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Real Time Technology Application Demonstration Project Final Report

at the

Paducah Gaseous Diffusion Plant
Paducah, Kentucky

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In collaboration with

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and
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Table of Contents

List of Figures

List of Tables

Acronyms

AOC – Area of Concern
BS - Biased Sample
COC – Contaminant of Concern
cpm – Counts per Minute
cps – Counts per Second
CSM – Conceptual Site Model
DPNAL - demonstration project no-action levels
$DCGL_w$ - Derived Concentration Guideline Level
DOE – United States Department of Energy
DOE-PPPO – DOE Portsmouth Paducah Project Office
EPA – United States Environmental Protection Agency
ES&H – Environmental Safety and Health
FIDLER – Field Instrument for Detecting Low Energy Radiation
FSP – Field Sampling Plan
FSS – Final Status Survey
FWHM – Full Width at Half Maximum
GPS – Global Positioning System
GWS – gamma walkover survey
HPGe - High Purity Germanium gamma spectroscopy for radionuclides
ICP – Inductively Coupled Plasma
KRCEE –Kentucky Research Consortium for Energy and Environment
LARADS – Laser-Assisted Ranging and Data System
L_c – Critical Level
L_d – Detection Limit
LBC – Little Bayou Creek
LTL – Lower Tolerance Limit
MARSSIM – Multi-Agency Radiation Survey and Site Investigation Manual
MDA – Minimum Detectable Activity
MIC – Multi Increment Composite sample
PAH – Polycyclic Aromatic Hydrocarbon
PCBs - polychlorinated biphenyls
PDA – Peak Differential Analysis
PGDP – Paducah Gaseous Diffusion Plant
PRS – Paducah Remediation Services
QAPP – Quality Assurance Project Plan
QC – Quality Control
RCRA – Resource Conservation Recovery Act
REMS – Radiation and Environmental Monitoring Section
RPD – Relative Percent Difference
SVOC – Semi-Volatile Organic Compounds
SWMU – Solid Waste Management Unit
UCL – Upper Confidence Limit
UTL – Upper Tolerance Limit
VOC - volatile organic compounds

WAC - Waste Acceptance Criteria
WKWMA – West Kentucky Wildlife Management Area
XRF - X-Ray Fluorescence

Disclaimer

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Executive Summary

The Paducah Gaseous Diffusion Plant (PGDP) is the only active uranium enrichment facility in the United States. DOE is conducting environmental restoration activities at PGDP in accordance with the requirements of the Commonwealth of Kentucky and the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). PGDP was placed on the National Priorities List in 1994. DOE, EPA, and the Commonwealth of Kentucky entered into a Federal Facility Agreement (FFA) in 1998 (EPA 1998a).

The PGDP has its roots in the Manhattan Project, and has been operational for more than fifty years. Historical industrial uranium enrichment and other activities at the PGDP resulted in localized contamination of soil and sediment with radionuclides, PCBs, process-related metals, and organic contaminants. The Department of Energy's (DOE) environmental restoration program under CERCLA is addressing legacy environmental contamination at the facility including contaminated soils and sediments.

The Kentucky Research Consortium for Energy and the Environment (KRCEE) works with DOE to introduce new approaches and technologies to PGDP's environmental restoration program. The field activities and data sets described by this report were intended to demonstrate real-time characterization technologies that can assist with the timely, technically-defensible, and cost-effective characterization and cleanup of contaminated surface and subsurface PGDP soils. The activities and objectives of this demonstration project are consistent with the goals established in the "Scoping Document for the Soils Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Paducah, Kentucky (DOE, 2007)." The field work for the demonstration project focused on surface soils (0-1 foot) in and around the AOC 492 area of the PGDP (Figure ES1 and Figure ES2).

Project Activities and Objectives

The real-time technology suite included logged gamma walkover surveys (GWS) for gamma-emitting radionuclides, discrete *in situ* gamma measurements, *in situ* High Purity Germanium (HPGe) gamma spectroscopy for radionuclides, *in situ* and *ex situ* X-Ray Fluorescence (XRF) for metals including total uranium, and field test kits for polychlorinated biphenyls (PCBs). In addition, multi-increment sampling and adaptive compositing techniques were included in the dynamic work strategy applied to the study area. In addition to in-situ and ex-situ measurements accomplished in the field, the composite samples were analyzed by fixed laboratory to support the real-time technologies.

The objectives of the field work and subsequent data analyses were to:

- Demonstrate the applicability of dynamic sampling approaches developed through Data Quality Objectives.

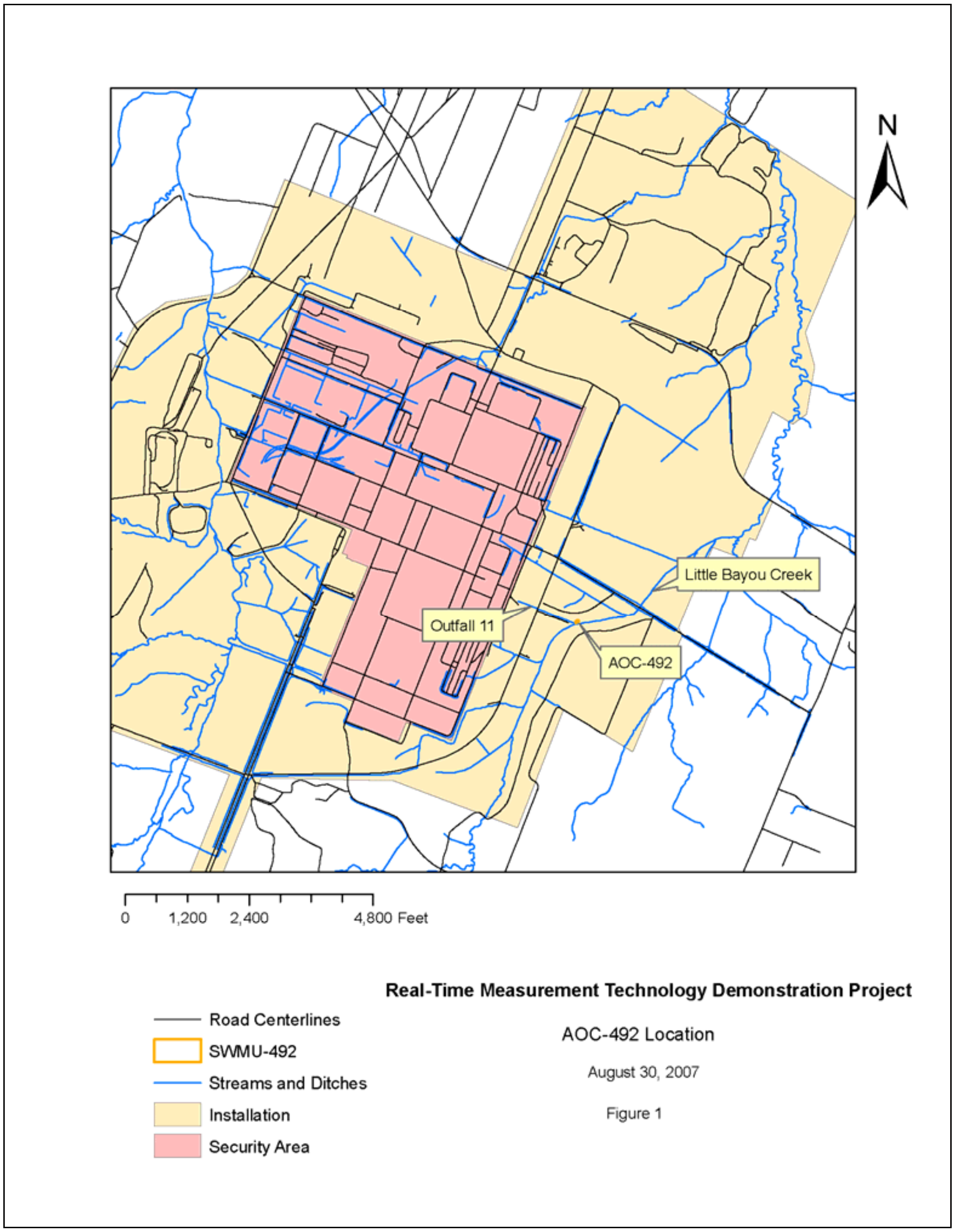


Figure ES 1. AOC 492 Location Map.

- Demonstrate the applicability of real-time measurement technologies to the evaluation of PGDP process related contaminants at demonstration project target levels in surface soils.

- Demonstrate the applicability of real-time measurement technologies to verifying that cleanup goals have been achieved for surface soil exposure units.

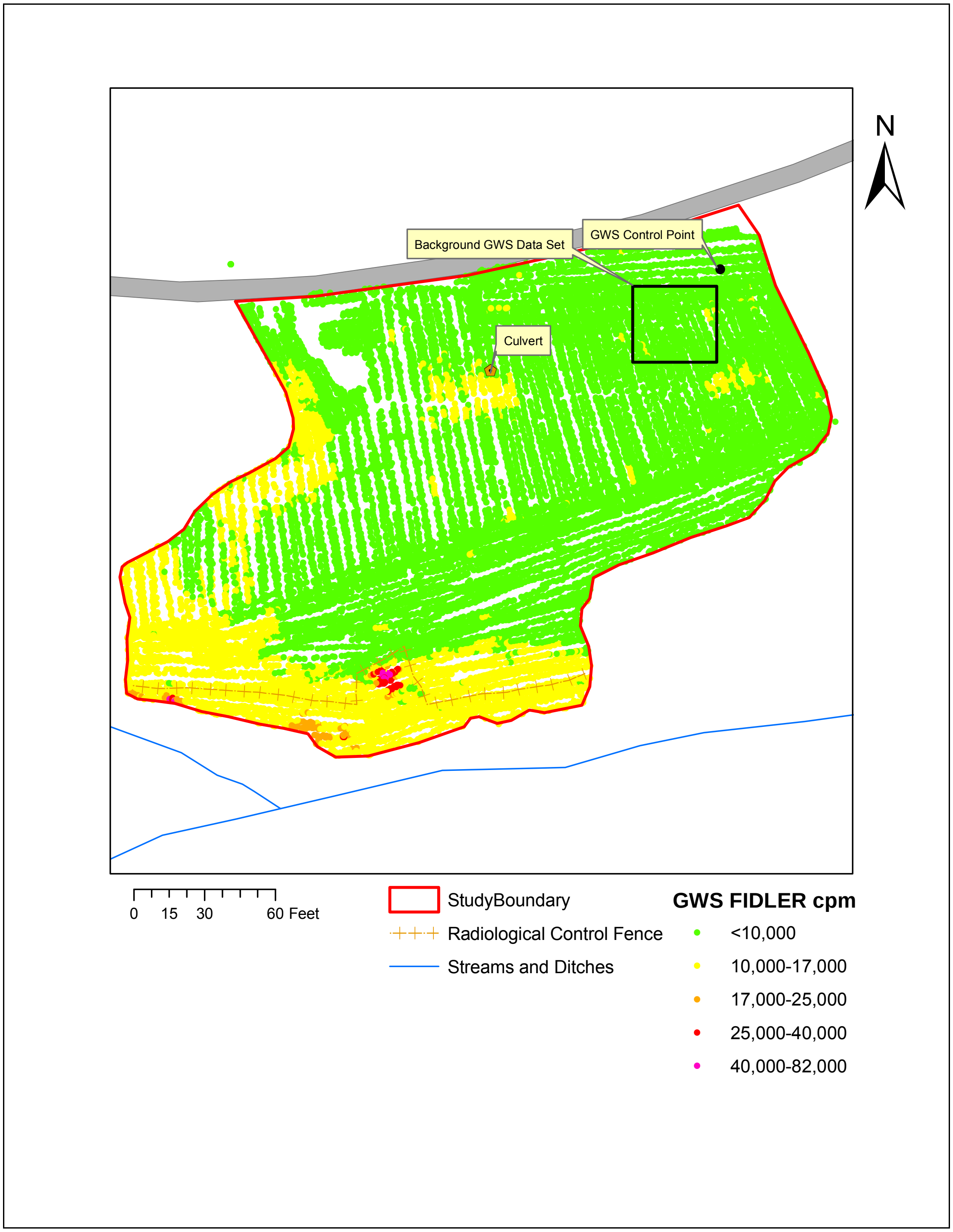


Figure ES 2. Gamma Walkover Survey Results

- Demonstrate the applicability of real-time measurement technologies to support excavation when soils exceed project target levels.

- Demonstrate the applicability of real-time measurement technologies to verify compliance with waste acceptance criteria (WAC) in support of the disposition of excavated soils.

- Determine the performance characteristics of real-time technologies in the context of the Paducah site.

This project's purpose was to show how real time technology suites could be deployed as part of dynamic work strategies for the Soils Operable Unit at the PGDP to expedite the characterization, remediation, and closure of site areas within one field effort. A core group including representatives from EPA Region 4, the Commonwealth of Kentucky, DOE, KRCEE, and Argonne National Laboratory participated in a systematic planning session that formed the basis for the dynamic work strategy employed at the site. The systematic planning process yielded default risk-based wide-area averaged and hot spot criteria for uranium and total PCBs that, in the case of uranium, were close to background conditions.

Limited historical information (3 samples) indicated likely contamination at AOC 492. The dynamic work strategy was comprised of three steps: 1) characterizing the level and extent of soil contamination for AOC 492; 2) supporting the removal of soils contaminated above project criteria; and 3) demonstrating post-excavation that project closure criteria had been attained across the site. Gamma walkover surveys (GWS) combined with a laser-based tracking system provided rapid, spatially-complete information about the presence of elevated gamma radiation in near surface soils. XRF and *in situ* gamma spectroscopy were used to establish a correlation between the qualitative GWS data and uranium concentrations for selected locations. The resulting quantitative GWS was used to carve the study area into exposure units. Within one exposure unit, the GWS/XRF/gamma spectroscopy data identified a uranium hot spot that was subsequently removed. Multi-Increment Composite (MIC) and Adaptive Composite (AC) sampling techniques were used to verify that PCB hot spots did not also exist and to demonstrate that average concentrations for uranium and PCBs met project cleanup criteria for each exposure unit.

Rigorous data quality control was developed and implemented for the project to ensure technically defensible data sets were obtained. The field work generated 24,000 individual GWS data points, several hundred XRF measurements, and almost 400 surface soil multi-increment samples. The use of MIC and AC minimized the number of necessary discrete sample analyses; only 23 were required to both verify compliance with hot spot and area-averaged cleanup criteria for the whole study area. The qualitative GWS data coupled to *in situ* XRF and *in situ* gamma spectroscopy were invaluable for identifying spatial trends in uranium contamination across the site. Data quality for the XRF uranium measurements was comparable to standard laboratory alpha spectroscopy data quality. The PCB test kits provided, in general, results that compared favorably with laboratory total PCB data. The demonstration field project successfully characterized study area soils, assessed the data, identified areas requiring remediation, supported soil removal, and verified that demonstration project cleanup criteria (Table ES 1) had been achieved with one consolidated field deployment.

Table ES 1. Primary Contaminants of Concern for AOC 492, No Action and Hot Spot Levels, and Detection Limits

	Demonstration Project No Action Level (DPNAL)	Demonstration Project Hot Spot Level	Detection Limits[4]				
			GWS	*in situ* HPGe	XRF[5]	Test Kit[3]	Standard Laboratory[2]
PCB (low risk)	3.64 ppm	33 ppm	NA[1]	NA	NA	0.5 ppm	0.1 ppm
U-238	3.64 pCi/g	33 pCi/g	30 pCi/g	3 pCi/g	6 pCi/g	NA	2 pCi/g

[1] Not applicable
[2] As reported in Sampling and Analysis Plan for SWOU, December, 2004
[3] There are a variety of test kits available, ranging from qualitative to quantitative, with actual detection limits and dynamic ranges varying depending on the type of kit used. The numbers quoted are for "screening" kits.
[4] For many systems, detection limits are a direct function of sampling and measurement protocols, including counting times in the case of spectroscopy (e.g., HPGe and XRF). The numbers quoted are for standard protocols, which may differ significantly from technique to technique (e.g., standard count times for an in situ HPGe measurement are 15 minutes, while for an XRF they are 2 minutes).
[5] Individual XRF measurements provide concentration information for a variety of metals. Table 2 summarizes detection limits as reported by EPA Method 6200. This information is dated; actual detection limits can be expected to be significantly better than these for some elements. In the case of U-238, total U is measured by the XRF. Detection limits provided assume natural U.

The study conclusions are that these technologies and approaches potentially provide significant cost, schedule, and performance benefits for future soil/sediment characterization and remediation needs at the Paducah site. Specifically the site should: (1) implement logged gamma walkover surveys as the standard procedure for initially addressing the radiological status of soil surfaces; (2) consider deploying FIDLER NaI units when there is the potential need (immediate or future) for identifying uranium soil contamination near background levels; (3) consider using laser-based data logging systems when excavations might be required; (4) routinely deploy XRF technologies for uranium characterization in soils; (5) develop SOPs for conducting in situ, bagged sample, and cup XRF analyses; (6) further explore the cost effectiveness and practicality of implementing in situ HPGe measurements in support of soil characterization work; (7) further evaluate the cost effectiveness of Abraxis PCB soil test kits as a complement to off-site laboratory total PCB analyses; (8) develop SOPs for using multi-increment sampling techniques when estimating average concentrations within exposure units; (9) consider using adaptive compositing techniques for clearing large areas of PCB concerns; and (10) reorganize work processes to allow characterization, remediation, and closure data collection to be implemented in single field deployments

1.0. Introduction

The work and results described in this report pertain to the demonstration of real-time characterization technologies applied to potentially contaminated surface soils in and around Area of Concern (AOC) 492 at the Paducah Gaseous Diffusion Plant (PGDP). The work was conducted under the auspices of the Kentucky Research Consortium for Energy and Environment (KRCEE). KRCEE was created to support the Department of Energy's (DOE) efforts to complete the expeditious and economically viable environmental restoration of the PGDP, the Western Kentucky Wildlife Management Area (WKWMA), and surrounding areas.

1.1. Study Purpose and Goals

The field activities and data sets described by this report were intended to demonstrate real-time characterization technologies that can assist with timely, technically-defensible, and cost-effective cleanup of contaminated surface and subsurface PGDP soils. The field work focused on surface soils (0-1 foot) in and around PGDP AOC 492.

The real-time technology suite included logged gamma walkover surveys (GWS) for gamma-emitting radionuclides, discrete *in situ* gamma measurements, *in situ* High Purity Germanium (HPGe) gamma spectroscopy for radionuclides, *in situ* and *ex situ* X-Ray Fluorescence (XRF) for metals including total uranium, and field test kits for polychlorinated biphenyls (PCBs). In addition, multi-increment sampling and adaptive compositing techniques were included in the dynamic work strategy applied to the study area. These composite samples were analyzed by fixed laboratory to support the real-time technologies.

The objectives of the field work and subsequent data analyses were to:

- Demonstrate the applicability of dynamic sampling approaches developed through Data Quality Objectives (DQO).
- Demonstrate the applicability of real-time measurement technologies to the evaluation of contaminants at demonstration-project target levels in surface soils.
- Demonstrate the applicability of real-time measurement technologies to verifying that cleanup goals have been achieved for surface soil exposure units.
- Demonstrate the applicability of real-time measurement technologies to support excavation when soils exceed project target levels.
- Demonstrate the applicability of real-time measurement technologies to verifying compliance with waste acceptance criteria (WAC) in support of the disposition of excavated soils.

- Determine the performance characteristics of real-time technologies in the context of the Paducah site.

The overall approach of this project was to deploy a real-time soil characterization technology suite at an area (AOC 492) which is believed to have soils contaminated with PGDP process related chemicals above likely project target levels. The entire area and areas adjacent to AOC 492 were evaluated for the presence of contamination in surface soils through the application of a quantitative GWS. Based on the quantitative GWS data sets, the study area was divided into areas consistent with Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance (DOE, 2000). Based on the quantitative GWS, the Class 1, 2, and 3 MARSSIM areas were further evaluated through application of in situ and ex situ measurements, and multi-increment and adaptive sampling approaches. Fixed laboratory analyses were used to characterize multi-increment and Final Status Survey (FSS) composite samples.

For one approximately 25 square meter (m^2) area within the Class 1 area, real-time technologies were used to guide excavation of soils that were above project target levels. Real-time technologies were used to guide excavation laterally and vertically within the area. Real-time data for excavated soils were used to demonstrate compliance with project target levels and with waste acceptance criteria. Prior to and during all phases of project field activities, technology-specific quality control data were collected to establish technology performance and to ensure data quality in the context of Paducah soils.

1.2. Initial Conceptual Site Model

1.2.1. Site Location

The AOC 492 area is located southeast of the PGDP security area (Figure 1) adjacent to the confluence of Outfall 011 and Little Bayou Creek.

1.2.2. Site History and Physical Setting

AOC 492 is adjacent to Outfall 011 and Little Bayou Creek (Figure 2). The proposed study boundary encompassed four distinct areas: 1) AOC 492, 2) a buffer area surrounding AOC 492, 3) portions of Outfall 011 ditch banks, and 4) the north bank of Little Bayou Creek.

One set of historical samples within and adjacent to the AOC 492 footprint identified the presence of elevated uranium and total PCBs (Figure 3). A mound of soil was the principal feature within by the AOC 492 boundary. The dimensions and volume of the mound were unknown. The mound was assumed to consist of sediment spoils from historical maintenance activities in Outfall 011 and/or Little Bayou Creek (LBC). There were also anecdotal reports which indicated that surface soil contamination might exist in the vicinity of AOC 492 without visually-identifiable mounding of soil.

Map layer data obtained from Paducah Remediation Services, LLC (PRS) prior to field work included a rectangle identifying AOC 492 (Figure 3). Mapping data indicated that the area of the rectangle was approximately 220 square yards (188 m^2). Given the AOC's

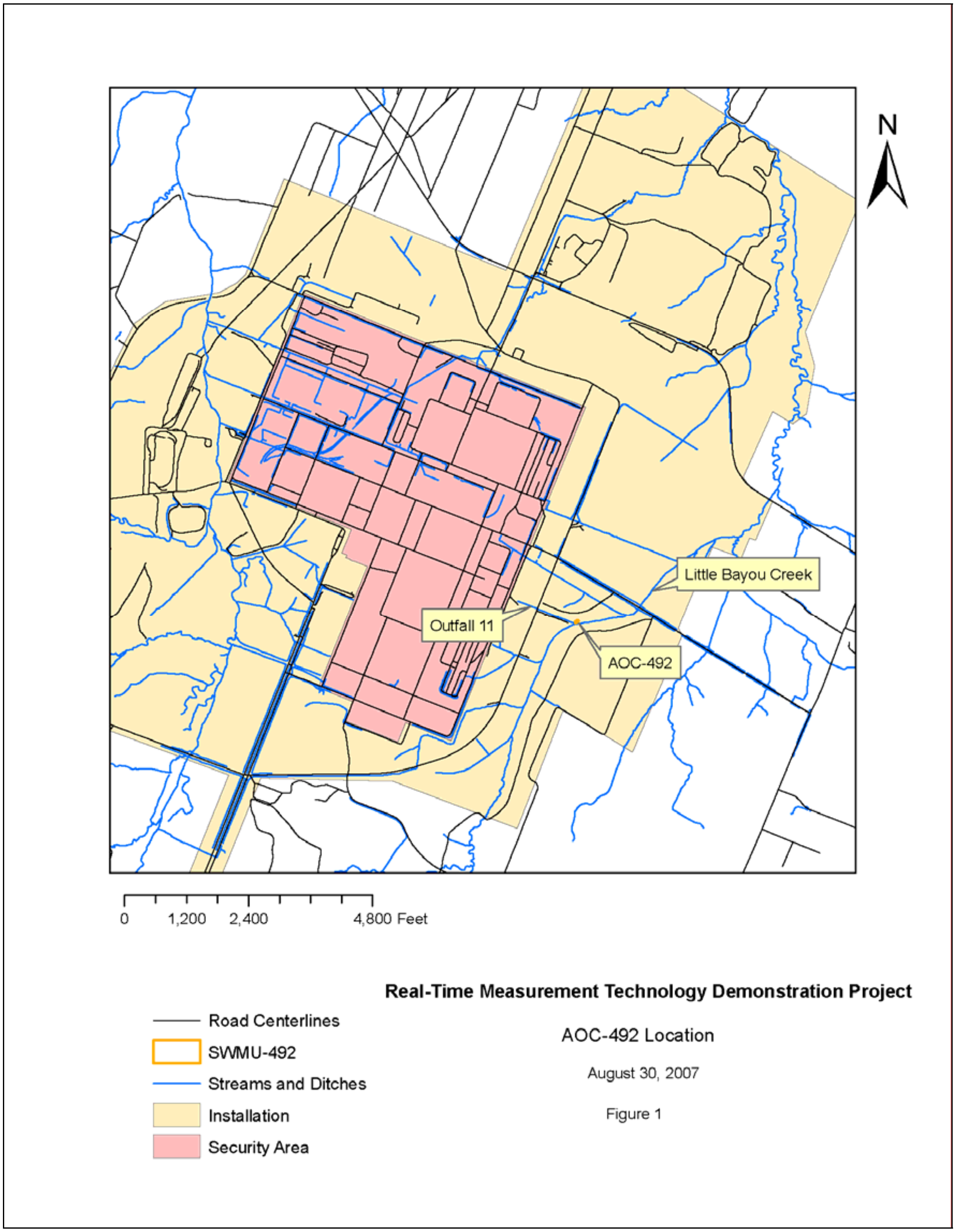


Figure 3. Gaseous Diffusion Plant with Location of AOC 492

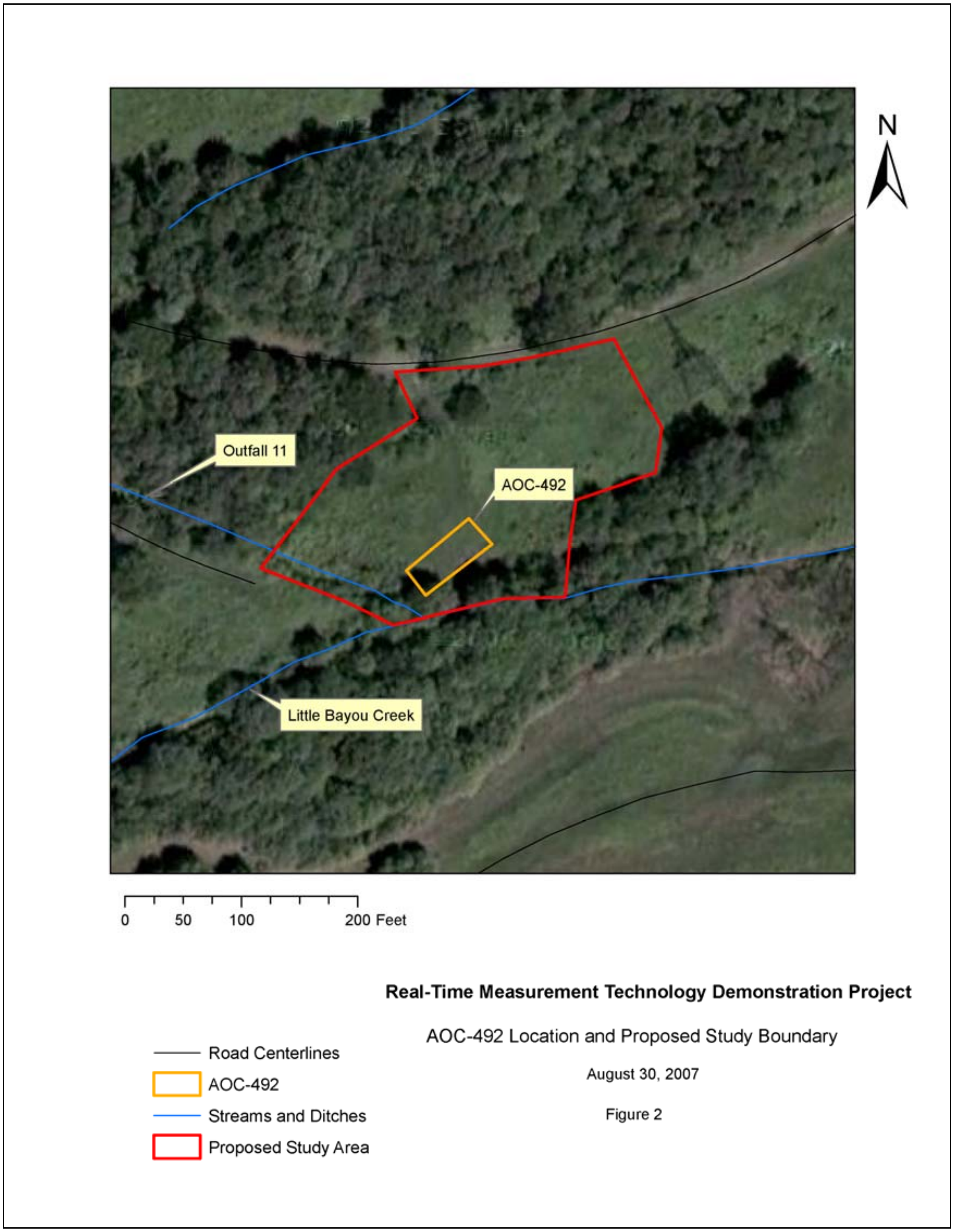


Figure 4. AOC 492

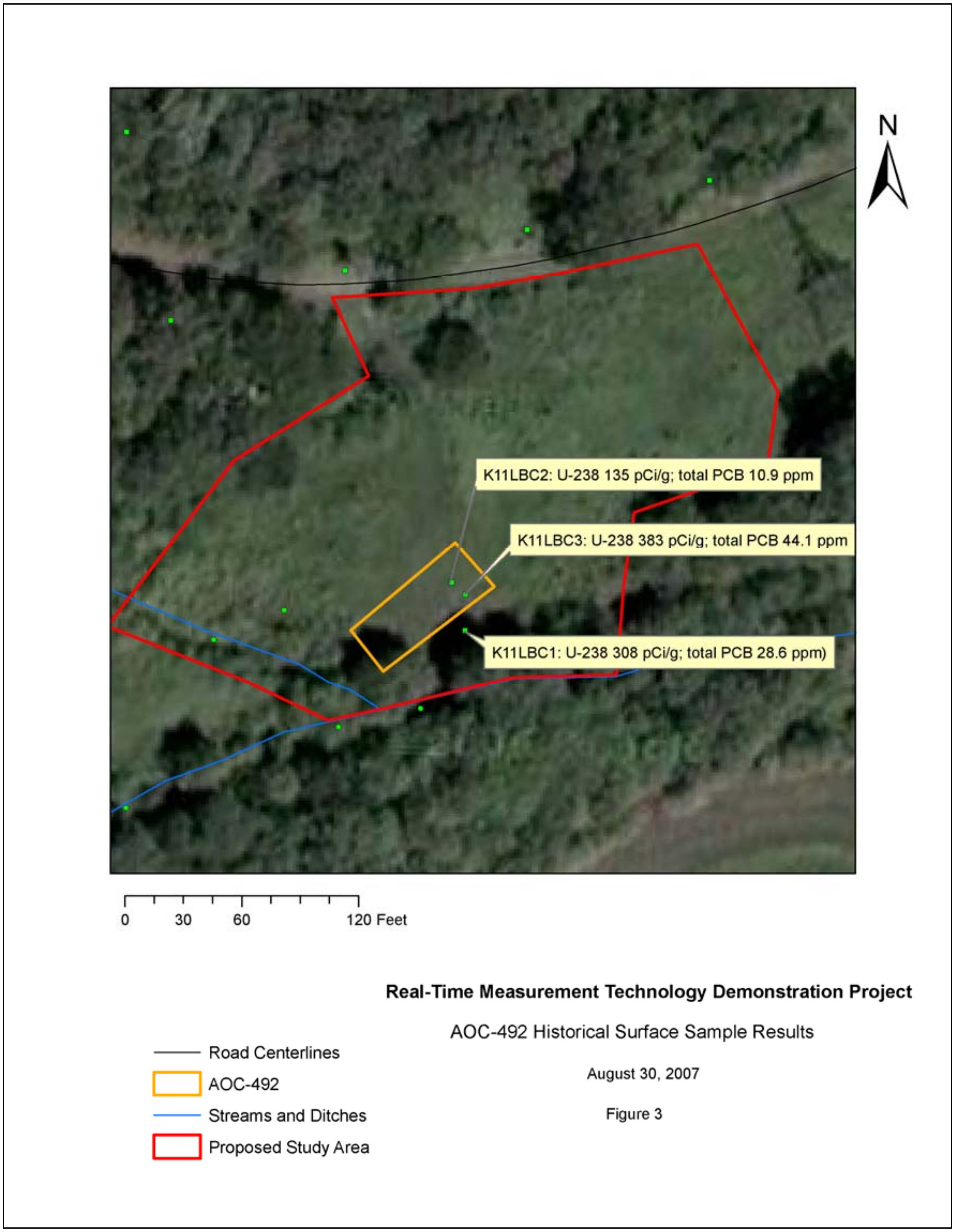


Figure 5. Historical Surface Soil Samples Associated with AOC 492

location relative to historical sampling that presumably targeted suspect soils, the map layer AOC 492 boundary was likely a schematic indicating the approximate boundaries of the AOC.

The historical contaminants in AOC 492 were assumed to be associated with sediments removed from Outfall 011 and/or LBC. Contaminants for this area were assumed to be potentially found within Outfall 011 and LBC sediments. Some of these contaminants were likely associated with activities at the C-340 building and included uranium and metals used in the process of reducing uranium hexafluoride (UF_6) to uranium tetrafluoride, and magnesium (Mg), and calcium (Ca) associated with the conversion of (UF_4) to uranium (U) metal.

Sedimentation is an integrating process relative to the deposition of contaminants. It was anticipated that contaminants would be co-located based on their physical and chemical properties and mechanisms of release. As such, contaminants were likely to have been deposited in well-defined sedimentary layers. Contamination in the banks of Outfall 011 and/or Little Bayou Creek was expected to be associated with a "bathtub ring" effect and was expected to be spatially extensive. Contamination in soils adjacent to banks was assumed to be associated with contaminated sediments removed from the Outfall 011/LBC and placed on top of native soils. Given the nature of the historical removal/placement practices, contaminated material footprints from maintenance activities were expected to be fairly localized. Soil mounds were of particular concern. A larger area of identifiable contamination was also expected to be present from flooding events. It was generally assumed that the likelihood of finding contamination would decrease with distance from Outfall 011 and LBC banks and channels

Complete exposure pathways of concern associated with the study area are ingestion, inhalation, and direct exposure to contaminated soils. Secondary exposure pathways are remobilization of contaminants via erosion and deposition into Little Bayou Creek.

1.2.3. Previous Investigations

Three surface soil samples were collected within and adjacent to the AOC 492 footprint in 2001. These samples were analyzed for PCBs, radionuclides, and metals. Metals with concentrations above background included cadmium (Cd) up to 3.1 ppm, chromium (Cr) up to 1,040 ppm, copper (Cu) up to 84.7 ppm, and zinc (Zn) up to 662 ppm. Elevated radionuclides included uranium-238 (^{238}U) up to 383 pCi/g and technetium-99 (^{99}Tc) to 14 pCi/g. PCBs were present in detectable concentrations in all three samples at concentrations up to 44.1 ppm total PCBs. Figure 3 shows historical sample locations, identifiers, and ^{238}U activity concentrations and total PCB concentrations. It was not known whether these three samples were taken from a soil pile or from surrounding soils.

There were a number of historical sediment and creek/outfall bank samples pertinent to the AOC 492 study area. Their locations are shown in Figure 4. PCBs were detected in

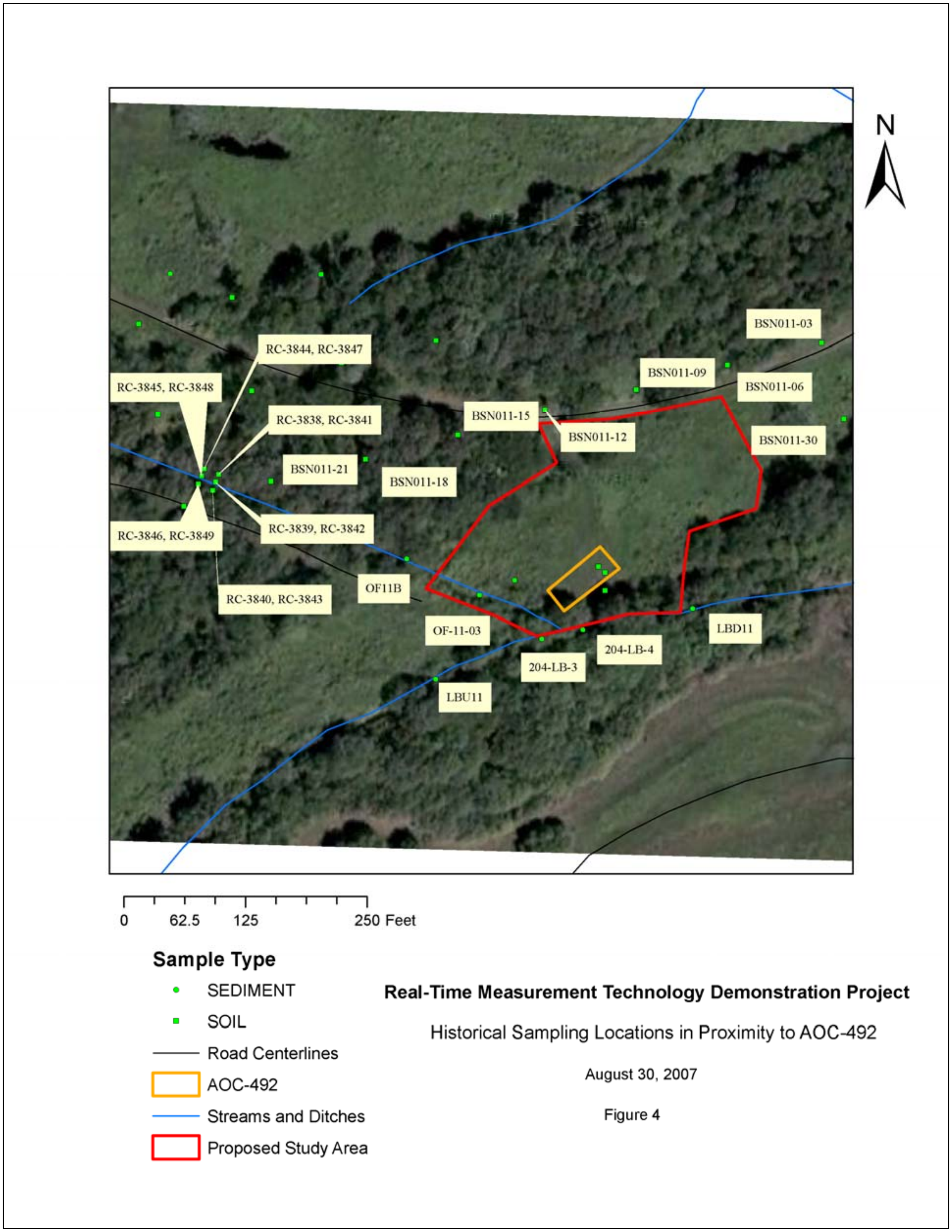


Figure 6. Historical Soil Samples in the Vicinity of AOC 492

all six (6) sediment samples. Detectable levels of PCBs in these samples were typically less than 1 ppm. The maximum total PCB detection of 5.4 ppm was identified at LBC location LBD11 downstream from the LBC Outfall 11 confluence. The only sediment sample analyzed for ^{238}U was from Outfall 011, location OF11B, where ^{238}U was detected at 48 pCi/g. Sediment sample OF11B was the only sediment sample in the vicinity of the study area analyzed for semi-volatile organic compounds (SVOCs) and metals. Zn, Cr, and Cu were all detected above background which is consistent with the soil sample results from AOC 492. Two polycyclic aromatic hydrocarbons (PAHs), fluoranthene and phenanthrene, were detected below 1 ppm in the OF11B samples at levels close to detection limits. Five (5) of the six (6) historical bank and sediment samples were analyzed for volatile organic compounds (VOCs); no VOCs were detected.

Historical "RC" series surface soil samples provided insight into the condition of bank soils for one cross-section of Outfall 011 upstream from AOC 492. These samples were analyzed for PCBs and radionuclides. In the cross-section RC samples total U was detected above background in every sample and concentrations ranged from 63 to 1,030 ppm. Likewise, PCBs were detected in every sample with concentrations from 0.5 ppm to 40 ppm.

Historical "BSN" series surface-soil samples provided historical information about the buffer area surrounding AOC 492. The BSN samples were analyzed for radionuclides, metals, PCBs, VOCs and SVOCs. With the exception of sample BSN011-21, the analytical metals results for "BSN" soil samples were near or below background and PCBs, SVOCs and VOCs were not detected. Soil sample BSN011-21 contained 15 pCi/g ^{238}U, 4.09 pCi/g ^{99}Tc, and 2.4 ppm total PCBs. BSN011-21 was the sample location from the "BSN" data set that was in closest proximity to Outfall 011 and was located approximately 20 feet from the center of the creek. The radionuclide and PCB detections were consistent with the site conceptual model. Information was not provided to determine whether BSN011-21 was associated with a soil pile.

1.2.4. Potential Contaminants of Concern

Based on historical sampling associated with AOC 492 and its immediate vicinity, total U, ^{238}U and PCBs were identified as the primary contaminants for the study area. Historical samples with both PCB and uranium analyses indicated that elevated PCBs were consistently co-located with elevated uranium.

Soil samples had low ^{99}Tc and ^{239}Pu activity. The activities of ^{99}Tc and ^{239}Pu were not at levels that would drive decision making. Their activities were not at levels that would drive decision making. There was limited evidence of elevated Zn, Cu, Cd, and Cr in some samples and these metals were co-located with elevated uranium. For the purposes of this technology demonstration, ^{99}Tc, ^{239}Pu, and metals other than uranium were identified as secondary contaminants because they were present above background levels but not at levels likely to drive decision-making.

There was no significant evidence of PAH contamination although this finding is based on only one sample from LBC and Outfall 011. There was also no evidence of VOC contamination in the BSN series samples or in sediment samples from LBC.

1.2.5. Demonstration Project Characterization & Cleanup Goals

There are a number of relevant demonstration project cleanup goals for real-time technologies at the PGDP (Table 1).

Table 1. Primary Contaminants of Concern for AOC 492, No Action and Hot Spot Levels, and Detection Limits

	Demonstration Project No Action Level (DPNAL)	Demonstration Project Hot Spot Level	Detection Limits[4]				
			GWS	*in situ* HPGe	XRF[5]	Test Kit[3]	Standard Laboratory[2]
PCB (low risk)	3.64 ppm	33 ppm	NA[1]	NA	NA	0.5 ppm	0.1 ppm
U-238	3.64 pCi/g	33 pCi/g	30 pCi/g	3 pCi/g	6 pCi/g	NA	2 pCi/g

[1] Not applicable

[2] As reported in Sampling and Analysis Plan for SWOU, December, 2004

[3] There are a variety of test kits available, ranging from qualitative to quantitative, with actual detection limits and dynamic ranges varying depending on the type of kit used. The numbers quoted are for "screening" kits.

[4] For many systems, detection limits are a direct function of sampling and measurement protocols, including counting times in the case of spectroscopy (e.g., HPGe and XRF). The numbers quoted are for standard protocols, which may differ significantly from technique to technique (e.g., standard count times for an in situ HPGe measurement are 15 minutes, while for an XRF they are 2 minutes).

[5] Individual XRF measurements provide concentration information for a variety of metals. Table 2 summarizes detection limits as reported by EPA Method 6200. This information is dated; actual detection limits can be expected to be significantly better than these for some elements. In the case of U-238, total U is measured by the XRF. Detection limits provided assume natural U.

The PGDP risk-methods document (DOE, 2000) identifies risk-based default action levels (Table A.1, DOE 2000) and no-action levels (Table A.4, DOE 2000) based on default exposure parameters for the teen-recreational-user scenario. The "closure" of this area, based on project demonstration levels, was one possible objective of characterization and soil removal. The PGDP risk-based default no-action levels were used as the demonstration project no-action levels (DPNAL). The DPNAL for ^{238}U and daughters is 3.64 pCi/g and is equivalent to 10.9 ppm total U uranium based on the assumption of natural isotopic abundance. The DPNAL for total uranium is 14.3 ppm. For uranium contamination that either has natural abundances of uranium isotopes or is depleted, the ^{238}U DPNAL is more restrictive than the total uranium DPNAL. For the purposes of this project, only the ^{238}U was used and the assumption made that ^{238}U activity concentrations could be directly converted to total U ppm values. The DPNALs for total PCBs are 0.127 ppm for high risk arochlors and 3.64 ppm for low-risk arochlors.

For the purposes of this project, two types of project demonstration levels were developed.

1. The first was an average level or Derived Concentration Guideline Level ($DCGL_w$) that must be achieved over an area the size of an exposure unit.
2. The second was a "hot spot" or "elevated area" level that must be achieved over an area of size much smaller than an exposure unit.

Consistent with MARSSIM guidance (MARSSIM 2000), exposure units were represented by Final Status Survey (FSS) units. MARSSIM defines three types of FSS units: Class 1, Class 2, and Class 3.

1. Class 1 units can be up to 2,000 m^2 (approximately 0.4 acre). Class 1 units represent areas with contamination at levels known to exceed cleanup requirements and/or areas where cleanup-level exceedences are likely.
2. Class 2 units can be up to 10,000 m^2 (approximately 2 acres). Class 2 units represent areas with contamination known to be present at less than cleanup levels, or possibly present but unlikely to exceed cleanup requirements.
3. Class 3 units have no size limitation. Class 3 units represent areas where it is highly unlikely contamination exists at levels that would be of concern.

For planning purposes, the study area was divided into MARSSIM FSS exposure units based on the site conceptual model and the anticipated distribution of contamination (Figure 5).

PGDP surface soils are defined as the top one foot (1') of soil. For the purposes of this demonstration project, the "hot spot" criterion was applied to 25 m^2 areas to a depth of one foot (1') below ground surface (bgs). The "hot spot" criterion is consistent with DOE Order 5400.5. The acceptable hot spot concentration or activity concentration for a particular contaminant is given by:

$$\text{Hot spot criterion} = DCGL_w * (\text{survey unit area/hot spot area})^{1/2}$$

Assuming a Class 1 FSS unit size of 2,000 m^2 and a hot spot area of 25 m^2, the area factor is nine (9). For ^{238}U, an area factor of nine (9) is approximately equal to the generic area factor corresponding to a 25 m^2 area identified the MARSSIM guidance document (Table 5.6, MARSSIM 2000). DOE Order 5400.5 establishes never-to-exceed criteria of 30 times the $DCGL_w$.

DPNALs and "hot-spot" levels for AOC 492 primary COCs are listed in Table 1. Table 1 also identifies the expected detection limits associated with the real-time measurement technologies deployed for this project. In the case of ^{238}U, the DPNAL is very close to the established PGDP-soil background activity. As such, the ^{238}U DPNAL provided a challenge for the real-time measurement technologies from a decision level perspective. One goal of this project was to determine the performance capabilities of real-time measurement techniques in the context of such demanding PGDP cleanup goals.

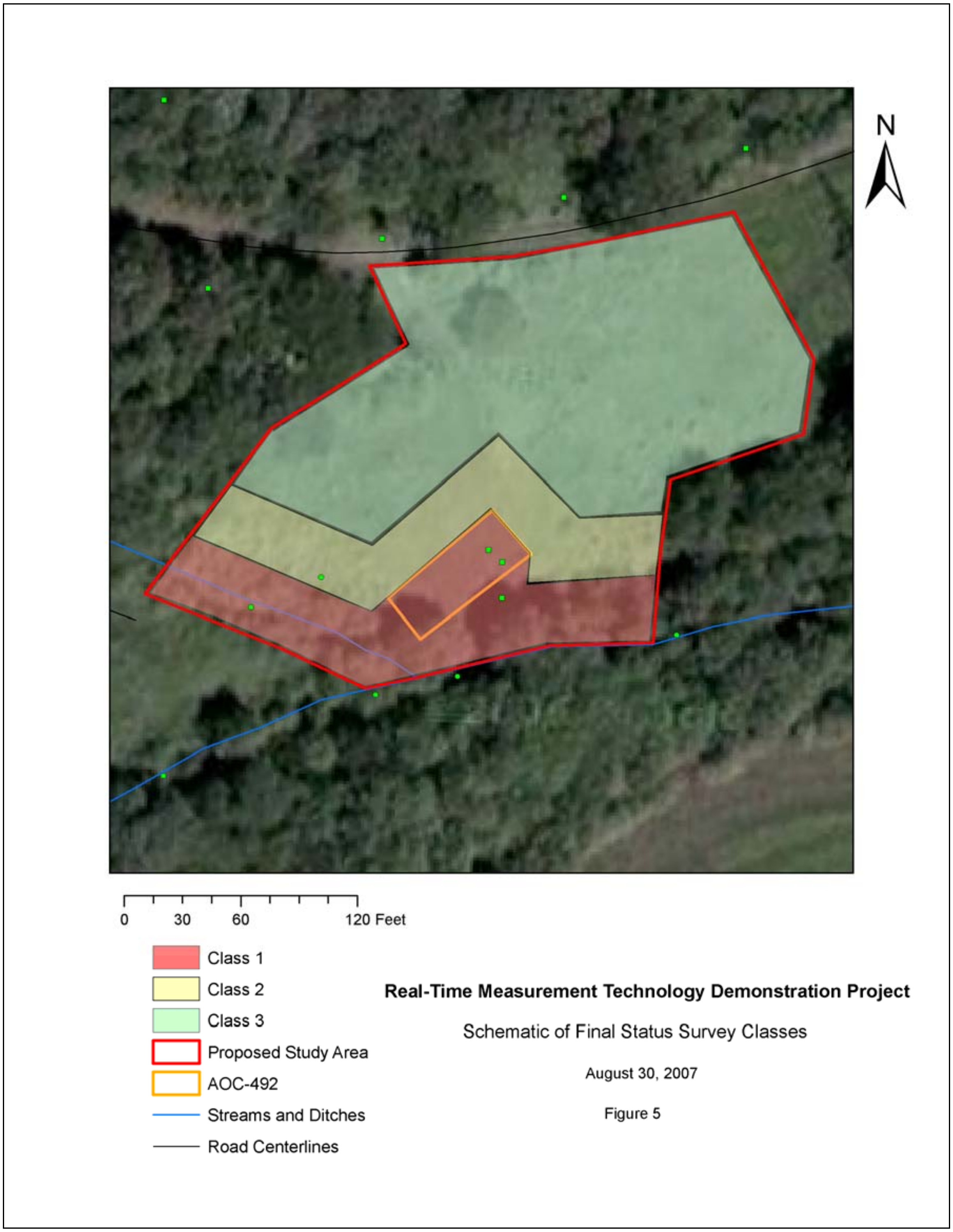


Figure 7. Schematic Layout of Final Status Survey Unit Classes
(Based on Initial Conceptual Site Model)

1.3. Project Participants

Work planning for the project received input from and was reviewed by representatives of KRCEE, KRCEE contractors, the DOE, DOE contractors, PRS, the Commonwealth of Kentucky, and the U.S. Environmental Protection Agency (EPA) Region 4. Field work was conducted by Eberline, Incorporated with on-site logistical support for site access and waste disposal. Health physics oversight operations were provided by Tricord, Inc.

2.0. Field Activity Description

This section provides an overview of actual field activities and identifies where field activities deviated significantly from planned activities. Details of planned field activities are in the AOC 492 Field Sampling Plan (FSP) (KRCEE, October 2007). A detailed list of field work deviations are in Appendix A.

The central and unifying theme for field work was to apply real-time field measurement technologies to support "on-the-fly" decision-making based on implementation of dynamic work strategies. This approach allows an area such as AOC 492 to move directly from planning to site characterization, remediation, and site closure in one (1) field deployment. Descriptions of specific field activities identified below highlight the types of decisions and dynamic work strategies that real-time data collection supported.

2.1. Pre-Field Work Studies

Two pre-field work studies were initiated to assist with understanding the performance of XRF and Abraxis PCB test-kit technologies at the site. The activities related to these two studies were supplemental to FSP activities and are not described in the FSP. They are described below.

The XRF study was conducted by KRCEE and KRCEE contractors with the cooperation of Thermo Fisher Scientific, Inc., maker of NITON XRF analyzers, and Innov-X Systems, Inc., the maker of Innov-X XRF analyzers. Thermo Fisher Scientific and Innov-X Systems are the leading manufacturers of hand-held XRF analyzers in the United States. The Abraxis PCB test test-kit study was conducted by the EPA Office of Superfund Remediation and Technology Innovation. The PCB test kit study, which is part of a larger EPA effort, is still underway.

Soil samples from four different locations were collected in January 2008 by PRS technical and field support staff. The sample locations were selected to encompass a range of expected contamination levels. Locations included one "background" area north of AOC 492 and outside the proposed study area, one location in the vicinity of AOC 492 that was expected to have some measurable but low level contaminant levels, and two locations from impacted areas within AOC 492 itself.

At each location a 1 m^2 area was outlined. One (1) kilogram (kg) soil samples were collected from five (5) different points in each 1 m^2 area. The five (5) points included the center and each of the four corners of the 1 m^2 areas. A Field Instrument for Detecting Low Energy Radiation (FIDLER) was used to obtain discrete count-rate readings above each sample point prior to sample collection. An additional soil sample was obtained from three (3) discrete depths (4, 10, and 15 cm) at the center of each of the four (4) 1 m^2 areas.

Surface and sub-surface soil samples were containerized and provided to the Commonwealth of Kentucky's REMS. The 20 samples collected for the EPA were sent directly to the EPA without treatment. The samples from the four locations at depths of 4, 10, and 15 cm were dried, minimally ground and split by the REMS. The four (4) split samples from the 4 cm depth were sent to Thermo Fisher Scientific and Innov-X for analyses using their newest XRF analyzers. The other split was analyzed by the REMS for ^{238}U via gamma spectroscopy and for uranium isotopes by alpha spectroscopy.

2.2. Initial Data Collection and Evaluation

There was very little historical data available to indicate the extent or level of contamination that might be encountered in AOC 492. Existing sample results were only sufficient to identify potential contaminants and to establish that they were likely to exist at levels exceeding PGDP DPNAL. Hence, at the outset of field activities, the spatial extent of contamination in the study area was unknown.

To address this data gap, field work commenced with a complete GWS of the study area using a FIDLER detector and a Laser-Assisted Ranging and Data System (LARADS) for location control and data logging. Technical details regarding LARADS operation and performance will be discussed in Section 4.1. Gross gamma count rate data were collected every second and logged in LARADS, providing a data density of approximately four measurements per square meter (/m^2).

In addition to collection of GWS gross-gamma count rate data, the study area was "walked-down" and potentially significant study area features were noted and mapped. The stream and ditch banks were not included in the study area data collection as originally planned because of thick undergrowth and safety considerations related to the steep banks of LBC and the Outfall 011 ditch. The study area boundary was modified to include those accessible areas north of Outfall 011 and west of Little Bayou Creek.

Based on the qualitative GWS results, 20 locations were selected that represented a range of gross-gamma count rates. At each of these locations a 1 square foot (ft^2) area was defined, *in situ* measurements were obtained and samples were collected. The measurements included:

- A discrete FIDLER gamma count rate reading above the center of the 1 ft^2 area. The discrete FIDLER gamma-count-rate measurement was obtained so that count rate data could be used with *in-situ* HPGe measurements, *in-situ* XRF measurements, and *ex-situ* sample XRF analyses for conversion of qualitative GWS to a quantitative GWS.

- An *in-situ* HPGe measurement was obtained with the instrument height set to an approximate 1 ft^2 field of view. The HPGe measurements focused on analysis of ^{238}U activity at each location that would be used with other data for conversion of the qualitative GWS to a quantitative GWS. HPGe measurements were also used to assess the potential presence of other radionuclides (e.g., Cs-137) above background levels.

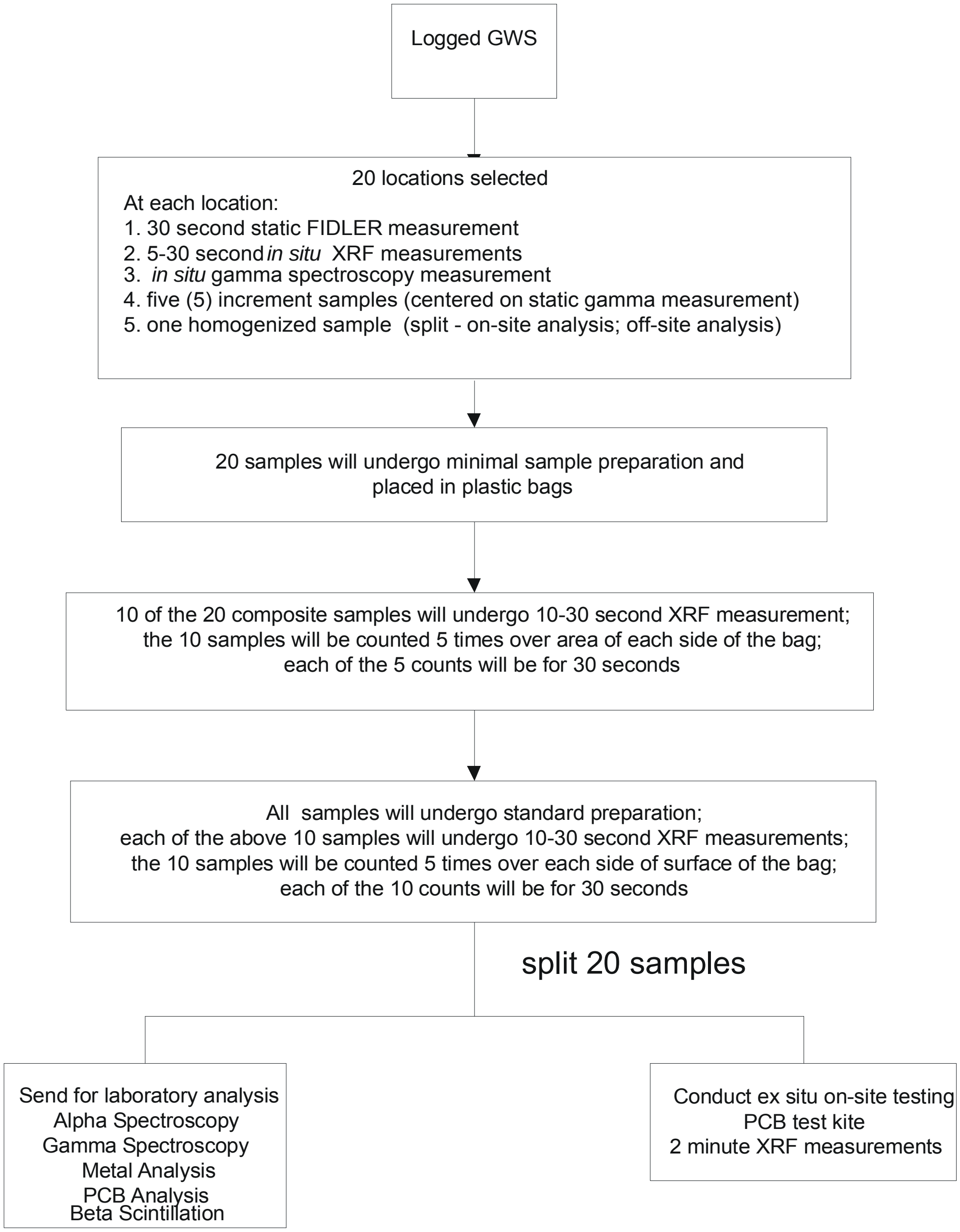
- *In-situ* XRF readings were obtained from the center and the four corners of each 1 ft^2 area. The XRF measurements were obtained to evaluate short-scale heterogeneities present in near-surface uranium concentrations and to provide uranium concentration estimates that could be used to convert the qualitative GWS to a quantitative GWS.

- Soil samples were collected to a depth of 1 ft bgs from the center and each of the four corners of the 1 ft^2 areas. For each 1 ft^2 area, the center soil sample was screened at three (3) different depths by XRF: 2, 6, and 10 inches. For seven (7) of the locations all five (5) soil samples were screened vertically by XRF. The vertical-XRF screening was a deviation from the work plan and was conducted to gain insight into the vertical distribution of the contamination.

- The five (5) soil samples collected for each location were combined to form one (1) 5-increment composite sample. This sample was bagged. For eight (8) of the bagged samples, repeated XRF measurements were obtained through the sample-bag walls. The purpose of the bagged sample measurements was to demonstrate the efficiency of bagged ex-situ sample measurements as a substitute for sample preparation when using an XRF. Ex-situ bagged sample measurements were also conducted to evaluate the degree of heterogeneity present in the samples prior to more thorough preparation.

- The bagged soil samples for each location were prepared and sub-sampled for XRF-cup analysis and Abraxis PCB test-kit analysis. In addition, sub-samples were obtained and sent to an off-site analytical laboratory for gamma spectroscopy, alpha spectroscopy (thorium, uranium, and plutonium isotopic analysis), beta scintillation (^{99}Tc), Resource Conservation and Recovery Act (RCRA) metals analyses, SVOC analyses, and PCB analyses. The SVOC analyses were a deviation from the FSP and resulted from a miscommunication with the laboratory. The purpose of the off-site laboratory analyses was to provide a point of comparison for the XRF and PCB test kit analyses and to ensure that secondary contaminants were evaluated when it was not possible to evaluate the contaminants with the deployed real-time technologies.

The initial data collection supported several key decision points in the dynamic work strategy. These included: (1) selecting the 20 locations that were further characterized as described above; (2) converting the GWS results from qualitative survey to quantitative survey; (3) determining the presence and location of uranium “hot spots” using the quantitative GWS data; and (4) dividing the study area into appropriate Class 1, 2, and 3 areas for FSS purposes using the quantitative GWS data. The work flow for this phase of activities is identified in Figure 6.



Logged GWS

20 locations selected
At each location:
1. 30 second static FIDLER measurement
2. 5-30 second *in situ* XRF measurements
3. *in situ* gamma spectroscopy measurement
4. five (5) increment samples (centered on static gamma measurement)
5. one homogenized sample (split - on-site analysis; off-site analysis)

20 samples will undergo minimal sample preparation and placed in plastic bags

10 of the 20 composite samples will undergo 10-30 second XRF measurement; the 10 samples will be counted 5 times over area of each side of the bag; each of the 5 counts will be for 30 seconds

All samples will undergo standard preparation; each of the above 10 samples will undergo 10-30 second XRF measurements; the 10 samples will be counted 5 times over each side of surface of the bag; each of the 10 counts will be for 30 seconds

Send for laboratory analysis
Alpha Spectroscopy
Gamma Spectroscopy
Metal Analysis
PCB Analysis
Beta Scintillation

Conduct ex situ on-site testing
PCB test kite
2 minute XRF measurements

Figure 8. Work Flow for Initial Data Collection Activities

2.3. Excavation Support

The initial GWS clearly identified at least one localized area with ^{238}U activity that was above the demonstration project “hot spot” criteria. This location corresponded to the soil mound located in the center of AOC 492. This soil mound was selected for excavation.

The excavation and supporting data collection deviated from the FSP in several significant ways.

1) The FSP called for excavating up to two (2) 25 m^2 areas. Because the footprint of the mound (both visually and from the perspective of elevated GWS data) was so distinct, excavation focused on the mound itself and the mound was removed. This resulted in the removal of an area roughly equal to 29 m^2.
2) The FSP called for significant data collection prior to excavation to confirm that the area in question exceeded hot spot criteria. No additional data was collected prior to mound removal for two reasons:
    a. Excavation contractor schedule constraints on field work
    b. Several of the initial 20 sampling locations fell within the mound footprint. The data from those locations confirmed that the hot spot criteria had been exceeded.
3) The FSP called for excavation to be conducted to a depth of one (1) foot bgs before additional data were collected. The excavation was conducted to an average depth of 0.84 ft bgs. Excavation was halted because saturated soil conditions were encountered. There were concerns that an adjacent wetland might be compromised and that the excavation would result in liquid wastes that would require handling and disposal, as well as possible health and safety considerations for the field crews.
4) Because of the water concerns, backfilling the excavation to pre-mound grade with clean cover was considered to be an immediately prudent action to secure the site.
5) The FSP called for data collection to be conducted after the first lift of soil was removed in order to determine whether excavation should continue into a second one (1) foot lift. Because of the rate of water infiltration into the dig, there was only time to conduct a GWS of the exposed surface, collect five (5) in *situ* XRF readings, and collect of one (1) sample from the center of the dig for *ex situ* analysis. *Ex situ* sample analysis included on-site XRF measurements, off-site laboratory gamma spectroscopy analysis, alpha spectroscopy (thorium, uranium, and plutonium isotopic analysis), beta scintillation (^{99}Tc), RCRA metals, SVOC, and PCB analyses. The post-excavation SVOC analyses were a deviation from the FSP.

As will be discussed in more detail in later sections, the analytical results for the sample from the excavated area were used to demonstrate that the excavation was successful in removing contamination exceeding the hot-spot criteria and combined with results from the rest of the Class 1 area, the Class 1 area as a whole met the DPNAL criteria.

The dynamic decision points for excavation included defining the excavation footprint, and determining whether the exposed dig face after excavation had attained the DPNAL criteria.

2.4. Final Status Survey Data Collection

Final Status Survey (FSS) data collection was used to confirm that the study area was in compliance with DPNALs. FSS data collection was designed to be consistent with MARSSIM. The study area was divided into three (3) different areas based on MARSSIM FSS guidance: a Class 1 area (990 m^2), a Class 2 area (830 m^2), and a Class 3 area (2,010 m^2). In each of these three areas one (1) MARSSIM FSS unit was defined. The size of the units was significantly less (much more conservative) than a typical MARSSIM final status survey unit. MARSSIM allows Class 1 units to range up to 2,000 m^2 and Class 2 units up to 10,000 m^2. Class 3 units can be any size. The size of the demonstration project study area limited the sizes of FSS units used for this project.

The Field Sampling Plan (FSP) provided a general schematic of the expected extent and layout of the FSS units. This schematic proved to be very close to what was actually required based on the GWS survey.

Based on DPNAL criteria, the Class 1 and Class 2 areas were divided into 25 m^2 sub-areas for sampling, in order to confirm that PCB "hot spots" did not exist. The quantitative GWS data provided a high level of confidence that ^{238}U "hot spots" would have been identified, if they existed in particular areas. There were thirty-seven (37) 25 m^2 sub-areas in the Class 1 unit and thirty-two (32) 25 m^2 sub-areas in the Class 2 unit. One (1) multi-increment-composite (MIC) soil sample consisting of five (5) soil increments was obtained from each 25 m^2 sub-area by sample collection to a depth of 1 ft. For each 25 m^2 sub-area, one increment of the MIC sample came from the center of the sub-area, and the other four increments from locations halfway between the center and each of the four corners.

In the Class 1 unit, the MIC soil samples from each 25 m^2 area were homogenized. Each MIC sample was archived. Before archiving each MIC sample was sub-sampled to form composite samples. Sub-samples from MIC soil samples from five (5) adjacent 25 m^2 areas were combined to form FSS composite samples. This resulted in seven (7) Class 1 FSS composite samples. Because of the number of 25 m^2 areas in the Class 1 unit, one Class 1 FSS composite sample contained soils from 6 adjacent 25 m^2 areas. The seven Class 1 FSS composite samples were homogenized and then analyzed by XRF and Abraxis PCB test kits. Splits of the Class 1 FSS composite samples were sent for off-site laboratory analysis that included gamma spectroscopy, alpha spectroscopy (thorium, uranium, and plutonium isotopic analysis), beta scintillation (^{99}Tc), RCRA metals, SVOC, and PCB analyses. The SVOC analyses were a deviation from the FSP.

XRF and PCB test kit results for the seven Class 1 FSS composite samples were compared to field investigation levels to determine whether there was evidence of "hot spot" concerns for each of the contributing individual 25 m2 sub-areas. Field investigation levels were DPNAL hot spot criteria divided by the number of samples contributing to the FSS composite. If the Class 1 FSS composite sample exceeded the field investigation level, then each of the MIC samples originally contributing to the FSS composite were analyzed to determine which, if any, exceeded the "hot spot" criteria. The FSP called for this re-analysis to be done by XRF and PCB test kits.

There was one Class 1 FSS composite sample that exceeded the field investigation level for uranium. The five (5) MIC 25 m^2 sub-area soil samples from this Class 1 FSS composite were sent for off-site laboratory analysis rather than analyzed by on-site XRF and PCB test kits.

In general, FSS data collection in a Class 1 area would not take place until all excavation was completed. In the case of this study's logistics and time constraints, FSS composite samples from the Class 1 area were obtained prior to the excavation of the soil mound. This actually provided a unique opportunity to evaluate whether the FSS composite sampling protocols were sufficient to identify the mound which had already been identified by the GWS. After the excavation of the mound, the post-excavation sample was included in the FSS analysis to determine whether the Class 1 area as a whole achieved the established PGDP DPNAL.

In the Class 2 unit, MIC soil samples from each 25 m2 sub-area were homogenized. Each MIC sample was archived. Before archiving each MIC sample was sub-sampled to form composite samples. Sub-samples from MIC soil samples from eight (8) adjacent 25 m^2 areas were combined to form four (4) Class 2 FSS composite samples. The four (4) Class 2 FSS composite samples were homogenized and analyzed by XRF and Abraxis PCB test kits. Splits of the four (4) Class 2 FSS composite samples were sent for off-site laboratory analysis that included gamma spectroscopy, alpha spectroscopy (thorium, uranium, and plutonium isotopic analysis), beta scintillation (^{99}Tc), RCRA metals, SVOC, and PCB analyses. SVOC analyses were a deviation from the FSP.

The XRF and PCB test kit results for the four (4) Class 2 FSS composite samples were compared to field investigation levels to determine whether there was evidence of “hot spot” concerns. This addressed contamination in the Class 2 area and in each of the contributing individual 25 m2 sub-areas in exactly the same fashion as was done for the Class 1 FSS composite samples. The field investigation levels for the Class 2 FSS composite samples were lower than the field investigation levels for the Class 1 FSS composite samples because more 25 m^2 sub-area MIC samples were used to form each Class 2 FSS composite sample.

Class 2 FSS composite soil sample results were not above field investigation levels. Consequently, none of the archived 25-m^2 sub-area MIC samples used to form the Class 2 FSS composite samples required re-analysis. The Class 2 FSS composite samples were used to verify that no individual Class 2 25 m2 sub-areas exceeded DPNAL “hot spot” criteria. The Class 2 unit as a whole met the DPNAL criteria.

In the Class 3 unit, eight (8) sampling locations were systematically located across the unit. One *in situ* HPGe measurement was obtained from each location. One MIC soil sample consisting of 5-incremental soil samples was collected from each location in a manner identical to the 25 m^2 areas in the Class 1 and 2 units. The FSP called for each MIC sample to be analyzed by XRF and PCB test kit before being sent off-site for laboratory analysis. Because of a miscommunication with the field team, one Class 3 FSS composite sample was formed from sub-samples from each of the eight (8) MIC samples analyzed by XRF and PCB test kits. Each of the original eight (8) MIC samples were sent off-site for laboratory analysis that included gamma spectroscopy, alpha spectroscopy (thorium, uranium, and plutonium isotopic analysis), beta scintillation (^{99}Tc), RCRA metals, SVOC, and PCB analyses. The SVOC analyses were a deviation from the FSP. The Class 3 MIC sample results were used to demonstrate that the eight (8) locations did not exceed demonstration project “hot spot” levels. The Class 3 unit as a whole met the DPNAL criteria.

The work flows for the Class 1, Class 2, and Class 3 areas are portrayed in Figures 7, 8, and 9, respectively. Key dynamic decision points in the FSS process included the finalized layout of the FSS units, the definition of 25- m^2 areas for “hot spot” sampling in the Class 1 and Class 2 units, the selection of the eight FSS sampling locations in the Class 3 unit, the evaluation of the adaptive-composite sample results for the Class 1 and 2 units, and a preliminary decision as to whether each unit would pass or fail the DPNAL criteria based on real-time data.

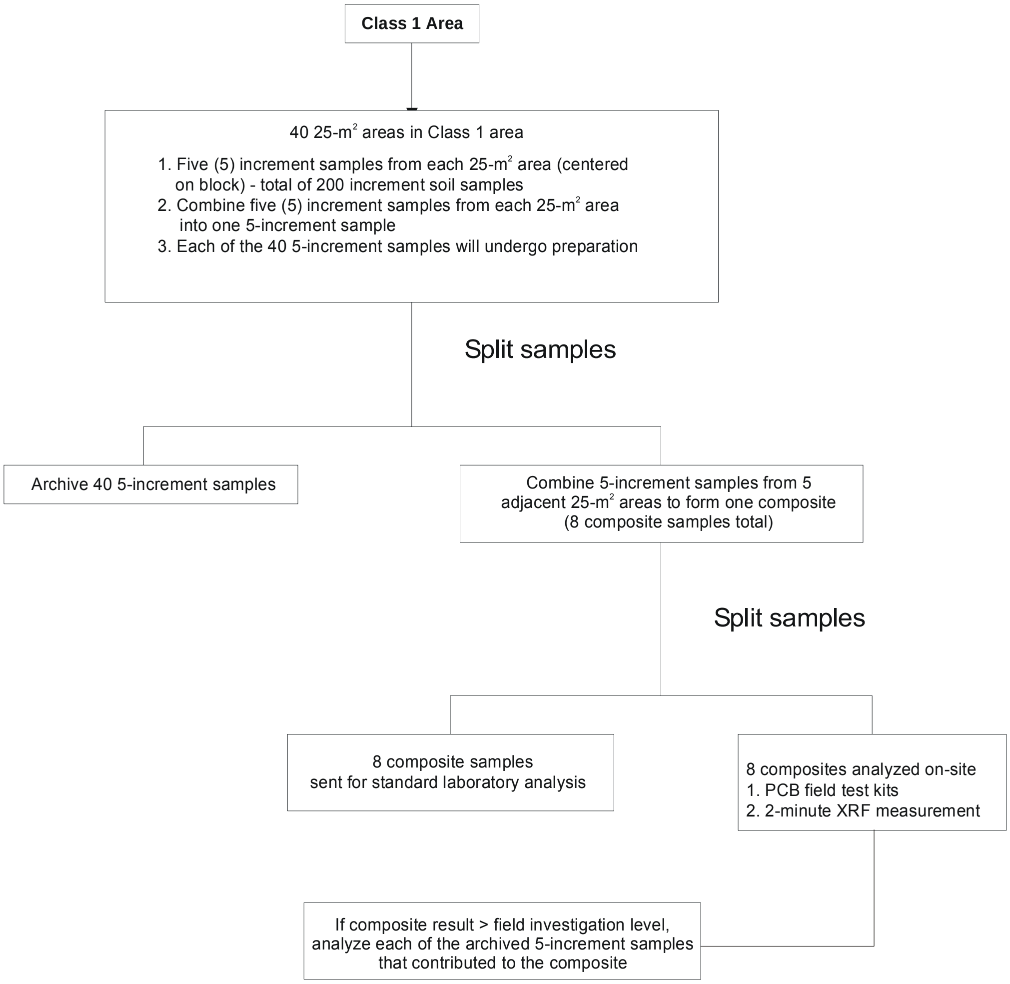


Figure 9. Work Flow for Class 1 Final Status Survey Unit

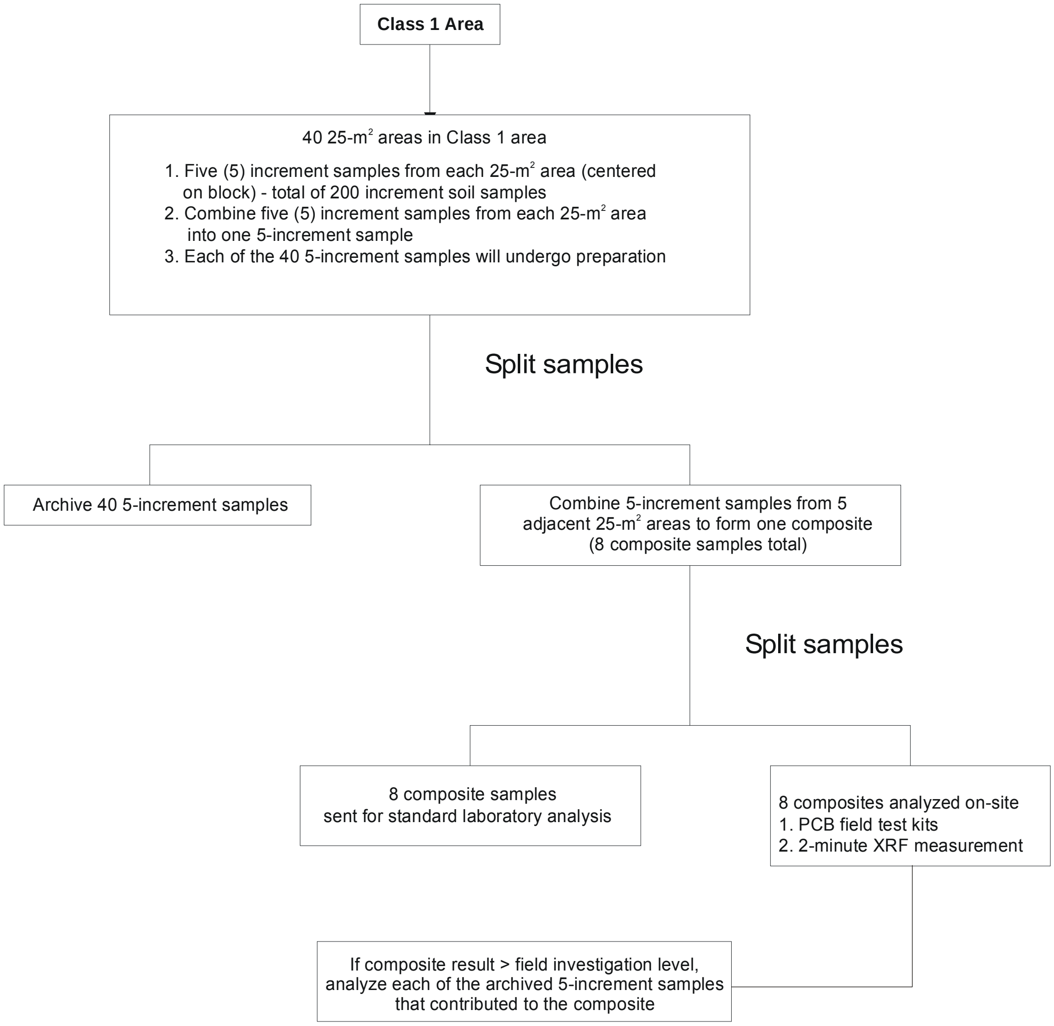


Figure 10. Work Flow for Class 1 Final Status Survey Unit

2.5. Waste Profile

Waste profile information is required for the proper disposition of excavated material. The FSP envisioned using GWS, XRF, *in situ* HPGe, and PCB test kit results for obtaining estimates of average contaminant concentrations for excavated soils. In practice these data were used to provide PRS as waste profile information for the soils removed by the excavation work.

The dynamic decision point for waste profiling was whether excavated soils met waste acceptance criteria for the on-site waste disposal facility.

2.6. Technology Performance

A significant component of the field work involved activities that were designed to establish and/or verify the performance of key technologies deployed as part of this project. In many cases these activities were above and beyond what would be required by characterization data needs in routine application of real-time technologies and

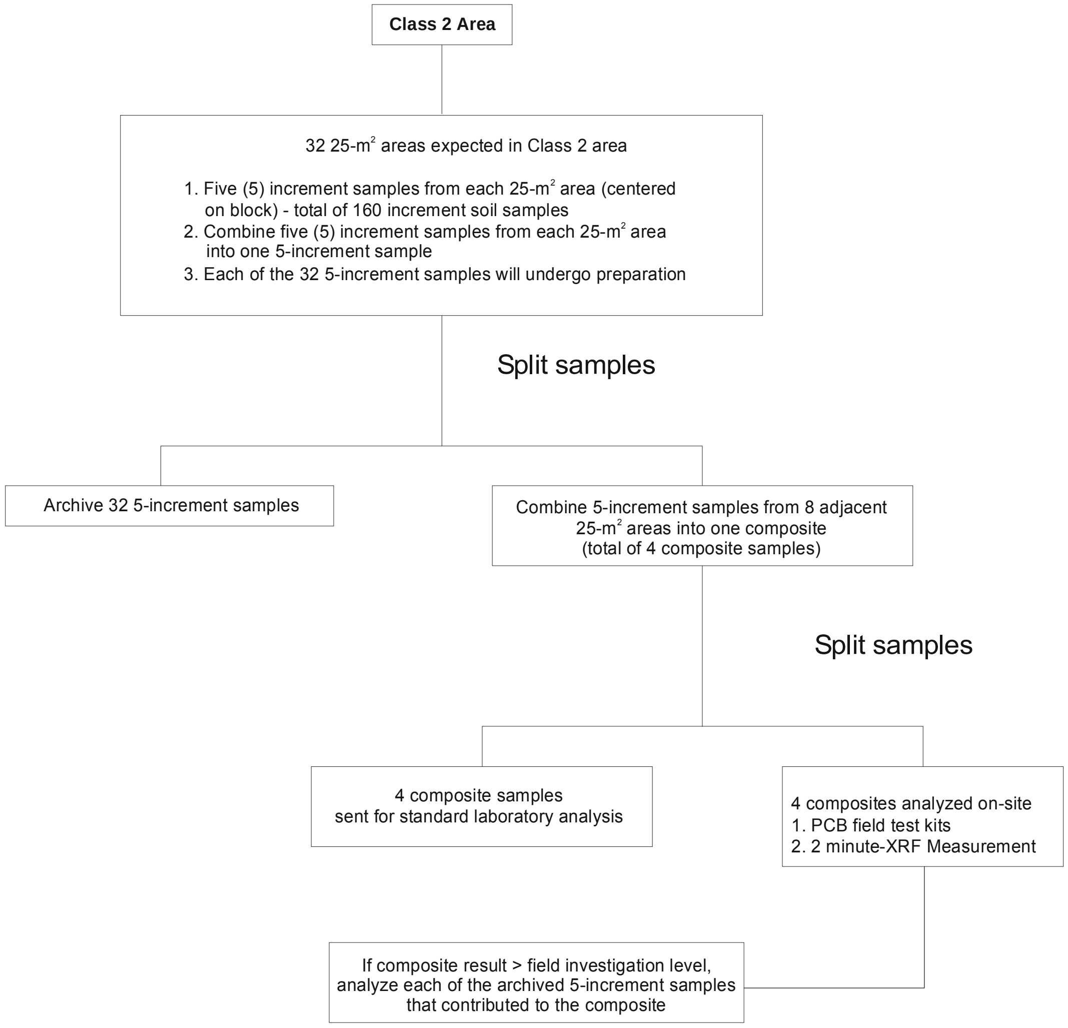


Figure 11. Work Flow for Class 2 Final Status Survey Unit

dynamic decision making practices. The following text summarizes activities by technology and identifies what was done and why. Performance results and conclusions will be discussed in subsequent sections of this report appendices dedicated to technology-specific quality control (QC) results.

2.6.1. GWS/LARADS

The GWS deployed at the site consisted of a FIDLER detector coupled with an Eberline LARADS system for data acquisition, logging and location control. Performance-related activities relevant to the GWS/LARADS deployment included:

- Establishing “a priori” instrument background, standard, and in-field background for the FIDLER detector. The purpose was to: (1) establish a critical level (L_C), (2) establish a detection limit (L_D), (3) verify FIDLER precision, (4) identify temporal trends in FIDLER in-field background readings (and the additional variability these trends might introduce into FIDLER result interpretation), and (5) establish control charts for FIDLER QC purposes that could be used to identify potential FIDLER problems if they developed.

- Obtaining daily soil moisture readings at the in-field background location. These data were used to evaluate variations in soil moisture conditions and their potential impacts on GWS data, *in situ* XRF readings, and *in situ* HPGe measurements.

- Estimating response to local conditions through an evaluation of observed FIDLER responses over an assumed "background" area with comparison to instrument background, in-field background, and incremental FIDLER responses to the presence of elevated uranium for impacted areas.

- Determining the quality of the relationship between FIDLER gross-gamma counts per minute (gross gamma count rate) and the presence of elevated uranium. Data from the initial 20 locations selected for intensive data collection (XRF and *in situ* HPGe results) were the basis for evaluating the relationship between FIDLER gross counts rate and ^{238}U activity concentrations in soils.

- Benchmarking GWS data production rates.

- Evaluating the locational accuracy of LARADS system. LARADS locational accuracy was evaluated by standard civil surveying methods (e.g., "closing" civil surveys by returning to the point of origin and verifying that the ending coordinate information for the point of origin matched the starting coordinate information, and recovering known survey benchmarks).

2.6.2. XRF

The XRF deployed by the project was Niton's newest hand-held XRF analyzer, the Niton XL3t. The Niton XL3t can be used in a variety of ways, including measuring exposed soil surfaces directly *in situ*, measuring bagged samples through bag walls, and measuring prepared samples in sample cups. Performance-related activities relevant to the XRF deployment included:

- Measurements of previously characterized AOC 492 samples to verify the instruments uranium calibration.

- Measurement of a Niton-provided RCRA standard to verify instrument calibration for other primary metals of potential concern.

- Repeated measurements of several selected samples to verify instrument estimates of analytical precision and to establish control charts for QC use.

- Multiple *in situ* measurements of surface soils at the initial 20 sampling locations to better understand short-scale uranium heterogeneity in impacted areas.

- Vertical profiling by XRF of selected 12-inch soil cores from the initial 20 sampling locations to better understand vertical uranium heterogeneity in impacted areas.

- Multiple measurements of bagged samples to evaluate the performance of XRF when directly measuring bagged samples without sample preparation.

- Off-site laboratory analysis of XRF-analyzed samples to verify XRF data comparability for uranium and other potential metals of concern.

- Benchmarking *in situ* XRF, bagged sample XRF, and prepared sample XRF measurement production rates.

2.6.3. In Situ HPGe

The HPGe instrument deployed by Eberline for *in situ* measurement purposes was an ORTEC p-type detector (thin beryllium window). Performance-related activities relevant to HPGe deployment included:

- Collection of HPGe measurements from the in-field background location to establish baseline performance parameters.

- *In situ* XRF measurements and collection of soil samples within *in situ* HPGe measurements fields of view for comparability purposes.

- An evaluation of the implications of source geometry assumptions for HPGe activity concentration estimation.

- Benchmarking *in situ* HPGe measurement data acquisition rates.

2.6.4. Abraxis PCB Test Kits

Abraxis PCB test kits were used for determining the total PCB content of soil samples. Performance-related activities relevant to PCB test kit deployment included:

- Duplicate analyses of soil extracts to establish extract analysis repeatability.

- Multiple sub-sampling and analyses of one soil sample with elevated PCB concentrations to evaluate analytical/sample preparation variability in PCB test kit results.

- Multiple sub-sampling and analyses by an off-site laboratory with the same sample to assist in separating the contributions of sample heterogeneity and analytical variability in the total variability observed in replicate Abraxis test kit results.

- Off-site laboratory analysis of sample splits to establish Abraxis test kit comparability.

- Benchmarking Abraxis test kit analysis production rates.

2.6.5. Multi-Increment Composite Sampling

Multi-Increment Composite sampling provides a mechanism for controlling the effects of short-scale heterogeneity on sample representativeness. MIC sampling is expected to improve the ability of a sample to provide a representative result for a given location. Performance-related activities relevant to MIC sampling deployment included:

- Multiple *in situ* XRF surface soil measurements for the 20 initial sampling locations to better understand the nature of short scale heterogeneity in uranium impacted soils.

- A retrospective analysis of individual sample results from the excavated “hot spot” to determine their individual effectiveness in identifying the presence of the “hot spot” as compared to the performance of MIC samples collected from that area.

2.6.6. Adaptive Compositing

Adaptive compositing provides a strategy for clearing areas of “hot spot” concerns via sampling. Performance-related activities relevant to adaptive compositing deployment included:

- A retrospective analysis of the ability of the Class 1 unit FSS composite samples to correctly identify the presence of ^{238}U “hot spots” identified by the quantitative GWS.

3.0. Field Work Results

This section presents the results of field activities, excluding technology performance evaluations and QC results. Technology results are presented in Section 4.0. Quality control results are in the appendices. Complete XRF, HPGe, PCB test kit, and off-site laboratory results are provided in Appendices B, C, D, and E, respectively. This section will reference data tables contained in those appendices as appropriate.

3.1. Pre-Field Work Study Results

As described in Section 2.1, pre-field work studies were undertaken for both the XRF and Abraxis PCB test kits to better determine their likely performance during field activities.

The XRF work involved samples sent to both Innov-X and Thermo Fisher Scientific for evaluation using their newest tube-based field-portable XRF units. The data generated by that effort along with data analysis and conclusions can be found in a report entitled “Real Time Demonstration Project XRF Performance Evaluation Report for Paducah Gaseous Diffusion Plant AOC 492”, prepared by Argonne National Laboratory for KRCEE dated April, 2008. The important conclusions pertinent to the field work were as follows:

- The study found no significant systematic difference in performance as measured by detection limits between instruments manufactured by the two companies.
- The instruments for both companies yielded detection limits for uranium that were close to background conditions.
- Both instruments identified chromium, zinc, and molybdenum at levels that appeared to be elevated above background levels and that were correlated with elevated uranium.
- Both instruments identified the presence of other elements (in particular, barium) that exceeded the 95% (Upper Tolerance Limit) UTL reported for the site based on site-specific background soil sample analyses.
- In the case of barium, there was significant disagreement between the Niton and Innov-X units regarding the level of barium present, suggesting part of the discrepancy lies with the XRF units and their calibrations for barium.

The PCB study is a part of a larger EPA study still underway at the time this report was finalized. A review of the initial results from that study identified three key findings pertinent to the field work.

- The first was that detection limits appeared to be around 0.5 ppm total PCBs, a level well below the DPNAL used for project field work.
- The second was that the presence of elevated total PCBs was strongly correlated with the presence of elevated uranium.
- The third was that there was a fair degree of scatter observed in replicate sub-sample total PCB results from the same samples. There are three potential explanations:

(1) PCB heterogeneity within the original samples that was not fully addressed by sample preparation;
(2) Varying levels of extraction efficiency from one sub-sample to the next; and
(3) Analytical variability inherent in the Abraxis methodology.

The first explanation is considered unlikely given the level of sample preparation used for the EPA study. The study had not progressed far enough to determine which of the other two explanations (or some combination of both) resulted in the variability observed in replicate results.

3.2. Initial Field Data Collection and Evaluation for AOC 492

3.2.1. Site Walk Down and Study Area Definition

Data collection began with a site walk-down and mapping of significant site surface features. Feature coordinates were determined using a civil survey-grade laser tracking system. Because of heavy undergrowth and concerns about bank slope and safety, the study boundaries were modified from what had originally been planned. The modified study area boundaries encompassed 3,958 m^2. Figure 10 shows the modified study boundaries along with significant study area features on an aerial photograph obtained from Google Maps. Of particular interest in this figure are the locations of the AOC 492 radiological control fence line and the position of a culvert pipe discharge point in the middle of the study area. The point of origination for the culvert pipe was not identified.

3.2.2. GWS Results

GWS work began with establishing a control point (Figure 11). This location was selected to be in the study area, but at a spot believed to be un-impacted by uranium contamination. The control point was used for a variety of purposes, including monitoring soil moisture content during the course of the field work and as a QC check for the FIDLER detector. A complete discussion of FIDLER QC activities and observed QC results can be found in Appendix F.

The critical level (L_C) and detection limit (L_D) count levels (gross cpm) were determined using the approach established in Section 3, NUREG 1507. Pre-operational data were used to calculate these values. The data used for this analysis can be found in Appendix F. Based on the preoperational data provided in the above table, the L_C was determined to be 6,170 gross cpm and the L_D was determined to 7,542 gross cpm for the FIDLER (E-600 01086 FIDLER JP-245).

The GWS of the study area generated more than 24,000 data points, or approximately six (6) measurements for every square meter. Each measurement was a 1-second acquisition. Figure 11 is a map of the GWS data, with individual readings color-coded by observed gross cpm. Figure 11 also identifies the GWS control point/background location that was used as the background project measurement location.

In-field discrete gamma measurements were taken prior to the GWS with the FIDLER (E-600 01086 FIDLER JP-245) at the GWS control point/background location to establish QC

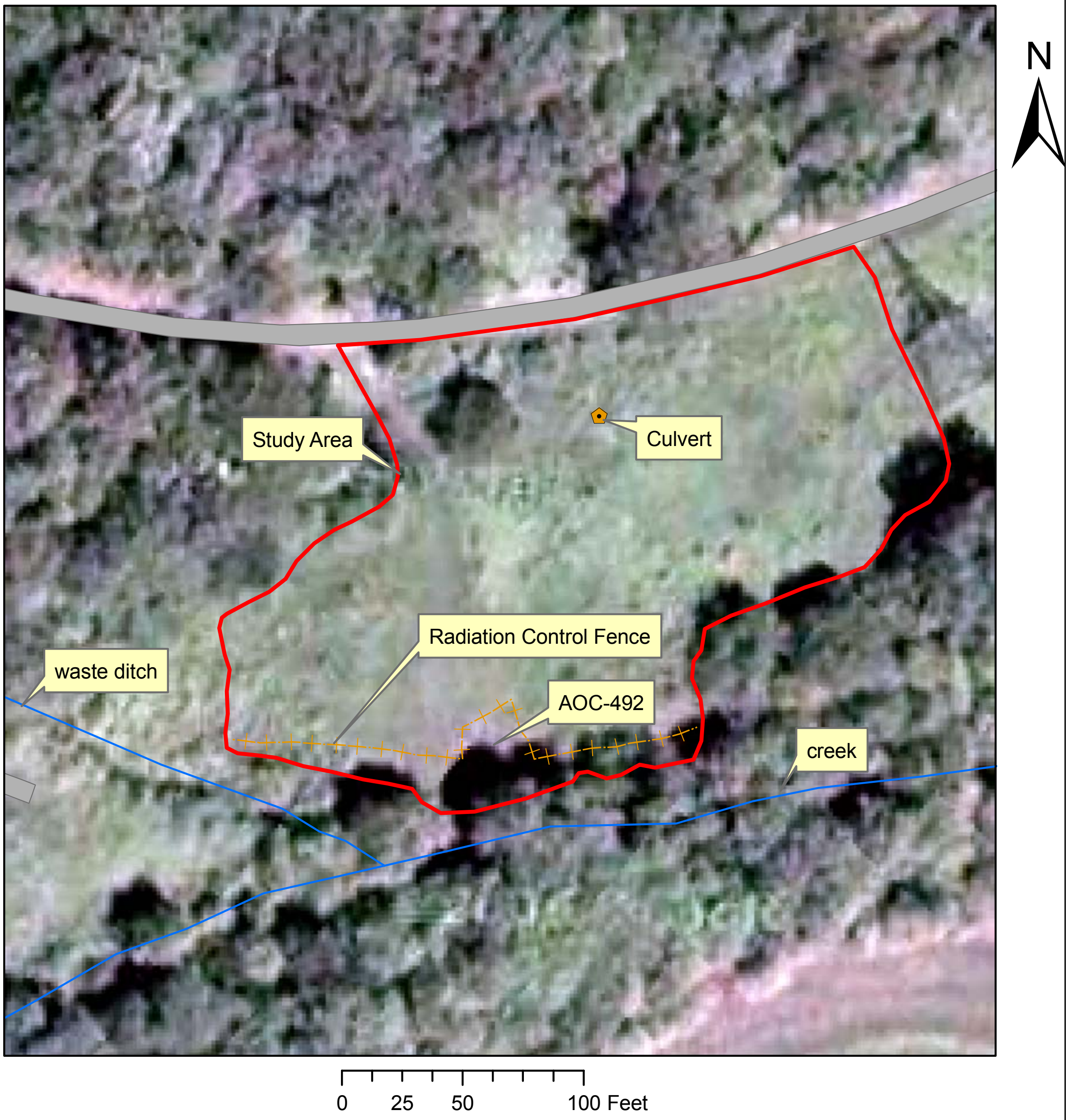


Figure 12. AOC 492 Study Area

and in-field data representative of background for the demonstration project study area. The in-field measurements, summary data and descriptive statistics are provided in Appendix F. The control point/background measurements established a pre-operational background of 8,118 cpm for this location with a standard deviation of 133 cpm.

In-field background field measurements were taken at the GWS control point/background location prior to each use of the FIDLER (E-600 01086 FIDLER JP-245). The in-field background measurements at the control point/background location taken prior to GWS measurements were 7,990, 8,020, 8,150, and 8,190 cpm. The in-field background measurements taken at the GWS control point/background location were within two (2) standard deviations of the mean background field cpm. These GWS background measurements were used to calculate "net cpm" from the "gross cpm" field GWS measurements.

Because of the potential for variable radiation levels in background locations and corresponding variability in the gross count rate, an assumed background area was chosen to test the validity of background measurement for the in-field control point/background (Figure 11). The assumed background area had an average of 8,628 cpm with standard deviation of 679 cpm. A t-test was run with the null hypothesis equal to the in-field control point/background location mean gross cpm of 8,118 cpm. The null hypothesis was tested using the assumed background area data. The t-test demonstrated that the null hypothesis was accepted and therefore the in-field control point/background location background count rate could be assumed to be 8118 cpm. Because of the uncertainties in background radiation activity and thus the gross count rate measurements, the assumed background area mean cpm of 8,628 cpm was used as the background level for the project.

The application of a moving window average to GWS data sets is one way to address counting uncertainty in individual measurements that might complicate the interpretation of individual readings. To calculate moving window averages, a grid is applied to the study area. At each grid node a rectangular "window" is centered on the node and the average of all measurements that fall within the window are assigned to the grid node. Figure 12 shows the results of applying a 25 m2 moving window average to the study area with a grid spacing of three feet. The grid nodes for this map have been color-coded by their average GWS result. A 25 m2 window is of particular interest because 25-m^2 is the area associated with the DPNAL hot spot criteria and thus provides a direct comparison between moving-window-averaged FIDLER results and the hot spot criteria for ^{238}U.

Figure 11 and Figure 12 both clearly identify areas with elevated cpm that are associated with the physical mound present within AOC 492, as well as generally elevated cpm along the western and southern boundary of the study area. This is consistent with the initial CSM for this area, which assumed surface contamination resulted from removing contaminated sediments from the ditch and creek and placing that material near the banks. The GWS data also identified a potentially impacted area where the culvert pipe discharges in the center of the study area that was not anticipated by the initial conceptual site model for the study area.

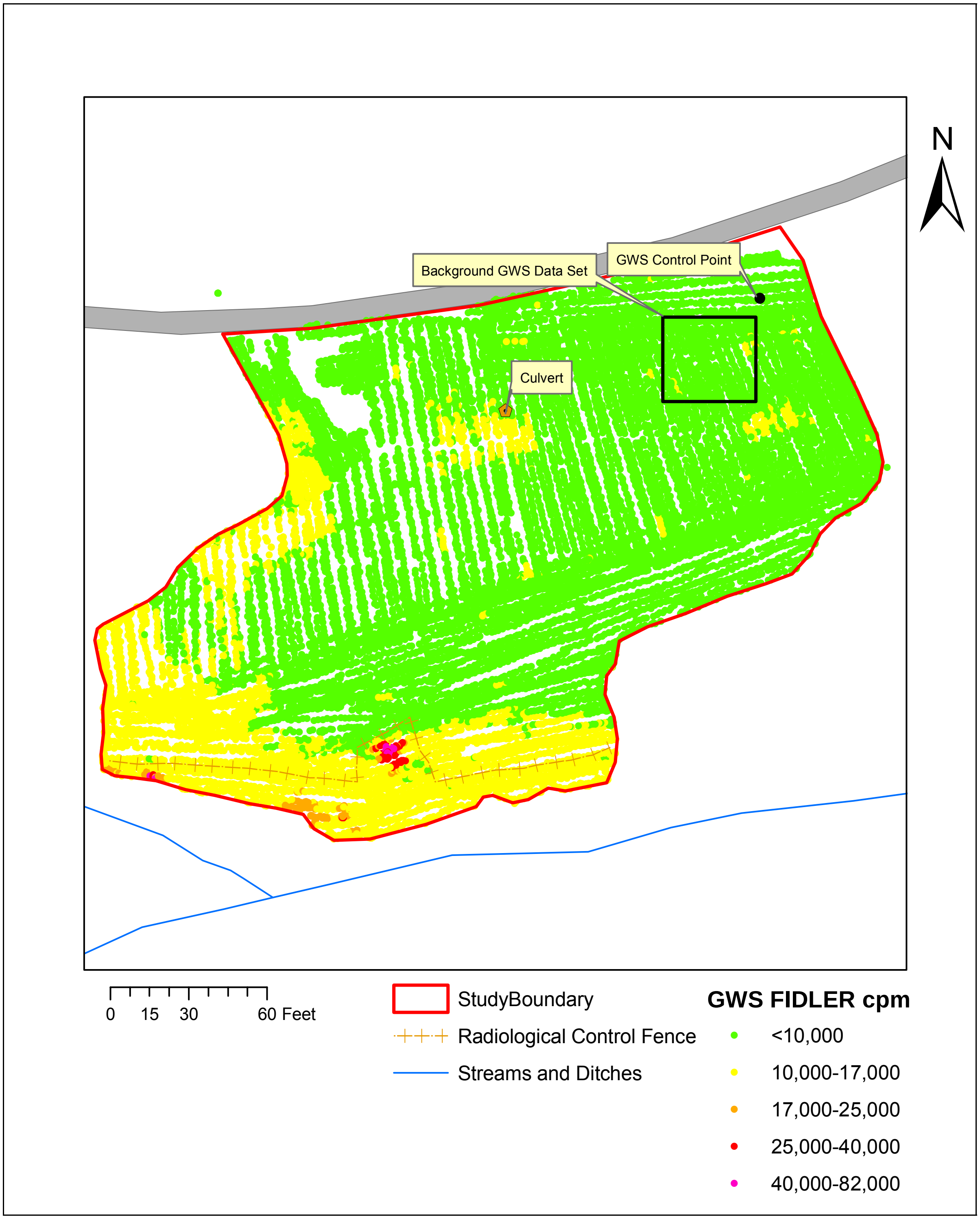


Figure 13. Pre-excavation GWS Results for the Study Area

3.2.3. Initial Sampling Location Results

While GWS data sets provide 100% coverage of soil surfaces, they may present a challenge from an interpretation perspective. In the case of this demonstration, the DPNAL for ^{238}U is 3.64 pCi/g as compared to ^{238}U background of 1.2 pCi/g established for PGDP soils. The question is what level of ^{238}U activity concentration would result in a FIDLER response above the DPNAL? Whereas it may be difficult to differentiate background from the DPNAL because of counting uncertainties, the ^{238}U hot-spot action level of 33 pCi/g should be easily differentiated from background. The second question addresses the level of ^{238}U that produces a FIDLER result that would be clearly distinguishable from background.

Twenty locations were selected based on the GWS gross cpm obtained in the study area. The twenty locations were selected to encompass the range of GWS gross cpm observed in the study area. All selected locations were identified along the southern boundary of the study area, and are shown in Figure 13. At each location the technologies implemented were discrete one minute *in-situ* gamma count rate measurements, *in-situ* gamma spectroscopy, and XRF measurements. In addition, samples were collected at each location, prepared and analyzed according to the procedures outlined in the FSP and flow chart in Section 2. I*n situ* and *ex situ* uranium and PCB data for the twenty locations are provided in Table 2.

Several conclusions can be drawn from Table 2:

- For most locations, the XRF cup reading was less than the average in situ surface XRF reading, indicating that within the 1-ft depth profile represented by soil sampling, the uranium contamination present was generally higher at the surface.
- PCB levels detectable by the Abraxis test kits only occurred when total U concentrations were around or above 190 ppm (equivalent to 63 pCi/g ^{238}U), a level approximately twice the hot spot criteria for ^{238}U.

Based on these data, preliminary conclusions would be that the uranium contamination is predominately surficial, that PCBs are collocated with uranium, and that addressing uranium DPNAL also addresses PCB concerns present.

3.2.4. GWS Interpretation

Figure 14 shows the relationship between the discrete one minute *in-situ* gamma count rate FIDLER measurements for the 20 locations, total U as represented by XRF cup data, and *in situ* HPGe results, based on the data contained in Table 2. The figure includes regression lines fitted to the data sets. While both XRF and HPGe data show a relationship with FIDLER cpm data, the HPGe relationship is much stronger, as by the tighter scatter of data points around the regression line, and the much higher R^2 value (0.9). This is likely the product of two realities: (1) The HPGe field-of-view much more closely matches the FIDLER field-of-view than the XRF field of view. The FIDLER utilizes an area-weighted average response to uranium activity over its field of view while the XRF utilizes the average of 5 sampling locations from a 1-ft^2 area. (2) A significant degree of short-scale heterogeneity is present in uranium concentrations for these locations (Sections 3.2.3 and 3.2.7.) The latter means that

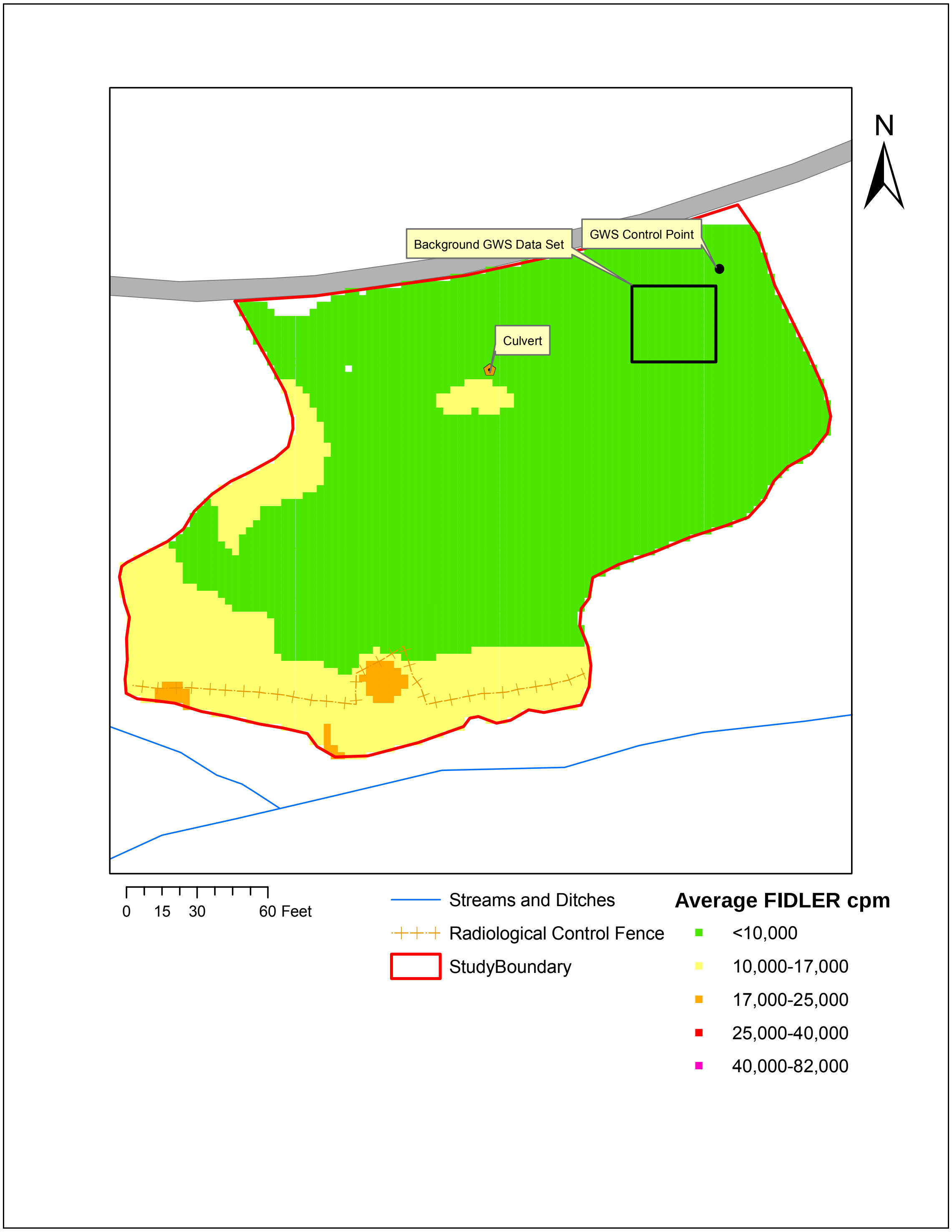


Figure 14. Pre-excavation Moving Window Averaged GWS Results

Table 2. Summary of Real-Time Results for Twenty Initial Locations

Coordinates	Location	FIDLER (cpm)	Average In Situ Surface XRF Total U (ppm)	Average In Situ Core XRF Total U (ppm)	Average XRF Bag Total U (ppm)	XRF Cup Total U (ppm)	In Situ HPGe Total U (ppm)	Abraxis Total PCB (ppm)
N6487.0 E1393.0	BS-1	52221	1935	174	na	338	501	1.26
N6487.0 E1396.0	BS-2	29394	1010	23	na	196	462	ND
N6488.0 E1382.0	BS-3	14054	8	-2	na	3	54	ND
N6483.0 E1438.0	BS-4	11041	6	165	na	7	12	ND
N6478.0 E1451.0	BS-5	18375	144	117	na	143	108	ND
N6476.0 E1459.0	BS-6	15064	63	5	15	14	36	ND
N6470.0 E1468.0	BS-7	13989	20	218	na	197	39	2.79
N6487.0 E1484.0	BS-8	14272	83	24	na	21	51	ND
N6467.0 E1468.0	BS-9	27001	152	595	na	560	189	5.48
N6476.0 E1477.0	BS-10	10196	17	-1	5	4	10	ND
N6495.0 E1479.0	BS-11	23365	353	183	229	213	234	0.86
N6490.0 E1479.0	BS-12	12661	36	20	15	18	25	ND
N6493.0 N1487.0	BS-13	34867	699	287	na	348	330	2.58
N6498.0 E1478.0	BS-14	17098	96	106	67	48	168	ND
N6498.0 E1481.0	BS-15	45035	705	477	na	649	546	11.12
N6499.0 E1485.0	BS-16	33034	514	187	360	112	378	ND
N6495 E1482.0	BS-17	31151	576	14	na	317	255	2.27
N6486.0 E1523.0	BS-18	11179	5	4	5	9	7	ND
N6490.0 E1492.0	BS-19	10247	9	1	na	8	14	ND
N6487.0 E1495.0	BS-20	11096	5	3	1	4	11	ND

Notes: “na” – measurement not available; “ND” – analyte not detected; HPGe total U is based on conversion from measured ^{238}U activity using conversions in Appendix C, Section C.23, NUREG/CR-6232

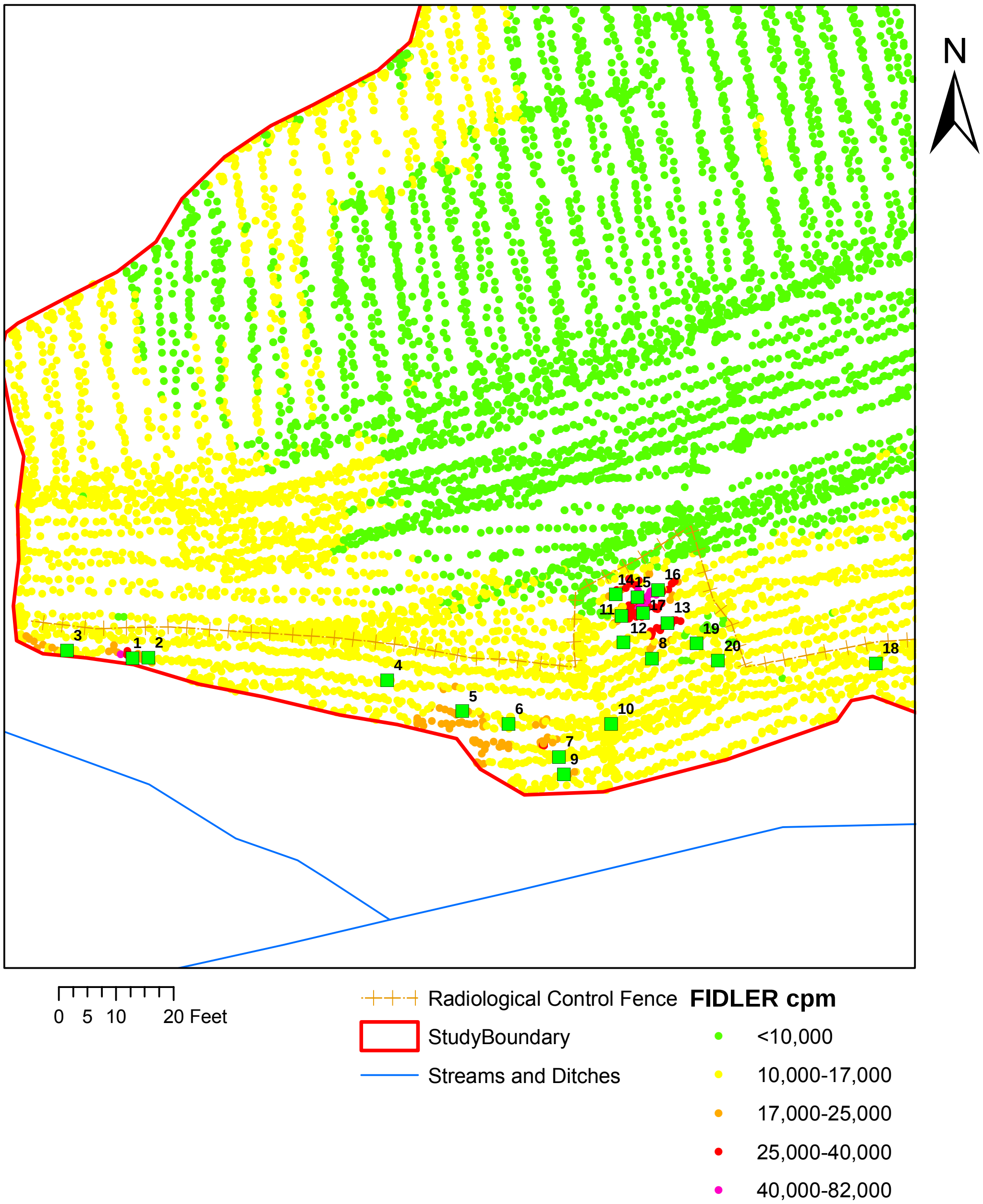


Figure 15. Location of Twenty Initial Sampling Locations

five *in situ* measurements probably are not sufficient to accurately estimate the true average concentration over the FIDLER field of view when higher levels of uranium contamination are present.

Based on the above, the HPGe data set was selected for interpreting the GWS gross activity data. The slope of the regression line estimates a 64 cpm incremental response from the FIDLER for every additional ppm of total uranium present, on average, in the FIDLER's field of view. The DPNAL for ^{238}U results is equivalent to a total uranium concentration that is approximately 7 ppm greater than one would expect in un-impacted soils within the study area. As shown in Figure 11 for an assumed background area, the average was 8,628 cpm with standard deviation of 679 cpm. Consequently, the presence of uranium at its DPNAL (3.64 pCi/g ^{238}U) would add approximately 450 cpm to a background FIDLER response. This count level falls within the assumed background area standard deviation of 685 suggesting as stated previously that it would be difficult to differentiate between background and the DPNAL. Two standard deviations (1,358 cpm) above the average background (or approximately 10,000 gross cpm / 27 ppm total U / 8-9 pCi/g ^{238}U) represents a result that would not be consistent with the range of background FIDLER values observed in the assumed background area.

The ^{238}U hot spot criteria (33 pCi/g) would yield an incremental FIDLER response equal to approximately 6,000 cpm, a response well above background as established by the measurements acquired with the FIDLER. Using the FIDLER/HPGe regression line, the ^{238}U hot spot criterion should yield a gross cpm reading of approximately 15,000 to 16,000 cpm for the study area. Based on this analysis, Figure 12 identifies three (3) distinct locations where ^{238}U hot spot criterion exceedences are possible: 1) two (2) areas along the southern edge of the study area, and 2) the AOC 492 soil mound. The soil mound has significantly higher average FIDLER gross activity readings than the two other locations, which are only slightly above the 15,000 to 16,000 cpm value (averaged over a 25 m2 area). Figure 12 identifies three generally distinct areas where uranium contamination above the DPNAL level is potentially present: 1) along the southern edge of the study area, 2) along the western edge of the study area, and 3) directly in front of the culvert discharge point in the middle of the study area.

3.2.5. Relationship between PCB and Uranium

The pre-field work PCB study suggested that the presence of PCBs were strongly correlated with the presence of elevated uranium (i.e., PCBs are not present if uranium is not also present and significantly elevated). If this finding is consistent for all soil piles, it could have implications for characterization program design since techniques targeting uranium (e.g., GWS and XRF) could also be used to identify areas where PCB analyses are warranted.

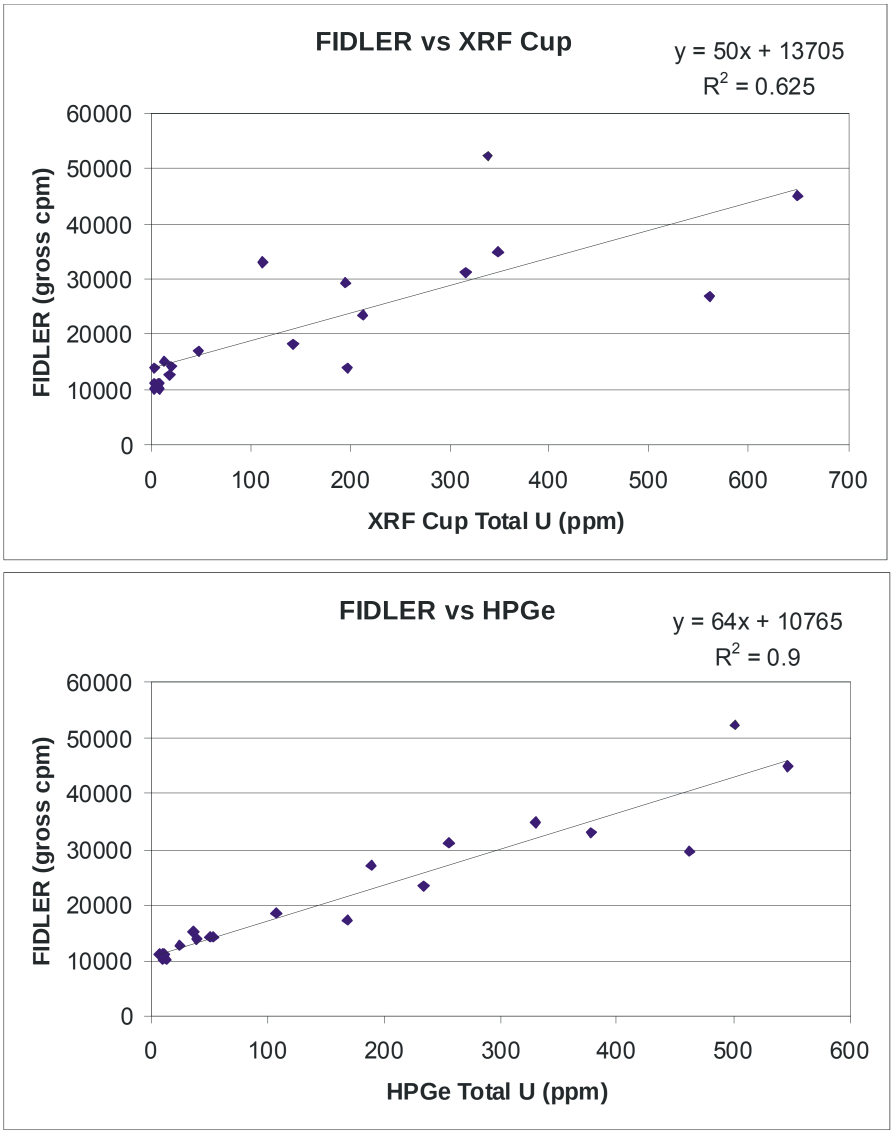


Figure 16. Comparison of FIDLER data with XRF and HPGe Total U Results

To determine whether this held for the study area as a whole, PCB test-kit data were compared with XRF total U cup results (Table 2) and laboratory PCB data were compared with laboratory ^{238}U results (Table 3).

Based on the Abraxis test kit results and XRF cup data contained in Table 2, detectable levels (>0.5 ppm) were not observed until total uranium concentrations exceeded 190 ppm (63 pCi/g ^{238}U). The laboratory results had much lower detection limits for PCBs and consequently identified the presence of PCBs at low levels in many more samples than the Abraxis test kits. Based on the data contained in Table 2, levels that should have been detectable by the Abraxis test kits (i.e., total PCBs > 0.5 ppm) only occurred in samples that contained ^{238}U activity concentrations greater than the 34 pCi/g, the uranium hot spot criterion for this study. Total PCB concentrations above the DPNAL were only observed for samples with ^{238}U activity concentrations greater than 190 pCi/g (Table 4).

Table 3. XRF Total U Results (Cup Analyses) Compared to Abraxis PCB Test Kit Data

Location	XRF Cup Total U (ppm)	Abraxis Total PCB (ppm)
BS-1	338	1.26
BS-2	196	ND
BS-3	3	ND
BS-4	7	ND
BS-5	143	ND
BS-6	14	ND
BS-7	197	2.79
BS-8	21	ND
BS-9	560	5.48
BS-10	4	ND
BS-11	213	0.86
BS-12	18	ND
BS-13	348	2.58
BS-14	48	ND
BS-15	649	11.12
BS-16	112	ND
BS-17	317	2.27
BS-18	9	ND
BS-19	8	ND
BS-20	4	ND
FSS-C1-01	6	ND
FSS-C1-02	9	ND
FSS-C1-03	7	ND
FSS-C1-04	11	ND
FSS-C1-05	12	ND
FSS-C1-06	29	ND
FSS-C1-07	3	ND
FSS-C2-01	5	ND
FSS-C2-02	8	ND
FSS-C2-03	10	ND
FSS-C2-04	6	ND
FSS-C3-01	5	ND
FSS-E1-01	4	ND

Notes: “ND” – analyte not detected

In conclusion, the study data supported the preliminary conclusions from the PCB study: For this area, PCBs are consistently co-located with elevated uranium, and PCB concentrations only reach the DPNAL when uranium concentrations are well above the uranium DPNAL hot-spot criterion. The implication of this conclusion is soil piles on the east side of the PGDP site characterization can focus on uranium initially, with PCB analyses targeting only soils that have a clearly identifiable uranium impact, and remediating uranium at its DPNAL will eliminate any PCB concerns present.

3.2.6. Presence of Other Metals of Potential Concern

Both the limited historical sampling from this area and the XRF performance study identified the potential for other metals to be elevated in soils contaminated with uranium. The primary metals observed with elevated concentrations were chromium, zinc, and molybdenum. The XRF deployed as part of the AOC 492 field work reported 32 different metals when all three filters were applied (see Appendix B for a complete listing of metals and results). Not all of these metals had useful detection limits. Consistently detectable concentrations were observed for the following metals: molybdenum (Mo), zirconium (Zr), strontium (Sr), uranium (U), rubidium (Rb), thorium (Th), lead (Pb), arsenic (As), zinc (Zn), iron (Fe), manganese (Mn), chromium (Cr), vanadium (V), titanium (Ti), calcium (Ca), potassium (K), barium (Ba), and palladium (Pd). The PDGP Risk Methods document (DOE, 2000) identified background 95% UTL concentrations for U, Pb, As, Zn, Fe, Mn, Cr, V, Ca, K, and Ba. Of this smaller set, two metals (Ca and K) did not have risk based default no-action levels assigned. In addition, the Risk Methods document provided risk based default no-action levels for Mo and Sn, but did not provide corresponding background values.

The remaining discussion in this section, will focus on eleven metals that have risk-based default no action levels and useful data reported by the XRF. These metals are identified in Table 5.

Table 5 provides XRF results for the 20 initial locations as well as XRF results for the Class 3 composite sample and corresponding laboratory results. Table 5 also includes the 95% UTL background values and risk based default no action levels (teenage recreational user scenario), where available. XRF results below detection limits are italicized. A full comparison of XRF data to corresponding laboratory results is found in Section 4. For the purposes of this section, laboratory data are referenced only to the extent that they clarify or are inconsistent with XRF data. The data for the 20 initial sampling locations are sorted by uranium concentration to assist in seeing correlations between elevated uranium and the presence of other metals.

The data in Table 5 indicate a relationship between elevated uranium and elevated Cr, Mo, Ba, and Zn. For Cr, Mo, and Zn, the relationship was a positive one (i.e., high levels of uranium also had elevated levels of Cr, Mo, and Zn). In the case of Ba the relationship was reversed. There are concerns, however, about the XRF Ba data that will be discussed in more detail in Section 4. Consequently it is not clear if this is a real relationship or potentially reflects interference between Ba and U. In the case of Cr, there also appeared to be a high bias with the XRF data that will be discussed in more detail in Section 4. Vanadium also appeared to be elevated above background conditions based on XRF data. There was no corresponding laboratory data with which to compare these particular XRF results. However vanadium did not show any relationship with uranium. The assumption is that the observed vanadium numbers represent a high bias for the XRF.

In conclusion, there is elevated Cr, Mo, and Zn associated with elevated uranium concentrations. While the XRF Cr data suggest that Cr levels are potentially a concern with respect to the PGDP risk-based default no-action level (teenage recreational user scenario), this was not substantiated by the corresponding laboratory analyses (Section 4).

Table 4. Laboratory ^{238}U Results Compared to Laboratory Total PCB Data

Location	Laboratory ^{238}U (pCi/g)	Laboratory Total PCB (ppm)[1]
BS-1	147.20	1.4900
BS-2	44.80	1.0800
BS-3	1.29	ND
BS-4	2.03	0.0096
BS-5	41.78	2.1800
BS-6	3.59	0.0690
BS-7	56.80	2.9100
BS-8	6.78	0.0910
BS-9	196.20	4.8000
BS-10	1.26	ND
BS-11	66.49	1.2100
BS-12	5.43	0.0670
BS-13	119.40	2.4200
BS-14	12.60	0.4200
BS-15	193.20	14.4000
BS-16	34.42	1.8200
BS-17	114.60	2.1600
BS-18	3.32	0.0047
BS-19	1.34	ND
BS-20	1.37	ND
FSS-C1-01	1.66	ND
FSS-C1-02	1.77	ND
FSS-C1-03	1.70	ND
FSS-C1-04	1.68	ND
FSS-C1-05	3.47	0.0193
FSS-C1-06	7.31	0.0740
FSS-C1-07	1.37	ND
FSS-C2-01	1.91	ND
FSS-C2-02	1.79	ND
FSS-C2-03	2.36	0.0120
FSS-C2-04	1.18	ND
FSS-C3-01	1.40	ND
FSS-E1-01	3.88	0.0780
FSS-ICSS-051	1.38	ND
FSS-ICSS-072	1.40	0.0094
FSS-ICSS-076	1.11	0.0098
FSS-ICSS-091	1.26	ND
FSS-ICSS-120	1.40	0.0076
FSS-ICSS-125	0.85	0.0140
FSS-ICSS-145	1.51	0.0100
FSS-ICSS-155	1.04	0.0150
FSS-ICSS-011	1.74	ND
FSS-ICSS-012[2]	1.24	0.0093
FSS-ICSS-013	2.24	0.0063
FSS-ICSS-014	1.97	0.0070
FSS-ICSS-024[2]	88.70	4.0900

Notes: “ND” – analyte not detected; [1]PCB laboratory results are usually provided to two significant figures – the four digits beyond the decimal in this table are to assist in comparing results and do not imply a particular level of accuracy; [2]Based on other information it is assumed that the results for FSS-ICSS-012 and FSS-ICSS-024 were swapped by the laboratory – in this table the results have been assigned to the proper samples.

Table 5. XRF Metal Result Summary

	Metals of Interest (ppm)										
	V	**Cr**	**Mn**	**Fe**	**Zn**	**As**	**Sr**	**Mo**	**Ba**	**Pb**	**U**
NAL:	2.12	227	29	1,350	1,800	0.35	3,600	56.4	148	50	14.7
AL:	3,090	100,000	39,100	100,000	100,000	314	100,000	41,700	100,000	400	683
95%UTL:	38	16	1,500	28,000	65	12	na	na	200	36	5
Class 3 Lab	na	16	na	na	na	8	na	na	94	14	na
Class 3 XRF	91	117	453	17,984	70	8	121	7	*-16*	18	*5*
BS-3	90	167	374	10,850	24	*3*	91	8	110	14	*3*
BS 20	*47*	173	456	8,526	20	5	100	8	124	13	*4*
BS-10	*52*	160	523	7,924	19	*4*	92	9	126	14	*4*
BS-4	*41*	146	413	10,971	23	6	93	8	85	13	7
BS 19	*60*	157	407	9,074	31	6	99	8	129	9	8
BS 18	84	167	374	8,014	27	6	93	9	119	12	9
BS-6	*54*	156	590	9,479	22	6	97	8	110	12	14
BS-12	88	153	555	9,612	29	*4*	100	7	117	17	18
BS-8	78	173	454	8,419	25	*4*	99	8	53	13	21
BS-14	105	166	349	9,307	28	*3*	103	8	52	15	48
BS-16	90	207	468	10,181	49	7	99	8	75	17	112
BS-5	*52*	235	402	11,995	59	5	111	9	89	17	143
BS 2	*53*	156	455	9,688	16	5	92	9	55	14	196
BS-7	64	196	440	9,748	48	6	93	10	*-31*	12	197
BS-11	*62*	282	420	10,050	63	*4*	102	12	*-14*	19	213
BS 17	*49*	338	433	9,753	93	*5*	91	15	*-43*	18	317
BS-1	*41*	169	502	9,985	33	8	92	11	*-4*	12	338
BS-13	100	331	463	11,148	88	6	98	12	*-25*	19	348
BS-9	*49*	237	361	10,705	58	*3*	85	14	*8*	18	560
BS-15	89	530	327	10,735	134	5	98	15	*-80*	21	649

Notes: “na” – not available; italicized entries were below reported detection limits

3.2.7. Surface and Subsurface Contaminant Heterogeneity

Standard sampling program designs often rely on drawing inferences from a limited number of samples drawn from discrete locations to reach conclusions about the contamination status of an area. The underlying assumption is that analytical results obtained for samples that are typically a few hundred grams of sample are representative of much larger areas and soil volumes.

Contaminant heterogeneity, or the variability associated with contaminant concentrations, can exist at a number of different scales including within samples, within the immediate vicinity of where a sample is taken, and across larger areas. Contaminant heterogeneity potentially complicates the ability to draw correct conclusions about the contamination status of individual samples, specific locations, and larger areas. The following sections discuss the heterogeneity observed in total uranium concentrations over various scales based on XRF data.

3.2.8. Within Sample Heterogeneity

Contaminant heterogeneity can exist within a standard soil sample. Heterogeneity at this scale can affect the quality of analytical results, since most analytical techniques (including XRF and Inductively Coupled Plasma (ICP)) rely on obtaining a relatively small sub-sample (~5 grams or less) from the original sample for analysis. Unless steps are taken to address this heterogeneity (e.g., thorough sample homogenization or multiple XRF measurements across a bagged sample surface), considerable variability in concentrations from multiple sub-samples obtained from the same original sample may be observed.

To investigate within sample heterogeneity, seven samples from the initial twenty Biased Sample (BS) locations were analyzed by XRF through sample bag walls prior to full homogenization. For each bagged sample, ten XRF measurements were obtained (five on each side), and an average and standard deviation calculated for the reported total U concentrations. The results are presented in Table 6.

Table 6. Average Total U Results from Unprepped Bag Samples

Location	XRF Total U Average (ppm)	XRF Total U Standard Deviation (ppm)
BS-20	1	3
BS-10	5	2
BS-18	5	4
BS-12	15	5
BS-6	15	8
BS-14	67	13
BS-11	229	100
BS-16	360	199

The data in Table 6 underscore two facts: 1) The heterogeneity present within a sample is a direct function of the average concentration of the sample. As the concentration increases, the variability within the bagged sample increases; and 2) The variability can be very significant. For example, in sample BS-16 the observed total U concentration as measured by XRF through the bagged sample wall ranged from 227 ppm to 864 ppm. This level of variability underscores the attention that needs to be paid to sample preparation in order to obtain defensible sample results when sub-samples are obtained for analytical purposes.

3.2.9. Short-Scale Lateral Heterogeneity

Contaminant heterogeneity can also exist on a scale slightly larger than a standard sample size. For example, if a sampling location is moved over six inches or a foot and a second sample collected, would the same contaminant concentration be obtained from both samples?

To evaluate this effect for the AOC 492 study area, five *in situ* surface-soil XRF measurements were obtained for each of the twenty sampling locations. At each location, one *in situ* XRF measurement was taken at the BS center location, and another four from each of the corners of a 1 ft^2 area centered on the BS center location. Table 7 provides a summary of the results from this data collection effort.

Table 7. Total U Results Collected from Center Locations

Location	XRF Total U Average (ppm)	XRF Total U Standard Deviation (ppm)
BS-18	5	3
BS-20	5	3
BS-4	6	6
BS-3	8	3
BS-19	9	2
BS-10	18	11
BS-7	20	12
BS-12	36	15
BS-6	63	47
BS-8	83	38
BS-14	96	57
BS-5	144	17
BS-9	152	58
BS-11	353	240
BS-16	514	441
BS-17	576	232
BS-13	699	547
BS-15	705	462
BS-2	1010	1820
BS-1	1935	2712

The conclusions based on the data in Table 7 match the conclusions for within-sample heterogeneity. First, in general, the level of variability present in uranium concentrations on a short-scale are a function of the general contamination levels at that location. Second, that variability can be severe. For example, in the case of the location for BS-1, the observed total U concentration in surface soils, based on *in situ* XRF measurements, ranged from 372 ppm up to 6,729 ppm. If the concern is what the level of contamination is at a particular location, the answer may vary dramatically for individual grab samples depending on exactly where the sample is collected.

3.2.10. Short-Scale Vertical Heterogeneity

The same short-scale heterogeneity that was described in the previous section was also present in the study area vertically. For the initial twenty BS sampling locations, the vertical distribution of contamination was evaluated by screening soils at three different depths (2”, 6”, and 10”) for the BS center location. In addition, for seven of the BS locations this vertical screening was conducted for the soil cores from the four corners of the 1 ft^2 area centered on the BS center location. Complete results from this screening can be found in

Appendix B. Table 8 summarizes the uranium results for the center soil cores from each of the twenty sampling locations.

Table 8. Total U Center Location Core Results by Depth

Location	Total Uranium (ppm)					
	Surface	2 inches	6 inches	10 inches	Average	Standard Deviation
BS-3	*3*	*-4*	*-2*	*2*	0	3
BS-19	*6*	*-2*	*-2*	*-3*	0	4
BS-20	*5*	*2*	*-6*	*-1*	0	5
BS-10	13	*1*	*-5*	*0*	2	8
BS-4	*-1*	na	*5*	*5*	3	4
BS-18	*7*	*2*	*4*	*3*	4	2
BS-6	29	*8*	*9*	*-1*	11	13
BS-12	22	39	*0*	na	20	19
BS-8	62	59	*9*	*2*	33	32
BS-16	170	23	70	*4*	67	74
BS-14	172	109	58	*10*	87	70
BS-2	365	58	*4*	*7*	108	173
BS-5	147	174	168	*8*	124	78
BS-11	*2*	393	154	*0*	137	185
BS-7	*8*	18	570	66	166	271
BS-17	823	14	20	*8*	216	405
BS-13	485	572	*5*	*1*	266	306
BS-1	755	455	52	16	319	352
BS-15	389	788	154	265	399	276
BS-9	64	717	798	269	462	353

Notes: “na” – not available; italicized entries were below reported detection limits

The data in Table 8 are consistent with the previous two sections. Vertical heterogeneity increases as concentrations increase. The level of heterogeneity vertically over this short distance is even greater than what was observed laterally, which is often the case for contamination in soils (i.e., lateral continuity in concentrations is greater than vertical).

3.2.11. Medium-Scale Lateral Heterogeneity

Of primary concern for this project is the level of heterogeneity one would expect among discrete soil samples within 25 m^2 areas when concentrations are near the hot spot criteria. The reason is that the level of heterogeneity within this scale among discrete samples will directly affect the ability of any one sample to correctly identify the presence of the hot spot based on soil sampling alone.

In the AOC 492 area there was one area that clearly exceeded the hot spot criteria for ^{238}U, the soil mound. Ten of the initial twenty sampling locations fell immediately adjacent to, or within, the footprint of the mound. Each of these ten locations had five soil cores retrieved. Prior to forming the 5-increment MIC samples, 25 of the 50 cores were screened down their length by XRF for total U concentration. Table 9 shows the average total U concentration for these 25 cores. Each of these 25 cores is equivalent to a traditional, one-location soil sample taken to a depth of 1 foot.

Table 9. Bagged Sample Total U Results

Location	Surface	2"	6"	10"	Average
BS-19-1	*9*	*-2*	*-2*	*-3*	1
BS-20-1	*5*	*3*	*-1*	*3*	3
BS-14-4	30	26	18	*2*	19
BS-12-1	22	39	*0*	na	20
BS-8-1	62	59	*9*	*2*	33
BS-14-3	114	*12*	*6*	*2*	33
BS-14-5	116	81	*9*	*-3*	51
BS-16-2	192	*6*	20	*7*	56
BS-16-1	170	23	70	*4*	67
BS-14-1	172	109	58	*10*	87
BS-11-1	*2*	393	154	*0*	137
BS-15-3	207	275	129	31	160
BS-17-1	823	14	20	*8*	216
BS-16-5	476	437	52	31	249
BS-13-1	485	572	*5*	*1*	266
BS-13-4	436	532	62	51	270
BS-15-5	694	341	112	24	293
BS-16-4	475	253	316	192	309
BS-14-2	49	1029	167	66	328
BS-15-1	389	788	154	265	399
BS-15-4	833	357	209	na	466
BS-13-5	365	857	717	14	488
BS-13-3	1670	751	14	*1*	609
BS-16-3	1257	986	241	162	661
BS-15-2	1403	3403	387	207	1350

Notes: "na" – not available; italicized entries were below reported detection limits

Ten of the 25 soil cores in Table 9 had an average uranium concentration less than the ^{238}U hot spot criteria (equivalent to 98 ppm total U). Based on the data, it was concluded that a single sample collected to a depth of 1 foot in the footprint of this hot spot would have failed to identify the fact that it exceeded the hot spot criteria 40% of the time.

3.2.11. Excavation Support

The AOC 492 soil mound was selected for excavation as it represented a well-defined, localized "hot spot" that contained, on average, the highest contamination observed for the study area. Because of time constraints, an excavation footprint was established by delineating the soil mound boundaries based on visual features. Excavation reached an average depth of 0.84 ft bgs. Excavation stopped when saturated soil conditions were encountered. The boundary of the excavation was "walked" using the LARADS system, and a GWS was conducted of the exposed soil surface. The excavated boundary and pre-excavation GWS data are shown in Figure 15. Also shown in Figure 15 are the positions of the ten initial sampling locations that fell near or within the excavated boundary. The excavated footprint covered 29 m^2. With an average depth of 0.84 ft (as determined using the LARADS pre- and post-excavation GWS data), the excavation produced 9.7 m^3 of soil (*in situ* volume).

The average FIDLER activity within the pre-excavation footprint was 23,200 cpm (representing a net activity above background that was about twice what one would expect for soils with ^{238}U activity concentrations at the hot spot criteria). There were ten initial sampling locations immediately adjacent toor within the excavation footprint. The average uranium concentration for those locations was 201 ppm (approximately twice the hot spot criteria), and the average Abraxis test kit total PCB concentration was 1.7 ppm. While the average uranium concentration clearly exceeded the hot spot criteria of 98 ppm total U, the average PCB concentration was below its 3.64 ppm DPNAL.

Figure 16 shows the same area with the post-excavation GWS results. Figure 16 also shows the location of the five *in-situ* surface XRF measurements, and the location of the 1 ft deep soil sample that was collected. The average FIDLER activity within the excavation footprint following excavation was 12,200 cpm, a value well-below the 15,000 cpm hot-spot threshold. The data indicated that the excavation was successful in removing the ^{238}U hot spot that had been present. The average *in situ* XRF total U ppm for the five surface measurements was 65 ppm, which was equivalent to approximately 22 pCi/g ^{238}U, also below the hot spot criterion. The average XRF total U value for the bagged sample (10 measurements through the bagged sample's walls) was 3.6 ppm, which was in the range of background for that particular location. The Abraxis test kit result for this sample was a non-detect for total PCBs. The laboratory ^{238}U activity concentration for this sample was 3.88 pCi/g. The laboratory total PCB result was 0.078 ppm, well below the Abraxis test kit detection limit.

Immediately post-excavation, the average total U and total PCB concentrations for the ten samples that fell adjacent to or within the excavation footprint were supplied to PRS as an estimate of the uranium and PCB concentrations within the excavated soils for waste disposal purposes.

3.2.12. Final Status Survey Data Collection

FSS samples were collected prior to the excavation work described in the previous section. While the sequence of activities were not the sequence in an actual remedial/closure effort, they offered the advantage of observing what the FSS results would have been for the area that was subsequently excavated. This provided an opportunity to evaluate the effectiveness of the FSS protocols to identify residual problems that existed in the study area.

The FSS protocols used for the site were described in detail in Section 2.4. This section presents the results and conclusions organized by FSS class. Figure 17 shows how the site was divided into FSS areas, and the positions of sampling locations within each of the areas. The GWS results were used to develop the footprints of each of the FSS areas. Complete

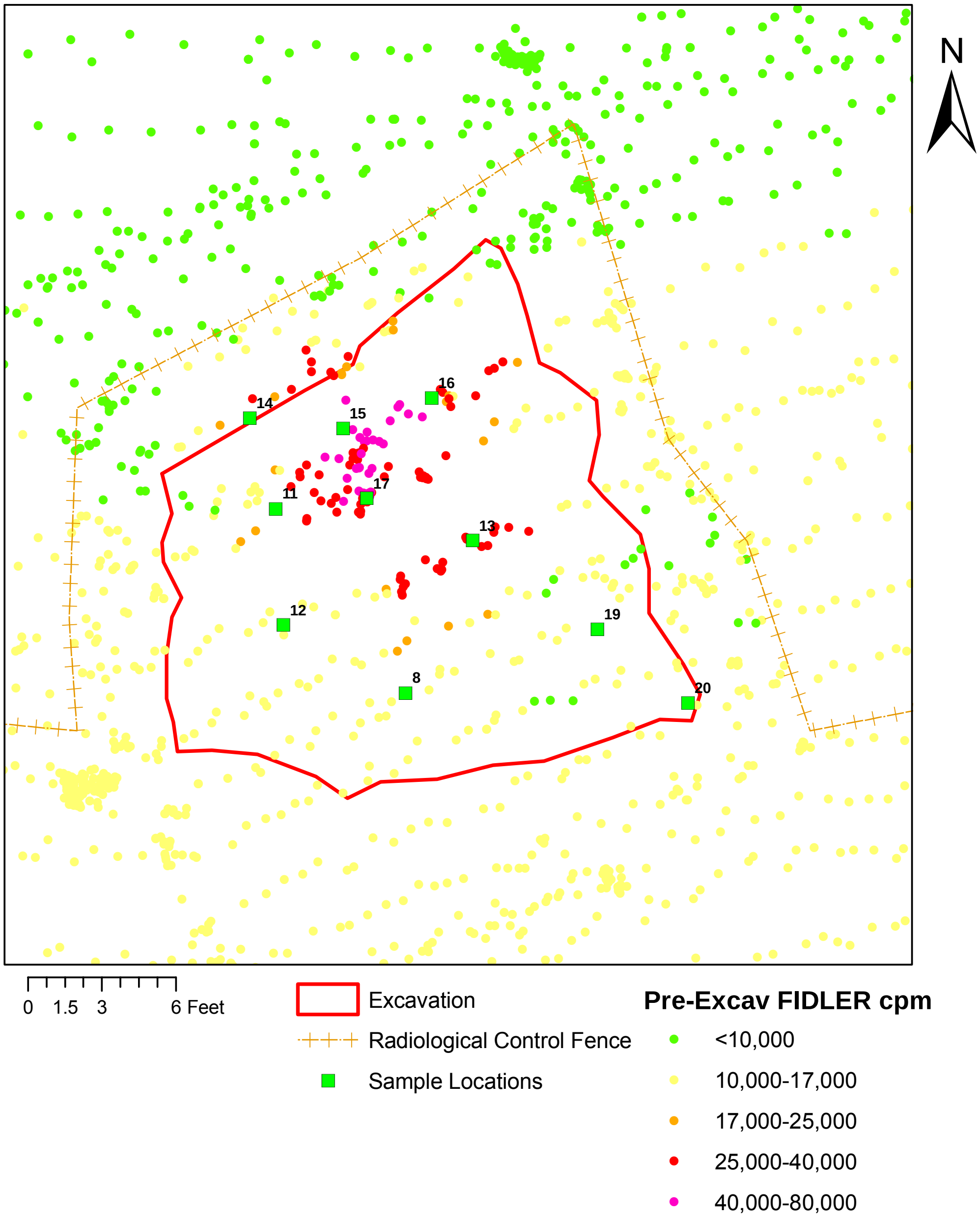


Figure 17. Pre-Excavation FIDLER Data and Sample Locations

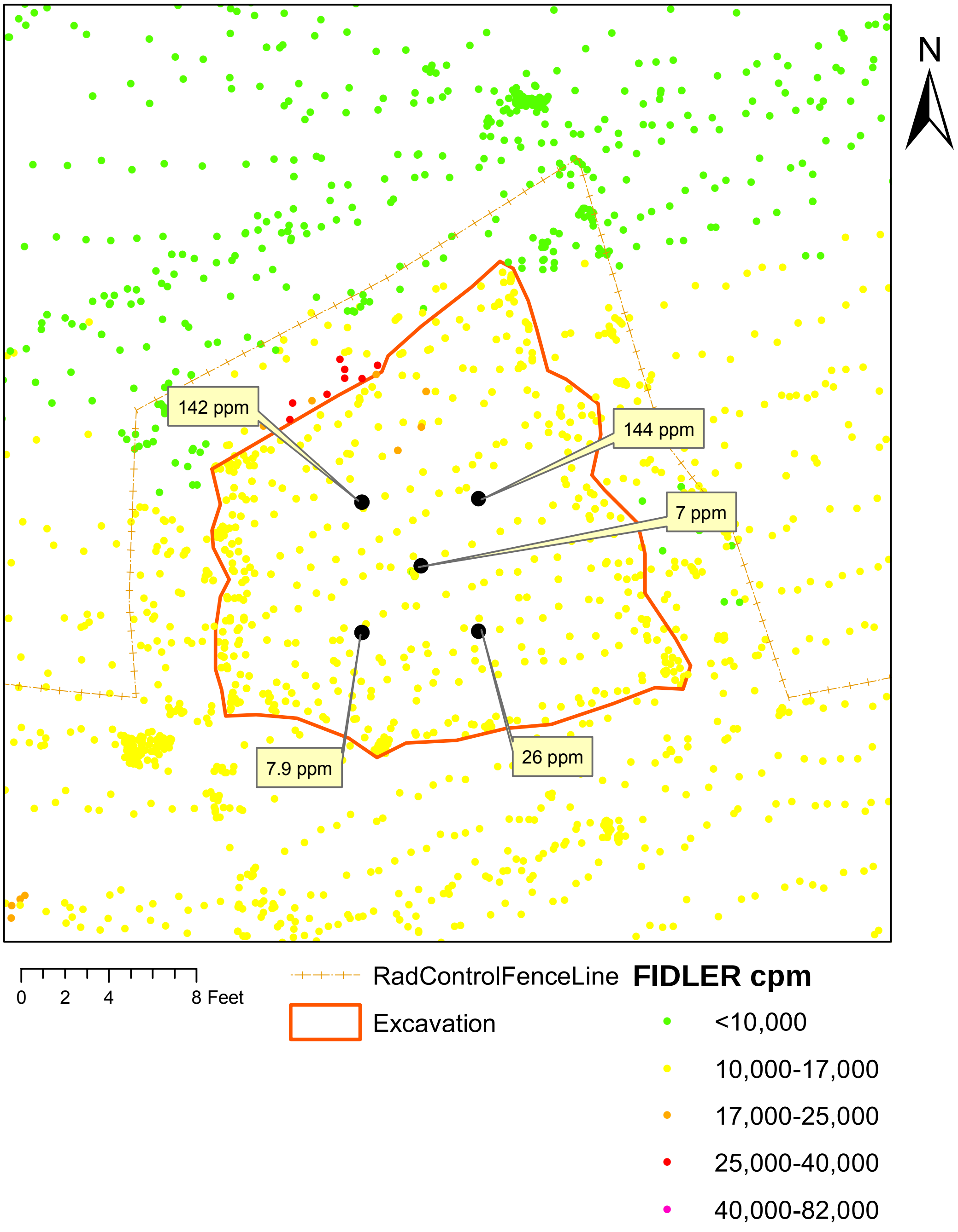


Figure 18. Post-Excavation FIDLER and XRF (Total U) Results

sample results (real-time and off-site laboratory) can be found in the appropriate appendices. The sections below summarize key findings and conclusions.

3.2.12.1. Class 1 Area

The Class 1 area consisted of one unit of 990 m^2. Thirty seven sampling locations representing 25 m^2 areas were distributed across the Class 1 unit (Figure 17). At each 25 m^2 location one 5-increment MIC sample was obtained to a depth of 1 foot. The MIC sample consisted of one increment taken from the center location, and four increments from positions halfway between the center and the four corners of a 25 m^2 area centered on the location. Each of these 5-increment MIC samples was homogenized then sub-sampled. The sub-samples were used to form seven FSS composite samples consisting of 5 MIC samples, except for FSS-C1-07 that consisted of 6 MIC samples. Each of the seven composite samples was homogenized before analysis.

The sampling locations contributing to each composite were as follows:

- FSS-C1-01: 159, 95, 82, 70, and 69
- FSS-C1-02: 68, 55, 42, 30, and 18
- FSS-C1-03: 6, 7, 8, 9, and 10
- FSS-C1-04: 19, 20, 21, 31, and 32
- FSS-C1-05: 1, 2, 3, 4, and 5
- FSS-C1-06: 11, 12, 13, 14, and 24
- FSS-C1-07: 15, 16, 17, 27, 28, and 29

Adjacent sampling locations were used to form composites, as shown in Figure 18. A deviation from the work plan occurred with location 109 that fell within the Class 1 area but was mistakenly included in the Class 2 composite FSS-C2-02.

Each Class 1 FSS composite sample was composed of five (5) 5-increment-MIC samples from the 25 m^2 sub-areas with the exception of FSS-C1-07 which included six (6) 5-increment-MIC sub-area samples. Consequently the field investigation level applied to the results for the first six Class 1 composite FSS samples was 1/5th of the hot spot criteria that equates to 6.6 pCi/g ^{238}U, 19.7 ppm total U, and 6.6 ppm total PCBs. In the case of FSSC1-07 the field investigation levels were slightly lower at 5.5 pCi/g ^{238}U, 16.4 ppm total U, and 5.5 ppm total PCBs. Each composite was analyzed by XRF cup analysis and by Abraxis test kits, with a split sent for laboratory analysis.

The XRF total U concentration for the seven (7) Class 1 composite results ranged up to 28.9 ppm (9.6 pCi/g ^{238}U), with an average of 11.0 ppm (3.7 pCi/g ^{238}U). One sample, FSS-C1-06, exceeded the field investigation level for ^{238}U. This FSS composite included a sampling location (location 24) that fell within the AOC 492 soil pile footprint. The average of the seven FSS composites also slightly exceeded DPNAL of 3.64 pCi/g for ^{238}U. The Abraxis test kit results were all non-detects for the seven (7) Class 1 FSS composite samples.

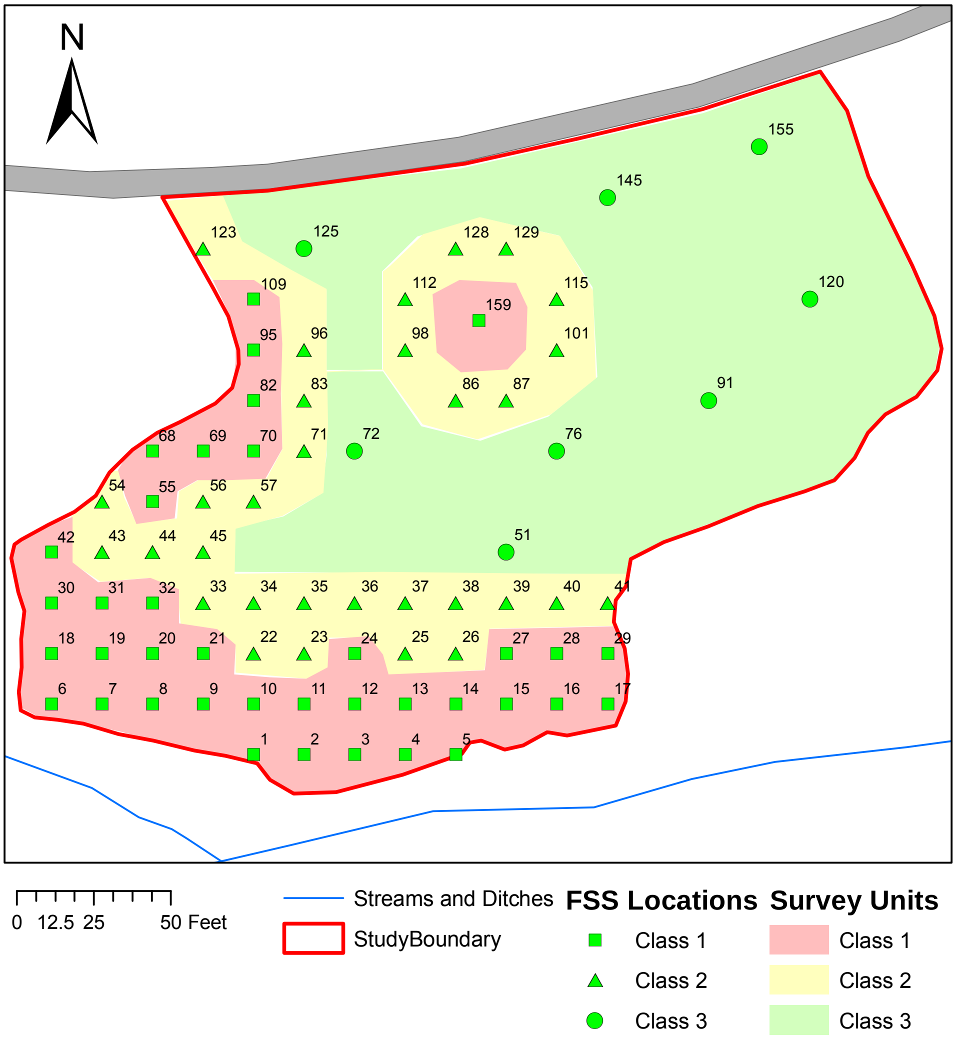


Figure 19. FSS Layout and Sampling Locations

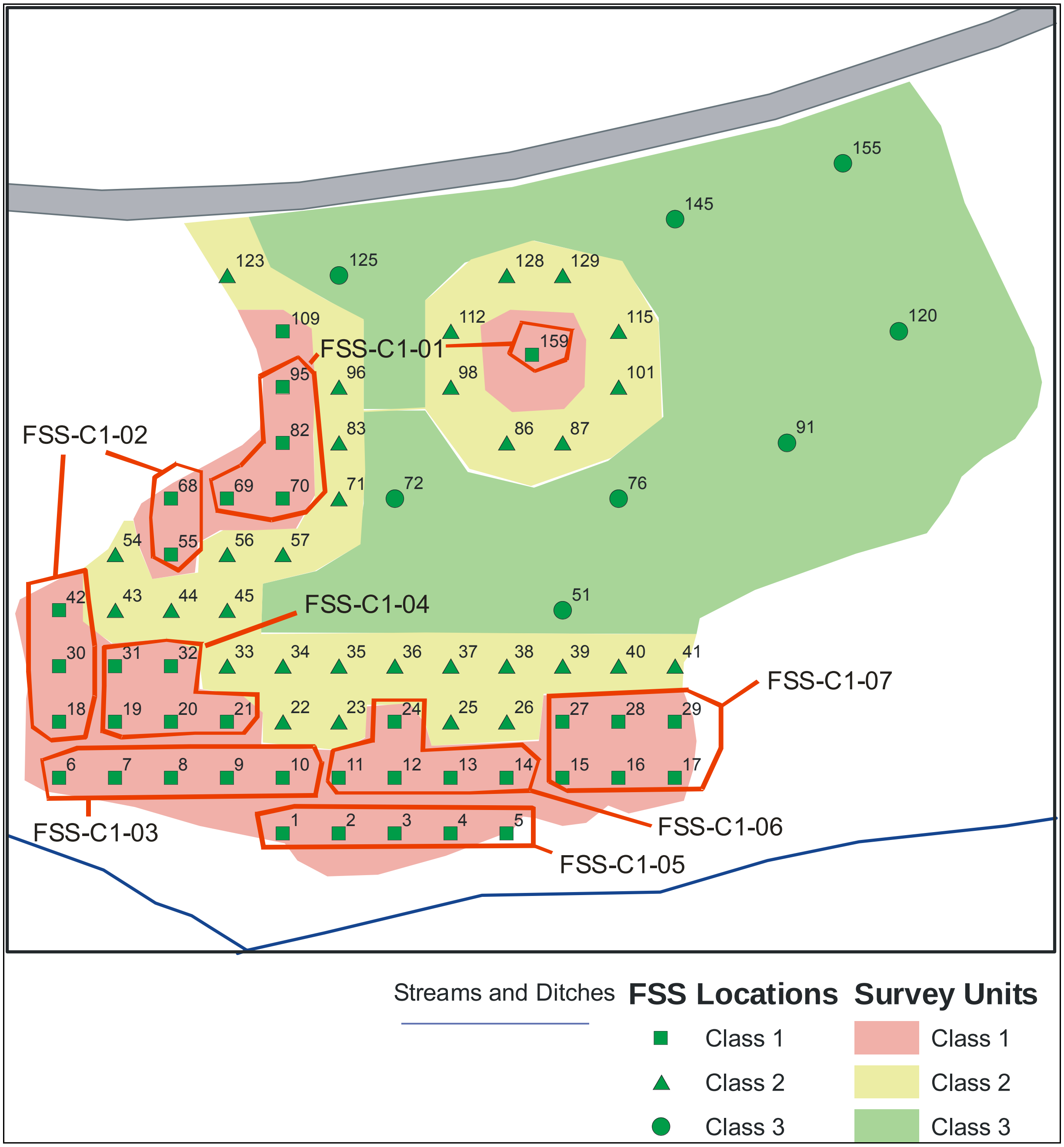


Figure 20. Class 1 Sample Composite Formation

The maximum laboratory result for ^{238}U was 7.31 pCi/g (21.9 ppm total U) and the average was 2.71 pCi/g (8.14 ppm total U). As with the XRF, gamma spectroscopy identified one FSS sample, FSS-C1-06, as exceeding the field investigation level for ^{238}U. The average laboratory result was slightly less than the DPNAL level of 3.64 pCi/g; however the 95%UCL on this mean value calculated using ProUCL and assuming normality is 4.3 pCi/g. Consequently one could not conclude the Class 1 unit meets the risk-based default no action level for ^{238}U.

Two of the seven FSS composite samples had total PCB levels above the laboratory detection limit. The maximum reported value was 0.075 ppm for FSS-C1-06. The level for FSS-C1-06 was well below the Abraxis test kit detection limit and the field investigation level. Because FSS-C1-06 exceeded the field investigation level for ^{238}U, each of the MIC sub-area samples contributing to the FSS composite were analyzed to determine if there were hot spot criteria exceedences in any of the contributing samples. Because of time constraints in the field, these samples were sent for off-site laboratory analysis.

The maximum laboratory ^{238}U activity for the MIC samples was 88 pCi/g (264 ppm total U) and the average was 19.1 pCi/g (6.4 ppm total U). The average compared very well with the composite ^{238}U result, which as 21.9 pCi/g. The next highest ^{238}U activity for the MIC samples was only 2.24 pCi/g (6.7 ppm total U). The maximum result was clearly associated with a hot spot. The laboratory identified this as location 12, and not 24 (the location corresponding to the soil pile), presumably representing a sample labeling error. This type of error underscores one of the key advantages of real-time techniques. If there had been time to evaluate each of the five MIC samples by XRF and this same result obtained, there could have been immediate resolution as to whether a labeling error was present. At worst, locations 24 and 12 would have been re-sampled to confirm the results.

The presence of a ^{238}U hot spot corresponding to one of the locations contributing to FSS-C1-06 is not surprising since the FIDLER data and results from the initial 20 locations identified and confirmed the presence of ^{238}U above the hot spot criteria in the AOC 492 soil pile.

Four of the five MIC samples yielded a laboratory total PCB value that was above the laboratory detection limit. Of these, three were less than 0.1 ppm total PCBs. One sample (the same sample with the maximum ^{238}U result) had 4.09 ppm total PCBs.

Assuming that the maximum results were associated with location 24, the location with the highest ^{238}U activity was remediated by excavation after FSS sampling was complete. As described in Section 3.3, the excavation eliminated the hot spot and cleared the Class 1 unit of hot spot concerns. The post-excavation laboratory results for this location can be substituted for the pre-excavation FSS results and averages across the unit re-calculated for ^{238}U (the only contaminant from a DPNAL perspective). The average ^{238}U activity for the five FSS locations corresponding to FSS-C1-06 would drop from 7.31 pCi/g to 2.21 pCi/g. Pooling this result with the other six FSS composite results for the Class 1 unit would give an overall average of 1.97 pCi/g ^{238}U (5.9 ppm total U) for the unit post-excavation. The 95% Upper Confidence Limit (UCL) on the mean ^{238}U activity concentration calculated using ProUCL and assuming a normal distribution would be 2.5 pCi/g, or well below the DPNAL.

The post-excavation conclusion is that the Class 1 unit meets the DPNAL.

3.2.12.2. Class 2 Area

The Class 2 area consisted of one Class 2 MARSSIM unit of 830 m^2. Thirty-one sampling locations representing 25 m^2 areas were distributed across the Class 2 unit (see Figure 17). At each location one 5-increment MIC sample was obtained to a depth of 1 foot. The MIC sample consisted of one increment taken from the center location, and four from positions halfway between the center and the four corners of a 25 m^2 area centered on the location. Each of these 5-increment MIC samples was homogenized then split, and the splits were used to form four composite samples. Each of the four composite samples was homogenized before analysis.

The sampling locations contributing to each composite were as follows:

- FSS-C2-01: 86, 87, 98, 101, 112, 115, 128, and 129
- FSS-C2-02: 45, 56, 57, 71, 83, 96, 109, and 123
- FSS-C2-03: 22, 23, 33, 34, 35, 43, 44, and 54
- FSS-C2-04: 25, 26, 36, 37, 38, 39, 40, and 41

Adjacent sampling locations were used to form composites, as shown in Figure 19. A deviation from the FSP occurred with location 109. Location 109 technically was located within the Class 1 area, but the location 109 sample was mistakenly included in the Class 2 composite FSS-C2-02.

Each Class 2 composite sample was composed of eight (8) 5-increment MIC samples from the 25 m^2 areas. The field investigation level applied to the composite sample results was 1/8th of the hot spot criteria that equates to 4.1 pCi/g ^{238}U, 12.3 ppm total U, and 4.1 ppm total PCBs. Each Class 2 composite sample was analyzed by XRF cup analysis and by Abraxis test kits and splits sent for laboratory analysis.

The XRF total U Class 2 FSS composite sample results ranged up to 9.5 ppm (3.2 pCi/g ^{238}U), with an average of 7.1 ppm (2.4 pCi/g ^{238}U). The Abraxis test kit results were all non-detects. The maximum laboratory result for ^{238}U was 2.36 pCi/g or 7.08 ppm total U. The Class 2 FSS composite sample laboratory average was 1.81 pCi/g (5.43 ppm total U). Only one (1) of the four (4) Class 2 FSS composite samples yielded a laboratory total PCB value that was a detection for that sample the total PCB reported was 0.012 ppm.

Class 2 FSS composite samples had levels less than the field investigation levels. Consequently none of the original 5-increment MIC samples used to form the Class 2 FSS composite samples required laboratory analysis. The conclusion is that there are no “hot spot” concerns within the Class 2 area.

Class 2 FSS composite samples had levels less than the DPNAL for ^{238}U and total PCBs. Since none of the results were above the DPNAL, statistics were not required to demonstrate compliance.

The conclusion for the Class 2 area is that it meets the DPNALs specified for this project.

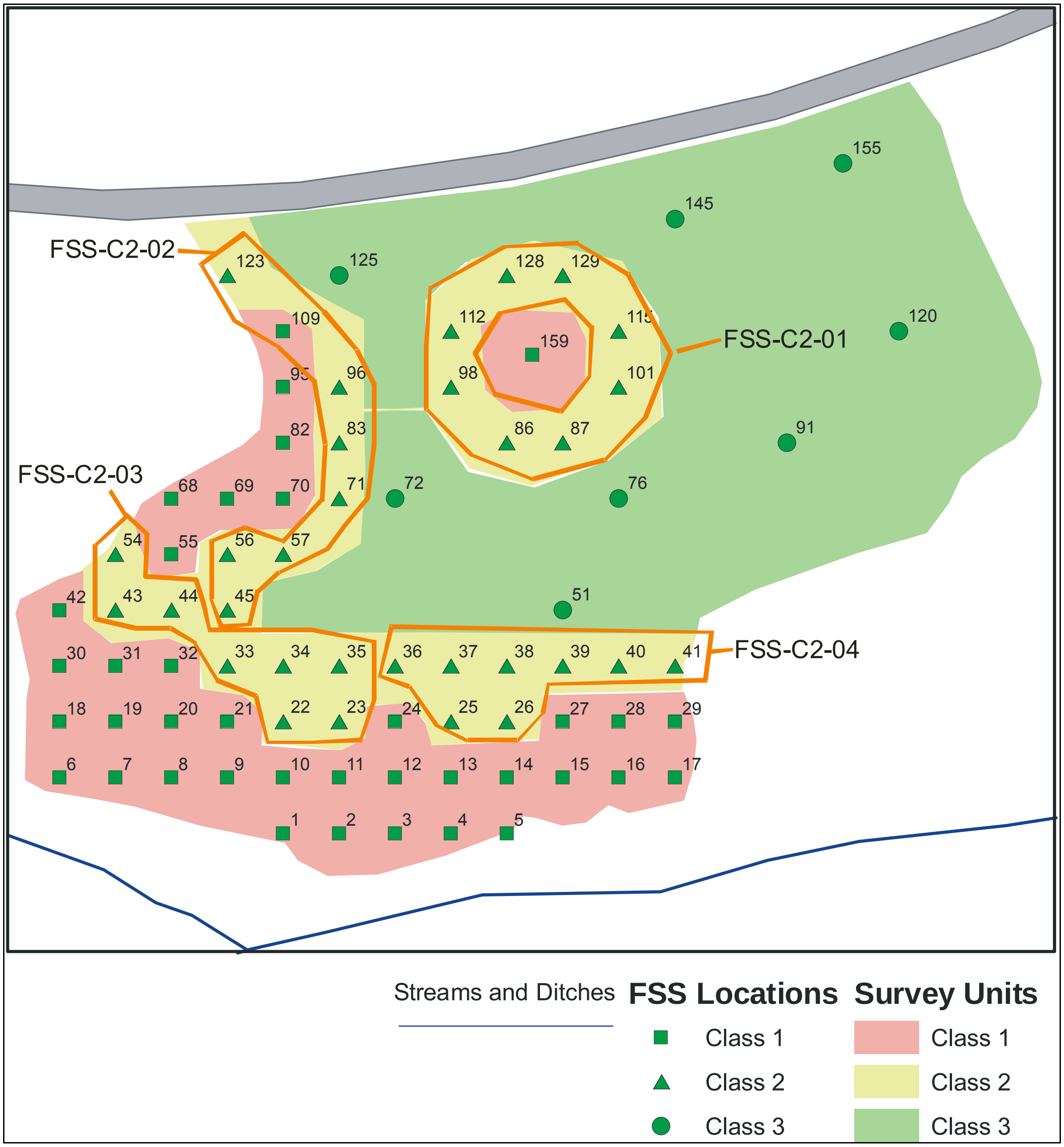


Figure 21. Class 2 Composite Sample Formation

3.2.12.3. Class 3 Area

The Class 3 area consisted of one Class 3 MARSSIM unit of 2,010 m^2. Eight (8) locations were systematically placed across the Class 3 area (see Figure 17). At each location an *in situ* HPGe measurement was taken and one (1) 5-increment MIC sample was obtained to a depth of 1 foot. The 5-increment MCI sample had one increment taken from the center location and four from positions halfway between the center and the four corners of a 25 m^2 area centered on the location. A Class 3 FSS composite sample was formed from the eight (8) 5-increment MIC samples and the FSS composite was homogenized and analyzed on-site by XRF (120-sec acquisition cup measurement) and by the Abraxis test kit. Splits from each of the original 8 5-increment MIC samples were submitted for off-site laboratory analysis, as well as a split of the Class 3 composite sample. Appendix C contains the HPGe results, Appendix B the XRF results, Appendix D the Abraxis test kit results, and Appendix E the laboratory results.

The maximum HPGe ^{238}U activity of 2.4 pCi/g (7.2 ppm total U) for Class 3 locations was observed at location 120. The average HPGe ^{238}U activity was 1.3 pCi/g (3.9 ppm total U). Since all of the results were below the DPNAL for ^{238}U, statistics were not necessary to establish that the Class 3 unit was in compliance with the DPNAL (as expected from the GWS results) based on *in situ* HPGe measurements. There also was no indication from HPGe measurements of the presence of additional radionuclides above background levels.

The XRF Class 3 FSS composite sample contained total U of 5 ppm which was below the detection limits for that particular measurement. The Abraxis test kit yielded a non-detect for total PCBs. The laboratory analysis of a split from the FSS composite yielded 1.4 pCi/g for ^{238}U (4.2 ppm total U), nearly identical to the average HPGe result, and a non-detect for total PCBs.

The eight (8) Class 3 5-increment MIC samples sent for laboratory analysis yielded a maximum activity of 1.51 pCi/g ^{238}U or based on the ^{238}U activity a concentration of 4.53 ppm total U. The average ^{238}U activity was 1.24 pCi/g. Laboratory analysis of Class 3 samples did not identify additional radionuclides above background levels. The laboratory results were consistent with the HPGe results for the Class 3 area. The maximum total PCB laboratory result was 0.014 ppm and the average laboratory result was 0.008 ppm total PCBs. PCB values were below the PGDP risk-based default no action level.

In conclusion, the Class 3 area meets the DPNALs.

4.0 Technology Performance

The purpose of this section is to review the performance of the six primary technologies and methodologies deployed as part of the AOC 492 field work: (1) FIDLER-based GWS using Eberline's LARADS; (2) *in situ* HPGe gamma spectroscopy; (3) Niton XL3t XRF; (4) Abraxis PCB test kits; (5) multi-increment composite sampling techniques; and (6) adaptive compositing techniques.

There are a variety of ways to measure performance. This section focuses on project method detection levels, quantitation levels, comparability of data with standard approaches (e.g., off-site laboratory analysis), ease of deployment, and data production rates.

4.1 FIDLER GWS with LARADS

Gamma walkover surveys were conducted using a FIDLER combined with Eberline's LARADS for locational control and data logging.

The FIDLER is a thin-window sodium iodide (NaI) detector optimized for detecting low-energy gamma rays such as those associated with ^{238}U and its progeny. In general, a variety of NaI detector geometries could potentially be used for the measurement of gross activity associated with surface soils. A FIDLER detector was selected for this demonstration project for two primary reasons: (1) for radionuclides with associated low-energy gamma rays such as ^{238}U (^{234}Th – 63 and 92 keV photon energy lines) the FIDLER has lower detection limits than other NaI detectors, and (2) it is less prone to geometry effects that might result from uneven ground surfaces (i.e., slopes, hills, or mounds) and from shine from contaminated buildings, casks, etc. The primary disadvantage of the FIDLER is that it is a heavier detector for field technicians to carry than 1x1 or 2x2 NaI detectors.

The LARADS was selected because it offers more precise locational control than standard differentially-corrected Global Positioning System (GPS) units. Standard differentially-corrected GPS typically offers accuracy on the order of two meters horizontally and ten to twenty meters vertically depending on the source of correction data. The LARADS system is based on civil survey-grade robotic laser surveying equipment, and is capable of sub-inch accuracy in all three spatial dimensions. The primary advantage of the LARADS system is the greatly improved quality of positioning information in all three dimensions. This can be particularly critical when supporting excavation work, which was a planned component of the field work. Also the surveying instrument is a stand-alone device, and so can be used for other purposes such as staking pre-determined sampling locations, accurately locating important site features such as fence lines and sampling points, and determining site topography pre- and post-excavation. The latter is typically a requirement for estimating pre-excavation contaminated soil volumes and accurately determining post-excavation volumes of soil removed. The LARADS disadvantages are it requires known survey control points in the vicinity of field work to produce data that can be readily combined with other mapping information, clear line-of-sight between the laser station and the target (i.e., the person conducting the walk-over with the FIDLER) is a necessity, and additional set-up requirements that a GPS-based survey system does not have. Figure 20 shows the LARADS base station and the technician with a FIDLER and corresponding LARADS backpack.

The LARADS was configured to record gross activity every second. The site was walked in parallel lines separated by no more than one meter. The rate of walking was approximately one foot per second. The result was a data density of approximately four data points per square meter for most of the site, although the density was significantly higher for areas where the technician encountered clearly elevated contamination since at that point he would often slow and more thoroughly cover the location of interest. The study area was slightly less than one acre in size, and required slightly less than eight hours to cover with a gamma walkover survey.

Positional control was verified by establishing a control point within the study area and "closing" the survey at the completion of each acquisition. "Closing" entails re-measuring the location of the control point at the end of a data collection effort to confirm the known location's coordinates. At the end of each data collection "block" (typically an hour or two of surveying), logged data was off-loaded and provided in a flat file format (*.dbf) that could be loaded into Excel or a mapping program. In the case of the AOC 492 field work, the data was imported into ArcGIS 9.2 for mapping purposes.

The robotic civil survey-grade laser base station was capable of sub-inch accuracy. In practice during walkovers, accuracy was a bit less because the laser tracked a reflector mounted on a pole that projected vertically from a backpack carried by the technician. Consequently, the reflector was off-set somewhat laterally from the position of the FIDLER detector, and vertically its height from the ground varied depending on how the technician was walking.

There were no deployment issues encountered with the FIDLER or LARADS. Eberline brought two FIDLER units to the field, one for primary use, and the second as a backup. Use of the backup was not required. FIDLER QC protocols and QC data are presented and summarized in Appendix F.

QC data for the FIDLER was used to establish the critical level (L_C) and detection limit (L_D) level (gross cpm) using the approach established in Section 3, NUREG 1507. Based on the preoperational data provided in the Appendix F, the L_C was determined to be 6,170 gross cpm and the L_D was determined to 7,542 gross cpm for the FIDLER (E-600 01086 FIDLER JP-245).

Prior to the initiation of the GWS, in-field discrete gamma measurements were taken with the FIDLER (E-600 01086 FIDLER JP-245) at the GWS control point/background location to establish QC and in-field data representative of background for the demonstration project study area. The in-field measurements, summary data and descriptive statistics are provided in Appendix F. The control point/background measurements established a pre-operational background of 8,118 cpm with a standard deviation of 133 cpm.

Figure 22. FIDLER and LARADS

Prior to each use of the FIDLER (E-600 01086 FIDLER JP-245) in-field background field measurements were taken at the GWS control point/background location. The in-field background measurements at the control point/background location taken prior to GWS measurements were 7,990, 8,020, 8,150, and 8,190 cpm. The in-field background measurements taken at the GWS control point/background location were within two (2) standard deviations of the mean in-field background field cpm. These GWS background measurement were used to calculate "net cpm" from the "gross cpm" for the field GWS measurements.

Because of the potential for variability in background gross activity, an assumed background area as shown in Figure 11, was chosen to test the validity of the in-field background location mean value of 8118 gross cpm. The assumed background area had an average of 8,628 cpm with standard deviation of 679 cpm.

As discussed in Section 3.2.4, the HPGe data set was selected for interpreting the GWS gross activity data. The slope of the regression line indicates a 64 cpm incremental response from the FIDLER for every additional ppm of total uranium present, on average, in the FIDLER's field of view. The DPNAL for ^{238}U of 3.64 pCi/g is equivalent to a total uranium concentration that is approximately 7 ppm greater than one would expect in un-impacted soils within the study area. The average for the count rate for the assumed background area was 8,628 cpm with standard deviation of 679 cpm. Consequently, the presence of uranium at its DPNAL (3.64 pCi/g ^{238}U) would add approximately 450 cpm to a background FIDLER response. This count level falls within the assumed background area standard deviation of 685 suggesting that it would be difficult to differentiate between background and the DPNAL. Using a value greater than the 2 standard deviations of 1358 cpm as outside background, the gross count rate that can be differentiate from the background gross count rate could be set at approximately 10,000 cpm or approximately 27 ppm (8-9 pCi/g ^{238}U). This gross count rate of 10,000 cpm is below the project demonstration hot spot level of 98 ppm (33 pCi/g ^{238}U).

Immediately prior to and during the course of gamma walkover surveys there were several significant rain events that would have affected moisture content in near surface soils. There was no observable effect on FIDLER data quality, other than during the excavation work when water ponding in one portion of the excavation precluded data collection.

The LARADS proved particularly useful for supporting other activities besides the gamma walkover surveys. For example, it was used to: (1) identify and precisely map other site features pertinent to the field work, including the radiological control fence, the culvert discharge point, etc.; (2) precisely delineate the excavation footprint as implemented; and (3) estimate the in situ volume of soil removed as part of the excavation effort. None of these would have been possible with standard differentially-corrected GPS units. In fact, there often are lingering location control and mapping issues associated with GPS-obtained datasets following data collection. These include recovering the exact locations of sampling points when field staking has been lost and matching excavations with GWS hot spots when the latter are localized.

4.2 In Situ HPGe

As part of the field work, Eberline deployed an Ortec GMX-75230-P-S (6.87cm diameter) 75% HPGe detector with a beryllium window for conducting *in situ* HPGe measurements. *In situ* HPGe measurements can be used to obtain real-time estimates of the average activity of select radionuclides within near surface soils encompassed by the measurement's field of view. The field of view is determined by the type of detector, the height of the detector above the soil surface, the use of a collimator, and the radionuclide of concern.

The primary benefits of *in situ* HPGe gamma spectroscopy are the potentially immediate availability of results and the fact that data represent average activity concentrations over a relatively large field of view. The latter means that the results are not as affected by spatial heterogeneity as discrete sample results. The data are also potentially more directly comparable to action levels/cleanup standards, which are usually expressed as levels that must be attained on average over a given area. The primary disadvantages are the equipment costs, the level of expertise required to obtain quality data, and the complexity of the equipment. HPGe-based gamma spectroscopy systems can be set up on-site within a mobile laboratory environment and used to conduct rapid gamma spectroscopy analyses on soil samples. However, the *ex situ* analysis of soils does not provide the same area averaging as *in situ* methods and *ex situ* analyses data would be affected by spatial heterogeneity. This type of deployment is well-documented and was not demonstrated as part of the AOC 492 work.

The radionuclides included in the gamma spectroscopy work were ^{241}Am, ^{137}Cs, ^{40}K, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{232}Th, ^{235}U, and ^{238}U. The primary contaminant of concern was ^{238}U. ^{137}Cs was potentially a secondary contaminant of concern. Although not related to plant processes, naturally occurring levels of ^{40}K, ^{226}Ra, and ^{228}Ra were of interest from the perspective of interpreting GWS data sets and potential effects variations in background might have on the response of the FIDLER.

Deploying HPGe instrumentation for *in situ* characterization work poses several challenges. Foremost among these is that the detector requires cooling by liquid nitrogen, and for accurate results a detector must be allowed to cool and stabilize before deployment. Consequently there are significant set-up requirements prior to use. Second, an HPGe is an expensive and relatively delicate piece of equipment, and requires care when handling in a field environment. Finally, estimating average activity for radionuclides requires properly calibrating the system to minimize assumptions about the distribution of contaminants vertically and laterally within the field of view. The latter was of particular concern for the study effort and will be discussed more fully.

Eberline deployed two detectors as part of the field work, a primary detector and a secondary backup unit. The primary detector developed stability problems early on in the field work that could not be resolved; consequently the backup unit was used for the field work. In addition, the primary Eberline field team member responsible for the *in situ* gamma spectroscopy was unable to be present for the bulk of the field work. Consequently interpretation of the HPGe-generated spectra took place remotely, introducing a time lag between the acquisition of data and the interpretation of the results. Figure 21 shows the HPGe as deployed at the site. HPGe QC protocols and QC data are presented in Appendix F.

The HPGe system achieved a detection limit of approximately 1.2 pCi/g ^{238}U and 0.02 pCi/g ^{137}Cs at the in-field background soil locations with a count time of 20 minutes and a detector height of 5 cm for the majority of the analyses (5 cm to 10.5 cm). The field of view in this configuration was approximately 6 m^2. The sample specific minimum detectable ^{238}U activity ranged from 1.6 to 3.9 pCi/g for *in situ* analysis at locations BS-07 and BS-08. The Minimum Detectable Activity (MDA) for ^{238}U was below its DPNAL of 3.64 pCi/g in all cases except the two measurements indicated above.

As discussed in Section 3.2.4, the HPGe data set showed an excellent correlation with the static FIDLER readings obtained from each of the twenty initial sampling locations. This is presumably due to the fact that the two detectors had nearly identical field of views. The *in situ* HPGe data did not compare very well with off-site laboratory composite splits from the same area for ^{238}U, as shown in Table 10. Figure 22 shows a scatter plot of the same data with a regression line. However, the average *in situ* HPGe ^{238}U activity for these 28 measurements compared very well with the average laboratory ^{238}U activity concentration for the corresponding 28 samples. The conclusion is that the HPGe was providing unbiased estimates of ^{238}U activity concentrations. The lack of location-specific comparability was likely due to the high degree of uranium heterogeneity at impacted locations, and the effect this variability had on individual laboratory sample results. A more complete discussion of the short-scale variability in observed ^{238}U activity concentrations is contained in Section 3.2.7.2.

At the outset, the assumption was made that ^{238}U contamination, if present, was uniformly distributed vertically and laterally throughout the detector field of view. However, initial *in situ* HPGe results from the first set of locations did not agree with XRF data for those sample locations. The XRF data indicated a high degree of spatial variability in ^{238}U activity concentrations across the field of view, and in particular vertically. The vertical variability is important for ^{238}U estimation because of attenuation of some of the energy lines used to quantify ^{238}U. After some experimentation, Eberline used peak differential analysis (PDA) to obtain an equivalent depth-of-contamination to use for average activity concentration calculations. PDA compares the intensity of lower and higher energy peaks for ^{238}U short-lived progeny to determine whether ^{238}U is uniformly distributed vertically, and if not, to calculate an equivalent mass depth that can be used for average activity calculations. Subsequently all *in situ* HPGe measurements were first evaluated to determine whether a uniform vertical contaminant distribution was an appropriate assumption. If it was, this assumption was used to estimate average activity concentrations. If not, PDA was applied to obtain average activity concentrations.

The maximum production rate obtained for *in situ* HPGe measurements was eight per day, or approximately one measurement per hour counting the time to move, set-up, stabilize, and acquire a 20-minute count, combined with the necessary QC checks at the start and end of the day.

Table 10. Comparison of *In Situ* HPGe and Laboratory Sample Results

	Cs137		U238	
Location	***In Situ* HPGe**	**Lab**	***In Situ* HPGe**	**Lab**
BS-1	0.04	0.12	167.0±8.4	147.20±27
BS-2	0.10	0.12	154.0±7.7	44.80±7.5
BS-3	0.06	0.08	18.0±4.9	1.29±0.3
BS-4	0.19	0.36	4.0±3.6	2.03±0.4
BS-5	0.05	0.12	36.0±4.7	41.78±7.1
BS-6	0.05	0.05	12.0±2.9	3.59±0.7
BS-7	0.07	0.31	13.0±11.1	56.77±8.9
BS-8	0.12	0.13	17.0±2.9	6.78±1.2
BS-9	0.07	0.14	63.0±8.2	196.20±35.8
BS-10	0.01	0.03	3.4±1.2	1.26±0.3
BS-11	0.12	0.27	78.0±6.2	66.49±12.1
BS-12	0.08	0.11	8.2±4.9	5.43±1.1
BS-13	0.16	0.32	110.0±5.5	119.40±21.2
BS-14	0.19	0.18	56.0±4.5	12.60±2.0
BS-15	0.14	0.26	182.0±9.1	193.20±37.6
BS-16	0.16	0.39	126.0±6.3	34.4±5.8
BS-17	0.11	0.21	85.0±6.0	114.60±20.4
BS-18	0.16	0.17	2.2±1.0	3.32±
BS-19	0.06	0.03	4.6±1.8	1.34±
BS-20	0.07	0.10	3.6±2.7	1.37±
51	0.17	0.17	1.6±0.8	1.38±
72	0.18	0.21	0.8±0.7	1.40±
76	0.13	0.15	1.0±0.8	1.11±
91	0.17	0.16	0.5±0.8	1.26±
120	0.19	0.25	2.4±0.9	1.40±
125	0.24	0.16	1.3±0.8	0.85±
145	0.15	0.25	1.5±0.8	1.51±
155	0.19	0.26	1.6±0.8	1.04±
Average:	0.12	0.18	41	38
StDev:	0.06	0.09	57	60
95%UCL	0.10	0.15	20	16
95%LCL	0.14	0.22	62	60

The absence of an Eberline team member capable of analyzing the HPGe spectra, and the challenges raised by vertical heterogeneity in contamination, prevented immediate access to activity concentration results from the HPGe. By the end of the field work the issue of vertical heterogeneity and its effects on activity concentration estimates had been resolved; presumably if an appropriate team member had been on site from that point forward real-time HPGe results would have been available.

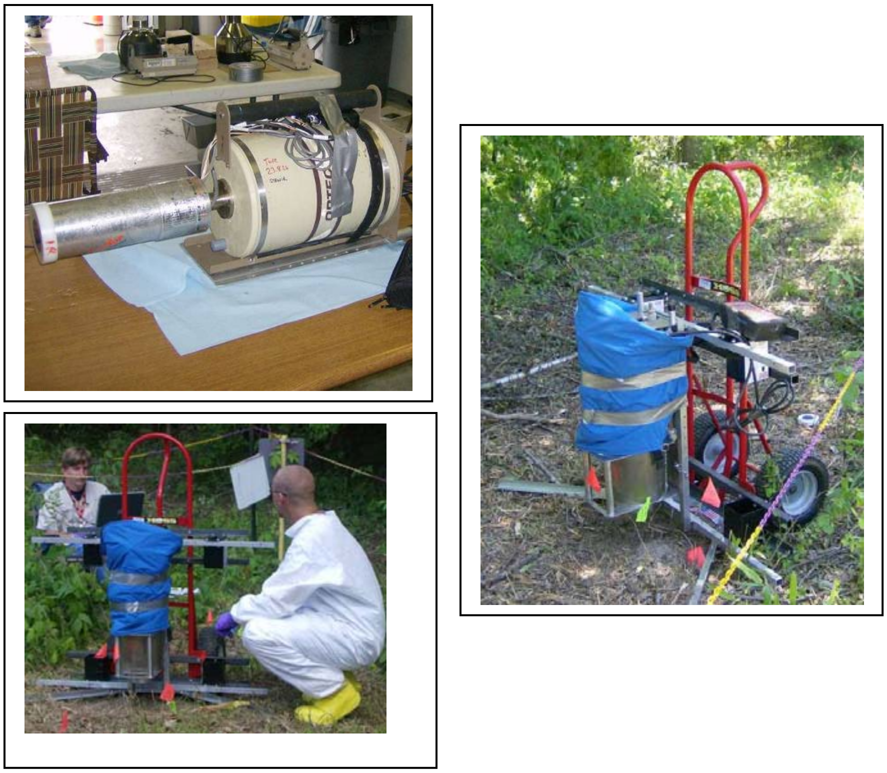


Figure 23. In Situ HPGe

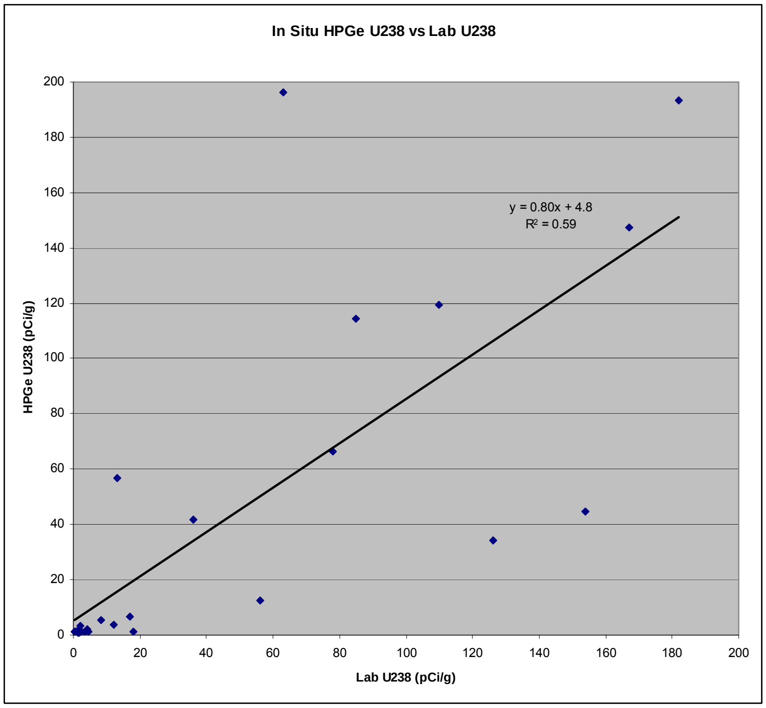


Figure 24. Comparison of In Situ HPGe ^{238}U and Laboratory ^{238}U Results

4.3. XRF

Eberline deployed a Thermo Fischer Scientific Niton 3XLt XRF unit as part of the demonstration work. The purpose of the XRF was to provide quantitative data for *in situ* and *ex situ* total uranium for soil areas and samples, as well as quantitative estimates of metal concentrations for other metals that might be measurable by the XRF and present at elevated levels.

The Niton 3XLt XRF unit is a tube-based XRF analyzer. It includes three energy filters that allow its performance to be optimized for various metals. It is a hand-held unit that also comes with a portable stand for cup sample analyses. It can be used for *in situ* readings of exposed soil surfaces, for *ex situ* readings through the walls of plastic bags that contain soil samples that have undergone minimal preparation, and for measurements of prepared soil samples in cups. Sample acquisition times can range from 10 to 600 seconds per filter. All three filters do not need to be used for each measurement.

The primary benefit of an XRF is the inexpensive acquisition of real-time concentration estimates of select metals in soils. An XRF is relatively easy to use and is a non-destructive measurement technique (i.e., repeated measurements can be taken of the same sample material without consuming or affecting the sample). Off-site Inductively Coupled Plasma (ICP) analysis is, in comparison, a destructive analytical technique that requires an extraction step. Both ICP and XRF physically measure a very small mass/surface area of soil (a few grams at most); consequently in both cases careful attention needs to be paid to soil sample and surface soil area heterogeneity and its potential effects on soil sample results.

Eberline deployed one XRF unit as part of the field work. The only deployment issue was the lack of extra power cords for both the battery charger and the XRF stand. This prevented the charging batteries while the stand was in use, which had some impacts on the availability of fully-charged batteries for deployment of the XRF for *in situ* measurements. Of the several hundred XRF measurements collected, only one was rejected for QC reasons (an *in situ* soil core screening measurement). Figure 23 shows various photographs of the XRF as deployed at the site. QC protocols and QC data for the XRF are presented in Appendix F.

With its short acquisition time, the XRF's daily throughput capacity was primarily constrained by sample acquisition and sample preparation. For example, 105 surficial 30-second acquisitions of *in situ* surface soils were obtained between 8:00 am and 1:00 pm on Tuesday, May 20. On Thursday, May 22, 74 soil core screening measurements were obtained (30-second acquisition) between 2:00 pm and 5:00 pm. On Friday, May 23, 80 individual bagged-sample measurements were obtained (30-second acquisitions) between 11:00 am and 1:30 pm, representing 8 different bagged samples (10 measurements per bag).

XRF detection limits are element and acquisition time-specific. In general, detection limits are halved as acquisition times are quadrupled. The detection limits of the Niton 3XLt XRF for a range of metals were reviewed as part of pre-field work performance assessment work, and are described in a report entitled "Real Time Demonstration Project XRF Performance Evaluation Report for Paducah Gaseous Diffusion Plant AOC 492", prepared by Argonne

Figure 25. Niton 3XLt XRF

National Laboratory for KRCEE (April, 2008). In the case of uranium, the detection limits observed during the field work were approximately 7 ppm for a 120-second acquisition on the main filter, and approximately 12 ppm for a 30-second acquisition on the main filter, values consistent with what was observed in the performance study. Seven (7) ppm total U is less than the ^{238}U (3.64 pCi/g) DPNAL assuming natural uranium, while 12 ppm is slightly higher than the DPNAL but less than the DPNAL for uranium metal of 14.7 ppm.

XRF comparability with laboratory analyses was evaluated in two ways: through the use of soil standards containing known concentrations of specific metals, and by comparison with laboratory sample analyses. In the case of uranium, there were several samples from the AOC 492 area that had been previously collected, prepared and well-characterized via alpha spectroscopy by the Commonwealth of Kentucky Radiation Health Branch Radiation/Environmental Monitoring Laboratory. A comparison of XRF total uranium results with known activity and the associated counting uncertainty for those samples is provided in Table 11. The average XRF result was calculated from the results of five sub-samples drawn from each sample and measured for 120 seconds. The standard deviation is the standard deviation observed among the five sub-sample results for each sample and represents the precision of the measurement. The analytical uncertainty represents the uncertainty associated with each measurement. Instead of reporting the analytical uncertainty for each measurement the average was reported for the five sub-sample results. Sample heterogeneity may be significant when comparing XRF results for these samples with the reported alpha spectroscopy results since the alpha spectroscopy results were based on single sub-samples, and so may not be necessarily completely representative of the original sample material. However, this was not the case for the samples since the alpha spectroscopy results with the associated reported uncertainty were within the results of the XRF measurement and well within the 95% Lower Tolerance Level (LTL) based on the XRF data. The conclusion is that there is no discernible bias in the XRF total uranium data set.

Table 11. XRF Total U Results Compared to Alpha Spectroscopy for Four Performance Samples

Sample	Average XRF Total U (ppm)	Sub-SampleSt Dev. (ppm)	Average Sub-Sample Analytical Error (ppm)	XRF 95%LTL (ppm)	XRF 95%UTL (ppm)	Lab Total U (ppm)	Counting Uncertainty (ppm)
50011	9	2	2	6	12	9	1.1
50016	1772	128	12	1521	2024	2066	324
50017	969	113	9	748	1190	732	131
50020	127	5	4	117	136	108	14

In the case of other metals, Niton provided a RCRA metals standard with the unit that contained approximately 500 ppm (+/- 100 ppm) for Cd, Ag, Pb, Se, As, and Cr. While the concentrations in this standard are not certified, they do provide a ball-park point of reference for the unit. A comparison of unit-measured values for this reference sample is provided in Table 12. For five of the six elements the XRF-reported values are well within expectations. However, for Cr the reported XRF value was significantly greater than what should have been present in this sample, indicating the presence of a potential bias.

Table 12. XRF Results for Niton-Supplied RCRA Soil Standard

	Metal Concentration (ppm)					
	Cd	Ag	Pb	Se	As	Cr
Standard	500	500	500	500	500	500
XRF	498	494	466	525	527	930

In addition to these soil "standards", sample splits sent for off-site laboratory analysis provide another point of comparison. In the case of alpha spectroscopy analyses for uranium, the cup of soil used for XRF analysis was sent for alpha spectroscopy analysis. This was important because it minimized the effects that incomplete sample homogenization might have on split-sample comparability. For all other laboratory analyses, the original sample mass was split and sent for analysis; consequently incomplete homogenization of the original sample material could potentially have an effect.

Off-site laboratory analysis provided results for uranium and eight RCRA metals: silver, arsenic, barium, cadmium, chromium, mercury, lead, and selenium. Of these, the XRF provided detectable data for arsenic, barium, chromium, and lead. Table 13 compares XRF results with laboratory data obtained from sample splits. Figure 24 shows two scatter plots of particular interest, XRF uranium versus alpha spectroscopy total uranium, and XRF chromium versus laboratory chromium.

The last row of Table 13 contains average values for each of the analytes across the comparability sample set. Based on the average results for uranium and arsenic, there appear to be excellent agreement between the XRF and laboratory analyses, with little evidence of systematic bias. In the case of lead, the agreement is good, although the XRF appears to be a bit higher, on average, than the laboratory. Figure 24 demonstrates the strength of the relationship between XRF uranium data and alpha spectroscopy results. The adjusted R^2 is 0.98, the slope of the line is not statistically different than one, and the y-intercept is near zero. The conclusion is the XRF is providing uranium data that appears to be as good as its laboratory alpha spectroscopy counterpart. A similar regression analysis for arsenic and lead was not possible because of the limited range of concentrations present in both data sets.

In the case of chromium and barium, the comparisons are not good. Barium is not a complete surprise. The Innov-X and Niton XRF analyses of performance samples prior to the field work yielded barium results that were not consistent with known background concentrations for the site, and that did not agree with each other. For the Niton deployed as part of this field effort, the average barium values were both significantly different than the reported laboratory result and significantly different from what the Niton instrument had reported that analyzed the performance samples. The conclusion is that the XRF is not yielding reliable barium results.

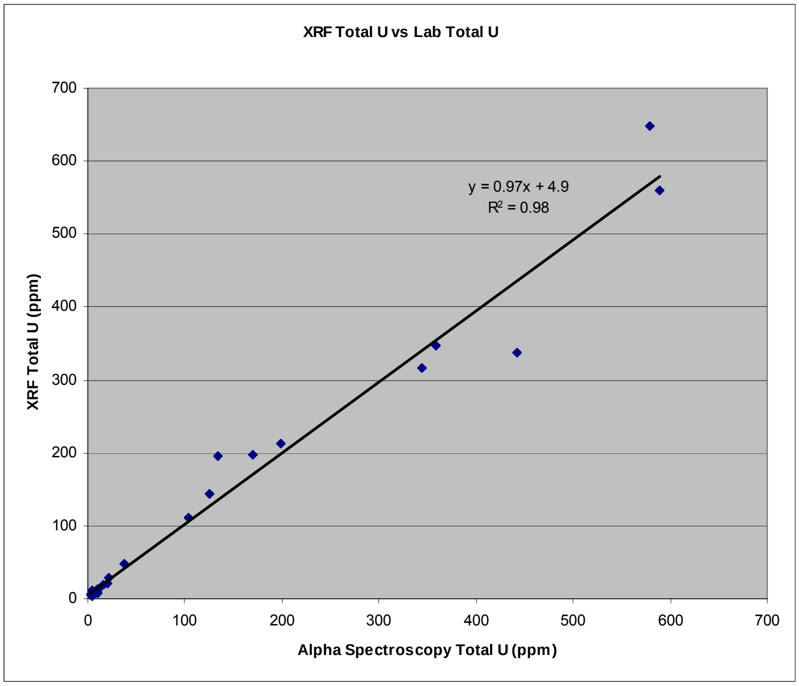
The chromium data are surprising, but consistent with what was observed in the calibration check performed with the reference standard supplied by Niton. For that calibration check, the instrument reported a chromium value that was approximately 80% higher than the reference material value. The chromium data in Table 13 confirm that the XRF measurements are reporting significantly higher chromium concentrations than the laboratory. Figure 24 shows a clear relationship between elevated laboratory chromium results and elevated XRF chromium data; however if a regression line is fit to these data (neglecting the high outlier), the slope of the line is 1.5 and the y-intercept equal to 134 ppm, indicating both an absolute bias and a systematic relative bias in XRF reporting. Chromium

Table 13. XRF Metal Results Compared to Laboratory Metal Results

	Uranium (ppm)		Arsenic (ppm)		Barium (ppm)		Chromium (ppm)		Lead (ppm)	
Sample	**XRF**	**Lab**	**XRF**	**Lab**	**XRF**	**Lab**	**XRF**	**Lab**	**XRF**	**Lab**
BS-1	338	441.6	8	6.4	-4	169	169	21.6	12	15.9
BS-2	196	134.4	5	5.5	55	132	156	10.5	14	16.3
BS-3	3	3.9	3	6.6	110	90	167	10.1	14	10.0
BS-4	7	6.1	6	4.3	85	87	146	10.6	13	11.0
BS-5	143	125.3	5	4.4	89	64	235	62.7	17	10.1
BS-6	14	10.8	6	4.7	110	95	156	12.1	12	10.2
BS-7	197	170.3	6	5.9	-31	76	196	75.7	12	13.6
BS-8	21	20.3	4	3.8	53	85	173	13.1	13	9.4
BS-9	560	588.6	3	6.4	8	91	237	78.1	18	13.8
BS-10	4	3.8	4	4.0	126	104	160	8.7	14	8.0
BS-11	213	199.5	4	4.7	-14	90	282	73.8	19	13.3
BS-12	18	16.3	4	4.9	117	85	153	11.6	17	10.2
BS-13	348	358.2	6	4.9	-25	90	331	113.0	19	13.9
BS-14	48	37.8	3	4.7	52	91	166	20.8	15	11.0
BS-15	649	579.6	5	5.2	-80	89	530	310.0	21	18.7
BS-16	112	103.3	7	5.6	75	90	207	95.7	17	14.3
BS-17	317	343.8	5	4.5	-43	96	338	95.6	18	12.1
BS-18	9	10.0	6	3.2	119	82	167	8.2	12	8.5
BS-19	8	4.0	6	3.7	129	89	157	8.3	9	7.8
BS-20	4	4.1	5	5.2	124	89	173	9.0	13	9.0
FSS-C1-01	6	5.0	9	7.1	52	140	133	12.0	15	24.0
FSS-C1-02	9	5.3	9	6.2	99	90	149	13.0	11	10.3
FSS-C1-03	7	5.1	3	8.0	132	98	156	12.7	18	11.2
FSS-C1-04	11	5.0	7	5.1	48	84	137	12.8	17	9.9
FSS-C1-05	12	10.4	2	8.4	86	80	167	12.7	15	13.3
FSS-C1-06	29	21.9	5	5.6	29	89	155	14.8	15	11.8
FSS-C1-07	3	4.1	6	6.9	51	88	151	12.8	14	10.7
FSS-C2-01	5	5.7	10	7.7	74	85	136	17.1	15	12.0
FSS-C2-02	8	5.4	6	8.0	60	83	120	14.8	20	11.1
FSS-C2-03	9	7.1	7	7.0	82	85	109	18.3	19	16.3
FSS-C2-04	6	3.5	8	6.5	98	105	116	12.7	19	11.5
FSS-C3-01	5	4.2	8	8.4	-16	94	117	15.6	18	13.5
Average:	104	101	6	6	58	94	186	38	16	12

has the potential for poor extraction efficiencies with standard laboratory analyses, which may explain part of this discrepancy, but the reference standard result suggests that there may have been a calibration issue with this particular unit in the case of chromium as well. The conclusion is that the XRF measurements are identifying a pattern of elevated chromium associated with elevated uranium consistent with what is observed in laboratory data, but that this XRF instrument was likely not providing accurate values of true chromium concentrations.

Finally, to evaluate the performance of measuring XRF concentrations through bags versus fully homogenizing samples and analyzing sub-sample cups by XRF, eight samples were analyzed through bag walls ten times (five on each side) prior to preparation and analysis by



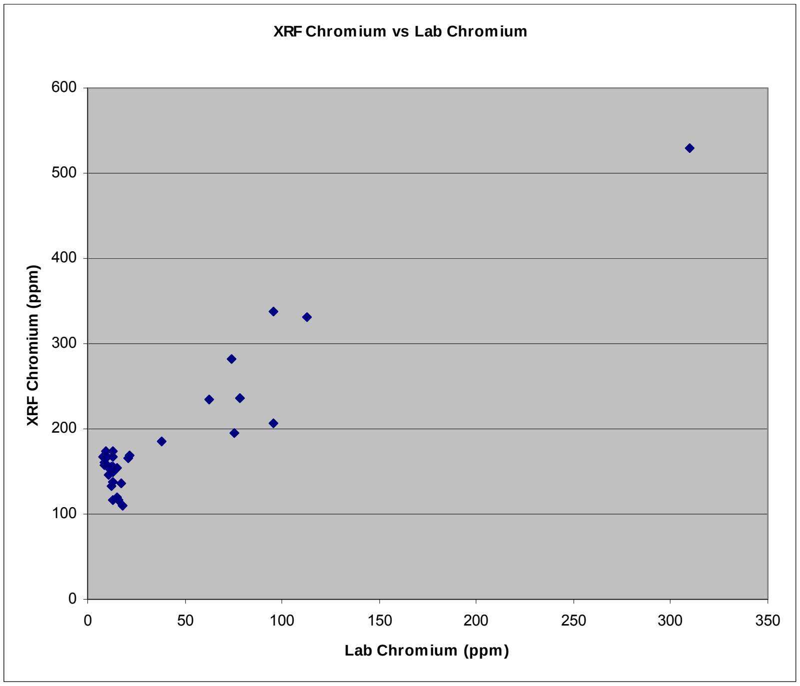


Figure 26. XRF Uranium and Chromium Comparability

XRF cups. Table 14 presents: (1) the average total uranium results for the XRF analysis of the bagged samples plus the observed total uranium standard deviation and average analytical error for each analysis, (2) the *in situ* HPGe results and counting uncertainty for these locations, (3) the XRF cup analytical results, and (4) the laboratory alpha spectroscopy analytical results plus the uncertainty for the measurement. Figure 25 shows scatter plots for

Table 14. Comparison of Bagged XRF Total U Results with XRF Cup, HPGe, and Laboratory Results

Sample	XRF Bag Sample Total U			Uranium (ppm)		
	Average	StDev	Av Error	In Situ HPGe	XRF Cup	Lab
BS-6	15	8	4	36	14	10.8
BS-10	5	2	4	10	4	3.8
BS-11	229	100	9	234	213	199.5
BS-12	15	5	4	25	18	16.3
BS-14	67	13	6	168	48	37.8
BS-16	360	199	11	378	112	103.3
BS-18	5	4	4	7	9	10.0
BS-20	1	3	4	11	4	4.1

the relationship between: (a) cup XRF total U and alpha spectroscopy analytical data, (b) average bag XRF total U results and alpha spectroscopy analytical data, and (c) bag XRF total U results and *in situ* HPGe analytical data. Each scatter plot includes a regression line. The scatter plot (a) underscores the earlier conclusion that the XRF cup analytical results provide nearly identical total uranium results as alpha spectroscopy analyses.

Scatter plot (b) shows that the comparison of the average analytical results for the bagged XRF total U to alpha spectroscopy is not nearly so good, particularly for samples with higher levels of contamination. The question is whether this indicates poorer performance for the bagged XRF measurements, or potentially the effects of inadequate sample homogenization for samples with higher levels of uranium. The variability in the bagged XRF data for higher total U concentrations indicates the large degree of total U heterogeneity present within these bagged samples. If this heterogeneity was not completely addressed by the sample preparation process, the sub-sampling conducted for XRF cup and subsequent alpha spectroscopy analyses may not have produced a sub-sample representative of the average conditions within the bag.

Scatter plot (c) shows how the bagged analytical results compared to the *in situ* HPGe analytical data (rather than the laboratory alpha spectroscopy). In this case the agreement, particularly for the higher total U concentration samples, improves dramatically. This would suggest that, in fact, the average bagged XRF total U analytical results are providing better estimates of the average concentration present within the bags (as represented by the *in situ* HPGe data) than the XRF cup or alpha spectroscopy data, presumably because the sample preparation process used did not fully eliminate the large degree of within-sample heterogeneity observed for these bags.

4.4. PCB Test Kits – ex situ Total PCB Analysis

Abraxis PCB test kits were used to estimate the concentration of total PCBs for study soil samples. Abraxis test kits are a multi-step wet chemistry technique that includes an

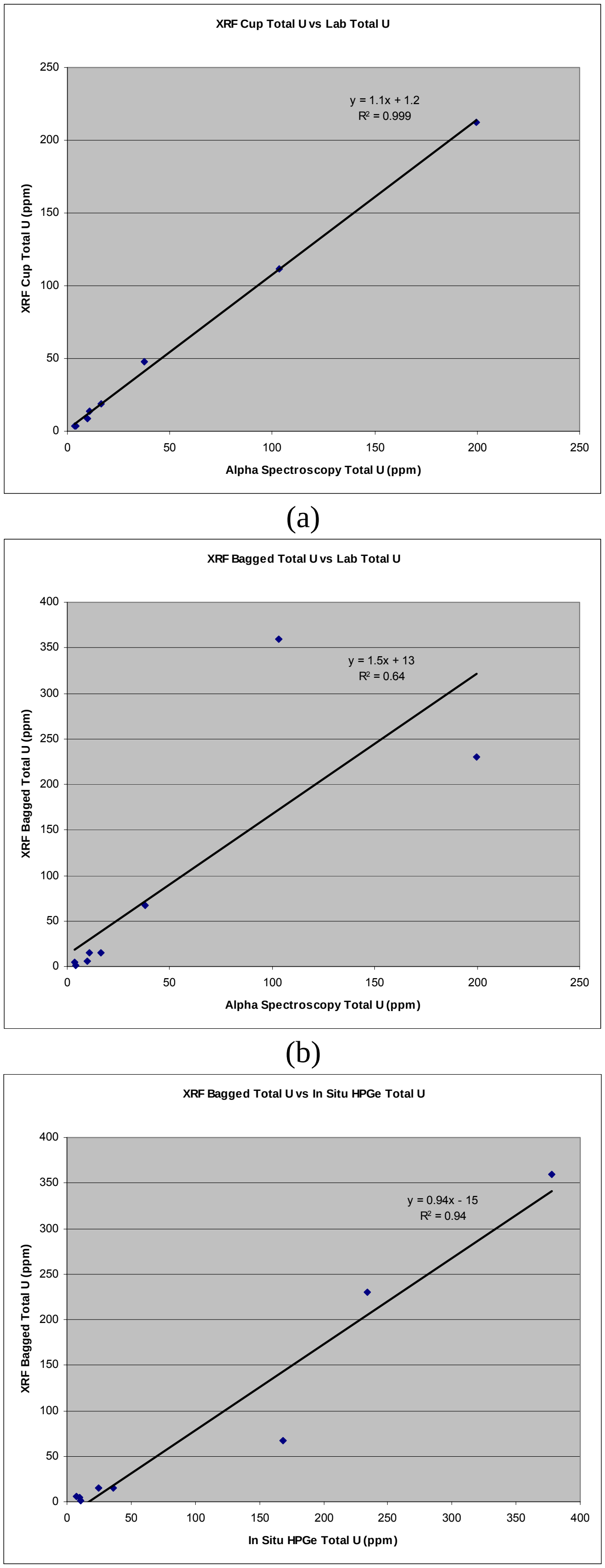


Figure 27. Analysis of XRF Bagged Sample Measurement Performance

extraction on sub-samples obtained from the original sample mass. The kits deployed for the field work were calibrated to provide a unit response to the presence of Arochlors 1254 and 1260. The published detection limit for the kits is 0.5 ppm total PCBs. The kits are intended to provide quantitative estimates of total PCB concentrations in soils. Appendix D contains the complete Abraxis test kit results. Appendix E contains the complete laboratory results, including PCB data.

Table 15 contains the Abraxis test kit total PCB data along with the corresponding laboratory data. In the case of the laboratory data, PCB concentrations were reported as arochlor-specific values. The total PCB laboratory value contained in Table 14 was obtained by summing all detectable arochlor-specific results for any particular sample. The only arochlors detected across the samples were 1248, 1254, and 1260. In the case of the Abraxis test kits, the final measurement step was conducted twice for each sample, and the average result is provided in this comparison. Figure 26 shows a scatter plot of these data for those samples with a laboratory result greater than the detection limit of the Abraxis test kits (0.5 ppm).

As Table 15 and Figure 26 demonstrate, in general there was excellent agreement between laboratory results and the test kits results, with the exception of three samples with laboratory total PCB results between 1 and 2 ppm, but with non-detects for the Abraxis test kits. All three of these samples, however, had laboratory results below the DPNAL for PCBs (3.64 ppm).

One of the concerns raised by pre-field work test kit performance evaluation work conducted by the EPA was the degree of variability observed in test kit results across multiple sub-samples obtained from a well-prepared sample mass. To further explore this observation, five sub-samples were taken from soil sample BS-15. Each sub-sample was analyzed five times using the Abraxis test kits. BS-15 was identified because it yielded the highest Abraxis test kit total PCB result. This exhausted the remaining sample mass. Consequently, after completion of the BS-15 gamma spectroscopy analysis, four sub-samples were taken from the soil mass that was used for gamma spectroscopy analysis (a non-destructive analytical method). The four sub-samples were submitted for laboratory PCB analysis. This yielded a total of five sub-samples submitted for PCB laboratory analysis for location BS-15 (one sub-sample had already been submitted from the field). In the case of the four sub-samples from the gamma spectroscopy work, the sample mass had gone through additional sample preparation (grinding and homogenization) at the laboratory prior to sub-sampling for PCB analyses; consequently the laboratory PCB results benefited from additional preparation work as compared to the Abraxis test kit data.

Table 16 presents the multiple sub-sampling results for location BS-15 for both the test kits and the laboratory analyses. These are not paired results; in other words, the five Abraxis test kit results and five laboratory results were generated from a total of ten sub-samples from the original soil sample. Of immediate note is the wide range in Abraxis test kit results for this sample, ranging from a non-detect value up to 11 ppm. The laboratory total PCB results

Table 15. Laboratory and Abraxis Test Kit Total PCB Results

Location	Abraxis Test Kit Total PCB (ppm)	Laboratory Total PCB (ppm)
BS-01	1.26	1.49
BS-02	<0.5	1.08
BS-03	<0.5	ND
BS-04	<0.5	0.0096
BS-05	<0.5	2.18
BS-6	<0.5	0.069
BS-07	2.79	2.91
BS-08	<0.5	0.091
BS-09	5.48	4.8
BS-10	<0.5	ND
BS-11	0.86	1.21
BS-12	<0.5	0.067
BS-13	2.58	2.42
BS-14	<0.5	0.43
BS-15	11.105	14.4
BS-16	<0.5	1.82
BS-17	2.53	2.16
BS-18	<0.5	0.0047
BS-19	<0.5	ND
BS-20	<0.5	ND
FSS-C1-01	<0.5	ND
FSS-C1-02	<0.5	ND
FSS-C1-03	<0.5	ND
FSS-C1-04	<0.5	ND
FSS-C1-05	<0.5	0.0193
FSS-C1-06	<0.5	0.074
FSS-C1-07	<0.5	ND
FFS-C2-01	<0.5	ND
FFS-C2-02	<0.5	ND
FFS-C2-03	<0.5	0.012
FFS-C2-04	<0.5	ND
FFS-C3-01	<0.5	ND

Table 16. Replicate PCB Results for BS-15

Sample	Abraxis Test Kit Total PCBs (ppm)	Sample	Laboratory Total PCBs (ppm)
BS-15	11.1	BS-15	14.4
BS-15-1	0.0	BS-15A	14.1
BS-15-2	4.3	BS-15B	10.6
BS-15-3	3.5	BS-15C	15.5
BS-15-4	2.4	BS-15D	9.1
Average:	4.3	**Average:**	12.7
St Dev:	4.2	**St Dev:**	2.7

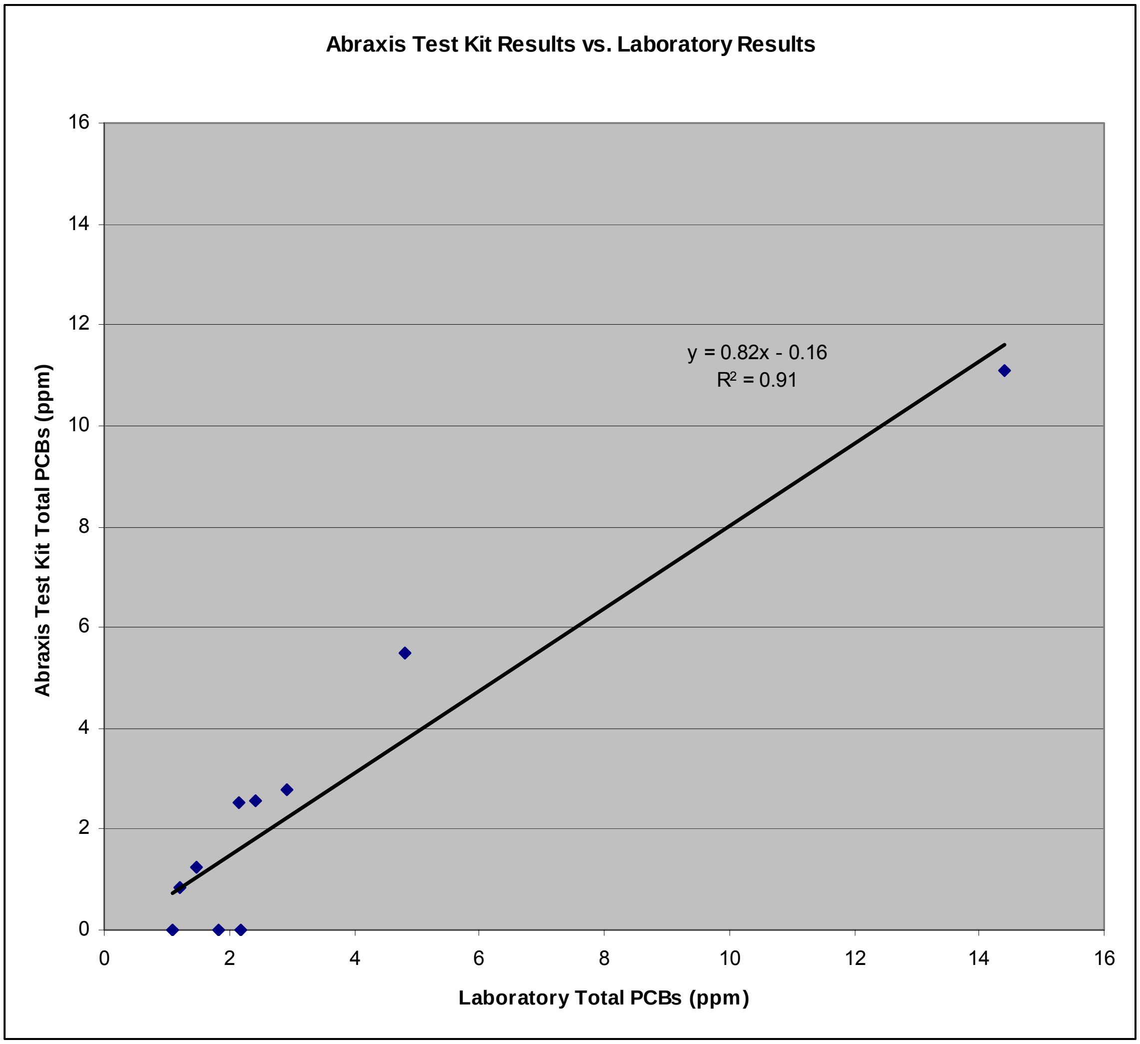


Figure 28. Comparison of Abraxis Test Kit and Laboratory Total PCB Results

also displayed a fair amount of variability, although not as great as the Abraxis test kit numbers. Also of note is that while the initial Abraxis test kit and laboratory result were fairly comparable, there was a significant difference between the average Abraxis test kit result and that observed from the laboratory analyses.

Abraxis noted that for weathered PCBs, such as those likely present in soils in the study area, the extraction procedure by the test kits would probably not be as efficient as that used in a laboratory setting, potentially resulting in a low bias. Abraxis estimated this bias might be as much as 20%. As the XRF demonstrated, within-sample heterogeneity was also significant for the study area samples even after sample preparation, and so might also explain discrepancies between Abraxis test kit data and the laboratory, and the variability within BS-15 Abraxis test kit replicate analyses. Unfortunately, unlike the XRF, PCB analyses are a destructive technique, so it is not possible to obtain exact sample splits for test kit and off-site laboratory analysis.

The primary effort with the Abraxis test kits was the sample preparation required prior to the analysis. The thoroughness of sample preparation would have a direct and significant impact on test kit data quality. The overall performance conclusion for the Abraxis test kits was that, in general, they provided data very comparable to that obtained from the off-site laboratory over the range of PCB concentrations encountered, but there was also a significant degree of variability observed in replicate sub-samples from the sample with the highest PCB concentrations. It was not clear from the study data to what degree this variability was attributable to Abraxis test kit analytical process, or to within-sample PCB heterogeneity. This is potentially an important issue for the site, since if it is the latter then it could adversely impact off-site laboratory data quality as well.

4.5. Multi-Increment Composite Samples

Multi-increment composite samples were used as part of the study to control the effects of short-scale heterogeneity on the representativeness of soil samples from specific locations. Multi-increment composite sampling introduces the additional cost of acquiring and handling the discrete soil increments that are used to form multi-increment composite samples. In addition, the use of multi-increment composite soil samples increases the need for careful homogenization.

Multi-increment composite samples were specifically used to improve the ability to correctly identify PCB or ^{238}U hot spots that might be present, and to improve the overall accuracy of average concentration estimates across the three MARSSIM FSS units. In the former case, the use of multi-increment samples potentially provides performance enhancements for hot spot detection. In the latter case, multi-increment samples potentially reduce analytical costs, since not all discrete soil increments are analyzed.

The hot spot criterion for PCBs was 33 ppm averaged over a 25 m2 area. There was no evidence from either the Abraxis test kit data or from corresponding laboratory data that total PCBs were present in the study above 33 ppm. Consequently, it is not possible to directly assess the performance of multi-increment composite samples for PCB hot spot detection. However, the GWS data pointed to three potential ^{238}U hot spot locations. Two of these were very isolated locations directly along the southern boundary of the study area, and the third was associated with the AOC 492 soil mound (Figure 12).

Ten (10) of the twenty initial BS sampling locations were within or adjacent to the soil mound footprint (Figure 13). The results from these samples (XRF and laboratory alpha spectroscopy) confirmed that the average ^{238}U activity/concentration for these locations was above the ^{238}U activity/concentration hot spot criterion. The samples drawn from each of these ten BS locations were actually 5-increment samples, with the five discrete soil increments collected from a very small area (1-ft^2 for each sampling location). Using the XRF cup analyses as a point of reference, 50% of these individual samples yielded a result greater than the hot spot criteria (or a hot spot rate of detection rate of 50% for these samples).

As a second point of comparison, 25 increment locations within the soil mound footprint were screened by XRF over the length of their cores. Of these 25, only ten yielded an average XRF result greater than the hot spot criterion for ^{238}U, a correct hot spot identification rate of only 40%.

In each case the center discrete soil increment was screened by XRF before being combined with the other four discrete soil increments to form the MIC sample for that specific BS location. Each of those ten center increments was equivalent to a typical grab sample. For those ten center increments only three (or 30%) yielded a total U result greater than the ^{238}U hot spot criteria; the average for these ten center locations was just a bit below the hot spot criteria (93 ppm, versus the 98 ppm criterion).

Another way of evaluating the performance of multi-increment samples is to estimate performance using the 10 XRF cup results. One can randomly pick pairs, triplets, quadruplets, etc. of locations and determine in each case with Monte Carlo analysis the frequency with which the hot spot would have been detected (as indicated by an average result greater than the hot spot criterion). For the scenario based on the XRF cup analyses, the hot spot detection rate for individual samples was 50%. This rose to 66% for 2-sample increments, 74% for 3-sample increments, 78% for 4-sample increments, and 85% for 5-sample increments. This analysis demonstrates the power of multi-increment composite samples to improve hot spot detection performance. The conclusion is that a sampling program based on single grab samples alone would not have been a reliable means for identifying the presence of this hot spot.

As will be discussed in Section 4.6, the one multi-increment composite sample collected from this area as part of the FSS process did identify the presence of the hot spot. In the case of that 5-increment sample, the 5 discrete soil increments were systematically distributed across a 25 m2 area.

Multi-increment samples would also be expected to potentially provide analytical cost savings when determining average concentrations over larger areas (such as an exposure unit or FSS unit). The number of samples required for statistical tests that compare average sample concentrations with action levels (e.g., the risk-based no action levels used for this demonstration) is driven in part by the concentration variability in the sample set. In the case of multi-increment composite sampling, combining and homogenizing several increments prior to analysis has the effect of reducing the variability that would be present in multi-increment composite sample results, as compared to the variability that would have been present if all of the increments had been analyzed. The relationship between the reduction in variability and the number of increments used to form samples is an inverse square root, i.e., quadrupling the number of increments used to form samples will reduce the variability observed in the final data set by a factor of slightly more than two. This assumes that each resulting multi-increment composite sample had been thoroughly homogenized before analysis.

The conclusion for this demonstration is that using 5-increment samples for FSS purposes reduced the number of sample analyses that would have been required to demonstrate compliance with the risk-based default no action levels by a factor of 2, while at the same time significantly increasing the ability of sampling to correctly identify the presence of hot spots.

4.6. Adaptive Compositing

Adaptive compositing is a cost effective sampling strategy when looking for contamination that is believed to be spotty if present. Adaptive compositing works by: (1) splitting discrete samples, (2) using one portion of the discrete sample splits to form a composite sample while archiving the other split, (3) homogenizing the composite sample, (4) analyzing the composite sample, and (5) comparing the results of the analysis to an investigation level established from the original action level and the number of samples used to form the composite. If the composite sample result is less than the investigation level, one can be confident that all of the samples contributing to the composite were below the original action level. If the composite yields a result greater than the investigation level, then each archived discrete split sample contributing to the composite is analyzed to determine which ones caused the exceedence.

For the demonstration, there were two hot spot criteria that were of concern, one for ^{238}U and one for total PCBs. Each was defined as applicable to 25 m2 areas. In the case of ^{238}U, the GWS provided spatially complete data that could be used to identify hot spots. The GWS data had detection limits well below the hot spot criterion for ^{238}U. In the case of total PCBs, the project had to rely on sample results to determine whether those hot spot concerns existed. PCB hot spot concerns were considered to be a potential issue only for the Class 1 and Class 2 areas. The Class 1 and 2 areas were divided into 25 m2 areas consistent with DOE orders and guidance. Five discrete soils samples were collected from each area. The five discrete soil samples were combined to form one 5-increment MIC sample from each area. As discussed in the previous section, using MIC samples greatly increased the probability that the sampling would have identified a hot spot, if it had been present.

There were 68 25 m2 areas in all with the Class 1 and Class 2 footprint. Rather than submit all 68 MIC composite samples for analysis, adaptive compositing was used to reduce the analytical burden. For the Class 1 area, composites were formed from sets of five MIC samples, resulting in a total of seven composite samples requiring analysis. For the Class 2 area, composites were formed from sets of eight MIC samples, resulting in four composite samples requiring analysis. When these eleven composite samples were analyzed, one of the composites samples from the Class 1 area had a ^{238}U result greater than its investigation level, and consequently the five contributing MIC samples were analyzed. One of these MIC samples had a result greater than the original ^{238}U hot spot criteria; that sample corresponded to the location of the AOC 492 soil mound, which had subsequently been excavated. The net result was that only 16 sample analyses were required using adaptive compositing rather than the 68 that would have been required otherwise, representing an analytical cost savings of more than 75%.

In terms of hot spot detection performance, there was no evidence from any analytical data (field or laboratory) that PCBs existed at levels above the hot spot criterion. The GWS did identify three areas that potentially posed ^{238}U hot spot concerns. Two of these were fairly isolated locations immediately along the southern edge of the study boundary. The third corresponded to the AOC 492 soil mound. Adaptive compositing was successful in identifying the presence of the AOC 492 soil mound hot spot. Adaptive compositing was not successful in identifying the other two more isolated locations along the southern boundary. Closer inspection of the FSS MIC sample locations determined that the individual samples would not have detected these areas either even if they had been analyzed, since the individual FSS MIC samples did not fall into the small, isolated footprints of these elevated areas as identified by the GWS.

Adaptive compositing performed as expected for this demonstration, resulting in significant analytical cost savings while not compromising the ability of sampling to identify potential hot spot concerns.

5.0. Conclusions and Recommendations

The real-time demonstration field work at AOC 492 spotlighted a number of innovative approaches and technologies that have broader application to the Paducah environmental remediation effort. These included (1) a FIDLER/LARADS-based gamma walkover system, (2) *in situ* HPGe gamma spectroscopy, (3) the latest hand-held XRF system from Niton, (4) Abraxis PCB test kits, (5) multi-increment composite sampling techniques, and (6) adaptive compositing techniques. These various techniques and technologies were deployed as part of a dynamic work strategy that rolled characterization, remediation, and closure data collection into one abbreviated field effort at AOC 492. The project demonstration goals for the study were based on default risk-based no action levels developed for PGDP (DOE, 2000). It was recognized that these default no-action levels may be near or below achievable detection limits for some of the real-time techniques; one of the goals was to determine what levels would be achievable.

Despite the loss of approximately 30% of the allocated field work time due to DOE organizational complications, the vast majority of the study objectives were achieved. The site was successfully characterized, assessed, soil excavation took place, and FSS closure sampling demonstrated that the DPNALs based upon PGDP default risk-based no action levels had been achieved for uranium and PCBs, the two primary contaminants.

Based on the field experience, the following sections provide conclusions and recommendations that can be applied to future PGDP activities:

5.1. GWS

- The FIDLER/LARADS GWS system exceeded its performance expectations.
- The FIDLER *a priori* critical level (L_C) was 6,170 gross cpm and the detection limit (L_D) 7,542 gross cpm.
- The L_C and L_D were below the in-field background level of 8,118 gross cpm with a standard deviation of 133 gross cpm
- The assumed area background was 8,628 gross cpm with standard deviation of 679 gross cpm.
- The in-field background point location and the assumed area background level were both greater than both the L_C and L_D.
- Although both the in-field point location and the assumed area background levels were greater than the L_C and L_D the counting uncertainty pushed the level at which background could be discerned from impacted soil to 8-9 pCi/g ^{238}U.
- The LARADS provided very accurate coordinate information for the walkover, and assisted in other civil surveying needs such as sampling location staking, as-built excavation surface surveying, and locating significant site features.
- There were no deployment issues.

- The recommendation is that the DOE consider using the FIDLER and/or LARADS for future gamma walkover surveying work.
- Based on demonstration project activities, the FIDLER is the appropriate instrument to apply at the PGDP in areas where: 1) at some point, there will be the need to demonstrate compliance with default risk-based no action levels; and/or 2) in areas where potential shine or topography issues complicate the interpretation of 2x2 NaI detector data presently used by DOE for GWS (such as near buildings or storage yards, along stream banks, and in excavation footprints).
- The LARADS would be particularly appropriate when excavations are expected to be required in the future, or as part of excavation support data collection.
- The LARADS would not be appropriate for wide area GWS work where line-of-sight is a potential constraint.

5.2. XRF

- The Niton 3XLt XRF exceeded its performance expectations with respect to uranium.
- Detection limits for the Niton 3XLt XRF were below the DPNAL.
- The XRF is a versatile data collection tool for uranium.
- Comparability with alpha spectroscopy was almost perfect.
- Sample measurement throughput rates were high, with individual measurement acquisitions of 120 seconds or less.
- The XRF demonstrated its utility as an *in situ* screening tool for exposed surfaces, as a means for rapidly screening soil cores in the field, as a method for quantifying contaminant concentrations within bagged samples without significant sample preparation, and as a potential replacement for alpha spectroscopy for prepared samples.
- Establishing XRF performance for other metals was more difficult given the limited range of concentrations encountered. There appeared to be quantitation problems with barium.
- The XRF unit deployed also appeared to be biased high with respect to chromium.
- The recommendation is that DOE fully incorporate XRF into characterization programs that target uranium.
- In the case of uranium, XRF data quality is equivalent to off-site laboratory data, and so should be considered usable for risk assessment and FSS purposes.
- Use of the XRF in these capacities assumes a well-established QC program that includes calibration checks through the use of appropriate standards and/or reference material.
- The DOE should consider how best to deploy XRF technologies for determining contamination depth in the case of subsurface contamination, and for supporting excavations when removal or remediation is necessary.

- In the case of other metals, the DOE should consider establishing background XRF-based metal concentrations that can be referenced.
- As new XRF units are brought on-site, DOE should use archived background sample material that can be re-used or conduct measurements in the area used for DOE radionuclide background study in order to verify performance and accuracy (note that the XRF is a non-destructive analytical technique and that performance can be unit-specific).
- The use of the XRF for metals as a quantitative source of metals data will likely require similar comparability work as to what was done for this demonstration, assuming DOE encounters other metal contamination at levels above background.

5.3. In Situ Gamma Spectroscopy

- The *in situ* HPGe gamma spectroscopy system deployed by Eberline at the site met some, but not all, of its performance expectations.
- After considerable experimentation with appropriate geometry assumptions, the HPGe provided accurate *in situ* activity for ^{137}Cs and ^{238}U with detection limits that were below risk-based default no action levels with reasonable acquisition times (20 minutes).
- There were reliability issues with the detectors deployed, however, and data was not available in "real-time."
- These issues could potentially be addressed if deployment protocols for *in situ* HPGe gamma spectroscopy measurement technologies were standardized for DOE for the site and DOE ensured that the appropriate expertise was available on-site.
- Although not demonstrated by this project, the same technology used for *in situ* measurements could also potentially be deployed as an *ex situ* gamma spectroscopy system in the more controlled setting of a near-site laboratory (e.g., in a trailer).
- The recommendation is that the DOE focus on applying *in situ* HPGe technologies and use *ex situ* "real-time" HPGe gamma spectroscopy capabilities to support the *in situ* soils work.
- Critical to this evaluation is an assessment of the relative costs of various deployment options as compared to reliance on off-site laboratory capacity, as well as the organizational requirements for maintaining the appropriate expertise in house if HPGe capabilities were internalized, or the minimum expertise requirements expected if on-site HPGe capabilities (*in si*tu or *ex situ*) were subcontracted for specific project support.

5.4. PCB Test Kits

- The Abraxis total PCB test kits deployed by the project met some, but not all, of their performance expectations.
- The detection limits for the kits were as expected at 0.5 ppm.

- The kit results, in general, showed excellent quantitative agreement with off-site sample splits.
- There was no evidence of false positive problems that are characteristic of other PCB test kit options.
- Sub-sample replicates for the sample with the highest PCB concentration showed an unacceptably high level of variability in kit results.
- Sub-samples from this sample submitted to the laboratory also showed a relatively high level of variability that was not as great as that displayed by the kits.
- Because of sample handling, it was not possible to determine from the study data whether the source of this variability (in the case of the kits) was due to within-sample PCB heterogeneity that was not completely addressed by field laboratory sample preparation, or because of something intrinsic to the kit analytical process itself.
- The issue of within sample PCB heterogeneity when soils have elevated PCB levels is an important one for DOE because it not only affects on-site field analytical performance, but also potentially the quality of data obtained from an off-site laboratory.
- The recommendations are that DOE evaluate the potential cost savings associated with on-site PCB test kit deployment as compared to continued sole reliance on off-site laboratory analyses to determine whether use of PCB test kits is justified from a cost perspective, and
- DOE should fully evaluate the issue of within sample PCB heterogeneity, the efficacy of standard sample preparation procedures to address that heterogeneity, and the implications for PCB-related decision-making at the site

5.5. Multi-Increment Composite (MIC) Sampling

- The multi-increment composite sampling protocols deployed as part of the study met their performance expectations.
- MICs significantly improved the ability of project sampling approach to correctly identify the presence of hot spot concerns.
- MICs significantly reduced the analytical costs associated with demonstrating that FSS unit average concentration levels met risk-based no action goals.
- MICs did introduce some additional concern about the quality of sample preparation (and in particular homogenization) for samples taken from impacted areas, given the level of within-sample heterogeneity that was observed prior to sample preparation, but these concerns can be addressed with appropriate sample preparation protocols.
- In the case of the study, 5-increment MIC samples appeared to be sufficient to allow hot spot identification to take place with a high degree of reliability given the heterogeneity observed in the AOC 492 soil mound.
- The recommendation is that the DOE adopt MIC sampling into soil sampling protocols, particularly when there are concerns about the potential presence of

hot spots, and/or when the level of residual contamination present, on average, is expected to be close to the relevant cleanup criteria.

- If and as DOE implements this recommendation, it is also important for the site to ensure that proper sample homogenization protocols are established to guarantee sufficient sample preparation so that the sub-sampling typically required for most analytical techniques yields a sub-sample representative of the total sample mass.

5.6. Adaptive Composite Sampling

- The adaptive compositing techniques used for the AOC 492 real time demonstration project met performance expectations.
- In particular, adaptive compositing was successful in identifying the presence of the AOC 492 ^{238}U hot spot while minimizing overall analytical costs.
- The combination of MIC sampling and adaptive compositing significantly reduced the analytical needs for demonstrating compliance with risk-based no action levels for the Class 1 and Class 2 FSS areas.
- The recommendation is that DOE consider using adaptive compositing in situations where hot spot identification relies solely on laboratory results (e.g., as is the case with PCBs).
- As is the case with MIC sampling, the use of adaptive compositing sampling requires proper sample homogenization protocols be established by DOE to ensure sufficient sample preparation so that the sub-sampling typically required for most analytical techniques yields a sub-sample representative of the total sample mass..

5.7. Additional Observations, Conclusions, and Recommendations

Beyond technology-specific conclusions and recommendations, the following observations, conclusions and recommendations are pertinent to contamination characteristics in the AOC 492 study area. To the extent that AOC 492 mirrors conditions for impacted areas on the east side of the PGDP site, these observations may have implications for future soil work.

- PCB contamination appeared to be tightly correlated with the presence of elevated uranium. For the AOC 492 soils, PCBs above risk-based default no action level were not observed until ^{238}U activities were above hot spot criteria (33 pCi/g).
- There are two main implications relative to the PCB-^{238}U correlation.
    - First, this indicates that measurement techniques that can identify elevated uranium (e.g., a GWS) effectively limit the area where PCB contamination concerns would be expected.
    - Second, assuming the risk-based default no action levels hold for other impacted areas on the east side of the site, remediating areas for uranium contamination will effectively remediate any PCB concerns at the same time.

- There was significant short scale heterogeneity observed for uranium in impacted soils.
- This variability was a function of concentration, i.e., as uranium concentrations increase, the degree of variability also increases.
- Short-scale heterogeneity is defined as heterogeneity that occurs over the distance of a few feet or less.
- The XRF measurements provided a means for measuring this variability; in the case of PCBs there was not an equivalent method available for evaluating the presence of short-scale heterogeneity, but presumably it was present for PCBs as well.
- Significant short-scale heterogeneity has two significant implications for sampling program design.
    - First, in such circumstances the results from single grab samples may yield misleading data regarding the presence or absence of contamination at levels of concern for the vicinity of the sample.
    - Second, the heterogeneity will carry-over into samples themselves, and will lead to analytical results that are not necessarily representative of the original sample or its location if the sample has not been thoroughly prepared.

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Appendix A. RTD Field Work FSP/QAPP Deviations

The following identifies deviations in the field work from the Field Sample Plan/Quality Assurance Project Plan (FSP/QAPP). In the majority of cases, these deviations were the product of schedule restrictions outside the control of the contractor. In some instances the changes reflected improvements to the proposed FSP activities, or additional tasks. There was only one instance where the change was a mistake by the implementing contractor.

1. The FSP identified the study boundary as extending down to the LBC water edge and across the outfall ditch to the top of the opposite bank. Because of Environmental Safety and Health (ES&H) concerns (very steep banks), the study area was confined to the relatively flat area north of Little Bayou Creek (LBC) and east of the Outfall 011 ditch.

2. The FSP called for splitting samples at various stages. This was modified to allow for one homogenized sample that was archived and subsequently sub-sampled for the purposes of XRF, PCB test kit, off-site laboratory, and further compositing. The purpose of the change was to simplify sample handling procedures without affecting the original purpose of sample splitting.

3. The FSP called for minimal sample preparation (i.e., simply removing stones and organic material) in the field. This was modified to allow Eberline to do sample preparation (e.g., initial homogenization of increments, etc.) wherever it made the most sense, which included doing it in the field rather than back at the staging area. The exception was the first 20 samples from the bias sample (BS) locations. For the BS soil locations, there was minimal sample preparation prior to bagging and measuring 8 selected samples through bag walls by XRF.

4. The FSP called for soil sampling from 1 square meter (m^2) areas for each of the 20 BS locations. This was changed to 1 square foot (ft^2) areas centered on 20 BS locations to reflect the high degree of spatial heterogeneity encountered. One outcome of this modification was an adjustment of the distance from the HPGe detector face to the soil for measurements. This modification allowed for a better match for the detector field of view with the 1 ft^2 sampled area.

5. The FSP called for initially measuring 10 bagged samples by XRF through bag walls prior to significant sample homogenization and then reanalysis of the same 10 bagged samples by XRF after significant sample homogenization. The purpose was to evaluate the effectiveness of sample homogenization in reducing within sample heterogeneity. Instead of 10 bagged samples analyzed by XRF as described by the FSP, 8 bagged samples were initially analyzed by XRF. However, because of time constraints, analyses subsequent to sample homogenization were not conducted.

6. Two soil samples (at least 5 kg) suspected of having elevated levels of uranium/polychlorinated biphenyl (U/PCB) were acquired from AOC541 and

analyzed by XRF and PCB test kits. The purpose of this sample collection was to obtain soils with PCB contamination exceeding 50 ppm for EPA study purposes. This activity was not included in the FSP.

7. To help determine the vertical distribution of uranium contamination, XRF screens (30-sec, main filter only) were conducted in the field on three depth intervals (2 in, 6 in, and 10 in) for selected increment positions during the BS location sampling. For 7 of the BS locations all 5 soil increment positions were screened by XRF. Because of time constraints, the center increment position was screened by XRF for the remaining 13 BS locations.

8. The QAPP called for labeling and chain-of-custody control on each of the five increments for individual locations during FSS sampling. To simplify sample handling and documentation, this requirement was reduced to apply only to the MIC sample produced by combining the five increments.

9. To control measurement time while obtaining necessary detection limits, HPGe measurements for Class 3 FSS sampling locations were obtained at the same height as the original 20 BS locations. If the HPGe had been set at the distance from the HPGe detector face to the soil for measurements specified by the FSP, the estimated measurement time to achieve the desired detection limits would have been more than 1 hour.

10. As specified by the FSP, 8 locations were sampled from the Class 3 area. Because of confusion over requirements, rather than all 8 samples being individually analyzed by XRF and PCB test kits, the 8 were homogenized and split, with 1 composite formed from the splits. This composite was sub-sampled and the sub-sample analyzed by XRF and PCB test kits, with a corresponding sub-sample submitted for off-site laboratory analysis. By the time the mistake was identified, there was insufficient time to analyze the splits by XRF and PCB test kits. However, sub-samples from each of the archived splits were sent for off-site laboratory analysis.

11. As specified by the FSP, each of the 7 composite samples from the Class 1 unit and 4 composite samples from the Class 2 unit were analyzed by XRF and PCB test kits, with the results compared to the appropriate field action levels. There was one Class 1 composite that was above its field action level for total uranium. However, because of time constraints, the 5 archived MIC samples used to form this composite were not analyzed by XRF and PCB test kits to determine which location(s) exceeded the relevant hot spot criteria.

12. Because of time constraints, the excavation support portion of the FSP was significantly modified. No additional data were collected from the proposed excavation area prior to the start of excavation. However the excavated area included 8 of the 20 BS locations; therefore, significant pre-excavation data was available. Only 1 lift of soil was removed to an average depth of 0.84 foot (ft) rather than 1 ft. Because saturated soil conditions were encountered and there were concerns about

compromising an adjacent wetland, the excavation was stopped at the above indicated depth. A post-excavation GWS was conducted for the majority of the exposed dig surface, with the exception of a small area where standing water was present. Five *in situ* XRF measurements (120-sec main filter) were obtained from five different locations. One 1-ft deep soil sample was collected from the center of the excavation. That sample was screened by XRF through the bag (ten 30-sec acquisitions) before being sent for off-site laboratory analysis.

13. The laboratory mistakenly conducted SVOC analyses in addition to the PCB analyses requested. This mistake was due to miscommunication with the laboratory; however the end result was more information regarding SVOC contamination status than was originally targeted by the FSP.

Appendix B. XRF Results

The XRF deployed as part of the project was a Niton 3XLt XRF Niton XLT handheld detector. The Niton 3XLT XLt has three different filters applied to the x-ray tube, with each filter designed to optimize performance for a particular set of elements. Measurements can be taken using one, two, or all three filters, depending on the elements/metals of interest. For example, the main filter is best for uranium, while the second filter is best for chromium.

The XRF data that were produced as part of the field work can be categorized in four (4) ways.

The first is by acquisition time.

- With the exception of quality control measurements, acquisition times for the XRF measurements were either 30 seconds per filter or 120 seconds per filter.

- Detection limits improve as acquisition time increases.
    - 30 Thirty seconds was used when screening for the presence of uranium.
    - One hundred-twenty (120) seconds was used for samples when more definitive data with lower detection limits were desired for samples.

The second is by measurement type.

- As deployed by the project, the XRF was used to measure:
    - prepared homogenized soils in sample cups, measurements of
    - bagged samples (minimal preparation) through bag walls,
    - *in situ* measurements of exposed soil surfaces (no preparation), and
    - field *in situ* measurements of soil cores intervals contained in sample pans (no preparation).

- Cup sample measurements were typically 120 seconds, while all other measurements types were typically 30 seconds.

The third is by the filters used.

- Cup measurements typically used all three filters to obtain results for all elements for which the XRF was calibrated.
- Only the main filter was used for the other measurements.
- Using all three filters increases measurement time by a factor of three.

The fourth is by measurement purpose.

- XRF data were collected for a wide range of purposes by the project.

  - QC (e.g., initial calibration verification, on-going verification monitoring, etc.),
  - Initial soils characterization,
  - FSS sampling,
  - Excavation support, etc.

The XRF data presented in this appendix are organized by the original purpose of the data collection.

- Tables B1 and B2 provide XRF results generated as part of the initial calibration check.

  - Table 1 includes one measurement of a RCRA metals standard provided by Niton (120-second acquisition for each filter).
  - Table 2 includes 20 measurements corresponding to 20 subsamples obtained from the four initial performance samples collected from AOC 492 in January 2008 (5 subsamples per each performance sample), 120-second acquisition main filter only.

- Table B3 includes 30 measurements representing 10 replicates each for three selected subsamples, 50020-3, 50016-5, and 50011-1 (30-second acquisition each for the main and second filter).

- Table B4 provides on-going calibration check results for 50020-3 (30-second acquisition each for the main and second filter), the subsample selected to monitor calibration performance over the course of field work.

A complete discussion of XRF QC data can be found in Appendix F.

- Table B5 contains the results of *in situ* 30-second acquisition (main filter only) measurements for the 20 targeted BS locations. Each targeted location included five XRF *in situ* measurements corresponding to the center and each corner of a 1 ft^2 area centered on the location.

- Table B6 contains the results of field *in situ* measurements of soil cores obtained from the 20 targeted BS locations.

  - XRF measurements were made of soils from depths of 2 inches, 6 inches, and 10 inches.
  - All 20 BS locations had the center soil cores screened by XRF in this manner.
  - A subset of seven 7 locations also had the four corners screened in this manner.
  - Each XRF measurement was a 30-second acquisition (main filter) of the soil surface.
  - In some cases core refusal was encountered, so not all cores screened had complete XRF data down the entire length of the core.

- Table B7 contains the results of XRF measurements of bagged samples from eight (8) of the 20 targeted BS locations.

    - Each bag was measured 10 times, 5 times on each side of the bag, with the 5 measurements systematically placed across the bag's surface.
    - Each XRF measurement was a 30-second acquisition (main filter) of soils through the bag's surface.

- Table B8 contains the results of XRF cup measurements for prepared subsamples from each of the 20 targeted locations.
    - Each XRF measurement was a 120-second per filter (3 filters) acquisition.

- Table B9 contains the results of five subsamples from one selected targeted location, BS-2.
    - Each XRF measurement was a 120-second per filter (3 filters) acquisition.

- Table B10 contains the results for XRF cup measurements from two samples obtained from AOC-541.
    - Each XRF measurement was a 30-second (main filter) acquisition.

- Table B11 contains the results for XRF cup measurements for prepared FSS samples.
    - Each XRF measurement was a 120-second per filter (3 filters) acquisition.

Finally,

- Table B12 contains the results for XRF measurements acquired to support excavation work.

    - Table B12 includes both *in situ* XRF readings of surface soils from five locations (120-second main filter only acquisitions), and
    - Bagged sample results for one sample obtained from a 1-ft core from the center of the excavation, with 10 measurements for the bag,
    - Each XRF measurement was a 30-second main filter only acquisitions.

In each table, results that are below the method detection limit as defined in SW846 Method 6200 are italicized. In these cases, the detection limit is three times the associated estimated measurement error. The errors reported in these tables are twice the estimated measurement error, which is the standard Niton method for reporting error.

Table B1. XRF RCRA Standard Measurement Results (ppm)

					Pb		Se		As		Cr		Cd		Ag	
Time	Duration	Sample	Type	Purpose	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
5/17/2008 10:26	360.27	RCRA	Cup	QC	466	17	525	11	527	17	930	30	498	9	494	9

Table B2. XRF Uranium Calibration Verification Measurement Results (ppm)

					Mo		Zr		Sr		U		Rb		Th	
Time	Duration	Sample	Type	Purpose	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
5/17/2008 11:24	120.12	50011-1	Cup	QC	8	3	633	8	103	3	8	5	55	3	12	3
5/17/2008 11:27	120.31	50011-2	Cup	QC	7	3	635	8	104	3	7	5	57	3	10	3
5/17/2008 11:32	120.22	50011-3	Cup	QC	8	3	637	8	105	3	9	5	54	3	11	3
5/17/2008 11:35	120.29	50011-4	Cup	QC	8	3	604	8	103	3	10	5	57	3	9	3
5/17/2008 11:37	120.19	50011-5	Cup	QC	8	3	580	8	105	3	11	5	59	3	12	3
5/17/2008 12:28	120.09	50016-1	Cup	QC	25	4	823	10	87	3	1728	24	48	8	14	4
5/17/2008 12:31	120.29	50016-2	Cup	QC	28	4	846	10	91	3	1637	23	48	7	11	4
5/17/2008 12:33	120.29	50016-3	Cup	QC	22	4	813	10	91	3	1722	23	47	8	8	3
5/17/2008 12:36	120.11	50016-4	Cup	QC	22	4	823	10	84	3	1796	24	47	8	11	4
5/17/2008 12:39	120.18	50016-5	Cup	QC	28	4	781	9	80	3	1978	25	48	8	6	4
5/17/2008 12:43	120.11	50017-1	Cup	QC	17	4	810	9	96	3	892	17	46	6	13	3
5/17/2008 12:45	120.24	50017-2	Cup	QC	14	4	826	9	93	3	909	17	42	6	11	3
5/17/2008 12:48	120.25	50017-3	Cup	QC	16	4	784	9	95	3	904	17	42	6	10	3
5/17/2008 12:51	120.08	50017-4	Cup	QC	21	4	826	9	91	3	979	18	42	6	11	3
5/17/2008 12:54	120.3	50017-5	Cup	QC	19	4	822	10	89	3	1161	19	45	6	9	3
5/17/2008 13:10	120.14	50020-1	Cup	QC	8	3	772	9	96	3	120	7	48	3	13	3
5/17/2008 13:12	120.17	50020-2	Cup	QC	9	3	778	9	95	3	124	7	45	3	14	3
5/17/2008 13:15	120.05	50020-3	Cup	QC	9	3	792	9	94	3	129	7	47	3	12	3
5/17/2008 13:18	120.02	50020-4	Cup	QC	10	3	759	9	95	3	130	7	48	3	10	3
5/17/2008 13:20	120.13	50020-5	Cup	QC	8	3	764	9	96	3	132	7	46	3	10	3

Table B2. XRF Uranium Calibration Verification Measurement Results (ppm) (continued)

					Pb		Se		As		Hg		Zn		W	
Time	**Duration**	**Sample**	**Type**	**Purpose**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
5/17/2008 11:24	120.12	50011-1	Cup	QC	17	4	*2*	2	8	3	*5*	4	38	7	*-42*	23
5/17/2008 11:27	120.31	50011-2	Cup	QC	20	4	*1*	2	7	3	*4*	4	36	7	*-34*	24
5/17/2008 11:32	120.22	50011-3	Cup	QC	18	4	*1*	2	8	3	*-1*	4	34	7	*-5*	25
5/17/2008 11:35	120.29	50011-4	Cup	QC	18	4	*0*	2	7	3	*0*	4	32	6	*-7*	25
5/17/2008 11:37	120.19	50011-5	Cup	QC	22	4	*2*	2	9	3	*2*	4	39	7	*-9*	25
5/17/2008 12:28	120.09	50016-1	Cup	QC	13	4	*-1*	2	8	3	*3*	4	87	8	*-28*	25
5/17/2008 12:31	120.29	50016-2	Cup	QC	16	4	*1*	2	8	3	*4*	4	82	8	*-47*	24
5/17/2008 12:33	120.29	50016-3	Cup	QC	20	4	*1*	2	6	4	*1*	4	88	9	*-24*	25
5/17/2008 12:36	120.11	50016-4	Cup	QC	22	4	*1*	2	*3*	3	*5*	4	92	9	*-42*	24
5/17/2008 12:39	120.18	50016-5	Cup	QC	21	4	*1*	2	6	4	*3*	4	94	9	*-48*	24
5/17/2008 12:43	120.11	50017-1	Cup	QC	30	5	*0*	2	6	4	*3*	4	183	11	*-25*	25
5/17/2008 12:45	120.24	50017-2	Cup	QC	25	4	*0*	2	11	4	*2*	4	185	11	*-15*	25
5/17/2008 12:48	120.25	50017-3	Cup	QC	28	4	*1*	2	9	4	*3*	4	183	11	*-37*	25
5/17/2008 12:51	120.08	50017-4	Cup	QC	34	5	*0*	2	*4*	4	*1*	4	190	11	*-16*	25
5/17/2008 12:54	120.3	50017-5	Cup	QC	30	5	*-1*	2	10	4	*1*	4	221	12	*-18*	26
5/17/2008 13:10	120.14	50020-1	Cup	QC	19	4	*1*	2	5	3	*3*	4	38	7	*-22*	24
5/17/2008 13:12	120.17	50020-2	Cup	QC	18	4	*1*	2	6	3	*4*	4	33	6	*-29*	24
5/17/2008 13:15	120.05	50020-3	Cup	QC	13	4	*1*	2	5	3	*4*	4	30	6	*-37*	23
5/17/2008 13:18	120.02	50020-4	Cup	QC	15	4	*0*	2	8	3	*0*	4	36	6	*-12*	24
5/17/2008 13:20	120.13	50020-5	Cup	QC	16	4	*2*	2	6	3	*5*	4	27	6	*-34*	23

Table B2. XRF Uranium Calibration Verification Measurement Results (ppm) (cont.)

					Cu		Ni		Co		Fe		Mn	
Time	**Duration**	**Sample**	**Type**	**Purpose**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
5/17/2008 11:24	120.12	50011-1	Cup	QC	*14*	10	*-8*	19	*46*	45	13646	159	333	40
5/17/2008 11:27	120.31	50011-2	Cup	QC	*5*	10	*3*	20	*52*	45	13776	160	299	38
5/17/2008 11:32	120.22	50011-3	Cup	QC	18	10	*-3*	20	*52*	45	13757	160	296	38
5/17/2008 11:35	120.29	50011-4	Cup	QC	*10*	10	*-1*	20	*54*	45	13961	161	343	40
5/17/2008 11:37	120.19	50011-5	Cup	QC	17	10	*-20*	19	73	47	14918	167	354	41
5/17/2008 12:28	120.09	50016-1	Cup	QC	*9*	10	*-8*	20	*56*	42	11685	149	339	41
5/17/2008 12:31	120.29	50016-2	Cup	QC	16	10	*19*	21	*43*	42	11480	147	263	37
5/17/2008 12:33	120.29	50016-3	Cup	QC	21	11	*-2*	20	*49*	43	11875	150	328	40
5/17/2008 12:36	120.11	50016-4	Cup	QC	16	10	*-11*	20	*43*	43	12346	154	383	43
5/17/2008 12:39	120.18	50016-5	Cup	QC	26	11	*-30*	20	68	45	12842	158	423	44
5/17/2008 12:43	120.11	50017-1	Cup	QC	27	11	*-9*	20	63	42	11597	148	320	41
5/17/2008 12:45	120.24	50017-2	Cup	QC	29	11	*-6*	20	*61*	43	12113	150	313	41
5/17/2008 12:48	120.25	50017-3	Cup	QC	26	11	*17*	20	*41*	42	11862	149	297	40
5/17/2008 12:51	120.08	50017-4	Cup	QC	45	11	*17*	20	*50*	42	12125	150	322	41
5/17/2008 12:54	120.3	50017-5	Cup	QC	31	11	*5*	20	*34*	44	13185	158	412	45
5/17/2008 13:10	120.14	50020-1	Cup	QC	*5*	10	*-13*	19	*31*	38	9818	135	701	51
5/17/2008 13:12	120.17	50020-2	Cup	QC	*3*	9	*-26*	19	*53*	39	9933	136	686	50
5/17/2008 13:15	120.05	50020-3	Cup	QC	*4*	9	*5*	19	*36*	38	9688	133	642	49
5/17/2008 13:18	120.02	50020-4	Cup	QC	*15*	10	*-12*	19	*-10*	39	10668	140	779	53
5/17/2008 13:20	120.13	50020-5	Cup	QC	*6*	10	*-7*	19	*21*	39	10506	139	785	53

Table B3. Replicate XRF Measurement Results for Uranium and Chromium (ppm)

					U		Cr	
Time	Duration	Sample	Type	Purpose	Result	Error	Result	Error
5/17/2008 14:26	60.01	50020-3	Cup	Replicate Measurement	125	16	130	32
5/17/2008 14:27	60.19	50020-3	Cup	Replicate Measurement	132	16	113	31
5/17/2008 14:28	60	50020-3	Cup	Replicate Measurement	126	16	133	32
5/17/2008 14:29	60.14	50020-3	Cup	Replicate Measurement	124	15	129	32
5/17/2008 14:30	60.26	50020-3	Cup	Replicate Measurement	147	16	126	32
5/17/2008 14:31	60.25	50020-3	Cup	Replicate Measurement	118	15	123	31
5/17/2008 14:32	60.23	50020-3	Cup	Replicate Measurement	122	15	113	31
5/17/2008 14:33	60.2	50020-3	Cup	Replicate Measurement	125	15	130	32
5/17/2008 14:34	60.21	50020-3	Cup	Replicate Measurement	111	15	98	31
5/17/2008 14:35	60	50020-3	Cup	Replicate Measurement	118	15	104	31
5/17/2008 14:49	60.34	50016-5	Cup	Replicate Measurement	1966	54	265	37
5/17/2008 14:50	60.18	50016-5	Cup	Replicate Measurement	2016	55	243	36
5/17/2008 14:51	60.08	50016-5	Cup	Replicate Measurement	1965	54	227	36
5/17/2008 14:52	60.13	50016-5	Cup	Replicate Measurement	1999	54	272	37
5/17/2008 14:53	60.05	50016-5	Cup	Replicate Measurement	1981	54	270	37
5/17/2008 14:54	60.01	50016-5	Cup	Replicate Measurement	1996	54	238	36
5/17/2008 14:55	60.08	50016-5	Cup	Replicate Measurement	2066	56	271	37
5/17/2008 14:56	60.23	50016-5	Cup	Replicate Measurement	1975	54	257	36
5/17/2008 14:57	60.06	50016-5	Cup	Replicate Measurement	1999	54	251	36
5/17/2008 14:58	60.31	50016-5	Cup	Replicate Measurement	1983	54	234	36
5/17/2008 15:01	60.16	50011-1	Cup	Replicate Measurement	*9*	10	130	34
5/17/2008 15:02	60.18	50011-1	Cup	Replicate Measurement	*10*	10	124	33
5/17/2008 15:03	60.22	50011-1	Cup	Replicate Measurement	*10*	10	115	33
5/17/2008 15:04	60.23	50011-1	Cup	Replicate Measurement	*9*	10	104	33
5/17/2008 15:05	60.2	50011-1	Cup	Replicate Measurement	*3*	9	107	33
5/17/2008 15:06	60.05	50011-1	Cup	Replicate Measurement	*6*	9	97	33
5/17/2008 15:07	60.3	50011-1	Cup	Replicate Measurement	*3*	9	112	33
5/17/2008 15:08	60.06	50011-1	Cup	Replicate Measurement	*6*	9	114	33
5/17/2008 15:09	60.17	50011-1	Cup	Replicate Measurement	*11*	10	98	32
5/17/2008 15:10	60.01	50011-1	Cup	Replicate Measurement	*16*	10	117	33

Table B4. On-Going XRF Calibration Monitoring Measurement Results for Uranium and Chromium (ppm)

Time	Duration	Sample	Type	Purpose	U		Cr	
					Result	Error	Result	Error
5/22/2008 13:00	60.29	50020-3	Cup	QC	125	16	128	31
5/23/2008 12:29	60.11	50020-3	Cup	QC	128	16	144	32
5/23/2008 12:30	60	50020-3	Cup	QC	132	16	132	32
5/28/2008 6:42	60.29	50020-3	Cup	QC	127	16	129	31
5/28/2008 14:24	60.06	50020-3	Cup	QC	124	16	131	31
5/29/2008 7:37	60.2	50020-3	Cup	QC	117	15	122	31
5/30/2008 12:02	60.03	50020-3	Cup	QC	121	16	152	32
5/30/2008 12:04	60.18	50020-3	Cup	QC	119	16	124	31

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-1-1	*8*	6	449	13	66	5	755	28	32	9	*5*	5	*6*	6	*1*	3	*7*	5
BS-1-2	57	8	565	15	66	6	1401	40	26	13	11	6	16	8	*-1*	3	*-2*	6
BS-1-3	*8*	6	536	14	66	5	415	22	29	8	8	5	*8*	6	*1*	3	*4*	5
BS-1-4	9	5	410	12	67	5	372	20	26	7	10	5	*6*	6	*-1*	3	*7*	5
BS-1-5	36	13	417	16	12	6	6729	93	*20*	29	*15*	10	*13*	10	*0*	4	*2*	7
BS-2-1	*6*	5	442	13	56	5	365	20	28	7	9	5	11	6	*0*	3	*-1*	5
BS-2-2	10	5	388	12	52	4	121	13	25	5	*6*	5	12	6	*1*	3	*2*	5
BS-2-3	*6*	10	444	15	35	6	4257	71	*11*	22	*8*	8	*12*	9	*2*	4	*3*	7
BS-2-4	*6*	5	354	12	54	5	261	18	26	6	*6*	5	11	6	*1*	3	*1*	5
BS-2-5	*6*	5	471	13	71	5	45	9	26	4	9	5	13	7	*0*	3	*1*	5
BS-3-1	*7*	5	419	13	52	4	*3*	7	28	4	*5*	4	*7*	6	*1*	3	*4*	5
BS-3-2	*5*	5	423	13	53	5	*8*	7	27	4	*7*	5	12	6	*-2*	2	*-3*	5
BS-3-3	*3*	4	424	13	62	5	*10*	7	28	4	8	5	*5*	6	*-1*	3	*3*	5
BS-3-4	*5*	4	457	13	64	5	*9*	7	31	4	7	4	*3*	5	*0*	2	*6*	4
BS-3-5	*6*	5	442	13	66	5	*7*	7	29	4	*7*	5	*6*	6	*1*	3	*6*	5
BS-4-1	8	5	352	12	56	5	*-1*	7	34	4	*5*	5	13	7	*0*	3	*3*	5
BS-4-2	12	5	375	13	57	5	16	8	27	4	*6*	5	17	7	*1*	3	*-2*	6
BS-4-3	*4*	5	406	13	59	5	*3*	7	34	4	*7*	5	12	7	*1*	3	*5*	5
BS-4-4	*4*	4	346	11	52	4	*6*	7	24	3	*5*	4	12	6	*0*	2	*3*	5
BS-4-5	*2*	5	347	12	57	5	*9*	8	26	4	*6*	5	13	7	*1*	3	*5*	6
BS-5-1	*5*	5	607	15	69	5	147	14	20	5	*3*	4	*7*	6	*1*	3	*8*	5
BS-5-2	*7*	5	429	14	62	5	130	14	19	5	*5*	5	*6*	6	*2*	3	*6*	5
BS-5-3	*7*	5	507	14	51	5	130	14	19	5	*6*	5	*5*	6	*3*	3	*6*	5
BS-5-4	8	5	431	13	61	5	143	14	17	5	*2*	4	18	7	*3*	3	*-6*	5
BS-5-5	*6*	5	507	14	71	5	172	15	19	5	*4*	5	11	7	*1*	3	*4*	5
BS-6-1	*7*	5	516	15	69	5	29	9	32	5	10	5	*9*	7	*2*	3	*4*	5
BS-6-2	*4*	5	505	14	66	5	98	12	22	5	*5*	5	11	6	*0*	3	*-2*	5
BS-6-3	8	5	401	12	54	4	127	13	17	5	*2*	4	*6*	6	*0*	3	*3*	5

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-1-1	*0*	6	66	13	*-13*	39	*16*	16	*5*	31	*12*	55	6005	194	722	92
BS-1-2	*6*	7	34	12	*-34*	42	*8*	17	*28*	36	*-5*	64	7420	228	587	91
BS-1-3	*6*	6	32	11	*-46*	39	*-3*	16	*1*	33	*0*	62	7234	220	570	87
BS-1-4	*-3*	6	46	12	*-12*	39	*18*	16	*3*	31	*36*	54	5652	188	923	102
BS-1-5	*-1*	7	102	18	*-29*	45	*19*	20	*-32*	37	*20*	71	7711	250	328	80
BS-2-1	*1*	6	28	10	*-40*	37	*5*	16	*-6*	31	*40*	56	5896	193	492	80
BS-2-2	*-2*	5	14	9	*-34*	37	*1*	15	*7*	32	*11*	52	5412	184	650	88
BS-2-3	*5*	7	63	14	*-53*	41	*-9*	17	*-13*	36	*33*	60	5844	209	305	73
BS-2-4	*-2*	6	26	10	*-27*	39	*-6*	15	*-16*	32	*77*	54	5051	182	365	72
BS-2-5	*0*	6	20	10	*-1*	41	*-13*	14	*2*	32	*42*	59	6538	204	594	87
BS-3-1	*1*	6	*13*	9	*-27*	40	*6*	16	*20*	34	*17*	52	5061	182	505	82
BS-3-2	*2*	6	17	10	*-32*	41	*3*	17	*-38*	31	*18*	53	4980	186	411	77
BS-3-3	*0*	6	*14*	9	*-33*	39	*-10*	15	*6*	32	*-31*	51	5396	188	535	83
BS-3-4	*-1*	5	*13*	9	*-25*	35	*6*	14	*-8*	29	*24*	51	5227	178	590	83
BS-3-5	*7*	6	23	10	*-64*	36	*1*	16	*11*	33	*28*	55	5727	194	511	81
BS-4-1	*9*	6	27	11	*-46*	38	*7*	16	*3*	33	*7*	61	7214	219	756	97
BS-4-2	*3*	7	34	13	*-48*	44	*5*	19	*-24*	36	*39*	69	7525	241	534	91
BS-4-3	*-3*	6	26	11	*2*	43	*12*	17	*4*	34	*71*	68	8232	234	629	91
BS-4-4	*3*	6	32	11	*-36*	37	*12*	16	*8*	31	*14*	56	6439	199	687	89
BS-4-5	*4*	6	20	10	*-63*	38	*14*	18	*-22*	33	*69*	63	6720	217	690	96
BS-5-1	*0*	6	55	13	*-44*	39	*13*	17	*-7*	33	*12*	62	7310	221	274	68
BS-5-2	*2*	7	70	15	*-39*	43	*10*	18	*-31*	34	*39*	61	6043	211	493	86
BS-5-3	*5*	6	30	11	*-57*	41	*-1*	17	*11*	36	*24*	65	7271	227	314	74
BS-5-4	*2*	7	56	13	*-23*	43	*-5*	16	*5*	35	*19*	56	5545	197	626	92
BS-5-5	*2*	6	60	14	*-13*	43	*-2*	16	*-11*	33	*-11*	62	7209	221	317	72
BS-6-1	*5*	6	28	11	*-62*	40	*-15*	16	*8*	36	*60*	67	7415	231	567	91
BS-6-2	*1*	6	48	12	*-56*	38	*0*	16	*4*	34	*56*	60	6455	208	611	90
BS-6-3	*3*	6	49	12	*-26*	38	*-6*	14	*-8*	31	*42*	49	4388	166	534	81

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-6-4	*0*	5	541	15	64	5	34	9	29	4	*7*	5	10	6	*-1*	3	*3*	5
BS-6-5	*-3*	5	530	15	74	5	27	9	26	4	*6*	5	*7*	6	*0*	3	*2*	5
BS-7-1	*4*	5	558	15	68	5	*8*	8	37	4	*1*	4	10	6	*1*	3	*4*	5
BS-7-2	*5*	4	457	13	57	4	13	7	31	4	*3*	4	*4*	5	*0*	3	*4*	4
BS-7-3	*4*	4	368	11	49	4	22	8	24	4	*6*	4	*7*	6	*0*	2	*3*	4
BS-7-4	*4*	4	427	12	59	4	39	9	27	4	*5*	4	*7*	6	*2*	3	*1*	4
BS-7-5	10	5	543	15	71	5	18	8	32	4	*6*	5	11	6	*0*	3	*1*	5
BS-8-1	8	5	477	13	70	5	62	11	34	5	12	5	6	6	*1*	3	*7*	5
BS-8-2	12	5	331	12	60	5	86	12	22	5	12	5	9	6	*0*	3	*2*	5
BS-8-3	*6*	5	540	14	69	5	136	14	37	6	8	5	5	6	*0*	3	*3*	5
BS-8-4	*2*	5	507	14	74	5	36	10	39	5	*6*	5	11	6	*-1*	3	*7*	6
BS-8-5	*7*	5	447	14	66	5	94	13	30	5	8	5	*8*	7	*2*	3	10	6
BS-9-1	8	5	422	13	54	4	64	10	24	4	*3*	4	*6*	6	*0*	3	*7*	5
BS-9-2	*6*	5	438	13	48	4	197	15	20	5	9	5	*8*	6	*0*	3	*3*	5
BS-9-3	11	5	590	15	66	5	123	14	33	5	*4*	5	11	7	*0*	3	*2*	5
BS-9-4	8	5	592	15	62	5	171	15	26	5	9	5	*9*	6	*-1*	2	*1*	5
BS-9-5	11	5	434	13	55	5	204	16	16	6	*6*	5	*9*	6	*-1*	3	*1*	5
BS-10-1	*2*	5	531	14	65	5	13	8	32	4	*6*	5	*6*	6	*1*	3	*4*	5
BS-10-2	9	5	430	15	64	6	*5*	8	29	5	*8*	6	24	9	*2*	4	*6*	7
BS-10-3	14	5	428	13	64	5	17	8	32	4	*6*	5	*4*	6	*1*	3	*7*	5
BS-10-4	*6*	5	466	14	58	5	23	9	31	4	10	5	*8*	6	*0*	3	*5*	5
BS-10-5	*7*	5	552	15	72	5	29	9	35	5	*6*	5	*7*	6	*0*	3	*4*	5
BS-11-1	8	5	258	11	121	7	*2*	8	39	5	*7*	5	16	7	*1*	3	*1*	6
BS-11-2	14	6	485	14	62	5	358	22	26	7	*6*	5	13	7	*-1*	3	*5*	6
BS-11-3	*4*	5	493	14	67	5	275	18	35	7	9	5	11	6	*-1*	3	*6*	5
BS-11-4	13	6	503	15	64	5	490	25	30	8	13	6	11	7	*0*	3	*8*	6
BS-11-5	11	6	441	13	65	5	639	26	25	9	*2*	5	21	7	*-1*	3	11	6
BS-12-1	*1*	4	440	13	63	5	22	8	30	4	*7*	5	*2*	5	*0*	3	*5*	4
BS-12-2	*4*	4	460	13	71	5	25	8	30	4	*6*	5	*9*	6	*2*	3	*7*	5

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations
(30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-6-4	*3*	6	20	10	*-41*	40	*6*	17	*2*	34	*39*	63	7092	220	458	81
BS-6-5	*-2*	6	19	11	*-23*	44	*-8*	17	*-33*	34	*74*	62	6026	210	301	73
BS-7-1	*1*	6	21	11	*-20*	42	*-6*	16	*41*	36	*-12*	59	6520	211	472	82
BS-7-2	*-1*	6	23	10	*-9*	38	*-8*	14	*-21*	30	*39*	52	5181	180	555	82
BS-7-3	9	6	26	10	*-60*	32	*8*	15	*0*	29	*7*	47	4594	166	428	73
BS-7-4	*-3*	6	21	10	*-4*	38	*13*	15	*19*	31	*11*	50	5076	175	517	78
BS-7-5	*0*	6	22	11	*-22*	41	*22*	18	*8*	34	*5*	57	6113	204	470	81
BS-8-1	*2*	6	22	10	*-28*	38	*9*	16	*-10*	31	*8*	59	6884	209	252	64
BS-8-2	*2*	6	51	13	*-35*	40	*8*	17	*-40*	31	*62*	49	3746	163	1055	112
BS-8-3	*-3*	6	19	10	*2*	42	*5*	16	*-13*	33	137	60	5773	197	402	76
BS-8-4	*-2*	6	23	11	*-10*	42	*12*	17	*-3*	33	*14*	62	7339	221	418	78
BS-8-5	*7*	7	55	14	*-68*	42	*-6*	17	*5*	37	*29*	62	6352	218	460	85
BS-9-1	*5*	6	23	10	*-57*	36	*5*	16	*42*	34	*13*	57	6600	204	670	89
BS-9-2	*-3*	6	52	12	*-23*	39	*13*	16	*24*	32	*-24*	51	5505	186	507	80
BS-9-3	*-2*	6	40	12	*-26*	42	*-9*	16	*7*	34	*17*	66	8100	235	502	84
BS-9-4	*3*	6	25	10	*-41*	37	*5*	15	*18*	33	*40*	57	6197	199	580	86
BS-9-5	*7*	6	55	13	*-57*	38	*-2*	16	*8*	34	*0*	79	12260	283	602	90
BS-10-1	*5*	6	15	9	*-32*	37	*-2*	15	*33*	33	*-9*	54	5871	193	515	81
BS-10-2	*3*	7	*14*	12	*-51*	49	*-1*	20	*-94*	41	469	124	18888	406	985	129
BS-10-3	*1*	6	33	11	*-31*	39	*4*	16	*16*	33	*-46*	50	5178	183	795	97
BS-10-4	*4*	6	27	11	*-45*	42	*-17*	16	*6*	36	*53*	57	5353	196	782	102
BS-10-5	*0*	6	24	11	*-10*	43	*-7*	16	*0*	35	*46*	61	6505	213	400	77
BS-11-1	*4*	6	43	13	*-90*	38	*-4*	17	*-23*	35	*21*	69	8140	244	211	65
BS-11-2	*1*	7	108	17	*-25*	44	*15*	18	*-10*	35	*-37*	61	7004	224	329	75
BS-11-3	*-1*	6	63	14	*-26*	40	*10*	16	*10*	33	*42*	61	6924	213	315	70
BS-11-4	*0*	7	71	15	*-14*	45	*17*	18	*-11*	35	*33*	66	7455	231	357	78
BS-11-5	*-4*	6	143	18	*4*	42	*13*	16	*-3*	32	*-1*	60	7391	216	371	74
BS-12-1	*-2*	6	16	10	*-24*	38	*17*	16	*-9*	31	*8*	55	5995	194	627	87
BS-12-2	*2*	6	27	11	*-14*	38	*6*	15	*0*	31	*52*	56	5977	194	476	78

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-12-3	8	5	408	13	66	5	34	9	28	4	*7*	5	*9*	6	*1*	3	*1*	5
BS-12-4	13	5	458	14	69	5	58	11	32	5	10	5	19	7	*1*	3	*2*	6
BS-12-5	*6*	5	484	14	70	5	43	10	37	5	10	5	*7*	6	*1*	3	*7*	5
BS-13-1	12	6	420	14	53	5	485	25	27	8	10	6	16	8	*1*	3	*1*	6
BS-13-2	15	6	496	14	64	5	539	25	30	8	*3*	5	13	7	*1*	3	*6*	6
BS-13-3	35	8	560	16	58	6	1670	46	23	14	*8*	7	18	9	*3*	4	*6*	7
BS-13-4	9	6	504	14	64	5	436	23	34	8	10	6	17	7	*0*	3	*3*	6
BS-13-5	10	5	485	14	60	5	365	21	28	7	*4*	5	11	7	*0*	3	*4*	5
BS-14-1	7	5	366	12	68	5	172	15	36	6	9	5	11	6	*-1*	3	*4*	5
BS-14-2	11	4	258	10	113	6	49	10	33	4	*2*	4	18	7	*0*	3	*1*	5
BS-14-3	*5*	5	367	13	99	6	114	14	33	6	*7*	5	13	7	*2*	3	*5*	6
BS-14-4	*2*	4	294	11	65	5	30	9	30	4	*2*	4	12	7	*2*	3	*5*	6
BS-14-5	*5*	5	361	12	69	5	116	13	31	5	11	5	12	7	*1*	3	*8*	6
BS-15-1	11	6	639	17	78	6	389	23	35	8	9	6	*9*	7	*-2*	3	*4*	6
BS-15-2	16	7	466	15	62	6	1403	42	29	13	*5*	6	37	10	*3*	4	*8*	8
BS-15-3	12	6	706	17	132	7	207	17	39	7	9	5	12	7	*1*	3	*7*	6
BS-15-4	15	6	446	14	86	6	833	31	41	10	9	6	13	7	*1*	3	*9*	6
BS-15-5	19	6	423	13	61	5	694	28	35	9	*7*	5	*10*	7	*2*	3	*2*	5
BS-16-1	14	5	410	14	64	5	170	16	32	6	*8*	5	*7*	7	*3*	3	10	6
BS-16-2	*4*	5	463	13	59	5	192	16	28	6	*6*	5	*8*	6	*-1*	3	*5*	5
BS-16-3	16	7	552	15	57	5	1257	38	21	12	*4*	6	25	8	*-2*	3	*1*	7
BS-16-4	*6*	6	426	13	53	5	475	24	28	8	*6*	5	16	7	*0*	3	*3*	6
BS-16-5	*7*	6	373	13	52	5	476	24	22	8	*8*	5	12	7	*2*	3	*5*	6
BS-17-1	13	7	608	16	57	5	823	32	33	10	*9*	6	12	7	*1*	3	*9*	6
BS-17-2	15	6	473	13	71	5	538	24	33	8	*8*	5	11	6	*0*	3	*5*	5
BS-17-3	13	6	373	13	61	5	248	19	27	7	*3*	5	18	8	*0*	3	*-3*	6
BS-17-4	16	7	628	16	61	5	774	31	22	10	*9*	6	23	8	*-1*	3	*3*	6
BS-17-5	11	6	437	14	77	6	496	25	35	8	8	6	18	7	*-1*	3	*5*	6

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-12-3	*0*	6	31	11	*-17*	40	*-7*	15	*-16*	31	*18*	53	5233	186	765	96
BS-12-4	*4*	6	27	11	*-64*	38	*-1*	16	*-6*	33	*13*	62	7130	221	620	91
BS-12-5	*1*	6	33	12	*-54*	39	*1*	16	*-42*	32	*78*	65	7260	224	645	94
BS-13-1	*0*	7	91	17	*-41*	45	*12*	19	*-24*	35	*19*	59	5611	206	367	79
BS-13-2	*4*	6	99	16	*-61*	38	*18*	17	*-24*	32	*3*	64	7719	228	386	78
BS-13-3	*8*	7	130	19	*-42*	46	*19*	20	*11*	38	*-22*	65	7133	235	437	85
BS-13-4	*8*	6	101	16	*-51*	39	*1*	16	*6*	34	*36*	62	6965	216	306	71
BS-13-5	*2*	6	113	17	*-19*	42	*10*	17	*1*	33	*-15*	60	7084	217	434	79
BS-14-1	*-1*	6	62	14	*-17*	40	*3*	16	*6*	33	*86*	72	9805	250	350	73
BS-14-2	*0*	6	29	11	*-33*	38	*5*	15	*10*	32	*27*	60	7259	212	213	60
BS-14-3	*4*	7	53	14	*-40*	43	*17*	19	*-7*	36	*72*	77	9885	269	334	77
BS-14-4	*6*	6	53	13	*-43*	40	*10*	17	*-6*	34	*23*	75	10669	268	394	78
BS-14-5	*-3*	6	61	14	*-35*	40	*1*	16	*-13*	33	*26*	70	9197	247	459	81
BS-15-1	*-3*	7	150	20	*-8*	47	*22*	19	*-39*	35	*45*	68	7620	238	274	73
BS-15-2	*2*	7	523	35	*-31*	51	52	22	*9*	38	*-66*	75	10263	278	388	90
BS-15-3	*8*	7	49	13	*-67*	40	*7*	18	*-10*	35	*-1*	65	7414	232	222	67
BS-15-4	*-5*	6	129	18	*-25*	43	*12*	18	*3*	35	*57*	63	6855	218	253	67
BS-15-5	*9*	6	187	20	*-57*	39	36	18	*-6*	32	*-7*	61	7233	218	354	74
BS-16-1	*4*	7	108	18	*-67*	43	*-3*	18	*-27*	35	*-36*	55	5335	202	341	77
BS-16-2	*0*	6	96	16	*-15*	41	*-9*	15	*-10*	32	*3*	52	5143	184	347	72
BS-16-3	*2*	7	423	31	*-10*	48	36	20	*1*	36	*37*	67	7961	237	165	65
BS-16-4	*-7*	6	132	18	*17*	46	*2*	17	*-22*	33	*79*	61	6321	209	443	83
BS-16-5	*3*	7	130	18	*-39*	43	*8*	18	*-24*	34	*15*	54	4978	191	728	100
BS-17-1	*-6*	7	167	21	*17*	49	*24*	19	*-11*	36	*47*	73	8996	256	296	76
BS-17-2	*2*	6	147	18	*-43*	37	*20*	16	*6*	31	*-23*	59	7276	213	402	75
BS-17-3	*4*	7	70	15	*-54*	45	*1*	19	*-28*	37	*4*	56	4821	197	402	83
BS-17-4	*2*	6	140	19	*-51*	42	*21*	19	*1*	36	113	68	7309	229	288	75
BS-17-5	*3*	7	114	17	*-21*	44	*17*	18	*-35*	32	*-42*	61	7057	223	327	75

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-18-1	7	5	437	13	60	5	*4*	7	28	4	10	5	*7*	6	*2*	3	*3*	5
BS-18-2	9	4	406	12	62	5	*8*	7	31	4	*7*	5	11	6	*0*	3	*2*	5
BS-18-3	12	5	448	14	68	5	*6*	8	29	4	*6*	5	12	7	*0*	3	*2*	5
BS-18-4	*4*	5	529	14	68	5	*7*	7	30	4	8	5	11	6	*-2*	3	*1*	5
BS-18-5	*6*	5	400	13	62	5	*2*	7	29	4	10	5	*9*	6	*0*	3	*1*	5
BS-19-1	*6*	4	329	11	62	5	*9*	7	30	4	*5*	4	6	6	*-2*	2	*3*	5
BS-19-2	*3*	4	326	12	60	5	*7*	7	30	4	11	5	6	6	*0*	3	*5*	5
BS-19-3	9	5	303	11	63	5	12	8	25	4	*7*	5	10	6	*1*	3	*1*	5
BS-19-4	8	5	381	14	76	6	*9*	9	33	5	*3*	5	13	8	*4*	4	*-1*	6
BS-19-5	14	6	305	13	60	6	*7*	9	29	5	10	6	12	8	*3*	4	*5*	7
BS-20-1	*5*	5	459	13	74	5	*5*	7	35	4	*5*	5	8	6	*-2*	2	*6*	5
BS-20-2	*4*	4	399	12	64	5	*4*	7	28	4	8	5	10	6	*0*	3	*0*	5
BS-20-3	9	5	375	13	59	5	*11*	8	26	4	*6*	5	9	7	*1*	3	*0*	5
BS-20-4	*5*	5	434	13	80	5	*4*	8	38	4	*5*	5	5	6	*2*	3	*6*	5
BS-20-5	10	5	383	13	73	5	*3*	8	38	4	*7*	5	13	7	*3*	3	*6*	6
PS-1-1	12	6	570	15	81	6	542	25	33	9	*8*	5	*9*	7	*1*	3	*4*	5
PS-1-2	8	5	380	12	75	5	90	12	24	5	8	5	*6*	6	*-1*	3	*4*	5
PS-1-3	10	5	404	12	59	5	147	14	24	5	*4*	5	9	6	*3*	3	*5*	5
PS-1-4	*6*	5	438	13	53	5	138	14	24	5	8	5	*6*	6	*0*	3	*5*	5
PS-1-5	9	5	433	13	58	5	168	15	23	5	*4*	4	9	6	*0*	3	*0*	5

Table B5. *In Situ* XRF Measurements from 20 Targeted Locations (30-sec acquisitions, main filter, all data collected 5/20/08) (cont.)

	Hg		**Zn**		**W**		**Cu**		**Ni**		**Co**		**Fe**		**Mn**	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-18-1	*2*	6	20	10	*-38*	39	*24*	18	*-31*	31	*22*	52	4794	180	405	76
BS-18-2	*1*	5	24	10	*-53*	36	*0*	15	*13*	32	*20*	50	4804	174	508	80
BS-18-3	*0*	7	19	11	*-5*	47	*-1*	18	*1*	36	*8*	57	5395	200	316	74
BS-18-4	*0*	6	25	11	*-24*	41	*-3*	16	*-19*	32	*-16*	57	6220	205	247	65
BS-18-5	*0*	6	25	11	*-32*	40	*-4*	16	*8*	34	*47*	53	4813	180	353	72
BS-19-1	*0*	6	38	12	*-28*	40	*-6*	15	*37*	34	*-25*	62	7826	224	649	90
BS-19-2	*2*	6	22	10	*-48*	39	*5*	17	*3*	34	*58*	66	7759	229	471	82
BS-19-3	*6*	6	40	12	*-73*	38	*12*	18	*-15*	34	*35*	61	6606	215	445	81
BS-19-4	*0*	8	26	13	*-28*	55	*10*	22	*26*	46	*97*	82	8753	281	377	88
BS-19-5	*2*	8	47	15	*-66*	53	*13*	23	*8*	46	*88*	99	12873	346	438	96
BS-20-1	*2*	6	27	11	*-43*	38	*-17*	14	*-5*	32	*-2*	66	8491	235	399	76
BS-20-2	*4*	6	16	9	*-28*	38	*-4*	15	*8*	32	*21*	56	6095	196	522	81
BS-20-3	*-1*	6	25	11	*-26*	44	*2*	18	*-13*	35	*-35*	55	5460	200	352	75
BS-20-4	*-1*	6	34	12	*4*	43	*10*	17	*-19*	33	*68*	72	9328	250	440	80
BS-20-5	*8*	7	40	12	*-47*	40	*19*	18	*-42*	32	*9*	73	9994	263	417	81
PS-1-1	*1*	6	66	14	*-52*	39	*-1*	16	*-7*	34	*96*	69	8069	234	250	67
PS-1-2	*0*	6	30	11	*-25*	39	*-4*	15	*-23*	31	*30*	53	5147	184	439	77
PS-1-3	*1*	5	74	14	*-54*	37	*-4*	15	*-26*	31	*51*	53	4970	180	870	101
PS-1-4	*5*	6	58	13	*-60*	37	*-1*	15	*44*	34	*-25*	51	5252	185	638	89
PS-1-5	*-2*	6	43	12	*-7*	40	*18*	17	*10*	32	*-4*	52	5346	184	546	83

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations (30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

Location ID	**Depth (in.)**	**Mo**		**Zr**		**Sr**		**U**		**Rb**		**Th**		**Pb**		**Se**		**As**	
		Result	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-1-1	2	*8*	6	556	15	76	5	455	23	42	8	8	5	*9*	6	*-2*	3	*5*	5
BS-1-1	6	*-1*	5	646	16	72	5	52	10	37	5	*6*	5	12	6	*-1*	3	*4*	5
BS-1-1	10	*8*	5	521	16	65	6	16	9	37	5	*7*	6	15	8	*-1*	3	*1*	6
BS-2-1	2	*2*	5	587	16	68	5	58	11	34	5	10	5	*6*	6	*1*	3	9	6
BS-2-1	6	*5*	5	538	15	72	5	*4*	8	38	4	*7*	5	*7*	6	*0*	3	*0*	5
BS-2-1	10	*-1*	5	710	16	88	6	*7*	8	43	5	9	5	12	7	*0*	3	*2*	5
BS-3-1	2	*2*	5	600	15	79	5	*-4*	7	47	5	*7*	5	16	7	*-1*	3	*2*	6
BS-3-1	6	*4*	5	608	15	77	5	*-2*	7	37	4	9	5	*6*	6	*2*	3	*7*	5
BS-3-1	10	*5*	5	591	15	78	5	*2*	7	34	4	*6*	5	*8*	6	*-1*	3	*4*	5
BS-4-1	2	*775*	2791	*-81*	223	*103*	339	*484*	1498	*-80*	232	*-28*	293	*301*	942	*-762*	2277	*-143*	429
BS-4-1	6	9	5	606	16	73	5	*5*	8	38	5	*7*	5	*7*	6	*1*	3	*5*	5
BS-4-1	10	*2*	5	635	16	82	6	*5*	8	45	5	11	6	12	7	*-1*	3	*6*	6
BS-5-1	2	9	5	604	16	75	5	174	15	24	6	*5*	5	12	7	*1*	3	*8*	6
BS-5-1	6	12	6	513	18	58	6	168	18	16	6	*9*	6	14	9	*2*	4	*1*	7
BS-5-1	10	9	5	594	17	77	6	*8*	9	38	5	16	6	13	7	*0*	3	*4*	6
BS-6-1	2	*1*	5	654	16	85	6	*8*	8	41	5	9	5	*9*	6	*1*	3	*7*	5
BS-6-1	6	*6*	5	645	16	86	6	*9*	8	41	5	10	5	*6*	6	*1*	3	12	6
BS-6-1	10	*1*	5	665	16	71	5	*-1*	7	37	4	11	5	*2*	6	*1*	3	10	5
BS-7-1	2	*6*	5	590	15	76	5	18	9	38	5	*7*	5	*5*	6	*3*	3	8	5
BS-7-1	6	*6*	6	594	16	64	5	570	27	25	9	12	6	14	7	*2*	3	*6*	6
BS-7-1	10	*5*	5	583	15	76	5	66	11	35	5	*5*	5	15	7	*0*	3	*4*	6
BS-8-1	2	*5*	5	493	13	68	5	59	10	32	5	*6*	5	10	6	*3*	3	*1*	5
BS-8-1	6	*2*	5	587	15	80	5	*9*	8	37	4	*5*	5	*9*	6	*0*	3	*2*	5
BS-8-1	10	*2*	5	628	15	85	6	*2*	7	39	4	*7*	5	*6*	6	*0*	3	*4*	5
BS-9-1	2	*9*	7	572	16	57	5	717	31	24	10	*6*	6	19	8	*0*	3	*-1*	6
BS-9-1	6	*8*	7	542	15	41	5	798	32	21	10	*8*	6	*10*	7	*0*	3	*6*	6
BS-9-1	10	*3*	5	551	14	73	5	269	18	34	7	8	5	10	6	*-2*	3	9	6
BS-10-1	2	*6*	5	560	15	67	5	*1*	7	34	4	*6*	5	13	7	*0*	3	*2*	5

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Depth (in.)**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-1-1	2	*-3*	6	22	11	*-3*	41	*0*	16	*-14*	32	*54*	63	7294	218	440	78
BS-1-1	6	*-2*	6	21	10	*-12*	40	*4*	16	*16*	34	*52*	72	9758	252	356	74
BS-1-1	10	*-1*	8	27	13	*-6*	53	*9*	21	*17*	42	*24*	71	7373	250	378	85
BS-2-1	2	10	7	16	10	*-85*	39	*-7*	17	*17*	38	*61*	68	7534	235	348	77
BS-2-1	6	*1*	7	17	10	*-12*	43	*-14*	15	*-34*	33	*17*	63	6998	222	407	79
BS-2-1	10	*2*	6	22	11	*-31*	39	*1*	16	*-28*	32	*97*	70	8626	240	473	83
BS-3-1	2	*0*	6	32	12	*-26*	41	*15*	17	*11*	35	*84*	72	9243	250	872	105
BS-3-1	6	*1*	6	*14*	10	*-26*	41	*-9*	16	*-11*	33	*6*	63	7261	223	329	72
BS-3-1	10	*3*	6	18	10	*-39*	40	*4*	17	*-4*	34	119	66	7135	220	435	80
BS-4-1	2	*-3667*	10991	*-2119*	6253	*35486*	106711	*-624*	1742	*-339*	2341	*-4588*	9595	*45520*	96733	*-327*	601
BS-4-1	6	*2*	7	25	12	*-18*	45	*11*	18	*-30*	35	*73*	69	7662	238	268	71
BS-4-1	10	*2*	7	26	12	*-15*	45	*-6*	17	*42*	39	*29*	74	9565	263	370	79
BS-5-1	2	*-5*	6	45	13	*-6*	43	*-9*	16	*-31*	32	*-29*	65	7995	236	158	60
BS-5-1	6	*-1*	9	33	15	*11*	65	*-12*	23	*14*	49	*2*	81	8048	287	173	75
BS-5-1	10	*0*	7	22	12	*-60*	44	*-6*	18	*-32*	37	*84*	77	8763	264	486	91
BS-6-1	2	*0*	6	28	11	*-2*	41	*-8*	15	*-10*	32	*68*	71	9509	250	553	86
BS-6-1	6	*2*	6	*13*	10	*-17*	41	*-9*	15	*-17*	33	*85*	70	8504	241	494	85
BS-6-1	10	*5*	6	18	10	*-75*	37	*0*	16	*8*	35	*75*	66	7398	226	328	73
BS-7-1	2	*7*	6	20	10	*-60*	39	*0*	16	*41*	36	*17*	63	7235	223	413	78
BS-7-1	6	*-3*	6	99	17	*-18*	45	*10*	18	*5*	36	*7*	82	12054	295	703	102
BS-7-1	10	*-2*	6	32	12	*-25*	41	*7*	17	*-2*	34	*2*	64	7617	227	404	78
BS-8-1	2	*2*	6	28	10	*-37*	36	*-1*	14	*21*	31	*2*	53	5828	190	344	69
BS-8-1	6	*2*	6	19	10	*-11*	42	*10*	17	*-2*	33	*-16*	59	6811	213	265	67
BS-8-1	10	*2*	6	*12*	9	*-27*	39	*2*	16	*7*	33	*38*	59	6418	205	312	70
BS-9-1	2	*7*	7	78	16	*-63*	44	*11*	19	*-18*	38	*66*	76	8888	263	308	77
BS-9-1	6	*-2*	7	45	13	*-10*	46	*-4*	18	*-28*	35	*23*	69	8019	245	158	63
BS-9-1	10	*-1*	6	55	13	*0*	40	*0*	15	*-7*	32	*86*	70	9062	241	485	82
BS-10-1	2	*3*	6	*10*	9	*-41*	39	*15*	17	*-1*	33	*11*	59	6592	211	520	84

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

Location ID	Depth (in.)	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-10-1	6	*2*	5	625	15	80	5	*-5*	7	41	4	10	5	*6*	6	*-3*	2	*6*	5
BS-10-1	10	*5*	5	460	15	67	6	*0*	8	35	5	*0*	5	12	7	*0*	3	*0*	6
BS-11-1	2	10	6	534	15	72	5	393	22	34	8	11	6	19	7	*1*	3	*5*	6
BS-11-1	6	*6*	5	452	13	63	5	154	15	31	6	*4*	5	19	7	*-1*	3	*-2*	5
BS-11-1	10	8	5	545	15	78	5	*0*	7	34	4	8	5	11	7	*-1*	3	*2*	5
BS-12-1	2	*2*	5	522	14	75	5	39	9	33	4	*6*	5	15	7	*2*	3	*4*	5
BS-12-1	6	7	5	620	15	80	5	*0*	7	36	4	*2*	4	12	6	*-1*	3	*7*	6
BS-13-1	2	12	7	506	16	61	6	572	29	33	10	*9*	6	23	9	*2*	4	*2*	7
BS-13-1	6	*1*	5	509	15	86	6	*5*	8	40	5	9	5	*10*	7	*0*	3	*3*	5
BS-13-1	10	*2*	5	640	16	80	5	*1*	7	39	4	*5*	5	*9*	6	*-1*	2	*5*	5
BS-13-2	2	*7*	5	501	14	77	6	148	15	40	6	9	5	16	7	*2*	3	*6*	6
BS-13-3	2	10	7	583	16	45	5	751	31	24	10	9	6	13	7	*2*	3	*6*	6
BS-13-3	6	*0*	5	533	15	87	6	14	9	38	5	11	5	*9*	7	*1*	3	*8*	6
BS-13-3	10	*4*	5	633	15	83	5	*1*	7	39	4	8	5	*8*	6	*0*	3	*8*	5
BS-13-4	2	11	6	583	16	60	5	532	26	29	9	*7*	6	10	7	*-2*	3	*2*	5
BS-13-4	6	*5*	5	553	15	79	6	62	11	40	5	*7*	5	10	6	*-1*	3	*5*	5
BS-13-4	10	14	6	556	17	82	6	51	12	41	6	*9*	6	14	8	*-3*	3	*4*	7
BS-13-5	2	18	7	529	16	50	5	857	35	32	11	*6*	6	26	9	*0*	4	*1*	7
BS-13-5	6	16	8	540	18	60	6	717	36	35	12	*9*	7	25	10	*1*	4	*7*	8
BS-13-5	10	*5*	5	578	15	83	6	14	9	42	5	*6*	5	10	7	*2*	3	*4*	5
BS-14-1	2	*5*	5	323	13	69	6	109	14	28	6	*6*	5	*9*	7	*2*	3	10	6
BS-14-1	6	*6*	5	312	12	76	6	58	11	37	5	*4*	5	17	7	*2*	3	*7*	6
BS-14-1	10	*4*	5	516	14	80	5	*10*	8	40	5	*5*	5	10	6	*4*	3	*1*	5
BS-14-2	2	17	8	516	17	69	6	1029	40	25	13	12	7	20	9	*0*	4	*7*	8
BS-14-2	6	*2*	5	348	13	85	6	167	16	33	6	10	6	11	7	*2*	3	*9*	6
BS-14-2	10	*2*	5	495	16	74	6	66	12	32	5	*5*	5	*10*	7	*-1*	3	*3*	6
BS-14-3	2	*3*	5	291	12	51	5	*12*	9	29	5	*6*	5	*9*	7	*-3*	3	*6*	6
BS-14-3	6	*0*	5	726	17	80	5	*6*	8	38	4	*7*	5	*8*	6	*0*	3	*2*	5

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Depth (in.)**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-10-1	6	*-1*	6	*13*	10	*2*	42	*-1*	16	*34*	35	*22*	62	7358	219	635	91
BS-10-1	10	*2*	7	*10*	11	*-66*	47	*8*	21	*-15*	40	*5*	58	4789	203	282	75
BS-11-1	2	*0*	7	111	17	*4*	46	*15*	18	*32*	37	*59*	74	9698	258	385	80
BS-11-1	6	*-2*	6	43	12	*-14*	43	*11*	17	*16*	35	*26*	63	7177	220	261	68
BS-11-1	10	*3*	6	*13*	10	*-33*	42	*-4*	16	*-5*	35	*71*	67	7573	231	358	76
BS-12-1	2	*6*	6	30	11	*-35*	37	*-9*	14	*45*	34	*89*	61	6686	206	789	97
BS-12-1	6	*-1*	6	*7*	9	*2*	42	*19*	17	*21*	34	*4*	64	7848	227	399	76
BS-13-1	2	*-1*	8	105	19	*-14*	53	*2*	21	*-17*	41	*15*	76	8465	269	354	86
BS-13-1	6	*3*	7	40	13	*-14*	46	*15*	19	*-13*	36	*36*	73	8929	258	340	77
BS-13-1	10	*5*	6	17	10	*-66*	38	*17*	17	*41*	36	*35*	59	6249	206	286	68
BS-13-2	2	*0*	6	50	13	*-30*	43	*6*	17	*22*	37	127	76	9656	260	368	77
BS-13-3	2	*1*	7	92	17	*-19*	46	*-2*	18	*-21*	37	*94*	82	10743	283	206	69
BS-13-3	6	*1*	6	36	12	*-36*	43	*16*	18	*38*	38	*14*	76	10323	271	499	87
BS-13-3	10	*2*	6	*9*	9	*-39*	38	*-1*	15	*-8*	32	*18*	59	6642	209	403	76
BS-13-4	2	*-1*	7	57	14	*20*	49	*2*	18	*-1*	37	*44*	67	7398	234	331	77
BS-13-4	6	*0*	6	35	12	*-35*	42	*10*	17	*14*	35	*7*	69	8740	246	304	72
BS-13-4	10	*0*	8	31	14	*-23*	55	*6*	22	*-78*	40	*103*	88	9934	303	633	109
BS-13-5	2	*-5*	8	154	22	*11*	55	*23*	22	*7*	42	*48*	81	9567	283	216	77
BS-13-5	6	*2*	8	97	20	*-74*	58	*3*	25	*-30*	48	*105*	91	9372	311	*110*	75
BS-13-5	10	*2*	6	25	11	*-45*	41	*10*	18	*-45*	32	*20*	61	6412	214	150	59
BS-14-1	2	*5*	7	54	15	*-48*	48	*15*	21	*-12*	40	*20*	95	14114	341	483	95
BS-14-1	6	*7*	6	61	14	*-67*	40	*15*	18	*1*	36	*10*	91	15041	329	595	96
BS-14-1	10	*1*	6	16	10	*-54*	38	*8*	16	*31*	35	*56*	63	7148	217	154	57
BS-14-2	2	*1*	8	131	21	*-50*	54	*10*	23	*-20*	43	*46*	84	9606	296	292	84
BS-14-2	6	*3*	7	67	15	*-40*	44	*12*	19	*-25*	37	*92*	95	14798	333	445	88
BS-14-2	10	*5*	8	37	14	*-34*	50	*-12*	19	*27*	43	*84*	82	9673	284	381	86
BS-14-3	2	*6*	8	35	14	*-35*	49	*6*	20	*-47*	38	*26*	98	14705	351	578	102
BS-14-3	6	*7*	6	28	11	*-60*	38	*0*	16	*9*	34	*-7*	61	7054	218	288	69

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

Location ID	Depth (in.)	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-14-3	10	*1*	5	609	15	75	5	*2*	7	36	4	8	5	17	7	*0*	3	*0*	5
BS-14-4	2	*4*	5	337	12	83	6	26	9	31	5	*6*	5	27	8	*1*	3	*2*	7
BS-14-4	6	*5*	6	251	13	55	6	18	10	29	5	*2*	5	22	9	*-1*	4	*10*	8
BS-14-4	10	*-2*	5	637	16	83	6	*2*	7	34	4	10	5	*4*	6	*-2*	3	*7*	5
BS-14-5	2	*8*	6	309	15	98	8	81	15	28	6	*6*	6	*11*	8	*1*	4	*0*	7
BS-14-5	6	*6*	5	187	10	50	5	*9*	8	28	4	*7*	5	*5*	7	*4*	4	*6*	6
BS-14-5	10	*4*	5	512	14	82	5	*-3*	7	35	4	10	5	10	6	*0*	3	*4*	5
BS-15-1	2	17	7	685	17	67	6	788	31	22	10	11	6	16	8	*1*	3	*4*	6
BS-15-1	6	*2*	5	549	14	75	5	154	15	35	6	*4*	5	14	7	*1*	3	*5*	6
BS-15-1	10	*6*	5	506	15	75	6	265	19	30	7	*5*	5	*4*	6	*0*	3	13	6
BS-15-2	2	*13*	11	483	18	46	7	3403	75	*26*	23	*10*	10	43	13	*1*	5	*10*	10
BS-15-2	6	13	6	768	18	81	6	387	22	41	8	*5*	5	12	7	*-1*	3	*5*	6
BS-15-2	10	*2*	5	451	13	75	5	207	16	31	6	*6*	5	*9*	6	*2*	3	*6*	5
BS-15-3	2	10	6	573	16	68	5	275	20	29	7	9	6	*10*	7	*-1*	3	10	6
BS-15-3	6	*4*	5	406	13	72	5	129	14	33	6	*7*	5	10	6	*-1*	3	*5*	5
BS-15-3	10	*7*	5	385	13	87	6	31	10	46	5	10	6	10	7	*0*	3	*4*	6
BS-15-4	2	*4*	6	533	16	65	6	357	23	33	8	*7*	6	*9*	7	*-1*	3	12	6
BS-15-4	6	*3*	5	375	13	91	6	209	18	37	7	11	6	18	8	*-1*	3	*4*	6
BS-15-5	2	*-2*	5	559	15	77	5	341	21	34	7	11	6	17	7	*1*	3	*5*	6
BS-15-5	6	*2*	5	451	14	98	6	112	13	35	5	*5*	5	18	7	*1*	3	*1*	6
BS-15-5	10	*1*	5	604	15	79	5	24	9	33	4	12	5	10	6	*-2*	3	*5*	5
BS-16-1	2	*4*	5	615	15	75	5	23	9	39	5	8	5	15	7	*1*	3	*1*	5
BS-16-1	6	*8*	6	542	16	75	6	70	13	31	5	15	6	13	8	*1*	3	*7*	7
BS-16-1	10	*0*	5	547	15	90	6	*4*	8	34	4	11	5	*6*	6	*0*	3	*8*	5
BS-16-2	2	8	5	589	15	73	5	*6*	8	41	4	*5*	5	*9*	6	*0*	3	*5*	5
BS-16-2	6	*2*	5	584	15	79	5	20	9	43	5	11	5	*8*	6	*0*	3	*4*	5
BS-16-2	10	8	5	387	14	76	6	*7*	9	35	5	10	6	11	7	*-2*	3	*3*	6
BS-16-3	2	31	8	547	17	55	6	986	38	44	12	*7*	7	23	9	*3*	4	13	8

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations (30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Depth (in.)**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-14-3	10	*5*	6	15	10	*-53*	38	*-6*	16	*-8*	34	112	64	6778	215	461	81
BS-14-4	2	*0*	7	37	13	*-33*	44	*21*	19	*21*	39	*119*	89	13234	311	439	85
BS-14-4	6	*1*	8	68	19	*-65*	57	*2*	24	*-18*	51	353	155	28638	535	453	108
BS-14-4	10	*0*	6	16	10	*-31*	41	*5*	16	*12*	34	*38*	58	5903	200	170	59
BS-14-5	2	*8*	10	72	20	*-63*	64	*0*	26	*14*	54	*9*	104	12469	373	455	107
BS-14-5	6	*-1*	7	26	13	*-20*	51	*-20*	18	*3*	42	*38*	108	18170	388	399	90
BS-14-5	10	*2*	6	*5*	9	*-23*	41	*-12*	15	*18*	34	*-6*	55	5805	197	383	75
BS-15-1	2	*6*	7	79	16	*-66*	43	*16*	19	70	41	*59*	68	7416	234	106	57
BS-15-1	6	*8*	6	45	12	*-55*	37	*-6*	15	63	36	*0*	64	8133	230	239	65
BS-15-1	10	*3*	7	60	14	*-30*	45	*-4*	17	*0*	36	*22*	71	8577	251	191	65
BS-15-2	2	*9*	9	549	41	*-71*	62	124	33	*2*	49	*23*	91	10220	321	175	91
BS-15-2	6	*2*	6	145	19	*-41*	42	*11*	18	*9*	35	*10*	68	8482	244	141	61
BS-15-2	10	*2*	6	82	15	*-30*	40	*11*	17	*-2*	33	*91*	68	8464	235	397	78
BS-15-3	2	*1*	7	90	17	*-26*	45	*4*	18	*-37*	35	*76*	72	8221	248	303	76
BS-15-3	6	*0*	7	30	12	*-7*	44	*9*	17	*-6*	34	*69*	66	7532	228	256	68
BS-15-3	10	*-3*	7	44	14	*-17*	47	*14*	19	*2*	39	*111*	92	13510	320	503	92
BS-15-4	2	*0*	7	129	19	*-18*	50	*-2*	19	*50*	41	*-1*	67	7167	237	289	75
BS-15-4	6	*-1*	7	77	16	*-27*	45	*2*	18	*13*	38	*53*	90	14023	320	480	89
BS-15-5	2	*0*	6	141	19	*-48*	41	*-11*	15	*13*	35	*78*	73	9606	255	393	79
BS-15-5	6	*-2*	6	49	13	*-7*	43	*19*	18	*-9*	34	*0*	80	12247	289	300	73
BS-15-5	10	*1*	6	*11*	9	*-13*	41	*-2*	15	*33*	35	*71*	66	8030	229	226	64
BS-16-1	2	*0*	6	26	11	*-33*	40	*3*	16	*15*	34	*2*	68	8894	243	317	71
BS-16-1	6	*7*	8	40	14	*-73*	48	*-4*	20	*14*	43	*76*	74	7575	255	483	94
BS-16-1	10	*-3*	7	26	11	*15*	46	*-3*	16	*35*	37	*18*	67	8258	239	254	68
BS-16-2	2	*1*	6	33	12	*2*	43	*-1*	16	*32*	35	*47*	60	6617	209	295	69
BS-16-2	6	*-3*	6	19	10	*-9*	41	*-7*	15	*-6*	33	*39*	64	7650	225	431	78
BS-16-2	10	*-1*	8	*16*	12	*15*	57	*15*	22	*13*	44	*62*	78	8278	271	239	75
BS-16-3	2	*9*	7	167	22	*-87*	46	*2*	20	*-4*	41	*47*	80	9328	280	490	97

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations (30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

Location ID	Depth (in.)	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-16-3	6	*7*	6	566	16	82	6	241	19	38	7	10	6	43	10	*-1*	3	*10*	8
BS-16-3	10	*4*	5	494	14	72	5	162	15	33	6	*7*	5	10	7	*-1*	3	*6*	6
BS-16-4	2	9	5	570	15	75	6	253	19	39	7	*8*	5	*6*	6	*2*	3	12	6
BS-16-4	6	*4*	6	544	16	60	5	316	21	29	7	*6*	6	15	8	*2*	3	*5*	6
BS-16-4	10	*7*	6	641	17	72	6	192	17	31	6	10	6	12	7	*1*	3	11	7
BS-16-5	2	15	6	559	15	76	6	437	23	35	8	*4*	5	19	8	*2*	3	*2*	6
BS-16-5	6	*5*	5	575	15	76	5	52	11	40	5	11	5	14	7	*2*	3	*3*	6
BS-16-5	10	*1*	5	531	14	78	5	31	9	41	5	*3*	4	*9*	6	*1*	3	*7*	5
BS-17-1	2	10	5	591	17	75	6	14	9	39	5	10	6	*11*	7	*1*	3	*8*	6
BS-17-1	6	*4*	5	722	18	66	5	20	9	40	5	11	6	25	9	*2*	3	19	8
BS-17-1	10	*4*	5	503	15	95	6	*8*	9	43	5	13	6	11	7	*1*	3	*2*	6
BS-18-1	2	12	5	419	13	62	5	*2*	7	28	4	7	5	*8*	6	*0*	3	*2*	5
BS-18-1	6	*4*	5	600	16	74	5	*4*	8	34	4	*3*	5	*6*	6	*3*	3	*4*	5
BS-18-1	10	*-1*	5	560	15	78	5	*3*	7	36	4	*6*	5	10	6	*2*	3	*0*	5
BS-18-2	2	*6*	5	530	14	69	5	*10*	8	32	4	8	5	15	7	*-1*	3	*5*	6
BS-18-2	6	*4*	5	478	14	74	6	*0*	8	36	4	*8*	5	13	7	*1*	3	*0*	5
BS-18-2	10	*6*	5	537	14	76	5	*8*	8	35	4	*6*	5	11	6	*0*	3	*-1*	5
BS-18-3	2	*4*	5	512	14	69	5	*4*	7	30	4	*6*	5	11	6	*-1*	3	*3*	5
BS-18-4	2	*4*	5	623	16	80	6	*3*	8	42	5	9	5	*4*	6	*-1*	3	*4*	5
BS-18-5	2	*7*	5	419	13	62	5	*8*	7	26	4	*5*	5	15	7	*0*	3	*-2*	5
BS-18-5	6	*4*	5	592	15	70	5	*0*	7	36	4	*6*	5	*9*	6	*-1*	3	*2*	5
BS-18-5	10	*2*	5	551	14	82	5	*0*	7	37	4	*7*	5	*6*	6	*0*	3	*7*	5
BS-19-1	2	*6*	5	428	14	95	6	*-2*	8	51	5	*7*	5	*7*	7	*3*	3	*5*	6
BS-19-1	6	*1*	5	586	16	69	5	*-2*	8	39	5	*4*	5	*7*	6	*-1*	3	*4*	5
BS-19-1	10	*1*	5	605	16	73	6	*-3*	8	43	5	9	5	13	7	*0*	3	*-1*	5
BS-19-2	2	*5*	5	483	14	94	6	*3*	8	47	5	12	6	13	7	*3*	3	*7*	6
BS-19-2	6	*4*	5	636	16	80	5	*-1*	7	37	4	*6*	5	10	6	*0*	3	*4*	5
BS-19-2	10	*1*	5	645	16	84	6	*3*	8	38	4	*5*	5	10	6	*-2*	2	*0*	5

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Depth (in.)**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-16-3	6	*-3*	7	114	19	*-10*	47	*26*	20	*19*	40	*150*	107	19142	375	626	101
BS-16-3	10	*-4*	7	78	16	*5*	46	*19*	18	*9*	36	*57*	76	10000	266	414	82
BS-16-4	2	*6*	6	62	14	*-76*	39	*14*	18	*-10*	35	*57*	68	7824	237	300	74
BS-16-4	6	*3*	7	73	16	*-37*	47	*14*	20	*-6*	39	*39*	81	10481	287	444	89
BS-16-4	10	*0*	7	55	14	*-40*	45	*13*	19	*-29*	36	*-13*	70	8193	252	361	82
BS-16-5	2	*4*	6	127	18	*-51*	41	*11*	18	*2*	35	*59*	68	8102	238	415	81
BS-16-5	6	*1*	6	46	13	*-32*	43	*4*	17	*19*	36	*32*	68	8058	239	345	76
BS-16-5	10	*-2*	6	44	13	*-9*	43	*-7*	16	*32*	35	*-15*	69	9245	249	415	79
BS-17-1	2	*10*	7	24	12	*-57*	46	*-6*	19	*-6*	39	*-4*	66	6929	237	407	85
BS-17-1	6	*-4*	7	26	13	*-4*	49	*5*	19	*-38*	40	296	125	23816	432	1091	130
BS-17-1	10	*7*	7	33	12	*-64*	42	*2*	18	*12*	38	*-15*	73	9374	265	253	71
BS-18-1	2	*0*	6	24	10	*-23*	38	*9*	16	*-49*	29	*62*	51	4474	170	363	71
BS-18-1	6	*0*	7	18	11	*-14*	45	*-10*	16	*27*	37	*13*	58	5831	204	105	54
BS-18-1	10	*4*	6	*12*	9	*-30*	39	*-1*	15	*20*	33	*5*	56	6082	199	312	69
BS-18-2	2	*4*	6	21	10	*-27*	40	*3*	16	*12*	34	*26*	60	6853	212	276	67
BS-18-2	6	*4*	6	17	10	*-56*	42	*-4*	17	*-3*	36	*-2*	59	5962	211	398	80
BS-18-2	10	*3*	6	20	10	*-28*	38	*-8*	15	*-10*	31	*0*	59	6842	209	364	72
BS-18-3	2	*0*	6	*13*	10	*-16*	40	*8*	16	*-17*	31	*32*	55	5643	192	289	67
BS-18-4	2	*2*	7	*15*	10	*-20*	42	*-2*	16	*-11*	34	*23*	62	6927	220	338	74
BS-18-5	2	*4*	7	36	12	*-34*	43	*-2*	17	*38*	37	*22*	51	4388	177	307	70
BS-18-5	6	*0*	6	15	10	*-18*	40	*10*	16	*-18*	31	*22*	57	6195	201	274	67
BS-18-5	10	*0*	6	25	11	*-21*	40	*1*	16	*37*	34	*-19*	58	6665	209	285	67
BS-19-1	2	*0*	7	31	13	*-8*	48	*21*	20	*-53*	36	*66*	97	15070	343	193	70
BS-19-1	6	*5*	7	*9*	10	*-25*	46	*13*	19	*-13*	37	*63*	73	8551	256	613	96
BS-19-1	10	*-1*	7	*14*	11	*5*	48	*3*	18	*-15*	37	114	65	6167	216	298	74
BS-19-2	2	*-3*	6	28	12	*-9*	45	*4*	17	*5*	36	*5*	81	12030	292	235	69
BS-19-2	6	*3*	7	16	10	*10*	43	*2*	16	*5*	34	*39*	61	6680	213	378	75
BS-19-2	10	*5*	6	18	10	*-22*	40	*8*	16	*-9*	33	*51*	60	6418	206	209	62

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations
(30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

Location ID	Depth (in.)	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-19-3	2	*-2*	5	526	15	71	5	*-3*	8	38	5	*7*	5	*7*	6	*0*	3	*3*	5
BS-19-3	6	*6*	5	597	16	73	6	*5*	8	35	4	*6*	5	*6*	6	*1*	3	*6*	5
BS-19-3	10	*6*	5	636	16	80	5	*0*	7	36	4	11	5	12	7	*1*	3	*4*	5
BS-19-4	2	*6*	6	428	16	86	7	*2*	9	40	5	*9*	6	12	8	*3*	4	*4*	7
BS-19-4	6	*2*	5	664	16	81	6	*6*	8	39	4	11	5	*9*	6	*0*	3	*5*	5
BS-19-4	10	*7*	5	585	15	76	5	*6*	8	33	4	*7*	5	*6*	6	*-1*	3	*1*	5
BS-19-5	2	*2*	5	598	15	79	5	*-4*	7	39	4	11	5	*6*	6	*3*	3	*1*	5
BS-19-5	6	*4*	5	629	16	82	6	*6*	8	35	4	11	5	*5*	6	*-2*	3	*4*	5
BS-19-5	10	*3*	5	642	16	82	5	*3*	8	40	4	9	5	*9*	6	*2*	3	9	6
BS-20-1	2	*6*	5	630	16	83	6	*2*	8	40	5	18	6	*7*	6	*-2*	3	*4*	5
BS-20-1	6	*3*	5	647	16	76	5	*-6*	7	40	4	*6*	5	*9*	6	*1*	3	*4*	5
BS-20-1	10	*1*	5	561	15	76	5	*-1*	7	39	4	*6*	5	12	7	*-3*	3	*0*	5
BS-20-2	2	*7*	5	513	14	74	5	*9*	8	33	4	8	5	*7*	6	*-1*	3	*5*	5
BS-20-2	6	*2*	5	644	16	77	5	*-1*	7	34	4	9	5	11	6	*0*	3	*6*	5
BS-20-2	10	*2*	5	588	15	79	5	12	8	36	4	*7*	5	*8*	6	*-1*	3	*5*	5
BS-20-3	2	8	5	606	17	76	6	*9*	8	32	4	11	6	*9*	7	*2*	3	*3*	6
BS-20-3	6	*4*	5	583	15	81	6	*3*	7	34	4	*6*	5	*4*	6	*1*	3	*5*	5
BS-20-3	10	*5*	5	574	15	79	5	*-2*	7	37	4	*7*	5	*6*	6	*0*	3	*5*	5
BS-20-4	2	*2*	5	575	16	90	6	*5*	9	46	5	*4*	5	16	7	*1*	3	*3*	6
BS-20-4	6	*7*	5	680	16	86	6	*-3*	7	41	4	11	5	*5*	6	*2*	3	*5*	5
BS-20-4	10	9	5	663	16	79	6	*-1*	7	37	4	9	5	*6*	6	*-2*	3	*5*	5
BS-20-5	2	*3*	5	608	16	76	6	*9*	8	34	4	*7*	5	*7*	6	*2*	3	*2*	5
BS-20-5	6	*4*	5	663	16	87	6	*2*	7	37	4	9	5	*6*	6	*3*	3	*5*	5
BS-20-5	10	*3*	5	631	16	80	6	*-1*	7	39	4	9	5	11	7	*-2*	2	*2*	5

Table B6. Soil Core XRF Measurement Results from 20 Targeted Locations (30-sec acquisition, main filter, data collected 5/22/08 and 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Depth (in.)**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-19-3	2	*4*	7	27	12	*-45*	44	*-6*	17	*43*	40	*72*	67	7082	231	326	76
BS-19-3	6	*3*	7	19	11	*-22*	45	*-12*	17	*4*	37	*34*	61	5917	211	306	73
BS-19-3	10	*-1*	6	20	10	*-28*	40	*-5*	16	*32*	35	*-7*	59	6624	210	362	74
BS-19-4	2	*2*	8	41	15	*-60*	56	*13*	24	*-12*	47	*39*	95	11435	336	390	95
BS-19-4	6	*0*	6	*7*	9	*-19*	42	*-6*	16	*10*	34	*-28*	58	6593	212	348	74
BS-19-4	10	*-1*	6	22	11	*-15*	43	*4*	17	*-3*	35	*39*	58	5805	202	383	77
BS-19-5	2	*2*	6	17	10	*-31*	41	*19*	18	*29*	35	*18*	62	7090	219	287	69
BS-19-5	6	*1*	6	20	11	*-29*	42	*-3*	16	*10*	35	*21*	61	6657	215	437	81
BS-19-5	10	*4*	6	*9*	9	*-50*	38	*14*	17	*20*	34	*-17*	59	6660	212	349	73
BS-20-1	2	*-3*	7	*16*	11	*18*	46	*-13*	16	*-14*	34	*-10*	64	7485	229	285	70
BS-20-1	6	*0*	6	15	10	*-13*	42	*-16*	15	*33*	36	95	61	6202	205	436	79
BS-20-1	10	*4*	7	21	11	*-1*	44	*4*	17	*-2*	35	*80*	63	6626	216	610	92
BS-20-2	2	*-6*	5	29	11	*-34*	39	*-4*	15	*1*	33	*41*	59	6436	205	299	69
BS-20-2	6	*3*	6	*8*	9	*-32*	40	*-10*	15	64	37	*31*	56	5818	196	269	65
BS-20-2	10	*-5*	6	24	11	*1*	43	*-2*	16	*-4*	33	*65*	61	6427	208	302	70
BS-20-3	2	*3*	7	*14*	11	*-35*	47	*3*	19	*43*	41	*38*	64	6284	222	217	69
BS-20-3	6	*0*	6	27	11	*-43*	40	*-3*	16	*-2*	34	*-6*	59	6348	210	401	78
BS-20-3	10	*8*	7	*0*	8	*-43*	41	*-1*	16	*45*	37	*-20*	57	6068	205	447	81
BS-20-4	2	*1*	7	32	13	*-38*	46	*11*	19	*-16*	38	*80*	82	10561	286	393	84
BS-20-4	6	*4*	6	*12*	10	*-29*	42	*1*	17	60	37	*-12*	59	6462	210	300	70
BS-20-4	10	*0*	6	*14*	10	*-33*	41	*-1*	16	*-10*	34	*68*	62	6336	211	473	83
BS-20-5	2	*5*	6	27	12	*-66*	41	*1*	18	*-4*	37	*47*	65	6883	227	221	67
BS-20-5	6	*0*	6	*11*	9	*-28*	40	*8*	17	*-1*	34	*90*	61	6359	207	351	73
BS-20-5	10	*2*	6	15	10	*-45*	40	*5*	17	*5*	34	*41*	59	6072	205	242	65

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations (30-sec acquisition, main filter, data collected 5/23/08)

Location ID	Sample	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-6	TOP-1	*6*	5	578	15	73	5	*11*	8	35	4	*7*	5	*7*	6	*1*	3	*5*	5
BS-6	TOP-2	*1*	5	553	15	71	5	30	9	32	4	*7*	5	*9*	6	*0*	3	*4*	5
BS-6	TOP-3	*4*	5	552	16	72	6	*9*	8	32	4	11	6	*8*	7	*-1*	3	*8*	6
BS-6	TOP-4	8	5	533	15	66	5	*12*	8	33	4	11	5	*3*	6	*1*	3	10	5
BS-6	TOP-5	*5*	5	586	15	75	5	13	8	32	4	11	5	*8*	6	*2*	3	*3*	5
BS-6	BOT-1	16	7	502	19	68	7	20	12	32	6	15	8	*8*	9	*2*	5	*6*	7
BS-6	BOT-2	*2*	5	482	15	101	6	*6*	8	33	4	*4*	5	14	7	*-2*	3	*0*	6
BS-6	BOT-4	*7*	5	519	16	64	5	25	9	31	5	*4*	5	*8*	7	*1*	3	*5*	6
BS-6	BOT-5	*5*	5	574	15	76	5	12	8	34	4	*7*	5	*7*	6	*4*	3	*5*	5
BS-10	TOP-1	9	5	575	15	66	5	*5*	7	37	4	8	5	*4*	6	*0*	3	*5*	5
BS-10	TOP-3	*5*	7	423	19	54	7	*7*	11	27	6	*10*	8	*13*	10	*-2*	5	*0*	8
BS-10	TOP-4	*5*	5	527	15	68	5	*3*	8	37	4	*7*	5	*8*	6	*2*	3	*3*	5
BS-10	TOP-5	*1*	5	495	16	65	6	*1*	8	39	5	12	6	*11*	7	*1*	4	*1*	6
BS-10	BOT-1	*5*	5	568	16	74	6	*7*	8	36	5	*6*	5	14	7	*0*	3	*5*	6
BS-10	BOT-2	*6*	5	535	15	67	5	*5*	8	32	4	*6*	5	*7*	6	*-1*	3	*4*	5
BS-10	BOT-3	*5*	5	505	14	66	5	*8*	8	33	4	*5*	5	*7*	6	*0*	3	*2*	5
BS-10	BOT-4	*1*	5	537	15	68	5	*6*	8	35	4	*7*	5	*9*	6	*2*	3	*5*	5
BS-10	BOT-5	*4*	5	561	15	71	5	*2*	7	36	4	10	5	*9*	6	*2*	3	*4*	5
BS-11	TOP-1	17	6	505	14	69	5	499	24	30	8	9	5	21	7	*0*	3	*1*	6
BS-11	TOP-2	*4*	5	476	14	67	5	139	15	29	6	*7*	5	*6*	6	*3*	3	*5*	5
BS-11	TOP-3	13	5	458	14	65	5	207	17	30	6	*3*	5	16	7	*1*	3	*2*	6
BS-11	TOP-4	10	6	445	14	57	5	207	18	26	6	*4*	5	*10*	7	*1*	3	*2*	6
BS-11	TOP-5	9	6	462	15	68	6	188	17	29	6	*3*	5	13	7	*0*	3	*2*	6
BS-11	BOT-1	*7*	5	486	14	67	5	181	16	30	6	9	5	15	7	*1*	3	*5*	6
BS-11	BOT-2	8	5	522	15	71	5	177	16	36	6	*7*	5	15	7	*2*	3	*7*	6
BS-11	BOT-3	9	5	479	14	77	5	234	17	36	6	10	5	18	7	*-2*	3	*-2*	5
BS-11	BOT-4	*7*	5	456	14	69	5	200	17	34	6	*3*	5	13	7	*3*	3	*8*	6
BS-11	BOT-5	10	5	374	12	67	5	263	18	25	6	*6*	5	*6*	6	*-1*	3	*5*	5

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations
(30-sec acquisition, main filter, data collected 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Sample**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-6	TOP-1	*4*	6	30	11	*-59*	38	*-17*	15	*2*	34	*48*	60	6384	209	360	74
BS-6	TOP-2	*4*	6	31	11	*-43*	40	*18*	18	*-2*	34	*42*	60	6403	208	390	76
BS-6	TOP-3	*-1*	7	46	14	*-31*	47	*2*	19	*17*	39	*66*	72	8162	251	490	89
BS-6	TOP-4	*4*	6	39	12	*-62*	41	*9*	18	*23*	37	*46*	61	6053	211	325	74
BS-6	TOP-5	*2*	6	31	11	*-17*	42	*20*	18	*-17*	33	*72*	63	6897	217	378	76
BS-6	BOT-1	*3*	10	65	20	*-78*	65	*17*	29	*-138*	47	*43*	85	7101	295	370	103
BS-6	BOT-2	*9*	8	40	13	*-8*	46	*20*	19	*-19*	35	*53*	66	7197	231	349	77
BS-6	BOT-4	*4*	7	44	13	*-72*	44	*-14*	18	*-15*	38	*63*	64	5855	217	385	82
BS-6	BOT-5	*6*	6	38	12	*-53*	40	*-2*	17	*15*	36	*70*	67	7606	230	350	75
BS-10	TOP-1	*-1*	6	21	10	*-11*	41	*16*	17	*-16*	32	*52*	56	5580	192	361	72
BS-10	TOP-3	*6*	13	28	18	*-36*	84	*0*	34	*-8*	65	*51*	78	4677	263	316	105
BS-10	TOP-4	*-1*	7	32	12	*-16*	44	*-13*	16	*-19*	34	*-14*	58	6062	209	348	75
BS-10	TOP-5	*1*	8	21	12	*13*	54	*0*	20	*-77*	37	102	65	5338	214	326	80
BS-10	BOT-1	*-2*	7	43	13	*-19*	46	*7*	18	*-3*	37	*4*	62	6495	221	515	89
BS-10	BOT-2	*-3*	7	23	11	*0*	46	*-9*	16	*23*	36	*-64*	54	5607	201	241	67
BS-10	BOT-3	*-2*	6	33	12	*-7*	44	*4*	17	*-16*	33	*33*	56	5512	196	352	74
BS-10	BOT-4	*1*	6	45	13	*-25*	43	*7*	17	*3*	35	*18*	57	5634	199	322	72
BS-10	BOT-5	*5*	6	26	11	*-55*	37	*13*	17	*-4*	33	*20*	58	6169	203	542	85
BS-11	TOP-1	*0*	6	115	17	*-6*	41	*24*	17	*18*	33	*50*	64	7920	224	313	70
BS-11	TOP-2	*6*	7	52	14	*-35*	44	*5*	18	*17*	37	*27*	63	6716	221	229	68
BS-11	TOP-3	*1*	7	76	15	*-22*	46	*17*	19	*23*	38	*54*	65	6948	226	318	74
BS-11	TOP-4	*0*	7	71	16	*-35*	48	*2*	19	*20*	40	*30*	63	6076	220	254	72
BS-11	TOP-5	*-2*	7	83	17	*-1*	50	*7*	19	*-13*	37	*-8*	65	6947	234	250	72
BS-11	BOT-1	*3*	6	85	15	*-53*	41	*-6*	16	*15*	35	*11*	61	6807	217	248	67
BS-11	BOT-2	*7*	6	64	14	*-74*	38	*7*	17	*0*	35	*78*	65	7247	223	276	70
BS-11	BOT-3	*-1*	6	98	16	*-20*	42	*9*	17	*4*	34	*2*	65	8070	232	238	66
BS-11	BOT-4	*2*	6	73	15	*-47*	41	*15*	18	*-2*	36	115	68	7312	227	245	67
BS-11	BOT-5	*3*	6	55	13	*-19*	40	*6*	16	*-15*	31	*25*	57	6164	199	246	63

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations (30-sec acquisition, main filter, data collected 5/23/08)

Location ID	Sample	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
		Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-12	TOP-1	*7*	5	471	14	65	5	18	9	30	4	*3*	5	*7*	6	*0*	3	*2*	5
BS-12	TOP-2	8	5	506	15	72	5	13	8	35	4	8	5	*9*	7	*2*	3	*7*	6
BS-12	TOP-3	*6*	6	426	16	59	6	24	10	26	5	11	6	*8*	8	*-2*	4	*0*	6
BS-12	TOP-4	10	5	482	14	61	5	14	8	29	4	8	5	*8*	6	*-1*	3	*4*	5
BS-12	TOP-5	7	5	513	14	70	5	18	8	35	4	11	5	*6*	6	*0*	3	*7*	5
BS-12	BOT-1	*5*	5	566	15	72	5	14	8	36	4	*6*	5	10	6	*1*	3	*3*	5
BS-12	BOT-2	7	5	515	14	72	5	14	8	38	5	*7*	5	*8*	6	*0*	3	*7*	5
BS-12	BOT-3	7	5	561	15	70	5	16	8	29	4	11	5	11	6	*-1*	3	*1*	5
BS-12	BOT-4	10	5	493	15	68	5	*10*	8	33	4	*7*	5	*7*	6	*3*	3	*4*	5
BS-12	BOT-5	*4*	5	526	15	70	5	*6*	8	34	4	*6*	5	18	7	*1*	3	11	7
BS-14	TOP-1	*5*	5	505	14	64	5	54	10	33	5	*5*	5	*7*	6	*0*	3	*6*	5
BS-14	TOP-2	*7*	5	379	14	69	6	61	12	30	5	9	6	*8*	7	*-3*	3	*6*	6
BS-14	TOP-3	*5*	5	366	13	70	5	67	11	29	5	11	6	13	7	*0*	3	*2*	6
BS-14	TOP-4	*7*	5	454	14	81	6	73	12	33	5	*8*	5	*6*	7	*3*	3	11	6
BS-14	TOP-5	*3*	5	391	14	74	6	71	12	29	5	*5*	5	*9*	7	*0*	3	*4*	6
BS-14	BOT-1	*5*	5	489	14	74	5	61	11	29	5	9	5	10	7	*-1*	3	*1*	5
BS-14	BOT-2	8	5	411	14	74	6	84	12	33	5	*5*	5	11	7	*0*	3	*5*	6
BS-14	BOT-3	12	5	388	13	67	5	67	11	27	5	11	6	*8*	7	*2*	3	*2*	5
BS-14	BOT-4	11	5	428	14	68	5	85	12	35	5	*0*	4	15	7	*1*	3	*5*	6
BS-14	BOT-5	10	5	459	14	77	5	44	10	34	5	10	5	*7*	6	*0*	3	10	6
BS-16	TOP-1	10	6	501	14	64	5	511	25	35	8	*4*	5	20	8	*-1*	3	*9*	6
BS-16	TOP-2	16	7	508	15	62	5	864	33	33	11	10	6	18	8	*0*	3	*7*	7
BS-16	TOP-3	12	6	501	15	60	5	396	23	32	8	*7*	5	20	8	*1*	3	*2*	6
BS-16	TOP-4	13	6	428	14	62	5	253	19	30	7	*5*	5	12	7	*0*	3	*5*	6
BS-16	TOP-5	10	6	483	16	68	6	272	21	30	7	11	6	13	8	*1*	4	*6*	6
BS-16	BOT -1	10	5	490	15	66	5	227	18	31	7	*1*	5	14	7	*0*	3	*9*	6
BS-16	BOT -2	*5*	5	561	15	68	5	338	20	28	7	*5*	5	22	8	*2*	3	*4*	6
BS-16	BOT -3	14	6	512	15	69	5	254	19	32	7	10	5	*10*	7	*5*	3	*7*	6

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations (30-sec acquisition, main filter, data collected 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Sample**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-12	TOP-1	*2*	7	45	13	*-8*	45	*19*	19	*-11*	35	*23*	59	6028	209	404	79
BS-12	TOP-2	*3*	6	29	11	*-51*	41	*5*	17	*-25*	34	*42*	64	6987	223	422	81
BS-12	TOP-3	*3*	9	37	15	*-24*	60	*10*	24	*-14*	47	*44*	76	6980	265	432	97
BS-12	TOP-4	*-1*	6	34	11	*-34*	39	*5*	16	*-10*	32	*69*	54	5071	182	369	72
BS-12	TOP-5	*7*	6	30	11	*-32*	38	*10*	16	*-3*	32	*-36*	58	7013	214	759	97
BS-12	BOT-1	*-2*	6	38	12	*-10*	42	*8*	17	*-2*	34	*56*	62	6771	214	335	73
BS-12	BOT-2	*2*	6	37	12	*-41*	40	*8*	17	*-6*	34	*56*	63	6938	218	623	91
BS-12	BOT-3	*0*	7	36	12	*1*	43	*16*	17	*8*	34	*-11*	58	6452	209	263	66
BS-12	BOT-4	*5*	7	30	12	*-19*	45	*19*	19	*-3*	36	*-8*	60	6331	215	431	82
BS-12	BOT-5	*5*	7	30	12	*-4*	46	*22*	19	*8*	37	158	81	10435	274	512	88
BS-14	TOP-1	*-4*	6	48	13	*9*	43	*19*	17	*-7*	33	*40*	70	9225	246	236	65
BS-14	TOP-2	*6*	7	50	14	*-75*	47	*-9*	19	*7*	42	*108*	73	7178	247	345	82
BS-14	TOP-3	*0*	6	70	15	*-38*	43	*4*	18	*-36*	35	114	74	8739	252	355	77
BS-14	TOP-4	*0*	7	51	14	*-21*	47	*14*	20	*-12*	37	*12*	70	8033	249	280	74
BS-14	TOP-5	*1*	7	56	15	*-14*	49	*18*	20	*-35*	37	*47*	71	7723	248	273	74
BS-14	BOT-1	*2*	7	49	13	*-12*	45	*7*	18	*-13*	35	*46*	65	7098	226	369	77
BS-14	BOT-2	*6*	7	50	14	*-40*	44	*-9*	17	*-12*	36	*46*	71	8496	250	308	74
BS-14	BOT-3	*2*	7	54	14	*-7*	47	*21*	19	*-46*	34	*31*	66	7278	233	201	65
BS-14	BOT-4	*1*	7	50	14	*-14*	45	*2*	18	*-14*	36	134	72	7950	240	372	78
BS-14	BOT-5	*4*	6	52	13	*-47*	40	*3*	17	*5*	35	*14*	65	7789	232	356	75
BS-16	TOP-1	*-3*	7	186	21	*15*	47	*30*	19	*-15*	34	123	73	8960	248	358	77
BS-16	TOP-2	*0*	7	202	22	*-25*	46	*4*	18	*-13*	36	*35*	73	9136	259	416	85
BS-16	TOP-3	*0*	6	111	17	*-36*	44	*28*	19	*2*	36	*70*	64	6747	221	359	77
BS-16	TOP-4	*7*	7	92	17	*-82*	42	*18*	20	*-16*	37	*86*	64	5909	214	214	67
BS-16	TOP-5	*1*	8	103	19	*-10*	52	*22*	22	*-77*	37	121	77	7998	260	418	89
BS-16	BOT -1	*-2*	7	75	16	*-2*	47	*16*	19	*-13*	36	*29*	68	7700	239	397	82
BS-16	BOT -2	*3*	7	84	15	*-5*	44	*7*	17	*1*	34	*80*	66	7602	227	358	75
BS-16	BOT -3	*4*	7	104	17	*-41*	42	*18*	18	*-21*	34	*54*	68	7735	235	322	75

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations (30-sec acquisition, main filter, data collected 5/23/08)

Location		Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
ID	Sample	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
BS-16	BOT -4	*8*	5	535	15	70	5	230	18	29	6	9	5	17	7	*-1*	3	*2*	6
BS-16	BOT -5	*6*	5	488	15	60	5	251	19	33	7	*5*	5	13	7	*2*	3	*8*	6
BS-18	TOP-1	*6*	5	557	14	64	5	*11*	7	29	4	*6*	5	15	7	*0*	3	*0*	5
BS-18	TOP-2	10	5	520	14	68	5	*5*	7	34	4	10	5	*7*	6	*2*	3	*7*	5
BS-18	TOP-3	*5*	5	482	14	66	5	*0*	7	35	4	*5*	5	*4*	6	*0*	3	*4*	5
BS-18	TOP-4	*6*	5	535	15	75	6	*2*	8	33	4	10	5	10	7	*0*	3	*3*	5
BS-18	TOP-5	8	5	509	14	65	5	*7*	7	32	4	9	5	*6*	6	*0*	3	9	5
BS-18	BOT-1	10	5	518	14	68	5	*6*	8	32	4	*7*	5	*2*	6	*1*	3	11	5
BS-18	BOT-2	*6*	5	524	14	76	5	*1*	7	38	4	*6*	5	*6*	6	*1*	3	*7*	5
BS-18	BOT-3	10	5	517	15	73	5	*4*	8	35	4	9	5	*7*	6	*0*	3	*7*	5
BS-18	BOT-4	*5*	5	542	14	74	5	*9*	8	35	4	*4*	4	14	7	*-1*	3	*0*	5
BS-18	BOT-5	8	4	446	13	57	4	*9*	7	27	4	*6*	4	10	6	*0*	3	*1*	5
BS-20	TOP-1	*7*	5	561	15	78	5	*-2*	7	35	4	*3*	4	10	6	*-3*	2	*3*	5
BS-20	TOP-2	8	5	523	14	71	5	*0*	7	31	4	*7*	5	*9*	6	*1*	3	*5*	5
BS-20	TOP-3	11	5	547	15	72	5	*2*	8	38	4	*6*	5	14	7	*1*	3	*-1*	5
BS-20	TOP-4	11	6	527	18	70	6	*5*	9	26	5	13	7	17	9	*1*	4	*4*	7
BS-20	TOP-5	8	5	604	16	78	6	*0*	8	39	5	13	6	14	7	*1*	3	*6*	6
BS-20	BOT-1	*5*	5	520	15	71	5	*-1*	7	36	4	*3*	5	11	7	*-1*	3	*3*	5
BS-20	BOT-2	*7*	5	542	15	70	5	*0*	7	32	4	11	5	*5*	6	*-1*	3	8	5
BS-20	BOT-3	*7*	5	562	15	76	5	*-1*	7	33	4	15	6	12	7	*-3*	2	*5*	6
BS-20	BOT-4	*3*	5	582	15	75	5	*2*	7	34	4	*6*	5	*5*	6	*1*	3	9	5
BS-20	BOT-5	9	5	469	14	61	5	*6*	8	29	4	9	5	*3*	6	*-1*	3	8	5

Table B7. Bagged Sample XRF Measurement Results for 8 Targeted Locations
(30-sec acquisition, main filter, data collected 5/23/08)

		Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Sample**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
BS-16	BOT -4	*2*	6	88	16	*-47*	42	*16*	18	*-21*	35	*64*	68	7727	235	387	80
BS-16	BOT -5	*3*	7	83	16	*-37*	44	*7*	18	*-9*	36	*79*	68	7361	233	369	79
BS-18	TOP-1	*-2*	6	32	11	*-14*	41	*8*	16	*24*	34	*13*	55	5760	193	268	65
BS-18	TOP-2	*1*	6	27	11	*-14*	41	*15*	17	*-33*	31	*44*	57	5760	196	277	67
BS-18	TOP-3	*5*	6	45	12	*-59*	38	*-4*	16	*1*	33	*-7*	55	5772	197	351	73
BS-18	TOP-4	*1*	7	29	12	*-22*	44	*-3*	17	*-51*	33	*40*	62	6436	217	332	74
BS-18	TOP-5	*-2*	6	*10*	9	*-8*	40	*14*	16	*14*	32	*-17*	51	5256	183	171	56
BS-18	BOT-1	*5*	6	40	12	*-50*	40	*19*	18	*24*	35	*-15*	54	5384	193	336	72
BS-18	BOT-2	*4*	6	33	11	*-48*	39	*10*	17	*18*	35	*78*	62	6553	211	335	72
BS-18	BOT-3	*-4*	6	31	12	*-5*	44	*15*	18	*-15*	34	*61*	60	6024	205	226	65
BS-18	BOT-4	*1*	6	41	12	*-9*	42	*17*	17	*26*	34	*12*	54	5576	192	296	67
BS-18	BOT-5	*-2*	6	33	11	*-6*	39	*3*	15	*3*	31	*59*	51	4846	173	262	62
BS-20	TOP-1	*2*	7	34	12	*4*	44	*6*	17	*-6*	34	*41*	60	6227	207	333	72
BS-20	TOP-2	*-2*	6	21	11	*-1*	43	*8*	17	*-10*	33	*52*	59	6014	202	328	71
BS-20	TOP-3	*2*	6	38	12	*-57*	40	*17*	18	*-27*	33	*52*	60	5945	205	266	68
BS-20	TOP-4	*10*	9	47	16	*-48*	59	*-2*	24	*-30*	46	*33*	71	5950	247	296	85
BS-20	TOP-5	*-1*	7	20	11	*-11*	44	*2*	17	*-9*	35	*84*	62	6200	211	334	74
BS-20	BOT-1	*-1*	7	35	12	*18*	46	*10*	18	*-11*	34	*61*	59	5717	201	332	73
BS-20	BOT-2	*0*	6	34	12	*-46*	40	*0*	17	*-12*	34	*10*	57	5892	203	331	73
BS-20	BOT-3	*1*	6	42	12	*-13*	42	*10*	17	*-17*	32	*-18*	58	6287	207	271	68
BS-20	BOT-4	*-3*	6	34	12	*-18*	42	*9*	17	*-4*	33	*5*	57	5937	201	258	66
BS-20	BOT-5	*6*	7	30	12	*-49*	42	*-3*	17	*-30*	34	*37*	61	6062	211	319	74

Table B8. XRF Results for Prepared Cup Samples from 20 Targeted Locations
(120-sec acquisitions for 3 filters, data collected 5/28/08 and 5/29/08)

Location ID	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As		Hg		Zn		W	
	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err
BS-1	11	3	751	9	92	3	338	11	49	4	13	3	12	4	*1*	2	8	3	*1*	3	33	6	*-47*	23
BS 2	9	3	733	9	92	3	196	9	44	3	11	3	14	4	*1*	2	5	3	*3*	4	16	6	*-37*	23
BS-3	8	3	742	9	91	3	*3*	4	43	2	12	3	14	4	*1*	2	*3*	3	7	4	24	6	*-63*	23
BS-4	8	3	762	9	93	3	7	4	42	2	13	3	13	4	*1*	2	6	3	*4*	4	23	6	*-35*	24
BS-5	9	3	843	10	111	3	143	8	43	3	11	3	17	4	*0*	2	5	3	*3*	4	59	7	*-48*	24
BS-6	8	3	784	9	97	3	14	5	44	3	11	3	12	4	*1*	2	6	3	*3*	4	22	6	*-37*	24
BS-7	10	3	729	9	93	3	197	9	44	3	12	3	12	4	*0*	2	6	3	*-1*	4	48	7	*-15*	25
BS-8	8	3	757	9	99	3	21	5	48	3	10	3	13	4	*1*	2	*4*	3	5	4	25	6	*-25*	24
BS-9	14	3	766	9	85	3	560	13	36	5	8	3	18	4	*0*	2	*3*	3	*2*	4	58	7	*-37*	23
BS-10	9	3	742	9	92	3	*4*	4	47	3	11	3	14	4	*0*	2	*4*	3	*2*	4	19	6	*-35*	23
BS-11	12	3	713	9	102	3	213	9	46	4	10	3	19	4	*1*	2	*4*	3	*2*	4	63	8	*-24*	24
BS-12	7	3	771	9	100	3	18	5	47	3	10	3	17	4	*1*	2	*4*	3	*0*	4	29	6	*-16*	25
BS-13	12	3	779	9	98	3	348	11	41	4	11	3	19	4	*2*	2	6	3	5	4	88	8	*-50*	24
BS-14	8	3	703	9	103	3	48	6	41	3	12	3	15	4	*0*	2	*3*	3	5	4	28	6	*-55*	23
BS-15	15	3	731	9	98	3	649	15	40	5	10	3	21	4	*0*	2	5	3	*3*	4	134	10	*-41*	24
BS-16	8	3	668	9	99	3	112	7	45	3	13	3	17	4	*0*	2	7	3	*3*	4	49	7	*-36*	24
BS 17	15	3	727	9	91	3	317	11	45	4	11	3	18	4	*0*	2	*5*	3	*1*	4	93	9	*-23*	24
BS 18	9	3	703	9	93	3	9	4	45	2	9	3	12	3	*-1*	1	6	3	*2*	4	27	6	*-28*	23
BS 19	8	3	723	9	99	3	8	4	45	3	13	3	9	3	*0*	2	6	3	*3*	4	31	6	*-37*	24
BS 20	8	3	745	9	100	3	*4*	4	47	3	9	3	13	4	*1*	2	5	3	7	4	20	6	*-52*	23

Table B8. XRF Results for Prepared Cup Samples from 20 Targeted Locations
(120-sec acquisitions for 3 filters, data collected 5/28/08 and 5/29/08)

Location ID	Cu		Ni		Co		Fe		Mn		Cr		V		Ti		Sc		Ca	
	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err	Res	Err
BS-1	*2*	10	*-7*	20	*21*	39	9985	137	502	45	169	18	*41*	42	5379	110	*8*	9	3325	147
BS 2	*4*	10	*-15*	19	*12*	38	9688	135	455	43	156	17	*53*	42	5713	110	*9*	9	3040	144
BS-3	*-3*	9	*-14*	19	*29*	40	10850	143	374	41	167	18	90	43	5793	112	*3*	9	3216	145
BS-4	*8*	10	*-19*	19	63	41	10971	144	413	42	146	17	*41*	42	5535	111	*0*	10	5898	174
BS-5	*3*	10	*-8*	20	*49*	43	11995	151	402	43	235	19	*52*	43	5422	111	*10*	11	5983	176
BS-6	*3*	10	*-6*	19	*24*	38	9479	133	590	48	156	17	*54*	42	5767	111	*7*	9	4249	157
BS-7	*4*	10	*-19*	19	*26*	39	9748	137	440	44	196	18	64	41	5453	107	*12*	9	3947	153
BS-8	*4*	10	*-1*	19	*8*	35	8419	126	454	43	173	17	78	42	5836	110	*9*	9	4530	159
BS-9	*1*	9	*-17*	19	*35*	40	10705	140	361	40	237	19	*49*	42	5482	110	*11*	10	5303	169
BS-10	*-3*	9	*-9*	19	*36*	35	7924	122	523	45	160	17	*52*	41	5307	106	*13*	9	3291	145
BS-11	*11*	10	*-10*	19	*32*	39	10050	137	420	43	282	19	*62*	43	5388	111	*5*	10	6020	176
BS-12	*-7*	9	*-2*	20	58	38	9612	134	555	47	153	17	88	42	5594	110	*5*	10	4954	165
BS-13	*7*	10	*-10*	20	*-16*	40	11148	146	463	45	331	20	100	42	5259	109	*5*	10	5216	169
BS-14	*1*	10	*-10*	19	*29*	37	9307	132	349	39	166	17	105	41	5375	107	*4*	11	7661	189
BS-15	16	10	*-16*	19	*17*	40	10735	142	327	40	530	22	89	42	5145	107	17	11	6402	180
BS-16	*-7*	9	*-12*	19	*24*	39	10181	138	468	44	207	18	90	41	5181	107	*13*	11	6058	176
BS 17	*1*	10	*-23*	19	*46*	38	9753	135	433	43	338	20	*49*	42	5461	110	15	10	4659	161
BS 18	*2*	9	*-19*	19	*40*	35	8014	121	374	40	167	17	84	42	5558	109	*0*	9	3392	146
BS 19	*1*	10	*-13*	19	*24*	37	9074	130	407	41	157	17	*60*	41	5330	108	*3*	10	4917	163
BS 20	*0*	9	*-16*	19	*46*	36	8526	126	456	43	173	17	*47*	41	5446	108	*8*	9	4399	157

Table B8. XRF Results for Prepared Cup Samples from 20 Targeted Locations (120-sec acquisitions for 3 filters, data collected 5/28/08 and 5/29/08)

	K		S		Ba		Cs		Te		Sb		Sn		Cd		Ag		Pd	
Location ID	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
BS-1	15994	367	*633*	5480	*-4*	22	*-48*	6	*-97*	19	*-29*	7	*-37*	6	*-5*	4	*-2*	3	9	4
BS 2	16403	370	*-3510*	5155	55	22	*-22*	6	*-39*	20	*-15*	7	*-27*	6	*-2*	4	*1*	3	10	4
BS-3	13958	348	*-704*	5362	110	23	*-9*	7	*-9*	20	*-2*	7	*-18*	6	*3*	4	*1*	3	7	4
BS-4	14675	357	*-5832*	5168	85	23	*-16*	6	*-37*	20	*-7*	7	*-22*	6	*2*	4	5	3	*6*	4
BS-5	14261	355	*183*	5677	89	23	*-18*	6	*-34*	20	*-9*	7	*-22*	6	*1*	4	*2*	3	*3*	4
BS-6	16090	367	*2933*	5674	110	23	*-17*	6	*-10*	20	*-2*	7	*-18*	6	*2*	4	*1*	3	*3*	4
BS-7	15581	361	*98*	5394	*-31*	22	*-48*	6	*-92*	19	*-28*	7	*-35*	6	*-2*	4	*3*	3	8	4
BS-8	16548	369	*749*	5453	53	23	*-22*	6	*-40*	20	*-16*	7	*-25*	6	*3*	4	*3*	3	7	4
BS-9	14336	354	*4375*	5880	*8*	22	*-34*	6	*-89*	19	*-26*	7	*-32*	6	*-3*	4	*-2*	3	20	4
BS-10	16070	363	*-3349*	5038	126	23	*-11*	6	*5*	20	*-3*	7	*-18*	6	8	4	*2*	3	*6*	4
BS-11	16102	370	*6394*	6029	*-14*	22	*-42*	6	*-91*	19	*-21*	7	*-38*	6	*-4*	4	*-1*	3	9	4
BS-12	16385	371	*3819*	5781	117	23	*-12*	6	*-18*	20	*-2*	7	*-23*	6	8	4	7	3	8	4
BS-13	16040	371	*-4897*	5249	*-25*	22	*-45*	6	*-89*	19	*-31*	7	*-40*	6	*-4*	4	*-2*	3	14	4
BS-14	15905	365	*-2028*	5425	52	23	*-27*	6	*-37*	20	*-12*	7	*-25*	6	*1*	4	*3*	3	*5*	4
BS-15	15617	367	*-890*	5572	*-80*	21	*-59*	6	*-146*	19	*-43*	7	*-46*	6	*-10*	4	*-5*	3	14	4
BS-16	16014	369	*-2816*	5377	75	23	*-20*	6	*-26*	20	*-11*	7	*-24*	6	*-1*	4	*0*	3	10	4
BS 17	15170	359	*3113*	5691	*-43*	22	*-52*	6	*-97*	19	*-29*	7	*-41*	6	*-5*	4	*-4*	3	*5*	4
BS 18	16067	363	*-2364*	5121	119	23	*-8*	6	*5*	20	*-1*	7	*-16*	6	*5*	4	*3*	3	*6*	4
BS 19	16250	368	*-552*	5407	129	23	*-12*	6	*-10*	20	*2*	7	*-12*	6	7	4	*1*	3	*6*	4
BS 20	16505	368	*-4707*	5046	124	23	*-7*	6	*-3*	20	*0*	7	*-20*	6	*6*	4	*2*	3	*6*	4

Table B9. XRF Results for 5 Prepared Cup Subsamples from BS-2
(120-sec acquisitions for 3 filters, data collected 5/29/08)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As		Hg		Zn		W	
Sample	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
BS 2-1	9	3	733	9	92	3	196	9	44	3	11	3	14	4	*1*	2	5	3	*3*	4	16	6	*-37*	23
BS 2-2	13	3	750	9	93	3	192	9	46	3	12	3	12	4	*1*	2	*4*	3	*2*	4	25	6	*-28*	24
BS 2-3	11	3	731	9	92	3	198	9	46	3	9	3	14	4	*2*	2	5	3	*2*	4	27	6	*-37*	24
BS 2-4	9	3	722	9	90	3	212	9	46	4	13	3	14	4	*1*	2	6	3	*5*	4	24	6	*-40*	24
BS 2-5	11	3	739	9	93	3	212	9	48	4	13	3	12	4	*-1*	2	7	3	*1*	4	26	6	*-29*	24

	Cu		Ni		Co		Fe		Mn		Cr		V		Ti		Sc		Ca	
Sample	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
BS 2-1	*4*	10	*-15*	19	*12*	38	9688	135	455	43	156	17	*53*	42	5713	110	*9*	9	3040	144
BS 2-2	*9*	10	*-27*	19	*24*	38	9839	137	491	45	162	17	84	42	5587	110	*9*	9	3156	145
BS 2-3	*1*	10	*-9*	19	*36*	39	10135	138	467	44	147	17	111	43	5592	110	14	9	3051	145
BS 2-4	*4*	10	*-14*	19	*32*	41	11340	147	565	48	148	18	73	44	5917	114	*9*	9	3066	146
BS 2-5	*7*	10	*-11*	19	*36*	41	11004	144	533	46	159	18	78	43	5704	113	*10*	9	3279	149

	K		S		Ba		Cs		Te		Sb		Sn		Cd		Ag		Pd	
Sample	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
BS 2-1	16403	370	*-3510*	5155	55	22	*-22*	6	*-39*	20	*-15*	7	*-27*	6	*-2*	4	*1*	3	10	4
BS 2-2	16506	371	*-1799*	5286	38	22	*-33*	6	*-45*	20	*-20*	7	*-30*	6	*-4*	4	*-1*	3	9	4
BS 2-3	16142	369	*-3502*	5196	66	23	*-22*	6	*-45*	20	*-13*	7	*-28*	6	*0*	4	*2*	3	12	4
BS 2-4	16051	372	*954*	5632	38	23	*-31*	6	*-60*	20	*-22*	7	*-28*	6	*-1*	4	*-1*	3	12	4
BS 2-5	17017	381	*-550*	5542	118	23	*-16*	6	*-22*	20	*-9*	7	*-19*	6	*1*	4	*1*	3	8	4

Table B10. XRF Results for Prepared Cup Samples from 2 AOC541 Samples
(30-sec acquisition, main filter only, data collected 05/21/08)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
O11CA-1-1	9	6	752	19	98	7	88	14	42	6	12	6	21	9	*1*	3	*-1*	7
O11CA-1-2	*-17*	20	486	20	*-37*	*8*	12805	144	*27*	45	*6*	15	37	15	*-1*	6	*15*	12

	Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
Location ID	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**	**Result**	**Error**
O11CA-1-1	*8*	8	32	13	*-40*	50	*-4*	20	*-40*	39	*-10*	80	9690	288	377	86
O11CA-1-2	*-2*	9	274	31	*-18*	61	*13*	25	*-36*	48	*45*	90	9738	317	259	86

Table B11. XRF Results for Prepared Cup Subsamples from FSS Samples
(120-sec acquisition, all three filters, data collected 05/29/08)

	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As		Hg		Zn		W	
Location ID	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
FSS C1-01	8	3	585	8	106	3	*6*	5	52	3	14	3	15	4	*0*	2	9	3	*2*	4	32	7	*-40*	24
FSS C1-02	7	3	725	9	98	3	9	5	48	3	12	3	11	4	*1*	2	9	3	*3*	4	22	6	*-38*	24
FSS C1-03	7	3	748	9	97	3	7	4	47	3	10	3	18	4	*1*	2	*3*	3	*4*	4	27	6	*-39*	24
FSS C1-04	4	3	710	9	96	3	11	5	47	3	12	3	17	4	*0*	2	7	3	*5*	4	32	6	*-48*	24
FSS C1-05	6	3	755	9	95	3	12	5	45	3	8	3	15	4	*0*	2	*2*	3	*3*	4	23	6	*-24*	24
FSS C1-06	8	3	718	9	102	3	29	5	47	3	12	3	15	4	*0*	2	5	3	*4*	4	35	6	*-42*	24
FSS C1-07	7	3	714	9	102	3	*3*	4	46	3	11	3	14	4	*1*	2	6	3	*5*	4	27	6	*-40*	24
FSS C2-01	8	3	559	8	132	4	*5*	5	51	3	14	3	15	4	*1*	2	10	3	*1*	4	54	8	*-32*	26
FSS C2-02	6	3	596	8	115	3	8	5	52	3	11	3	20	4	*2*	2	6	3	*3*	4	49	7	*-52*	24
FSS C2-03	6	3	648	9	110	3	9	5	49	3	10	3	19	4	*3*	2	7	3	*2*	4	40	7	*-32*	25
FSS C2-04	5	3	620	8	117	3	*6*	5	51	3	9	3	19	4	*1*	2	8	3	*4*	4	48	7	*-47*	24
FSS C3-01	7	3	576	8	121	4	*5*	5	52	3	9	3	18	4	*1*	2	8	3	*3*	4	70	8	*-32*	26

	Cu		Ni		Co		Fe		Mn		Cr		V		Ti		Sc		Ca	
Location ID	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
FSS C1-01	*7*	10	*-5*	20	*52*	47	14564	168	399	43	133	18	89	43	5292	111	*19*	14	11706	230
FSS C1-02	*4*	10	*-10*	20	*57*	43	12007	151	461	44	149	18	82	43	5742	113	*10*	10	5524	173
FSS C1-03	*5*	10	*-15*	19	*21*	40	10677	142	654	50	156	17	71	42	5587	111	*9*	10	4908	165
FSS C1-04	*7*	10	*-11*	20	*26*	43	12455	154	496	46	137	18	83	43	5564	113	*5*	12	7610	193
FSS C1-05	*0*	10	*-3*	19	*2*	35	8555	127	504	45	167	17	*34*	41	5770	109	*13*	9	3513	148
FSS C1-06	*4*	10	*-7*	20	*33*	39	10053	138	454	43	155	17	87	42	5584	110	*16*	11	7522	189
FSS C1-07	*6*	10	*5*	20	*32*	39	9900	137	447	43	151	17	77	42	5461	109	*6*	10	5637	171
FSS C2-01	*10*	11	*-5*	21	*31*	53	17869	190	466	47	136	19	87	44	4801	112	51	23	35280	377
FSS C2-02	*2*	10	*0*	21	*37*	49	15752	175	410	44	120	18	99	45	5349	115	*27*	20	26578	330
FSS C2-03	*-2*	10	*-1*	20	*15*	48	15244	171	501	47	109	18	77	44	5317	114	*24*	18	20398	292
FSS C2-04	*-5*	10	*0*	21	*22*	49	16145	177	421	44	116	18	124	45	5312	114	33	17	16825	270
FSS C3-01	*5*	10	*14*	22	*54*	53	17984	189	453	46	117	19	91	44	5017	113	*16*	19	23575	315

Table B11. XRF Results for Prepared Cup Subsamples from FSS Samples (120-sec acquisition, all three filters, data collected 05/29/08)(cont'd)

	K		S		Ba		Cs		Te		Sb		Sn		Cd		Ag		Pd	
Location ID	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**	**Res**	**Err**
FSS C1-01	15861	380	*-1879*	6047	52	23	*-25*	7	*-49*	20	*-14*	7	*-29*	6	*2*	4	*3*	3	*6*	4
FSS C1-02	15514	369	*1724*	5815	99	23	*-11*	7	*-7*	20	*8*	7	*-18*	6	*6*	4	*3*	3	*3*	4
FSS C1-03	15284	363	*3261*	5780	132	23	*-11*	7	*-23*	20	*3*	7	*-12*	6	*4*	4	*0*	3	9	4
FSS C1-04	16056	376	*5660*	6223	48	23	*-29*	6	*-50*	20	*-11*	7	*-27*	6	*2*	4	*4*	3	*3*	4
FSS C1-05	16047	364	*-3048*	5117	86	23	*-18*	6	*-18*	20	*-6*	7	*-20*	6	*5*	4	*3*	3	10	4
FSS C1-06	16357	372	*3406*	5890	*29*	23	*-31*	6	*-55*	20	*-9*	7	*-29*	6	*3*	4	*2*	3	*6*	4
FSS C1-07	16371	371	*1203*	5632	51	23	*-25*	6	*-34*	20	*-9*	7	*-23*	6	*5*	4	*1*	3	*4*	4
FSS C2-01	17572	410	*6333*	7732	74	24	*-26*	7	*-27*	21	*-11*	8	*-20*	6	*7*	4	*3*	3	8	4
FSS C2-02	17094	402	*7298*	7448	60	23	*-22*	7	*-25*	20	*-9*	7	*-19*	6	*2*	4	*0*	3	*6*	4
FSS C2-03	16654	394	13101	7457	82	23	*-23*	7	*-25*	20	*-8*	7	*-22*	6	*3*	4	*2*	3	*5*	4
FSS C2-04	17515	403	*4833*	6867	98	24	*-16*	7	*-29*	20	*0*	8	*-18*	6	*3*	4	*3*	3	10	4
FSS C3-01	17878	411	*-4349*	6650	*-16*	23	*-43*	7	*-72*	20	*-20*	7	*-33*	6	*-1*	4	*2*	3	*5*	4

Table B12. XRF Excavation Support Results for five (5*)* *In Situ* Surface Soil Measurements and One Bagged Sample (120-sec main filter only for in situ and 30-sec acquisition, main filter only for bag measurements, data collected 05/30/08)

Location ID	Sample	Type	Mo		Zr		Sr		U		Rb		Th		Pb		Se		As	
			Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
E-1	Hot Zone-1	In Situ	8	3	536	8	69	3	7	4	31	2	9	3	9	3	*1*	2	*3*	3
E-2	Hot Zone-2	In Situ	5	2	569	7	77	3	26	4	35	2	8	2	10	3	*0*	1	4	3
E-3	Hot Zone-3	In Situ	6	2	538	7	77	3	8	4	38	2	6	2	11	3	*1*	1	*1*	2
E-4	Hot Zone-4	In Situ	8	3	370	7	58	3	144	8	25	3	*4*	3	10	4	*1*	2	7	3
E-5	Hot Zone-5	In Situ	8	2	519	7	77	3	142	7	35	3	7	2	13	3	*0*	1	4	3
E-1	Top-1	Bag	*2*	5	543	14	83	5	*5*	7	38	4	*3*	4	*8*	6	*-2*	3	*2*	5
E-1	Top-2	Bag	10	5	613	15	77	5	*-2*	7	37	4	11	5	*3*	6	*-1*	3	9	5
E-1	Top-3	Bag	6	3	530	10	78	4	*3*	5	35	3	7	3	*5*	4	*0*	2	6	3
E-1	Top-4	Bag	*6*	5	540	14	80	5	*8*	7	33	4	10	5	*6*	6	*-1*	3	*4*	5
E-1	Top-5	Bag	*3*	5	605	15	81	5	*8*	8	35	4	*4*	4	10	6	*0*	3	*3*	5
E-1	Bot-B1	Bag	10	5	554	15	82	5	*-2*	7	38	4	9	5	*7*	6	*1*	3	*3*	5
E-1	Bot-B2	Bag	8	5	592	15	76	5	*5*	7	34	4	*7*	5	*6*	6	*1*	3	*5*	5
E-1	Bot-B3	Bag	*3*	4	638	12	78	4	*1*	6	36	3	6	4	13	5	*0*	2	*2*	4
E-1	Bot-B4	Bag	11	5	514	14	76	5	*3*	7	36	4	*7*	5	*9*	6	*0*	3	*0*	5
E-1	Bot-B5	Bag	*1*	5	523	14	78	5	*5*	8	37	4	*5*	5	*5*	6	*2*	3	*4*	5

Location ID	Sample	Type	Hg		Zn		W		Cu		Ni		Co		Fe		Mn	
			Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error	Result	Error
E-1	Hot Zone-1	In Situ	*3*	4	10	5	*-56*	23	*-11*	9	*-22*	19	*35*	30	5513	104	272	36
E-2	Hot Zone-2	In Situ	*1*	3	20	5	*-13*	20	*-3*	8	*2*	16	*7*	29	7301	105	399	36
E-3	Hot Zone-3	In Situ	*4*	3	14	5	*-44*	19	*2*	8	*-4*	16	*27*	30	7015	104	279	32
E-4	Hot Zone-4	In Situ	*4*	4	59	8	*-45*	27	*-5*	11	*-13*	22	*47*	43	10451	151	414	45
E-5	Hot Zone-5	In Situ	*3*	3	47	6	*-46*	20	*6*	8	*-14*	17	*24*	32	8097	115	383	38
E-1	Top-1	Bag	*-1*	6	30	11	*8*	42	*-1*	15	*7*	33	*46*	55	5477	188	414	75
E-1	Top-2	Bag	*4*	7	31	11	*-2*	42	*12*	17	*9*	34	119	59	5872	195	214	61
E-1	Top-3	Bag	*4*	4	27	7	*-43*	26	*15*	12	*5*	23	*43*	39	6037	136	451	54
E-1	Top-4	Bag	*-3*	6	36	11	*-18*	41	*1*	16	*11*	33	*66*	59	6489	203	382	73
E-1	Top-5	Bag	*4*	6	37	12	*-31*	40	*-12*	15	*12*	33	*-21*	57	6611	208	318	70
E-1	Bot-B1	Bag	*4*	6	35	11	*-46*	39	*-2*	16	*15*	34	*34*	58	6135	200	273	66
E-1	Bot-B2	Bag	*5*	6	27	11	*-51*	38	*14*	17	*32*	35	*38*	57	6006	197	425	76
E-1	Bot-B3	Bag	*-1*	5	38	9	*-16*	33	*12*	13	*0*	26	*65*	47	6221	160	394	59
E-1	Bot-B4	Bag	*1*	6	44	12	*-41*	39	*-3*	16	*22*	34	*60*	58	6064	199	396	75
E-1	Bot-B5	Bag	*8*	6	44	12	*-80*	36	*-1*	16	*17*	34	*72*	60	6480	204	269	65

Appendix C. HPGe Data

Table C1 summarizes *in situ* HPGe measurement results acquired as part of the field work.

- All field measurements were acquired from a height of 5 cm with an acquisition time of 20 minutes.
- Gamma spectroscopy analysis was performed for the following radionuclides: ^{241}Am, ^{137}Cs, ^{40}K, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{232}Th, ^{235}U, and ^{238}U (based on ^{234}Th and ^{234m}Pa).
- *In situ* HPGe gamma spectroscopy analysis requires assumptions about the geometry for the measurement and the distribution of the radionuclides of interest within that media.
- Based on ^{234}Th and ^{234m}Pa, the only radionuclide observed above its MDA and background conditions was ^{238}U.
- For several measurement locations it was clear that ^{238}U activity was not uniformly distributed with depth.
- Consequently, for some measurements, peak differential analysis was used to determine an appropriate “center of activity” depth.
- In other cases peak differential analysis indicated a uniform depth distribution assumption was appropriate.
- The “PDA” column in the table indicates whether calculating an equivalent “center of activity” depth was required for the measurement when estimating ^{238}U activity concentrations.

In situ HPGe measurements were acquired from each of the 20 BS locations (BS-1 through BS-20), and from each of the eight (8) Class 3 sampling locations (locations Pt-51 through Pt-155).

Following the HPGe summary tables are more detailed analytical reports for each of the radionuclides. Locations Pt-1 through Pt-20 are the BS sample locations and are equivalent to locations BS-1 through BS-20 used to identify soil sample locations in Table C1.

Table C1. *In situ* HPGe measurement results

Date	Location	Count Time (min)	PDA	Am241 (pCi/g)	Am241 MDA (pCi/g)	Am241 2s Error (%)	Cs137 (pCi/g)	Cs137 MDA (pCi/g)	Cs137 2s Error (%)	K40 (pCi/g)	K40 MDA (pCi/g)	K40 2s Error (%)	Ra226 (pCi/g)	Ra226 MDA (pCi/g)	Ra226 2s Error (%)	Ra228 (pCi/g)	Ra228 MDA (pCi/g)	Ra228 2s Error (%)
5/23/2008	BS-1	20	√	0.2	0.8	265%	0.04	0.03	56%	3.1	0.4	31%	0.31	0.06	33%	0.4	0.1	33%
5/23/2008	BS-2	20	√	0	0.6	168%	0.1	0.03	36%	2.4	0.5	33%	0.38	0.07	32%	0.4	0.1	35%
5/23/2008	BS-3	20	√	0	0.9	314%	0.06	0.02	37%	2.4	0.3	31%	0.32	0.04	32%	0.4	0.1	34%
5/23/2008	BS-4	20	√	0	0.3	492%	0.19	0.02	32%	2.6	0.4	32%	0.33	0.05	32%	0.4	0.1	32%
5/23/2008	BS-5	20	√	0	0.7	350%	0.05	0.02	41%	1.3	0.3	35%	0.28	0.05	32%	0.3	0.1	33%
5/22/2008	BS-6	20	√	0.2	0.5	143%	0.05	0.02	41%	1.1	0.4	39%	0.65	0.06	31%	0.3	0.1	34%
5/23/2008	BS-7	20	√	0	2.2	135%	0.07	0.02	37%	1.5	0.3	34%	0.29	0.05	32%	0.3	0.1	32%
5/22/2008	BS-8	20	√	0	0.5	817%	0.12	0.02	33%	1.5	0.5	36%	0.33	0.05	32%	0.3	0.1	35%
5/23/2008	BS-9	20	√	0.1	1.5	1060%	0.07	0.03	38%	0.7	0.4	46%	0.29	0.05	32%	0.3	0.1	35%
5/22/2008	BS-10	20	√	0	0.6	472%	0.01	0.02	115%	2.1	0.4	33%	0.33	0.05	32%	0.3	0.1	34%
5/22/2008	BS-11	20	√	0	0.8	199%	0.12	0.03	34%	2.5	0.4	32%	0.34	0.05	32%	0.4	0.1	33%
5/22/2008	BS-12	20	√	0	0.7	350%	0.08	0.02	35%	2.5	0.3	32%	0.29	0.05	32%	0.4	0.1	32%
5/21/2008	BS-13	20	√	0	0.7	8373%	0.16	0.03	32%	2.5	0.4	32%	0.35	0.06	32%	0.4	0.1	33%
5/22/2008	BS-14	20	√	0	0.6	318%	0.19	0.02	32%	2	0.3	32%	0.28	0.05	33%	0.3	0.1	34%
5/22/2008	BS-15	20	√	0	0.8	125%	0.14	0.03	34%	3	0.4	31%	0.41	0.06	32%	0.4	0.1	33%
5/21/2008	BS-16	20	√	0	0.7	737%	0.16	0.03	33%	2.1	0.4	33%	0.33	0.06	32%	0.4	0.1	33%
5/22/2008	BS-17	20	√	0.1	0.7	698%	0.11	0.03	34%	2	0.4	33%	0.28	0.06	33%	0.4	0.1	34%
5/21/2008	BS-18	20		0	0.4	504%	0.16	0.02	32%	3.6	0.4	31%	0.34	0.04	32%	0.4	0.1	33%
5/21/2008	BS-18 duplicate	20		0	0.4	8400%	0.15	0.02	32%	2.8	0.4	32%	0.3	0.05	32%	0.4	0.1	33%
5/21/2008	BS-19	20	√	0	0.4	360%	0.06	0.02	38%	2.7	0.4	32%	0.31	0.04	32%	0.4	0.1	32%
5/21/2008	BS-20	20	√	0.2	0.5	183%	0.07	0.02	37%	1.7	0.4	34%	0.31	0.04	32%	0.4	0.1	32%
5/28/2008	Pt-51	20		0.1	0.3	149%	0.17	0.02	32%	1.1	0.3	36%	0.25	0.04	32%	0.2	0.1	37%
5/27/2008	Pt-72	20		0	0.3	352%	0.18	0.02	32%	0.9	0.4	40%	0.21	0.04	33%	0.2	0.1	36%
5/27/2008	Pt-76	20		0	0.3	244%	0.13	0.02	32%	1.7	0.4	34%	0.23	0.04	33%	0.3	0.1	34%
5/27/2008	Pt-91	20		0	0.3	518%	0.17	0.02	32%	2.5	0.3	32%	0.22	0.04	33%	0.3	0.1	34%
5/27/2008	Pt-120	20		0	0.3	2179%	0.19	0.02	32%	2.3	0.4	32%	0.27	0.04	32%	0.3	0.1	33%
5/27/2008	Pt-125	20		0	0.3	2200%	0.24	0.02	31%	1.4	0.3	34%	0.23	0.03	32%	0.2	0.04	34%
5/27/2008	Pt-145	20		0	0.3	197%	0.15	0.02	32%	1.6	0.3	33%	0.22	0.04	33%	0.2	0.1	36%
5/27/2008	Pt-155	20		0	0.3	351%	0.19	0.02	31%	2.9	0.3	31%	0.25	0.04	32%	0.28	0.05	33%

Table C1. *In situ* HPGe measurement results

Date	Location	Count Time (min)	PDA	Th228 (pCi/g)	Th228 MDA (pCi/g)	Th228 2s Error (%)	Th230 (pCi/g)	Th230 MDA (pCi/g)	Th230 2s Error (%)	Th232 (pCi/g)	Th232 MDA (pCi/g)	Th232 2s Error (%)	U235 (pCi/g)	U235 MDA (pCi/g)	U235 2s Error (%)	U238 (pCi/g)	U238 MDA (pCi/g)	U238 2s Error (%)
5/23/2008	BS-1	20	√	0.4	0.1	34%	4	49	776%	71	152	132%	0.4	0.6	103%	167	3.3	30%
5/23/2008	BS-2	20	√	0.4	0.1	34%	0	43	246%	29	147	303%	0.4	0.6	128%	154	3.1	30%
5/23/2008	BS-3	20	√	0.4	0.1	32%	22	51	140%	0	144	286%	0	0.5	951%	18	2.6	40%
5/23/2008	BS-4	20	√	0.4	0.1	33%	6	24	245%	18	104	349%	0	0.4	1902%	4	2.2	93%
5/23/2008	BS-5	20	√	0.3	0.1	33%	10	43	261%	33	130	240%	0.1	0.5	276%	36	2.7	32%
5/22/2008	BS-6	20	√	0.3	0.1	34%	0	35	220%	1	125	5770%	0	0.5	537%	12	2.1	38%
5/23/2008	BS-7	20	√	0.3	0.1	35%	0	106	132%	0	206	284%	0.1	0.7	300%	13	3.9	90%
5/22/2008	BS-8	20	√	0.3	0.1	34%	6	31	317%	13	112	537%	0.3	0.4	94%	17	1.9	34%
5/23/2008	BS-9	20	√	0.4	0.1	33%	0	81	738%	0	188	234%	0.3	0.6	153%	63	3.8	32%
5/22/2008	BS-10	20	√	0.3	0.1	33%	3	36	748%	0	121	434%	0	0.4	172%	3.4	1.9	45%
5/22/2008	BS-11	20	√	0.4	0.1	33%	1	46	2344%	0	140	260%	0	0.5	538%	78	2.9	31%
5/22/2008	BS-12	20	√	0.4	0.1	33%	0	43	155%	0	133	321%	0	0.4	541%	8.2	2.2	67%
5/21/2008	BS-13	20	√	0.4	0.1	33%	0	46	409%	25	150	366%	0.5	0.5	69%	110	2.9	30%
5/22/2008	BS-14	20	√	0.3	0.1	34%	0	38	686%	0	123	313%	0.3	0.4	105%	56	2.4	31%
5/22/2008	BS-15	20	√	0.4	0.1	34%	6	54	505%	0	171	385%	0.7	0.6	58%	182	3.6	30%
5/21/2008	BS-16	20	√	0.4	0.1	33%	0	47	1120%	0	152	360%	0.6	0.6	61%	126	2.9	30%
5/22/2008	BS-17	20	√	0.4	0.1	33%	0	47	246%	32	144	275%	0.5	0.5	74%	85	2.8	30%
5/21/2008	BS-18	20		0.3	0.1	34%	0	26	565%	21	105	296%	0.1	0.4	225%	2.2	1.6	53%
5/21/2008	BS-18 duplicate	20		0.3	0.1	34%	0	27	3108%	24	105	266%	0.1	0.4	225%	1.1	1.6	89%
5/21/2008	BS-19	20	√	0.4	0.1	32%	1	27	1443%	19	106	335%	0.1	0.4	366%	4.6	1.6	50%
5/21/2008	BS-20	20	√	0.4	0.1	33%	4	31	464%	76	112	95%	0	0.4	334%	3.6	1.7	82%
5/28/2008	Pt-51	20		0.2	0.1	35%	0	20	261%	0	85	587%	0	0.3	481%	1.6	1.2	56%
5/27/2008	Pt-72	20		0.2	0.1	36%	0	19	712%	0	86	146%	0	0.3	430%	0.8	1.2	98%
5/27/2008	Pt-76	20		0.3	0.1	34%	0	20	200%	0	89	721%	0	0.3	445%	1	1.3	81%
5/27/2008	Pt-91	20		0.2	0.1	35%	0	20	208%	30	87	179%	0	0.3	491%	0.5	1.3	163%
5/27/2008	Pt-120	20		0.3	0.1	34%	2	23	728%	0	100	335%	0.1	0.4	188%	2.4	1.4	47%
5/27/2008	Pt-125	20		0.17	0.05	36%	3	19	417%	8	84	610%	0	0.3	597%	1.3	1.2	66%
5/27/2008	Pt-145	20		0.2	0.1	34%	0	20	1302%	0	86	2089%	0.1	0.3	259%	1.5	1.3	60%
5/27/2008	Pt-155	20		0.3	0.1	33%	4	21	336%	35	89	157%	0	0.3	887%	1.6	1.3	57%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{238}U										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.137	0.182	1.2	1.6	81%	86%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.196	0.204	1.8	1.8	64%	71%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.249	0.176	2.2	1.6	44%	53%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.128	0.176	1.1	1.6	84%	89%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.524	0.258	3.6	1.7	76%	82%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.591	0.210	4.6	1.6	40%	50%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	12.3	0.319	110	2.9	5%	30%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	14.0	0.323	126	2.9	5%	30%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.159	0.203	1.4	1.8	78%	84%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	20.3	0.398	182	3.6	5%	30%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	10.9	0.367	85	2.8	7%	30%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	7.2	0.310	56	2.4	8%	31%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	48.9	11.5	86290	138	10.8	0.395	78	2.9	8%	31%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	1.6	0.434	8.2	2.2	60%	67%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	2.1	0.247	17	1.9	17%	34%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.573	0.315	3.4	1.9	34%	45%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	1.8	0.305	12	2.1	24%	38%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.138	0.144	1.2	1.3	64%	71%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.052	0.202	0.5	1.8	237%	239%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	18.6	0.372	167	3.3	5%	30%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	12.4	0.252	154	3.1	5%	30%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	3.8	0.543	18	2.6	27%	40%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.380	0.206	4.0	2.2	88%	93%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	6.1	0.460	36	2.7	13%	32%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	4.8	1.5	13	3.9	85%	90%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	15.5	0.929	63	3.8	13%	32%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.055	0.195	0.5	1.7	214%	216%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.117	0.170	1.0	1.5	89%	94%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.090	0.138	0.8	1.2	93%	98%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.115	0.143	1.0	1.3	76%	81%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.054	0.142	0.5	1.3	160%	163%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.269	0.160	2.4	1.4	37%	47%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.142	0.136	1.3	1.2	59%	66%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.167	0.141	1.5	1.3	52%	60%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.180	0.143	1.6	1.3	49%	57%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.128	0.130	1.1	1.2	62%	69%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.014	0.167	0.1	1.5	708%	709%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.174	0.136	1.6	1.2	48%	56%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{241}Am										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.001	0.042	0.0	0.4	1752%	1752%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.051	0.0	0.5	1976%	1976%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.042	0.0	0.4	503%	504%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.050	0.0	0.4	8400%	8400%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.024	0.070	0.2	0.5	181%	183%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.000	0.051	0.0	0.4	359%	360%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.000	0.083	0.0	0.7	8373%	8373%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.000	0.081	0.0	0.7	736%	737%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.007	0.045	0.1	0.4	382%	383%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.000	0.091	0.0	0.8	121%	125%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.008	0.093	0.1	0.7	697%	698%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.000	0.078	0.0	0.6	317%	318%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	48.9	11.5	86290	138	0.000	0.110	0.0	0.8	197%	199%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.000	0.144	0.0	0.7	349%	350%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.000	0.060	0.0	0.5	816%	817%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.000	0.095	0.0	0.6	471%	472%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.034	0.077	0.2	0.5	140%	143%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.016	0.034	0.1	0.3	135%	138%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.005	0.043	0.0	0.4	476%	477%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.020	0.085	0.2	0.8	263%	265%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.000	0.047	0.0	0.6	165%	168%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.000	0.200	0.0	0.9	313%	314%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.004	0.031	0.0	0.3	491%	492%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.000	0.110	0.0	0.7	349%	350%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.000	0.848	0.0	2.2	132%	135%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.021	0.368	0.1	1.5	1060%	1060%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.006	0.043	0.1	0.4	439%	440%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.010	0.036	0.1	0.3	220%	222%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.032	0.0	0.3	351%	352%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.033	0.0	0.3	242%	244%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.004	0.031	0.0	0.3	517%	518%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.001	0.037	0.0	0.3	2179%	2179%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.031	0.0	0.3	2200%	2200%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.033	0.0	0.3	195%	197%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.036	0.0	0.3	350%	351%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.028	0.0	0.3	463%	464%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.013	0.034	0.1	0.3	154%	157%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.014	0.033	0.1	0.3	146%	149%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{137}Cs										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.021	0.003	0.19	0.03	14%	33%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.003	0.22	0.02	12%	32%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.018	0.002	0.16	0.02	12%	32%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.017	0.003	0.15	0.02	13%	32%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.011	0.004	0.07	0.02	22%	37%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.008	0.003	0.06	0.02	24%	38%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.018	0.003	0.16	0.03	13%	32%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.017	0.004	0.16	0.03	15%	33%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.022	0.003	0.19	0.03	13%	32%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.016	0.004	0.14	0.03	17%	34%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.014	0.003	0.11	0.03	17%	34%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.024	0.003	0.19	0.02	11%	32%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	48.9	11.5	86290	138	0.016	0.003	0.12	0.03	16%	34%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.016	0.004	0.08	0.02	18%	35%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.016	0.003	0.12	0.02	15%	33%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.002	0.003	0.01	0.02	111%	115%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.007	0.003	0.05	0.02	29%	41%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.025	0.002	0.22	0.02	9%	31%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.003	0.22	0.02	12%	32%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.005	0.004	0.04	0.03	47%	56%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.008	0.003	0.10	0.03	21%	36%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.013	0.004	0.06	0.02	23%	37%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.018	0.002	0.19	0.02	11%	32%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.008	0.004	0.05	0.02	29%	41%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.027	0.009	0.07	0.02	22%	37%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.017	0.006	0.07	0.03	24%	38%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.023	0.003	0.21	0.03	13%	32%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.002	0.00	0.02	579%	580%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.020	0.002	0.18	0.02	11%	32%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.015	0.003	0.13	0.02	13%	32%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.019	0.002	0.17	0.02	11%	32%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.021	0.002	0.19	0.02	11%	32%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.027	0.002	0.24	0.02	9%	31%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.017	0.002	0.15	0.02	11%	32%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.022	0.002	0.19	0.02	10%	31%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.017	0.003	0.16	0.02	12%	32%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.002	0.00	0.01	327%	328%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.019	0.002	0.17	0.02	11%	32%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{40}K										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.285	0.030	2.6	0.3	11%	32%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.159	0.057	1.4	0.5	25%	38%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.405	0.040	3.6	0.4	9%	31%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.314	0.044	2.8	0.4	11%	32%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.247	0.064	1.7	0.4	18%	34%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.350	0.052	2.7	0.4	11%	32%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.280	0.045	2.5	0.4	12%	32%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.234	0.048	2.1	0.4	14%	33%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.268	0.042	2.4	0.4	13%	32%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.331	0.042	3.0	0.4	10%	31%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.253	0.052	2.0	0.4	15%	33%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.258	0.044	2.0	0.3	13%	32%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.353	0.051	2.5	0.4	11%	32%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.486	0.067	2.5	0.3	11%	32%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.195	0.059	1.5	0.5	20%	36%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.346	0.067	2.1	0.4	14%	33%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.169	0.066	1.1	0.4	25%	39%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.261	0.032	2.3	0.3	10%	31%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.159	0.057	1.4	0.5	25%	39%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.348	0.042	3.1	0.4	10%	31%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.194	0.042	2.4	0.5	15%	33%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.518	0.069	2.4	0.3	10%	31%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.246	0.039	2.6	0.4	12%	32%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.226	0.057	1.3	0.3	18%	35%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.570	0.129	1.5	0.3	16%	34%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.160	0.090	0.7	0.4	35%	46%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.249	0.043	2.2	0.4	14%	33%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.039	0.028	0.3	0.3	49%	57%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.099	0.040	0.9	0.4	27%	40%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.189	0.043	1.7	0.4	16%	34%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.280	0.037	2.5	0.3	11%	32%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.258	0.039	2.3	0.4	12%	32%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.156	0.034	1.4	0.3	16%	34%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.181	0.035	1.6	0.3	14%	33%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.324	0.029	2.9	0.3	9%	31%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.100	0.040	0.9	0.4	26%	39%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.053	0.023	0.5	0.2	32%	44%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.122	0.037	1.1	0.3	21%	36%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{226}Ra/^{214}Bi										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.023	0.005	0.21	0.05	17%	34%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.006	0.26	0.05	17%	34%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.038	0.005	0.34	0.04	11%	32%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.033	0.005	0.30	0.05	12%	32%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.046	0.006	0.31	0.04	11%	32%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.040	0.006	0.31	0.04	12%	32%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.040	0.006	0.35	0.06	12%	32%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.037	0.006	0.33	0.06	13%	32%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.006	0.26	0.05	17%	34%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.046	0.007	0.41	0.06	11%	32%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.036	0.008	0.28	0.06	15%	33%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.036	0.007	0.28	0.05	14%	33%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.047	0.007	0.34	0.05	12%	32%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.057	0.009	0.29	0.05	12%	32%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.042	0.006	0.33	0.05	12%	32%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.055	0.008	0.33	0.05	11%	32%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.096	0.009	0.65	0.06	8%	31%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.004	0.26	0.04	12%	32%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.006	0.26	0.05	17%	34%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.035	0.007	0.31	0.06	14%	33%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.031	0.005	0.38	0.07	13%	32%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.069	0.009	0.32	0.04	11%	32%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.031	0.004	0.33	0.05	12%	32%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.047	0.008	0.28	0.05	13%	32%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.109	0.019	0.29	0.05	13%	32%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.071	0.013	0.29	0.05	13%	32%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.030	0.005	0.27	0.05	16%	34%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.026	0.005	0.24	0.04	16%	34%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.023	0.005	0.21	0.04	15%	33%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.026	0.005	0.23	0.04	14%	33%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.005	0.22	0.04	15%	33%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.030	0.005	0.27	0.04	13%	32%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.026	0.004	0.23	0.03	12%	32%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.004	0.22	0.04	14%	33%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.005	0.25	0.04	13%	32%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.017	0.004	0.15	0.04	19%	35%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.012	0.003	0.10	0.03	24%	38%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.004	0.25	0.04	13%	32%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{228}Ra/^{228} Ac										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.020	0.008	0.2	0.1	30%	42%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.021	0.008	0.2	0.1	32%	44%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.040	0.007	0.4	0.1	15%	33%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.041	0.007	0.4	0.1	15%	33%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.054	0.008	0.4	0.1	13%	32%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.049	0.008	0.4	0.1	13%	32%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.045	0.008	0.4	0.1	14%	33%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.047	0.008	0.4	0.1	14%	33%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.008	0.3	0.1	23%	37%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.044	0.008	0.4	0.1	15%	33%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.045	0.009	0.4	0.1	16%	34%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.038	0.008	0.3	0.1	17%	34%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.054	0.009	0.4	0.1	14%	33%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.070	0.011	0.4	0.1	13%	32%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.039	0.010	0.3	0.1	18%	35%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.055	0.011	0.3	0.1	16%	34%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.046	0.011	0.3	0.1	17%	34%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.005	0.26	0.05	16%	34%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.019	0.008	0.2	0.1	32%	44%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.045	0.008	0.4	0.1	14%	33%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.029	0.008	0.4	0.1	19%	35%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.088	0.017	0.4	0.1	16%	34%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.040	0.006	0.4	0.1	13%	32%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.053	0.010	0.3	0.1	15%	33%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.133	0.021	0.3	0.1	13%	32%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.070	0.017	0.3	0.1	18%	35%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.006	0.2	0.1	23%	37%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.003	0.004	0.03	0.04	80%	85%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.023	0.006	0.2	0.1	21%	36%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.030	0.006	0.3	0.1	16%	34%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.006	0.3	0.1	17%	34%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.035	0.006	0.3	0.1	15%	33%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.023	0.004	0.20	0.04	17%	34%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.022	0.006	0.2	0.1	21%	36%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.032	0.005	0.28	0.05	15%	33%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.022	0.006	0.2	0.1	20%	36%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.007	0.005	0.06	0.04	50%	58%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.020	0.006	0.2	0.1	22%	37%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{228}Th/^{208}Tl										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.025	0.008	0.2	0.1	24%	38%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.032	0.008	0.3	0.1	20%	36%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.034	0.008	0.3	0.1	17%	34%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.035	0.008	0.3	0.1	16%	34%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.053	0.010	0.4	0.1	14%	33%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.052	0.007	0.4	0.1	12%	32%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.048	0.009	0.4	0.1	14%	33%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.050	0.010	0.4	0.1	14%	33%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.008	0.3	0.1	21%	36%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.044	0.011	0.4	0.1	17%	34%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.052	0.010	0.4	0.1	15%	33%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.039	0.009	0.3	0.1	17%	34%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.051	0.010	0.4	0.1	15%	33%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.071	0.013	0.4	0.1	14%	33%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.041	0.009	0.3	0.1	16%	34%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.057	0.011	0.3	0.1	15%	33%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.046	0.011	0.3	0.1	17%	34%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.006	0.2	0.1	16%	34%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.032	0.008	0.3	0.1	20%	36%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.044	0.011	0.4	0.1	17%	34%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.035	0.008	0.4	0.1	16%	34%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.089	0.013	0.4	0.1	12%	32%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.036	0.007	0.4	0.1	15%	33%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.054	0.011	0.3	0.1	15%	33%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.113	0.029	0.3	0.1	18%	35%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.092	0.018	0.4	0.1	15%	33%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.031	0.008	0.3	0.1	21%	36%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.002	0.006	0.0	0.1	224%	226%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.021	0.006	0.2	0.1	21%	36%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.029	0.006	0.3	0.1	17%	34%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.024	0.006	0.2	0.1	19%	35%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.033	0.007	0.3	0.1	16%	34%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.020	0.006	0.17	0.05	21%	36%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.027	0.006	0.2	0.1	16%	34%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.034	0.006	0.3	0.1	14%	33%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.018	0.006	0.2	0.1	25%	39%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.007	0.004	0.07	0.04	43%	52%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.025	0.006	0.2	0.1	18%	35%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{230}Th										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.4	3.0	3	27	461%	462%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	1.2	3.3	10	30	174%	176%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.9	0	26	564%	565%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	3.1	0	27	3108%	3108%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.6	4.6	4	31	463%	464%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.1	3.5	1	27	1443%	1443%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.0	5.2	0	46	408%	409%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.0	5.2	0	47	1120%	1120%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	3.4	0	30	5324%	5324%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.7	6.0	6	54	504%	505%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.0	6.1	0	47	244%	246%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.0	4.8	0	38	685%	686%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.2	6.4	1	46	2344%	2344%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.0	8.5	0	43	152%	155%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.8	3.9	6	31	316%	317%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.5	6.0	3	36	747%	748%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.0	5.2	0	35	218%	220%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.8	2.4	7	22	194%	196%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.4	3.1	3	28	480%	481%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.4	5.4	4	49	775%	776%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.0	3.5	0	43	244%	246%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	4.8	10.7	22	51	137%	140%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.6	2.3	6	24	243%	245%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	1.7	7.2	10	43	259%	261%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.0	40.4	0	106	129%	132%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.0	20.0	0	81	737%	738%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.6	3.1	5	27	362%	363%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.7	0	24	282%	284%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.2	0	19	711%	712%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.3	0	20	198%	200%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.2	0	20	206%	208%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.2	2.5	2	23	727%	728%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.3	2.2	3	19	416%	417%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.3	0	20	1302%	1302%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.4	2.4	4	21	335%	336%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.1	2.1	1	18	1870%	1870%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.9	2.5	8	22	166%	169%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	2.3	0	20	259%	261%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{232}Th										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	12.9	0	116	160%	163%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	1.8	14.0	16	126	478%	479%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	2.4	11.7	21	105	295%	296%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	2.7	11.7	24	105	264%	266%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	11.2	16.5	76	112	90%	95%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	2.5	13.6	19	106	334%	335%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	2.8	16.7	25	150	365%	366%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.0	17.0	0	152	359%	360%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	3.7	14.0	33	126	229%	231%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.0	19.1	0	171	384%	385%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	4.1	18.6	32	144	273%	275%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.0	15.9	0	123	312%	313%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	49.0	11.6	87460	140	0.0	19.6	0	140	258%	260%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.0	26.4	0	133	320%	321%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	1.6	14.5	13	112	536%	537%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.0	20.2	0	121	433%	434%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.2	18.5	1	125	5770%	5770%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.9	9.7	8	87	630%	631%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	14.1	0	126	4554%	4554%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	8.0	17.0	71	152	129%	132%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	2.4	11.8	29	147	302%	303%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.0	30.4	0	144	284%	286%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	1.7	9.9	18	104	348%	349%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	5.5	21.7	33	130	238%	240%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.0	78.6	0	206	282%	284%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.0	46.2	0	188	232%	234%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	13.6	0	122	128%	131%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	12.5	0	112	234%	236%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	9.6	0	86	143%	146%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	10.0	0	89	720%	721%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	3.3	9.7	30	87	177%	179%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	11.1	0	100	334%	335%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.9	9.3	8	84	609%	610%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	9.6	0	86	2089%	2089%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	3.9	10.0	35	89	154%	157%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	9.0	0	81	219%	221%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	2.5	11.0	22	99	265%	267%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.0	9.5	0	85	586%	587%

Table C2. Detailed Radioanalytical results

Analyst:	David Lasher, Eberline Services Inc. - Denver, CO																
Project:	Paducah KRCEE Soils (AOC 492 and Surrounding)																
Detector:	Eberline B2008 (75% HPGe w/Be window) Serial No: 31TN40279A																
Configuration: Detector extended 4cmOut from shielding																	
Detector to Surface distanced1 (cm):		15															
Detector FOV at 80 degrees:		2.2 sqm															
Effective Angle of Incidence (degrees):		67															
Effective Angle of Incidence (radians):		1.17															
Tangent:		2.36															
SNAP 2s Calibration Error:		29.6%															
Results Avg. Bias (high) - angular response		16%					^{235}U										
			Count	Material	Density	U238	Effective Material Dimensions **				Material Wt.	Results of Analysis					
Date	Spectrum ID	Location	Time (min)	Matirx	(g/cm3)	PDA	d2 (cm)	radius (cm)	depth (cm)	volume (cm3)	Total Wt (kg)	Act. (uCi)	MDA (uCi)	Conc.(pCi/g)	MDA (pCi/g)	2s GeoError (%)	2s TotError (%)
5/21/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.020	0.043	0.2	0.4	162%	164%
	Point Bravo endof-day PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.048	0.2	0.4	105%	109%
	Pt18	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.011	0.042	0.1	0.4	224%	225%
	Pt18 duplicate	N6486 E1523	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.011	0.045	0.1	0.4	223%	225%
	Pt20	N6487 E1495	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.000	0.060	0.0	0.4	333%	334%
	Pt19	N6490 E1492	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.008	0.049	0.1	0.4	365%	366%
	Pt13 *	N6493 E1487	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.060	0.061	0.5	0.5	63%	69%
	Pt16*	N6499 E1485	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.072	0.063	0.6	0.6	54%	61%
5/22/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.052	0.0	0.5	435%	436%
	Pt15 *	N6498 E1481	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.090	0.072	0.7	0.6	49%	58%
	Pt17 *	N6495 E1482	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.062	0.069	0.5	0.5	68%	74%
	Pt14 *	N6498 E1478	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.035	0.058	0.3	0.4	101%	105%
	Pt11 *	N6495 E1479	20.0	Soil (10% H2O)	1.60	√	5.8	48.9	11.5	86290	138	0.000	0.073	0.0	0.5	537%	538%
	Pt12	N6490 E1479	20.0	Soil (10% H2O)	1.60	√	7.2	52.3	14.4	123679	198	0.000	0.073	0.0	0.4	540%	541%
	Pt8 *	N6487 E1484	20.0	Soil (10% H2O)	1.60	√	5.5	48.3	11.0	80561	129	0.036	0.052	0.3	0.4	89%	94%
	Pt10	N6476 E1477	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.000	0.072	0.0	0.4	169%	172%
	Pt6	N6476 E1459	20.0	Soil (10% H2O)	1.60	√	6.0	49.5	12.0	92224	148	0.000	0.067	0.0	0.5	536%	537%
5/23/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.036	0.0	0.3	597%	598%
	Point Bravo PM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.028	0.048	0.2	0.4	105%	109%
	Pt1 *	N6487 E1393	20.0	Soil (10% H2O)	1.60	√	5.0	47.1	10.0	69709	112	0.041	0.067	0.4	0.6	99%	103%
	Pt2 *	N6487 E1396	20.0	Soil (10% H2O)	1.60	√	4.0	44.8	8.0	50330	81	0.030	0.047	0.4	0.6	125%	128%
	Pt3	N6488 E1382	20.0	Soil (10% H2O)	1.60	√	7.5	53.0	15.0	132337	212	0.007	0.105	0.0	0.5	951%	951%
	Pt4	N6483 E1438	20.0	Soil (10% H2O)	1.60	√	4.5	45.9	9.0	59640	95	0.001	0.035	0.0	0.4	1902%	1902%
	Pt5 *	N6478 E1451	20.0	Soil (10% H2O)	1.60	√	6.5	50.7	13.0	104724	168	0.018	0.080	0.1	0.5	274%	276%
	Pt7	N6470 E1468	20.0	Soil (10% H2O)	1.60	√	10.5	60.1	21.0	237972	381	0.051	0.253	0.1	0.7	299%	300%
	Pt9 *	N6487 E1468	20.0	Soil (10% H2O)	1.60	√	8.2	54.7	16.4	153832	246	0.064	0.159	0.3	0.6	150%	153%
5/27/08	Point Bravo AM	Point Bravo	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.004	0.048	0.0	0.4	638%	639%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.044	0.0	0.4	7034%	7034%
	Pt71	N6574.8 E1481.8	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.034	0.0	0.3	429%	430%
	Pt76	N6574.8 E1547.4	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.036	0.0	0.3	444%	445%
	Pt91	N6591.2 E1596.7	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.004	0.035	0.0	0.3	490%	491%
	Pt120	N6624.0 E1629.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.013	0.039	0.1	0.4	186%	188%
	Pt125	N6640.4 E1464.5	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.003	0.033	0.0	0.3	596%	597%
	Pt145	N6656.9 E1563.9	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.008	0.034	0.1	0.3	257%	259%
	Pt155	N6673.3 E1613.1	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.036	0.0	0.3	887%	887%
5/28/08	Point Bravo AM	Point Bravo	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.032	0.0	0.3	1036%	1036%
	Point Office PM	755 Area	10.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.000	0.042	0.0	0.4	198%	200%
	Pt51	N6542.0 E1531	20.0	Soil (10% H2O)	1.60		5.0	47.1	10.0	69709	112	0.004	0.033	0.0	0.3	480%	481%

Table C2. Detailed Radioanalytical results

Notes:	1) Results are based upon "heterogeneous" radionuclide distribution within the detector FOV, modeled to a depth of 10cm (or as otherwise indicated through PDA) and distributed within a standardized area of homogenation based on XRF profiling.
	2) Interference from Cs137 and other higher energy radionuclides in the form of Compton scatter will increase MDAs within the lower energy regions of the spectrum.
	3) * U235 peaks were detected within gamma spectrums of Pt1, Pt2, Pt5, Pt8, Pt9, Pt13, Pt14, Pt15, Pt16, and Pt17
	4) Altitude was estimated at 0.8 km.
	5) Results have not been adjusted for surface layer vegetation nor humidity of surrounding air.
	6) Attenuation of gamma radiation is significant beyond 10 cm soildepth (density 1.6 g/cm3) at lower energies.
	7) GeoError increases with increasing soildepth and decreasing radionuclide activity.
	8) The closer estimates are to actual radionuclide distributions and existing soil conditions the more accurate the results.
	9) U238 results are determined through Th234 and Pa234m gamma peaks in secular equilibrium.
	10) Results were not adjusted for additional water saturation due to recent rains within 2 hours prior to or during survey.
	11) √ PDA peak differential analysis was performed for improved depth profiling.
	12) d2 = average depth of U238 activity per location determined through PDA.
	13) ** Effective Material Dimensions (area of homogenation) derived through XRF profiling.
	14) Total error does not include XRF associated error, modeling and radionuclide distribution error.

Appendix D. Abraxis PCB Test Kit Results

The Abraxis PCB test kit data provided in this appendix were from analyses conducted on three (3) different days. The tabular test kit results are organized by date of analysis and their sequence in the day.

The samples were associated with three different sampling objectives.

- Samples identified as “BS-x” corresponded to the twenty initial biased sample locations.
    - Each of those samples was a 5-increment MIC sample, with the increments collected to a 1-foot depth from the center and corners of a 1 ft^2 area centered on the location of interest.
- Samples identified as “O11CA-x” corresponded to two locations from AOC541 that targeted elevated uranium locations with the expectation that they would also contain elevated PCB contamination.
- Samples identified as “FSS-x” corresponded to FSS composite samples from the Class 1, Class 2, or Class 3 area.
- Also included in this table are QC analyses results (controls and calibration standards).

All samples were prepared (homogenized and dried) before sub-sampling and analysis. The extract from each sample was analyzed twice, producing two sets of results for each sample. The results are reported as total PCB concentrations (ppm).

Table D1. Abraxis PCB Test Kit Results

Analysis Date	Analysis Number	Location	Result (ppm)	Comments
5/28/2008	7	BS-01	1.27	
5/28/2008	8	BS-01	1.25	
5/28/2008	1	BS-02	<0.5	
5/28/2008	2	BS-02	<0.5	
5/28/2008	9	BS-03	<0.5	
5/28/2008	10	BS-03	<0.5	
5/28/2008	3	BS-04	<0.5	
5/28/2008	4	BS-04	<0.5	
5/28/2008	11	BS-05	<0.5	
5/28/2008	12	BS-05	<0.5	
5/23/2008	1	BS-6	<0.5	
5/23/2008	2	BS-6	<0.5	
5/28/2008	13	BS-07	3.03	
5/28/2008	14	BS-07	2.55	
5/28/2008	5	BS-08	<0.5	
5/28/2008	6	BS-08	<0.5	
5/28/2008	15	BS-09	5.52	
5/28/2008	16	BS-09	5.44	
5/23/2008	3	BS-10	<0.5	
5/23/2008	4	BS-10	<0.5	
5/23/2008	5	BS-11	0.55	
5/23/2008	6	BS-11	0.59	
5/28/2008	17	BS-11	1.24	
5/28/2008	18	BS-11	1.06	
5/23/2008	7	BS-12	<0.5	
5/23/2008	8	BS-12	<0.5	
5/28/2008	19	BS-13	2.81	
5/28/2008	20	BS-13	2.35	
5/23/2008	9	BS-14	<0.5	
5/23/2008	10	BS-14	<0.5	
5/28/2008	21	BS-15	13.48	
5/28/2008	22	BS-15	8.73	
5/29/2008	1	BS-15	6.47	Run from same extract as 5/28/08 sample
5/29/2008	2	BS-15	6.61	Run from same extract as 5/28/08 sample
5/29/2008	3	BS-15-1	<0.5	
5/29/2008	4	BS-15-1	<0.5	
5/29/2008	5	BS-15-2	5.27	
5/29/2008	6	BS-15-2	3.34	
5/29/2008	7	BS-15-3	3.46	
5/29/2008	8	BS-15-3	4.20	
5/29/2008	9	BS-15-4	1.87	
5/29/2008	10	BS-15-4	2.92	
5/23/2008	11	BS-16	<0.5	
5/23/2008	12	BS-16	<0.5	
5/28/2008	23	BS-17	2.00	
5/28/2008	24	BS-17	2.53	
5/23/2008	13	BS-18	<0.5	

Table D1. Abraxis PCB Test Kit Results

Analysis Date	Analysis Number	Location	Result (ppm)	Comments
5/23/2008	14	BS-18	<0.5	
5/28/2008	25	BS-19	<0.5	
5/28/2008	26	BS-19	<0.5	
5/23/2008	15	BS-20	<0.5	
5/23/2008	16	BS-20	<0.5	
5/28/2008	27	FSS-C1-01	<0.5	
5/28/2008	28	FSS-C1-01	<0.5	
5/28/2008	29	FSS-C1-02	<0.5	
5/28/2008	30	FSS-C1-02	<0.5	
5/28/2008	31	FSS-C1-03	<0.5	
5/28/2008	32	FSS-C1-03	<0.5	
5/28/2008	33	FSS-C1-04	<0.5	
5/28/2008	34	FSS-C1-04	<0.5	
5/28/2008	35	FSS-C1-05	<0.5	
5/28/2008	36	FSS-C1-05	<0.5	
5/28/2008	37	FSS-C1-06	<0.5	
5/28/2008	38	FSS-C1-06	<0.5	
5/28/2008	39	FSS-C1-07	<0.5	
5/28/2008	40	FSS-C1-07	<0.5	
5/29/2008	11	FFS-C2-01	<0.5	
5/29/2008	12	FFS-C2-01	<0.5	
5/29/2008	13	FFS-C2-02	<0.5	
5/29/2008	14	FFS-C2-02	<0.5	
5/29/2008	15	FFS-C2-03	<0.5	
5/29/2008	16	FFS-C2-03	<0.5	
5/29/2008	17	FFS-C2-04	<0.5	
5/29/2008	18	FFS-C2-04	<0.5	
5/29/2008	19	FFS-C3-01	<0.5	
5/29/2008	20	FFS-C3-01	<0.5	
5/23/2008	17	O11CA-1-1	<0.5	
5/23/2008	18	O11CA-1-1	<0.5	
5/23/2008	19	O11CA-1-2	21.8	
5/23/2008	20	O11CA-1-2	21.8	
5/23/2008	21	Control (10.00 ppm)	10.44	
5/23/2008	22	Control (10.00 ppm)	10.24	
5/29/2008	29	Control (10.0 ppm)	10.13	
5/29/2008	30	Control (10.0 ppm)	10.55	
5/28/2008	41	Control (10.00ppm)	12.16	
5/28/2008	42	Control (10.00ppm)	9.54	
5/29/2008	21	0 ppm	<0.5	Calibration standard
5/29/2008	22	0 ppm	<0.5	Calibration standard
5/29/2008	23	0.5 ppm	<0.5	Calibration standard
5/29/2008	24	0.5 ppm	1.19	Calibration standard
5/29/2008	25	5.0 ppm	6.07	Calibration standard
5/29/2008	26	5.0 ppm	6.61	Calibration standard
5/29/2008	27	50.0 ppm	45.79	Calibration standard
5/29/2008	28	50.0 ppm	49.14	Calibration standard

Appendix E. Laboratory Data

Laboratory Data is provided on the CD-ROM distributed with this report.

Laboratory analyses for the data in this appendix were conducted under subcontracts with Tricord, Inc. and Eberline Services, Inc. Samples were prepared and shipped under chain of custody to the appropriate laboratory utilizing laboratory-specific preparation, preservation, packaging and labeling requirements. Eberline Services Lionville Laboratory conducted analyses for SVOAs and metals utilizing proprietary modifications to EPA SW 846 methods that are identified in the associated data packages. Eberline Services Laboratory, Oak Ridge, conducted radionuclide analyses utilizing proprietary modifications to EPA SW 846 methods identified in the radionuclide analytical data packages.

Appendix F. Quality Control Results

This appendix summarizes quality control information for the various technologies deployed and demonstrated as part of the AOC 492 field work. The presentation of information is organized by technology.

FIDLER/LARADS GWS

There were several quality control checks implemented for the FIDLER/LARADS GWS system.

In the case of location control (LARADS) for GWS data collection, data collection began by surveying a known control point and ended by surveying a known control point to verify that positional information was accurate. During the course of a GWS survey, some variation could be expected in the precise coordinates assigned to FIDLER data acquisitions. This variation was due to the fact that the LARADS used a reflector projecting from the backpack worn by the technician performing the walk. The reflector was offset slightly laterally from the detector itself. The walking motion of the technician would also have introduced some variability in the recorded vertical coordinate for each data point. Both sources of error are believed to have resulted in a 3-D positional error of less than one (1) foot.

Calibration control charts were developed for each FIDLER detector for instrument background and check source response (Figure F1). The calibration control chart in both cases was based on 10 replicate measurements taken sequentially of both instrument background and the check source on the first day of deployment. The observed mean response and standard deviation were used to form the control chart. Subsequently the instruments were typically re-checked twice a day when in use; once in the morning and once in the afternoon. The instruments were considered “in control” if both the background and check source responses were within two standard deviations of the originally observed mean instrument response. Based on these criteria, the instruments were “in control” each time they were checked. Figure F1 shows the replicate data and control chart information for the primary FIDLER used for the field work.

At the start of the field work, an in-field background quality control location was established for the FIDLER (see Figure F2). Ten one-minute replicate measurements were obtained for each of the two FIDLER detectors brought to the site, with the detector held stationary six inches above the ground. The average and standard deviation for each detector was recorded, and the information used to construct a control chart. Subsequently, each day a FIDLER was deployed, up to three static one-minute readings from a height of six inches were obtained over the in-field background control point, the result observed, and recorded in the control chart. The detector was considered “in control” if the result fell within two standard deviations of the original mean calculated from the initial set of replicate measurements. Figure F2 provides the control chart and replicate information for the primary FIDLER used for data collection at the site. The detector was “in control” throughout the course of field work.

In addition to these formal QC checks, GWS data were mapped as they were generated to verify that the position information for individual measurements conformed to expectations, and that the instrument response was not showing signs of instrument problems. Examples of the latter would have included sequentially elevated or depressed gross activity measurements whose observed cpm values were not substantiated by the next adjacent “line” walked. There were no observed position discrepancies, nor was there evidence of instrument malfunction in the mapped data.

The conclusion was that the FIDLER performed within expected QC parameters for the duration of the deployment.

XRF

Quality control for the XRF involved several distinct activities. These included the following:

- Initial calibration checks for uranium were performed using previously characterized site samples that had uranium present at several different concentrations ranging from background to around 2,000 ppm.
- Initial calibration checks for RCRA metals were performed using vendor-supplied reference material.
- On-going calibration checks for uranium were conducted using control charts and one well-characterized soil sample.
- Initial precision checks were performed using replicate measurements and comparisons of observed measurement error as represented by replicate data standard deviations with analytical errors reported by the instrument.
- On-going precision checks were performed by monitoring reported analytical errors for evidence of reported errors that were significantly different from expectation for uranium measurements.
- Comparability checks for uranium were performed using off-site laboratory alpha spectroscopy results for selected XRF-analyzed soil sample cups.

The initial calibration check results for both uranium and the RCRA metals are described in detail in Section 4. In the case of uranium, there was no discernible bias present in the XRF total uranium results as compared to alpha spectroscopy data available for several historical samples. In the case of RCRA metals, the XRF provided results consistent with reported metals concentrations for all RCRA metals except chromium. In the case of chromium, the XRF reported a concentration that was significantly greater than the reported concentration for the reference material.

The chromium and uranium calibration was monitored over the course of the field work through the development of an appropriate control chart using replicate measurements for one of the initial, well-characterized samples, and re-measuring that sample three (3) times each day the XRF was deployed (morning, midday, and afternoon). The instrument calibration for chromium and uranium was considered in control if the measured result was within two standard deviations of the observed average concentration of replicate measurements obtained during XRF setup. Figure F3 shows the replicate measurement information and control chart results for the field work. All of these QC measurements were “in control”.

Instrument precision was initially evaluated by comparing the variability observed in replicate uranium measurements obtained during equipment setup with the average reported analytical error for those measurements. Ten replicate measurements were obtained for three samples with three very different uranium concentrations (sample 50016-5: 1,994 ppm total U; sample 50020-3: 125 ppm total U; and sample 50011-1: 8 ppm total U). The observed standard deviations agreed very well with the average reported analytical error provided by the XRF, with differences on the order of 5% or less. The conclusion was that the XRF was accurately reporting analytical precision for uranium over a wide range of concentrations.

Instrument precision was monitored during the course of field work by comparing reported uranium analytical precision for individual XRF measurements with what would be expected given the uranium concentration present. Reported analytical precision that deviated significantly from expectations (e.g., significantly greater) would be indicative of potential problems with a particular measurement. Those problems could have been the product of incorrect instrument positioning with respect to the sample material, or matrix interferences present with the soil in question. There was only one measurement, an *in situ* XRF measurement for a soil core interval, that was rejected because of obvious analytical precision problems.

Finally, XRF data comparability was evaluated by comparing the results of XRF total uranium measurements for selected soil cups with off-site alpha spectroscopy analyses of those same cups. A regression analysis was used to evaluate comparability quality. Section 4 contains a detailed discussion of this analysis. The conclusion was that in the case of uranium the XRF was providing data of quality comparable to off-site alpha spectroscopy over the range of uranium concentrations evaluated for comparability purposes.

In Situ HPGe Gamma Spectroscopy

The in situ HPGe gamma spectroscopy QC program involved the use of energy-specific check sources and the in-field background quality control point located within the study area and previously described as part of the FIDLER QC discussion.

Eberline deployed two HPGe systems as part of the field work. The primary system developed obvious QC issues within the first day of deployment. Eberline subsequently switched to the back-up system. The following discussion is specific to QC procedures applied to the second system.

Before the field deployment of the second HPGe system, Eberline developed QC control charts. These control charts consisted of energy-specific check source data for three different energy levels (Cs-137 @ 32.06 keV; Cs-137 @ 661.7 keV; and Co-60 @ 1,332 keV), and a measurement at the in-field background location for ^{234}Th @ 92.6 keV. In each case twelve replicate measurements were obtained. The mean instrument response and corresponding standard deviations were calculated for each of the check sources and the in-field background location. In the case of the check sources, the parameters of interest were the observed centroid keV value, the Full Width at Half Maximum (FWHM), and the net counts per second (cps) within the energy region of interest. In the case of the in-field background location the parameter of interest was the total cps observed in the energy region of interest for ^{234}Th @ 92.6 keV,. Control charts were constructed based on these data. Subsequently QC measurements were performed using each of the check sources and the in-field background location twice a day when the instrument was in use (once in the morning, and once in the evening). Results for any of the parameters of interest that were within two standard deviations of the original mean value were considered in control. Parameter results that were between two and three standard deviations of the original mean were flagged as warning. Parameter results that were more than three standard deviations from the original mean were flagged as out of control.

Figures F4 through F9 provide the QC results for the HPGe detector. The data indicated that the HPGe was "in control" during the course of field deployment.

Abraxis PCB Test Kits

Abraxis test kit QC included replicate analyses for each sample extract, a standard curve to check linearity (Figure F10), a 10 ppm total PCB standard check that was performed each day Abraxis test kit analyses were conducted, and one round of multiple sub-sampling and sub-sample analyses for a selected soil sample. Finally, sample splits were used to evaluate Abraxis test kit comparability with laboratory analyses.

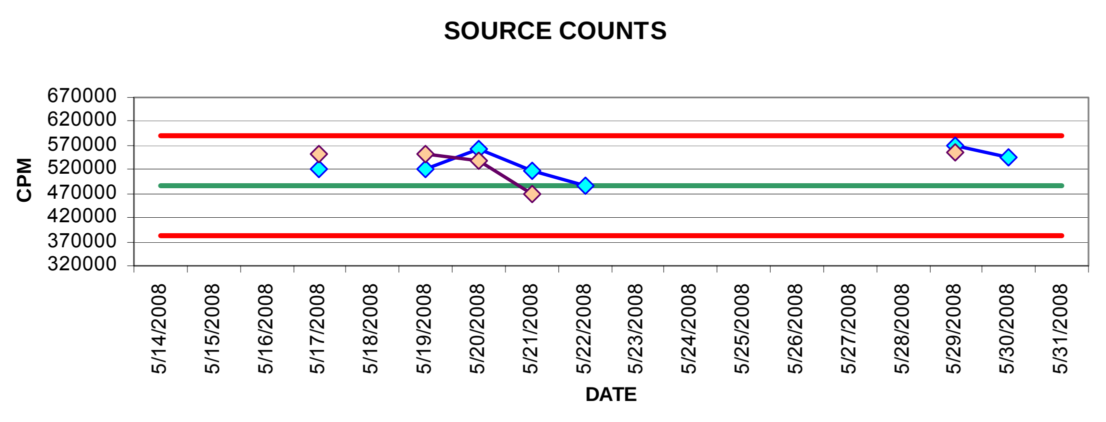
The purpose of the replicate extract analysis was to verify repeatability for Abraxis test kit results once a prepared extract had been obtained. The purpose of the standards check was to verify that the Abraxis test kit calibration was correct and that the kits were returning unbiased results for the standard. The purpose of the multiple sub-sampling and analysis of one selected sample was to verify that the test kits were yielding repeatable results when the complete sub-sampling selection, preparation, and analysis sequence was considered. Finally, the purpose of the sample splits was to determine whether the Abraxis test kits were yielding data comparable to off-site laboratory analyses.

The relative percent difference (RPD) for replicate extract analyses was generally 10% or less for those samples that yielded detectable levels of PCBs. Likewise, the 10 ppm standard check yielded a result that was generally within 10% of the known standard value.

As described in Section 4, the evaluation of multiple sub-samples from one selected sample identified a high degree of variability in test kits results. Similar sub-sample analyses by the laboratory suggested that at least some of this variability was likely due to intrinsic heterogeneity within the original sample even after preparation.

As described in Section 4, the split samples in general (but not always) yielded laboratory results that were very comparable to the Abraxis test kit data.

E-600 01086 FIDLER JP-245	**1 MINUTE BKG COUNTS**		**1MINUTE SRC COUNTS**
1	5360		573000
2	5390		445000
3	5400		467000
4	6090		401000
5	6040		449000
6	5310		467000
7	6120		503000
8	5950		471000
9	6160		540000
10	6130		533000
MEAN	**5795**	**MEAN**	**484900**
UCL CPM	**6545**	**UCL CPM**	**588594**
LCL CPM	**5045**	**LCL CPM**	**381206**
STD DEV	375	**STD DEV**	51846
2 STD DEV	750	**2 STD DEV**	103693



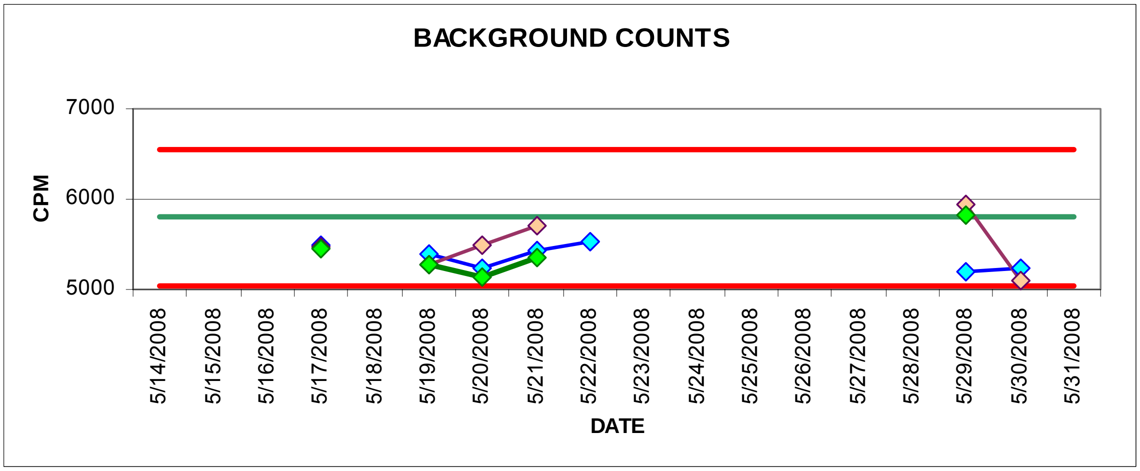


Table & Figure F1. Calibration QC Checks for the FIDLER

E-600 01086 FIDLER JP-245	**1 MINUTE BKG COUNTS**
1	8140
2	8220
3	8130
4	8120
5	8040
6	8190
7	7990
8	8170
9	7850
10	8330
MEAN	**8118**
UCL CPM	**8383**
LCL CPM	**7853**
STD DEV	132
2 STD DEV	265

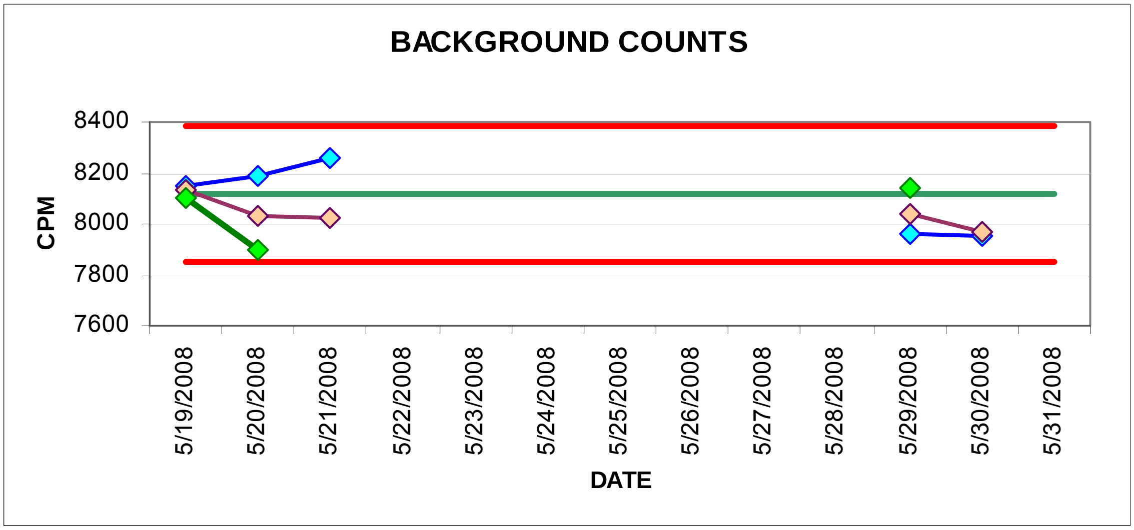
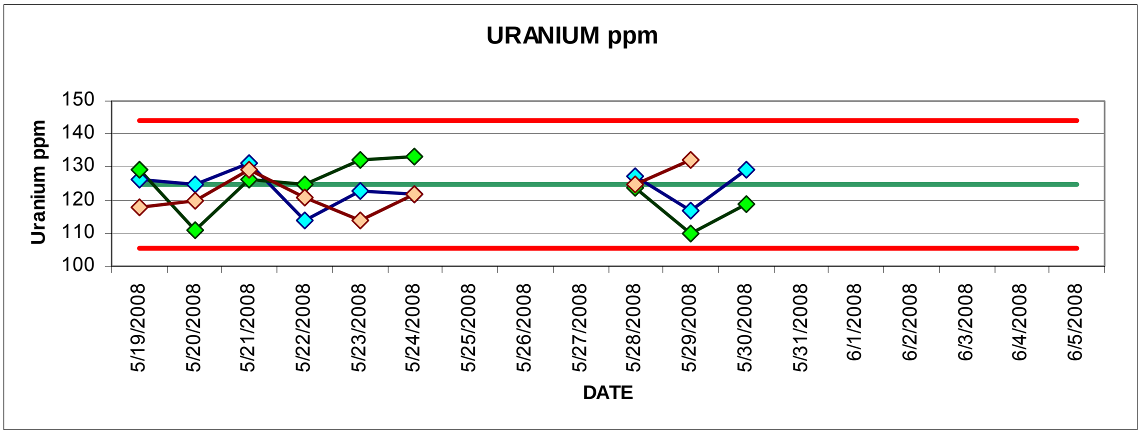


Table & Figure F2. Field Background QC Check for FIDLER

THERMO FISHER MODEL XL3t 800 SERIAL NO. 31059	1 MINUTE CHROMIUM		1 MINUTE URANIUM
1	129.53		124.61
2	113.32		132.37
3	132.7		126.48
4	128.69		124.42
5	126.29		146.54
6	123.07		118.37
7	113.42		122.04
8	129.65		124.62
9	97.85		110.68
10	103.93		117.74
MEAN	**120**	**MEAN**	**125**
UCL CPM	**144**	**UCL CPM**	**144**
LCL CPM	**96**	**LCL CPM**	**106**
STD DEV	12	**STD DEV**	10
2 STD DEV	24	**2 STD DEV**	19



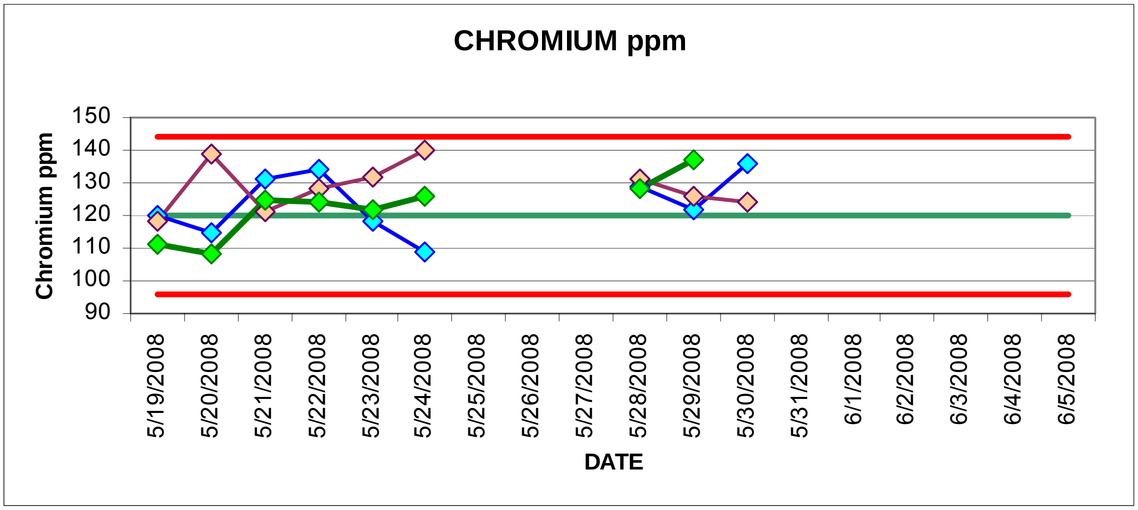


Table & Figure F3. On-Going Calibration Check Results for the XRF

Project:		Paducah KRCEE Soils								
Detector:		Eberline Services B2008 Ser# 31TN40279A								
Source No.:		Cs137 ESI576607 (5.4 uCi), Co60 ESI576507 (0.298 uCi)								
DigiDart:		638								
Voltage:		4000								
Settings:		1.35 (2x, 0.6776), 12, 0.80, 0.04688								
Energy Cal. (kev/ch):		0.25								
Cs137 (32.06 kev) ROI:		28.76 34.06								
Cs137 (661.7 kev) ROI:		655.91 666.5								
Co60 (1332 kev) ROI:		1328.46 1334.77								
Bkg Th-234 (92.6 kev) ROI:		90.82 93.59								
QC Chart Baseline Development										
Initial	Peak 1			Peak 2			Peak 3			Th234
Data	Cs137 (32.06 kev)			Cs137 (661.7 kev)			Co60 (1332 kev)			Bkg (92.6)
5/19/2008	Centroid (kev)	FWHM	Net CPS	Centroid (kev)	FWHM	Total CPS	Centroid (kev)	FWHM	Total CPS	Total CPS
1	31.90	1.79	16.48	661.27	2.04	127.07	1331.65	2.16	13.15	2.80
2	31.91	2.04	18.05	661.25	2.16	126.38	1331.64	2.46	13.15	2.74
3	31.92	1.83	16.57	661.27	2.08	124.45	1331.76	2.65	12.70	2.69
4	31.93	1.75	17.42	661.30	2.12	123.27	1331.66	2.26	14.13	2.74
5	32.03	1.96	16.30	661.29	2.18	125.02	1331.76	2.65	12.70	2.69
6	31.93	1.59	16.48	661.30	2.14	123.07	1331.77	2.67	13.28	2.64
7	31.90	1.72	15.95	661.31	2.15	124.93	1331.87	2.54	13.02	1.92
8	31.96	2.13	16.60	661.33	2.20	123.18	1331.85	2.66	13.65	1.95
9	31.97	2.01	17.52	661.32	2.20	120.30	1331.74	2.62	13.23	1.94
10	31.99	1.95	17.98	661.35	2.18	128.00	1331.86	2.27	13.08	2.53
11	31.86	1.70	19.00	661.25	1.83	126.80	1331.63	2.19	14.70	
12	31.88	1.49	19.70	661.24	1.95	127.20	1331.86	1.71	13.27	
Mean	31.93	1.83	17.46	661.29	2.10	124.57	1331.75	2.40	13.47	2.46
StdDev	0.048	0.193	1.132	0.035	0.113	2.255	0.092	0.294	0.545	0.370

Table F4. HPGe QC Control Chart Development

Project:		Paducah KRCEE Soils					
Detector:		Eberline Services B2008 Ser# 31TN40279A					
Source No.:		Cs137 ESI576607 (5.4 uCi), Co60 ESI576507 (0.298 uCi)					
DigiDart:		638					
Voltage:		4000					
Settings:		1.35 (2x, 0.6776), 12, 0.80, 0.04688					
Energy Cal. (kev/ch):		0.25					
Cs137 (32.06 kev) ROI:		28.76	34.06				
Cs137 (661.7 kev) ROI:		655.91	666.5				
Co60 (1332 kev) ROI:		1328.46	1334.77				
Bkg Th234 (92.6 kev) ROI:		90.82	93.59				
	Point Bravo Background QC Checks						
Th234 Bkg (CPS)		Th234 (92.6 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	2.64	2.46	1.35	1.72	3.20	3.57	good
pm	1.92	2.46	1.35	1.72	3.20	3.57	good
5/21/2008 am	1.95	2.46	1.35	1.72	3.20	3.57	good
pm	2.53	2.46	1.35	1.72	3.20	3.57	good
5/22/2008 am	2.35	2.46	1.35	1.72	3.20	3.57	good
pm		2.46	1.35	1.72	3.20	3.57	not performed
5/23/2008 am	2.41	2.46	1.35	1.72	3.20	3.57	good
pm	2.23	2.46	1.35	1.72	3.20	3.57	good
5/27/2008 am	2.11	2.46	1.35	1.72	3.20	3.57	good
pm	1.65	2.46	1.35	1.72	3.20	3.57	warning
5/28/2008 am	2.03	2.46	1.35	1.72	3.20	3.57	good
pm	1.51	2.46	1.35	1.72	3.20	3.57	warning

Table F5. Field Background Location HPGe QC Check Results

	Standard Source QC Checks						
	Peak 3						
	Centroid (kev)	Co60 (1332 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	1335.28	1331.75	1331.48	1331.57	1331.94	1332.03	readjust gain
pm		1331.75	1331.48	1331.57	1331.94	1332.03	not performed
5/21/2008 am	1331.63	1331.75	1331.48	1331.57	1331.94	1332.03	good
pm	1331.86	1331.75	1331.48	1331.57	1331.94	1332.03	good
5/22/2008 am	1331.61	1331.75	1331.48	1331.57	1331.94	1332.03	good
pm	1331.65	1331.75	1331.48	1331.57	1331.94	1332.03	good
5/23/2008 am	1331.78	1331.75	1331.48	1331.57	1331.94	1332.03	good
pm	1331.68	1331.75	1331.48	1331.57	1331.94	1332.03	good
5/27/2008 am	1331.66	1331.75	1331.48	1331.57	1331.94	1332.03	good
pm	1331.59	1331.75	1331.48	1331.57	1331.94	1332.03	good
5/28/2008 am	1331.68	1331.75	1331.48	1331.57	1331.94	1332.03	good
pm	1331.76	1331.75	1331.48	1331.57	1331.94	1332.03	good
	FWHM	Co60 (1332 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	3.04	2.40	1.52	1.82	2.99	3.29	warning
pm		2.40	1.52	1.82	2.99	3.29	not performed
5/21/2008 am	2.19	2.40	1.52	1.82	2.99	3.29	good
pm	1.71	2.40	1.52	1.82	2.99	3.29	warning
5/22/2008 am	2.21	2.40	1.52	1.82	2.99	3.29	good
pm	2.34	2.40	1.52	1.82	2.99	3.29	good
5/23/2008 am	2.10	2.40	1.52	1.82	2.99	3.29	good
pm	2.90	2.40	1.52	1.82	2.99	3.29	good
5/27/2008 am	2.00	2.40	1.52	1.82	2.99	3.29	good
pm	2.26	2.40	1.52	1.82	2.99	3.29	good
5/28/2008 am	2.19	2.40	1.52	1.82	2.99	3.29	good
pm	1.97	2.40	1.52	1.82	2.99	3.29	good
	ROI Net CPS	Co60 (1332 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	16.25	13.5	11.8	12.4	14.6	15.1	out of control
pm		13.5	11.8	12.4	14.6	15.1	not performed
5/21/2008 am	14.70	13.5	11.8	12.4	14.6	15.1	warning
pm	13.27	13.5	11.8	12.4	14.6	15.1	good
5/22/2008 am	14.12	13.5	11.8	12.4	14.6	15.1	good
pm	14.83	13.5	11.8	12.4	14.6	15.1	warning
5/23/2008 am	13.23	13.5	11.8	12.4	14.6	15.1	good
pm	13.55	13.5	11.8	12.4	14.6	15.1	good
5/27/2008 am	13.78	13.5	11.8	12.4	14.6	15.1	good
pm	14.12	13.5	11.8	12.4	14.6	15.1	good
5/28/2008 am	12.97	13.5	11.8	12.4	14.6	15.1	good
pm	13.75	13.5	11.8	12.4	14.6	15.1	good

Table F6. Standard Co-60 Source HPGe QC Check Results

	Standard Source QC Checks						
	Peak 1						
	Centroid (kev)	Cs137 (32.06 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	32.03	31.93	31.79	31.83	32.03	32.08	warning
pm		31.93	31.79	31.83	32.03	32.08	not performed
5/21/2008 am	31.86	31.93	31.79	31.83	32.03	32.08	good
pm	31.88	31.93	31.79	31.83	32.03	32.08	good
5/22/2008 am	31.99	31.93	31.79	31.83	32.03	32.08	good
pm	31.83	31.93	31.79	31.83	32.03	32.08	warning
5/23/2008 am	31.93	31.93	31.79	31.83	32.03	32.08	good
pm	31.98	31.93	31.79	31.83	32.03	32.08	good
5/27/2008 am	31.93	31.93	31.79	31.83	32.03	32.08	good
pm	31.89	31.93	31.79	31.83	32.03	32.08	good
5/28/2008 am	31.88	31.93	31.79	31.83	32.03	32.08	good
pm	31.97	31.93	31.79	31.83	32.03	32.08	good
	FWHM	Cs137 (32.06 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	2.12	1.83	1.25	1.44	2.22	2.41	good
pm		1.83	1.25	1.44	2.22	2.41	not performed
5/21/2008 am	1.70	1.83	1.25	1.44	2.22	2.41	good
pm	1.49	1.83	1.25	1.44	2.22	2.41	good
5/22/2008 am	1.38	1.83	1.25	1.44	2.22	2.41	warning
pm	1.86	1.83	1.25	1.44	2.22	2.41	good
5/23/2008 am	1.95	1.83	1.25	1.44	2.22	2.41	good
pm	1.87	1.83	1.25	1.44	2.22	2.41	good
5/27/2008 am	1.44	1.83	1.25	1.44	2.22	2.41	warning
pm	2.00	1.83	1.25	1.44	2.22	2.41	good
5/28/2008 am	1.39	1.83	1.25	1.44	2.22	2.41	warning
pm	1.56	1.83	1.25	1.44	2.22	2.41	good
	ROI Net CPS	Cs137 (32.06 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	15.3	17.5	14.1	15.2	19.7	20.9	good
pm		17.5	14.1	15.2	19.7	20.9	not performed
5/21/2008 am	19.0	17.5	14.1	15.2	19.7	20.9	good
pm	19.7	17.5	14.1	15.2	19.7	20.9	good
5/22/2008 am	17.7	17.5	14.1	15.2	19.7	20.9	good
pm	18.2	17.5	14.1	15.2	19.7	20.9	good
5/23/2008 am	17.0	17.5	14.1	15.2	19.7	20.9	good
pm	14.9	17.5	14.1	15.2	19.7	20.9	warning
5/27/2008 am	19.6	17.5	14.1	15.2	19.7	20.9	good
pm	19.8	17.5	14.1	15.2	19.7	20.9	warning
5/28/2008 am	18.3	17.5	14.1	15.2	19.7	20.9	good
pm	19.5	17.5	14.1	15.2	19.7	20.9	good

Table F7. Standard Cs-137 Low Energy Source HPGe QC Check Results

	Standard Source QC Checks						
	Peak 2						
	Centroid (kev)	Cs137 (661.7 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	662.80	661.29	661.19	661.22	661.36	661.39	readjust gain
pm		661.29	661.19	661.22	661.36	661.39	not performed
5/21/2008 am	661.25	661.29	661.19	661.22	661.36	661.39	good
pm	661.24	661.29	661.19	661.22	661.36	661.39	good
5/22/2008 am	661.30	661.29	661.19	661.22	661.36	661.39	good
pm	661.35	661.29	661.19	661.22	661.36	661.39	good
5/23/2008 am	661.38	661.29	661.19	661.22	661.36	661.39	warning
pm	661.26	661.29	661.19	661.22	661.36	661.39	good
5/27/2008 am	661.27	661.29	661.19	661.22	661.36	661.39	good
pm	661.31	661.29	661.19	661.22	661.36	661.39	good
5/28/2008 am	661.37	661.29	661.19	661.22	661.36	661.39	warning
pm	661.33	661.29	661.19	661.22	661.36	661.39	good
	FWHM	Cs137 (661.7 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	2.86	2.10	1.76	1.88	2.33	2.44	check settings
pm		2.10	1.76	1.88	2.33	2.44	not performed
5/21/2008 am	1.83	2.10	1.76	1.88	2.33	2.44	warning
pm	1.95	2.10	1.76	1.88	2.33	2.44	good
5/22/2008 am	1.92	2.10	1.76	1.88	2.33	2.44	good
pm	2.41	2.10	1.76	1.88	2.33	2.44	warning
5/23/2008 am	2.11	2.10	1.76	1.88	2.33	2.44	good
pm	2.33	2.10	1.76	1.88	2.33	2.44	warning
5/27/2008 am	1.72	2.10	1.76	1.88	2.33	2.44	check settings
pm	2.33	2.10	1.76	1.88	2.33	2.44	warning
5/28/2008 am	1.96	2.10	1.76	1.88	2.33	2.44	good
pm	2.00	2.10	1.76	1.88	2.33	2.44	good
	ROI Net C PS	Cs137 (661.7 kev)					
Date	Value	Mean	LCL	LWL	UWL	UCL	Status
5/20/2008 am	151.2	124.6	117.8	120.1	129.1	131.3	out of control
pm		124.6	117.8	120.1	129.1	131.3	not performed
5/21/2008 am	126.8	124.6	117.8	120.1	129.1	131.3	good
pm	127.2	124.6	117.8	120.1	129.1	131.3	good
5/22/2008 am	127.8	124.6	117.8	120.1	129.1	131.3	good
pm	129.8	124.6	117.8	120.1	129.1	131.3	warning
5/23/2008 am	122.6	124.6	117.8	120.1	129.1	131.3	good
pm	125.7	124.6	117.8	120.1	129.1	131.3	good
5/27/2008 am	123.8	124.6	117.8	120.1	129.1	131.3	good
pm	130.0	124.6	117.8	120.1	129.1	131.3	warning
5/28/2008 am	127.1	124.6	117.8	120.1	129.1	131.3	good
pm	128.3	124.6	117.8	120.1	129.1	131.3	good

Table F8. Standard Cs-137 High Energy Source HPGe QC Check Results

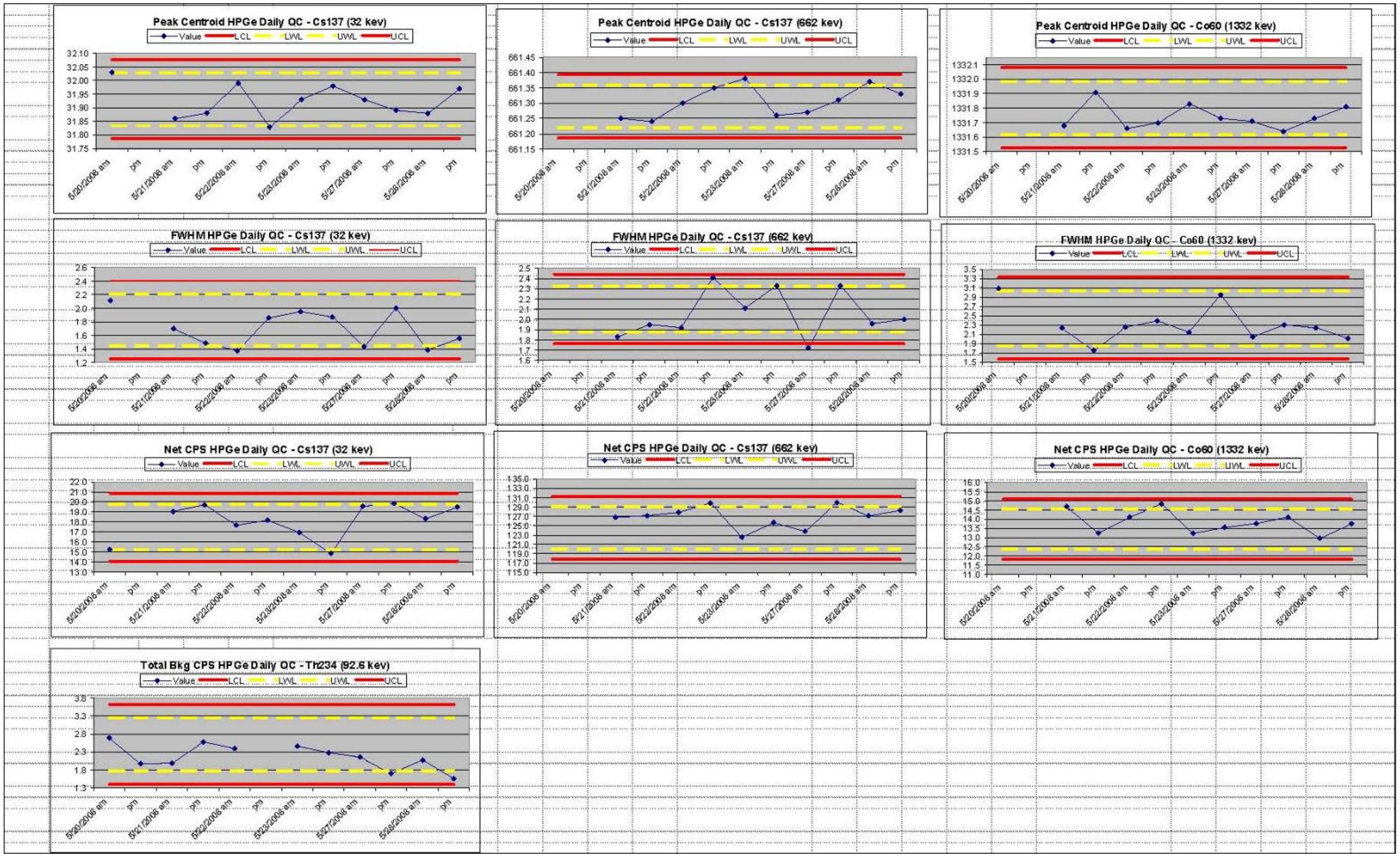


Figure F9. HPGe Control Chart

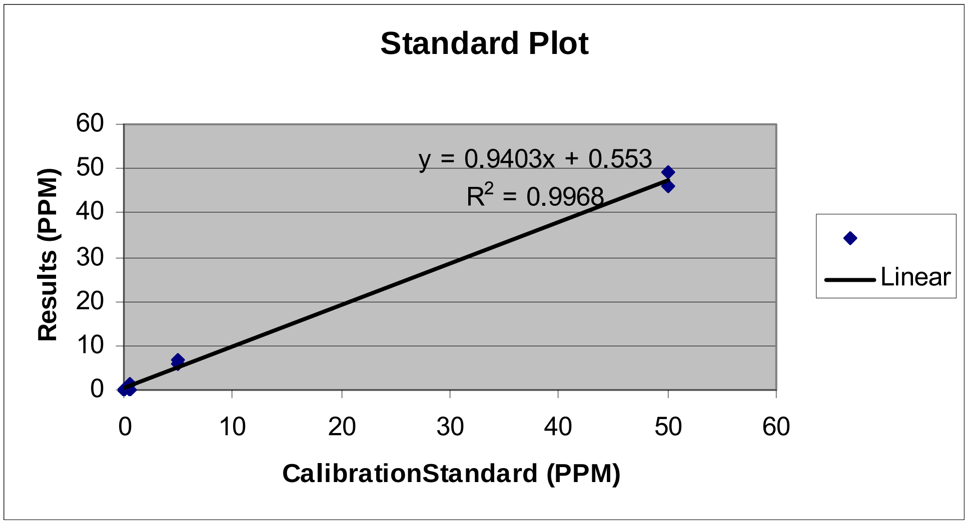


Figure F10. Standard Plot for Test Kits