria for arsenic (58-CS-48-P-8; 32.8 mg/kg). All exceedance locations were beneath the water table (8.0 feet bgs), and, therefore, no further excavation was performed. Analytical results for the remaining locations were reported as non-detect.

Building 231

A total of 24 floor soil confirmation samples (Figure 3-22) were obtained from the Building 231 excavation. All samples were located below the water table (7.0 feet bgs). Seven of the confirmation samples exceeded the cleanup criteria for either lead or mercury. Lead concentrations ranged from 887 mg/kg to 1,060 mg/kg, while mercury concentrations ranged from 11.1 mg/kg to 34.9 mg/kg. Due to the presence of groundwater, no further excavation was performed.

Building 48 USTs

Three USTs were removed from the Building 48 area and disposed of off-site. Six floor confirmation soil samples were collected at a depth of 1.0 foot bgs in the footprint of each UST for a total of 18 samples, a shown on Figure 3-23. All soil samples were analyzed for VOCs and SVOCs. Analytical results were reported as non-detect.

During remediation of the Building 48 USTs, an unknown UST was discovered. As waste characterization sample results did not indicate the presence of contamination, further responsibility for the UST was transferred to the property owner.

In total, 88 cubic yards of PCB-contaminated soil and 2,051 cubic yards of hazardous and non-hazardous waste soil were excavated and transported to licensed landfills.

3.2.6.4 Area I Interim Removal Action, Cabrera Services, February 2013

The IRA conducted in February 2013 encompassed the remediation of a leaking sump discovered in the Building 58 area.

After removal of the sump structure and the excavation of underlying contaminated soil 18 confirmation soil samples were collected (eleven wall samples and seven floor samples), as shown in Figure 3-24. The samples were analyzed to verify the removal of soil contamination above the cleanup levels for VOCS, SVOCs and PCBs. Fifteen of the 18 samples exceeded the cleanup criteria for TCE while 10 samples exceeded the TSCA PCB level. This contamination was subsequently addressed in the May 2013 mobilization. The remaining three confirmation wall samples were below the cleanup criteria.

3.2.6.5 Area I Interim Removal Action, Cabrera Services, May 2013 to June 2013

The IRA conducted between May and June 2013 encompassed follow-on remediation of the Building 58 leaking sump.

After excavating contaminated soil from the Building 58 sump, soil confirmation samples were collected from the walls and floor of the excavation and were analyzed to verify the removal of soil contamination above the cleanup levels for VOCs, SVOCs and the TSCA PCB level. Seven of 29 floor confirmation samples exceeded the cleanup criteria for VOCs and SVOCs and the TSCA PCB level, as shown on Figure 3-25. PCB concentrations ranged from 1.1 mg/kg to 3.9 mg/kg while TCE concentrations ranged from 4,400 µg/kg to 145,000 µg/kg. Sample location 58EM-CS-17-P12 also contains PCE at a concentration of 805 µg/kg and methylene chloride at a concentration of 1,390 µg/kg.

No further excavation was performed as all sample locations were beneath the water table (12 feet bgs). Two of the 26 wall locations, exceeded the cleanup criteria for TCE (west wall) and PCBs (east wall) (See Figure 3-26). The west wall TCE exceedance was subsequently addressed during the August 2013 mobilization.

In total, 27 cubic yards of PCB-contaminated soil and 1,161 cubic yards of hazardous waste soil were excavated and transported to licensed landfills during the May and June 2013 IRA.

3.2.6.6 Area I Interim Removal Action, Cabrera Services, August 2013

The August 2013 mobilization was a follow-on mobilization to continue remediation activities at the Building 58 leaking sump, as the confirmation samples obtained in June 2013 did not meet the PADEP MSC for TCE.

The August excavation overlapped the elevated TCE sample location and proceeded westward. Ten confirmatory samples were obtained; four from the floor (depth of 12 ft bgs) and six from the walls of the excavation (see Figures 3-25 and 3-27). All confirmation samples from the floor of the excavation were obtained from below the water table (12 feet bgs). The confirmation samples were analyzed for VOCs, SVOCs and PCBs. All sample results were below the respective cleanup criteria or TSCA PCB level.

A total of 136 cubic yards of material was removed from the Building 58 sump excavation during the August 2013 mobilization and shipped off-site.

4.0 INVESTIGATION METHODS

The primary objective of the 2007 SSI and 2008 Data Gap Investigation was to refine the estimate of the extent of soil contamination at 10 of the 16 AOIs identified by the previous investigations and included AOIs 1 through 10. In order to achieve this objective, the following activities were performed:

- Utility clearance was conducted in the ten AOIs, using a combination of the Pennsylvania One-Call system, geophysical surveys, and comparison of the AOIs with the utility diagrams provided by representatives of the site owner.
- MEC avoidance support was provided by a qualified technician during the intrusive activities.
- Soil boring stations were identified by placing a grid pattern in the AOIs. Sampling began at the center of the AOI and proceeded outward to determine the horizontal extent of contamination. All borings were terminated at the water table.
- Soil sampling was conducted using direct push technology (DPT) to collect continuous soil scores from surface to the water table.
- An onsite Gas Chromatograph lab was used to analyze for VOCs and PCBs. This real time analytical data was used to help delineate the horizontal and vertical extent of contamination in each AOI. Field duplicates were collected at the rate of 10% and MS/MSD were collected at the rate of 5% and sent to an off-site laboratory to verify the onsite lab data. The off-site lab also performed waste characterization analysis for the determination of the disposition of investigation derived wastes.

4.1 Methodology

Procedures for MEC avoidance, utility avoidance, DPT advancement, equipment decontamination, and investigative-derived waste handling were performed in accordance with the procedures outlined in the *Final Site-Wide Investigation Work Management Plan* (Cabrera, 2005a). Field operations were documented using the procedures documented in Cabrera SOP No. 059. Both sampling methodologies and analytical methodologies that were used during Langan 2005 RI, 2007 SSI and 2008 data gap site investigations were also utilized for six interim removal actions.

4.1.1 Soil Borings

The following is a summary of the procedure that was used to collect soil samples with the DPT rig:

- Move the rig to a sampling station. Station locations were identified in the work plans based on either 15-foot or 10-foot grids, depending on the size of the AOI.
- Insert a new dedicated acetate liner into the DPT coring tube.

- Scan the location with a magnetic locator for utility and anomaly avoidance (if the location is covered with reinforced concrete, scan the location after coring through the reinforced concrete). Scan the bottom of the boring with a magnetic locator prior to each push.
- Advance the coring tube two ft with a hydraulic hammer.
- Remove the coring device from the borehole using the DPT jacking system.
- Remove the acetate liner from the coring tube.
- Place the acetate liner on a flat surface covered with polyethylene sheeting.
- Slice open the acetate liner with a pre-cleaned utility knife.
- Scan the sample with a Geiger-Mueller (GM) detector and with a PID.
- Describe the core by logging soil textures according to the Unified Soil Classification System.
- Containerize samples for analytical testing.

Discrete samples were preferentially selected from sample intervals exhibiting PID or GM readings and/or having visual staining. In order to reduce the loss of VOCs due to volatilization, VOC samples were collected first using sub-core (e.g., EnCore®) samplers. The remaining sub-samples for SVOC or PCB analysis were placed into decontaminated stainless steel bowls, homogenized, and placed into new factory-pre-cleaned sample containers. The sample identification number, sampling depth, GM radiological survey result, and PID results were noted on a field logging form.

Boreholes were abandoned following sample collection by tremie-grouting, starting from the bottom of the borehole. A Portland cement/bentonite grout mixture was used. The filled borings were inspected between 24 hours and 72 hours after filling to check for grout settlement and were re-filled to grade if necessary.

4.1.2 Decontamination Methods

Reusable equipment was decontaminated based on the type of sampling being conducted, in accordance with the *Final Site-Wide Investigation Work Management Plan* (Cabrera, 2005a) and the *Field Sampling Plan Addendum* (Cabrera, 2008). In general, equipment decontamination activities consisted of the following steps:

- Remove the visible dirt/debris or sample residue from sampling equipment.
- Wipe sampling equipment with dry towel.
- Decontaminate with distilled water, nitric acid, Alconox®, isopropyl alcohol, and air dry.
- Perform a radiation contamination check using a GM meter.

Following decontamination all reusable sampling items (e.g., stainless steel bowls and trowels) were wrapped in aluminum foil to prevent cross-contamination.

4.1.3 Sample Analysis

Onsite Lab

Onsite analysis was performed for VOCs and PCB compounds using a gas chromatograph lab. VOCs were analyzed using USEPA Method SW 8260C. PCB analysis was performed using USEPA Method SW 8082. Results were of EPA Level 3 data quality. In most cases, results were available within one hour of sampling. See Section 6 for discussion of other sampling and results.

Off-Site Lab

Selected soil samples were submitted to the off-site laboratory for the purpose of quality assurance, for comparison with the results from the onsite laboratory, and for analysis of SVOCs, metals, explosives, and radiological constituents. In accordance with the Field Sampling Plan, these quality assurance samples were submitted at a rate of 10% and analyzed for Target Analyte List metals via USEPA Method 6010 and USEPA Method 7471 (mercury). Organics were analyzed using USEPA Methods SW 8260B (VOCs) and SW 8270C (SVOCs). PCB analysis was performed using USEPA Method SW 8082. Radiological analysis was performed using Gamma Spectroscopy (USEPA Method SW 901.0/901.1). Explosives compounds were analyzed using USEPA Method SW 8270C. All results were of EPA Level 4 data quality.

Quality Assurance/Quality Control (QA/QC) samples including field duplicate samples, matrix spike/matrix spike duplicate (MS/MSD) samples, and USACE QA laboratory confirmation split samples were also analyzed in an off-site laboratory. Laboratory analytical results are presented in Appendix D. Analyses performed for this project were consistent with the *Final Site-Wide Quality Assurance Project Plan* (Cabrera, 2005b).

4.1.4 Surveying of Sampling Stations

The locations of borings were surveyed by Cabrera personnel using a Trimble® GeoExplorer 3000 series (also called GeoXH) global positioning system. The GeoXH handheld uses EVEREST multipath rejection technology as well as H-Star technology to provide subfoot (30 cm) accuracy using the internal Antenna. The coordinate system used was: NAD 1983 – State Plane - Pennsylvania South FIPS 3702 (Feet).

4.1.5 Investigation Derived Waste

Investigation derived waste (IDW) was handled as specified in the Site-Wide FSP Addendum (Cabrera 2008) and Cabrera SOP No. OP-036. Aqueous IDW and soil cuttings were characterized for disposition. Constituent concentrations of both soil and aqueous IDW were below the most-conservative PADEP medium-specific concentrations and were, therefore, discarded onsite, in accordance with PADEP regulations. Aqueous IDW was released to a soil surface and prevented from flowing to a storm drain. Soil cuttings were dispersed in an open field on the site.

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5.0 DATA QUALITY ASSESSMENT

The culmination of the field and laboratory data of soil obtained during 1999 through 2013 form the basis for the evaluation of the nature and extent of soil contamination in Area I. The Data Quality Objectives (DQO) process (for the USACE investigations) and data quality assessments are summarized in this section.

5.1 Data Review, Data Compilation, and Data Sufficiency

Analytical results from the investigations conducted by Langan and Cabrera (1999 to 2013) were combined into one statistical population or dataset for the determination of the nature and extent of soil contamination at Area I (Note: laboratory analytical reports for the Langan investigations of 1999 and 2005 are presented in Appendix E).

Prior to combining the datasets, the 1999-2005 data was evaluated for quality. The USACE did not receive the complete Langan data package from the Site owner; however, they did receive three laboratory analysis reports for the Langan investigation. Hardcopy data from those reports were utilized to provide complete results for use in the data quality evaluation. The hard copy sampling results included information such as sample identification, date of sampling, analytical methods, analyte name, results, and laboratory qualifiers. A comparison was performed of the Langan sampling events to the 2007-2008 site investigations. The results of this comparison indicated that the sample preparation and sample analytical methods used during Langan investigations were the same as those used in the Cabrera investigations. The Langan data package did not include the limits of quantitation; therefore, no evaluation could be performed to satisfy measurement quality objectives of sensitivity. However, most of the sampling results for the Langan sampling events were non-detect, and in most cases, the detection limits were comparable with respect to the detection limits obtained during Cabrera investigations (within a factor of 2). In addition, the reporting limits are less than corresponding PADEP MSCs. Both investigations utilized similar field sampling methodologies to collect the samples.

Data quality assessments were performed for sampling results collected as a part of the 2007 SSI, 2008 RI, and the six IRAs conducted between 2009 and 2013. The results of the assessments, which are presented in Appendix F, indicate that the overall data quality meets the established project objectives. The assessment demonstrated that the sampling results produced during the SSI are technically defensible and are of known and acceptable sensitivity, precision, and accuracy. Therefore, the sampling results collected during recent site investigations and the previous Langan investigations were combined into a single population for Area I soil. The combined dataset was then utilized to determine the nature and extent of elevated constituents present in Area I soil.

5.1.1 QA/QC Samples

QA/QC samples for the 2007 SSI data, 2008 Data Gap Investigation data and the IRAs (including field duplicate samples, MS/MSD samples, and USACE QA laboratory confirmation split samples) were collected at a rate of one per 20 field samples for each matrix. An analysis of data precision was conducted in order to qualify the analytical data generated in the laboratory. This analysis is presented in Appendix F. Precision was determined through the use of positive duplicate pair responses. The analytical precision met the project goal of ensuring that more than 90% of the samples presented in Table 2 of Appendix F were within the project’s acceptable criterion for RPD (the RPD criteria was 50%).

5.2 Selection of Site-Specific Soil Screening Limits

5.2.1 Site-Specific Soil Screening Limits for RCOPCs

The surface soil screening values in Table 6.91 of the *Residual Radioactive Contamination from Decommissioning,* NUREG/CR 5512, Volume 3, were selected as the site-specific soil screening values for radionuclides (NRC 1999). Table 6.91 screening level derived using Pcrit=0.10 were selected for comparison. The concentrations for radiological constituents were compared with those surface soil screening values to determine the existence of radiological contamination present at Area I of the FFA.

5.2.2 Site-Specific Soil Screening Limits for Chemical Constituents

As discussed in Section 1.2, USACE is seeking to address the contamination at the Site using PADEP Act 2 MSC standards. Area I is zoned as industrial; therefore, the site-specific soil screening levels for chemical constituents are based on the guidelines provided in the corresponding PADEP Act 2 non-residential MSC standards.

PADEP has developed different sets of MSCs, which must be applied depending on the potential exposure pathways that are anticipated. For Area I the potential MSCs are:

- Non-Residential, Used-Aquifer, Soil-to-Groundwater Pathway, 100x Groundwater Value;
- Non-Residential, Used-Aquifer, Soil-to-Groundwater Pathway, Generic Value;
- Non-Residential, Direct-Contact, Surface Soil (zero to two ft) Value; and
- Non-Residential, Direct-Contact, Subsurface Soil (two to 15 ft) Value.

Two steps were performed to select the soil MSCs. During this RI/RA, both surface and subsurface soil MSCs were determined. They are summarized below:

- Step 1: Selection of Soil-to-Groundwater MSCs - The soil-to-groundwater value was determined by selecting the greater of the two Soil-to-Groundwater numeric values (100x Groundwater or Generic).
- Step 2: Selection of Soil MSCs - The selected Soil-to-Groundwater MSC for each analyte was compared to its Direct Contact value for surface soil or subsurface soil to determine the surface and/or subsurface soil MSC for each chemical constituent present at Area I. The lower of the Soil-to-Groundwater MSC or Direct Contact value was selected as the MSC (PADEP, 1998).

Table 5-1 presents the surface and subsurface soil MSCs for metals, VOCs, SVOCs, PCBs, and explosive compounds. The PADEP surface and subsurface soil MSCs for PCBs are 130 and 1,900 mg/kg, respectively. However, USACE is following the Federal TSCA “high occupancy” standards for PCB contamination. The TSCA level contained in 40 CFR 761.61 establishes a soil cleanup goal of 1.0 mg/kg for PCB mixtures in high occupancy areas. This level was selected as the site-specific soil screening value for PCBs in Area I. These screening values were utilized to determine areas of contaminated soil by comparing the screening levels to the analytical results.

6.0 NATURE AND EXTENT OF CONTAMINATION

Post-remediation soil analysis results and the residual soil concentrations from the most recent investigations conducted by Langan and Cabrera (1999 to 2013) were compared against the site-specific soil screening limits to determine the nature and extent of contamination in Area I soil. Tables 6-1 through 6-4 present the constituent concentrations that exceed their respective PADEP MSCs or the TSCA high occupancy level for PCBs for those sample locations remaining following completion of the six IRAs. Section 6.1 presents a summary of remaining constituents by AOC based on previous investigation results, while Section 6.2 presents a summary of the horizontal and vertical extent of contamination across Area I.

As discussed in Section 3.2.6, the MSC for arsenic was modified by PADEP after 2009. Therefore, the 2009 IRA remediation was performed relative to the standard in place at the time (arsenic MSC of 53 mg/kg surface soil/150 mg/kg subsurface soil). Some AOCs that were remediated for arsenic in 2009 contain arsenic concentrations in excess of the current standard of 29 mg/kg for both surface and subsurface soil. As this IRA/RA utilizes the current arsenic standard, these residual arsenic locations from 2009 are discussed within Sections 6.1.1 and 6.2 and depicted on Figure 6-1, even though they are not presented in Section 3.2.6.1 and associated Section 3 figures,

As presented in Section 3.2.6, the scope of work for the IRAs was limited to excavation of contaminated soil to the groundwater table. No excavation dewatering/water treatment activities were initiated, therefore, no additional soil removal was attempted once groundwater was reached. Any soil contamination remaining at depths below the groundwater table will be addressed during a subsequent Groundwater RI.

6.1 Previous Investigation Results

6.1.1 Metals

Metal contamination, primarily lead and mercury, remains at depth in AOI/AOCs 5 through 9, AOI/AOC 13, Building 44/47 Tank Pit and in the footprints of the former Buildings 58 (AOC 14), Building 231 (AOI/AOC 12), Building 238, and at the southeast corner of Area I as shown in Figure 6-1. Locations of the individual AOCs are presented on Figure 3-2.

In AOI/AOC 5, concentrations of lead and mercury in excess of the MSCs remain at a depth of four ft bgs in the location of sample AOC5-SO-03. Lead was reported at a concentration of 770 mg/kg, (MSC of 450 mg/kg), and mercury was reported at a concentration of 18.7 mg/kg (MSC of 10 mg/kg). Chromium (235 mg/kg) and arsenic (34 mg/kg) are also present at a depth of six ft bgs in sample AOC5-SO-07. Due to the use of benching for construction safety purposes, the contamination could not be removed and was left in-place.

In AOI/AOC 6 there were two sample locations that exceeded the MSC of arsenic (29 mg/kg). Sample location AOC6-SO-04 and AOC6-SO-06 had concentrations of 72.5 and 45.4 mg/kg, respectively. Both samples were collected at a depth of two ft bgs and at the time of sampling, were compared to the 2009 subsurface arsenic MSC of 150 mg/kg.

Within AOI/AOC 7, arsenic remains at a depth of two ft at location B149-SO-01 with a concentration of 48 mg/kg. As with the arsenic concentrations remaining at AOC 6, AOC 7 was remediated with respect to the higher 2009 arsenic MSC standard.

Arsenic contamination remains at the Compound Area and Buildings 141 through 143 (AOI/AOC 11) at three near surface locations. These locations include B142A-SO-10 (29 mg/kg at 1.0 ft bgs), B143-SO-14 (43.1 mg/kg at 1 ft bgs), and CMP1-SO-03 (31.6 mg/kg at 2 ft bgs). This area was also remediated in 2009 when the arsenic MSC was higher than the current standard.

In AOI/AOC 8, lead remains at a depth of three ft bgs. In the location of sample AOC8-SO-02, lead was reported at a concentration of 609 mg/kg. Due to the concrete grade beam on the eastern half of the excavation, the vertical extent of excavation could not be expanded further. In the location of sample AOC8-SO-03c, lead and arsenic contamination remains at concentrations of 518 mg/kg and 55.7 mg/kg, respectively. Due to the presence of concrete foundations, contamination could not be removed and was left in place. In sample AOC8-SO-07d, arsenic remains at a concentration of 30.9 mg/kg. At the time of remediation of AOC 8, arsenic contamination was compared to a higher MSC than is currently utilized.

To the southeast of AOC 8 at Building 238, arsenic remains at the surface soil sample location, 238-SS-1 with a concentration of 32 mg/kg. In AOC 9, arsenic remains at two locations, AC09-SB-02-B-P-01 (45 mg/kg) at a depth of 1.0 ft bgs and 301-STP-5 (63 mg/kg). At the time of the AOC 9 investigation, arsenic contamination was compared to a higher MSC than is currently utilized.

At the southeast corner of Area I, two locations associated with AOI/AOC 10 and AOI/AOC 15 have arsenic, chromium, and lead at concentrations exceeding their respective MSCs. Sample STP-10A (nine ft bgs) arsenic remains at concentration of 30 mg/kg, chromium remains at 227 mg/kg, and lead at 544 mg/kg. At sample location STP-11A (seven ft bgs) concentrations of arsenic (34 mg/kg), chromium (210 mg/kg), and lead (786 mg/kg) remain. These locations are below the groundwater table; therefore no additional investigative actions were taken.

Lead remains in one location at a depth of 14-15 ft bgs within the Building 44/47 Tank Pit Area. In this location (sample TP44-SO-11), lead was reported at a concentration of 1,810 mg/kg. Groundwater was encountered at depth within the excavation, precluding further excavation.

In the Building 58 footprint (AOC 14), arsenic remains at a depth of eight ft bgs at a concentration of 32.8 mg/kg (sample location 58-CS-48-P-8). The MSC for arsenic is 29 mg/kg. As the depth of excavation in the area of this sample was at groundwater, no further soil remediation was undertaken.

At seven locations within the Building 231 footprint (AOI/AOC 12), lead and mercury remain at a depth of seven ft bgs, as follows:

- 231-CS-5-P7 (mercury 18.1 mg/kg)
- 231-CS-6-P7 (lead, 1,060 mg/kg)
- 231-CS-11-P7 (mercury, 30.5 mg/kg)
- 231-CS-12-P7 (mercury, 34.9 mg/kg)
- 231-CS-13-P7 (lead, 887 mg/kg; mercury, 11.1 mg/kg)
- 231-CS-16-P7 (lead, 978 mg/kg)
- 231-CS-18-P7 (mercury, 20.2 mg/kg)

Because groundwater was encountered in the excavation at the seven-ft depth, no further remediation was conducted.

Arsenic and chromium remain at concentration of 60 mg/kg and 284 mg/kg, respectively in one location in AOC 13 (S131-TP-25) at a depth of 9.5 to 10 ft bgs. This location is below the groundwater table; therefore no additional investigative actions were taken.

6.1.2 VOCs

Volatile organic compounds, primarily TCE, remain in AOI/AOCs 9, 10, 13, 14, 15 and 16, and at the Building 58 leaking sump, as presented in Table 6-2 and shown on Figure 6-2.

In AOI/AOC 10, soil concentrations exceeding the MSCs for benzene and TCE were detected in three locations. The concentrations for TCE range from 1,200 µg/kg (five ft bgs) in sample AC10SB10 to 2,800 µg/kg (four ft bgs) in sample AC10SB08, while benzene was reported at a concentration of 3,930 µg/kg at a two ft depth (sample W19-MW003). Carbon tetrachloride was also detected in sample W19-MW003 at a concentration of 795 µg/kg which exceeded its MSC of 500 µg/kg. These locations are below the groundwater table; therefore no additional investigative actions were taken.

In AOI/AOC 13, PCE exceeding the MSC of 500 µg/kg was detected in two surface soil sample locations (126-SS-101 and 125-SS-1) with concentrations of 700 µg/kg and 12,000 µg/kg. At the Building 58 leaking sump, the concentrations of TCE at a depth of 12 ft bgs ranged from 4,400 µg/kg to 145,000 µg/kg in floor excavation sample locations 58EM-CS-19-P12, 58EM-CS-18-P12 and 58 EM-CS-17-P12. Sample location 58EM-CS-17-P12 also contains PCE at a concentration of 805 µg/kg and methylene chloride at a concentration of 1,390 µg/kg at a depth of 12 ft bgs. Due to the presence of groundwater within the excavation, no further remediation was undertaken. Sample FillSB3 (AOI 15) contains TCE at a depth of 6 ft bgs (710 µg/kg). This location is below the groundwater table; therefore no additional investigative actions were taken.

Two samples collected from AOI/AOC 16, 46-SB-16 (zero to two ft bgs) and S46-TP-22 (8.5 to nine ft bgs) exceed the TCE MSC with concentrations of 3,180 and 640 µg/kg, respectively. These locations are below the groundwater table; therefore no additional investigative actions were taken.

6.1.3 SVOCs

Semi-volatile organic compounds remain at depth within AOI/AOC 9, as shown in Figure 6-2. One constituent, benzo(a)pyrene exceeded the MSC of 11,000 µg/kg in one surface soil sample (0.5 ft) (AC09-SB02-B-P-01) with a concentration of 11,400 µg/kg. Based upon the initial risk assessment performed with 2008 Data Gap samples, there was no unacceptable risk associated with remaining AOC 9 soil contamination.

6.1.4 Polychlorinated Biphenyls

Concentrations of PCBs above the TSCA level of 1.0 mg/kg remain in the areas of Tank Pit 44/47, AOI/AOCs 8, 9, 13, and14, the Building 58 footprint (AOI/AOC 14), and the Building 58 leaking sump, as shown on Figure 6-3.

In AOI/AOC 9, one location (AC09-SB02-B-P-01) contains PCB 1260 at a concentration of 3.01 mg/kg at a depth of 1.5 ft.

Two sample locations within the Tank Pit 44/47 area (TP44-SO-07 and TP44-SO-08) had PCB 1248 concentrations of 5.5 and 7.6 mg/kg, respectively. The area had been excavated to a depth of 15 ft bgs, upon which groundwater was encountered, concluding further excavation.

Tw0e sample locations in the Building 58 footprint (AOI/AOC 14) contained PCBs at a concentration of 1.4 mg/kg and 4.4 mg/kg (samples 58-CS-P-8 and 58-CS-47-p-8, respectively). As the depth of excavation in the area (8 ft bgs) was at groundwater, no further soil remediation was undertaken.

Four locations at the Building 58 leaking sump contain PCBs at a depth of 12 ft bgs, with concentrations ranging from 1.1 mg/kg to 3.60 mg/kg (excavation floor sample locations 58EM-CS-26-P12, 58EM-CS-18-P12, 58EM-CS-12-P12 and 58EM-CS-17-P12). Two of these PCB locations have collocated VOC contamination (58EM-CS-17-P12 and 58EM-CS-18-P12). Due to the presence of groundwater within the excavation, no further remediation was undertaken. A fifth sample location, 58EM CS –E05, was obtained as an excavation wall sample and contained PCBs at a concentration of 3.9 mg/kg.

Ownership of the PCB transformers transferred to the site owner, who used then after FFA was decommissioned. Both the transformers and buildings became the responsibility of the subsequent site owner, who was responsible for their management and remediation/disposition.

6.1.5 Explosives

The explosive compound 2,4-Dinitrotoluene (2,4-DNT) exceeded the MSC of 840 μg/kg in AOI/AOC 15. At a depth of 6 ft bgs, sample FillSB-3 contains a concentration of 8,500 μg/kg. As 2,4-DNT was analyzed via the analytical method for SVOCs (and reported within the SVOC dataset), the impacted sample locations and associated sample concentrations are shown on Figure 6-2 as a subset of SVOC concentrations**.** This location is below the groundwater table; therefore no additional investigative actions were taken.

6.2 Horizontal and Vertical Extent of Contamination

The horizontal and vertical extent of contamination was assessed based upon the investigation results presented in Section 6.1 and is described in the following subsections.

6.2.1 Metals

Of the twenty-six locations exhibiting metals contamination, twelve are isolated samples unrelated to each other. The remaining locations are clustered in four distinct areas: the Building 231 footprint (AOI/AOC 12), and AOI/AOCs 5, 6 and 8. A discussion of the full confirmation sampling effort and analytical results for these areas is presented in Sections 3.2.6.1 and Figures 3-10, 3-11 and 3-13 (for AOI/AOCs 5,6 and 8) and in Section 3.2.6.3 and Figure 3-22 for Building 231.

Of the nine remaining lead locations, six are at depths of 7 ft bgs or greater with concentrations between 549 mg/kg and 1,810 mg/kg. With the exception of one nine-ft sample (STP-10A) in the southeastern portion of Area I, the deeper locations are below the water table. Three of these locations are within the Building 231 footprint (AOI/AOC 12); one is within the TP-44 footprint (see Section 3.2.61 and Figure 3-4 for confirmation sampling results), and one in STP-11A. Three sample locations in the center of Area I (in AOI/AOC 5 and AOI/AOC 8) contain lead at a shallower depth (three ft bgs) with concentrations ranging between 518 mg/kg and 770 mg/kg.

Lead is also collocated with arsenic, chromium and/or mercury in five locations (Figure 6-1). The TP 47 area has been backfilled and re-paved.

Of the 16 remaining arsenic locations, ten are at depths of three ft bgs or less and six are at depths of six ft to 10 ft bgs. Locations with shallower depths of contamination include two locations each within AOI/AOCs 6 and 8, AOC 9, CMP 1 (AOI/AOC 11) and the footprints of Building 238, Buildings 142A, 143 and 149 AOI/AOCs 7 and 11). Deeper depths of contamination remain in AOI/AOC 5, S131, 301-STP-05, STP-10A and STP-11A, and the footprint of Building 58 (AOI/AOC 14). The Building 58 arsenic sample (58-CS-48-P-8) is located below the water table. Contamination levels in both depth ranges are similar: shallower depths range from 29 mg/kg to 72.5 mg/kg, while the deeper contamination ranges from 34 mg/kg to 63 mg/kg.

It should be noted that many of the remaining arsenic locations were part of the 2009 IRA effort which was conducted prior to the PADEP revision of the arsenic MSCs from 53 mg/kg surface/150 mg.kg subsurface to 29 mg/kg surface/subsurface. These locations have been backfilled and in some cases (i.e., AOC 6) have been re-paved.

Chromium remains at four locations (AOI/AOC 5, S131, STP-10A and STP-11A) with depths between six ft and 10 ft bgs and concentrations of 210 mg/kg to 284 mg/kg. In all locations, chromium is collocated with arsenic, and two locations with lead (STP-10A and STP-11A).

Mercury remains at six locations. Five of the six are at a depth of seven ft bgs (concentrations of 11.1 mg/kg to 3,439 mg/kg) and centered in the Building 231 footprint (AOI/AOC 12). These samples are beneath the water table. The remaining sample is located at a depth of four ft bgs with a concentration of 18.7 mg/kg (AOC5-SO-03).

6.2.2 VOCs

The horizontal extent of VOC contamination is confined to four distinct areas. Two exceedances are contained within the Building 46 footprint (AOI/AOC 16). Another two exceedances are located adjacent to Building 125 (AOI/AOC 13). The Building 58 leaking sump footprint contains three locations, while the remaining four VOC exceedances are situated to the eastern side of Area I, in AOI/AOC 10 and adjacent to Building 322. These last two locations are isolated and unrelated to the other areas of VOC contamination. A discussion of the full confirmation sampling effort and analytical results for the Building 58 leaking sump is presented in Section 3.2.6 and Figure 3-27.

There are eight remaining TCE locations at depths from surface to 12 ft bgs**.** Soil concentrations range from 640 µg/kg to 145,000 µg/kg. Three locations, including the maximum concentration sample, are located beneath the water table in the Building 58 leaking sump.

Remaining PCE contamination is restricted to three locations: two surface soil locations within AOI/AOC 13 (700 µg/kg and 12,000 µg/kg) and at 12 ft bgs in the Building 58 leaking sump area. This deep sample location (805 µg/kg) is beneath the water table. Due to the presence of groundwater within the excavation, no further remediation could be undertaken

Benzene contamination is restricted to one location in AOI/AOC 10 at a depth of two ft bgs (3,930 µg/kg). Carbon tetrachloride at 795 µg/kg was also collocated with benzene in sample W19-MW-003 (AOI/AOC 10).

6.2.3 SVOCs

The extent of SVOC contamination is limited to two isolated and unrelated locations (one each in AOI/AOC 9 and AOI/AOC 15) at depths of 0.5 ft bgs and six ft bgs, respectively.

6.2.4 Polychlorinated Biphenyls

The majority of the horizontal extent of PCB contamination is contained within the footprint of Building 58 (AOI/AOC 14) and the adjacent Building 58 leaking sump (seven of 10 locations). Another two locations are adjacent to each other in the Tank Pit 44/47 area. A single, isolated PCB exceedance is located in AOI/AOC 9. Figure 6-3 presents the distribution of PCB contamination across the site. A discussion of the full confirmation sampling effort and analytical results for Building 58 and the leaking sump is presented in Sections 3.2.6.3 and 3.2.6.5 and Figures 3-21 and 3-26. Section 3.2.6.1 and Figure 3-4 presents confirmation sampling results for the Tank Pit 44/47 area.

Eight of the PCB locations are between eight ft and 15 ft bgs and are beneath the water table. Concentrations range from 1.2 mg/kg to 7.6 mg/kg. One location is at surface to 1.0 ft bgs, with a concentration of 3.01 mg/kg (AC09-SB02-B-P-01). One composite location remains in the Building 58 leaking sump footprint with a concentration of 3.9 mg/kg.

7.0 CONSTITUENT FATE AND TRANSPORT

This section provides a qualitative discussion of: the chemical and physical properties of site constituents; potential sources and fate and transport of constituents identified in Area I soil; mechanisms of constituents transport in air, groundwater, surface water, and sediment and the fate of the Site constituents. This section is not intended to describe the fate and transport of each individual constituent that exceeded the soil screening values. Instead, the discussion is focused on those constituents and classes of compounds that were most frequently detected above soil screening values. These constituents include metals, VOCs and SVOCs, and PCBs.

7.1 Physical Setting

The FFA is located in the Coastal Plain physiographic province. The Site is underlain by 9 to 15 ft of fill materials on top of approximately 21 ft of gravelly sand. These unconsolidated deposits overlie the Wissahickon Formation, a mica-schist with about three ft of weathering at the soil-bedrock interface.

The topography of the Site is flat, with a very gentle slope to the south and southeast towards Frankford Creek and the Delaware River. Storm water in Area I is controlled by a combined storm-sewer system owned and operated by the City of Philadelphia.

Groundwater, at four to 12 ft bgs, is unconfined, and flows from northwest to south-southeast. There appears to be a groundwater trough in the middle of FFA, probably due to the presence of paleochannel deposits; this feature appears to be aligned with the groundwater flow direction. The hydraulic gradient ranges from 0.001 to 0.003 ft/ft, inducing an estimated flow velocity of 0.28 to 0.84 ft per day (ft/day) (Langan, 2005).

7.2 Constituent Chemical and Physical Properties

Chemical and physical properties of constituents affect their fate and transport through and among environmental media. The general chemical characteristics of a variety of constituents are summarized from published sources (USEPA 1979, Dragun 1988, Knox et al. 1993).

Mobility and persistence in the environment are two key terms used to describe the movement and partitioning of chemicals in the environment media (air, surface water, groundwater, soil, and sediment). Mobility is the potential for a chemical to migrate through a medium and persistence is a measure of how long a constituent will remain in the environment. Several physicochemical properties are typically used to predict the mobility and persistence of constituents in media. Principal properties that influence the mobility and persistence include water solubility, vapor pressure, and carbon/water partition coefficient.

7.2.1 Water Solubility

Water solubility is the maximum concentration of a chemical that can dissolve in pure water at a given temperature and pH. Water solubility is a critical property affecting the environmental transport of a chemical. Highly soluble chemicals can be rapidly leached from contaminated soil and are generally mobile in groundwater. Chemicals that are not readily soluble in water have a tendency to adsorb to soils. The pure metal forms of the COPCs arsenic, chromium, lead and mercury have comparatively low solubilities at the circum-neutral pH found at the site. The VOC COPCs have relatively high water solubilities, in the range of 1.3 grams per liter (g/L) for benzene and 1 x 10^{-1} g/L for PCE. The single SVOC COPC is benzo(a)pyrene, which has a low solubility of 1.1x 10^{-4} g/L (USEPA, 2013). The PCB Aroclor 1260 also has very low solubility (in the range of 3 x 10^{-7} g/L).

7.2.2 Vapor Pressure / Henry's Law Constant

The VOC and SVOC COPCs can be sorbed to soil, dissolved in the soil pore water, and present in the soil air spaces. Two properties of organic compounds can be used to estimate the degree to which the compound occurs in the gas state: vapor pressure and Henry's Law Constant. Vapor pressure is defined as the pressure of the vapor of a compound in equilibrium with its liquid phase. Vapor pressure tends to increase as temperature increases. Compounds with higher vapor pressures are more volatile than compounds with low vapor pressures. Henry's Law constant expresses the amount of chemical partitioning that can occur between air and water at equilibrium (USEPA 1993). Generally, the greater the Henry's Law constant, the more volatile a compound, and the more easily it can be removed from solution.

The vapor pressure of the VOC COPCs is fairly high; for instance benzene vapor pressure is 95 millimeters (mm) mercury, and the vapor pressure of carbon tetrachloride is 100 mm mercury, compared to the vapor pressure of water, which is 18 mm mercury. Aroclor 1260 has extremely low vapor pressure of 1.30 x 10^{-7} mm mercury. The vapor pressure of the SVOC COPC benzo(a)pyrene is even lower at 10 x 10^{-10} mm mercury.

The Henry's law constant for carbon tetrachloride is 2 x 10^{-2} atmospheres-cubic meter/moles (atm-m^3/mol), which means it readily transfers from aqueous phase to gas phase. Tetrachloroethene and TCE also have comparatively high Henry's Law Constants of 1.6 x 10^{-2} and 2.3 x 10^{-2} atm-m^3/mol, respectively. Benzo(a)pyrene and Aroclor 1260 have very low Henry's Law Constants.

The combination of solubility and Henry's Law Constants indicates that for the VOC COPCs, migration in aqueous phase and transfer from aqueous phase to gas phase are tenable migration routes, while for the SVOC COPC benzo(a)pyrene and for Aroclor 1260 these would not be important routes of migration.

7.2.3 Carbon/Water Partition Coefficient (Koc)

The fate and transport of constituents in soil are influenced by two processes that tend to bind the constituents to the soil: adsorption and fixation. Adsorption is the process whereby dissolved ions are removed from the liquid phase and become chemically attached to the surfaces of soil particles. Positively charged metals (cations) are adsorbed to balance the negative surface charges on soil and organic matter particles. The cation exchange capacity (CEC) of the soil, the presence and relative quantity of other cations, and various other factors affect adsorption rates. The CEC of a soil is greatly influenced by the surface area of the soil particles, since ions are exchanged on the exposed mineral surfaces. Clay particles generally consists of a larger surface area, compared to sand grains, and can exchange cations within their layered structures to a greater or lesser degree depending on the clay species present. The CEC of a typical clay-rich soil may be two to 30 times higher than the CEC of a typical sandy soil (Dragun, 1988). Therefore, a soil with a high clay content can be expected to attenuate dissolved ions during transport more readily than a clay-free soil through the process of cation exchange.

Sorption processes are less complicated for organic constituents. The affinity of a chemical for sorption on natural organic matter is expressed by its carbon/water partition coefficient (K_{oc}). A high K_{oc} indicates the compound is more likely to become fixed to organic matter within the soil matrix. Chemicals with low K_{oc} values (less than 10 milliliters per gram) are found mainly in the water phase. The amount of naturally occurring organic carbon present in a soil affects the adsorption of organic compounds in that soil. The greater the organic carbon content in the soil, the more likely it is that the organic compounds migrating through the soil will become adsorbed by the organic component of the soil. Soils with increased organic matter content generally have a higher CEC. The organic material in the soil may also sorb certain metals by other solutes through complexation reactions and cation exchange. Typically, organic matter constitutes less than 5% of a particular soil.

The carbon-water partition coefficient for carbon tetrachloride is 1.78 (log soil organic carbon-water partitioning coefficient [K_{oc}]), for benzene is 1.85, for TCE is 2.0, and for PCE is 2.37, in order of increasing affinity for soil organic matter. The log K_{oc} for Aroclor 1260 is 5.2 and for benzo(a)pyrene is 6.0 (USEPA, 2013). The K_{oc} values for Aroclor 1260 and benzo(a)pyrene indicate that they will be strongly sorbed to soil organic matter, thus reducing their mobility (USEPA, 2013 and USGS, 2006). Sorption processes are expected to be more pronounced at the southeastern part of the site (the 300-series buildings) where fine-grained soils predominate.

7.2.4 Persistence

Persistence is a measure of how long a chemical will exist in air, water, or soil. Phase transfer and chemical or biological degradation are major forms of removal and transformation processes. Persistence is expressed as a half-life ($t^{1/2}$), generally in days. A $t^{1/2}$ is the period of time during which half of a given number of atoms of a specific constituent decay. After one $t^{1/2}$, half of the original amount of the constituent will remain.

Degradation can occur by both chemical and biological processes. Chemical degradation can occur through such processes as hydrolysis and photolysis. Hydrolysis occurs when a water molecule (or hydroxide ion) substitutes for another atom or group of atoms present in organic compounds. Because water is plentiful in most soils, hydrolysis is an important reaction. In this reaction, a functional group from the organic molecule is exchanged with a hydroxyl functional group from the water. One example of this reaction is the hydrolysis of chlorinated compounds, which often yields an alcohol or an alkene. This reaction is significant because typically chlorinated compounds are not readily biodegraded.

Photolysis is the degradation of dissolved organic compounds by sunlight. Light is absorbed by the compound, resulting in a chemical reaction involving molecular rearrangement, dissociation, or oxidation of the energized molecules. Indirect photolysis occurs when an organic compound reacts with other previously energized molecules, rather than directly with solar radiation. Generally, compounds in the subsurface are not significantly affected by photolysis until released into the atmosphere.

Biological degradation is the breakdown of organic compounds through biological processes. Biodegradation can occur through processes such as bioaccumulation, biotransformation, or biodegradation. Biodegradation occurs most readily among organic compounds, with VOCs typically being more biodegradable than SVOCs. An example of biodegradation is the reduction of chlorinated organic compounds, which may be consumed by aerobic and anaerobic bacteria as food sources. Biodegradation may occur aerobically and/or anaerobically, depending upon the molecular structure of the chemical and the environmental conditions. Chemicals that may be completely, but slowly, degradable can be persistent in the environment over long periods of time.

Rates of degradation are available in literature but vary greatly according to the nature and conditions of the experiments used to obtain the data. Other environmental factors that may affect the mobility and persistence of constituents include pH, concentration of other constituents in the media, soil moisture, oxidation/reduction potential, water chemistry, organic-matter content, and the presence and types of microorganisms in the subsurface.

Inorganic constituents may undergo chemical species transformation that affects the mobility of the constituents in the environment. For metals, the natural attenuation processes are dilution and sorption. Dilution may occur by dispersion of dissolved constituents in water percolating through the soil column or in groundwater. Sorption generally includes the processes of adsorption, co-precipitation, precipitation, and diffusion into the soil matrix. These are processes by which solutes become associated with the immobile, solid phase. Sorption may be either reversible or slowly reversible. Slowly reversible sorption of constituents from solid phases exposed to uncontaminated groundwater may also contribute to dilution of the constituents. The extent of dilution is determined by the rate of constituent release into solution relative to the velocity of water flow.

Most organic constituents interact with the soil and do not move at the same rate that water does through the soil matrix. This phenomenon is referred to as retardation. Retardation is the dynamic process of adsorption to and desorption from soil materials and is specific to individual chemical compounds. In general, if a compound is strongly adsorbed, it is highly retarded. Biochemical reactions (in addition to retardation) have a major effect on the fate and transport of organic compounds.

Most of the COPCs are persistent in the environment, including the four metals arsenic, chromium, lead and mercury, the SVOC benzo(a)pyrene, and the PCB Aroclor 1260 (USEPA, 2013). The chlorinated VOC COPCs carbon tetrachloride, PCE, and TCE are also persistent in the environment. The remaining VOC COPC benzene is not considered to be persistent in the environment due primarily to its biodegradability (USGS, 2006).

7.3 Constituent Source Areas

The FFA has an extensive history of use (from 1816 to 1976) focusing on research, development, and production of ammunition. The Site has undergone many investigations and several removal efforts have been undertaken, as discussed in Section 3.0. Source areas are identified by elevated constituent concentrations beneath buildings and storage areas and attenuation of constituent levels with increasing distance from the source areas. As a result of previous environmental cleanup programs, several source areas, including drains, sumps, and pits, have been remediated. The following section of the report summarizes the source areas of the classes of constituents that remain.

7.3.1 Metals

Arsenic was detected at several locations in Area I surface and subsurface soils. Based on soil-texture descriptions and locations of the samples it is evident that the arsenic is associated with clinker and ash that was used as fill material. Coal ash was observed as surface fill around the 140-series buildings, the 120-series buildings and Building 301. There was both a steam generation plant and a manufactured gas plant that were coal-fired, in the vicinity of Building 120. Soil textures at those locations consist mainly of sand to silty sand with varying amounts of debris (wood, concrete, coal). Adjacent to Building 231 soil texture consists of a dark gray silty sand. Soil boring logs are provided in Appendix A.

The presence of lead in Area I is most likely attributable to the production of lead styphnate and also the production and testing of bullets. Buildings in the 300-series included powder magazines, trinitrotoluene (TNT) storage, and a small-arms firing range. Lead styphnate would have been associated with powder and TNT, because it was the primary charge to set off secondary explosives such as TNT. Heavy metal residues within buildings (lead, chromium, and mercury) were primarily associated with lead-based paints, plating and metallurgical laboratory operations conducted at the FFA. Building 231 was used as a foundry and has lead and mercury COPCs in soil beneath the building footprint.

7.3.2 VOCs and SVOCs

Probable leaks and/or spills from a tank field of 10 ASTs and several USTs are the most likely sources of VOCs and SVOCs exceedances at the Site. According to the Phase I Environmental Site Assessment report (PSI 1996) and Remedial Action Decision Document (USATHAMA, 1988), the demolition and construction debris from various buildings were placed around AOC 10 (approximately 160 to 250 ft east of Building 308) prior to their final disposal to offsite landfills. Detections of benzene, TCE and carbon tetrachloride could be a result that temporary storage. Tetrachloroethene and TCE are common solvents and were used extensively at the FFA. Detections in the soil at Buildings 45/46, 58, 125/126 are most likely the result of spills or leaks.

There are several remaining exceedances for TCE, PCE, and methylene chloride beneath the southeast corner of Building 58 at a depth of 12 feet bgs. Building 58 was an artillery casing machine shop that had sumps, buried tanks and a neutralization pit (Rockwell, 1977). The solvents are probably present due to degreasing operations. There are exceedances for PCE in surface soil near Building 125, which was a sheet metal shop (Rockwell, 1977). Vapor degreasing was commonly used to clean sheet metals during fabrication. Vapor degreasers of that era used PCE almost exclusively so the PCE is probably due to spills from this equipment (USEPA, 1990b). The location of Building 46 has exceedances for TCE both in surface soil and subsurface soil. This building was an instrument shop and also contained a laboratory (Rockwell, 1977). Sumps and dip tanks were present, which indicates that degreasers were also used, which is the probable cause for the TCE releases.

The surface soil sampling result for only one SVOC, benzo(a)pyrene, exceeded its corresponding MSC at one location (AOC 9). It is most likely due to the presence of coal tar as a result of burning coal at Building 301. This location is just southeast of Building 301 Power Plant.

7.3.3 PCBs

PCBs have been used as coolants and lubricants in transformers, capacitors, and other electrical equipment because they are not readily ignitable and are good insulators. The manufacture of PCBs was banned in the U.S. in 1977. The remaining detections of PCBs are all of Aroclor 1260, which was formerly used in electrical transformers, hydraulic fluids, plasticizer in synthetic resins and dedusting agents (ATSDR, 2001). The PCB exceedances near Buildings 44 and 58 are most likely due to leaking transformers formerly located near these buildings. All of these detections are at depths of 12 to 15 feet bgs. There is one additional exceedance in AOC 9 in surface soil, whose provenance is unknown.

7.3.4 Nitro Aromatics

The nitro aromatics that were detected in the soil are most likely a result of manufacturing of small arms munitions, the storage, supplying and maintenance of munitions, and the use of FFA as the national center for the development of cartridges and propellants devices. The source area for the nitro aromatics detected in soil may be associated with surface runoff and/or flooding.

Among nitro compounds, 2,4-DNT was detected above its MSC value. The exceedance of 2,4-DNT is most likely the result of landfilling in that area. Boring log for FillSB3 indicates a layer of slag fill at six feet below ground surface. The boring was located near former Building 322, which was used as a storage shed (Rockwell, 1977).

7.4 Mechanisms of Constituent Transport

There are a number of mechanisms by which constituents may migrate from contaminated areas to onsite and off-site receptors. Precipitation infiltration can leach residual constituents from vadose zone soil to groundwater. Migration of constituents from surface soil to air can occur via fugitive dust emissions and vaporization. Organic chemical vapors can migrate laterally through the soil via permeable zones or along man-made conduits such as buried utility lines. Surface water runoff or groundwater discharge can lead to contamination of surface water bodies. The potential for site constituents to migrate from soil to other media via these mechanisms is evaluated in the following subsections.

7.4.1 Migration into Air

Transport of constituents from surface soil to air can occur via dust generation or volatilization. Constituents adsorbed to surface soils may be released to the atmosphere as particles transported by near-surface winds in the form of airborne contaminated dust. Soil particles containing constituents may be eroded from areas containing little vegetative cover and transported to areas downwind of these sites.

Volatilization is defined as the transfer of matter from a liquid phase to a gaseous phase. A common example of volatilization is the evaporation of water. Constituents within the groundwater or in the soil may volatilize with the vapors moving into the aerated pore spaces in the soil or directly to the atmosphere. The tendency of a compound to transfer to the gas phase is determined by its vapor pressure. Vapor pressure is defined as the pressure of the vapor of a compound in equilibrium with its liquid phase. Vapor pressure tends to increase as temperature increases. Compounds with higher vapor pressures are more volatile than compounds with low vapor pressures. The constituents associated with this type of release mechanism are VOCs.

VOCs are chemicals with high vapor pressures facilitating their rapid transition from a liquid state to a gaseous state at normal ambient temperatures.

Fugitive dust emissions with organic and inorganic particulates could occur from soil that are not paved or covered with vegetation. Because the soil surface at Area I is predominantly paved, the potential for the constituents in surface soil to be released to air via fugitive dust emission is significantly minimized.

There are PCE exceedances in surface soil near Building 125 (see Figure 6-2), which could continue to volatilize and impact air quality. Additionally, there are chlorinated solvents in subsurface soil at the former locations of Buildings 46, 58 and 125 which can volatilize into soil gas and be transported through the vadose zone, only to be redeposited in the subsurface after rain events (Imbrogiotta et.al., 1997).

7.4.2 Migration to Groundwater

Surface and subsurface soil contamination at the Site potentially serve as sources of groundwater contamination. The most important soil properties that affect the transport of constituents through the soil into the groundwater include infiltration capacity (i.e., permeability), CEC, and organic carbon content.

Infiltration capacity is a measure of the rate at which soil material can absorb precipitation. Soil permeability is a measure of the ability of soil to permit gas or liquid to pass through. Both properties are based largely upon the texture and structure of the soil material. In general, coarse-grained soils like sand and gravel will transmit water more readily than fine-grained soils such as silt or clay. CEC and organic carbon content, are chemical characteristics that can affect constituent migration by chemically interacting with dissolved constituents as they percolate through the soil.

Percolation of precipitation through the unsaturated, contaminated soil can dissolve certain constituents, transporting them to the underlying groundwater. The rates of migration by this process vary greatly for different constituents, depending upon the rate of transfer between the soil and water and the amount of precipitation. Chemicals that are the most susceptible to leaching to groundwater are those with high water solubility and low K_{oc} values. Constituent migration through the unsaturated zone to the water table generally reduces the soil leachate concentration through processes such as adsorption (adhesion to the surfaces of soil particles) and degradation. Groundwater transport in the saturated zone further reduces concentrations through attenuation (reduction in concentration through sorption, degradation, and dilution).

Precipitation falling on the Site may run off and accumulate as surface water, return to the atmosphere through evaporation or through plant uptake and evapotranspiration, or may also infiltrate the soil, where it can remain fixed in the (unsaturated) vadose zone soils or percolate to the water table. The mean annual precipitation at the FFA is approximately 41 inches. Runoff and an evapotranspiration rates are not currently known, but are expected to change as the site is redeveloped and the amount of impervious cover and vegetation is altered. However, the soils present at the Site are characterized pale or reddish-brown, gravelly sand and inter-bedded clayey-silt layers. In general, soil textures are coarse- and medium- sands in the northern part of the site, with increasing amounts fine sands and silts toward the south. The Site soil types are considered permeable. The future amount of impermeable soil cover will affect migration rates of COPCs to the groundwater. This is particularly true for the metal- and VOC- COPCs and much less so for the SVOC and PCB COPCs.

Solutes dissolved in groundwater can undergo several processes that remove them from the groundwater. These processes include sorption to the aquifer materials, sorption to organic carbon present within the aquifer, biodegradation, oxidation-reduction reactions, and chemical precipitation. The sorption processes tend to slow the movement of a constituent through the groundwater. The other processes can reduce the concentration of the solute in groundwater but may not slow its movement within the groundwater.

Site soil was not specifically analyzed for CEC or organic carbon. However, inferences can be made based on information reported by the USGS (USGS, 1991). The surface and subsurface soils contain relatively low clay content. Therefore, these soils have less potential to attract and chemically adsorb the positively charged ions found in metal complexes, such as lead complexes. Because of the presence of fine-grained, organic-rich fill materials in the soil in the southern part of the site, contaminants are expected to exhibit little or no migration in this area.

7.4.3 Groundwater to Indoor Air Pathway

Vapor intrusion into basements depends on the volatility of the constituents, soil type, and building construction details. The Act 2 Statewide Health Standards outline the evaluation of potential vapor intrusion pathway(s) for organic contamination in soils and groundwater (PADEP, Document 253-0300-100, 2004a). The Johnson and Ettinger (J&E) Vapor Intrusion Model predicts indoor (basement) air concentrations of organic pollutants in the subsurface, using analytical results for VOCs from soil samples collected between the surface and five ft bgs. These predicted concentrations are then compared to actual measurements to calibrate the model. Then the predicted concentrations are compared to the non-residential indoor air MSCs to estimate risk. Results from samples deeper than five ft are directly compared to the Act 2 propagated non-residential PA default volatilization to indoor air screening criteria for soils.

The Langan 2005 report evaluated the analytical results from the 1999 and 2005 investigations using the J&E model and the Act 2 non-residential default indoor air screening MSCs. Based on this evaluation, chloroform and TCE concentrations in several surface soil samples exceeded their respective non-residential indoor air MSCs of 5.3 microgram per cubic meter ($\mu g/m^3$) and 48 $\mu g/m^3$, respectively. These sample locations have since been remediated. All of the VOC compounds remaining at depths are below groundwater will be considered during the groundwater RI. One surface location, 046-SB-016, does contain TCE in excess of its MSC.

7.4.4 Migration into Surface Water and Sediment

Transport mechanisms that could potentially lead to migration of contaminants in soil to surface water and sediment are surface runoff, groundwater discharge, and flooding. The degree and direction of surface runoff is determined mainly by the surface topography and the relative proximity of nearby receiving surface waters. Surface water runoff from precipitation can erode soil from contaminated areas and carry dissolved and suspended contaminants to local surface water features.

There are no wetlands, streams, or other surface watercourses located on the FFA property proper. Regional drainage surrounding the FFA is controlled by the Frankford Creek and the Delaware River, which border the FFA to the south/southeast. Surface water at the FFA site is controlled by a system of catch basins and storm water pipes. The storm water is conveyed by this system to a pumping or "lift station" located adjacent to the creek. The storm water is discharged to Frankford Creek at this point. Frankford Creek flows in a southwesterly direction towards its confluence with Delaware River. Frankford Creek forms the boundary to the south/southwest of the FFA and ultimately discharges into the Delaware River. Tacony Creek is located approximately 7,000 ft west of the FFA and flows in a southerly direction towards its confluence with the Delaware River.

One of the most significant exposure routes associated with the surface and groundwater pathways is use of these media as potable sources. To assess these pathways, Cabrera conducted a search of federal, State, and municipal records to determine if there were any supply wells or surface water intakes within 0.5 miles of FFA. Records from the PA Geological Survey, the PA Groundwater Information System, the Delaware River Basin Commission, the Philadelphia Department of Public Works (PDPH) and the Philadelphia Water Department (PWD) were reviewed for information about water wells and intakes within 0.5 miles of the Site. Thirty-seven wells were identified, 23 of which were labeled as destroyed or no longer in use. Twelve wells, belonging to Rohm & Hass, are monitoring wells. One well is owned by Allied Chemicals and is used for industrial purposes. Another, owned by Krometal Manufacturing, Inc. located at 5825 Tacony Street, approximately 2,000 ft northeast and hydraulically cross gradient of the Site, is used for industrial processes. PWD confirmed that there were no surface or groundwater intakes within 0.5 miles of the Site. The groundwater RI will more fully address this pathway.

It is possible that site runoff could have deposited contamination at the outfalls of sewer lines and storm drains. No site-specific sampling results are available to address the surface water runoff from contaminated areas to local surface water bodies. The Langan 2005 report evaluated the impact of theoretical discharge of impacted site groundwater to Frankford Creek through permeable sewer trench backfill materials using Pennsylvania's Single Discharge Wasteload Allocation Model for Toxic Substances, Version 2.0.

7.4.5 Migration into Groundwater from Surface Water Pathways

Groundwater at the Site discharges to Frankford Creek and the Delaware River. A future analysis of this pathway during the Groundwater RI will include an evaluation of the fate and transport of the constituents, and a determination of the constituent concentrations that reach surface waters.

7.4.6 Vapor Intrusion Screening Process

Residual VOCs and SVOCs were screened for potential impacts to indoor air quality. The remaining SVOC was in sample AC09-SB02-B-P-01, which contained benzo(a)pyrene. There are 12 locations where there are residual VOC concentrations in soil exceeding MSCs. These locations were evaluated for their potential for VOC migration into future buildings that are being planned by the site owner. The evaluation was performed using PADEP guidance provided in the *Land Recycling Program Technical Guidance Manual- Section IV.A.4. Vapor Intrusion into Buildings from Groundwater and Soil* under the Act 2 Statewide Health Standard (PADEP, 2004a). The guidance takes the form of decision matrices and is applicable when the Statewide Health standards (in other words, the MSCs) are used. The objective of the guidance is to evaluate a whether a completed vapor intrusion exposure pathway exists to future receptors.

The Soil Indoor Air Quality Decision Matrix for the PADEP Statewide health standard is shown in Figure 7-1. The first step in the vapor intrusion screening process for FFA Area I was to determine whether the soil contamination was within 100 feet of a building. Figure 7-2 presents the locations of residual VOC and SVOC contamination in soil with respect to the planned building locations.

The following sample locations were more than 100 feet from planned building locations and were excluded from further consideration:

- 046-SB-016
- 58EM-CS-17P-12
- 58EM-CS-19P-12
- 58-CS-18P-12
- 125-SS-101
- 126-SS-101
- AC09-SB02-B-P-01
- FillSB-3

Sample AC09-SB02-B-P-01 contained the remaining SVOC concentration exceeding the MSC; therefore all remaining samples evaluated in the screening process contained VOCs. The following sample locations were within 100 feet of a planned building location and were considered further:

- S46-TP-22
- AC10SB08
- AC10SB10
- W19-MW-003

The second step was to consider whether preferential pathways exist that could allow VOCs to more easily migrate into buildings. There are no known existing or planned subsurface structures in Area I that would allow preferential migration of VOCs.

The third step was to consider whether the VOC contaminant was present as separate phase liquid (SPL). This was not the case, although it must be noted that SPL (as waste oil) was noted in the past at the location of W19-MW-003. The VOCs detected in the area of W19-MW-003 were benzene and carbon tetrachloride, which are not components of waste oil.

Upon completion of the three evaluations presented above, an assessment was made to determine if chemicals of potential indoor air concern (COPIACs) were present. A COPIAC is a compound that has a USEPA indoor screening value that is less than the appropriate PADEP MSC. VOC compounds are present as TCE, benzene and carbon tetrachloride in the four locations that passed the initial screening. Of these compounds, only carbon tetrachloride was considered a COPIAC as it was detected at W19-MW-003 in concentrations exceeding both PADEP and USEPA screening values.

Non-COPIAC VOC concentrations were then evaluated to determine if they were less than the Soil Screening Values for Protection of Indoor Air and whether the contamination was greater than or equal to five feet in depth. For the Area I non-COPIAC VOC concentrations, none met both criteria.

The last step was to determine whether the appropriate J&E screening level was met and whether the contamination was greater than or equal to five feet in depth. Samples AC10SB10 (1,200 ug/kg of TCE at five feet) and S46-TP-22 (640 ug/kg TCE at depth 8.5 feet) passed both the depth criteria and the concentration screening level of 2,200 ug/kg TCE.

In summary, four sample locations are within 100 feet of a planned building: S46-TP-22, AC10SB08, AC10SB10, and W19-MW-003. Of these locations, two failed further concentration- and depth-related- screenings; sample AC10SB08 (TCE at 4 feet bgs) and sample W19-MW-003 (carbon tetrachloride at 795 ug/kg and benzene at 3,930 ug/kg at two ft bgs). Sample W19-MW-003 was collected from a very shallow depth and lies approximately 80 feet from the planned building location, making this location an unlikely source for indoor air quality concerns. The remaining sample that failed initial screening was AC10SB08-BP-04, which is within 20 feet of a building footprint. This sample was collected from the 4.5-5.0 foot depth interval and had a TCE concentration of 2,800 ug/kg. Groundwater sampled from nearby well location MW-03 did not contain detectable TCE concentrations. Another sample collected from 1 ft bgs did not contain detectable TCE concentrations. Finally, the TCE concentration at AC10SB08-BP-04 is slightly above the PADEP screening value of 2,200 ug/kg, which is based on a carcinogenic risk level of 1 x 10-5. If the 1 x 10-4 CERCLA risk threshold were applied to this individual sample, then the sample result would not pose an unacceptable risk. For these reasons, this individual sample exceedance is not considered significant, and does not warrant additional evaluation.

7.5 Fate of Site Constituents

The site constituents include metals, SVOCs (including nitro aromatics), VOCs, and PCBs. The fate of these constituents is discussed in this section. The constituents have been grouped together according to similar physical and chemical properties because their fate would also be expected to be similar. Radionuclides are not considered to be constituents of concern at the FFA because their concentrations are consistent with background levels. Additionally, the NRC determined in 2003 that there was no indication of radioactive contamination remaining and released the FFA for unrestricted use.

7.5.1 Metals

Eight sampling results for only one metal (arsenic) exceeded its corresponding MSCs in surface soil. Six of those sample locations were located adjacent to Buildings 128, 141-143, 149, and 150, which are proximate to each other. The metal concentrations for the subsurface samples collected from the same locations did not exceed the appropriate MSCs. The metal concentrations for the subsurface samples collected from the same locations did not exceed the MSCs. The source for the surface soil arsenic exceedances is most likely due to the use of ash and clinker as fill material, which was identified in these areas during the IRA (Katrinak, et.al., 1994, Dahl, et.al., 2008, Popescu, et.al., 2013).

Inorganics tend to be adsorbed to fine-grain soil particles. As a result, fugitive dust emissions could be the important transport mechanism of these constituents from surface soil to the atmosphere. The PADEP MSC values incorporate an evaluation of inhalation risks related to fugitive dust emissions. It is likely that this process occurs at higher rates during dry weather and windy conditions. Future commercial development will likely cover surface soil with buildings, concrete and asphalt, and landscaping.

A number of subsurface soil sampling results for four metals (arsenic, chromium, lead and mercury) exceeded their corresponding MSCs. Most of those samples are located 7 ft bgs. This contamination most likely occurred from unregulated discharged through floor drains and subsequent leakage of underground piping during operations at the electroplating and metallurgical laboratories

If the COPC metals migrate to groundwater, they will be influenced by physical properties, in addition to the flow of the aquifer. Dispersion and adsorption continue to affect the migration rates. The greater the degree of dispersion, the lower the concentration is along the centerline of the migrating plume and the more broadly the constituents are distributed. The higher the degree of adsorption; the slower the rate of metal migration, because metal migration is retarded by the exchange process.

7.5.2 VOCs and SVOCs

Several soil sampling results for TCE, PCE, carbon tetrachloride, and benzene exceeded their corresponding MSCs. However, among those four VOCs, the concentrations of TCE exceeded in a number of locations. VOCs have relatively high vapor pressures and relatively low solubilities. Their properties allow them to move between water and air and be mobile and persistent in ground water (Bender et al., 1999). It is likely that these VOCs will leach from soils and migrate to groundwater, which will be the subject of a subsequent groundwater remedial investigation.

The soil sampling results for only one SVOC, benzo(a)pyrene, exceeded its MSC. Benzo(a)pyrene has low water solubility, low vapor pressure, and a low Henry's Law Constant. Benzo(a)pyrene tends to be adsorbed to fine-grain soil particles. The single exceeding sample was collected from AOC 9 at a depth of nine feet bgs. There are few available paths for migration for this SVOC.

The physical properties of benzo(a)pyrene indicate that it is non-reactive and not likely to significantly leach from soil in the environment. Benzo(a)pyrene has a high K_{oc} value and tends to be strongly adsorbed onto soils and suspended matter, especially those high in organic matter. Henry's Law constant and vapor pressure for benzo(a)pyrene are too low to volatilize into the atmosphere. In addition, because of its low aqueous solubility, it does not readily leach into the groundwater.

7.5.3 PCBs

The soil sampling results for Aroclor 1260, collected from various AOCs, exceeded the TSCA level of one mg/kg. PCBs released to soil will persist for relatively long periods and may become airborne through either slow evaporation or adsorption on dust particles. Aroclor 1260 can travel by attaching to dust particles, which can then be transported by the wind. It can also evaporate slowly from soil, but has very low vapor pressure. However, due to future plans to cover much of the site during commercial redevelopment, and the fact that the majority of the PCB exceedances are in subsurface soil, transport via airborne particulates is not considered to be significant and their release from soil to air will be limited. In addition, Aroclor 1260 has low water solubility and strong adsorption to soil, which makes leaching to groundwater unlikely. The Aroclor 1260, therefore, is inferred to remain in place and resist degradation.

7.5.4 Nitro Aromatics

The soil sampling results for 2,4-DNT exceeded the MSC at one sampling location at a depth of six feet bgs. Due to its depth of burial, the potential for release of 2,4-DNT from soil to air is considered to be insignificant. Nitro aromatic adsorption rates vary depending on the type of soil and sediment and the ionic strength of the surface and groundwater. Generally, nitro aromatics adsorb less than PCBs and metals. Nitro aromatics have a relatively high solubility and tend to be more stable in water and less likely to breakdown. The lower adsorption coefficients suggest nitro aromatics have a slight tendency to sorb to sediments, suspended solids, and biota, but are moderately mobile to highly mobile in soil.

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8.0 RISK ASSESSMENT

A risk assessment was performed to evaluate the potential health impacts to human and ecological receptors from exposure to chemical contamination present in soils within Area I of the FFA. A summary of both the human health and ecological risk assessments is provided in this Section.. As no surface water and sediment samples were collected from the Site, and groundwater beneath the Site is not currently utilized, groundwater, surface water, and sediment media were not evaluated as part of this RA. The soils Human Health Risk Assessment (HHRA) is included in its entirety in Appendix G, Baseline Risk Assessment.

Past operations at the FFA have resulted in releases of chemicals to environmental media that may pose risks to human and ecological receptors. The RA conducted as part of this site-wide RI is intended to provide an assessment of risks to human health and ecological receptors that will support the selection of a remedy to eliminate, reduce, or control those risks. Additional objectives of the HHRA include:

- estimate potential human health and ecological risks associated with the FFA if no active remedial actions are taken;
- Identify areas that pose no unacceptable risks to human health or the environment and, thus, require no further action; and
- Develop a list of COPCs that contribute to unacceptable risks to human health or the environment.

Results of the RI soil sampling program constitute the analytical data set that was evaluated in the HHRA. For the purposes of characterizing risk to the types of human receptors to be evaluated, soil sampling results were segregated into two data sets: 1) surface soil, and 2) surface plus subsurface soil. The soil sampling results for both surface and subsurface samples were pooled into one population, named “total soils.”

As discussed in Sections 3.2 and 6.0, soil contamination remains at depths below the water table in several areas. This contamination will be addressed during a subsequent Groundwater RI. A list of the areas and soil depths being deferred for risk evaluation under the Groundwater RI are:

- AOI/AOC 10; two to seven ft bgs
- AOC 13; 9.5 to 10 ft bgs.
- AOI 15; 6 ft bgs
- AOI/AOC 16, two to nine ft bgs)
- Building 44/47 Tank Pit Area; 14-15 ft bgs.
- Building 58 footprint (AOC 14); eight ft bgs.
- Building 58 leaking sump;12 ft bgs
- Building 231 footprint (AOI/AOC 12); seven ft bgs

8.1 Human Health Risk Assessment Summary

A HHRA was performed using guidelines established by the USEPA and the USACE. The objective of the HHRA was to provide an analysis of baseline human health risks that will be used to determine the need for remedial action at the Site. The risk assessment also provides a basis for determining the concentrations of chemical constituents that can remain onsite and still be protective of human health. In accordance with USEPA guidance, the HHRA was performed in four steps: identification of COPCs; exposure assessment; toxicity assessment; and risk characterization.

8.1.1 Identification of COPCs

COPCs differ from site constituents in that COPCs are a subset of the constituents that have been detected at the Site, which have gone through an extensive screening process and then retained for quantitative analysis in the HHRA. No distinction of original source is made in selecting the COPCs. Only soil sampling results related to the site constituents were evaluated to identify the COPCs for the entire site.

COPCs were identified through an extensive screening process that involved three different types of screens – elimination of essential nutrients, weight of evidence screen, and comparison to risk-based screening levels. No background screening was conducted because the constituents retained following the first three screens were all site-related, and their maximum detected concentrations were higher than their corresponding USEPA Regional Screening Level (RSL) table concentration values.

Elimination of Essential Nutrients

Essential nutrients (calcium, magnesium, potassium, and sodium) were screened from further consideration. Iron was also eliminated during this stage, as it is not considered a CERCLA hazardous substance and, therefore, would not be considered a COPC for the FFA.

Weight of Evidence

During the second screen, chemical constituents that were detected in less than 5% of the total soil samples were eliminated from consideration as COPC.

Risk-Based Screening

The USEPA regional screening levels (RSLs) table was considered as the screening criteria for soil (USEPA, May 2013). Chemical constituents that passed the first two screens were compared against the USEPA RSLs. For carcinogenic chemicals, the maximum detected concentration for any constituent was compared to its corresponding RSL value under the most conservative residential land use scenario, even though the Site is zoned as industrial. For non-carcinogenic chemicals, the maximum detected concentration of any constituent was compared to 1/10 of its corresponding residential soil RSL for screening purposes. If the maximum detected concentration for the chemical constituent was less than its corresponding carcinogenic and non-carcinogenic criteria, the chemical was not retained as a COPC. Table 8-1 presents a summary of the soils COPCs identified in the HHRA.

Table 8-1: Summary of Constituents of Potential Concern

COPC	Total Soils
METAL COPCs	
ALUMINUM	√
ANTIMONY	√
ARSENIC	√
CHROMIUM	√
COBALT	√
COPPER	√
LEAD	√
MANGANESE	√
MERCURY	√
VANADIUM	√
VOC COPCs	
BENZENE	√
CARBON TETRACHLORIDE	√
CHLOROFORM	√
TETRACHLOROETHENE	√
TRICHLOROETHENE	√
SVOC COPCs	
BENZO(A)ANTHRACENE	√
BENZO(A)PYRENE	√
BENZO(B)FLUORANTHENE	√
BENZO(K)FLUORANTHENE	√
CHRYSENE	√
DIBENZO(A,H)ANTHRACENE	√
INDENO(1,2,3-CD)PYRENE	√
NAPHTHALENE	√
PCB COPC	
AROCLOR 1254	√
AROCLOR 1260	√

8.1.2 Exposure Assessment

The objectives of the exposure assessment are to estimate the magnitude, frequency, duration and routes of potential human exposures to COPCs at the Site. The exposure assessment was performed in two steps: development of a CSM and quantification of exposure concentrations.

Conceptual Site Model

A CSM was developed to show the relationship among contaminant sources, contaminated soils, and the migration pathways from each source through the soil media for each receptor scenario identified. Four reasonable maximum exposure (RME) receptors were identified based upon the current industrial land use scenario: an industrial/commercial worker, a construction worker, a utility worker, and a maintenance worker. These receptors were assumed to come into contact with soils while working at the Site. The industrial/commercial worker scenario was considered as the only likely potential future RME scenario for the FFA. The intent of the RME scenario was to focus the assessment on a conservative exposure that represents the maximum exposure that is reasonably expected to occur (USEPA, 1989a,b).

Three exposure pathways – soil ingestion, dermal contact, and inhalation of VOCs – were considered for each RME scenario. It was assumed that all receptors may be exposed to both surface soil and subsurface soil.

Quantification of Exposure Concentrations

To calculate a cancer risk or a non-cancer hazard, an exposure point concentration (EPC) or an estimate must be made of the chemical concentration in the environmental medium to which an individual may be exposed. In order to quantify exposure to each receptor, an EPC was calculated for each COPC. An EPC is an estimation of the constituent concentration a receptor is likely to come in contact with over the duration of exposure. For the conservative approach used in evaluating the RME scenario, EPCs for soil were determined by calculating the 95% upper confidence limit (95% UCL) of the mean. The ProUCL program, version 4.1, was utilized to calculate the UCL. The 95% UCL was used as the EPC except in cases where the maximum detected value was less than the EPC. In these cases, the maximum detected value was used as the EPC, rather than the 95% UCL.

The EPC for each COPC, the exposure parameters for each RME receptor, and USEPA's standard equations were utilized during the derivation of intake for each COPC. Appendix G presents the equations used and the resulting calculated intakes.

The objectives of the exposure assessment are to estimate the magnitude, frequency, duration and routes of potential human exposures to COPCs at the Site. The exposure assessment was performed in two steps: development of a CSM and quantification of exposure concentrations.

8.1.3 Toxicity Assessment

The toxicity assessment results in the selection of toxicity values to use in generating estimates of potential health risks associated with chemical COPC exposure. The hierarchy for toxicological sources of information presented in USEPA's Office of Solid Waste and Emergency Response Directive 9285.7-53 (USEPA, 2003) was utilized to assign toxicity values for each COPC.

8.1.4 Risk Characterization

During the risk characterization step, the results of intake and toxicity information for each COPC were utilized to calculate both carcinogenic risk and non-carcinogenic hazards for each RME receptor. For carcinogens, incremental lifetime cancer risks (ILCR) were calculated. For non-carcinogenic chemicals, a hazard index (HI) was calculated for the non-carcinogens encountered for each pathway.

The resulting ILCRs were compared to the range specified in the NCP (USEPA, 1990) of 10^{-6} to 10^{-4}, or one in one million to one in 10,000 persons developing cancer. ILCRs below 10^{-6} are considered acceptable risks. ILCRs above 10^{-4} are considered unacceptable risks. Risks between

10^{-6} and 10^{-4} are generally referred to as the "acceptable risk range". An HI greater than one has been defined as the level of concern for potential adverse non-carcinogenic health effects (USEPA 1989a). If the total risk for a specified receptor and medium exceeds 1×10^{-4}, those individual COPCs with a risk greater than 1×10^{-6} were identified as carcinogenic major risk contributors for the FFA. If the total hazard for a specified receptor and medium exceeds one, those COPCs with a hazard quotient greater than 0.1 were identified as non-carcinogenic major risk contributors for the Site.

Table 8-2 presents a summary of the chemical risk assessment for the industrial/commercial worker, construction worker, utility worker, and maintenance worker scenarios. The results of the carcinogenic chemical risk assessments for both current and future receptor scenarios showed that the carcinogenic risks for all four receptors - industrial/commercial worker, construction worker, maintenance worker and utility worker did not exceed the CERCLA acceptable cancer risk range.

Table 8-2: Results of Chemical Risk Assessments

Receptor	Medium	Exposure Pathway	Carcinogenic Risk	Hazard Indices
Industrial Worker	Surface and Subsurface Soil	Ingestion	1E-05	7E--02
		Inhalation	2E-07	2E-03
		Dermal Contact	4E-06	9E-03
		Total	**1E-05**	**8E--02**
Construction Worker	Surface and Subsurface Soil	Ingestion	3E-06	5E-01
		Inhalation	6E-09	8E-03
		Dermal Contact	4E-07	3E-02
		Total	**3E-06**	**5E-01**
Maintenance Worker	Surface and Subsurface Soil	Ingestion	2E-06	1E-02
		Inhalation	2E-08	2E-04
		Dermal Contact	7E-07	2E-03
		Total	**3E-06**	**2E-02**
Utility Worker	Surface and Subsurface Soil	Ingestion	1E-07	2E-02
		Inhalation	2E-10	7E-05
		Dermal Contact	5E-08	3E-03
		Total	**2E-07**	**2E-02**

The results of the non-carcinogenic hazard assessment for both current and future receptor scenarios presented in the above table show that neither individual exposure pathways, nor the cumulative hazards summed across pathways demonstrates an HI greater than the de minimis level of concern, 1.0 (1E+00).

8.1.5 Lead

Although exposures to lead are known to cause adverse effects, neither a cancer slope factor (CSF) nor a reference does (RfD) has been developed. In addition, there may not be a true threshold for effects of lead. Since the chronic health effects associated with the lead exposure have been related to elevated blood lead levels, the risk evaluation performed for lead during this HHRA was based on calculation of the lead concentrations in the blood.

8.1.5.1 Risk Model

The USEPA *Adult Lead Model* (ALM) was selected for the estimation of blood lead levels of current and future receptors because of the current and future industrial land use of the Site (USEPA, 1999 and 2003). The USEPA ALM model was developed by the Technical Review Workgroup (TRW) to provide a consistent approach for evaluating long-term non-residential exposures to lead in soil. The ALM model predicts the blood lead concentrations in women of childbearing age, as well as for the most sensitive potential receptor - the fetus of a pregnant adult worker. If the predicted fetal blood lead concentration is above the USEPA threshold level of 10 microgram per deciliter (µg/dL), the risk is considered to be unacceptable. The ALM results also indicate the probability of blood lead concentrations exceeding the established 10 µg/dL threshold for an exposed population. If the ALM results show that greater than 5% of the exposed population group (fetuses of pregnant adult workers) has blood lead concentrations exceeding 10 µg/dL, USEPA considers this risk to also be unacceptable. These USEPA threshold levels (USEPA 1994) are derived to be protective for the most sensitive population (the developing fetus), which in turn will ensure protectiveness to older population groups.

8.1.5.2 Source Term and Exposure Parameters for Risk Model

The ALM model is designed to account for exposures that occur on a regular basis, and USEPA recommends the use of input variables and exposure parameters that represent central tendencies (USEPA, 2003). The central tendencies include the use of the arithmetic mean concentration of lead rather than the 95% UCL as the model input value for soil lead concentration (PbS).

To derive a PbS for the exposure scenarios evaluated, the arithmetic mean lead concentration was calculated. Calculations of the arithmetic mean for lead in surface plus subsurface soil was 112.6 mg/kg. The soil ingestion rate of 330 milligrams per day (mg/d) was used for the construction and maintenance worker. However, based on a Central Tendency Exposure (CTE) scenario, the soil ingestion rate for both workers was assigned 100 mg/d in the ALM model (USEPA, 1997). The exposure frequencies for each receptor were remained the same. However, due to the short exposure times associated with the maintenance worker and the utility worker scenarios, the ALM results are presented on a time-weighted average (TWA) basis also, in accordance with USEPA guidance (USEPA, 2003). The TWA evaluation assumes that the maintenance and utility worker may perform duties at the site once per week. Table 8-3 presented the assigned for four receptor scenarios identified in the BRA.

Table 8-3: Assigned Values for Exposure Parameters

Parameter	Units	Industrial / Commercial Worker	Construction Worker	Utility Worker	Maintenance Worker
Exposure frequency	days/year	250	250	90	26
Averaging Time	days/year	365	365	365	365
Time Weighted - Exposure frequency	days/year	NA	NA	1	1
Time Weighted - Averaging Time	days/year	NA	NA	7	7
Incidental ingestion for Surface plus Subsurface Soil					
Soil ingestion rate	mg/day	50	100	100	100

NA = Not Applicable
mg/day = milligram per day

8.1.5.3 Additional Input Parameters for Risk Model

Model inputs were derived based on specific recommendations presented by USEPA in *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil* (USEPA, 2003) and *Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from Phases 1 and 2 of the National Health and Nutrition Evaluation Survey* (NHANES III; USEPA, 2002c). Table 8-4 presents the assigned values for additional input parameters for the risk model.

Table 8-4: Assigned Values for Additional Input Parameters

Description of Exposure Variable	Units	Assigned Value
Fetal/maternal PbB ratio	--	0.9
Biokinetic Slope Factor	µg/dL per ug/day	0.4
Geometric standard deviation PbB (Assuming a heterogeneous population)	--	2.11
Baseline PbB (Assuming a heterogeneous population)	µg/dL	1.53
Absorption fraction (same for soil and dust)	--	0.12

PbB = Blood lead concentration
µg/dL = microgram per deciliter

8.1.5.4 Risk Characterization Results for Lead

Results of the lead risk characterization for the four receptors, as predicted by the ALM, are presented in the following tables. Due to the short exposure times associated with the maintenance worker scenario, and in accordance with USEPA guidance (USEPA, 2003), the

ALM results are presented on a time-weighted average (TWA) basis. Table 8-5 presents the summary of the lead risk assessments for all four receptor scenarios.

Table 8-5: Summary of Estimated Blood Lead Concentrations

Receptor Scenarios	Blood Lead Concentration (µg/dl)			Probability of Fetal PbB Target Exceedance (%)[3]	
	Adult[1]	Fetus of Adult Worker[2]	Target Level (µg/dl)	Population Risk Level	Target Level (%)
Industrial/Commercial Worker	1.7	5.1	10	0.6	5
Construction Worker	1.9	5.7		0.8	
Maintenance Worker	1.5	4.7		0.4	
Maintenance Worker (TWA)	1.6	4.8		0.4	
Utility Worker	1.5	4.7		0.4	
Utility Worker (TWA)	1.8	5.4		0.6	

µg/dl = microgram per deciliter;
[1] Blood lead concentration of adult worker is based on geometric mean
[2] Fetal PbB based on 95th percentile
[3] Probability that fetal PbB will exceed the target level, assuming lognormal distribution

The ALM model results predicted estimated blood lead concentrations of up to 1.7 µg/dL in an adult site industrial/commercial worker and 5.1 µg/dL in the fetus of a pregnant adult site industrial/commercial worker. Both of the results are less than the 10 µg/dL benchmark established by USEPA. The probability that the blood lead concentration in the fetus of a pregnant adult industrial/commercial worker would exceed 10 µg/dL was 0.6%, which is less than the 5% benchmark established by USEPA. Based on these results, lead is not considered a COC for the FFA.

8.1.6 Uncertainty

Uncertainty can be found in every phase of the risk assessment: in the analytical data, the exposure assessment, the toxicity assessment, and the risk characterization. Uncertainty is inherent in the selection of input parameters and in every step of the risk assessment process. This inherent uncertainty affects the level of confidence which can be placed in the final results. However, because the assumptions used in the exposure and toxicity assessments tend to be health-protective and conservative in nature, the estimated risks are likely to exceed the most probable risk posed to potential receptors at the Site. The use of site-specific factors can decrease uncertainty, but it persists in even the most site-specific risk assessments. Therefore, risk assessment of contaminated sites must not be viewed as yielding single value, invariant results. Rather, the results of risk assessment are estimates that span a range of possible values, and must be understood only in light of the assumptions and methods used in the evaluation.

Due to the lack of background concentration data and the industrialized nature of the site, there is significant uncertainty regarding where all of the contaminants identified as COPCs are site-related.

8.2 Summary of Ecological Risk Evaluation

An ecological risk evaluation was performed for Area I to evaluate whether releases of chemicals to onsite soils may adversely affect ecological receptors. The scope of this ecological evaluation is exclusively Area I onsite soils. Evaluation of potential ecological risks due to surface water, sediments or groundwater pathways associated with Area I will be conducted at a later time as part of a future groundwater remedial investigation.

Langan conducted an ecological screening for FFA in 2005, including an exhaustive information and data gathering effort from federal, State, and local wildlife and gaming commissions with jurisdiction over FFA - the PA Natural Diversity Inventory Commission, the US Fish and Wildlife Service, and the PFBC. Based on these reviews, it was concluded that there are no protected or endangered species in the vicinity of FFA. A wetland scientist conducted a site visit and reconnaissance, and documented that there are no freshwater wetlands on or in the vicinity of FFA. While a data gathering effort from federal, state and local wildlife and game commissions with jurisdiction over the FFA indicated that there were no threatened or endangered species at the Site. However, the PFBC does list the Atlantic Sturgeon (*Acipenser oxyrinchus*) and the Sheepnose Mussel (*Plethobasus cyphyus*) as threatened and endangered species within the Commonwealth of Pennsylvania (PA Code Title 58 Part II Chapter 75). Additionally, information from the PADEP project representative indicates that both species have been found in the Delaware River. It should be noted that while the Site does not come in direct contact with the Delaware River, it is proximate.

The current land use for Area I is commercial/industrial. The probable future land use for Area I is also commercial/industrial. The Site currently has physical features that would severely reduce potential exposure to soil, including buildings, parking lots, paved areas, and maintained landscaping. These types of features are expected to continue to be maintained in Area I in the future. As a result, no ecological habitats and associated receptors are known to be associated with the current and future land use for Area I. The physical features of Area I and the absence of ecological habitats and associated receptors were confirmed during the ecological site reconnaissance conducted by Cabrera as part of the Area I Soil RI/RA.

The current and probable future land use for Area I is commercial/industrial. The Site currently has and is expected in the future to continue to have physical features that would severely reduce potential exposure to Area 1 soil. As a result, no ecological habitats and associated receptors are known to be associated with the current and future land use for Area I. Since the soil exposure pathway, and ecological habitats and associated receptors are not present, no additional ecological evaluation is necessary for soils at Area I.

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9.0 SUMMARY

Cabrera, on behalf of USACE, conducted an RI of the soils in Area I of the FFA. This investigation supplements two previous investigations conducted by Langan Engineering and Environmental Services in 1999 and 2005. Based on a review of those reports, Cabrera developed a scope of work for an SSI, which was conducted in the summer of 2007. The scope of this investigation included the installation of monitoring wells, the drilling and sampling of soil borings, and the collection and analysis of soil and groundwater samples. Subsequently, in the spring of 2008, Cabrera conducted another investigation consisting of soil sampling and analysis for the purpose of addressing data gaps, and delineating source areas to facilitate interim source removal actions. Based on the combined results of these investigations, a total of six IRAs were performed within Area I. This section summarizes the data and information gathered, presents the conclusions drawn based on analysis of the information, and outlines the recommended strategy and path forward for addressing site contamination.

9.1 Site Physical Characteristics

The FFA is located in the Coastal Plain Physiographic Province, approximately 0.5 miles south of the Fall Line between the Coastal Plains and the Piedmont (Langan, 2005). The topography of the Site is relatively flat, with a gentle southeasterly slope toward the Delaware River. The Site is underlain by unconsolidated sands, gravel, silts and clays corresponding to the Trenton gravel, which overlies crystalline bedrock consisting of oligoclase-mica schist.

Boring logs suggest that the ground-surface consists largely of fill materials up to 9 ft thick. Native soils of the Trenton gravel, consisting of a mixture of sands, silts and clays, extend to about 50 ft bgs. These unconsolidated materials are underlain by crystalline bedrock, which is believed to be part of the confined aquifer system formed by the Wissahickon Formation. Groundwater is unconfined in the northern part of the Site, and was encountered at depths ranging from four to 14 ft bgs. In the southern part of the Site, the Trenton gravel aquifer is partially confined by fine-grained, saturated marsh sediments. This upper water bearing zone has heads that are up to one foot higher than the piezometric surface in the Trenton gravel. Groundwater flow is generally to the south-southeast, with an apparent groundwater divide in the center of the Site with a northwest to southeast alignment.

9.2 Nature and Extent of Constituents

A number of soils investigations were conducted in Area I to determine the nature and extent of constituents. As part of those investigations, samples were collected and analyzed for metals, VOCs, SVOCs, explosives, PCBs, and radionuclides. The soil sampling results were compared to their corresponding site-specific soil screening limits. These included the PA Act 2 MSCs (metals, VOCs, SVOCs, and explosives), TSCA residential levels (PCBs), and the NRC soil screening values (radionuclides). Based upon the results of these investigations, six IRAs were conducted between 2009 and 2013.

In general, metals contamination is limited to subsurface soils (greater than three ft bgs). Some locations have arsenic contamination near the surface (Compound Area, Building 238 and AOCs 6 and 9). The MSC for arsenic was modified by PADEP after 2009 to be reduced to 29 mg/kg surface and subsurface. The 2009 IRA remediation was performed relative to the standard in place at the time (arsenic MSC of 53 mg/kg surface soil/150 mg/kg subsurface soil). All of the arsenic exceedances presented in this RI/RA are relative to the updated standard of 29 mg/kg..

Some VOC contamination remains in the form of PCE, TCE, carbon tetrachloride, and benzene. The majority of the contamination is at depth as indicated within Building 58 leaking sump at a depth of 12 ft bgs. Some contamination remains in near surface soil are located in AOI 10, 13, and 16. PCB contamination remains at depth within the limits of the Building 58 leaking sump and the Building 44/47 Tank Pit. Contamination is below the groundwater and will be the subject of a separate groundwater RI.

9.3 Fate and Transport

The FFA is underlain by up to 15 ft of fill materials that overlie approximately 20 ft of gravelly sand, beneath which is fractured gneiss bedrock. The topography slopes gently to the south and southeast towards Frankford Creek and the Delaware River. Groundwater is present four to 12 ft bgs and flows toward Frankford Creek and the river at an estimated seepage velocity of 0.28 to 0.84 ft/day.

Area I is zoned for industrial/commercial use and this is the planned future use as well. There is a possible risk of exposure to contamination in the soils by industrial and construction workers. HSAs helped identify source zones that were confirmed with sampling and analysis.

Analysis of soil samples has confirmed the presence of contamination that exceeds non-residential MSCs. Metals –, arsenic, lead, and to a lesser extent, chromium and mercury; VOCs – PCE, TCE, benzene and carbon tetrachloride, and Aroclor 1260 are the site-related constituents for the Site. The potential for site constituents to migrate from soil to other media are summarized by the following:

- **Migration into Air** – Transport of constituents from surface soil to air can occur via dust generation or volatilization. Because the soil surface at the Site is predominantly paved, the potential for the contaminants in surface soil to be released to air via dust emission is significantly minimized. However, the inhalation pathway was considered during the HHRA. There are PCE exceedances in surface soil near Building 125 (see Figure 6-2), which could continue to volatilize and impact air quality. Additionally, there are chlorinated solvents in subsurface soil at the former locations of Buildings 46, 58 and 125 which can volatilize into soil gas and be transported through the vadose zone, only to be redeposited in the subsurface after rain events (Imbrogiotta et.al., 1997).
- **Soil and Groundwater to Indoor Air Pathway** - Vapor intrusion into basements depends on the volatility of the contaminant, soil type, and building construction details. The Act 2 Statewide Health Standards outline the evaluation of potential vapor intrusion pathway(s) for organic contamination in soils and groundwater (PADEP, Document 253-0300-100, 2004a). Langan evaluated the analytical results from the 1999 and 2005 investigations using the J&E model and the Act 2 non-residential default indoor air screening MSCs. Based on this evaluation, chloroform (sample 47SS-102) and TCE (47SS-102 and 149SS-5) concentrations exceeded their respective non-residential indoor air MSCs of 5.3 $\mu g/m^3$ and 48 $\mu g/m^3$, respectively. It should be noted that the sample locations listed have been remediated during the various IRAs and no longer exist.. PADEP indoor air quality guidance was also used to evaluate residual VOC and SVOC contamination remaining after completion of the IRAs. Twelve locations were evaluated

with respect to the building locations being planned by the site owner. Ten of the sample locations were eliminated from further consideration due to their distance from planned buildings. Of the two remaining locations, residual contamination at W-19-MW-003 was shallow in depth and the location was distant from the planned building and in an area where permeable cover is planned. This location was discounted as a potential source for impact to indoor air quality. The final location of residual VOC contamination was AC10SB08, which contained 2,800 ug/kg of TCE at a depth of four feet bgs and appears to be within approximately 20 feet of a building footprint. A soil sample collected from 1 ft bgs at this station did not have detectable TCE and nearby monitor well MW-03 did not have detectable TCE. If the 1 x 10-4 CERCLA risk threshold were applied to this individual sample, the sample result would not pose an unacceptable risk. For these reasons, this individual sample exceedance is not considered significant, and does not warrant additional evaluation.

- **Migration into Groundwater, Surface Water and Sediment** - The most significant exposure route associated with surface and groundwater pathways is use of these media as potable sources. To assess these pathways, Cabrera conducted a search of federal, State, and municipal records to determine whether there were any supply wells or surface water intakes within 0.5 miles of FFA. Records from the PA Geological Survey, the PA Groundwater Information System, the Delaware River Basin Commission, the PDPH, and the PWD were reviewed. Thirty-seven wells were identified, 23 of which were labeled as destroyed or no longer in use. Twelve wells, belonging to Rohm & Haas, are monitoring wells. One well is owned by Allied Chemicals and is used for industrial purposes. Another, owned by Krometal Manufacturing, Inc. located at 5825 Tacony Street, approximately 2,000 ft northeast and hydraulically cross gradient of the Site, is used for industrial processes. Cabrera determined, and the PWD confirmed, that there were no surface or groundwater intakes within 0.5 miles of the Site.
- **Migration into Groundwater from Surface Water Pathways** - Groundwater at the Site discharges to Frankford Creek and the Delaware River. The Langan investigation used a numerical model developed by PADEP (the Quick Domenico [QD] Model) to simulate the fate and transport of the following VOCs – carbon tetrachloride, chloroform, TCE, PCE, vinyl chloride, 1,4-dichlorobenzene, benzene, cis-1,2-dichloroethylene, and 1,1-dischloroethane at FFA (Langan, 2005). The model predicted the maximum distance downgradient that each compound would travel in groundwater before it is attenuated to a concentration below its groundwater MSCs. This model incorporates natural attenuation processes of dispersion, biodegradation and retardation. The results of simulations showed that the predicted maximum downgradient distance for each VOC would be well short of the nearest potential surface water body adjoining the site. In addition, there are no known private or public supply wells or surface water intakes within a half mile of the Site. The remaining mass of VOCs is considerably less as compared to the mass used in the Langan model. The predicted maximum downgradient distances would be well short of the nearest potential surface water body as compared to the higher VOC mass used during the Langan model. Therefore, based on groundwater fate and transport analysis, the pathway of VOC transport via groundwater to surface water is incomplete.

9.4 Human Health Risk Assessment

A HHRA was performed to measure the potential health impacts to human and ecological receptors from exposure to chemical contamination present in Area I of the FFA. The results of the assessments are summarized below.

Human Health Risk Assessment

The results of the carcinogenic chemical risk assessments for both current and future receptor scenarios showed that the carcinogenic risks for the industrial/commercial worker, construction worker, and maintenance worker were within the CERCLA acceptable cancer risk range of 1E-06 to 1E-04. The carcinogenic risk ranged from 1E-05 for the industrial worker to 2E-07 for the utility worker.

Noncancer hazard indices did not exceed the CERCLA limit of one for any receptor. HIs ranged from 5E-1 for the construction worker to 2E-2 for both the utility and maintenance worker.

The USEPA Adult Lead Model (ALM) was used to predict blood lead concentrations in the four Area I receptors. The results of the Adult Lead Model evaluation for the four receptors predicted the estimated blood lead concentrations and the probability of blood lead concentrations exceeding the established 10 µg/dL threshold in the fetus of a pregnant adult. Neither predictor exceeded their corresponding benchmark limits, established by USEPA. The results of the ALM model indicate that no potential adverse human health impacts are likely to occur as a result of exposure to lead at FFA.

Ecological Evaluation

An ecological risk evaluation was performed for Area I soils to evaluate whether releases of chemicals to onsite soils may adversely affect ecological receptors. The current and probable future land use for Area I is commercial/industrial. There are no protected or endangered species or freshwater wetlands on or in the vicinity of the Site. The Site currently has and is expected in the future to continue to have physical features that would severely reduce potential exposure to Area 1 soil. As a result, no ecological habitats and associated receptors are known to be associated with the current and future land use for Area I. Since the soil exposure pathway, and ecological habitats and associated receptors are not present, no additional ecological evaluation is necessary for soils at Area I.

10.0 CONCLUSIONS

Based on the investigations and IRAs, soil constituents within in Area I that exhibit concentrations exceeding the site-specific screening limits have been identified as VOCs (TCE, PCE, carbon tetrachloride and benzene); SVOCs (benzo(a)pyrene and 2,4-DNT) PCBs (Aroclor 1248, 1254 and 1260), and metals (arsenic, chromium, lead and mercury). Based upon the results of the HHRA, there are no unacceptable risks to the four potential receptors of industrial worker, commercial worker, utility worker, and maintenance worker.

Based on the analytical data and the results of the risk assessment, Cabrera recommends that no further remedial action be taken at Area I. The CERCLA processes will be completed, including the preparation of a Proposed Plan and Decision Document. As the site does not pose a risk to human health or the environment, no Feasibility Study will be required. Any submissions required under PADEP Act 2 will be completed by the current property owner.

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TABLES

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Table 3-1: AOI/AOC Summary

AOI/AOC	FFA Building	Site Constituents	Final Status
1/1	47	VOCs	Remediated 2009-2013 IRA No remaining exceedances
2/2	47	VOCs	Remediated 2009-2013 IRA No remaining exceedances
3/3	47/48	VOCs	Remediated 2009-2013 IRA No remaining exceedances
4/4	64	PCBs	Remediated 2009-2013 IRA No remaining exceedances
5/5	127-128	Arsenic, chromium, lead, mercury	Remediated 2009-2013 IRA Remaining exceedances due to existing foundations or revised arsenic MSC*
6/6	128	Arsenic	Remediated 2009-2013 IRA Remaining exceedances due to revised arsenic MSC
7/7	149-150	VOCs, SVOCs, arsenic	Remediated 2009-2013 IRA Remaining exceedances due to revised arsenic MSC
8/8	237	PCBs	Remediated 2009-2013 IRA Remaining exceedances due to existing foundations or revised arsenic MSC
9/9	301	Arsenic, PCBs	Urban fill, depth 1-2 ft, acceptable risk**
10/10	Landfill (MW-3)	Arsenic, chromium, lead, VOCs	Contamination below groundwater table; address in Area IV RI
11/11	141-143/ Compound Area	Arsenic	Remediated 2009-2013 IRA Remaining exceedances due to revised arsenic MSC
12/12	231	Lead, mercury	Remediated 2009-2013 IRA Remaining exceedances below groundwater table; address in Area IV RI
13/13	125-126	PCE	Small hotspot; address in Area IV RI
14/14	55-58	Arsenic, PCBs, VOCs	Remediated 2009-2013 IRA Remaining exceedances below groundwater table; address in Area IV RI
15/15	324	Arsenic, chromium, lead	Remaining exceedances below groundwater table; address in Area IV RI

Table 3-1: AOI/AOC Summary (Continued)

AOI/AOC	FFA Building	Site Constituents
16/16	46	TCE
58 Leaking Sump (discovered during building demolition)	PCBs, SVOCs, VOCs	Remediated 2009-2013 IRA Remaining exceedances below groundwater table; address under Area IV RI
Building 47 Oil/Water Separator (discovered during building demolition)	PCBs, VOCs	Remediated 2009-2013 IRA No remaining exceedances
Building 48 USTs (discovered during building demolition)	SVOCs,VOCs	Remediated 2009-2013 IRA No remaining exceedances
Building 44/47 Tank Pit (2008 CON/HTRW UST removal)	lead ,PCBs	Remediated 2009-2013 IRA Remaining exceedances below groundwater table; address in Area IV RI
Building 128 transformer pad	PCBs	Remediated 2009-2013 IRA No remaining exceedances

* In 2011, PADEP MSC for arsenic was reduced to 29 mg/kg surface/subsurface from 53mg.kg surface/150 mg/kg subsurface

**Based upon initial risk assessment performed with 2008 Data Gap samples.

TABLE 5-1: NEW MSCs BASED ON NEW PADEP VALUES (NON-RESIDENTIAL, USED AQUIFER SCENARIO)

Analytes	PADEP Non-Res Used Aquifers Soil to GW Pathway 100x GW MSC	PADEP Non-Res Used Aquifers Soil to GW Pathway Generic MSC	PADEP Non-Res Direct Contact Surface Soil 0-2 ft	PADEP Non-Res Direct Contact Subsurface Soil 2-15 ft	Appropriate Surface Soil MSC	Appropriate Subsurface Soil MSC
Metal (mg/kg)						
Aluminum, Total	NA	NA	190000	190000	190000	190000
Antimony, Total	0.6	27	1100	190000	27	27
Arsenic, Total	1	29	53	190000	29	29
Barium, Total	200	8200	190000	190000	8200	8200
Beryllium, Total	0.4	320	5600	190000	320	320
Cadmium, Total	0.5	38	1400	190000	38	38
Calcium, Total	NA	NA	NA	NA	NA	NA
Chromium, Total (Cr VI)	10	190	8400	20000	190	190
Cobalt, Total	3.1	140	840	190000	140	140
Copper, Total	100	43000	100000	190000	43000	43000
Iron, Total	NA	NA	190000	190000	190000	190000
Lead, Total	0.5	450	1000	190000	450	450
Magnesium, Total	NA	NA	NA	NA	NA	NA
Manganese, Total	30	2000	130000	190000	2000	2000
Mercury, Total	0.2	10	450	190000	10	10
Nickel, Total	10	650	56000	190000	650	650
Potassium, Total	NA	NA	NA	NA	NA	NA
Selenium, Total	5	26	14000	190000	26	26
Silver, Total	10	84	14000	190000	84	84
Sodium, Total	NA	NA	NA	NA	NA	NA
Thallium, Total	0.2	14	200	190000	14	14
Vanadium, Total	72	72000	20000	190000	20000	72000
Zinc, Total	200	12000	190000	190000	12000	12000
VOCs (ug/kg)						
1,1,1-Trichloroethane	20000	7200	10000000	10000000	20000	20000
1,1,2,2-Tetrachloroethane	430	130	38000	44000	430	430
1,1,2-Trichloroethane	500	150	140000	160000	500	500
1,1-Dichloroethane	16000	3900	1400000	1600000	16000	16000
1,1-Dichloroethene	700	190	10000000	10000000	700	700
1,2,4-Trichlorobenzene	7000	27000	10000000	10000000	27000	27000
1,2-Dichlorobenzene	60000	59000	10000000	10000000	60000	60000
1,2-Dichloroethane	500	100	86000	98000	500	500
1,2-Dichloropropane	500	110	220000	260000	500	500
1,3-Dichlorobenzene	60000	61000	8400000	10000000	61000	61000
1,4-Dichlorobenzene	7500	10000	200000	230000	10000	10000
2-Butanone	400000	76000	10000000	10000000	400000	400000
2-Chloroethyl Vinyl Ether	NA	NA	NA	NA	NA	NA
2-Hexanone	4400	1100	400000	460000	4400	4400
4-Methyl-2-Pentanone	820000	130000	10000000	10000000	820000	820000
Acetone	9200000	1000000	10000000	10000000	9200000	9200000
Benzene	500	130	290000	330000	500	500
Bromodichloromethane	8000	2700	60000	69000	8000	8000
Bromoform	8000	3500	2000000	2300000	8000	8000
Bromomethane	1000	540	400000	460000	1000	1000
Carbon Disulfide	620000	530000	10000000	10000000	620000	620000
Carbon Tetrachloride	500	260	150000	170000	500	500
Chlorobenzene	10000	6100	4000000	4600000	10000	10000
Chloroethane	90000	19000	10000000	10000000	90000	90000
Chloroform	8000	2000	97000	110000	8000	8000
Chloromethane	3000	380	1200000	1400000	3000	3000
cis-1,2-Dichloroethene	7000	1600	10000000	10000000	7000	7000
cis-1,3-Dichloropropene	NA	NA	NA	NA	NA	NA
Dibromochloromethane	8000	2500	82000	95000	8000	8000
Ethylbenzene	70000	46000	10000000	10000000	70000	70000
Methylene Chloride	500	76	4700000	5400000	500	500
Naphthalene	10000	25000	56000000	190000000	25000	25000
Styrene	10000	24000	10000000	10000000	24000	24000
Tetrachloroethene	500	430	1500000	4400000	500	500
Toluene	100000	44000	10000000	10000000	100000	100000
trans-1,2-Dichloroethene	10000	2300	4800000	5500000	10000	10000
trans-1,3-Dichloropropene	NA	NA	NA	NA	NA	NA

TABLE 5-1: NEW MSCs BASED ON NEW PADEP VALUES (NON-RESIDENTIAL, USED AQUIFER SCENARIO)

Analytes	PADEP Non-Res Used Aquifers Soil to GW Pathway 100x GW MSC	PADEP Non-Res Used Aquifers Soil to GW Pathway Generic MSC	PADEP Non-Res Direct Contact Surface Soil 0-2 ft	PADEP Non-Res Direct Contact Subsurface Soil 2-15 ft	Appropriate Surface Soil MSC	Appropriate Subsurface Soil MSC
Trichloroethene	500	170	1300000	1500000	500	500
Trichlorofluoromethane	200000	87000	10000000	10000000	200000	200000
Trimethylbenzeneisomer	NA	NA	NA	NA	NA	NA
UnknownAlkane	NA	NA	NA	NA	NA	NA
Vinyl Chloride	200	27	110000	580000	200	200
Xylene (Total)	1000000	990000	8000000	9100000	1000000	1000000
SVOCs (ug/kg)						
1,2 Diphenylhydrazine	330	580	99000	190000000	580	580
1,2,4,5-Tetrachlorobenzene	3100	14000	840000	190000000	14000	14000
1,2,4-Trichlorobenzene	7000	27000	10000000	10000000	27000	27000
1,2-Dichlorobenzene	60000	59000	10000000	10000000	60000	60000
1,3-Dichlorobenzene	60000	61000	8400000	10000000	61000	61000
1,3-Dinitrobenzene	100	49	280000	190000000	100	100
1,4-Dichlorobenzene	7500	10000	200000	230000	10000	10000
2,3,4,6-Tetrachlorophenol	310000	4800000	84000000	190000000	4800000	4800000
2,4,5-Trichlorophenol	1000000	6100000	190000000	190000000	6100000	6100000
2,4,6-Trichlorophenol	10000	29000	2800000	190000000	29000	29000
2,4-Dichlorophenol	2000	1000	8400000	190000000	2000	2000
2,4-Dimethylphenol	200000	87000	10000000	10000000	200000	200000
2,4-Dinitrophenol	20000	2300	5600000	190000000	20000	20000
2,4-Dinitrotoluene	840	200	260000	190000000	840	840
2,6-Dinitrotoluene	10000	3000	2800000	190000000	10000	10000
2-Chloronaphthalene	820000	18000000	190000000	190000000	18000000	18000000
2-Chlorophenol	4000	4400	10000000	10000000	4400	4400
2-Methyl-4,6-dinitrophenol	1000	750	280000	190000000	1000	1000
2-Methylnaphthalene	41000	1600000	11000000	190000000	1600000	1600000
2-Naphthylamine	140	46	44000	190000000	140	140
2-Nitroaniline	31000	5500	8400000	190000000	31000	31000
2-Nitrophenol	82000	17000	22000000	190000000	82000	82000
3,3-Dichlorobenzidine	580	32000	180000	190000000	32000	32000
3-Nitroaniline	3100	480	840000	190000000	3100	3100
4-Bromophenyl-phenylether	NA	NA	NA	NA	NA	NA
4-Chloroaniline	1300	1600	400000	190000000	1600	1600
4-Chlorophenyl-phenylether	NA	NA	NA	NA	NA	NA
4-Nitroaniline	13000	1900	4000000	190000000	13000	13000
4-Nitrophenol	6000	4100	22000000	190000000	6000	6000
Acenaphthene	380000	4700000	170000000	190000000	4700000	4700000
Acenaphthylene	610000	6900000	170000000	190000000	6900000	6900000
Acetophenone	1000000	540000	10000000	10000000	1000000	1000000
Anthracene	6600	350000	190000000	190000000	350000	350000
Benzidine	1.1	1500	340	190000000	340	1500
Benzo(a)anthracene	360	320000	110000	190000000	110000	320000
Benzo(a)pyrene	20	46000	11000	190000000	11000	46000
Benzo(b)fluoranthene	120	170000	110000	190000000	110000	170000
Benzo(g,h,i)perylene	26	180000	170000000	190000000	180000	180000
Benzo(k)fluoranthene	55	610000	1100000	190000000	610000	610000
Benzoic acid	41000000	7800000	190000000	190000000	41000000	41000000
Benzyl Alcohol	5100000	1800000	10000000	10000000	5100000	5100000
Biphenyl	510000	2200000	140000000	190000000	2200000	2200000
Bis(2-Chloroethoxy)methane	31000	8200	8400000	10000000	31000	31000
Bis(2-Chloroethyl)ether	76	23	6700	7700	76	76
Bis(2-Ethylhexyl)Phthalate	600	130000	5700000	10000000	130000	130000
bis(2-Ethylhexyl)phthalate	600	130000	5700000	10000000	130000	130000
Butylbenzylphthalate	140000	10000000	10000000	10000000	10000000	10000000
Chrysene	190	230000	11000000	190000000	230000	230000
Dibenzo(a,h)anthracene	36	160000	11000	190000000	11000	160000
Dibenzofuran	10000	260000	2800000	190000000	260000	260000
Diethylphthalate	8200000	2600000	10000000	10000000	8200000	8200000
Dimethoate	2000	770	560000	190000000	2000	2000
Dimethylphthalate	NA	NA	NA	NA	NA	NA
Di-n-Butylphthalate	1000000	4100000	10000000	10000000	4100000	4100000
Di-n-Octylphthalate	300000	10000000	10000000	10000000	10000000	10000000

TABLE 5-1: NEW MSCs BASED ON NEW PADEP VALUES (NON-RESIDENTIAL, USED AQUIFER SCENARIO)

Analytes	PADEP Non-Res Used Aquifers Soil to GW Pathway 100x GW MSC	PADEP Non-Res Used Aquifers Soil to GW Pathway Generic MSC	PADEP Non-Res Direct Contact Surface Soil 0-2 ft	PADEP Non-Res Direct Contact Subsurface Soil 2-15 ft	Appropriate Surface Soil MSC	Appropriate Subsurface Soil MSC
Diphenylamine	260000	150000	70000000	190000000	260000	260000
Fluoranthene	26000	3200000	110000000	190000000	3200000	3200000
Hexachlorobenzene	100	960	50000	190000000	960	960
Hexachlorobutadiene	3300	39000	1000000	10000000	39000	39000
Hexachlorocyclopentadiene	5000	91000	10000000	10000000	91000	91000
Hexachloroethane	100	560	550000	640000	560	560
Indeno(1,2,3-cd)pyrene	360	28000000	110000	190000000	110000	28000000
Isophorone	10000	1900	10000000	10000000	10000	10000
mp-Cresol	NA	NA	NA	NA	NA	NA
Naphthalene	10000	25000	56000000	190000000	25000	25000
Nitrobenzene	20000	8700	5600000	10000000	20000	20000
N-Nitrosodimethylamine	1.8	0.24	160	180	1.8	1.8
N-Nitrosodi-n-butylamine	48	59	15000	10000000	59	59
N-Nitroso-di-n-propylamine	37	5.1	11000	10000000	37	37
N-Nitrosodiphenylamine	53000	83000	16000000	190000000	83000	83000
o-Cresol	510000	85000	140000000	190000000	510000	510000
Pentachlorobenzene	8200	660000	2200000	190000000	660000	660000
Pentachlorophenol	100	5000	660000	190000000	5000	5000
Phenanthrene	110000	10000000	190000000	190000000	10000000	10000000
Pyrene	13000	2200000	84000000	190000000	2200000	2200000
Pyridine	10000	1100	2800000	10000000	10000	10000
Resorcinol	NA	NA	NA	NA	NA	NA
PCBs						
Aroclor-1016	0.72	200	200	10000	200	200
Aroclor-1221	0.13	0.63	40	10000	0.63	0.63
Aroclor-1232	0.13	0.5	40	10000	0.5	0.5
Aroclor-1242	0.13	16	40	10000	16	16
Aroclor-1248	0.13	62	40	10000	40	62
Aroclor-1254	0.13	260	40	10000	40	260
Aroclor-1260	0.13	590	40	190000	40	590
Aroclor 1262	NA	NA	NA	NA	NA	NA
Aroclor-1268	NA	NA	NA	NA	NA	NA
EXPLOSIVES (ug/kg)						
2,4-Dinitrotoluene	840	200	260000	190000000	840	840
2,6-Dinitrotoluene	10000	3000	2800000	190000000	10000	10000
Nitrobenzene	20000	8700	5600000	10000000	20000	20000

Table 6-1. Detected Soil Concentrations Greater than Metals MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC	AOC 5				AOC 6			
			Sample ID	AOC 5-SO-03		AOC 5-SO-07		AOC6-SO-04		AOC6-SO-06	
			Date	11/4/2009		11/16/2009		10/13/2009		10/13/2009	
			Depth (Ft)	4 Ft		6 Ft		2 Ft		2 Ft	
			Units	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Arsenic, Total	29	29	mg/kg	-		34		73		45	
Barium, Total	8,200	8,200	mg/kg	-		-		-		-	
Chromium, Total	190	190	mg/kg	-		235		-		-	
Lead, Total	450	450	mg/kg	770		-		-		-	
Mercury, Total	10	10	mg/kg	19		-		-		-	

Notes:
mg/kg = milligrams per kilogram
"- " = Sample result below MSC

Table 6-1. Detected Soil Concentrations Greater than Metals MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC 7		AOC 8						AOC 9			
			B149-SO-01		AOC 8-SO-02		AOC 8-SO-03c		AOC 8-SO-07d		301-STP-5		AOC 9-SB-B-P-01	
			1/13/2010		10/26/2009		11/12/2009		11/18/2009		9/8/1999		3/19/2008	
			2 Ft		3 Ft		3 Ft		3 Ft		7.5 Ft		1 Ft	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Arsenic, Total	29	29	48		-		-		30.9		63.0		45.0	
Barium, Total	8,200	8,200	-		-		-		-		-		-	
Chromium, Total	190	190	-		-		-		-		-		-	
Lead, Total	450	450	-		609		609		-		-		-	
Mercury, Total	10	10	-		-		-		-		-		-	

Notes:
mg/kg = milligrams per kilogram
"- " = Sample result below MSC

Table 6-1. Detected Soil Concentrations Greater than Metals MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC 10		AOC 11						AOC 12	
			STP-11A		CMP-1-SO-03		B142A-SO-10		B143-SO-14		231-CS-5-P7	
			10/8/1999		1/13/2010		11/12/2009		11/16/2009		1/28/2013	
			7 Ft		2 Ft		1 Ft		1 Ft		7 Ft	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Arsenic, Total	29	29	24		31.6		29		43.1		-	
Barium, Total	8,200	8,200	-		-		-		-		-	
Chromium, Total	190	190	210		-		-		-		-	
Lead, Total	450	450	786		-		-		-		-	
Mercury, Total	10	10			-		-		-		18.1	

Notes:
mg/kg = milligrams per kilogram
"- " = Sample result below MSC

Table 6-1. Detected Soil Concentrations Greater than Metals MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC 12										AOC 12	
			231-CS-6-P7		231-CS-11-P7		231-CS-12-P7		231-CS-13-P7		231-CS-16-P7		231-CS-18-P7	
			1/28/2013		1/28/2013		1/28/2013		1/28/2013		1/28/2013		1/28/2013	
			7 Ft		7 Ft		7 Ft		7 Ft		7 Ft		7 Ft	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Arsenic, Total	29	29	**33**		-		-		-		-		-	
Barium, Total	8,200	8,200	-		-		-		-		-		-	
Chromium, Total	190	190	-		-		-		-		-		-	
Lead, Total	450	450	-		-		-		887		978		-	
Mercury, Total	10	10	-		30.5		34.9		11.1		-		20.2	

Notes:
mg/kg = milligrams per kilogram
"- " = Sample result below MSC

Table 6-1. Detected Soil Concentrations Greater than Metals MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC 13		AOC 14		AOC 15					
			S131-TP-25		58-CS-48-P8		STP-10A		238-SS-1		TP44-SO-11	
			8/208/2007		1/29/2013		10/8/1999		6/8/1999		1/7/2010	
			9.5 Ft		8 Ft		9 Ft		0 Ft		15 Ft	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Arsenic, Total	29	29	60		32.8		30		32		-	
Barium, Total	8,200	8,200	-		-		-		-		-	
Chromium, Total	190	190	284		-		227		-		-	
Lead, Total	450	450	-		-		544		-		1810	
Mercury, Total	10	10	-		-		-		-		-	

Notes:
mg/kg = milligrams per kilogram
"- " = Sample result below MSC

Table 6-2. Detected Soil Concentrations Greater than VOC MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC	AOC 10						AOC 13			
			Sample ID	**AC10SB08**		**AC10SB10**		**W19-MW-003**		**125-SS-101**		**126-SS-102**	
			Date	**3/24/2008**		**3/24/2008**		**7/25/2007**		**8/09/1999**		**8/09/1999**	
			Depth (Ft)	**4 Ft**		**5 Ft**		**2 Ft**		**0 Ft**		**0 Ft**	
			Units	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
1,1,2-Trichloroethane	500	500	ug/kg	-		-		-		-		-	
Benzene	500	500	ug/kg	-		-		3930		-		-	
Carbon Tetrachloride	500	500	ug/kg	-		-		7950		-		-	
Methylene Chloride	500	500	ug/kg	-		-		-		-		-	
Tetrachloroethene	500	500	ug/kg	-		-		-		12000		700	
Trichloroethene	500	500	ug/kg	2800		1200		-		-		-	

Notes:

ug/kg = micrograms per kilogram

"- " = Sample result below MSC

Table 6-2. Detected Soil Concentrations Greater than VOC MSCs

Analyte	MSC (Surface)	MSC (Subsurface)	AOC 15		AOC 16				Building 58 Leaking Sump					
			FillSB-3		S46-TP-22		046-SB-016		58EM-CS-17-P12		58EM-CS-18-P12		58EM-CS-19-P12	
					12/8/1999		7/19/2007		6/18/2013		6/18/2013		6/18/2013	
			6 Ft		8.5 Ft		1 Ft		12 Ft		12 Ft		12 Ft	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
1,1,2-Trichloroethane	500	500	-		-		-		-		-		-	
Benzene	500	500	-		-		-		-		-		-	
Carbon Tetrachloride	500	500	-		-		-		-		-		-	
Methylene Chloride	500	500	-		-		-		1390		-		-	
Tetrachloroethene	500	500	-		-		-		805		-		-	
Trichloroethene	500	500	710		640		3180		145000		4510		4400	

Notes:

ug/kg = micrograms per kilogram

"- " = Sample result below MSC

Table 6-3. Detected Soil Concentrations Greater than SVOC MSCs

Analyte	**MSC (Surface)**	**MSC (Subsurface)**	**AOC**	**AOC 9**		**AOC 15**	
			Sample ID	**AC09-SB02-B-P-01**		**FillSB-3**	
			Date	**3/19/2008**			
			Depth (Ft)	**1 Ft**		**6 Ft**	
			Units	**Result**	**Qual**	**Result**	**Qual**
2,4-Dinitrotoluene	840	840	ug/kg	-		8500	
Benzo(a)pyrene	11,000	46,000	ug/kg	11400		-	

Notes:
ug/kg = micrograms per kilogram
"- " = Sample result below MSC

Table 6-3. Detected Soil Concentrations Greater than PCB TSCA Limit

Analyte	**TSCA Level**	**AOC**	**AOC 9**		**Tank Pit 44**				**AOC 14**			
		Sample ID	**AC09-SB02-B-P-01**		**TP44-SO-07**		**TP44-SO-08**		**58-CS-38-P-8**		**58-CS-47-P8**	
		Date	**3/19/2008**		**12/16/2009**		**12/16/2009**		**12/4/2012**		**1/29/2013**	
		Depth (Ft)	**1 Ft**		**15 Ft**		**15 Ft**		**8 Ft**		**8 Ft**	
		Units	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**
Aroclor-1248	1.0	mg/kg	-		5.50		7.60		-		-	
Aroclor-1254	1.0	mg/kg	-		-		-		-		-	
Aroclor-1260	1.0	mg/kg	3.01		-		-		1.40		4.40	

Notes:
mg/kg = milligram per kilogram
PCB = Polychlorinated Biphenyls
TSCA = Toxic Substance and Control Act
"- " = Sample result below MSC
[1] Composite sample collected at varying depths

Table 6-3. Detected Soil Concentrations Greater than PCB TSCA Limit

Analyte	TSCA Level	Building 58 Leaking Sump									
		58EM-CS-12-P12		58EM-CS-17-P12		58EM-CS-18-P12		58EM-CS-E5		58EM-CS-E5-DUP	
		6/18/2013		6/18/2013		6/18/2013		6/19/2013		6/19/2013	
		12 Ft		12 Ft		12 Ft		Composite[1]		Composite[1]	
		Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Aroclor-1248	1.0	-		-		-		-		-	
Aroclor-1254	1.0	1.20		-		-		3.90		3.70	
Aroclor-1260	1.0	-		3.60		1.20		-		-	

Notes:

mg/kg = milligram per kilogram

PCB = Polychlorinated Biphenyls

TSCA = Toxic Substance and Control A

"- " = Sample result below MSC

[1] Composite sample collected at varying dep

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FIGURES

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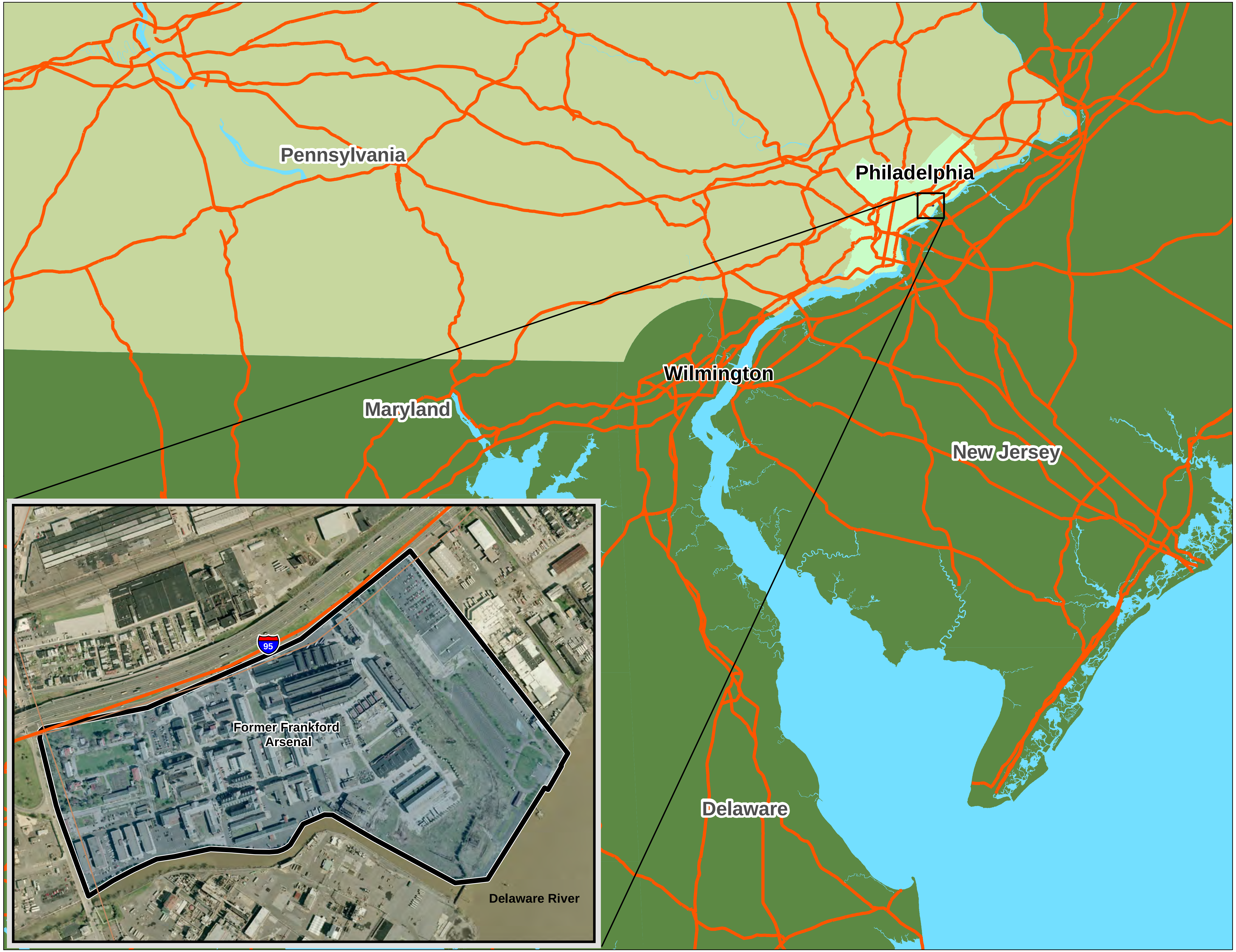


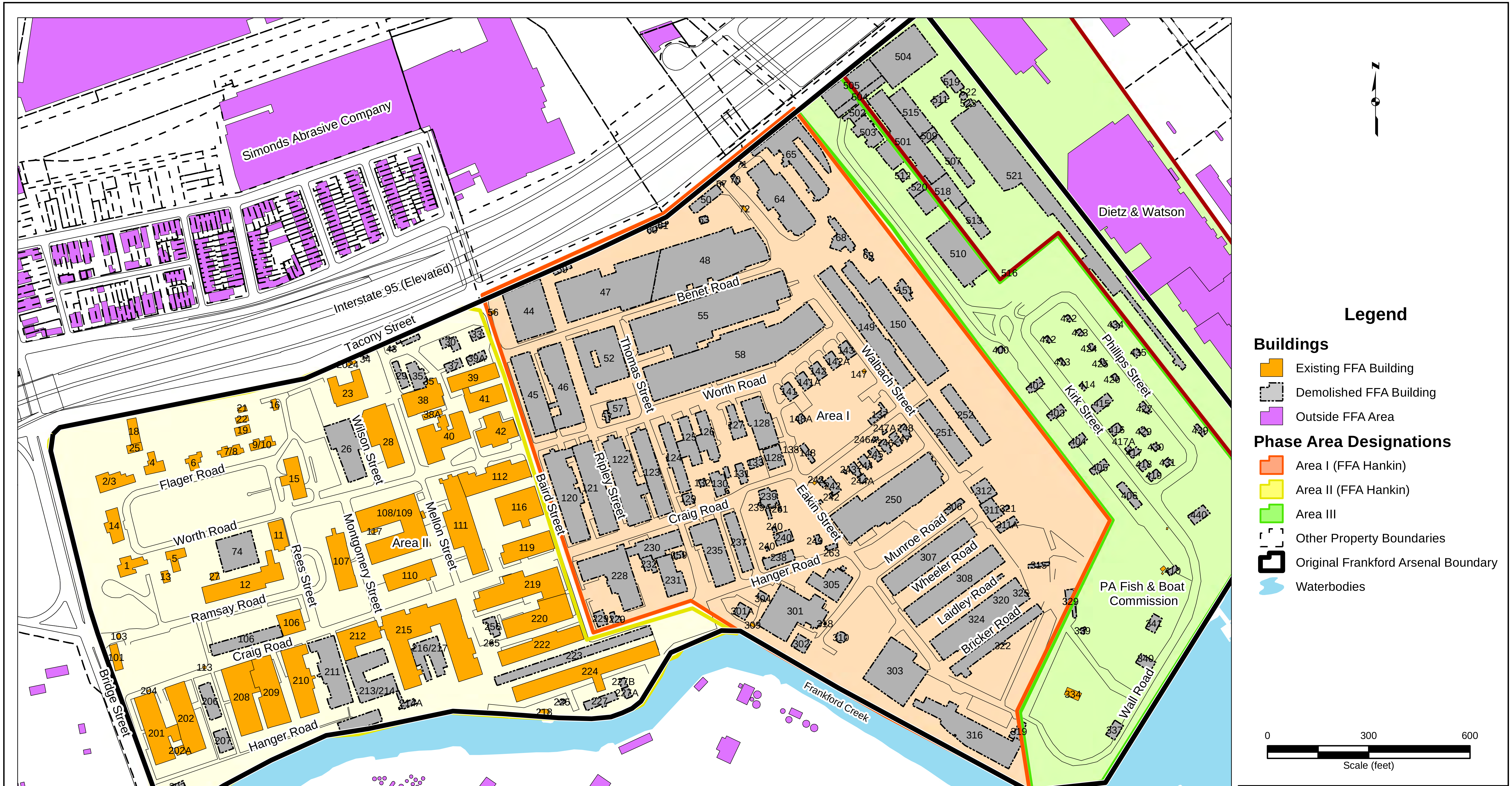
FORMER FRANKFORD ARSENAL
SITE LOCATION MAP

AREA 1 SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 1-1

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



FORMER FRANKFORD ARSENAL
LAYOUT MAP

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 1-2

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District

**SUBSTATION AND UTILITY TUNNEL
LOCATION MAP**

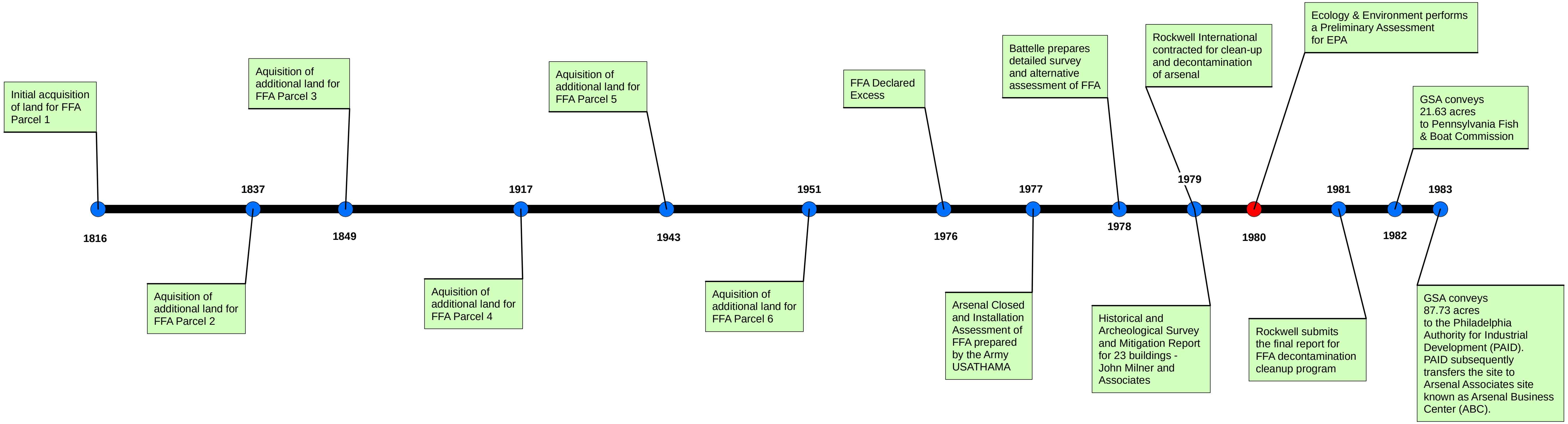
**AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA**

7/13	**CABRERA Project No. 08-3103.00**	**FIGURE 1-3**

**Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201**

**U.S. Army Corps
of Engineers,
Baltimore District**

HISTORICAL TIMELINE OF EVENTS
1816 - 1983



1816
Initial acquisition of land for FFA Parcel 1

1837
Aquisition of additional land for FFA Parcel 2

1849
Aquisition of additional land for FFA Parcel 3

1917
Aquisition of additional land for FFA Parcel 4

1943
Aquisition of additional land for FFA Parcel 5

1951
Aquisition of additional land for FFA Parcel 6

1976
FFA Declared Excess

1977
Arsenal Closed and Installation Assessment of FFA prepared by the Army USATHAMA

1978
Battelle prepares detailed survey and alternative assessment of FFA

1979
Rockwell International contracted for clean-up and decontamination of arsenal

Historical and Archeological Survey and Mitigation Report for 23 buildings - John Milner and Associates

1980
Ecology & Environment performs a Preliminary Assessment for EPA

1981
Rockwell submits the final report for FFA decontamination cleanup program

1982
GSA conveys 21.63 acres to Pennsylvania Fish & Boat Commission

1983
GSA conveys 87.73 acres to the Philadelphia Authority for Industrial Development (PAID). PAID subsequently transfers the site to Arsenal Associates site known as Arsenal Business Center (ABC).

Legend

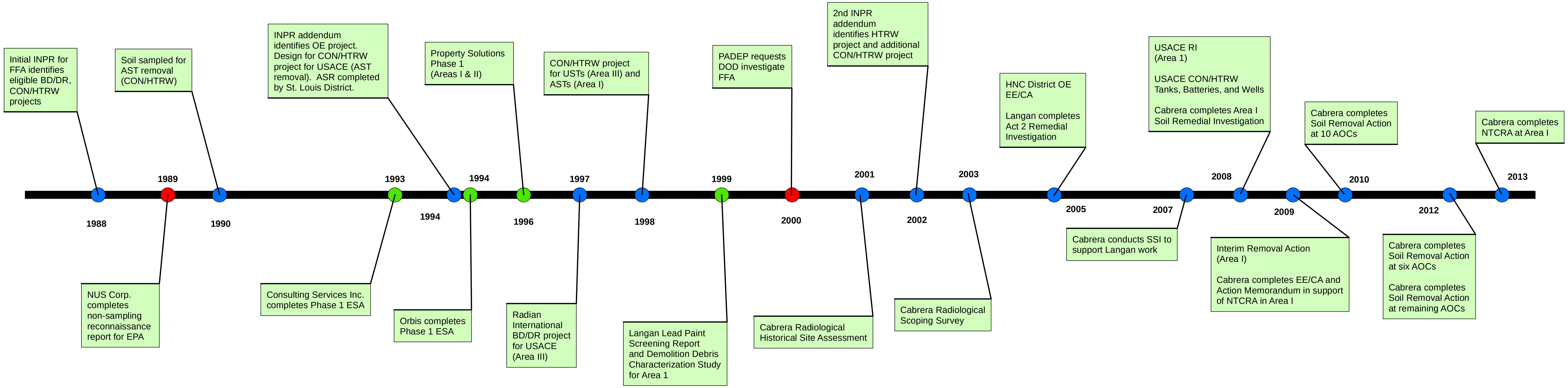
- 🔵 Actions performed by DOD/Government
- 🔴 Actions performed by PADEP/EPA
- 🟢 Actions performed by Owner

HISTORICAL TIMELINE
(1816 - 1983)

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 1-4
Cabrera Services 103 E. Mount Royal Ave. Baltimore, MD 21202		U.S. Army Corps of Engineers, Baltimore District

HISTORICAL TIMELINE OF EVENTS
1984 - 2013



Initial INPR for FFA identifies eligible BD/DR, CON/HTRW projects

NUS Corp. completes non-sampling reconnaissance report for EPA

Soil sampled for AST removal (CON/HTRW)

Consulting Services Inc. completes Phase 1 ESA

INPR addendum identifies OE project. Design for CON/HTRW project for USACE (AST removal). ASR completed by St. Louis District.

Orbis completes Phase 1 ESA

Property Solutions Phase 1 (Areas I & II)

Radian International BD/DR project for USACE (Area III)

CON/HTRW project for USTs (Area III) and ASTs (Area I)

Langan Lead Paint Screening Report and Demolition Debris Characterization Study for Area 1

PADEP requests DOD investigate FFA

Cabrera Radiological Historical Site Assessment

2nd INPR addendum identifies HTRW project and additional CON/HTRW project

Cabrera Radiological Scoping Survey

HNC District OE EE/CA

Langan completes Act 2 Remedial Investigation

Cabrera conducts SSI to support Langan work

USACE RI (Area 1)

USACE CON/HTRW Tanks, Batteries, and Wells

Cabrera completes Area I Soil Remedial Investigation

Interim Removal Action (Area I)

Cabrera completes EE/CA and Action Memorandum in support of NTCRA in Area I

Cabrera completes Soil Removal Action at 10 AOCs

Cabrera completes Soil Removal Action at six AOCs

Cabrera completes Soil Removal Action at remaining AOCs

Cabrera completes NTCRA at Area I

Legend

🔵 Actions performed by DOD/Government

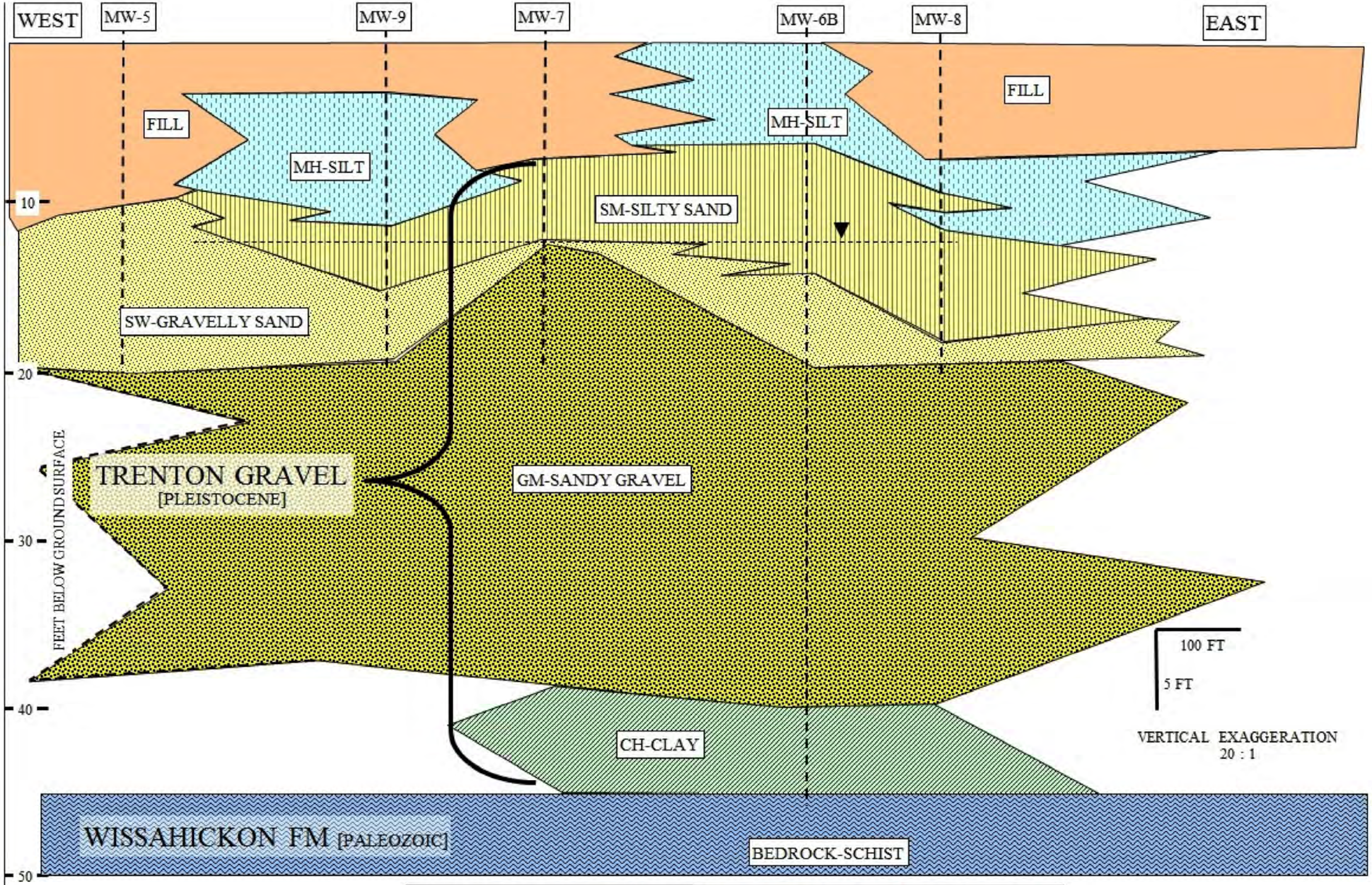
🔴 Actions performed by PADEP/EPA

🟢 Actions performed by Owner

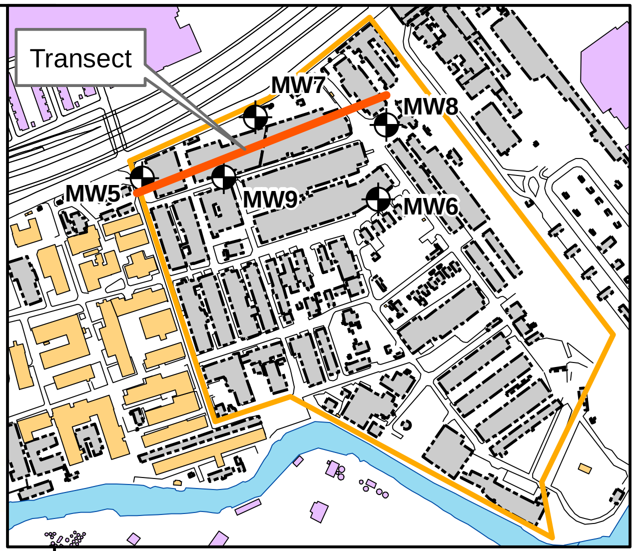
HISTORICAL TIMELINE
(1984 - 2013)

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 1-4
	Cabrera Services 103 E. Mount Royal Ave. Baltimore, MD 21202	U.S. Army Corps of Engineers, Baltimore District



EAST / WEST CROSS SECTION PARALLEL TO TACONY STREET



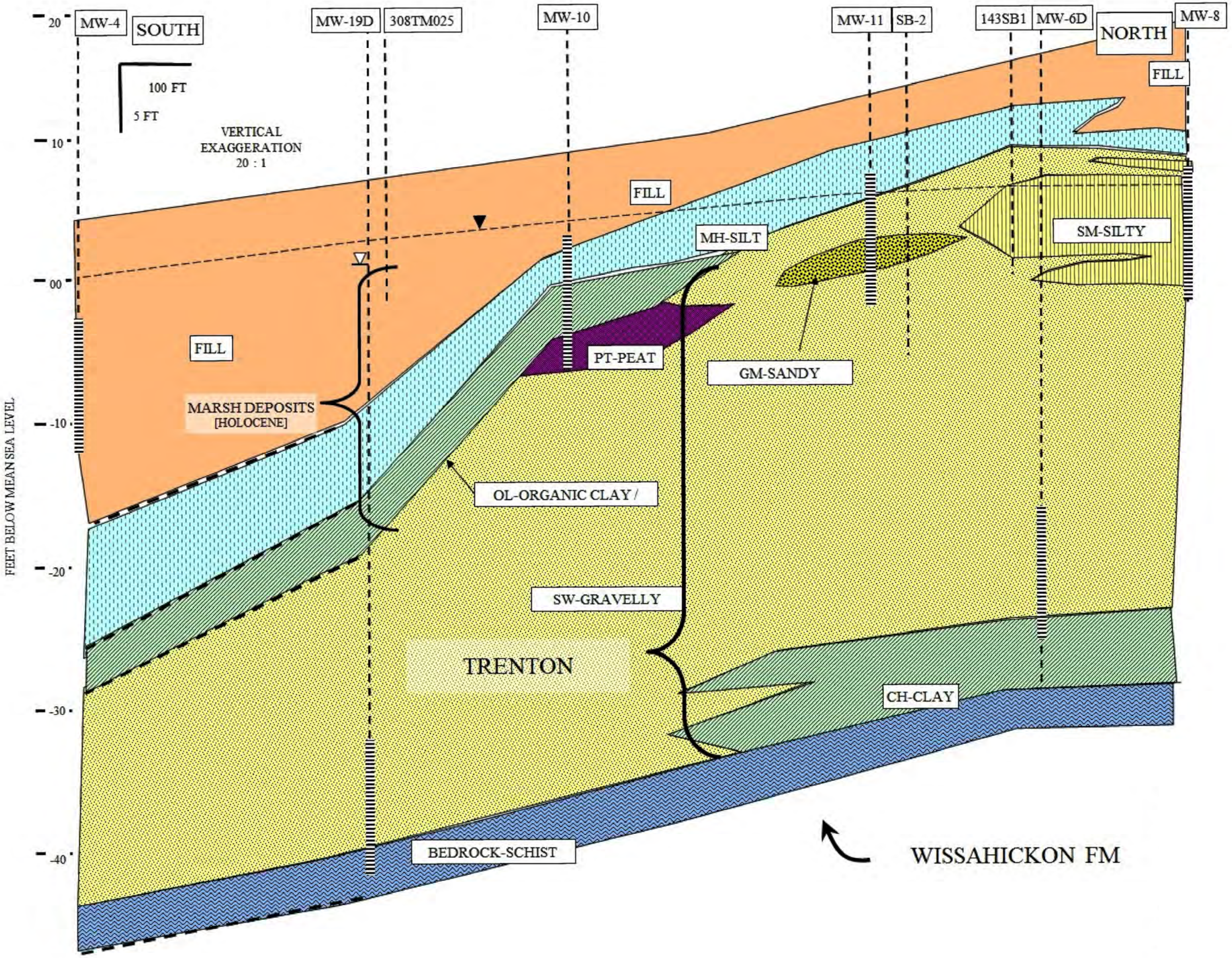
EAST / WEST CROSS SECTION
PARALLEL TO TACONY STREET

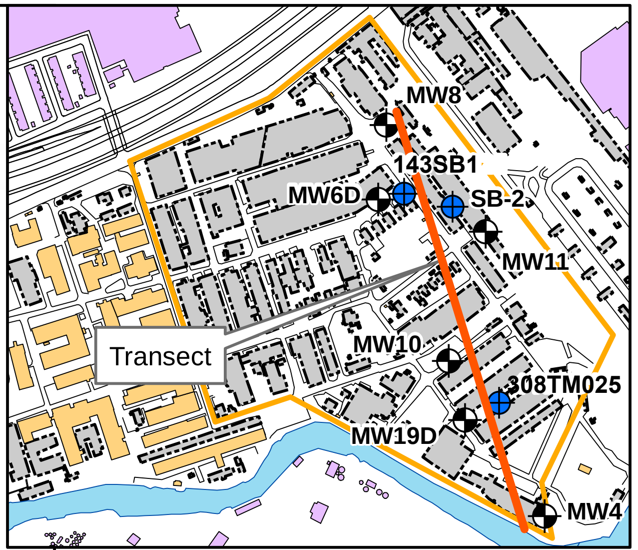
AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 2-1

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District





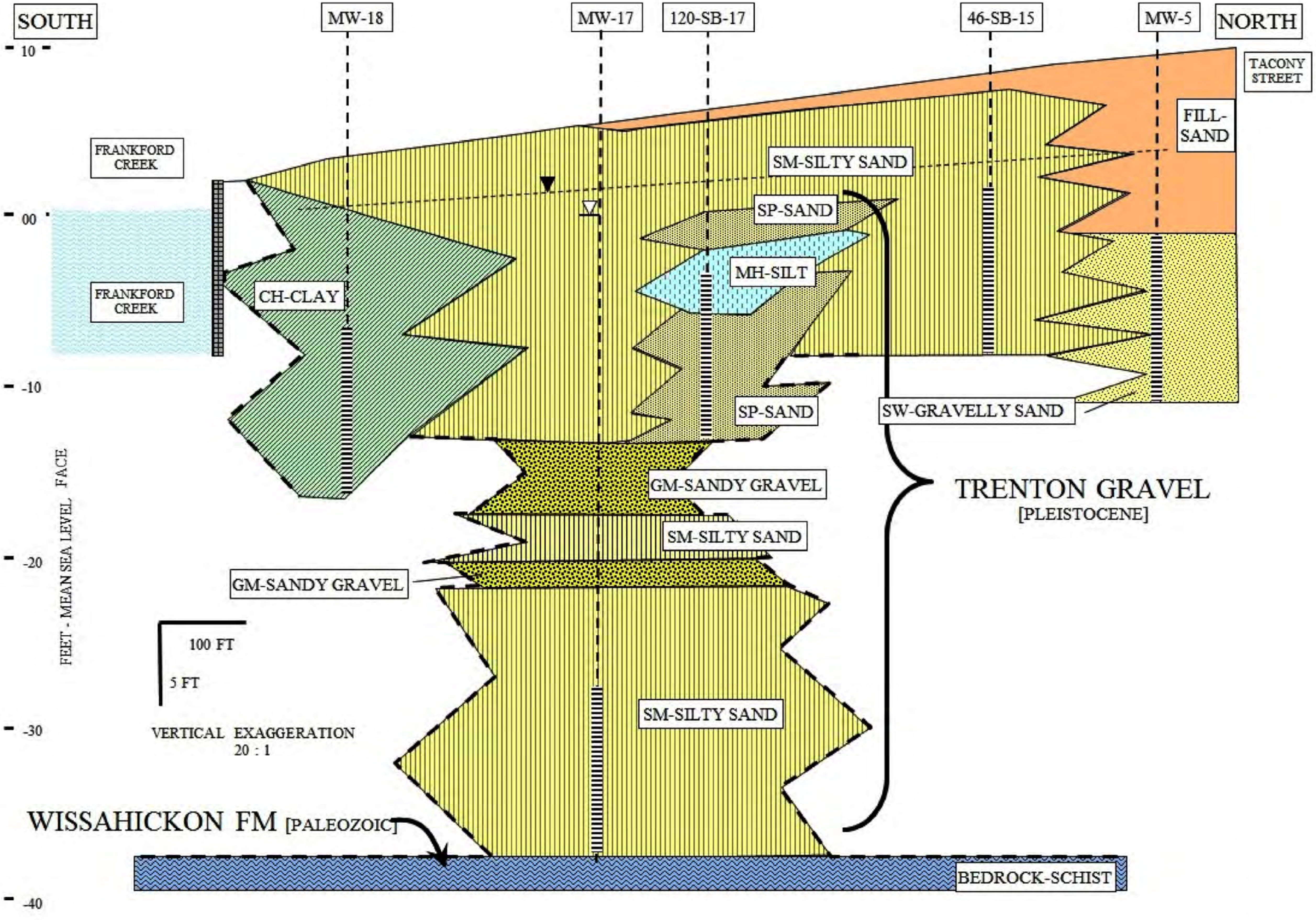
NORTH / SOUTH CROSS SECTION
PARALLEL TO SANGER STREET

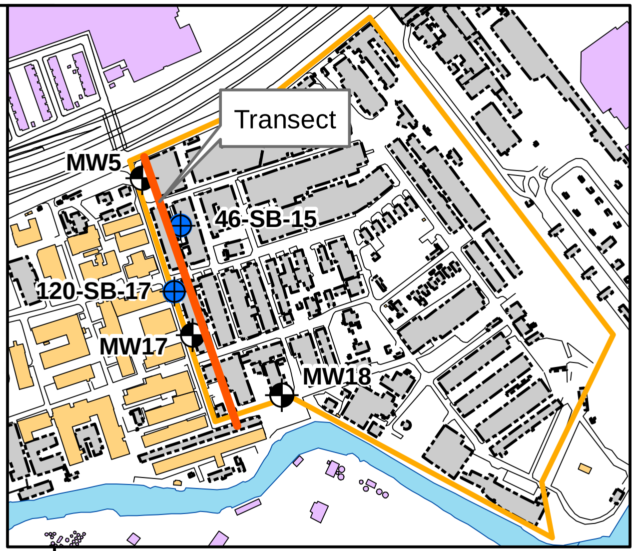
AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 2-2

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District





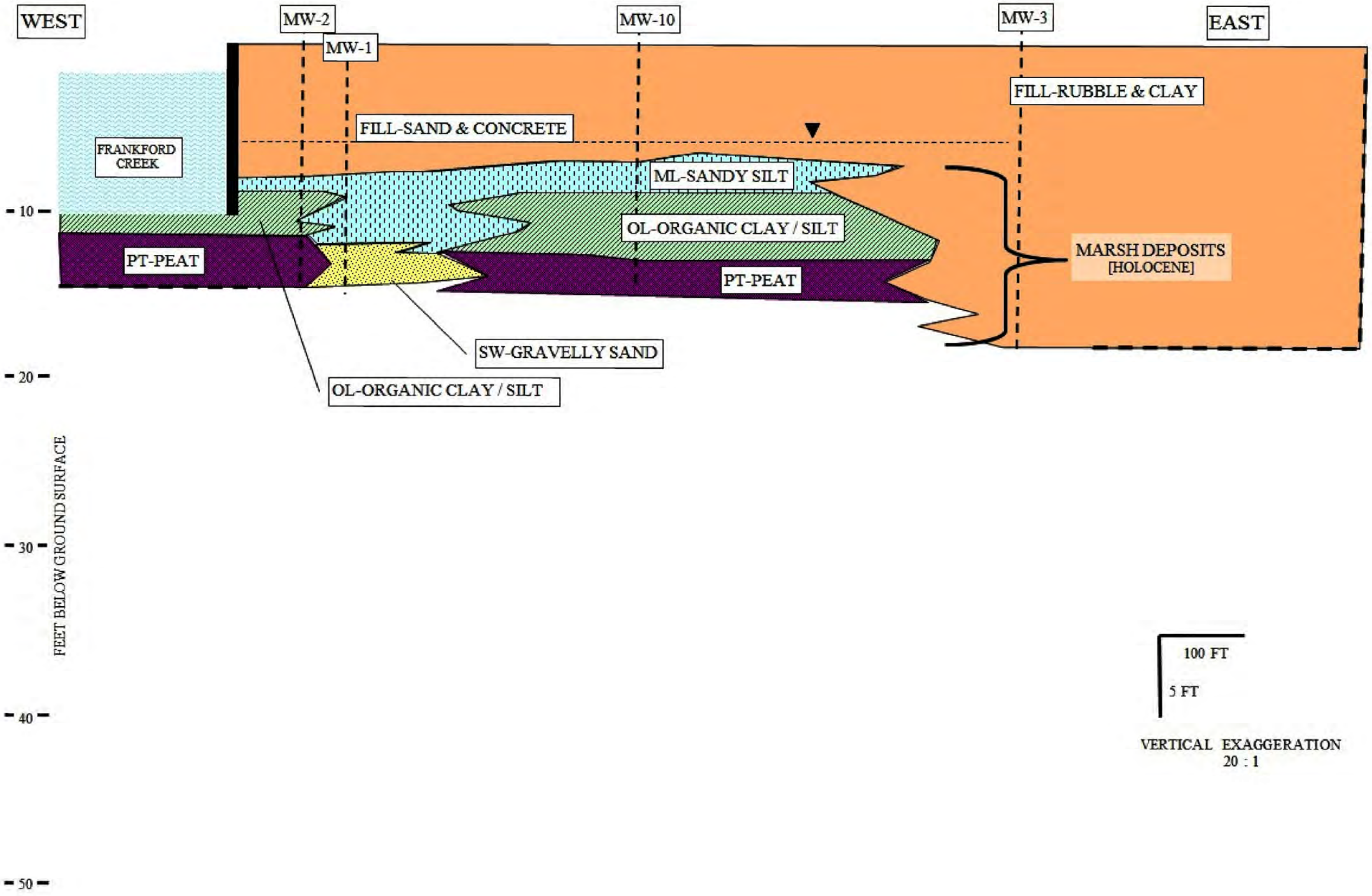
NORTH / SOUTH CROSS SECTION
PARALLEL TO BAIRD STREET

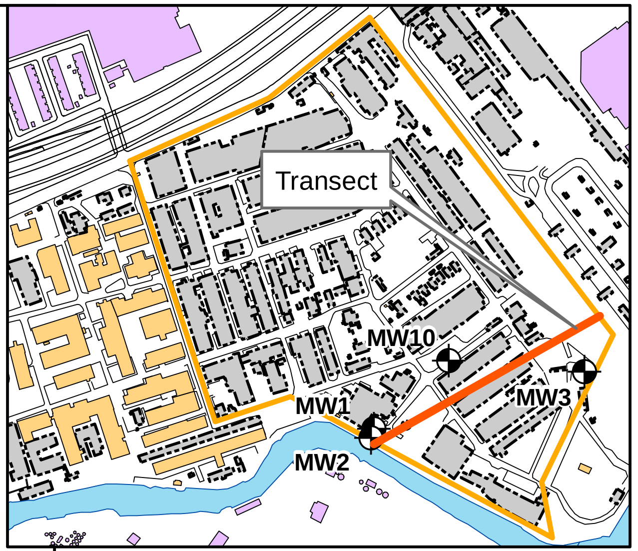
AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 2-3

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District





EAST / WEST CROSS SECTION
PARALLEL TO BUILDING 308

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 2-4

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District

N

Legend

- ⟋ Roads Edges
- ▨ Outside FFA Area
- ⬛ Original Frankford Arsenal Boundary
- ▨ Waterbodies

Buildings

- 🟧 Existing Building (FFA)
- ⬜ Demolished Building (FFA)
- ▨ Radiological Decontamination
- ▨ Explosives Decontamination
- ⬚ Area Outside Building Decontaminated for Radionuclides

Note: 135 Buildings were Decontaminated for Heavy Metals. Building numbers were not specified in report.

0 300 600
Scale (feet)

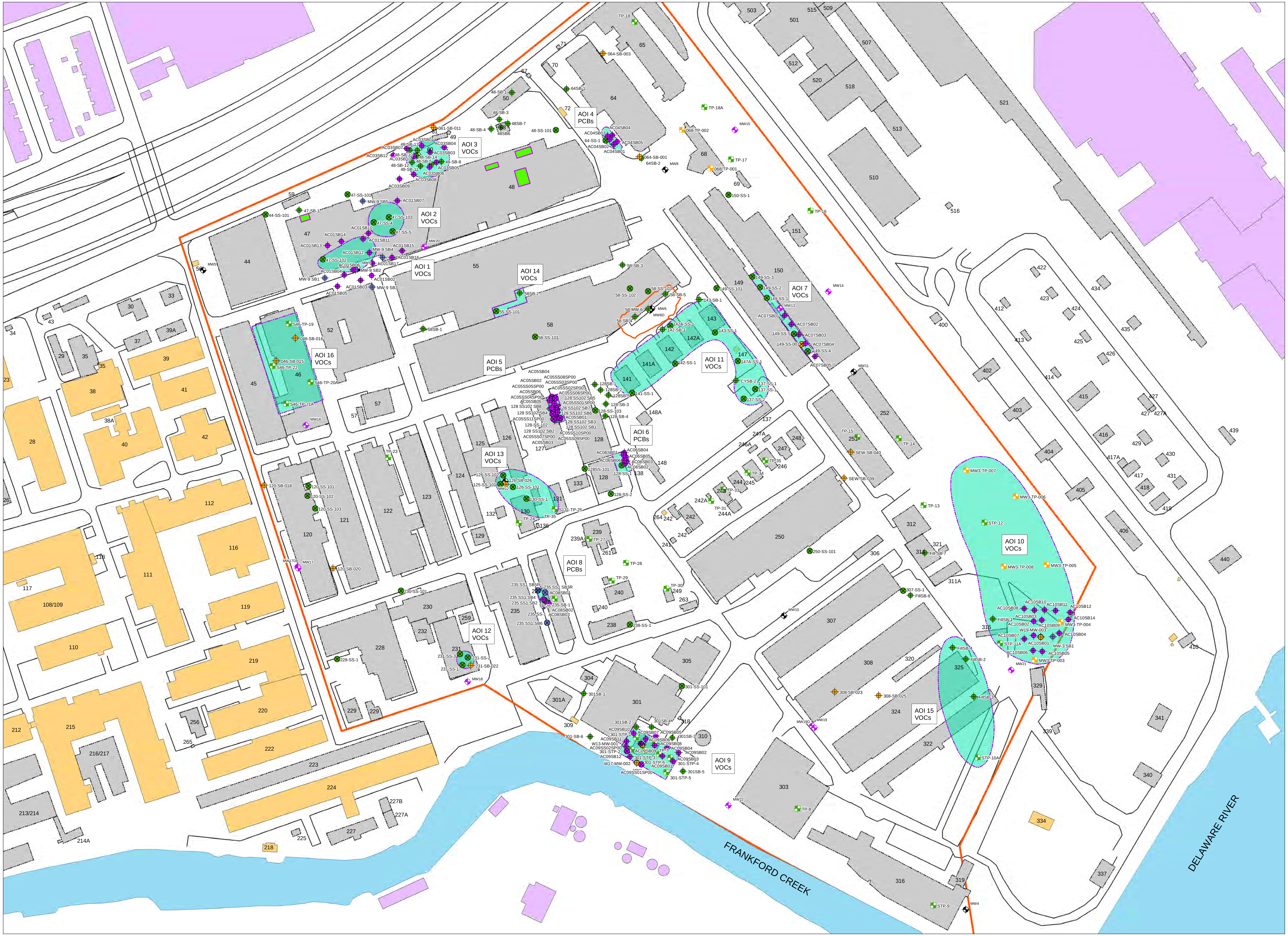
USATHAMA BUILDING DECONTAMINATION (1980 - 1981)

AREA I SOIL REMEDIAL INVESTIGATION FORMER FRANKFORD ARSENAL PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 3-1

Cabrera Services
1106 N Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps of Engineers, Baltimore District



Legend

- 2008, Soil Boring
- 2007, Soil Boring
- 2005, Soil Boring
- 1999, Soil Boring
- 2008, Surface Soil
- 2007, Surface Soil
- 2005, Surface Soil
- 1999, Surface Soil
- 2007, Test Pit
- 1999, Test Pit
- Monitoring Well (2007)
- Monitoring Well (Installed before 2007)
- Building 58 Leaking Sump
- UST Locations/ CON Items
- Waterbodies

BUILDINGS

- Demolished (FFA)
- Existing (FFA)
- Area I Boundary
- Outside FFA Area
- Potential Source Zones

0 80 160 320

Scale (feet)

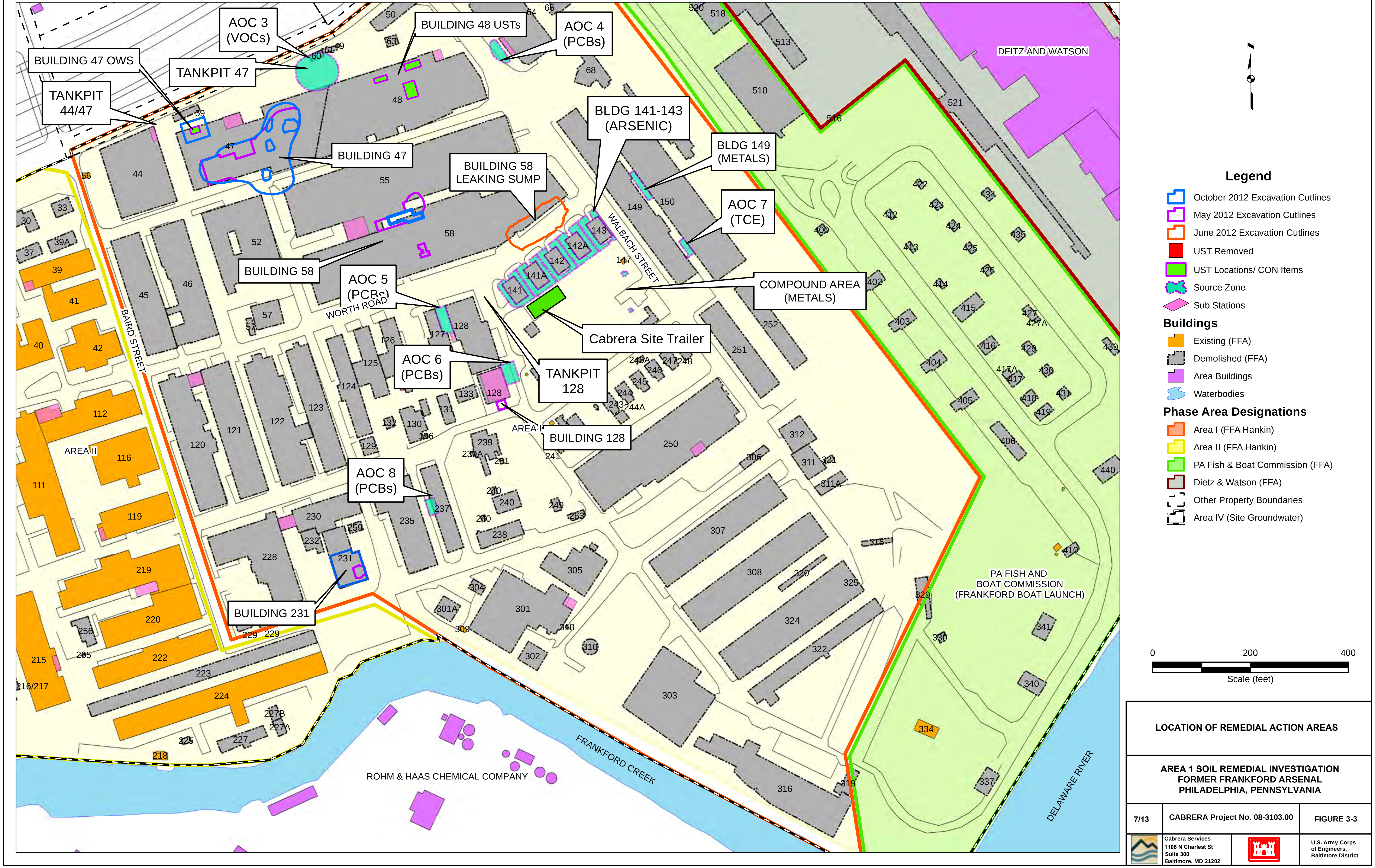
AREA I POTENTIAL SOURCE ZONES

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 3-2

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



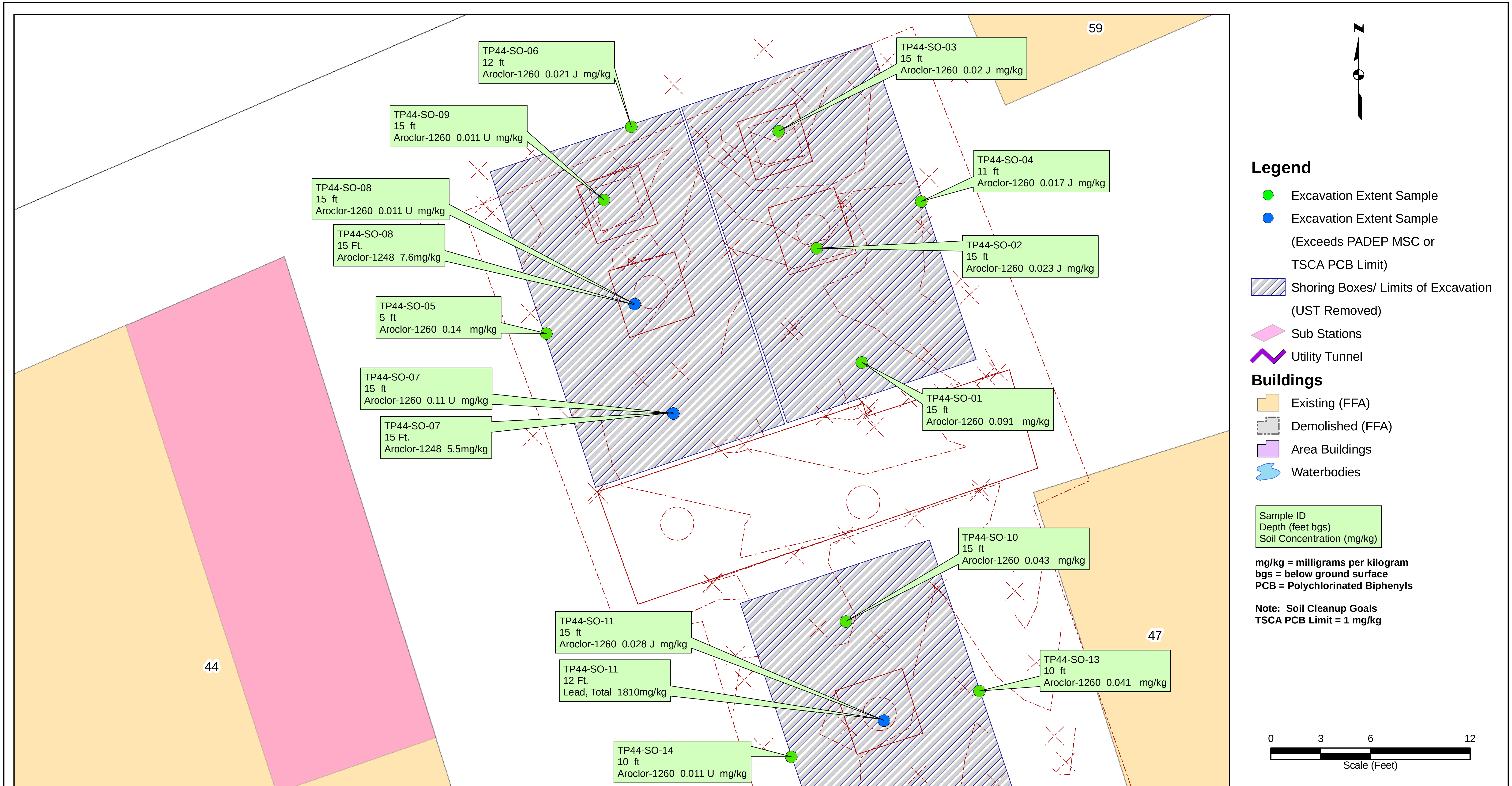
LOCATION OF REMEDIAL ACTION AREAS

AREA 1 SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 3-3

Cabrera Services
1106 N Charlest St
Suite 300
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



44/47 TANK PIT
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	**CABRERA Project No. 08-3102.00**	**FIGURE 3-4**

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- ▨ Shoring Boxes/ Limits of Excavation (UST Removed)
- ◆ Sub Stations
- ⩘ Utility Tunnel

Buildings

- ▭ Existing (FFA)
- ▭ Demolished (FFA)
- ▭ Area Buildings
- ▭ Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
MSC = Medium Specific Concentration

Note: Soil Cleanup Goals
(PADEP Soil MSCs)
Arsenic = 53 mg/kg

0 10 20 40
Scale (Feet)

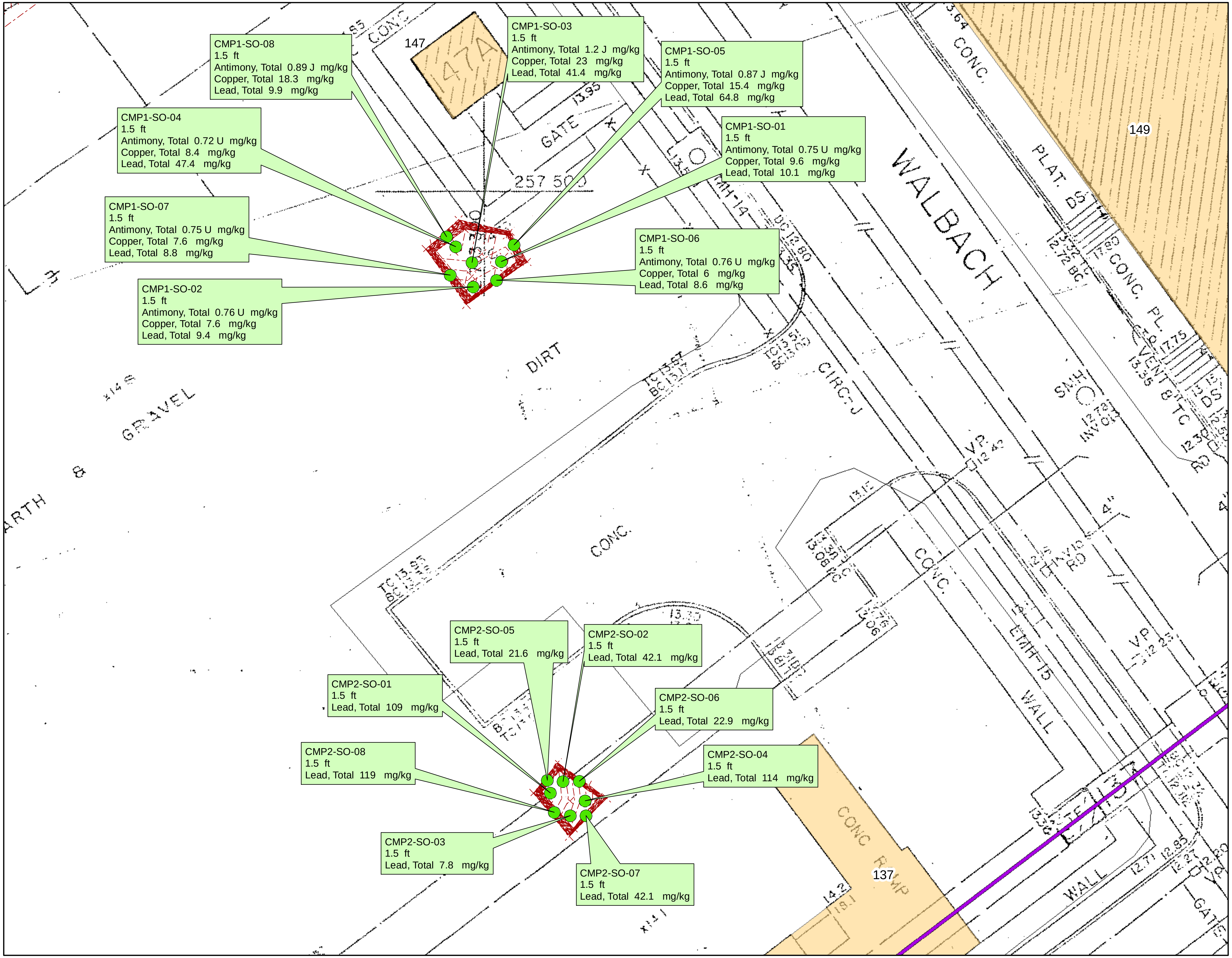
BUILDING 141-143
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	CABRERA Project No. 08-3102.00	FIGURE 3-5

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- ⌒ Excavation Contour
- 🟥 UST Removed
- ◆ Sub Stations
- ∧ Utility Tunnel

Buildings

- ▨ Existing (FFA)
- ▨ Demolished (FFA)
- ▨ Area Buildings
- ▨ Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
MSC = Medium Specific Concentration

Note: Soil Cleanup Goals
(PADEP Soil MSCs)
Antimony = 27 mg/kg
Copper = 36,000 mg/kg
Lead = 450 mg/kg

0 6 12 24
Scale (Feet)

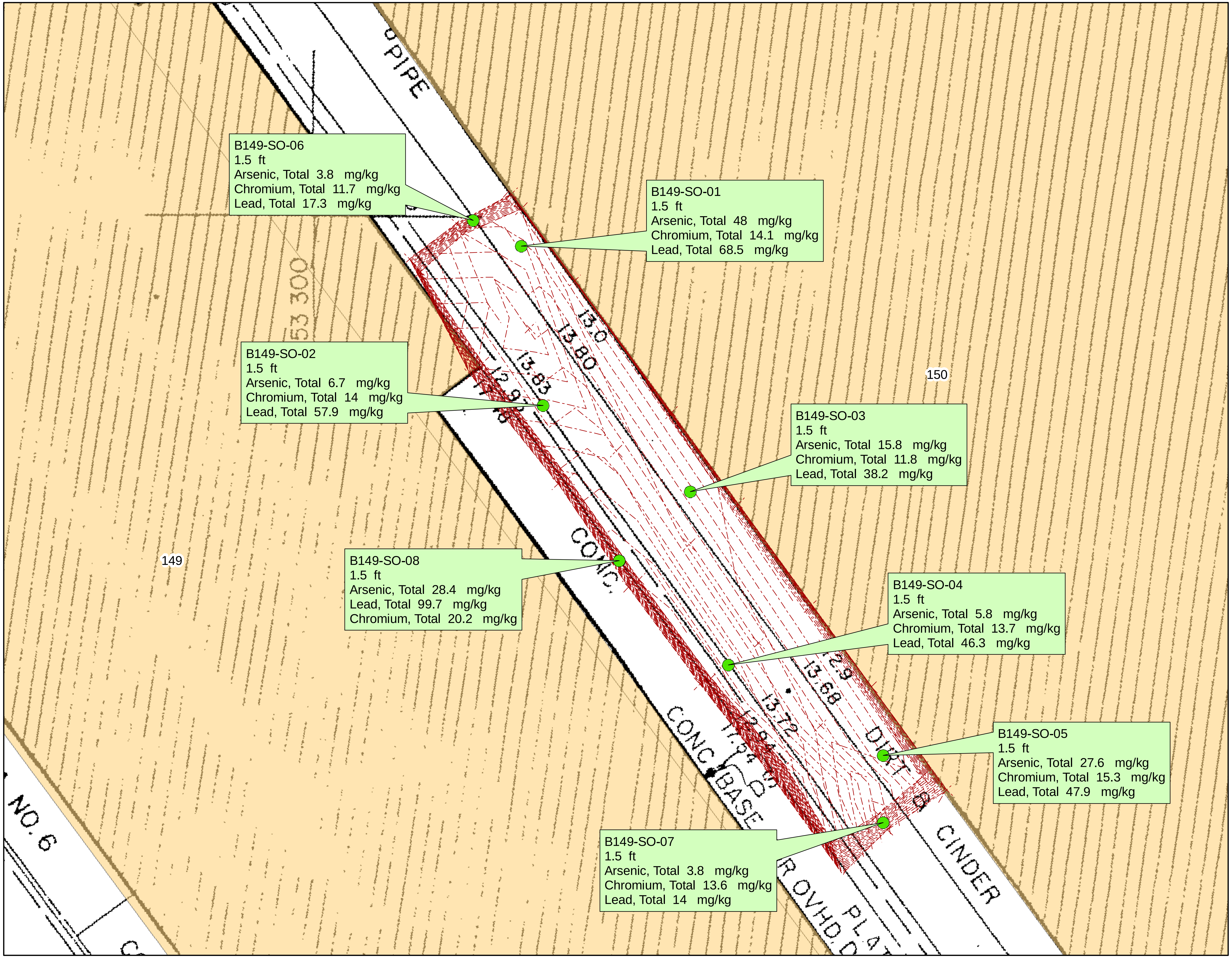
COMPOUND AREA
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	CABRERA Project No. 08-3102.00	FIGURE 3-6

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



B149-SO-06
1.5 ft
Arsenic, Total 3.8 mg/kg
Chromium, Total 11.7 mg/kg
Lead, Total 17.3 mg/kg

B149-SO-01
1.5 ft
Arsenic, Total 48 mg/kg
Chromium, Total 14.1 mg/kg
Lead, Total 68.5 mg/kg

B149-SO-02
1.5 ft
Arsenic, Total 6.7 mg/kg
Chromium, Total 14 mg/kg
Lead, Total 57.9 mg/kg

B149-SO-03
1.5 ft
Arsenic, Total 15.8 mg/kg
Chromium, Total 11.8 mg/kg
Lead, Total 38.2 mg/kg

B149-SO-08
1.5 ft
Arsenic, Total 28.4 mg/kg
Lead, Total 99.7 mg/kg
Chromium, Total 20.2 mg/kg

B149-SO-04
1.5 ft
Arsenic, Total 5.8 mg/kg
Chromium, Total 13.7 mg/kg
Lead, Total 46.3 mg/kg

B149-SO-05
1.5 ft
Arsenic, Total 27.6 mg/kg
Chromium, Total 15.3 mg/kg
Lead, Total 47.9 mg/kg

B149-SO-07
1.5 ft
Arsenic, Total 3.8 mg/kg
Chromium, Total 13.6 mg/kg
Lead, Total 14 mg/kg

N

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- Excavation Contour
- 🟥 UST Removed
- Sub Stations
- Utility Tunnel

Buildings

- Existing (FFA)
- Demolished (FFA)
- Area Buildings
- Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
MSC = Medium Specific Concentration

Note: Soil Cleanup Goals
(PADEP Soil MSCs)
Arsenic = 53 mg/kg
Chromium = 190 mg/kg
Lead = 450 mg/kg

0 5 10 20
Scale (Feet)

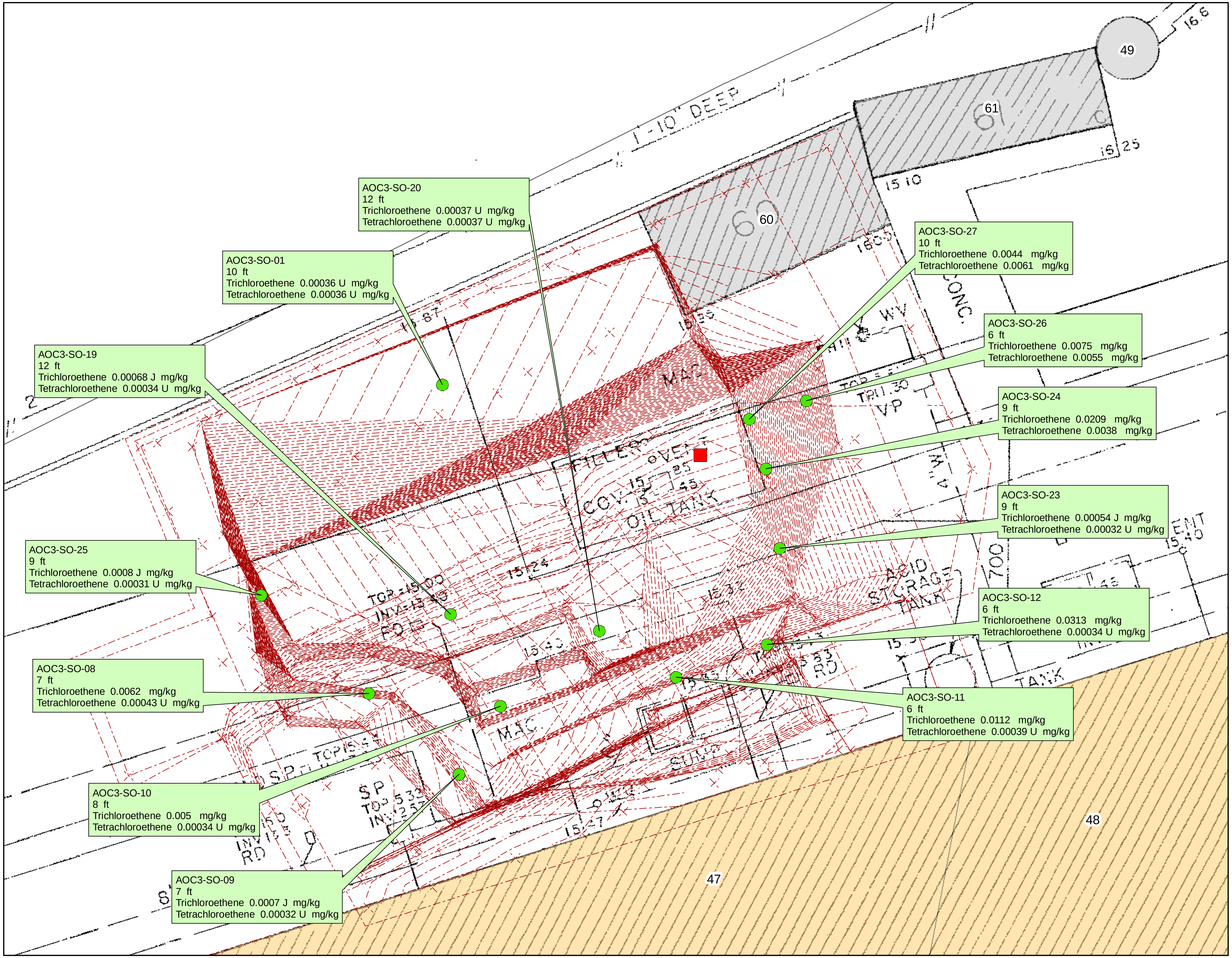
BUILDING 149
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	**CABRERA Project No. 08-3102.00**	**FIGURE 3-7**

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



AOC3-SO-20
12 ft
Trichloroethene 0.00037 U mg/kg
Tetrachloroethene 0.00037 U mg/kg

AOC3-SO-01
10 ft
Trichloroethene 0.00036 U mg/kg
Tetrachloroethene 0.00036 U mg/kg

AOC3-SO-19
12 ft
Trichloroethene 0.00068 J mg/kg
Tetrachloroethene 0.00034 U mg/kg

AOC3-SO-25
9 ft
Trichloroethene 0.0008 J mg/kg
Tetrachloroethene 0.00031 U mg/kg

AOC3-SO-08
7 ft
Trichloroethene 0.0062 mg/kg
Tetrachloroethene 0.00043 U mg/kg

AOC3-SO-10
8 ft
Trichloroethene 0.005 mg/kg
Tetrachloroethene 0.00034 U mg/kg

AOC3-SO-09
7 ft
Trichloroethene 0.0007 J mg/kg
Tetrachloroethene 0.00032 U mg/kg

AOC3-SO-27
10 ft
Trichloroethene 0.0044 mg/kg
Tetrachloroethene 0.0061 mg/kg

AOC3-SO-26
6 ft
Trichloroethene 0.0075 mg/kg
Tetrachloroethene 0.0055 mg/kg

AOC3-SO-24
9 ft
Trichloroethene 0.0209 mg/kg
Tetrachloroethene 0.0038 mg/kg

AOC3-SO-23
9 ft
Trichloroethene 0.00054 J mg/kg
Tetrachloroethene 0.00032 U mg/kg

AOC3-SO-12
6 ft
Trichloroethene 0.0313 mg/kg
Tetrachloroethene 0.00034 U mg/kg

AOC3-SO-11
6 ft
Trichloroethene 0.0112 mg/kg
Tetrachloroethene 0.00039 U mg/kg

N

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- Excavation Contour
- 🟥 UST Removed
- Sub Stations
- Utility Tunnel

Buildings

- Existing (FFA)
- Demolished (FFA)
- Area Buildings
- Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
MSC = Medium Specific Concentration

Note: Soil Cleanup Goals
(PADEP Soil MSCs)
Trichloroethene = 0.5 mg/kg
Tetrachloroethene = 0.5 mg/kg

0 5 10 20
Scale (Feet)

AOC 3
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	**CABRERA Project No. 08-3102.00**	**FIGURE 3-8**

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District

N

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- ⌒ Excavation Contour
- 🟥 UST Removed
- ◆ Sub Stations
- ⋀ Utility Tunnel

Buildings

- ▭ Existing (FFA)
- ▭ Demolished (FFA)
- ▭ Area Buildings
- ▭ Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
PCB = Polychlorinated Biphenyls

Note: Soil Cleanup Goals
TSCA PCB Limit = 1 mg/kg

0 5 10 20
Scale (Feet)

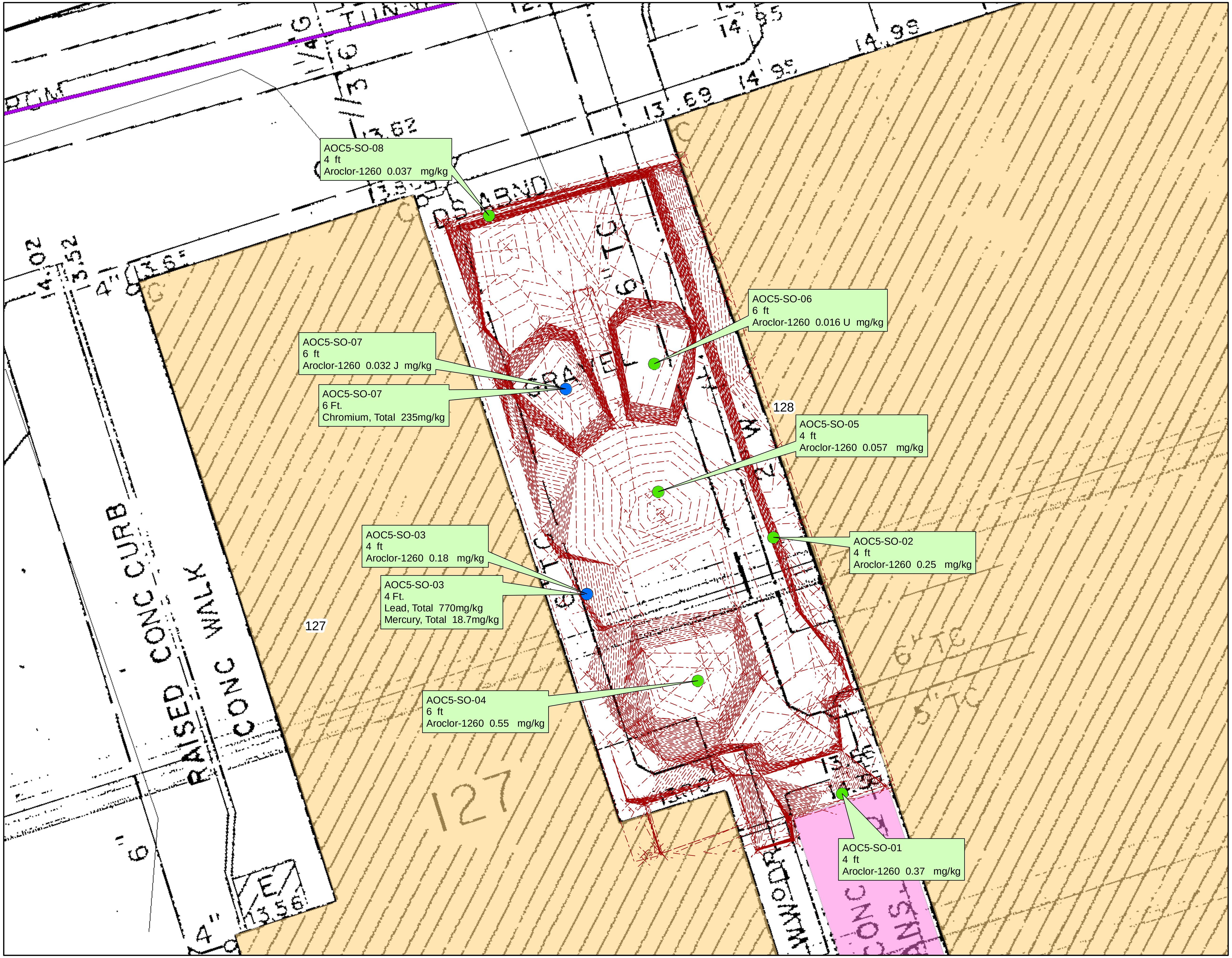
AOC 4
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	CABRERA Project No. 08-3102.00	FIGURE 3-9

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- Excavation Contour
- 🟥 UST Removed
- Sub Stations
- Utility Tunnel

Buildings

- Existing (FFA)
- Demolished (FFA)
- Area Buildings
- Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
PCB = Polychlorinated Biphenyls

Note: Soil Cleanup Goals
TSCA PCB Limit = 1 mg/kg

0 5 10 20
Scale (Feet)

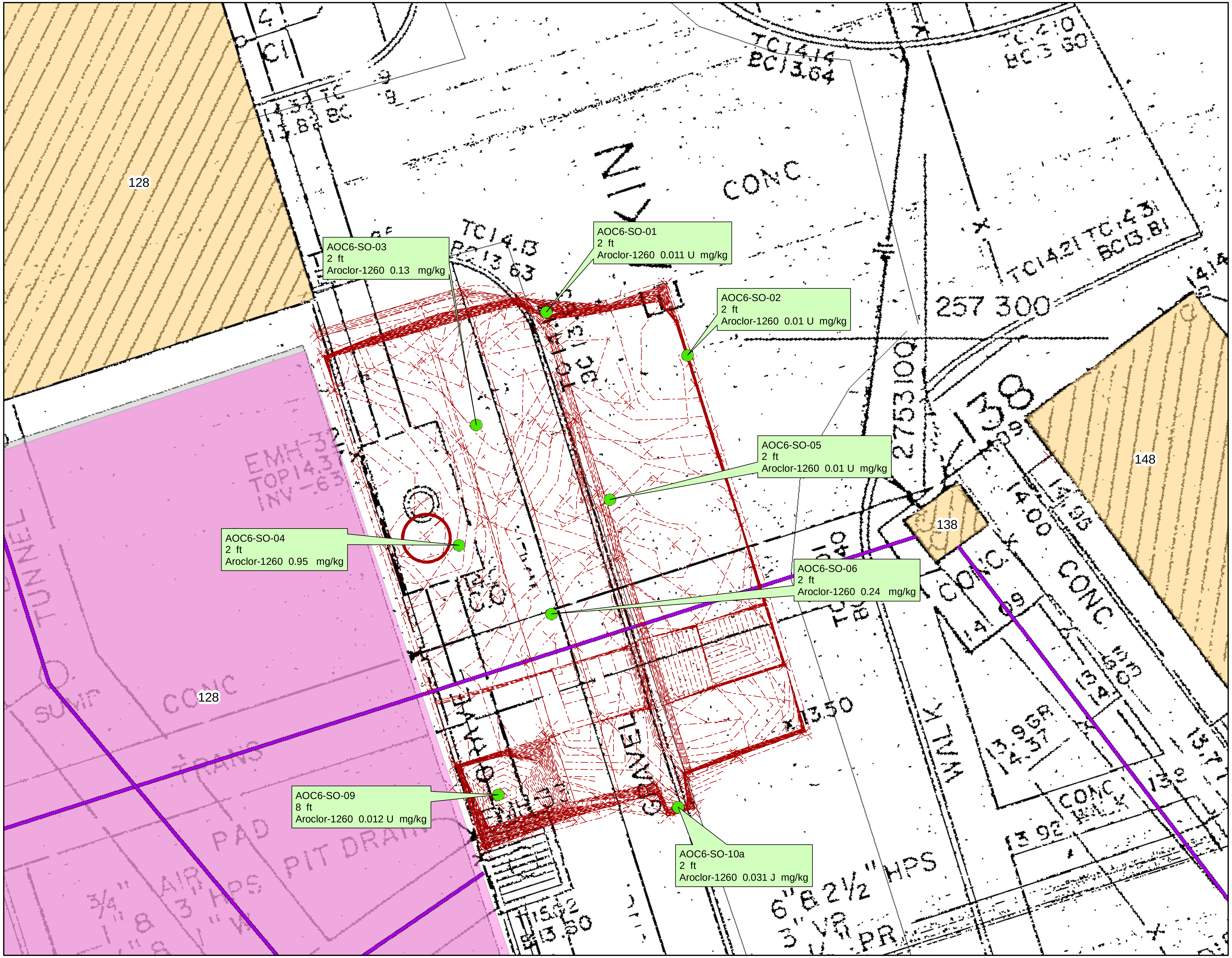
AOC 5
POST-EXCAVATION CONTOURS AND SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	CABRERA Project No. 08-3102.00	FIGURE 3-10

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



N

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- Excavation Contour
- 🟥 UST Removed
- Sub Stations
- Utility Tunnel

Buildings

- Existing (FFA)
- Demolished (FFA)
- Area Buildings
- Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
PCB = Polychlorinated Biphenyls

Note: Soil Cleanup Goals
TSCA PCB Limit = 1 mg/kg

0 5 10 20
Scale (Feet)

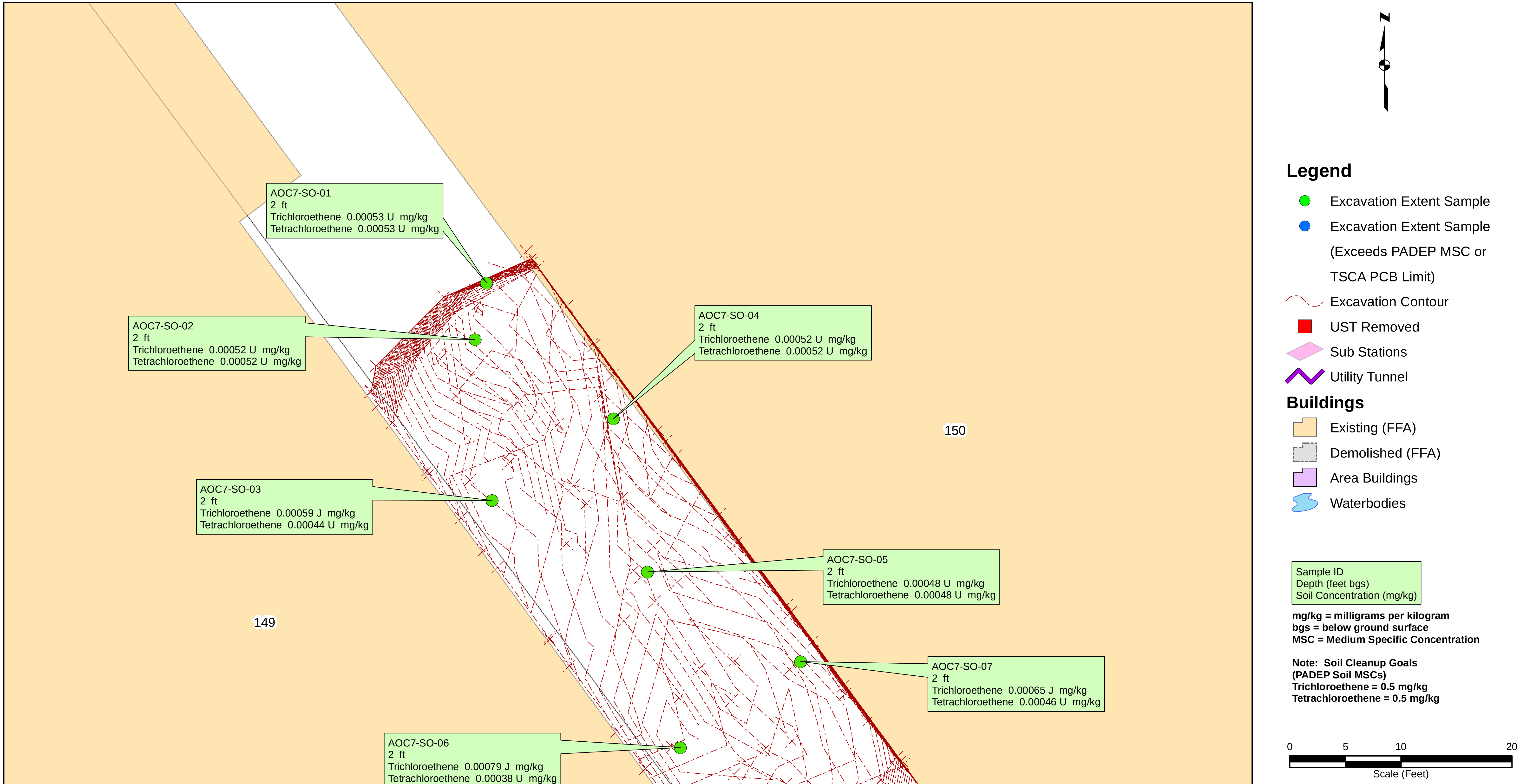
AOC 6
POST-EXCAVATION CONTOURS AND SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	CABRERA Project No. 08-3102.00	FIGURE 3-11

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps of Engineers, Baltimore District



mg/kg = milligrams per kilogram
bgs = below ground surface
MSC = Medium Specific Concentration

Note: Soil Cleanup Goals
(PADEP Soil MSCs)
Trichloroethene = 0.5 mg/kg
Tetrachloroethene = 0.5 mg/kg

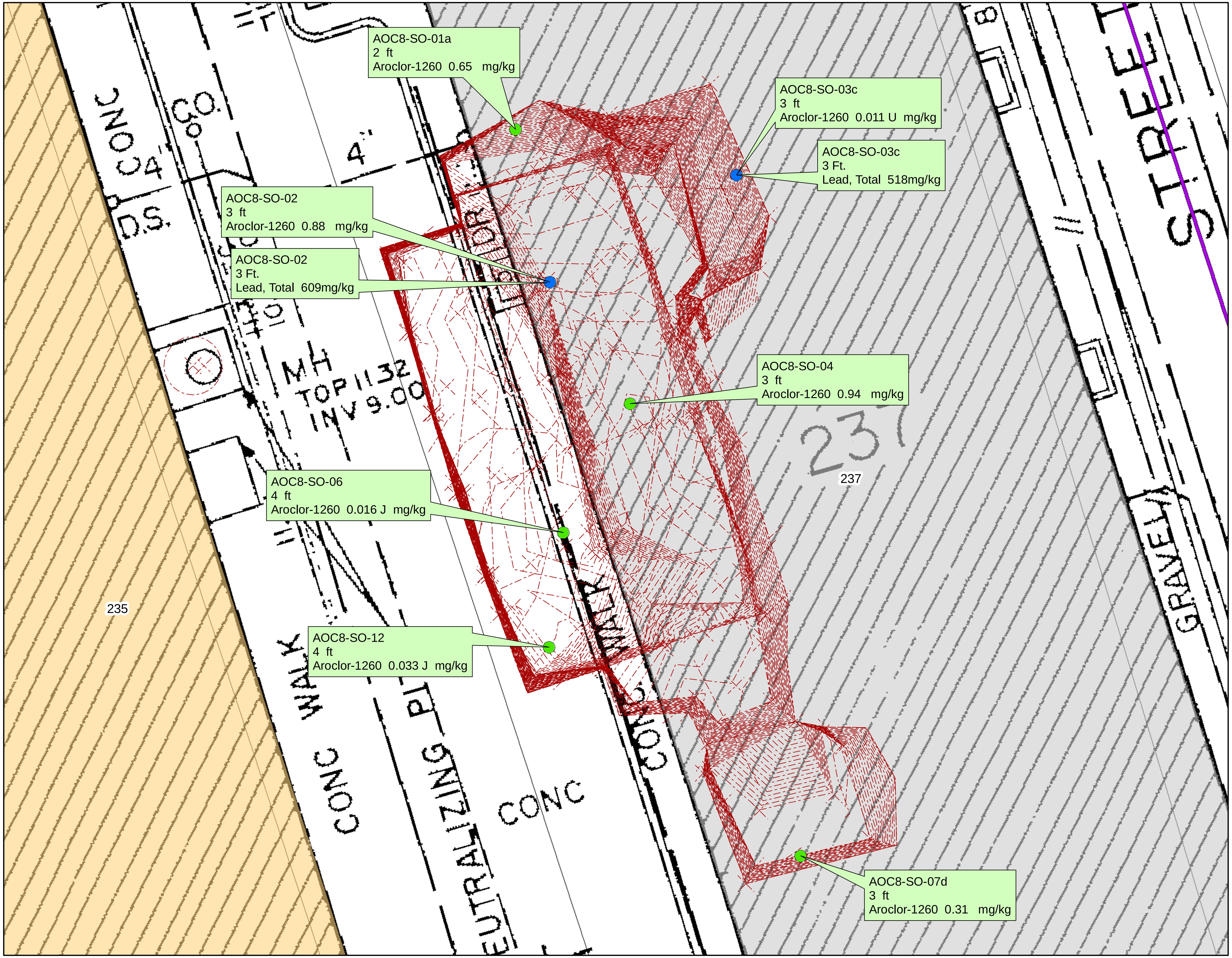
AOC 7
POST-EXCAVATION CONTOURS AND SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	**CABRERA Project No. 08-3102.00**	**FIGURE 3-12**

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



AOC8-SO-01a
2 ft
Aroclor-1260 0.65 mg/kg

AOC8-SO-03c
3 ft
Aroclor-1260 0.011 U mg/kg

AOC8-SO-03c
3 Ft.
Lead, Total 518mg/kg

AOC8-SO-02
3 ft
Aroclor-1260 0.88 mg/kg

AOC8-SO-02
3 Ft.
Lead, Total 609mg/kg

AOC8-SO-04
3 ft
Aroclor-1260 0.94 mg/kg

AOC8-SO-06
4 ft
Aroclor-1260 0.016 J mg/kg

AOC8-SO-12
4 ft
Aroclor-1260 0.033 J mg/kg

AOC8-SO-07d
3 ft
Aroclor-1260 0.31 mg/kg

N

Legend

- ● Excavation Extent Sample
- ● Excavation Extent Sample (Exceeds PADEP MSC or TSCA PCB Limit)
- ⌒ Excavation Contour
- 🟥 UST Removed
- ◆ Sub Stations
- ⋀ Utility Tunnel

Buildings

- ▢ Existing (FFA)
- ▨ Demolished (FFA)
- ▢ Area Buildings
- ▢ Waterbodies

Sample ID
Depth (feet bgs)
Soil Concentration (mg/kg)

mg/kg = milligrams per kilogram
bgs = below ground surface
PCB = Polychlorinated Biphenyls

Note: Soil Cleanup Goals
TSCA PCB Limit = 1 mg/kg

0 4 8 16
Scale (Feet)

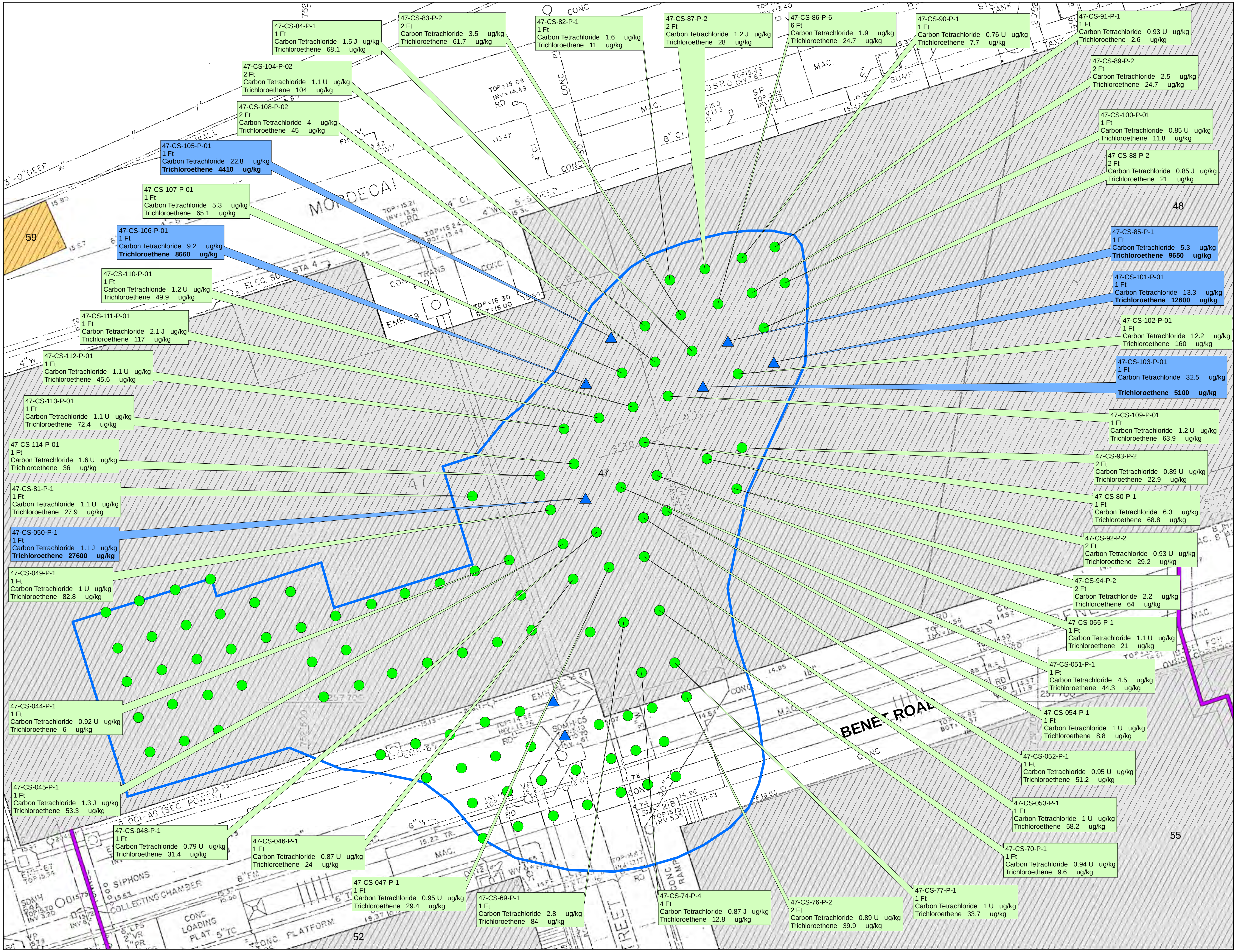
AOC 8
POST-EXCAVATION CONTOURS AND
SAMPLE LOCATIONS

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

3/10	**CABRERA Project No. 08-3102.00**	**FIGURE 3-13**

Cabrera Services
103 E. Mount Royal Ave.
Baltimore, MD 21202

U.S. Army Corps
of Engineers,
Baltimore District



Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- Excavation Extent
- Utility Tunnel

Buildings

- 🟧 Existing (FFA)
- ▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
U = Not detected above method detection limit
J = Estimated Value

Bold result indicates sample concentration exceeds soil standard

0 30 60
Scale (feet)

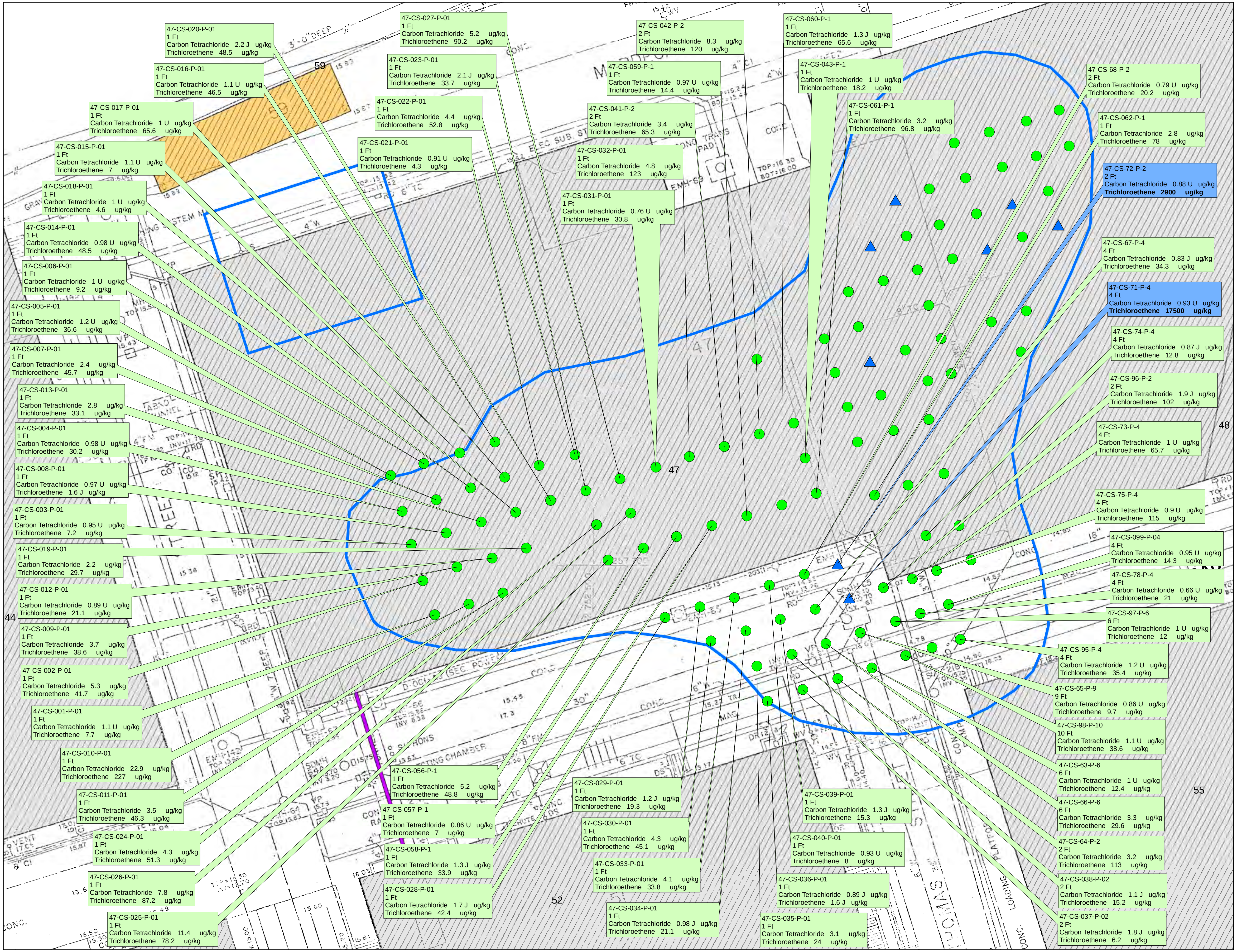
BUILDING 47 - NORTH
CONFIRMATORY SAMPLE RESULTS
MAY 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/12	CABRERA Project No. 08-3102.00	FIGURE 3-14

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- Excavation Extent
- Utility Tunnel

Buildings

- 🟧 Existing (FFA)
- ▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
U = Not detected above method detection limit
J = Estimated Value

Bold result indicates sample concentration exceeds soil standard

0 30 60
Scale (feet)

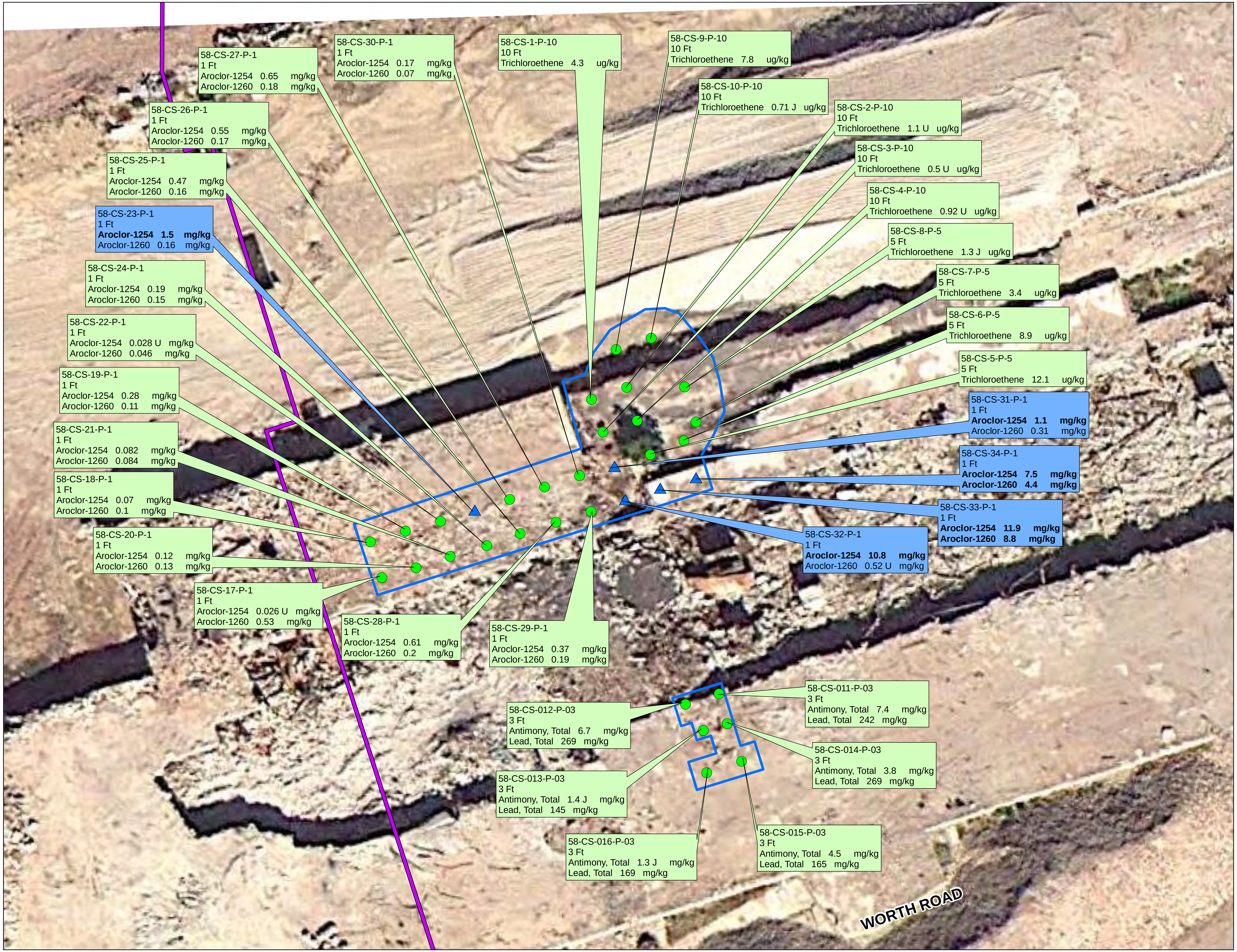
BUILDING 47 - SOUTH
CONFIRMATORY SAMPLE RESULTS
MAY 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/12	CABRERA Project No. 08-3102.00	FIGURE 3-15

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- Excavation Extent
- Utility Tunnel

Buildings

- 🟧 Existing (FFA)
- ▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
U = Not detected above method detection limit
J = Estimated Value

Bold result indicates sample concentration exceeds soil standard

0 30 60
Scale (feet)

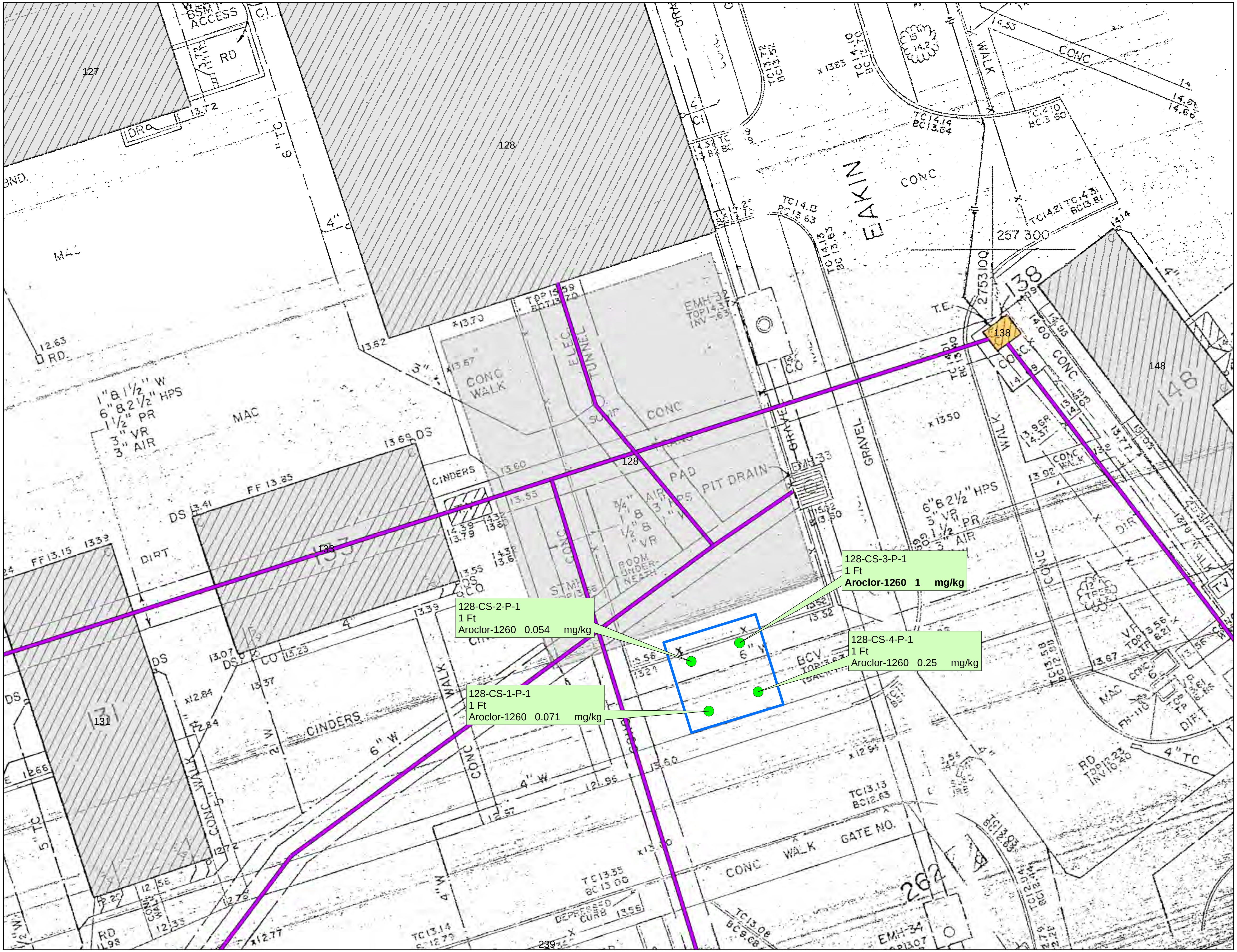
BUILDING 58
CONFIRMATORY SAMPLE RESULTS
MAY 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/12 | CABRERA Project No. 08-3102.00 | FIGURE 3-16

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- Excavation Extent
- Utility Tunnel

Buildings

- 🟧 Existing (FFA)
- ▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
U = Not detected above method detection limit
J = Estimated Value

Bold result indicates sample concentration exceeds soil standard

0 20 40
Scale (feet)

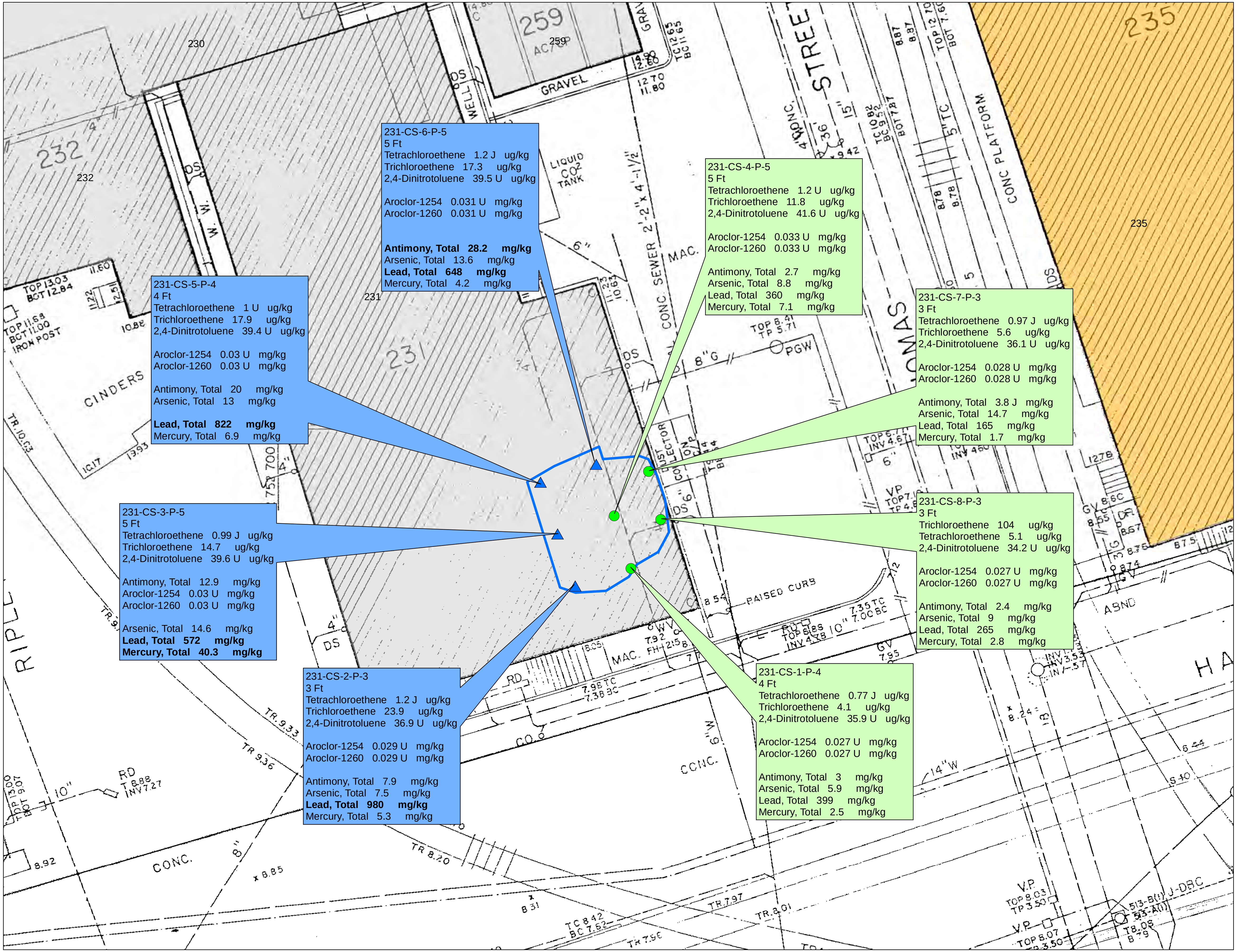
BUILDING 128
CONFIRMATORY SAMPLE RESULTS
MAY 2012

AREA I SOIL INTERIM REMOVAL ACTION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/12	CABRERA Project No. 08-3102.00	FIGURE 3-17

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



231-CS-6-P-5
5 Ft
Tetrachloroethene 1.2 J ug/kg
Trichloroethene 17.3 ug/kg
2,4-Dinitrotoluene 39.5 U ug/kg

Aroclor-1254 0.031 U mg/kg
Aroclor-1260 0.031 U mg/kg

Antimony, Total 28.2 mg/kg
Arsenic, Total 13.6 mg/kg
Lead, Total 648 mg/kg
Mercury, Total 4.2 mg/kg

231-CS-4-P-5
5 Ft
Tetrachloroethene 1.2 U ug/kg
Trichloroethene 11.8 ug/kg
2,4-Dinitrotoluene 41.6 U ug/kg

Aroclor-1254 0.033 U mg/kg
Aroclor-1260 0.033 U mg/kg

Antimony, Total 2.7 mg/kg
Arsenic, Total 8.8 mg/kg
Lead, Total 360 mg/kg
Mercury, Total 7.1 mg/kg

231-CS-5-P-4
4 Ft
Tetrachloroethene 1 U ug/kg
Trichloroethene 17.9 ug/kg
2,4-Dinitrotoluene 39.4 U ug/kg

Aroclor-1254 0.03 U mg/kg
Aroclor-1260 0.03 U mg/kg

Antimony, Total 20 mg/kg
Arsenic, Total 13 mg/kg

Lead, Total 822 mg/kg
Mercury, Total 6.9 mg/kg

231-CS-7-P-3
3 Ft
Tetrachloroethene 0.97 J ug/kg
Trichloroethene 5.6 ug/kg
2,4-Dinitrotoluene 36.1 U ug/kg

Aroclor-1254 0.028 U mg/kg
Aroclor-1260 0.028 U mg/kg

Antimony, Total 3.8 J mg/kg
Arsenic, Total 14.7 mg/kg
Lead, Total 165 mg/kg
Mercury, Total 1.7 mg/kg

231-CS-3-P-5
5 Ft
Tetrachloroethene 0.99 J ug/kg
Trichloroethene 14.7 ug/kg
2,4-Dinitrotoluene 39.6 U ug/kg

Antimony, Total 12.9 mg/kg
Aroclor-1254 0.03 U mg/kg
Aroclor-1260 0.03 U mg/kg

Arsenic, Total 14.6 mg/kg
Lead, Total 572 mg/kg
Mercury, Total 40.3 mg/kg

231-CS-8-P-3
3 Ft
Trichloroethene 104 ug/kg
Tetrachloroethene 5.1 ug/kg
2,4-Dinitrotoluene 34.2 U ug/kg

Aroclor-1254 0.027 U mg/kg
Aroclor-1260 0.027 U mg/kg

Antimony, Total 2.4 mg/kg
Arsenic, Total 9 mg/kg
Lead, Total 265 mg/kg
Mercury, Total 2.8 mg/kg

231-CS-2-P-3
3 Ft
Tetrachloroethene 1.2 J ug/kg
Trichloroethene 23.9 ug/kg
2,4-Dinitrotoluene 36.9 U ug/kg

Aroclor-1254 0.029 U mg/kg
Aroclor-1260 0.029 U mg/kg

Antimony, Total 7.9 mg/kg
Arsenic, Total 7.5 mg/kg
Lead, Total 980 mg/kg
Mercury, Total 5.3 mg/kg

231-CS-1-P-4
4 Ft
Tetrachloroethene 0.77 J ug/kg
Trichloroethene 4.1 ug/kg
2,4-Dinitrotoluene 35.9 U ug/kg

Aroclor-1254 0.027 U mg/kg
Aroclor-1260 0.027 U mg/kg

Antimony, Total 3 mg/kg
Arsenic, Total 5.9 mg/kg
Lead, Total 399 mg/kg
Mercury, Total 2.5 mg/kg

Confirmatory Samples

● Soil Sample (Below MSC)
▲ Soil Sample (Exceeds MSC)
Excavation Extent
Utility Tunnel

Buildings

🟧 Existing (FFA)
▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram
mg/kg = Milligrams per kilogram
U = Not detected above method detection limit
J = Estimated Value

Bold result indicates sample concentration exceeds soil standard

0 20 40
Scale (feet)

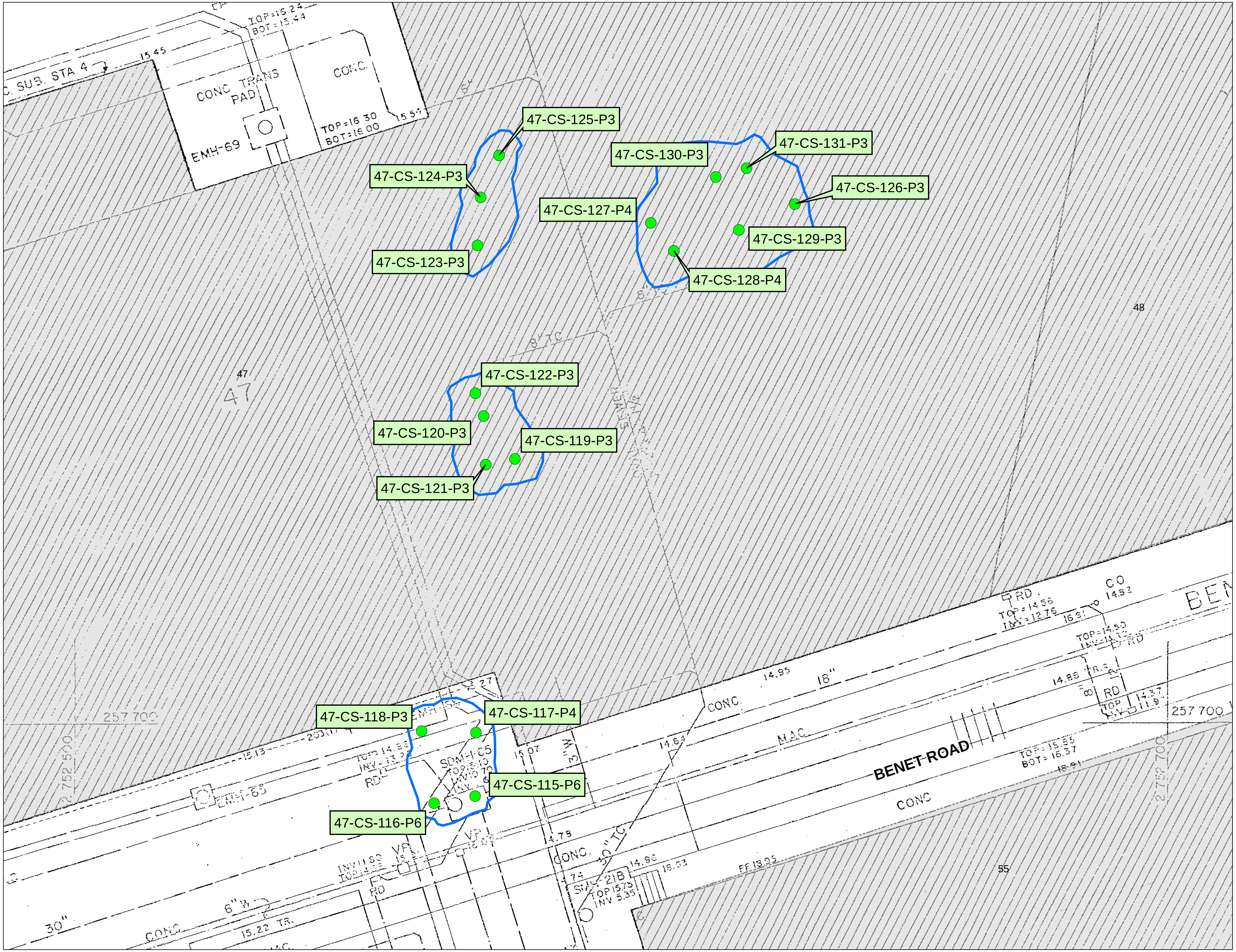
BUILDING 231
CONFIRMATORY SAMPLE RESULTS
MAY 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/12	CABRERA Project No. 08-3102.00	FIGURE 3-18

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Confirmatory Samples

- ● Soil Sample (Below MSC)
- ● Soil Sample (Exceeds MSC)
- Excavation Extent
- Utility Tunnel

Buildings

- 🟧 Existing (FFA)
- ▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram

0 20 40
Scale (feet)

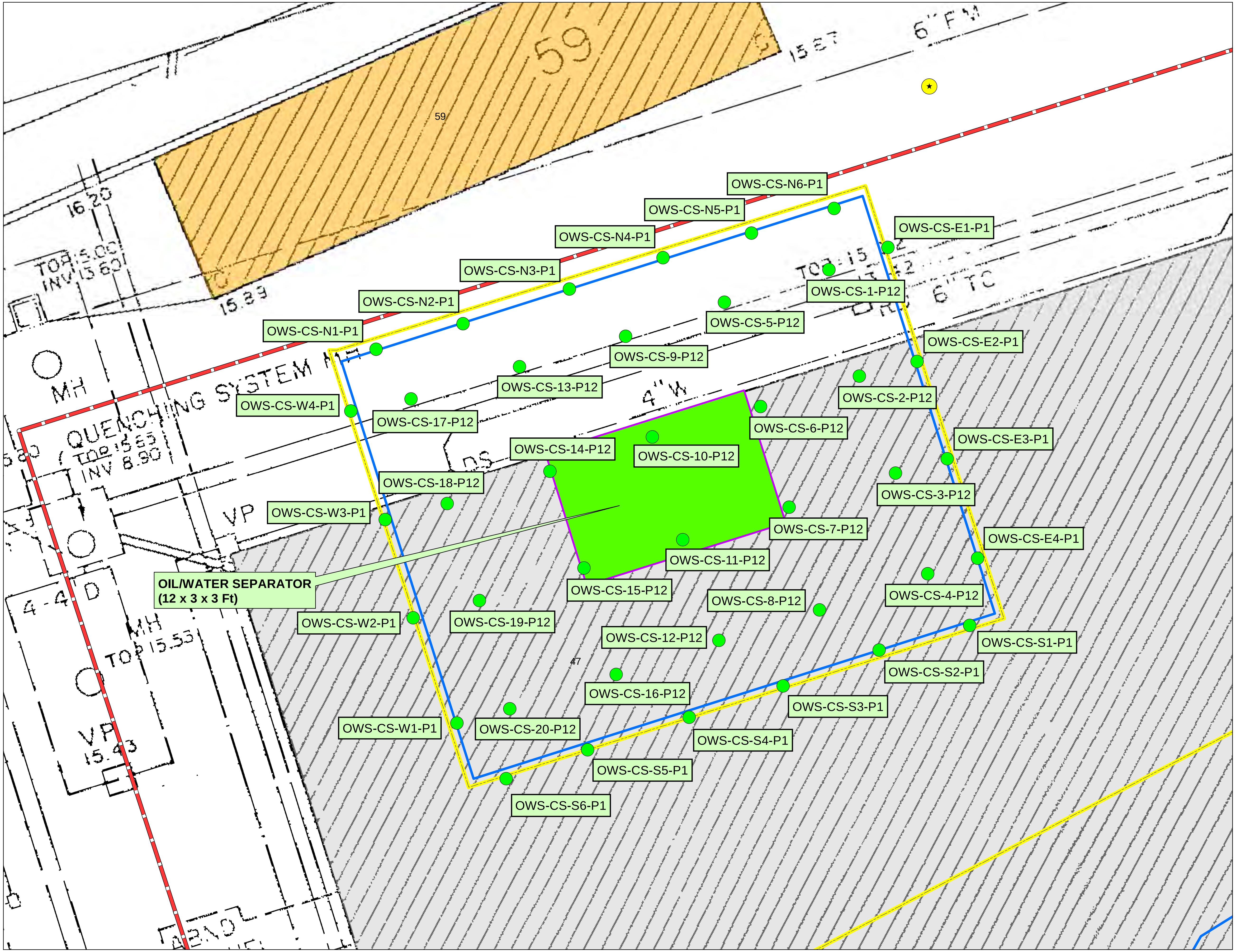
BUILDING 47
SOILS FINAL SAMPLE LOCATIONS
OCTOBER 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

10/12	CABRERA Project No. 08-3102.00	FIGURE 3-19

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



N

★ Signal Person

Confirmatory Samples

● Soil Sample (Below MSC)

● Soil Sample (Exceeds MSC)

Excavation Extent

Excavation Area Barricade (Snow Fence)

Truck Route

Utility Tunnel

🟩 UST Locations/ CON Items

🟪 Substations

Buildings

🟧 Existing (FFA)

▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram

0 10 20
Scale (feet)

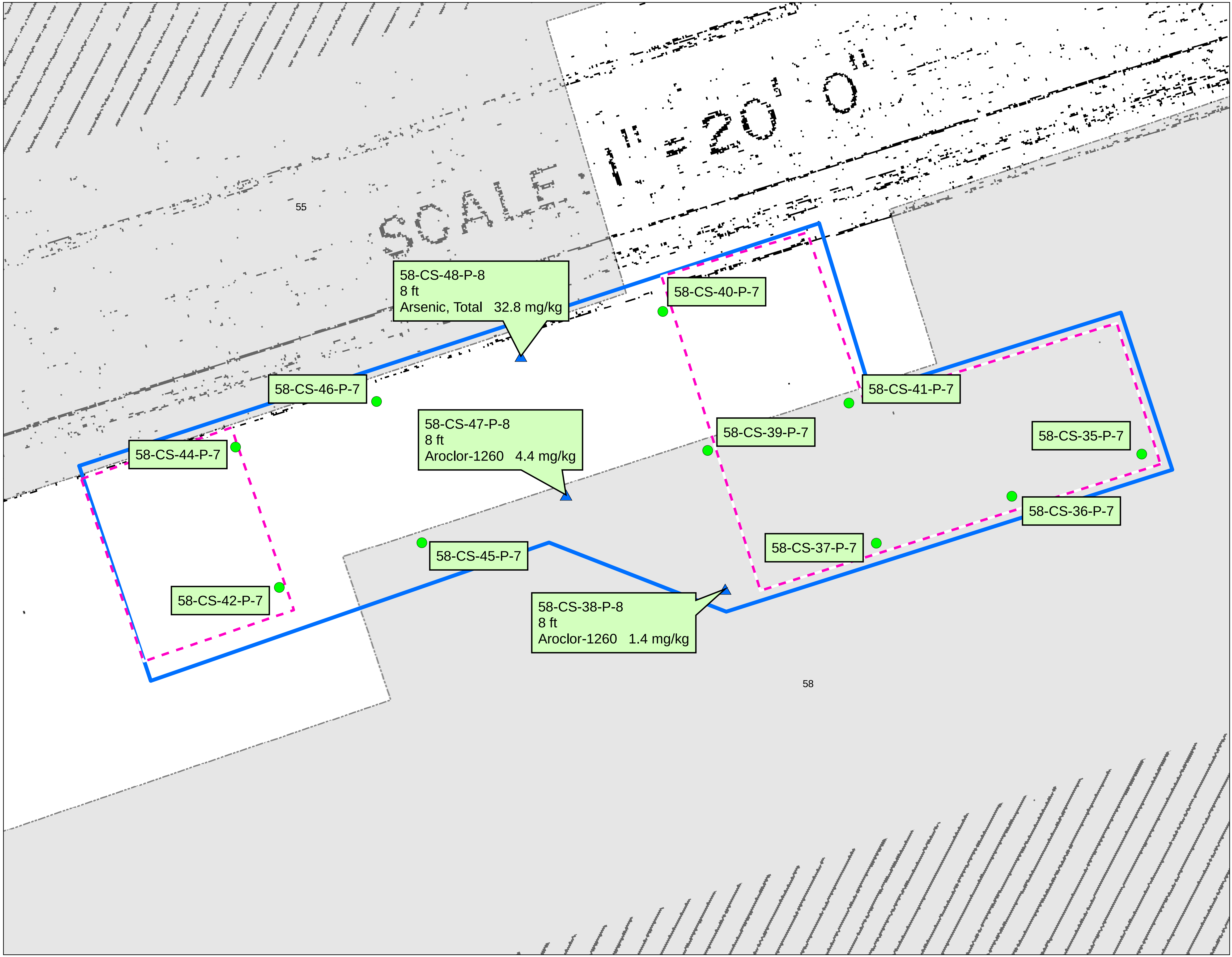
BUILDING 47
OW SEPARATOR FINAL SAMPLE LOCATIONS
OCTOBER 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

10/12	CABRERA Project No. 08-3102.00	FIGURE 3-20

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



N

Planned Excavation Boundary

Excavation Extent (2012)

Soil IRA - Confirmatory Samples

● Soil Sample (Below MSC)

▲ Soil Sample (Exceeds MSC)

Buildings

Existing (FFA)

Demolished (FFA)

Utility Tunnel

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram

0 5 10 15
Scale (feet)

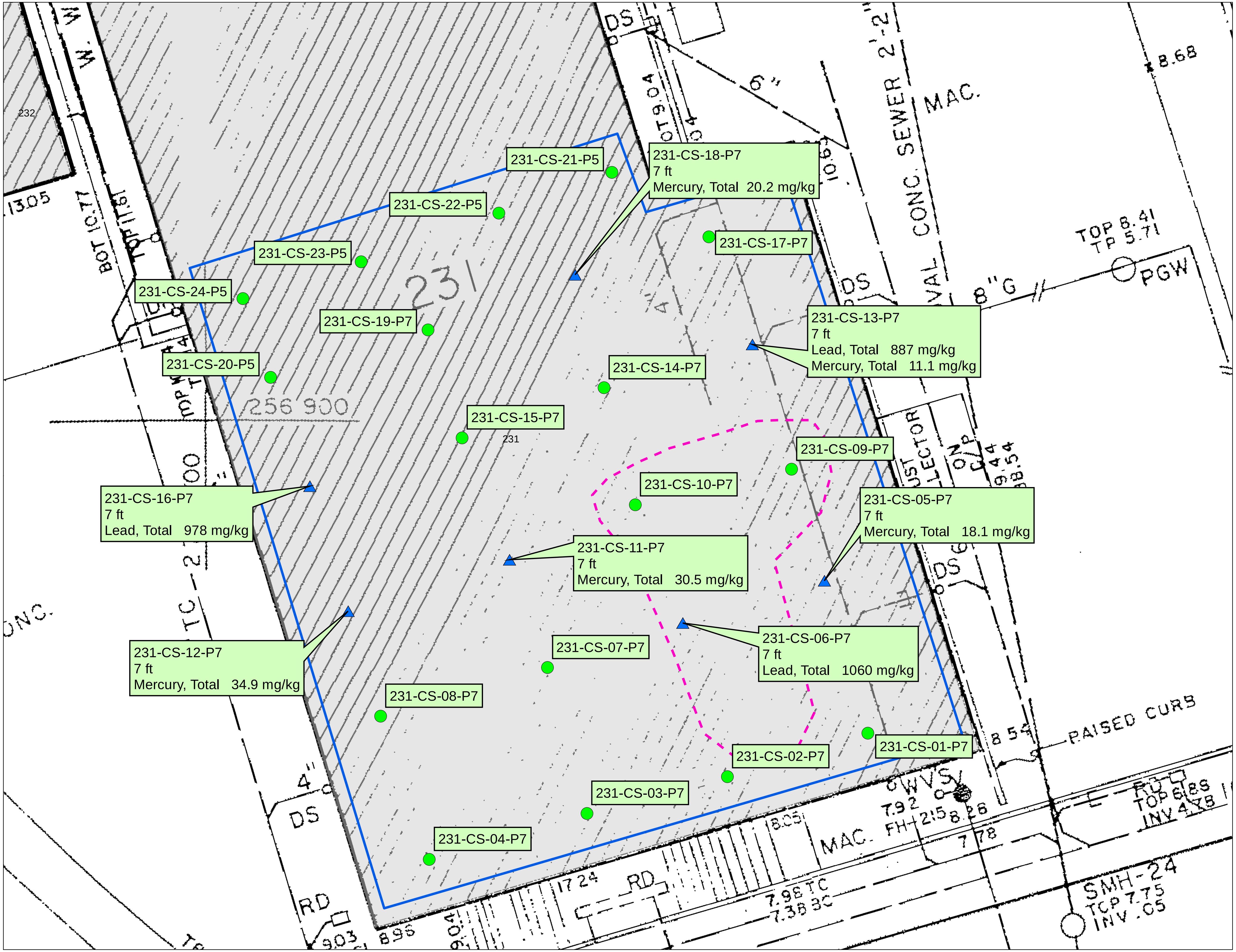
BUILDING 58
FINAL SAMPLE LOCATIONS
OCTOBER 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

10/12	CABRERA Project No. 08-3102.00	FIGURE 3-21

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



⬭ Planned Excavation Boundary

⬭ Excavation Extent

Soil IRA - Confirmatory Samples

● Soil Sample (Below MSC)

▲ Soil Sample (Exceeds MSC)

〰 Utility Tunnel

Buildings

🟧 Existing (FFA)

▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Notes:

1. Ft = Feet
2. BGS = Below Ground Surface
3. mg/kg = millagrams per kilogram
5. All Samples taken in groundwater except for CS-21 through CS-24.

0 10 20
Scale (feet)

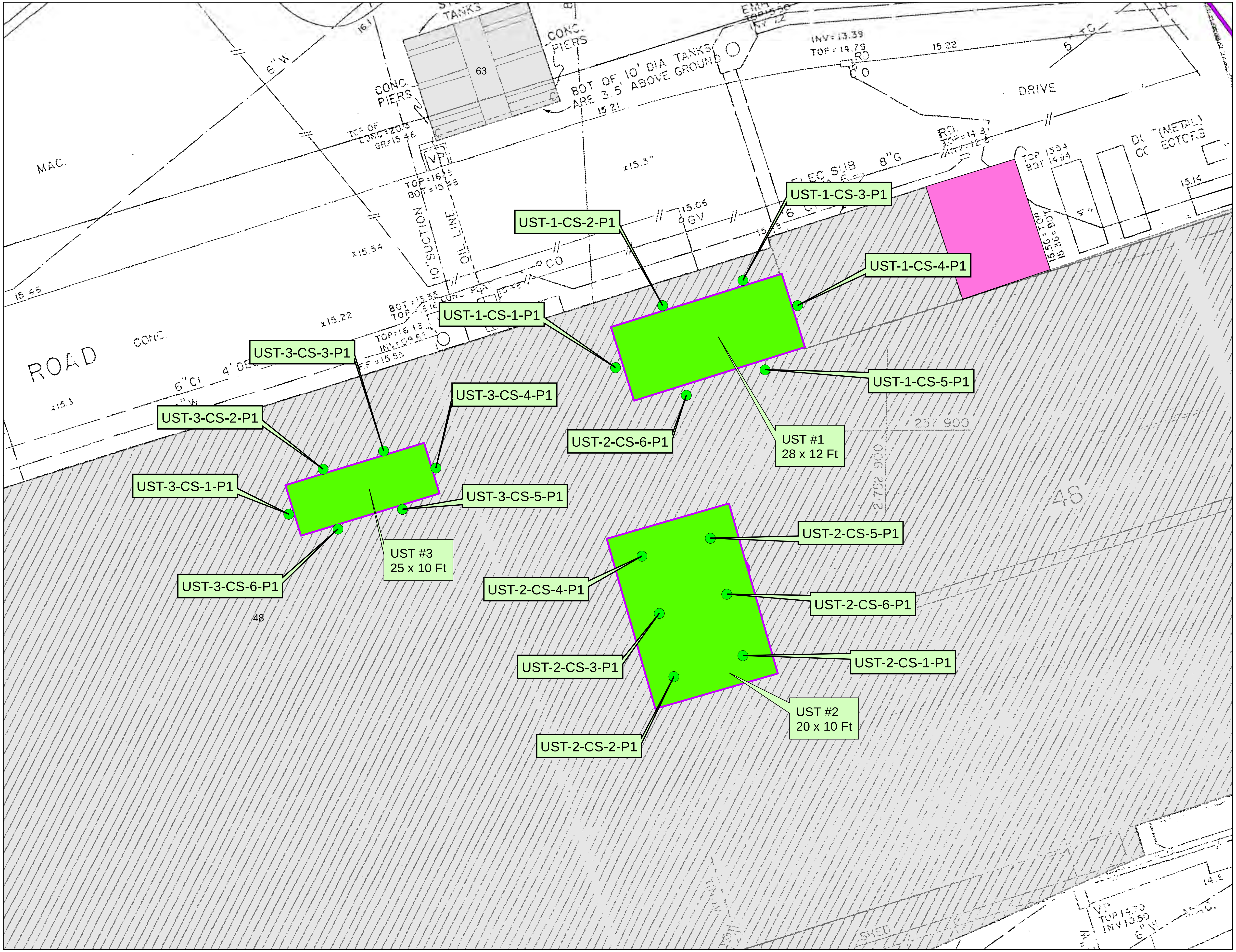
BUILDING 231
FINAL SAMPLE LOCATIONS
OCTOBER 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

10/12	CABRERA Project No. 08-3102.00	FIGURE 3-22

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps of Engineers, Baltimore District



UST Sample Locations

● Soil Samples (Below MSC)

🟩 UST Locations/ CON Items

🟪 Substations

Utility Tunnel

Buildings

🟧 Existing (FFA)

▨ Demolished (FFA)

Sample ID
Sample Depth (Feet BGS)
Concentration

Ft = Feet
BGS = Below Ground Surface
ug/kg = Micrograms per kilogram

0 20 40
Scale (feet)

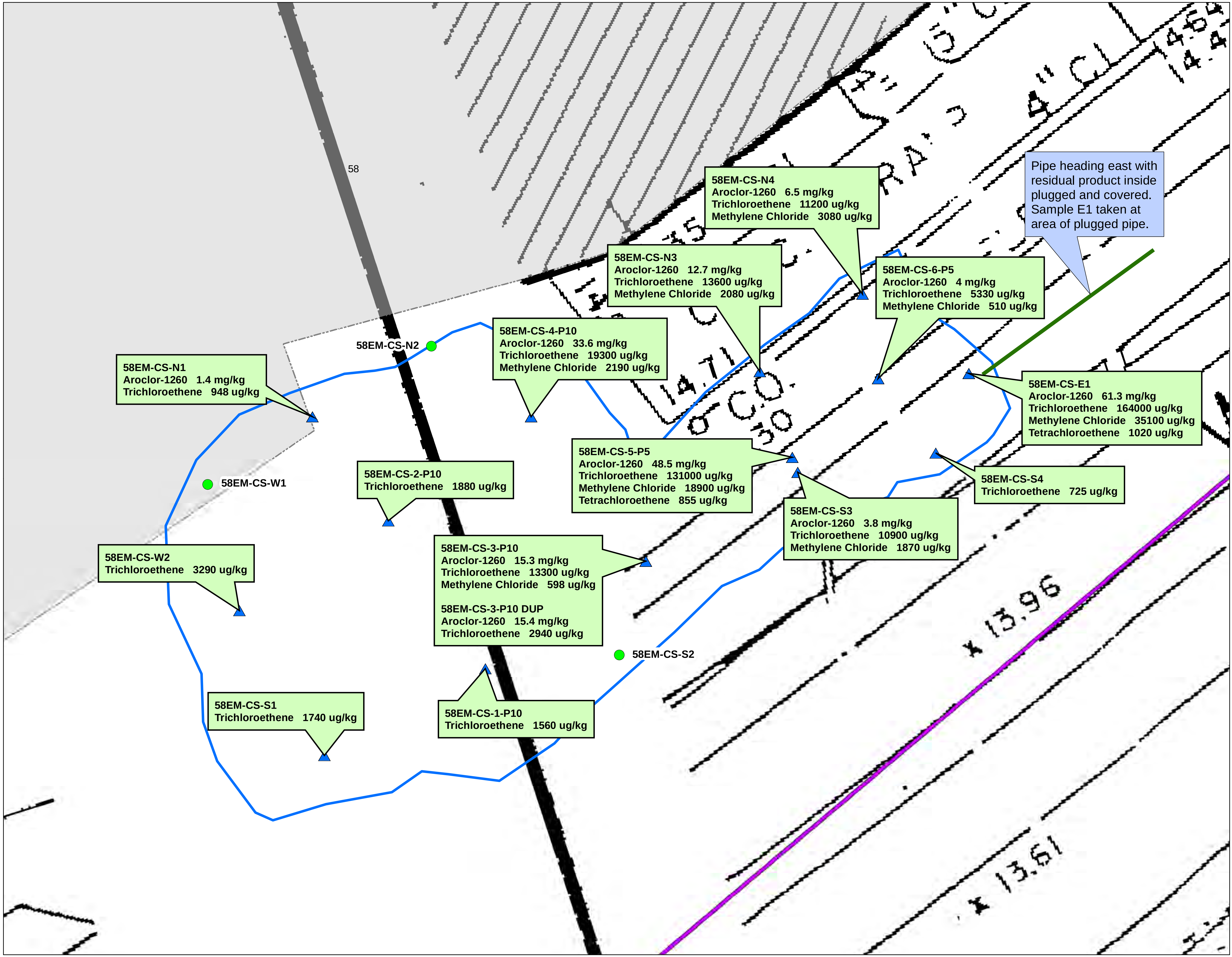
BUILDING 48
USTs FINAL SAMPLE LOCATIONS
OCTOBER 2012

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

10/12	CABRERA Project No. 08-3102.00	FIGURE 3-23

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Excavation Extent

Soil IRA - Confirmatory Samples

● Soil Sample (Below MSC)

▲ Soil Sample (Exceeds MSC)

Utility Tunnel

Sample ID
Concentration

Notes:
mg/kg = Milligrams per kilogram
ug/kg = Micrograms per kilogram

MSCs
Aroclor-1260 1 mg/kg
Methylene Chloride 500 ug/kg
Tetrachloroethene 500 ug/kg
Trichloroethene 50 ug/kg

0 5 10
Scale (feet)

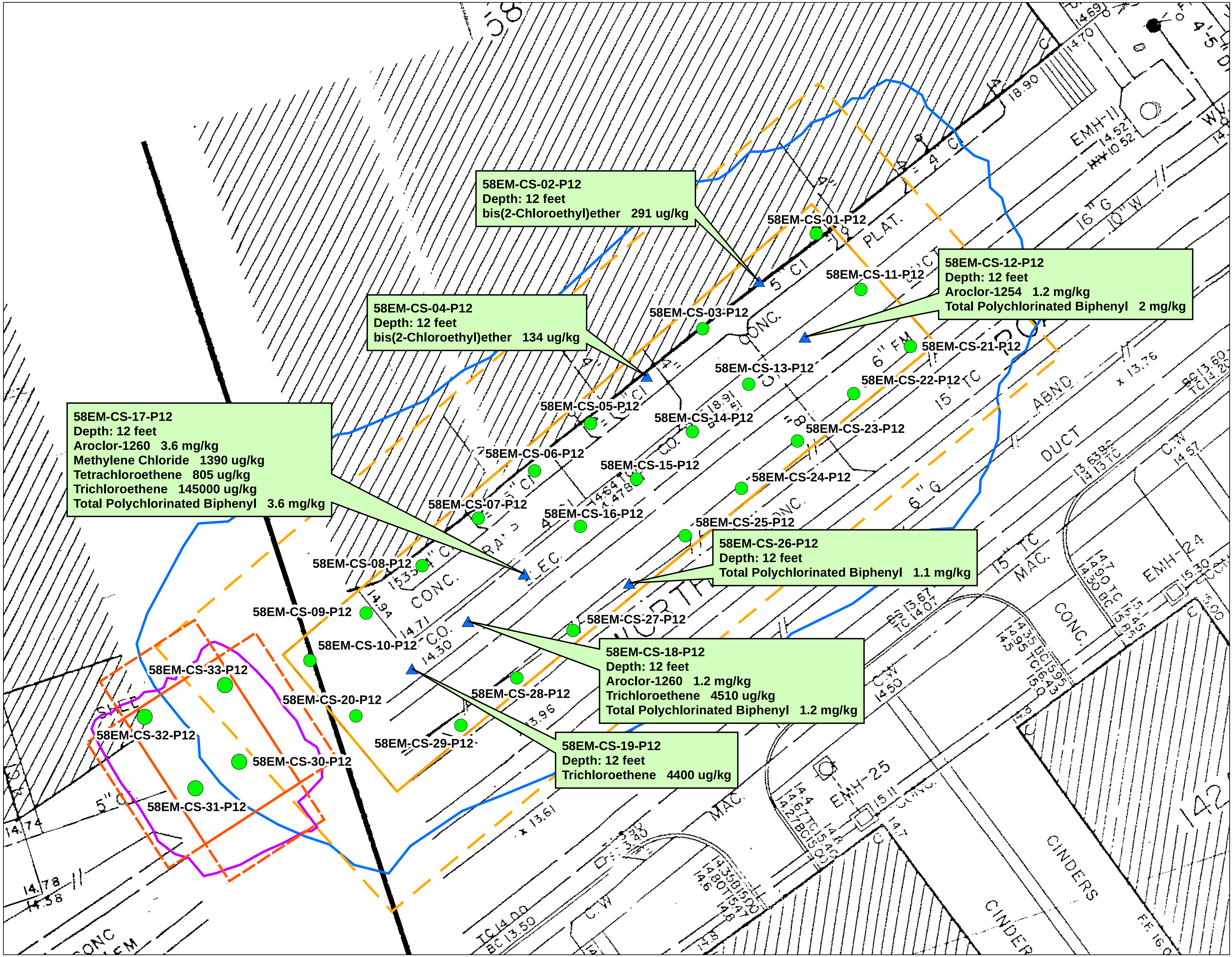
**BUILDING 58 LEAKING SUMP
FINAL SAMPLE LOCATIONS
FEBRUARY 2013**

**AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA**

3/13	CABRERA Project No. 08-3102.00	FIGURE 3-24

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



58EM-CS-02-P12
Depth: 12 feet
bis(2-Chloroethyl)ether 291 ug/kg

58EM-CS-04-P12
Depth: 12 feet
bis(2-Chloroethyl)ether 134 ug/kg

58EM-CS-12-P12
Depth: 12 feet
Aroclor-1254 1.2 mg/kg
Total Polychlorinated Biphenyl 2 mg/kg

58EM-CS-17-P12
Depth: 12 feet
Aroclor-1260 3.6 mg/kg
Methylene Chloride 1390 ug/kg
Tetrachloroethene 805 ug/kg
Trichloroethene 145000 ug/kg
Total Polychlorinated Biphenyl 3.6 mg/kg

58EM-CS-26-P12
Depth: 12 feet
Total Polychlorinated Biphenyl 1.1 mg/kg

58EM-CS-18-P12
Depth: 12 feet
Aroclor-1260 1.2 mg/kg
Trichloroethene 4510 ug/kg
Total Polychlorinated Biphenyl 1.2 mg/kg

58EM-CS-19-P12
Depth: 12 feet
Trichloroethene 4400 ug/kg

- 🟦 Excavation Extent with Benching (June 2013)
- 🟪 Excavation Extent (August 2013)

Soil IRA - Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- 🟧 Excavation Floor (June 2013)
- ┌ Excavation Wall (June 2013)
- 🟧 Excavation Floor (August 2013)
- ┌ Excavation Wall (August 2013)
- ⌇ Utility Tunnel

Sample ID
Depth
Concentration

Notes:
mg/kg = Milligrams per kilogram
ug/kg = Micrograms per kilogram

MSCs
Aroclor-1260 1 mg/kg
Aroclor-1254 1 mg/kg
bis(2-Chloroethyl)ether 76 ug/kg
Methylene Chloride 500 ug/kg
Tetrachloroethene 500 ug/kg
Trichloroethene 50 ug/kg
Total Polychlorinated Biphenyl 1 mg/kg

0 15 30
Scale (feet)

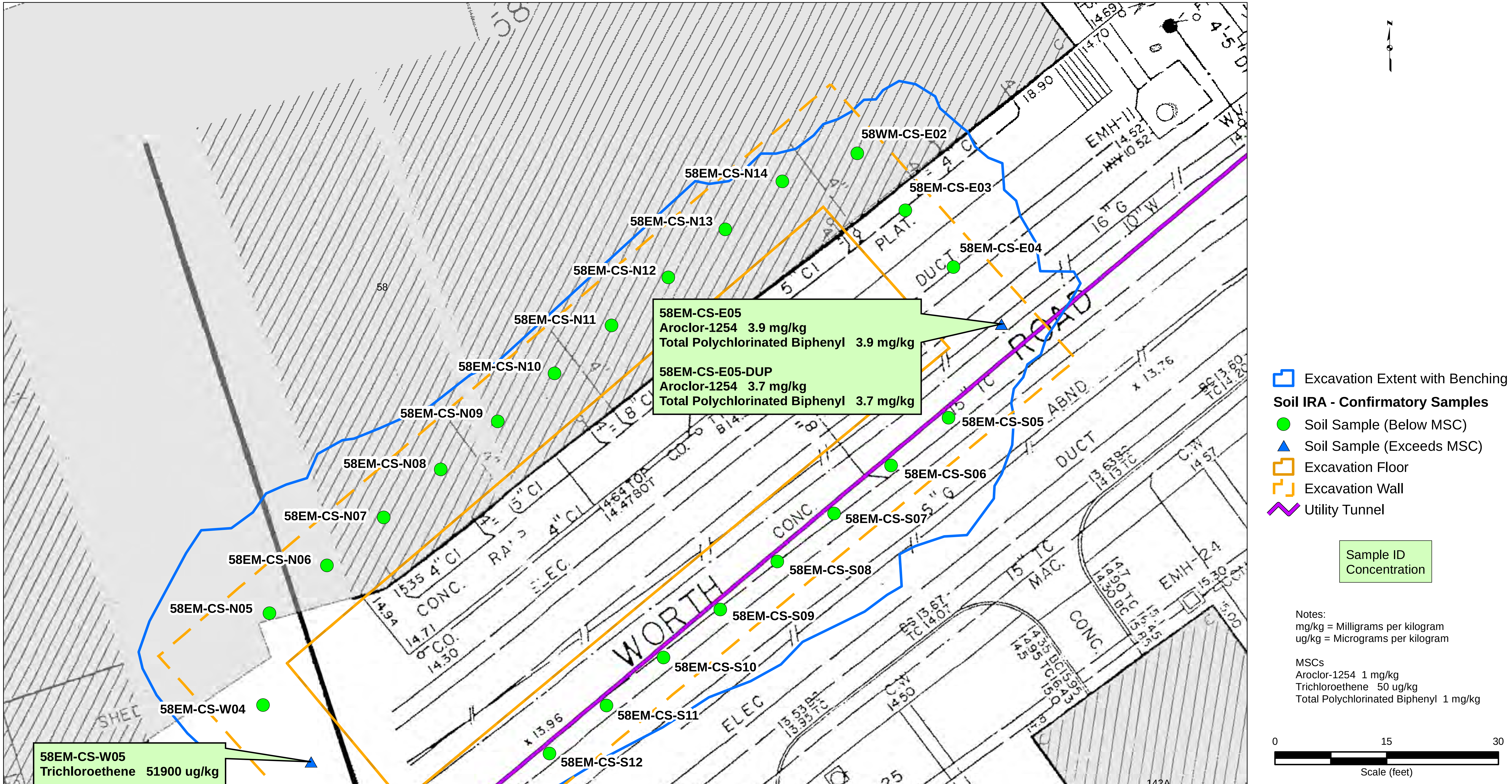
BUILDING 58 LEAKING SUMP
FINAL FLOOR SAMPLE LOCATIONS
JUNE AND AUGUST 2013

AREA I SOIL INTERIM REMOVAL ACTION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/13	**CABRERA Project No. 08-3102.00**	**FIGURE 3-25**

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



58EM-CS-E05
Aroclor-1254 3.9 mg/kg
Total Polychlorinated Biphenyl 3.9 mg/kg

58EM-CS-E05-DUP
Aroclor-1254 3.7 mg/kg
Total Polychlorinated Biphenyl 3.7 mg/kg

58EM-CS-W05
Trichloroethene 51900 ug/kg

Notes:
mg/kg = Milligrams per kilogram
ug/kg = Micrograms per kilogram

MSCs
Aroclor-1254 1 mg/kg
Trichloroethene 50 ug/kg
Total Polychlorinated Biphenyl 1 mg/kg

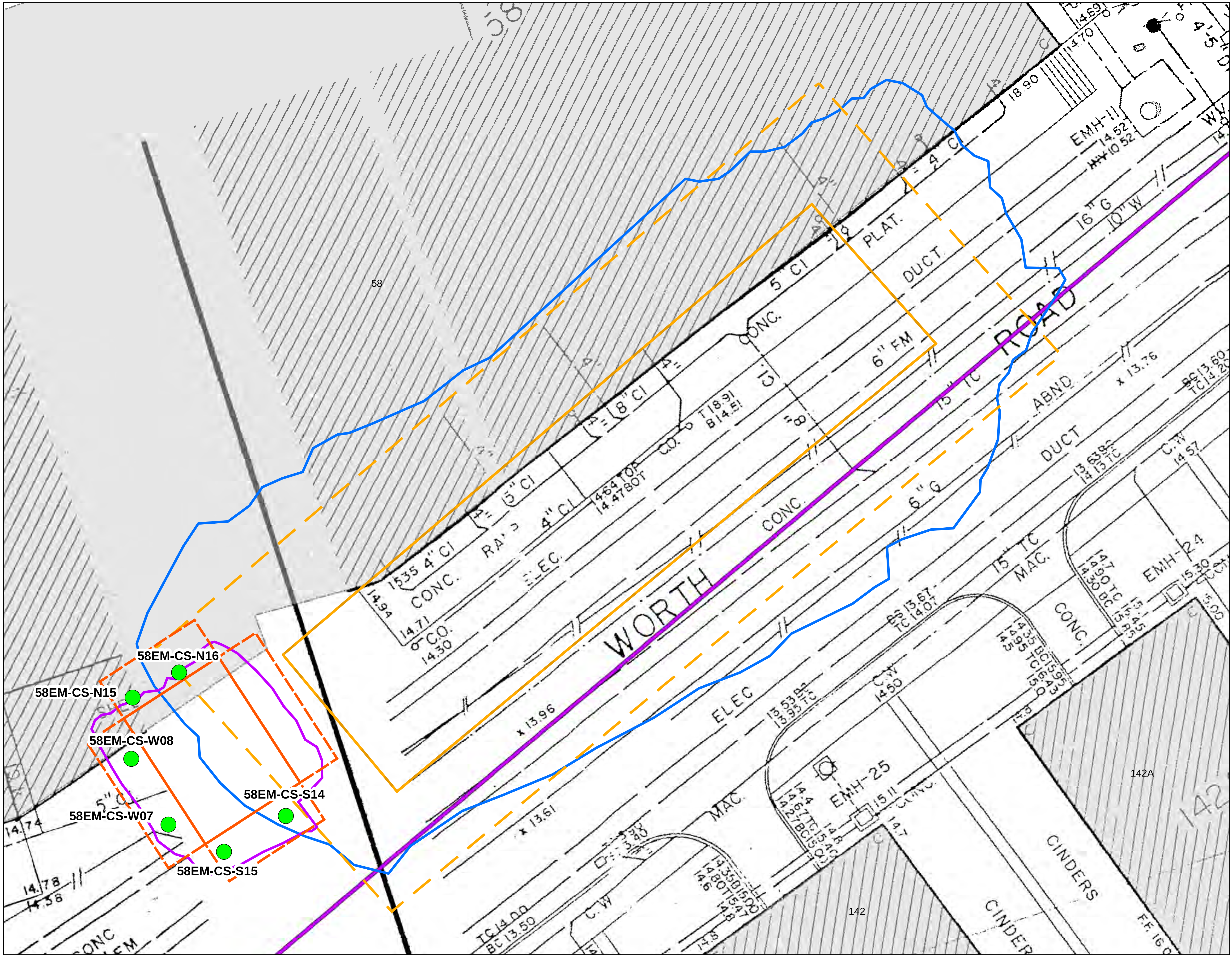
BUILDING 58 LEAKING SUMP
FINAL WALL SAMPLE LOCATIONS
JUNE 2013

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/13	CABRERA Project No. 08-3102.00	FIGURE 3-26

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



- 🟦 Excavation Extent with Benching (June 2013)
- 🟪 Excavation Extent (August 2013)

Soil IRA - Confirmatory Samples

- ● Soil Sample (Below MSC)
- ▲ Soil Sample (Exceeds MSC)
- 🟧 Excavation Floor (June 2013)
- ⌐ Excavation Wall (June 2013)
- 🟥 Excavation Floor (August 2013)
- ⌐ Excavation Wall (August 2013)
- Utility Tunnel

Sample ID
Concentration

Notes:
mg/kg = Milligrams per kilogram
ug/kg = Micrograms per kilogram

MSCs
Aroclor-1254 1 mg/kg
Trichloroethene 50 ug/kg
Total Polychlorinated Biphenyl 1 mg/kg

0 15 30
Scale (feet)

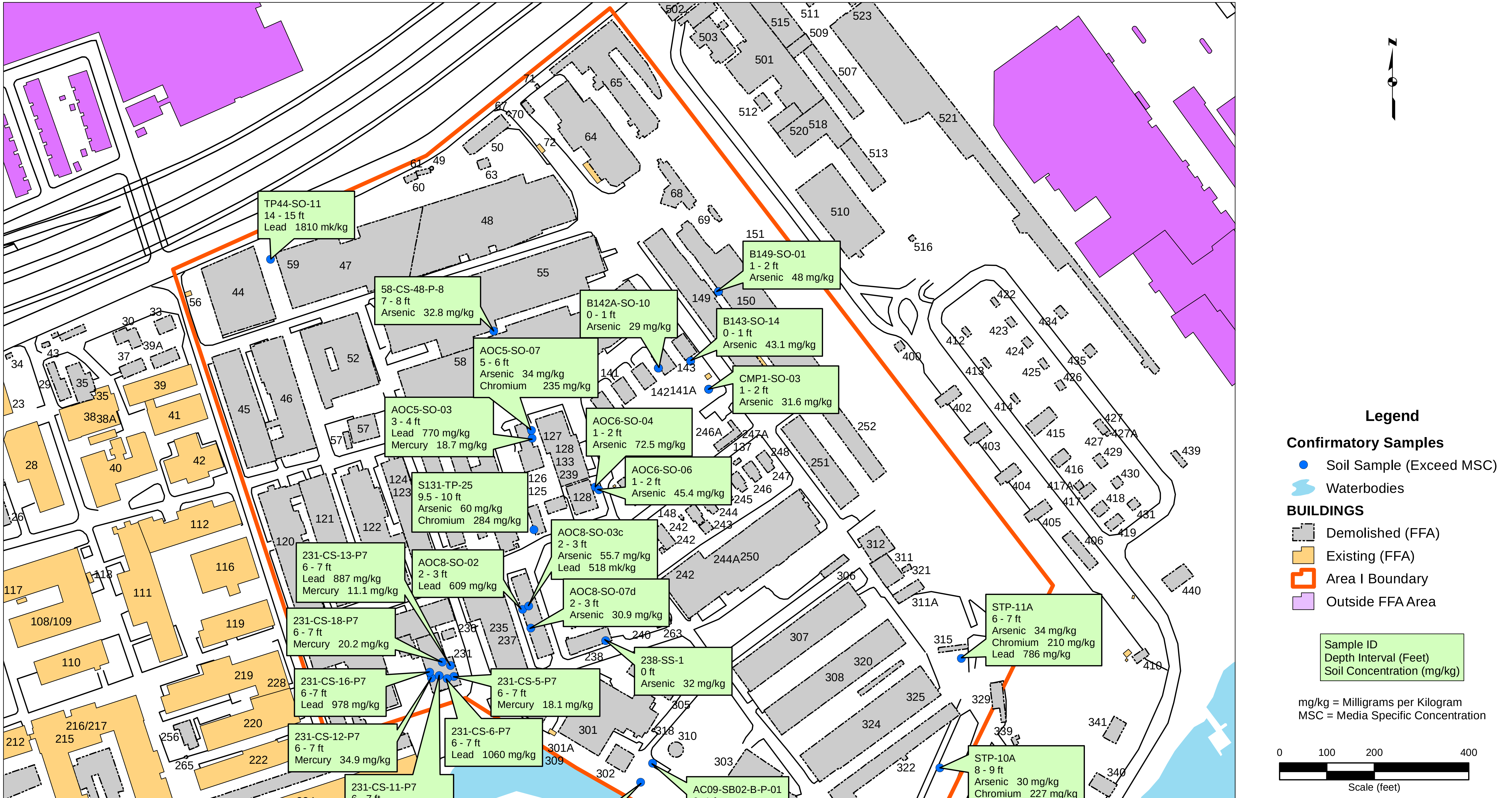
BUILDING 58 LEAKING SUMP
FINAL WALL SAMPLE LOCATIONS
AUGUST 2013

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

6/13	CABRERA Project No. 08-3102.00	FIGURE 3-27

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



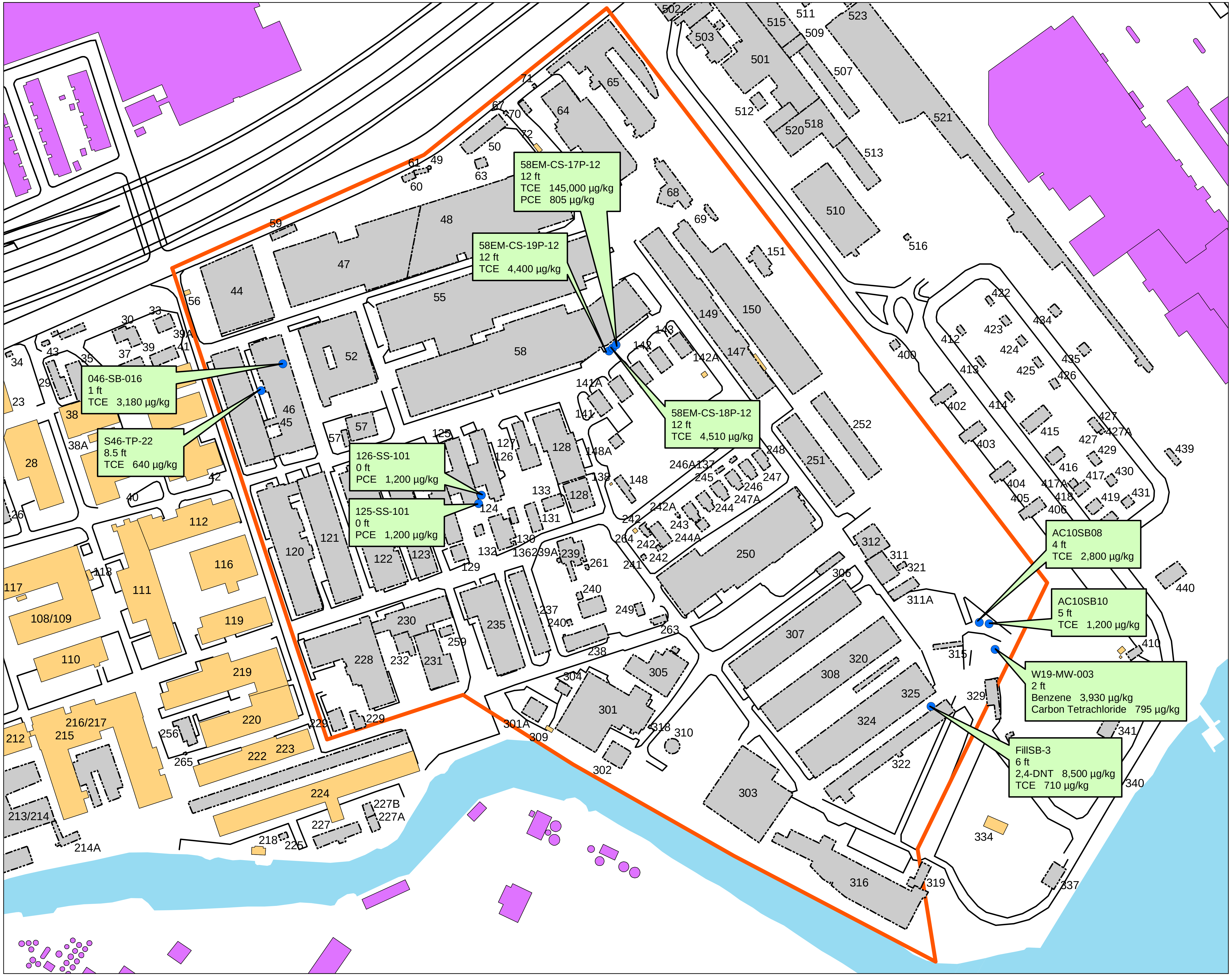
METALS SOIL CONCENTRATION EXCEEDING PADEP MSCs, 2013

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 6-1

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



N

Legend

Confirmatory Samples

● Soil Sample (Exceed MSC)

Waterbodies

BUILDINGS

▨ Demolished (FFA)

🟧 Existing (FFA)

🟥 Area I Boundary

🟪 Outside FFA Area

Sample ID
Depth Interval (Feet)
Soil Concentration (mg/kg)

µg/kg = Micrograms per Kilogram
MSC = Media Specific Concentration

0 100 200 400

Scale (feet)

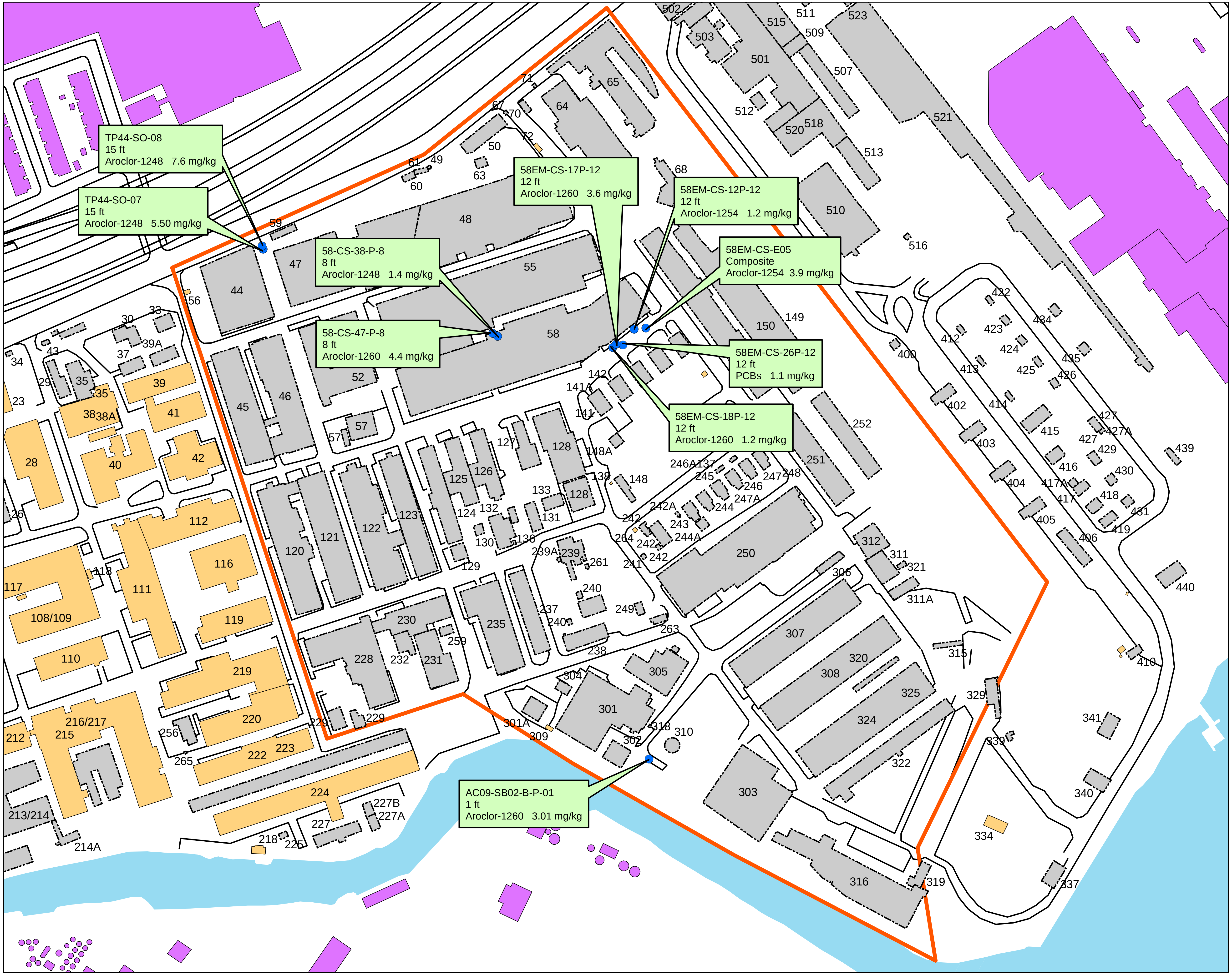
SVOC/VOC SOIL CONCENTRATION EXCEEDING PADEP MSCs, 2013

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

7/13	CABRERA Project No. 08-3103.00	FIGURE 6-2

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



Legend

Confirmatory Samples

- ● Soil Sample (Exceed MSC)
- Waterbodies

BUILDINGS

- ▨ Demolished (FFA)
- 🟧 Existing (FFA)
- 🟥 Area I Boundary
- 🟪 Outside FFA Area

Sample ID
Depth Interval (Feet)
Soil Concentration (mg/kg)

mg/kg = Milligrams per Kilogram
MSC = Media Specific Concentration

0 100 200 400
Scale (feet)

**PCB SOIL CONCENTRATION
EXCEEDING TSCA VALUES, 2013**

**AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA**

7/13	CABRERA Project No. 08-3103.00	FIGURE 6-3

Cabrera Services
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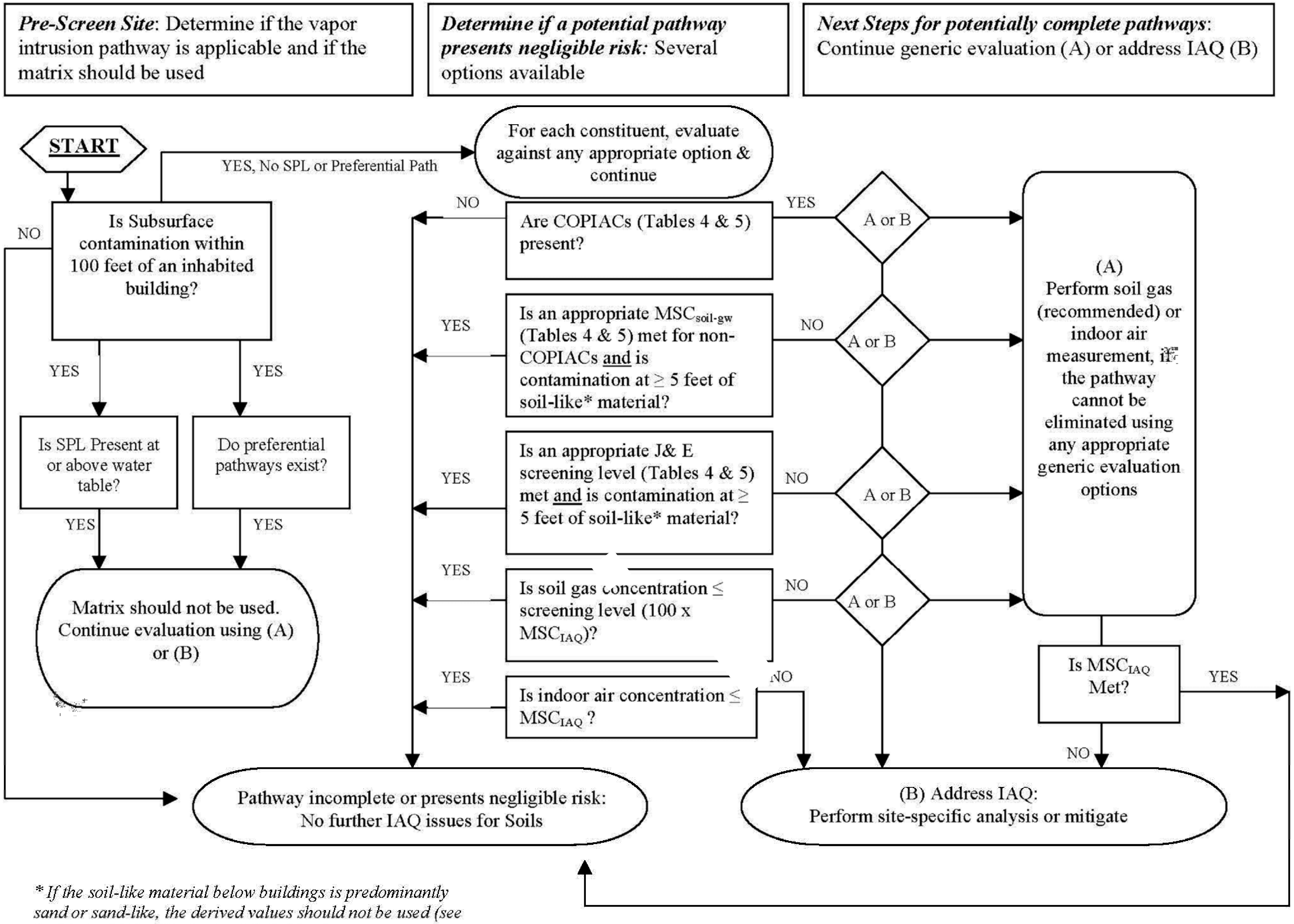
Suite 300
Baltimore, MD 21201

U.S. Army Corps
of Engineers,
Baltimore District



** If the soil-like material below buildings is predominantly sand or sand-like, the derived values should not be used (see the Statewide health standard definitions).*

SOIL INDOOR AIR QUALITY DECISION MATRIX FOR THE PENNSYLVANIA STATEWIDE HEALTH STANDARD

AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA

2/14	CABRERA Project No. 08-3103.00	FIGURE 7-1

Cabrera Services
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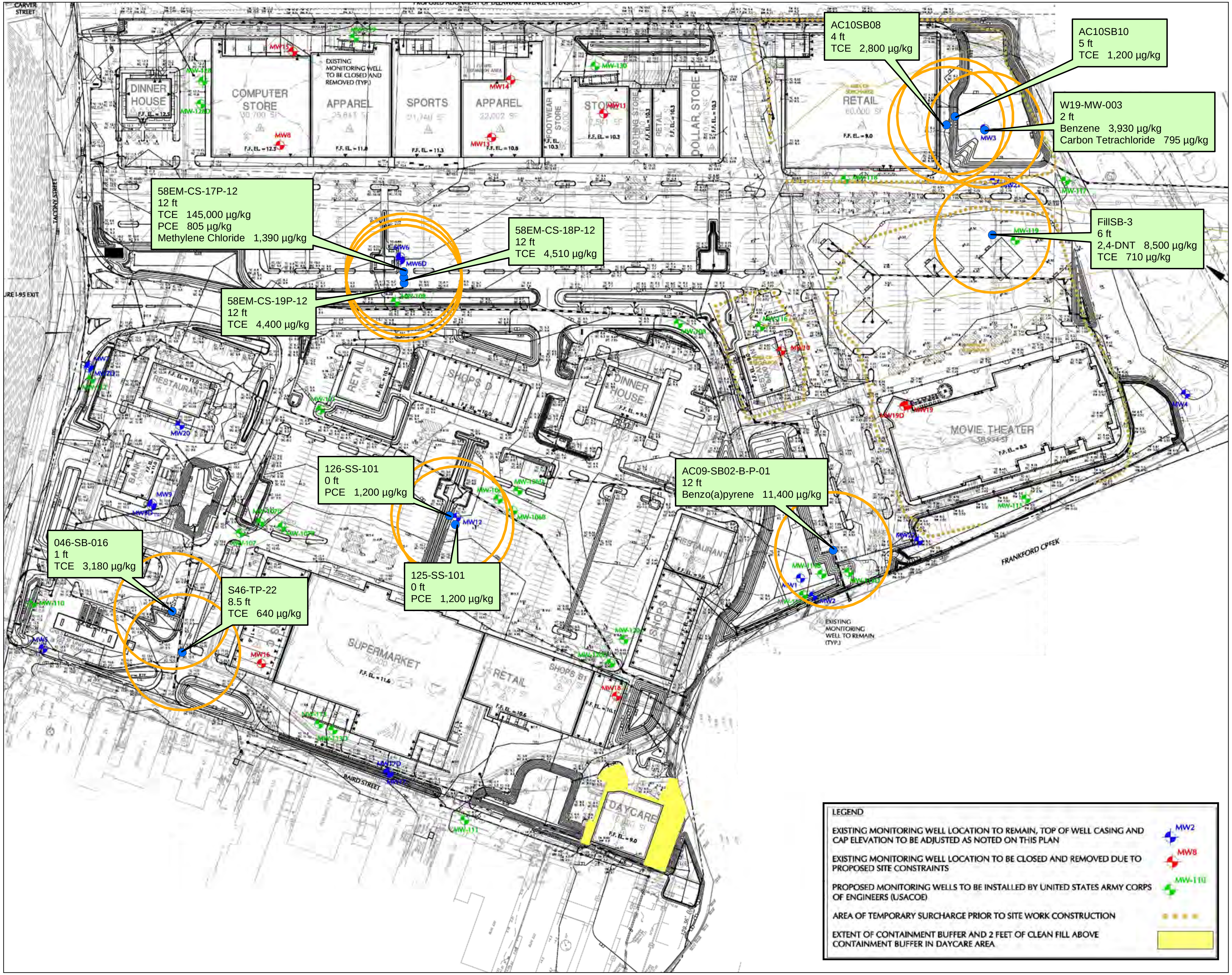
Suite 300
Baltimore, MD 21201

U.S. Army Corps of Engineers, Baltimore District



Legend

Confirmatory Samples

- ● Soil Sample (Exceed MSC)
- ○ 100-foot buffer around sample stations

Sample ID
Depth Interval (Feet)
Soil Concentration (mg/kg)

mg/kg = Milligrams per Kilogram
MSC = Media Specific Concentration

0 100 200 400
Scale (feet)

RESIDUAL SVOC/VOC SOIL CONCENTRATION EXCEEDING PADEP MSCs, 2013 WITH 100-FOOT VAPOR INTRUSION BUFFER

**AREA I SOIL REMEDIAL INVESTIGATION
FORMER FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA**

1/14	CABRERA Project No. 08-3103.00	FIGURE 7-2

Cabrera Services
1106 N. Charles St
Suite 300
Baltimore, MD 21201

U.S. Army Corps of Engineers, Baltimore District

APPENDIX A

Soil Boring Logs

(Provided on accompanying electronic CD)

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APPENDIX B

Field Notes and Calibration Logs

(Provided on accompanying electronic CD)

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APPENDIX C

Interim Removal Action Completion Report

(Provided on accompanying electronic CD

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APPENDIX D

Laboratory Analysis Results from the USACE 2007 & 2008 Investigations and 2009-2013 IRAs

(Provided on accompanying electronic CD)

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APPENDIX E

Laboratory Analysis Results from the Langan 1999 - 2005 Investigations

(Provided on accompanying electronic CD)

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APPENDIX F

Data Quality Assessment

(Provided on accompanying electronic CD)

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APPENDIX G

Baseline Risk Assessment

(Provided on accompanying electronic CD)

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