Deployment of the Fernald Radiation Scanning System (RSS) at the Ashtabula Site

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Accelerated Site Technology Deployment (ASTD) Program

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Table of Contents

Tables

Figures

Executive Summary

In the fall of 2002, with DOE ASTD support, the Radiation Surveying System (RSS) was deployed as part of the Ashtabula Environmental Management Program (AEMP). The RSS is a mobile NaI-based scanning system designed for rapid, complete coverage for soil surfaces. The RSS includes locational control and data logging capabilities. The RSS has been deployed successfully for a number of years at the Fernald site with ASTD support. The RSS provides both gross activity data and radionuclide-specific activity concentration estimates. The deployment of the RSS at the AEMP had several goals. These included to: 1) determine its detection sensitivity for uranium; 2) identify issues that might affect its performance for subsequent deployments at the site; 3) provide information about the contamination status of various areas of the site; and 4) support final status conclusions for selected areas of the site.

As part of the AEMP deployment, the RSS surveyed eight acres of the AEMP and generated more than 20,000 individual measurements. Analysis of system performance indicated the following:

- The RSS was an efficient and effective means for scanning large exposed areas at the site. The RSS identified several previously unknown areas of contamination at the site.

- With appropriate data analysis, the RSS was capable of providing detection sensitivities for total uranium around or below 30 pCi/g using either its total uranium activity concentration data or its gross activity data.

- The RSS's total uranium activity concentration estimates exhibited a negative bias of about 30 pCi/g. This bias would have to be addressed if the system is to be redeployed at the site.

- Gross activity background levels vary significantly across the site as a function of surface type (e.g., exposed subsurface soil, grass, asphalt, gravel backfill, etc.). Effective use of gross activity data requires that this variability be understood and incorporated in the RSS data analysis.

- False positive concerns associated with RSS data can be easily addressed through static readings over potentially contaminated areas identified by scanning.

- As currently configured, the locational data for the RSS contains systematic errors. These should be corrected if the system is to be redeployed at the site.

- Two issues may complicate the deployment of the RSS to support excavation work at the site. The first is accessibility concerns for excavated areas. The second is potential shine or interference issues from dig face walls.

The RSS established that real-time scans combined with a locational control system and logging capabilities have the ability to assist in soil segregation during excavation and soil surface closure post-remediation of the Ashtabula site. An alternative to the 4x4x16 NaI crystal used by the RSS is a FIDLER (Field Instrument for Detecting Low Energy Radiation) deployed as a walkover survey combined with GPS and data logging. The FIDLER would likely have similar or slightly better detection sensitivities, would be operational over a wider range of surface conditions, would be less susceptible to interference problems from dig face walls, and would be cheaper to procure and maintain.

The recommendation is that the AEMP procure FIDLER systems, perform performance evaluation data collection to determine detector sensitivity and best operating procedures, develop excavation and data collection protocols to support future soil remediation and segregation work that incorporate the FIDLER systems, and modify existing final status survey protocols to include FIDLER scans.

1.0 Introduction

1.1 Background

The Ashtabula site falls under the Ohio Field Office, and is on track for closure in 2006. As part of that closure process, soils contaminated with uranium above site-specific cleanup requirements must be excavated and shipped for disposal off-site. While there has been significant soil remediation work completed to date, the remaining contaminated soils pose additional technical complications. The remaining soil contamination is associated with building foundations, at times at depth, and at times covered with clean backfill. Because of the unit cost associated with removal and disposal of the remaining contamination, there is a need for developing more cost effective ways for minimizing off-site waste disposal volumes.

The Department of Energy (DOE) Office of Science and Technology's (OSTD) Accelerated Site Technology Deployment (ASTD) Program is aimed at deploying proven technologies to meet site-specific needs at DOE sites undergoing remediation. With ASTD funding, specialized, proven real-time soil characterization equipment currently in use to support the Fernald cleanup activities was brought to Ashtabula for an initial deployment. The characterization system brought to the site is known as the Radiation Scanning System (RSS). The purposes of this deployment were to:

- Determine RSS detection capabilities for *in situ* soil uranium activity concentration measurements,
- Investigate possible modifications to the system to improve its performance and applicability to Ashtabula's unique circumstances,
- Identify and characterize surficial soil areas at the Ashtabula site that might require remediation for areas where this characterization information was incomplete, and
- Provide final survey information per Ohio Department of Health (ODH) license termination requirements for areas either believed to be clean or that had been previously remediated.

1.2 Report Purpose

The purpose of this report is to summarize the deployment of the RSS system at the Ashtabula site. This summary includes a review of the data collected, an analysis of system performance in light of the deployment objectives and closure needs of the site, and recommendations about the role the RSS, or some variation of the RSS, could play in enhancing the remediation and closure of the Ashtabula site. In particular, this report focuses on the first two deployment objectives. A more complete discussion of the performance of the RSS for the last two deployment objectives can be found in "Summary Report for Radiation Scanning System (RSS)", RTIMP, 2002.

1.3 Report Structure

Section 2 of this report provides a background to remediation activities at the Ashtabula site. This includes a description of the site, contaminants of concern and their action levels, the current base line approach to contaminated soil remediation and closure, and technology needs in the context of the base line approach.

Section 3 provides background to the RSS system. This includes a description of its hardware and software, deployment history at Fernald, and the current calibration process used for the system at Fernald.

Section 4 describes the deployment of the system at the Ashtabula site. This includes a description of the deployment activities and a summary of the data that were collected.

Section 5 provides an analysis of system performance. This includes coverage capabilities, field of view, sensitivity, comparability, and potential deployment complications encountered.

Section 6 summarizes the results of the deployment and performance of the RSS system at Ashtabula. Section 6 includes recommendations about a path forward for enhancing the base line approach to providing data collection support for excavation and closure.

2.0 Ashtabula Site Background

2.1 Site History

The RMI Titanium Extrusion Plant facility (RMI) covers 32 acres, including 25 buildings and pads with a footprint of approximately seven acres. The facility is located in Ashtabula County, Ohio, northeast of the city Ashtabula. Uranium extrusion operations began for the US Atomic Energy Commission in 1962, and continued until 1990. The extrusion plant was the main focal point for these activities. The extrusion plant is currently slated for demolition and disposal. The site has been designated by the DOE Ohio Field Office as the Ashtabula Environmental Management Project (AEMP). Remediation work at the site is underway, with site closure currently projected for 2006.

Figure 2.1 shows the locations of buildings at the AEMP, area designations, and the location of the Corrective Action Management Unit (CAMU) (former evaporation pond). Figure 2.2 provides an aerial photograph of the site before recent demolition of building structures began. Remediation activities at the site have focused on three primary areas: demolition and removal of site structures, excavation and remediation of contaminated soils, and remediation of subsurface soil and groundwater contamination associated with a former evaporation pond (CAMU area).

2.2 Contaminants of Concern

The principal contaminant of concern for soils is uranium. Uranium is assumed to either have isotopic ratios characteristic of natural uranium, or to be slightly depeleted. Remediation activities at the site are governed by a radioactive materials license currently administered by the ODH and an associated decommissioning plan. The decommissioning plan specifies the following free release criteria for surficial soils:

- Total uranium must be less than 30 pCi/g (44 ppm) when averaged over a 100 square meter area.
- All soils must be less than 90 pCi/g (132 ppm) for total uranium.

There are also technetium-99 (Tc-99) concerns at the site. However, apart from the CAMU area, all soil characterization work conducted to date indicates that Tc-99 only exceeds its standards when uranium also exceeds its standards. The majority, if not all, of remaining remediation work for soils will be driven by uranium contamination concerns. Figure 2.3 provides the estimated footprints of excavation work that will be required for Area B, the largest area still requiring contaminated soil remediation, along with soil sample results for total uranium.

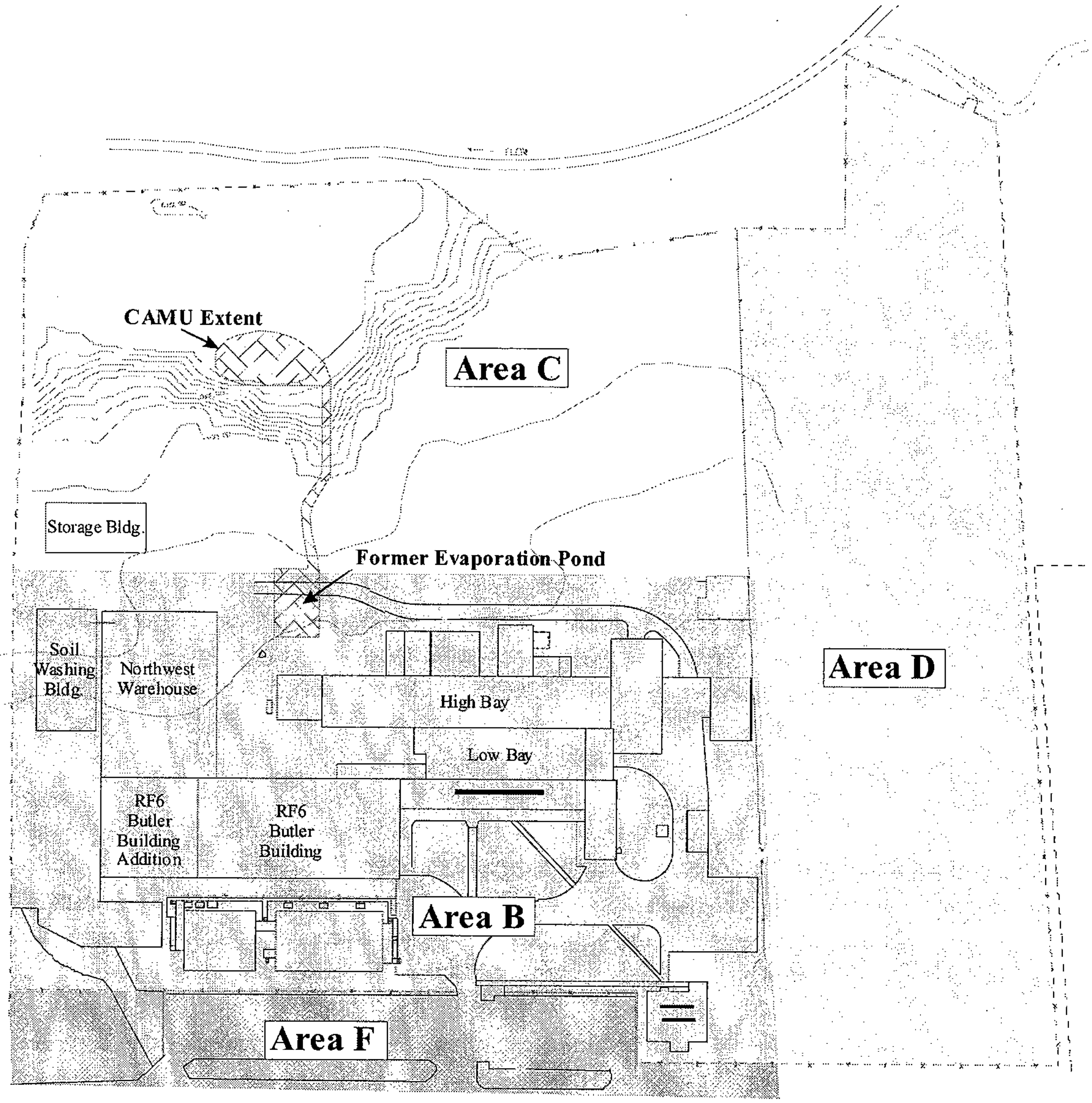

Figure 2.1 AEMP Layout

2.3 Baseline Excavation and Closure Process for Soils

Contaminated soil excavation has taken place at the site in the past so there is a well-established baseline process for conducting this work. This baseline consists of the following process and technologies. Impacted areas are screened using field instruments for open face characterization. This open face characterization includes a combination of the most sensitive field instruments available and *in situ* XRF analysis. Based on these data, excavation footprints are defined and only soils containing measured levels of contamination are remediated. Upon completion of excavation, NaI 2x2 scans are performed to document the final status survey is consistent with the site's closure criteria

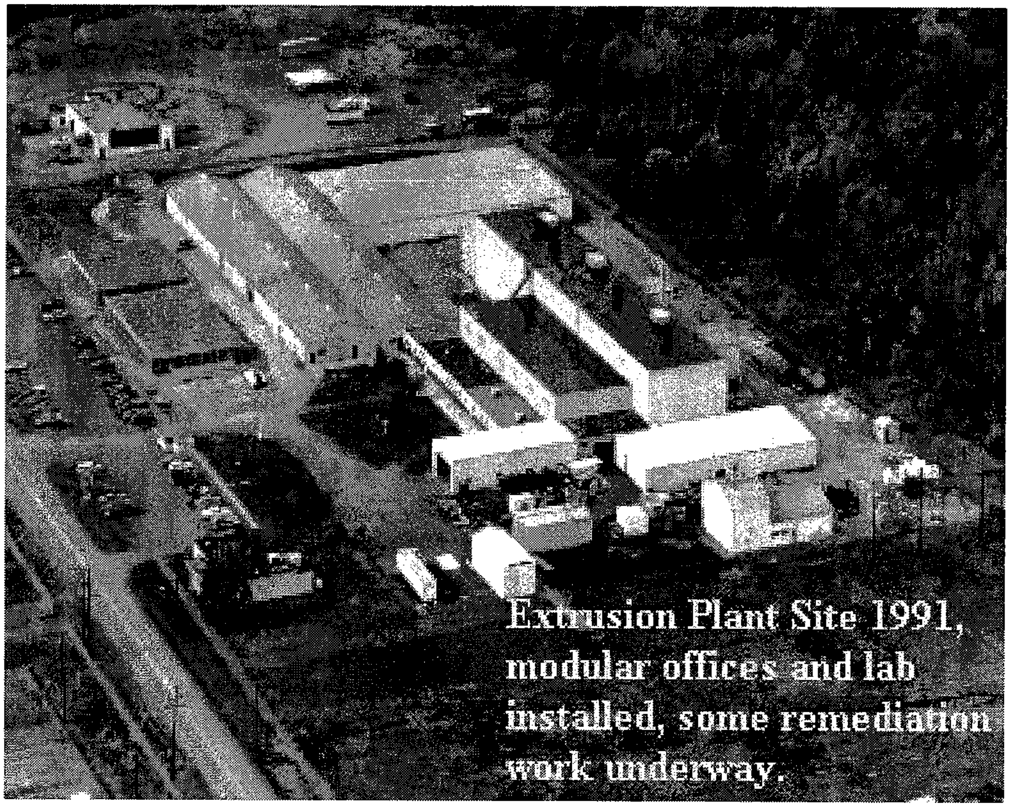

Figure 2.2 Extrusion Plant Site, 1991

(RMIES SOP Final Survey Plan of Soils, RDP-ESH-029). This consists of four samples taken per 100 square meters with the average compared to the site guidelines. Sample locations are either systematically gridded in each quadrant of a 10x10 meter grid, or biased if the NaI identifies an elevated area. In addition, samples are pooled and subjected to a student-t test using the 95% upper confidence level as a point of comparison to the cleanup criteria.

The principal issues with this approach as excavation moves into the remaining areas of the site are:

- More contamination at depth is expected adjacent to buildings, requiring layback that will include a substantial amount of clean soil unless shoring is used;
- Existing data sets used to support contaminated-volume estimates lack sufficient detail to provide accurate footprints suitable for excavation design; and
- Scanning technologies currently in use at the site lack sufficient sensitivity to accurately identify total U concerns around the cleanup guideline.

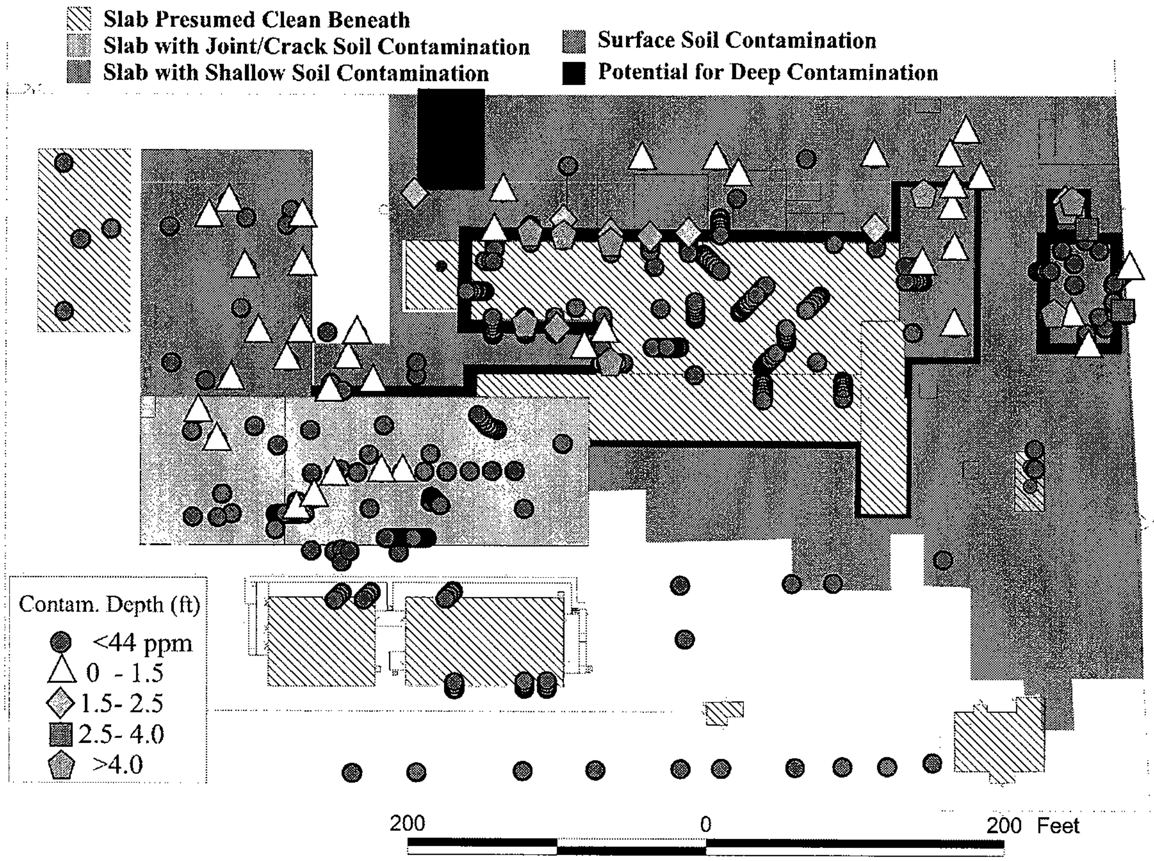

Figure 2.3 Presumed Excavation Footprints in Area B

2.4 Technology Support Needs

As the site moves into its final phases of contaminated soil remediation, the site will require a way to segregate excavated contaminated soils from excavated clean soils. One means for accomplishing this is to screen exposed dig faces to better delineate contamination footprints while excavation progresses. This requires a technology for rapidly and accurately determining the contamination status of soils as excavation work proceeds. In addition, the existence of this kind of technology would simplify the current closure process in use at the site.

The RSS was brought to the site for an initial deployment as a potential system that could fulfill these technology support needs for Ashtabula.

3.0 RSS Technical Description

3.1 Mobile NaI Systems

The RSS system is a specific example of a more generic class of mobile NaI-based gamma surface scanning systems that are coupled with locational control technologies and data logging capabilities. These systems typically have three components: a sensor appropriate for the radionuclide and cleanup levels of concern (e.g., NaI), a means for determining locations of measurements in real-time, and a method for logging, managing and displaying the data that have been collected.

NaI-based scanning systems are well-suited to real-time mobile scans. NaI gamma detectors have excellent efficiency over a broad range of gamma photon energies. This means that with relatively short measurement times (on the order of seconds), these systems can acquire sufficient gamma counts so that gross activity counting errors are minimal. NaI-based detectors come in a variety of sizes and geometries. Common commercially-available examples are the ubiquitous 2x2 inch and FIDLER (Field Instrument for Detecting Low Energy Radiation) detectors. However, NaI crystal sizes range from geometries much smaller than a 2x2 up to large single detectors (such as the devices in use at Fernald) or arrays of detectors. The size and shape of detectors impact their efficiency for particular gamma photons, their "field of view", and the overall number of gamma rays they intercept.

While NaI systems have high efficiencies, allowing for stable gross activity counting statistics with relatively short acquisition times, they have poor energy resolution. Gamma photon energy resolution is key to identifying radionuclides contributing to overall gross gamma activity and quantifying their activity concentrations. Because of poor energy resolution capabilities, most mobile NaI scanning systems are used strictly in a gross activity mode, with no attempt made to perform gamma spectroscopy on the resulting measured spectrum. Other, more complex systems, attempt rough gamma spectroscopy through the use of multi-channel analyzers and calibration equations developed through regression analysis. The success of gamma spectroscopy using a mobile NaI system depends on a variety of factors, including the mix of radionuclides present and the particular radionuclides of concern. For example, the RSS system with a 4 second acquisition time has excellent sensitivity for Th-232, but sensitivity for U-238 is two orders of magnitude worse and susceptible to interference from other radionuclides that might be elevated.

There are a number of different means for providing real-time location information during a mobile scan with a NaI system. These range from differentially corrected Global Positioning Systems (GPS), to civil survey-grade GPS systems, to tracking laser-based systems, to laser broadcasting systems. Costs and complexity vary significantly, and are primarily dependent on the level of accuracy desired. Differentially corrected GPS systems provide positional control with an error of approximately two meters horizontally and tens of meters vertically. Civil-survey grade systems, whether GPS or laser-based, can provide sub-centimeter accuracy in all three dimensions, but at significantly greater costs. The primary value of laser-based systems is their ability to provide 3D location control for excavation work, and their ability to operate even when GPS satellites are not available (for example, inside or adjacent to buildings).

Electronically recording gross activity data along with locational control information provides several important benefits compared to traditional gross activity surveys where the results of surveys were not electronically recorded. These include:

- Enhanced QA/QC of data sets. Logging and mapping scan data after their collection allows the completeness of coverage to be evaluated, as well as potential problems with sensors to be flagged and evaluated.

- Enhanced documentation. Logging and mapping scan data after their collection provide a record of what was done, and visual evidence of anomalies (or lack of anomalies) that can be entered into the closure documentation for a site.

- Enhanced data analysis. Logging scan data allows for post-data collection analysis. This can include aggregating data through moving window averages to further reduce counting errors, identifying suspect areas that might require additional discrete sample collection, and determining and demarcating excavation footprints based on these data.

Key parameters that can be used to characterize or influence mobile NaI system performance include the field of view of the instrument, the acquisition time used, measurement error, and sensitivity to specific radionuclides. The *field of view* refers to the surface area that contributes the majority of gamma photons intercepted and recorded by the instrument. The field of view for common NaI mobile scanning platforms is influenced by the geometry of the crystal used, the distance or height of the sensor from the ground, the speed of the scan, the duration of the scan, any shielding or collimation that is applied to the sensor crystal, the energy levels of the radionuclides of concern, and the shape of the surface being scanned. In general, thin crystal NaI sensors such as a FIDLER will have smaller fields of view than something like a 2x2 inch NaI sensor. The higher a sensor is above the ground, the greater the field of view. The higher the energy levels of gamma rays from the radionuclides of concern, the larger the field of view. The greater the shielding or collimation used, the smaller the field of view. The faster the pace of the scan and/or the longer the acquisition time, the greater the field of view.

Fields of view are important in the context of the cleanup goals that must be met. For example, an instrument with a field of view of 100 square meters will likely not be appropriate for detecting hot spots where hot spot sizes are a square meter or less. Conversely, individual readings from an instrument with a field of view of one square meter would provide limited information about a cleanup criteria that was averaged over 100 square meters. Finally, it is important to remember that the gross activity recorded by an instrument is an area-weighted average of activity over its field of view. Area-weighted simply means that soils directly beneath the detector will contribute relatively more activity to the recorded reading than soils on the edge of the field of view.

The *acquisition time* of an instrument refers to the duration of a measurement. For some systems the acquisition time can be varied over a broad range of values. For other systems there may be only discrete choices for acquisition times. Acquisition time is important because it plays a key role in determining the *measurement error* associated with system measurements and the field of view for mobile scanning systems. For gross activity, the observed error in repeat stationary measurements varies as the square root of the number of counts recorded. As measurement times increase, the relative error associated with the measurement decreases. In a similar fashion, as the field of view increases (resulting in more "counts" captured per measurement), the relative error associated with the measurement decreases. For a moving system, increasing acquisition times is synonymous with increasing the field of view.

Most mobile NaI scans focus on detecting gross gamma activities in surficial soils that are elevated above background levels, indicating contamination is present. A fundamental question for mobile NaI scans is how *sensitive* the instrument is to elevated levels of the radionuclides of concern. To flag a reading as indicative of contamination means that the reading is high enough that it likely is not representative of the natural variability one would see when measuring background conditions. This is true both for gross activity measurements and for isotope-specific activity concentration estimates obtained via gamma spectroscopy. There are two contributors to the overall variability observed in gross gamma measurements. The first is attributable to the measurement error associated with repeat measurements of the same location. The second is the natural variability that is present across an area in background gross activity levels. The first error can be reduced by increasing acquisition times. The second cannot be reduced by changing system parameters. In general, when measuring gross activity with commonly used mobile NaI systems and acquisition times, natural variability in background gross activity levels is significantly greater than measurement error.

Figure 3.1 is adapted from MARSSIM's Figure 6.2. Figure 3.1 illustrates the concepts of detection sensitivities for scanning systems that measure gross activity. The probability distribution to the left represents what one might expect from a detector scanning soils at background levels. The probability distribution to the right represents what one might expect from a detector scanning soils with an elevated average activity of L_D. The critical level (or L_C) refers to the level of gross activity that, if encountered, is likely to represent radionuclide levels that are above background. Any observed activity above this level is considered to be greater than background. Alpha refers to the probability of a background measurement actually yielding a detector response greater than L_C. The detection limit or sensitivity (L_D) refers to the level of gross activity that can be reliably differentiated from background. Beta refers to the probability of an elevated measurement (where the true level is L_D) actually yielding a detector response less than L_C. Usually alpha and beta are required to be 0.05. If one has a means of relating incremental gross activity to pCi/g for the radionuclide of concern, one can convert both L_C and L_D to corresponding activity concentrations.

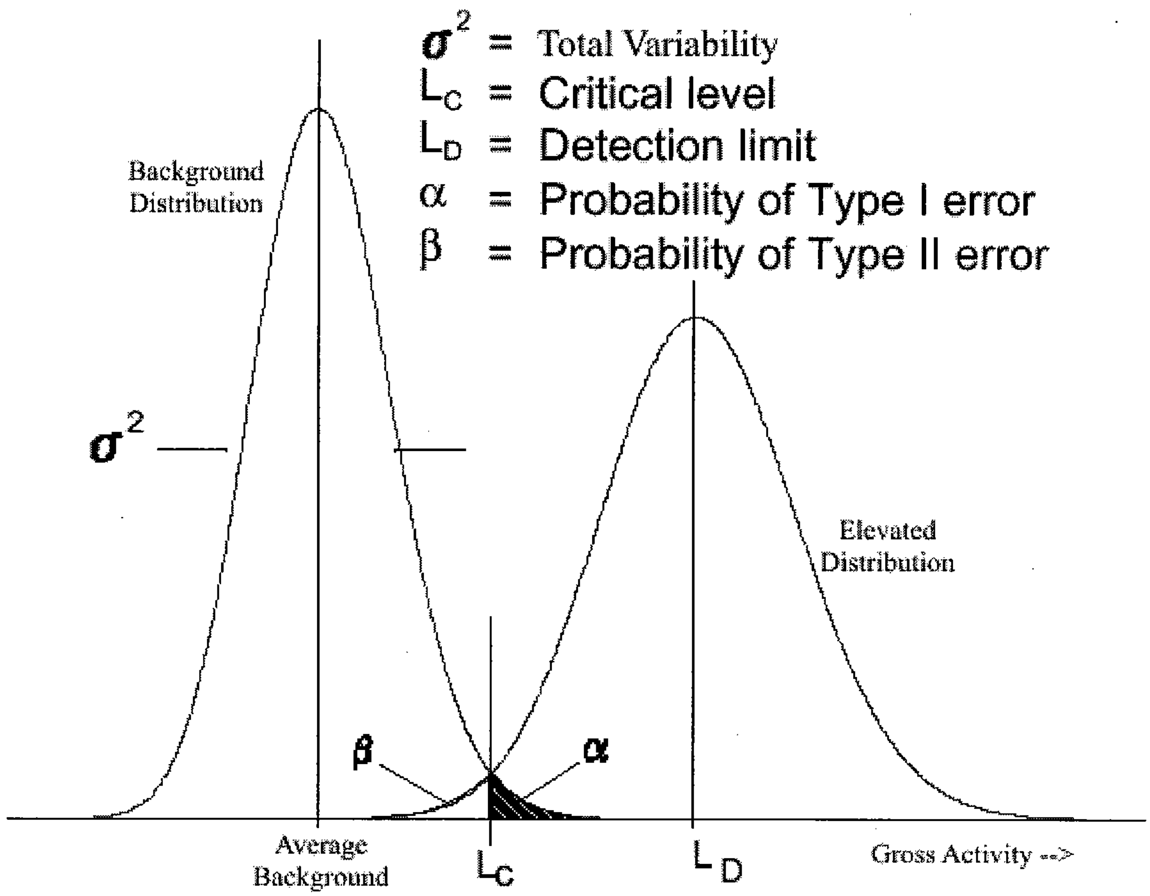

Figure 3.1 Relationship Between Variability and Instrument Sensitivity

Total variability, or sigma, refers to the total variability one sees in background measurements, which is a combination of measurement error and the natural variability present. Detection limits are lowered by reducing the total variability of measurements. For NaI systems, natural variability in background gross activity levels is usually much larger than measurement error. Consequently, the best way for lowering detection limits for NaI gamma scans is to control the natural variability one observes in background concentrations. This is done by ensuring that average background gross activity estimates are developed for each type of surface that one would expect to encounter across a site. For example, the investigation level and detection limit developed for a site where asphalt cover was pooled with grassy areas would be worse than if investigation levels and detection limits were developed individually for asphalt and grassy areas.

There is also a generic set of environmental factors that can affect system performance. These include moisture content, the actual distribution of contamination vertically and horizontally, surface geometry irregularities, variations in background activity concentrations for common naturally occurring radionuclides, and atmospheric conditions. As moisture content increases, observed gross activity levels will decrease. Since cleanup criteria are typically assumed to apply to dry soils, saturated soil conditions can result in underestimating contamination levels unless corrections are made for moisture content. The actual distribution of contamination vertically and horizontally also affects system performance. NaI system response to contamination that is overlain by a layer of clean soil will be different than if contamination is evenly distributed vertically, even if the average activity concentration values are the same over the vertical profile. Variations in background activity concentrations introduce variability into the background gross activity levels observed, which in turn affects system sensitivity and detection limits. Surface geometry irregularities also impact performance. For example, the performance of a detector will be different for a flat surface than in a trench, or against the sidewall of an excavation. Finally, atmospheric conditions can play a role if there is a significant amount of radon gas emanating from a site's soil, resulting in either "pooling" of radon along surface soils or dispersal.

3.2 RSS System Hardware/Software Components

The RSS system is a mobile NaI scanning system developed for use at the Fernald site. It is one of a family of systems employed at Fernald, which include the RTRAK, the Gator, and the EMS system. All are similar in that they make use of a large (4x4x16 inch) NaI sensor coupled with a multi-channel analyzer, differentially-corrected GPS, and a laptop computer for collecting and analyzing scan data. They differ in the platform they are mounted on. The RTRAK makes use of a modified tractor. The Gator employs a six wheel all terrain vehicle. The EMS is a specialized attachment used with an excavator. The RSS is based on a "baby buggy" (Figure 3.2), a three wheel platform that is pushed by a technician during data collection. The operational parameters of all of these systems are very similar, with slightly varying sensitivities that are a product of the unique characteristics of the NaI crystals used and the shielding introduced by their platforms. They are all calibrated in a similar fashion, and at the Fernald site are deployed for basically the same function. For Fernald, the particular realities of the surfaces to be scanned (i.e., large open flat areas, steep excavated walls, rough excavation surfaces, etc.) dictate which platform is employed. The systems are custom built for use at Fernald, although the components are commercially available equipment.

The RSS and its sister systems are uncommon in that they are scanning systems capable of both measuring gross gamma activity and providing limited gamma spectroscopy capabilities. The output from an RSS scan includes gross activity and isotopic activity concentration estimates for thorium-232, radium-226, and uranium-238. The latter is converted to total uranium estimates (ppm) based on presumed isotopic ratios for uranium isotopes at the site. The radionuclide-specific activity concentration estimates are automatically corrected for soil moisture content, assuming that one has a means for measuring soil moisture content. Based on calibration information obtained prior to the deployment of the RSS at the AEMP, the *a priori* radionuclide-specific activity concentration detection limits for the RSS with a four second reading were approximately 1.5 pCi/g for Th-232, 6.6 pCi/g for Ra-226, and 221 pCi/g for total uranium.

Figure 3.2 RSS System

The typical deployment of the RSS at the Fernald site involves mobile scans with 4 second acquisition times at speeds of approximately 1 mph. With a stationary field of view radius equal to 1.2 meters, this results in a field of view for each measurement that is oblong in shape, approximately 8.8 square meters in size. Scans are conducted along parallel lines, with line spacing set so that the consecutive fields of view overlap, providing complete coverage of the site. With the line spacing used at Fernald, the RSS can cover approximately one acre per hour of continuous operation.

3.3 Deployment History

The RSS and its sister NaI systems have been used extensively to support remediation and closure work at Fernald. At Fernald, the mobile NaI systems serve several distinct purposes. These include pre-remedial design support, Waste Acceptance Criteria (WAC) compliance verification, and hot spot compliance verification during site closeout. At the Fernald site the primary radionuclide of concern for soils is uranium. The cleanup level for most of the site is 82 ppm (55 pCi/g) for total uranium. Soils that exceed the cleanup criteria are excavated and placed for disposal in the on-site disposal facility (OSDF). The OSDF has a WAC for total uranium that is equal to 1,030 ppm (690 pCi/g). Soils that exceed this level must be segregated and disposed off-site. Because the OSDF needs soil to buffer building debris and because of the relatively low disposal costs associated with the OSDF, at the Fernald site there has not to date been an emphasis on soil waste stream minimization. Instead the emphasis has been on WAC identification during excavation and demonstrating compliance with cleanup criteria once excavation is complete.

While the detection limits for the RSS as currently used at the Fernald site are not sufficient to detect total uranium at 55 pCi/g, the system can readily detect soils that are above both the WAC and "hot spots" critieria. As currently used at the site, the RSS and its sister systems scan each excavated soil lift for above WAC soils, allowing for segregation if encountered. After excavation work is complete, the RSS and its sister systems demonstrate that hot spot compliance has been achieved. Final certification or verification that all cleanup goals have been achieved is attained through discrete sampling of the exposed surface.

The RSS and its sister systems have undergone extensive calibration and performance verification work. These include calibration studies, baseline comparability studies, applicability studies and cost evaluation studies. In general these have demonstrated that the RSS and its sister systems provide data of sufficient quality to meet the performance objectives of the FEMP. In particular, the cost studies have demonstrated significant analytical laboratory cost savings as compared to data collection programs based solely on discrete sample collection and analysis.

3.4 Current Calibration Process

The Fernald mobile NaI systems are calibrated using a special pad constructed for this purpose. The calibration pad is a circular area with a regular array of embedded "cups" that allow for the placement of sources. By placing different sources of known strengths in the calibration pad and measuring NaI system response, calibration equations have been developed that convert measured activity in particular energy windows into radionuclide-specific activity concentrations. The three sources used for calibration are Th-232, Ra-226, and U-238. This calibration process also provides insights into gross activity response to incremental increases in Th-232, Ra-226 and U-238 activity concentrations.

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4.0 RSS Ashtabula Deployment

The RSS was brought from Fernald in the fall of 2002 for deployment at Ashtabula. The deployment was intended to satisfy several goals, as specified in Section 1.0. To meet these goals, a number of deployment activities were undertaken. These included a system calibration, site surveys, and stationary readings over selected locations. Overall, 20,565 individual measurements were collected and logged by the RSS system during the AEMP deployment. During the deployment, soil moisture estimates were obtained for the areas being scanned by collecting physical soil samples and determining their soil moisture content. The RSS system uses soil moisture estimates to automatically convert isotopic activity concentration estimates to dry weight standards, which is how cleanup criteria are defined for the AEMP.

4.1 Calibration

The RSS system used at the AEMP was calibrated on October 1, 2002, using the calibration pad at the FEMP. Calibration consisted of acquiring four sets of static readings over the calibration pad, with each reading including 300 seconds of live acquisition time. One reading was a background reading. For the second reading, the pad was loaded with Th-232 sources at an average activity concentration equivalent to 9.045 pCi/g over the RSS's field of view. For the third reading, the pad was loaded with Ra-226 sources at an average activity concentration level equivalent to 20.37 pCi/g over the RSS's field of view. For the final reading, the pad was loaded with U-238 sources at an average activity concentration level equivalent to 326.5 pCi/g over the RSS's field of view. The detector's response for predefined energy stripping windows was measured in each case. Table 4.1 summarizes the data obtained from the calibration. The results from all four acquisitions were then combined and analyzed using regression techniques to develop linear predictive equations for isotopic activity concentration estimates for Th-232, Ra-226 and U-238.

Background for the pad was determined to be 2,186 cps. The incremental counts per pCi/g for total uranium, Ra-226, and Th-232 were determined to be 9.4 cps, 646 cps, and 799 cps, respectively. In addition, a low-energy stripping window was applied to the calibration data (30 – 210 kev) in an attempt to focus on that energy range most appropriate for uranium and its daughters. Background for the pad for this low-energy window was 1,200 cps. For this low-energy stripping window, the incremental counts per pCi/g for total uranium, Ra-226, and Th-232 were determined to be 5.2 cps, 277 cps, and 344 cps, respectively.

4.2 Site Surveys

The RSS system was used at the AEMP to provide surface scans for several site areas encompassing approximately 8 acres of unaffected, un-remediated but affected, and remediated areas. These included:

Platform	Location	Source	Equiv. Aver. Activity (pCi/g)	Live Time	Real Time	Date Collected	gross counts	30-210 keV gross cts
RSS2	CalPad	U-238	326.5	300s	389	10/1/2002	2505221	1387559
RSS2	CalPad	Ra-226	20.37	300s	391	10/1/2002	4602419	2053074
RSS2	CalPad	Th-232	9.045	300s	390	10/1/2002	2824955	1293916
RSS2	CalPad	Background	NA	300s	388	10/1/2002	655918	360139

Table 4.1 Selected Calibration Results

Area F: Area F is an unaffected area outside the Extrusion Plant Controlled Area fence. Area F includes a parking lot, and runs parallel to East 21st Street. 100% of the soil surfaces within Area F were surveyed from the Controlled Area fence up to the shoulder of East 21st Street.

Area B Yard: Area B Yard is an affected area inside the Extrusion Plant Controlled Area fence. The yard area had not been previously remediated and includes asphalt sidewalks and some areas know to contain contaminated soil. 100% of the unremediated soil surfaces within the Area B Yard were surveyed.

Area D: Area D is an affected area where previous remediation work had been performed to remove a contaminated outfall pipe. Subsequent to remediation, portions of Area D were backfilled using clean soil from the Soil Washing Facility treated soil. 100% of the soil surfaces that had not been remediated and/or backfilled were surveyed.

Area Upper C: Area Upper C is an affected area that had been partially remediated. This remediation had included removing (grubbing) approximately 9 inches of soil. The western portion of Upper C is primarily clay soil, and the eastern half of Upper C includes a thin topsoil surface on top of the clay substrata.

Area B Restricted Area: RSS measurements were performed in a portion of the Area B Restricted Area known to contain contaminated soil. These measurements were performed to establish locations for sampling to validate the accuracy of RSS *in situ* measurements. The area surveyed is an area of minimal surface soil disturbance located between the Main Extrusion Plant and RF-6 Building pads.

Area E: Area E is an unaffected area that had been previously surveyed for unrestricted use. However, a portion of Area E had been used to store equipment and contaminated pipe during remediation of Area D. Therefore, the portion of Area E affected by Area D work (i.e., area used to store contaminated pipe) was 100% surveyed.

Main Plant Pad: The Main Plant concrete pad is what remains of the original Main Plant building. The concrete surface is believed to be contaminated with uranium. The RSS was used to scan portions of the Main Plant pad.

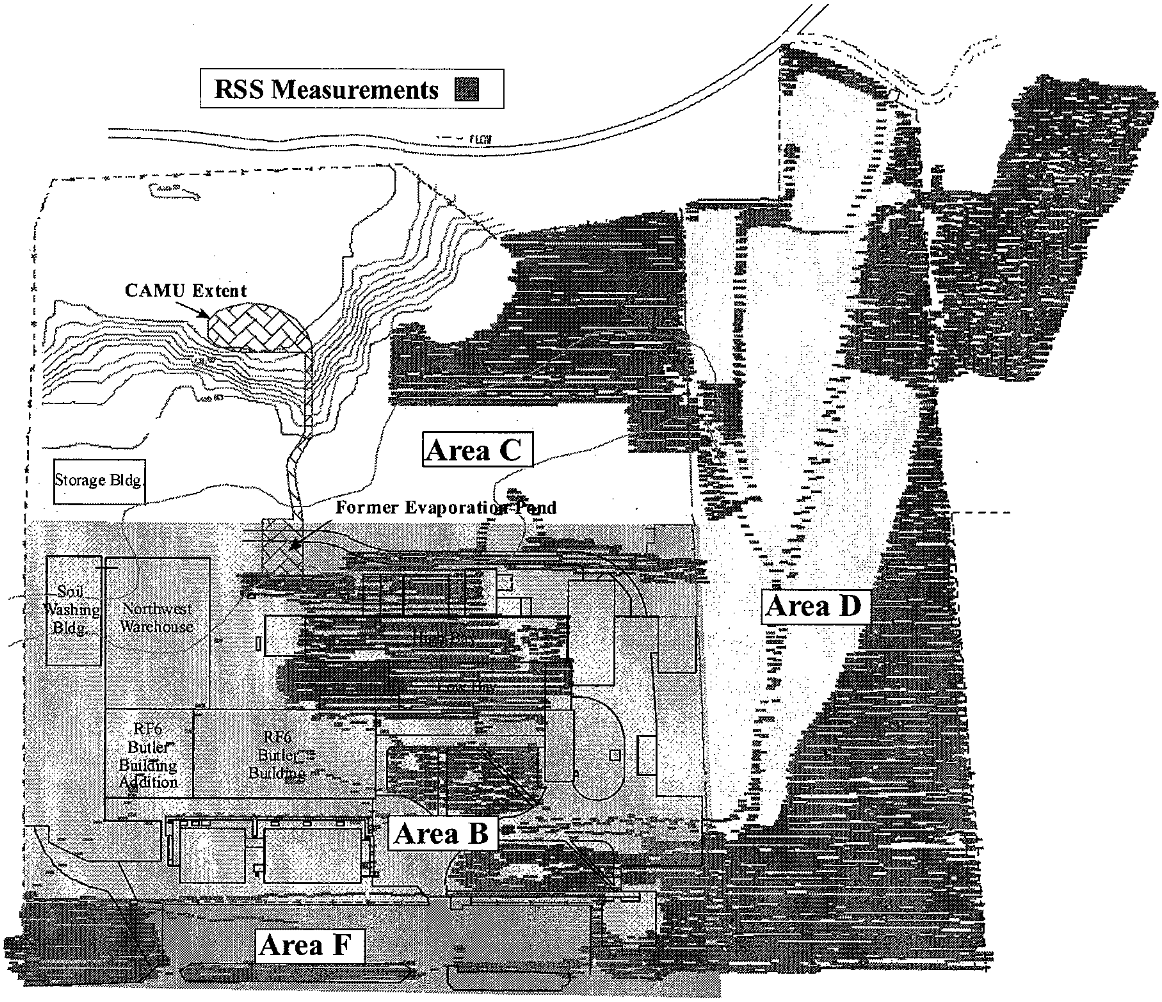

Figure 4.1 RSS Coverage for the AEMP Deployment

Figure 4.1 contains a posting plot that shows the footprint of RSS coverage for the AEMP. Most surveys were conducted at a speed of 1 mph with a distance of approximately 1 meter between scan lines. With a four second acquisition time, this resulted in an approximate measurement density of 1 measurement for every 2 m^2. Each measurement yielded a location (latitude and longitude), a gross activity value, an activity level associated with a low-energy stripping window, and moisture-corrected isotopic activity concentration estimates for total uranium, thorium-232, radium-226 and potassium-40.

Figure 4.2 shows the RSS results color-coded by the gross activity (counts per second) observed. As Figure 4.2 clearly demonstrates, the RSS is quite capable of identifying relatively small variations in gross activity levels, whether those are attributed to changes in surface type (e.g., grass, concrete, asphalt, etc.) or elevated levels of uranium.

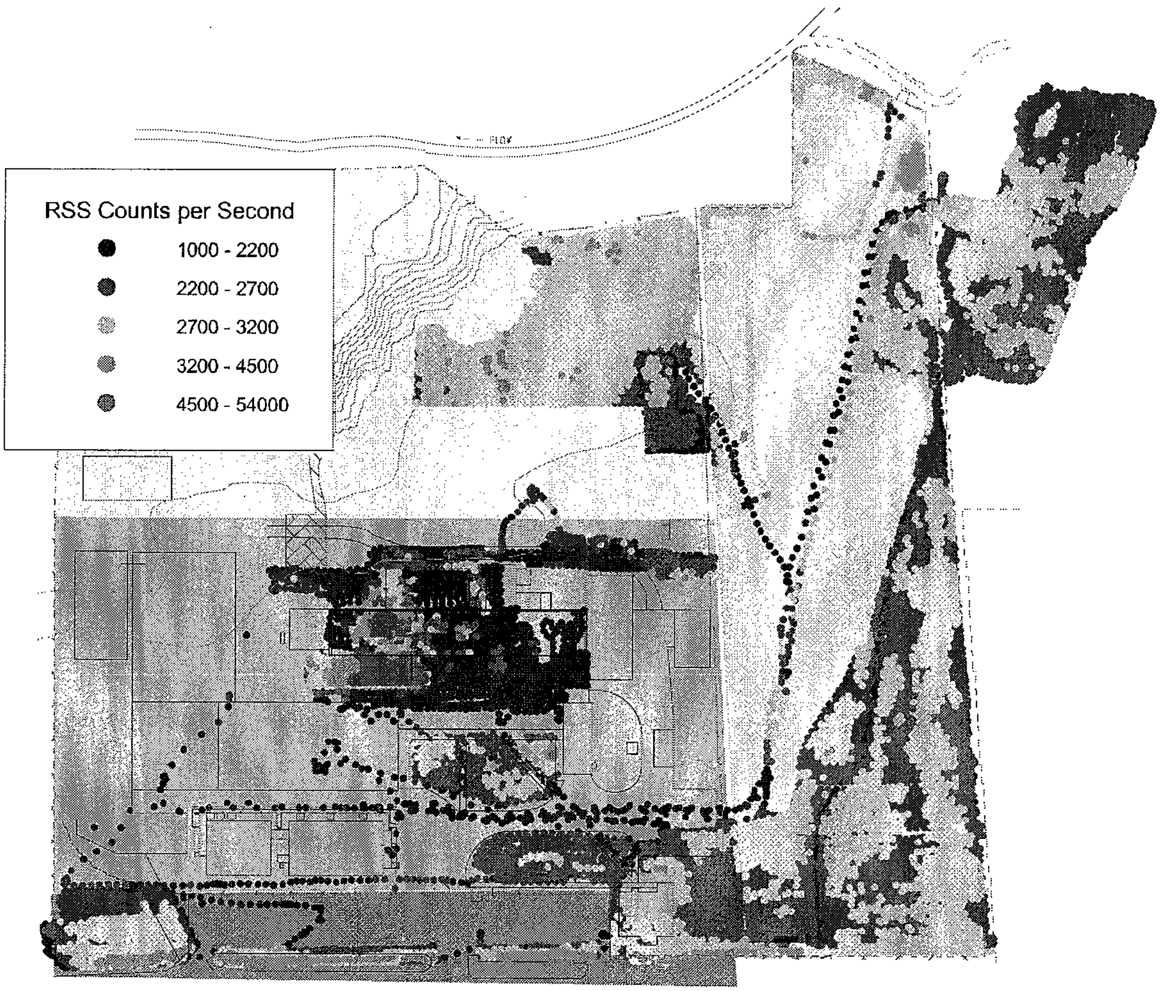

Figure 4.2 RSS Measurements Color-Coded by Gross Activity

4.3 Stationary Readings

Stationary readings were taken at a number of locations where scans identified elevated readings. The acquisition times for these ranged from 60 to 600 seconds. Forty one stationary measurements were collected in all. Their results can be found in Table 4.2. Table 4.2 also contains the results from gamma spectrometry analysis of surface samples collected from the same locations where available. Samples were collected to investigate unexpected elevated readings the RSS identified, to provide comparability data in areas where contamination was known to exist (e.g., Area B Restricted Area), and to evaluate detection sensitivity of the instrument. Figure 4.3 shows a subset of the RSS stationary reading locations, those that had GPS coordinates.

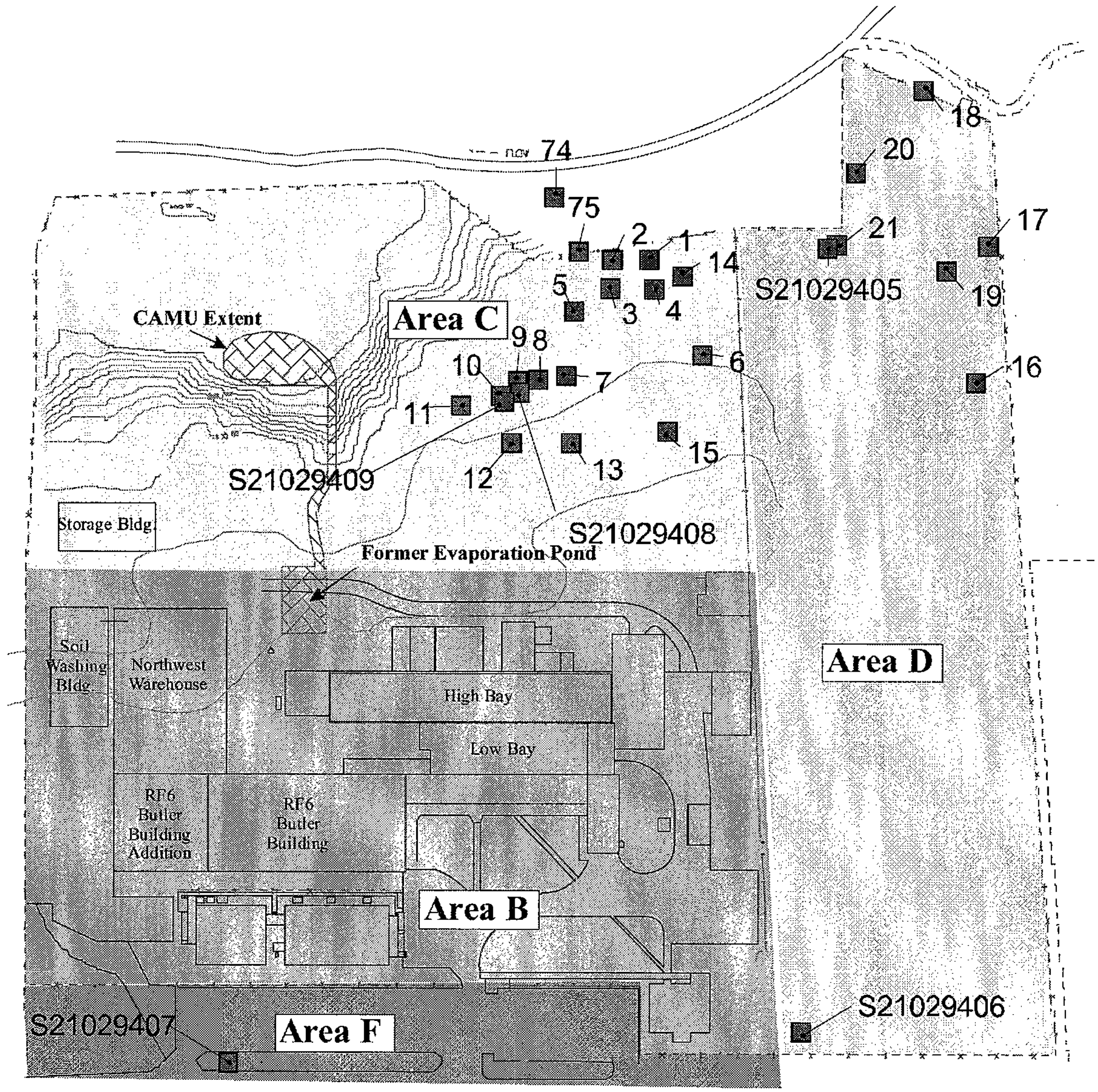

Figure 4.3 Locations of Stationary RSS Measurements

Table 4.2 Stationary RSS Measurement Results

Date	Time (sec)	Sample ID	Northing ft	Easting ft	RSS Gross Activity cps	RSS Ra226 pCi/g	RSS Th232 pCi/g	RSS Total U ppm	RSS Total U pCi/g	RSS 30-210 keV Gross Activity cps	Gamma Spectr. Total U pCi/g	Gamma Spectr. % Moisture Content
18Oct021	600	S21018404	NA	NA	4916	2.6	3.0	520	349	2765	489	25.9
18Oct021	600	S21018404	NA	NA	4926	2.9	2.9	471	316	2516	489	25.9
18Oct021	600	S21018405	NA	NA	3960	2.1	2.1	397	266	2065	396	27.6
18Oct021	600	S21018406	NA	NA	6160	1.3	1.2	677	454	3742	2661	22.9
18Oct021	600	S21018407	NA	NA	3161	1.2	0.9	192	129	1928	172	16.6
21Oct021	600	S21021403	NA	NA	3750	1.5	1.9	482	323	1992	278	18.3
21Oct021	600	S21021404	NA	NA	4156	2.0	1.9	562	376	2338	193	16.9
21Oct021	600	S21021405	NA	NA	3505	1.7	1.8	418	280	1648	110	15.8
21Oct021	600	S21021406	NA	NA	6996	2.0	1.9	1465	982	3709	524	26.8
21Oct021	600	S21021407	NA	NA	5433	2.3	2.4	933	625	3324	376	17.3
21Oct021	600	S21021408	NA	NA	7394	1.5	2.1	1570	1052	4409	1243	28.4
25Oct021	300	R1	NA	NA	2957	1.4	1.6	-82	-55	1534	NA	NA
25Oct021	60	1	815197.5	2469403	3063	1.9	1.8	-99	-67	1456	NA	NA
25Oct021	60	2	815196.9	2469366	3077	0.9	1.7	-80	-54	1581	NA	NA
25Oct021	60	3	815168	2469364	3052	1.5	1.5	-63	-42	1451	NA	NA
25Oct021	60	4	815167.4	2469408	2948	0.4	1.4	-103	-69	1568	NA	NA
25Oct021	60	5	815144.8	2469327	2931	1.2	1.4	-17	-11	1632	NA	NA
25Oct021	60	6	815100.6	2469458	2982	1.4	1.9	-90	-60	1419	NA	NA
25Oct021	60	7	815079.5	2469319	3053	2.2	2.0	-95	-64	1577	NA	NA
25Oct021	60	8	815075.3	2469291	2976	2.0	1.6	-42	-28	1487	NA	NA
25Oct021	60	9	815073.6	2469270	3019	1.4	1.7	30	20	1693	NA	NA
25Oct021	60	10	815059.1	2469253	2859	1.9	1.4	-36	-24	1370	NA	NA
25Oct021	60	11	815048.7	2469212	2981	0.4	1.0	-5	-3	1525	NA	NA
25Oct021	60	12	815010.9	2469264	2894	1.6	1.6	-17	-12	1468	NA	NA
25Oct021	60	13	815010.9	2469324	2916	0.9	1.7	-88	-59	1564	NA	NA
25Oct021	300	14	815181.2	2469437	2892	1.4	1.7	-119	-79	1376	NA	NA
25Oct021	300	15	815023	2469422	2488	1.3	1.3	-36	-24	1354	NA	NA
25Oct021	60	16	815073	2469736	2792	2.0	1.2	23	15	1549	NA	NA
25Oct021	60	17	815212	2469748	3138	1.0	1.6	-161	-108	1466	NA	NA
25Oct021	60	18	815371	2469681	3099	2.4	1.5	-17	-11	1675	NA	NA
25Oct021	60	19	815187	2469706	2951	1.7	1.8	-34	-23	1571	NA	NA
25Oct021	60	20	815287	2469614	2891	1.2	1.6	-27	-18	1441	NA	NA
25Oct021	60	21	815213	2469594	3001	1.2	1.7	-108	-72	1493	NA	NA
28Oct021	300	74	815261	2469307	3234	1.1	0.9	1	1	1669	NA	NA
28Oct021	300	75	815206	2469332	3026	1.1	1.0	20	13	1672	NA	NA
28Oct021	300	S21029405	815210	2469585	2940	0.6	0.9	-14	-10	1567	11	18.4
29Oct021	300	S21029406	814409	2469560	2247	2.5	2.7	-61	-41	1214	6	25.7
29Oct021	300	S21029407	814377	2468975	3579	5.7	8.2	-46	-31	1858	8	11.1
29Oct021	300	S21029408	815062	2469272	3472	1.0	1.2	136	91	1801	217	24.5
29Oct021	600	S21029408	815062	2469272	3482	1.0	1.2	136	91	1912	217	24.5
29Oct021	600	S21029409	815053	2469256	3443	1.2	1.2	150	101	1878	260	28.2

5.0 Performance Analysis

There are a number of performance parameters important to the AEMP when considering the success of the RSS deployment at the site, and possible limitations or issues. These include coverage rates, field of view, instrument sensitivity, comparability, and logistical issues. The following sections discuss each of these in turn in light of the results obtained from the RSS deployment at the AEMP.

5.1 Coverage Rates

As deployed at the site (with a scan speed of 1 mph, a scan line spacing of approximately one meter, and four-second acquisition times), the RSS produced one measurement for every 2 square meters. At this rate of coverage, the RSS is capable of covering an acre in a little less than four hours of constant scan time.

5.2 Field of View

The field of view for static RSS readings is approximately 5 square meters. When moving at 1 mph with a four-second acquisition time, the field of view is approximately 9 square meters. As deployed at the site, there is significant overlap for the fields of view from consecutive and adjacent RSS measurements. Aggregating approximately 50 adjacent measurements provides an equivalent overall field of view equal to 100 square meters, which is the definition of the averaging area applied to the AEMP's total uranium activity concentration cleanup requirement. The field of view for both a static and mobile RSS scan are significantly greater than the fields of view associated with smaller NaI systems such as a FIDLER. The result is that a small NaI system such as a FIDLER can provide greater spatial resolution in its scanning measurements than the RSS can. Whether this provides any significant benefit to the AEMP depends on scanning performance requirements. Although the AEMP has an operational elevated area standard (three times the cleanup criteria for total uranium), this standard lacks an area definition. This lack of an area definition makes it difficult to determine whether the relatively finer spatial resolution offered by a FIDLER scanning system provides better performance for hot spot identification than the RSS.

5.3 Isotopic Activity Concentration Detection Limits

Based on the calibration and subsequent error analysis, the *a priori* minimum detection limits for isotopic activity concentrations (dry weight) for the RSS were estimated to be 221 pCi/g, 6.6 pCi/g, and 1.5 pCi/g for total uranium, Ra-226, and Th-232, respectively, assuming a four second acquisition time. An alternative means for estimating isotopic activity concentration detection limits is through the analysis of repeat static measurements. During the deployment of the RSS at the AEMP, there were a number of instances when the RSS was stationary while logging sequential four-second measurements. More than 40 distinct locations had at least ten or more sequential measurements collected while the RSS was stationary. An analysis was done of

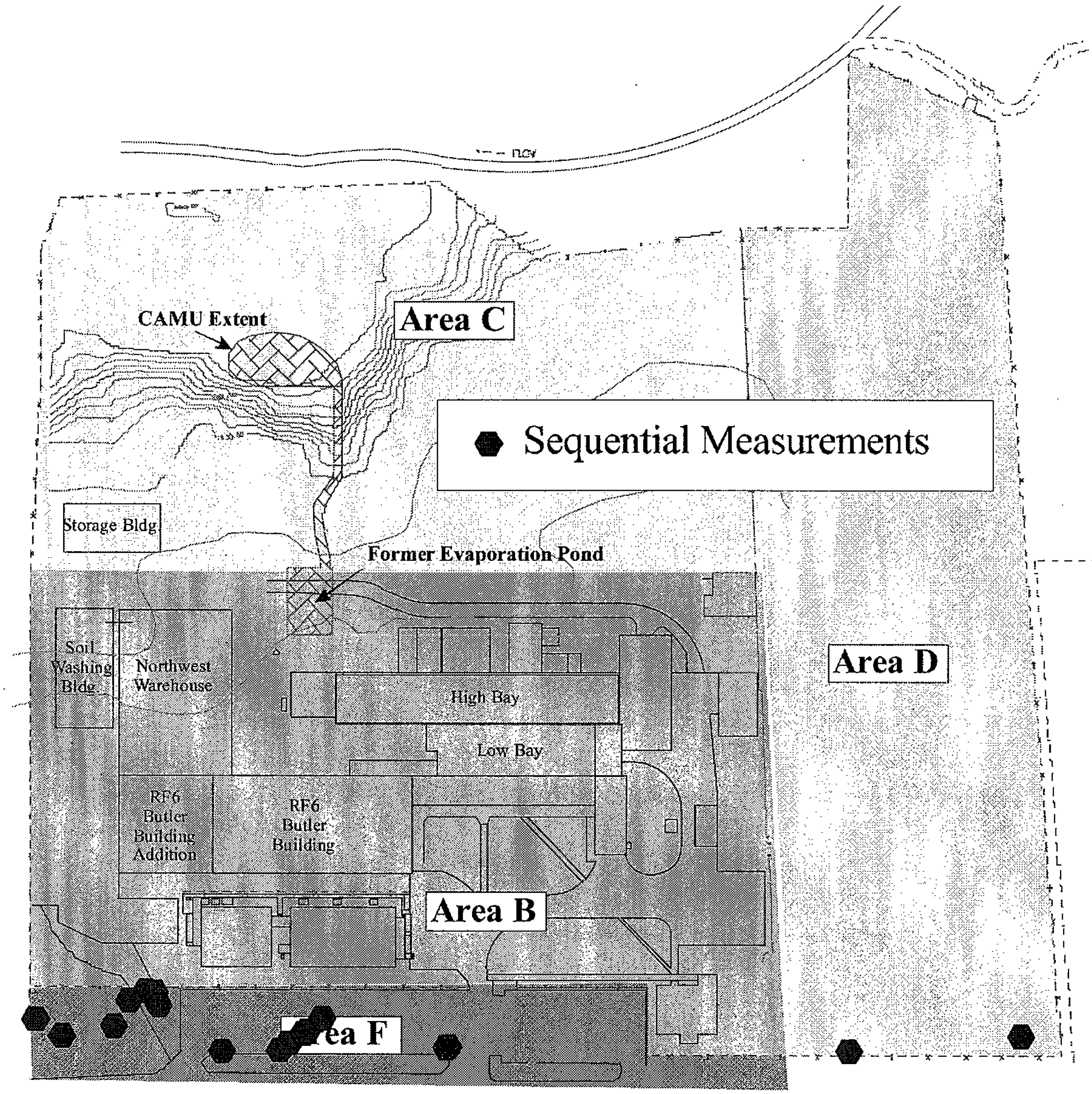

Figure 5.1 Locations of Static Sequential Readings

seventeen of these cases. Figure 5.1 shows their locations. Each of these was in an area where total uranium activity concentrations were expected to be at or near background levels.

The average total uranium activity concentration reported by the RSS for these eleven locations (comprising almost 700 individual readings) was -27 pCi/g. The average standard deviation observed among multiple measurements for each location was 52 pCi/g. Setting alpha to 0.05, the critical activity concentration for the RSS would be 86 pCi/g. The critical concentration assists in identifying RSS results that are likely associated with elevated total uranium. Setting beta to 0.05, the observed detection sensitivity for the instrument was 171 pCi/g, which is slightly better than the value calculated from calibration pad data. This detection limit means that if one sets an investigation level at the critical concentration (86 pCi/g) for total uranium and if the actual concentration is 171 pCi/g for a particular location, that location would be flagged by the RSS 95% of the time.

For gamma spectroscopy, detection limits can be improved by increasing acquisition times. For total uranium, acquisition times would have to be increased to 16 seconds in order to achieve isotopic activity concentration detection limits less than 90 pCi/g (site hot spot criteria), and to 132 seconds in order to achieve isotopic activity concentration detection limits less than 30 pCi/g (100-square-meter requirement) for total uranium. In the case of 16 seconds of acquisition time, this is equivalent to aggregating four individual four-second readings and averaging their total uranium activity concentration estimates. In the case of 132 seconds of acquisition time, this is equivalent to aggregating 33 individual readings and averaging their total uranium activity concentration estimates. Because of overlapping fields of view, aggregating four individual readings would produce an overall effective field of view of approximately 15 square meters, given the speed and line spacing used for scans at the AEMP. In the case of 33 aggregated individual readings, the equivalent field of view would be approximately 70 square meters.

The conclusion for isotopic activity concentration detection limits is that individual four-second acquisitions (with a field of view of approximately 9 square meters) do not have sufficient sensitivity to reliably detect total uranium at the AEMP hot spot criteria or at its cleanup criteria. However, if used as deployed at the site, the system does have the sensitivity to reliably detect 15 square meter areas with average concentrations above 90 pCi/g for total uranium. It also has the sensitivity to reliably detect 70 square meter areas with average concentrations greater than 30 pCi/g for total uranium. For areas the size of 100 square meters (the definition of the cleanup criteria for the AEMP), the detection limit of the instrument is 24 pCi/g for total uranium. This means that with appropriate moving window average techniques the RSS as deployed at the AEMP can reliably determine whether the 30 pCi/g total uranium requirement has been achieved over 100 square meter areas, and can reliably determine whether 90 pCi/g total uranium has been achieved over areas the size of 15 square meters.

The above conclusions assume that the total uranium activity concentration estimates produced by the RSS are unbiased. However, the analysis of static sequential readings from background areas indicates that there is a significant bias in RSS total uranium activity concentration results when uranium activity concentrations are low. At background levels (assuming a background activity concentration of 3 pCi/g for total uranium), the RSS results were on average 30 pCi/g too low. With its current calibration, total uranium activity concentration values would have to be corrected upward by 30 pCi/g to provide unbiased estimates around the cleanup level. This bias does not affect the detection limits of the instrument, but does affect data interpretation.

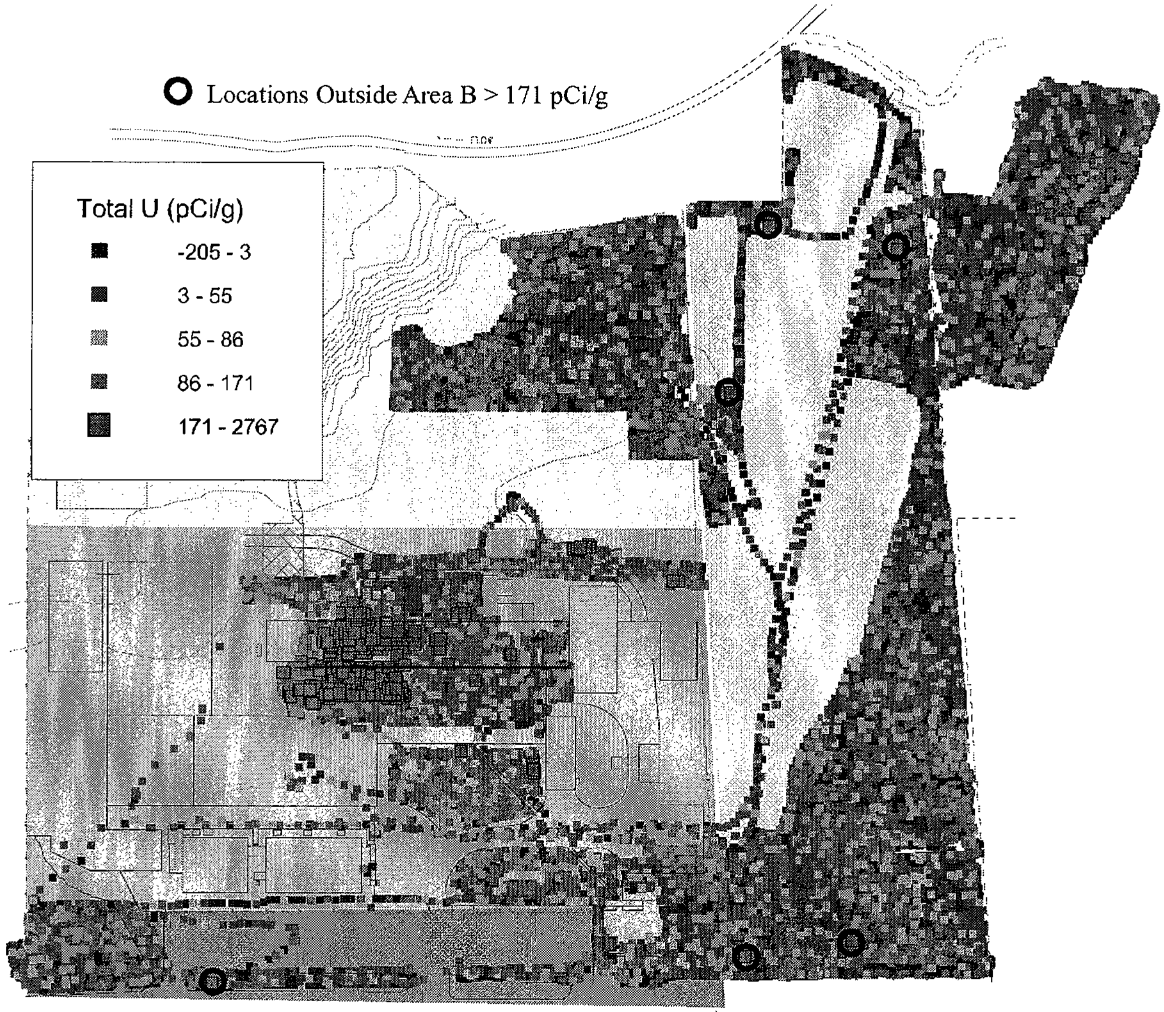

Figure 5.2 Raw RSS Total Uranium Activity Concentration Estimates

Individual RSS measurements with a four-second acquisition time have considerable measurement error associated with them, and can only be used for identifying highly elevated levels of uranium. The detection sensitivity for individual four-second measurements is 171 pCi/g for total uranium. Even at background levels, one would expect to see a minimal number of RSS measurements that are above 171 pCi/g because of measurement error alone. Figure 5.2 illustrates this fact. Figure 5.2 maps and color-codes RSS results by their total uranium activity concentration estimates, after adjusting activity concentration estimates upward by 30 pCi/g to reflect the bias observed in static sequential readings. For the more than 20,000 four-second scanning measurements collected, the adjusted total uranium pCi/g range was from -205 to 2,767 pCi/g. The -205 pCi/g minimum is obviously an impossible value and gives some sense of the maximum magnitude of measurement error associated with four-second total uranium activity concentration estimates.

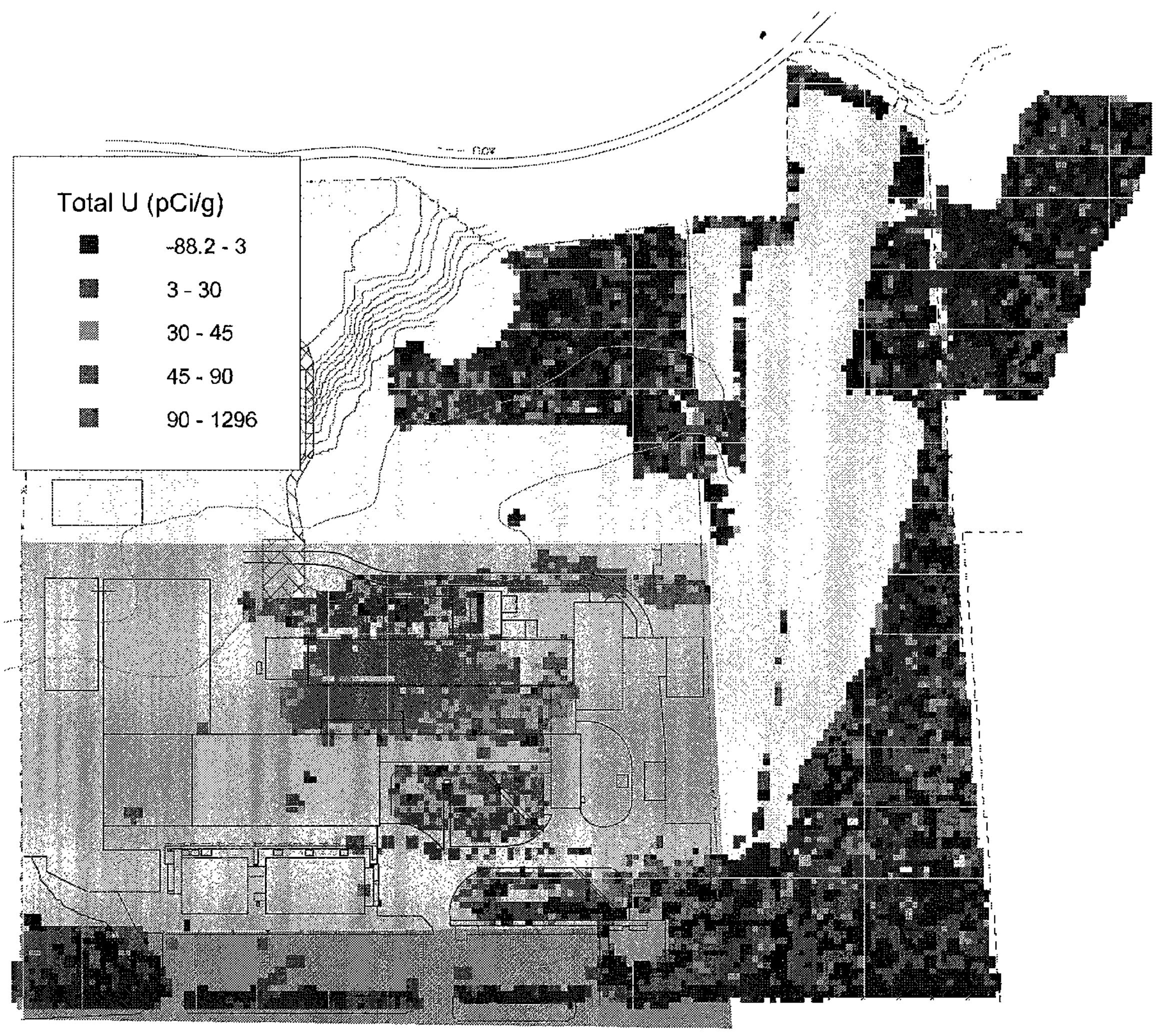

Figure 5.3 RSS Total Uranium Measurements Averaged Over 15 m^2

Based on these readings, soils adjacent to the Main Plant in Area B and the Main Plant pad itself clearly have uranium impacts. Outside of Area B, Figure 5.2 flags six other locations as potentially of concern from an elevated reading perspective (values above the 171 pCi/g detection limit). These include three locations along the frontage road, and three spots in northern Area D. Four of these locations were revisited with stationary RSS readings. Three were sampled, with samples analyzed by gamma spectroscopy (Figure 4.3 and Table 4.2). In all four cases the static RSS readings with extended measurement times gave total uranium activity concentration estimates around background, findings that were confirmed by the gamma spectrometry analyses. In these cases, the high individual RSS readings were false positives.

The large measurement error present in individual RSS total uranium measurements can be reduced by averaging together adjacent readings using moving window averages. Figure 5.3 shows the results of a moving window average of size 15 square meters applied to the RSS data set. When constructing the moving window average, only averages that had at least 4 measurements contributing to the average were

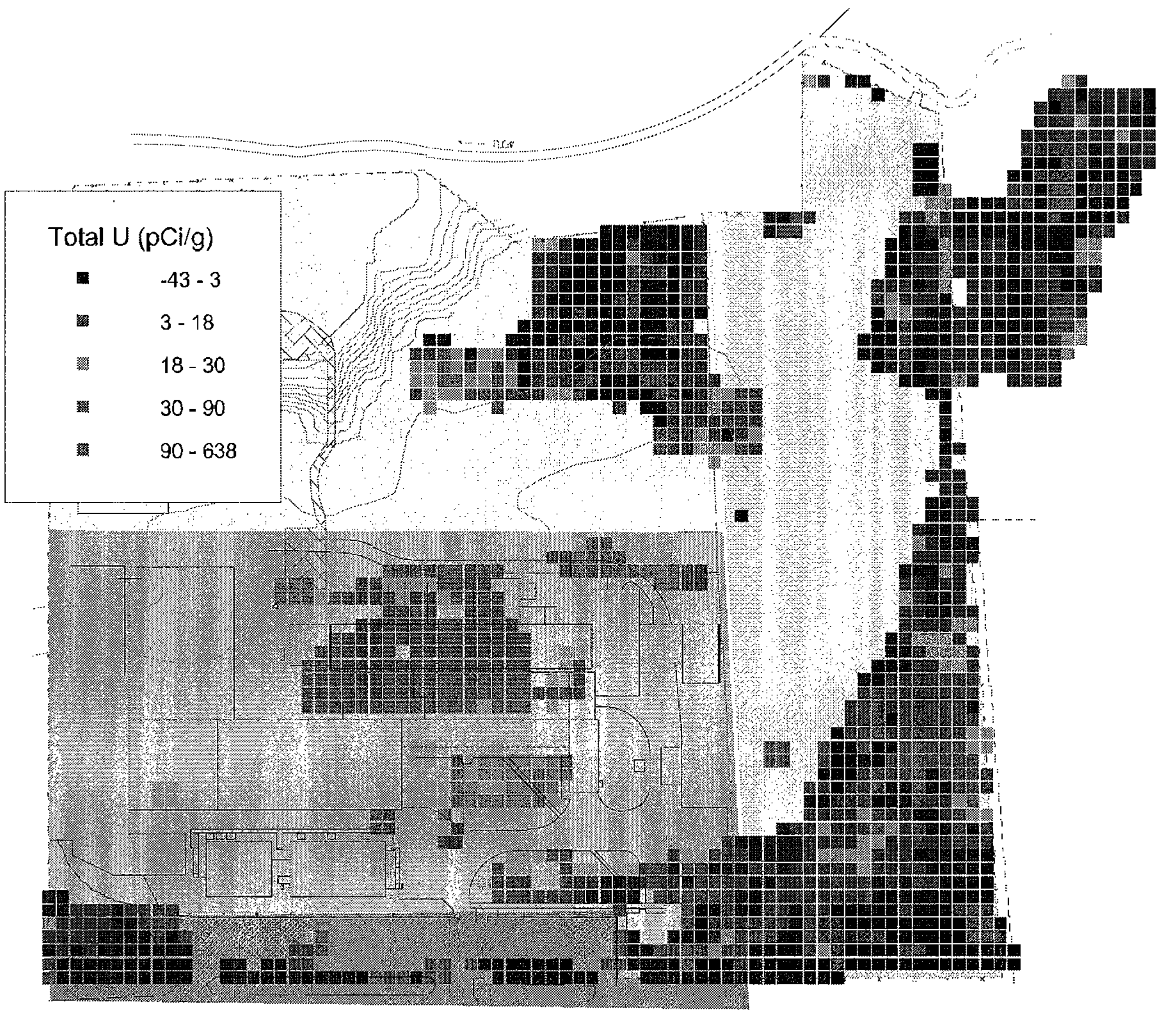

Figure 5.4 RSS Total Uranium Measurements Averaged Over 100 m^2

retained. In this case, the moving window averages effectively reduced the overall measurement error associated with each average from 52 pCi/g to 26 pCi/g, and the detection limit to less than 90 pCi/g. The results, as are evident from Figure 5.3, are maps where the general patterns of surficial uranium contamination are much more visible. Figure 5.3 can be used to evaluate the presence of hot spots above 90 pCi/g total uranium that are 15 square meters in size or larger. Based on Figure 5.3, there are no locations outside of Area B that are likely to be above 90 pCi/g, although there are several areas that are possibly greater than 90 pCi/g (i.e., averaged measurement is greater than 45 pCi/g).

If enough RSS measurements are averaged together, total uranium detection limits for the RSS can be lowered below 30 pCi/g. Figure 5.4 shows RSS data with the moving window average expanded to 100 square meters. With this level of averaging, total uranium detection limits are lowered to 26 pCi/g. When constructing the moving window averages, only averages that had at least 25 measurements contributing to the average were retained. Figure 5.4 can be used to identify areas where contamination is,

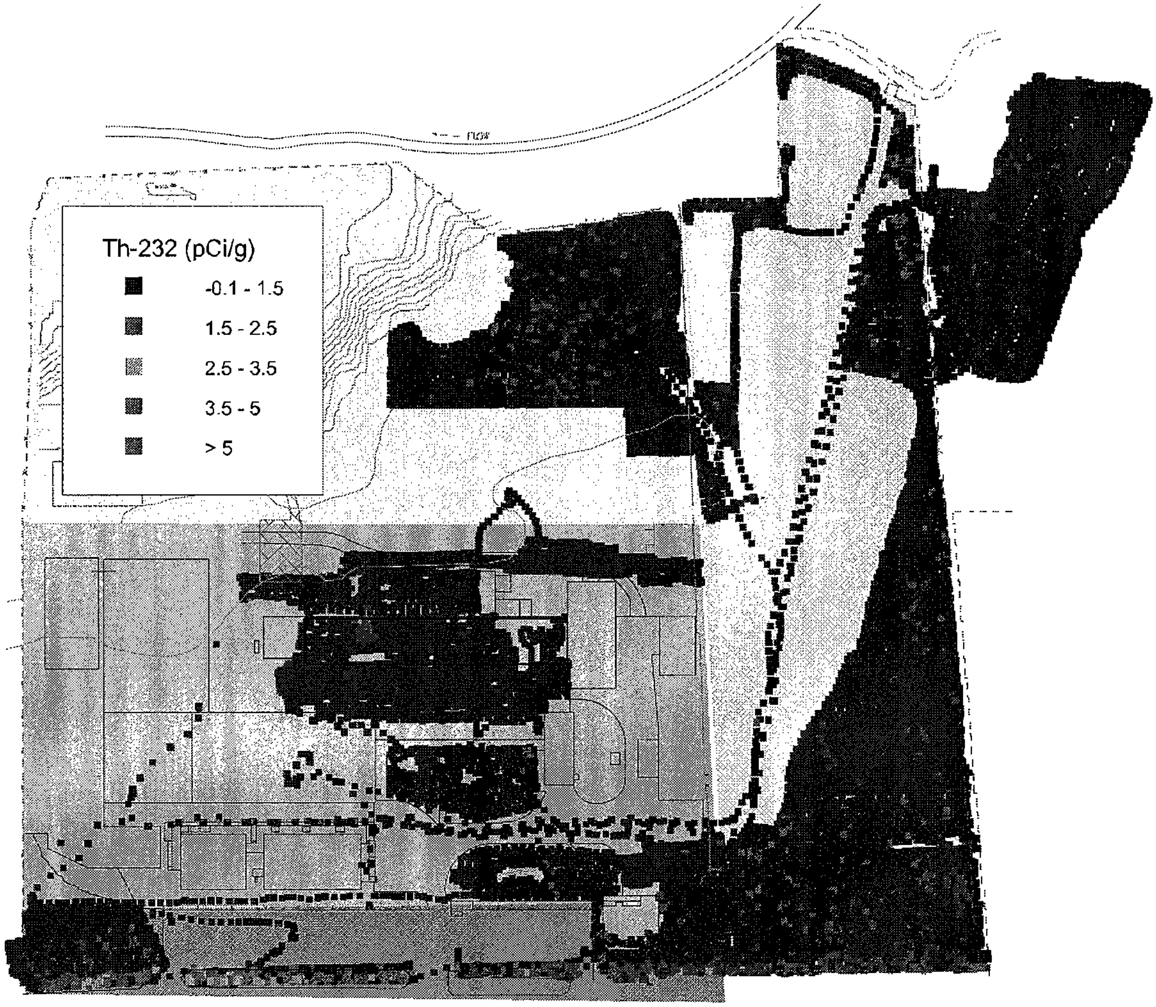

Figure 5.5 Th-232 RSS Measurement Results (pCi/g)

on average, elevated above 30 pCi/g. Outside of Area B, Figure 5.4 identifies several areas as either possibly or likely above the 30 pCi/g cleanup requirement. Measurement error is reduced by this level of spatial averaging at the expense of less spatial resolution of the uranium contamination patterns.

As a point of comparison, the measurement error levels for Th-232 activity concentration estimates for the RSS are much lower, with a detection sensitivity for a four-second reading on the order of 1.5 pCi/g. Figure 5.5 maps and color-codes the RSS results by their Th-232 values for areas covered by the RSS. The RSS identified elevated Th-232 activity concentrations along the frontage road and on the Main Plant pad. The Th-232 along the frontage road is presumably due to NORM. The Th-232 on the Main Plant pad is coincident with uranium contamination.

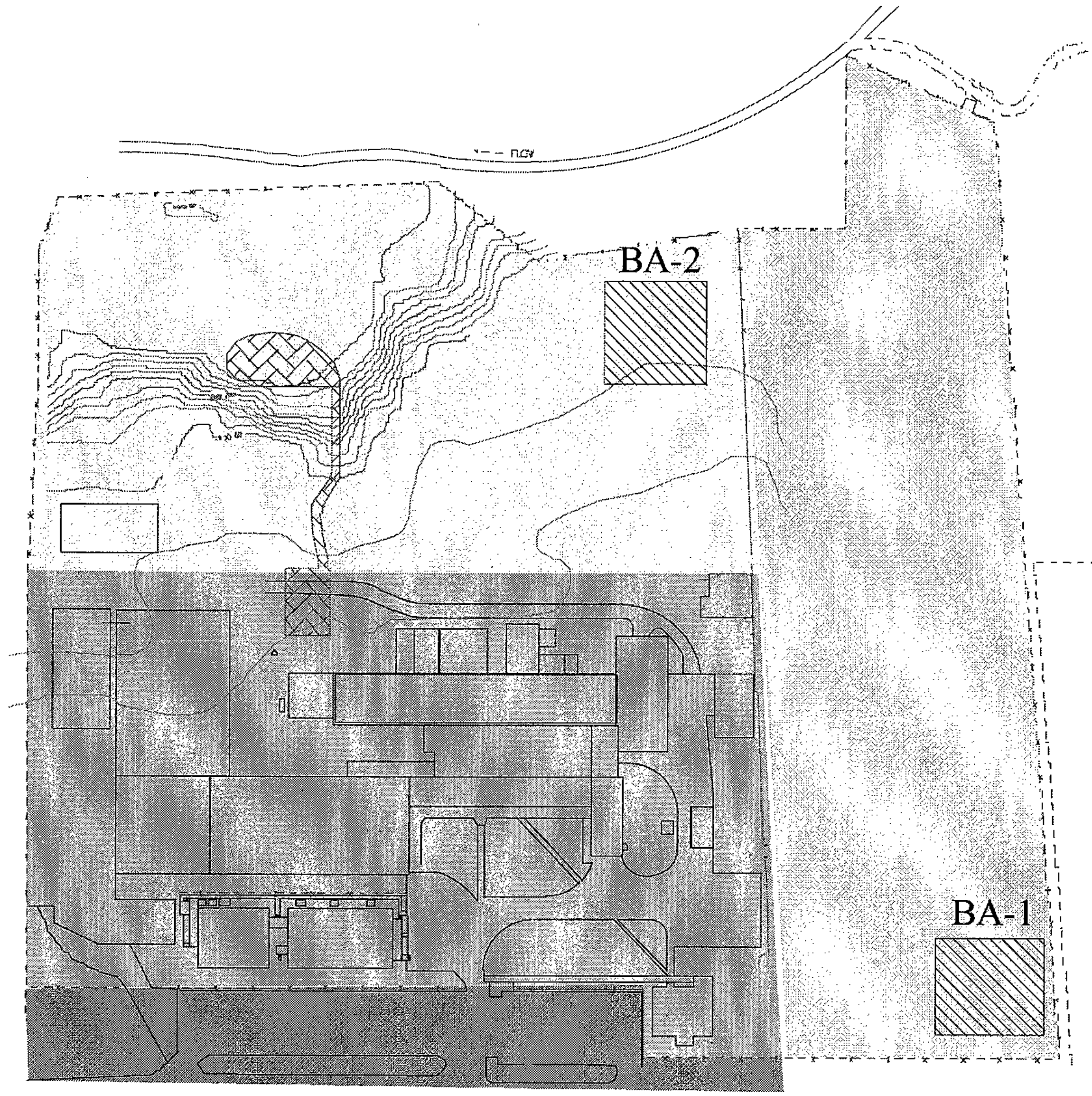

Figure 5.6 Background Area Locations

5.4 Gross Gamma Activity Detection Limits

As an alternative to the activity concentration estimates for total uranium, gross activity produced by the RSS during scans can also be used to identify areas where elevated uranium might be a concern. Focusing on gross activity has the advantage of making full use of the complete spectrum of gamma photons logged by the instrument. This results in relatively low measurement errors for four-second acquisition times. There are two primary disadvantages, however. The first is that gross activity by itself can be difficult to interpret when multiple radionuclides are present and elevated. Secondly, spatial variations in gross activity may also be caused by natural variations in background activity, and not by the presence of elevated uranium activity concentrations. The first disadvantage is not important for the AEMP site since uranium is exclusively the gamma-emitting radionuclide of concern for soils across the site. The second disadvantage, however, must be considered.

Determining average background levels of gross activity and the potential variability associated with background levels is necessary to determine gross activity detection sensitivity for the RSS. During its deployment at the AEMP, the RSS clearly surveyed both impacted and non-impacted areas. For this reason, determining average background values and the variability associated with background from the complete data set is problematic. In addition, even for non-impacted areas background may vary considerably depending on surface cover (e.g., grass, exposed earth, backfill gravel, etc.)

Based on the total uranium concentration information from the RSS, two different areas were selected as likely representative of different background conditions. The first was located in the southeast corner of the facility (background area BA-1). BA-1 would be representative of undisturbed soil. The second was in the center of Area C where excavation had already taken place (background area BA-2). BA-2 would be representative of exposed subsurface soils such as would be encountered during excavation activities. Figure 5.6 shows the locations of BA-1 and BA-2. In both cases the area used was 1,000 square meters in size. RSS measurements from these locations were selected, and summary statistics developed. In the case of BA-1, there were 610 RSS measurements. The average total uranium concentration was -1 pCi/g, indicating background conditions (with a measurement error of 2.1 pCi/g). The average gross activity was 2,742 cps, with a standard deviation of 119 cps. At this gross activity level, counting errors should be only 26 cps, indicating that the observed standard deviation is dominated by natural background variability. In the case of BA-2, there were 539 RSS measurements. The average total uranium concentration was -3 pCi/g, again indicating background conditions (with a measurement error of 2.2 pCi/g). The average gross activity was 3,008 cps, with a standard deviation of 85 cps.

Applying the definitions found in Section 3, the critical value and detection sensitivity for BA-1 were 2,938 and 3,135 cps, respectively. The critical value and detection sensitivity for BA-2 were 3,149 and 3,288 cps, respectively. Based on the calibration work performed at Fernald, the response of the RSS to an incremental pCi/g of total uranium is 9.4 cps. Using this value, the detection sensitivity for BA-1 would be 42 pCi/g total uranium. For BA-2, it would be 30 pCi/g. A portion of the variability associated with gross gamma activity is attributable to counting error, which can be controlled by increasing count times. This can be accomplished by either increasing acquisition time for individual readings or by aggregating adjacent readings. For example, aggregating the approximately 50 four-second readings contained in a 100 square meter area would decrease counting error by a factor of seven. If counting errors were controlled in this fashion, the detection sensitivity for BA-1 could be reduced to 33 pCi/g, and to 19 pCi/g for BA-2.

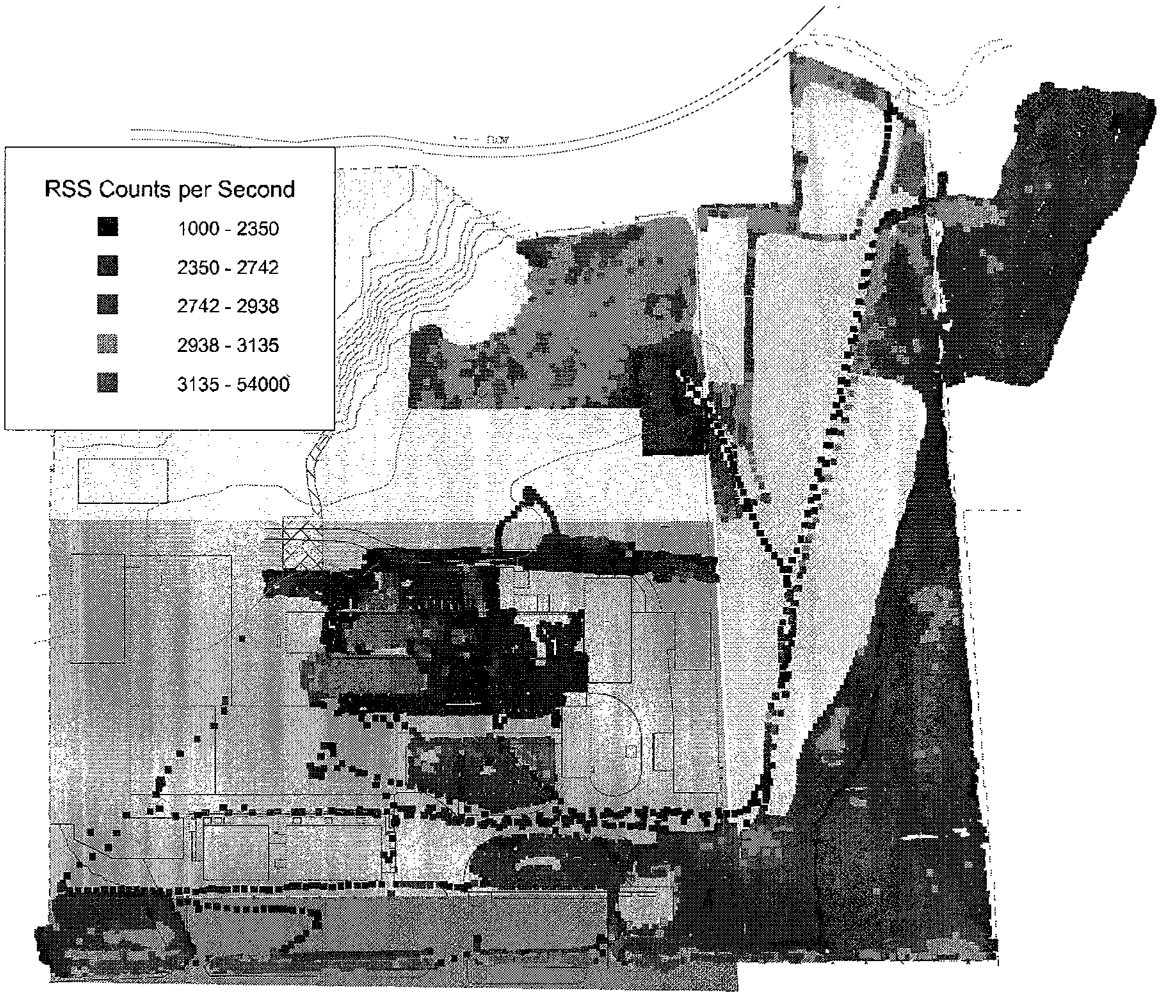

Figure 5.7 RSS Gross Activity Color-Coded Based on BA-1 Results

Gross activity data are not susceptible to the measurement biases exhibited by the RSS's total uranium measurements. Investigation levels based on detection sensitivity analyses are susceptible to unexpected changes in background. In these cases, a system like the RSS might identify an area as a uranium concern, when in fact only the natural background activity increased for whatever reason. Alternatively, it might identify an area as cleared of uranium concerns when in fact the presence of elevated uranium was masked by falling average background levels. Fortunately, background levels can stay relatively constant over relatively large areas of homogenous material. Changes in surface conditions that would result in different background levels are also usually readily identifiable visually (e.g., grassy areas versus exposed soil, etc.), allowing for the derivation of area-specific background values.

Figure 5.7 shows the RSS gross activity data color-coded by the investigation levels derived from BA-1. Figure 5.8 shows the RSS gross activity data color-coded by the investigation levels derived from BA-2. In Figure 5.7, the excavated and exposed portion of Area C appears as an area of concern across its entirety because of elevated background conditions. The results portrayed in Figure 5.7 are consistent with those

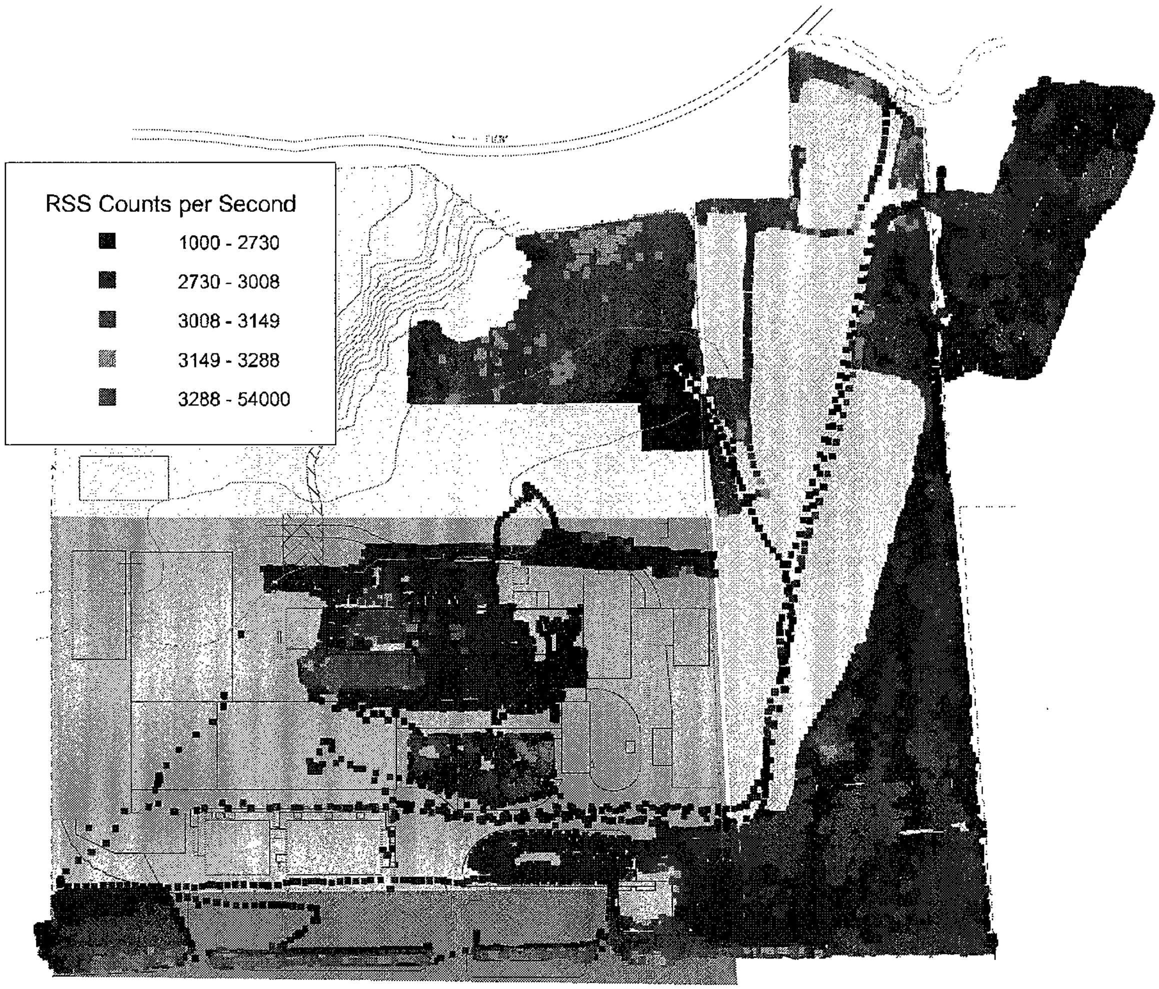

Figure 5.8 Gross Activity Color-Coded Based on BA-2 Results

contained in Figure 5.4 for the southern portion of Area D. Conversely, the results contained in Figure 5.8 show the same general patterns of elevated uranium activity for the excavated portions of Area C as shown in Figure 5.4. The main difference is that to get detection limits down to around 30 pCi/g for the RSS's total uranium activity concentration estimate required averaging individual measurements over a large area. In contrast, the results displayed in Figures 5.7 and 5.8 are based on individual readings, providing much better spatial resolution of elevated areas.

5.5 Low Energy-Stripped Detection Limits

In another attempt to improve detection sensitivity, a low energy stripping window (30 – 210 keV) was used to isolate that portion of the gross activity thought to be most sensitive to the relatively low energy gamma photons associated with uranium and its daughters. Using the same background areas, BA-1 and BA-2, detection sensitivities were derived based on these data. For BA-1, the average stripped low energy gross activity was 1,367 cps, with a standard deviation of 102 cps. For BA-2, the average gross activity was 1,500 cps, with a standard deviation of 102 cps. Applying the definitions found in Section 3, the critical value and detection sensitivity for BA-1 were 1,535 and 1,703 cps, respectively. The critical value and detection sensitivity for BA-2 were 1,668 and 1,836 cps, respectively. Based on the calibration work performed at Fernald, the response of the RSS's low energy window to an incremental pCi/g is 5.25 cps. Using this value, the detection sensitivity for BA-1 and BA-2 would be 64 pCi/g for total uranium.

Based on this analysis, the performance of the low energy stripping window appears to be inferior to using gross activity as a whole. A more detailed analysis of static sequential readings suggested a reason. While gross activity variability conformed to counting statistics expectations (i.e., the standard deviation observed in repeat static readings was the square root of the average gross activity observed), the variability of the stripped low energy window data was significantly greater than counting statistics alone would account for. This increased relative variability would raise detection sensitivity.

5.6 Comparability

Comparability refers to the RSS's ability to provide activity concentration estimates comparable to those obtained by sample analysis via gamma spectroscopy. The concept of comparability only applies to the RSS's activity concentration estimates, and not to its gross activity numbers. Comparability analysis for the RSS is complicated by the fact that the sample support for an RSS measurement corresponds to its field of view. In contrast, the sample support for a gamma spectrometry result is typically less than one kilogram of soil. For this reason, if one were to sample and analyze soil from directly beneath a stationary RSS reading, one would not expect to see particularly good correlation between sample gamma spectrometry results and RSS results. Comparability analysis at the FEMP attempted to address sample support issues by comparing NaI activity concentration estimates to those measured using *in situ* HPGe gamma spectroscopy techniques with a similar field of view. The FEMP found reasonable comparability between results.

As part of the deployment of the RSS system at the AEMP, there were a number of locations where stationary RSS readings were taken, and soil samples collected from directly beneath the instrument and analyzed via gamma spectroscopy. Table 5.1 summarizes the results. Figure 5.9 shows a scatter plot of the results contained in Table 5.1. If there had been perfect agreement, all points would have fallen on a straight line. Points that fall above the diagonal are cases where gamma spectroscopy yielded higher values than the RSS. There are two reasons for discrepancies. The first is the previously mentioned fact that the RSS appeared to be underestimating total uranium activity concentrations by 30 pCi/g. The second has to do with the relationship between the location of hot spots and the field of view for the RSS. For samples collected the 18th of October, the RSS measurement was centered for hot spots, and then the hot spot was sampled. For these locations, the soil sample would overestimate average activity concentrations for the field of view of the RSS. On the 19th of October, stationary RSS measurements in the restricted area of Area B were selected so that they were not over hot spots. After the stationary measurement, a soil sample was collected from directly below the detector. If a hot spot existed in the field of view of the RSS, the sampling

			RSS Results (pCi/g)			Gamma
RSS Date	Time	Sample	Ra226	Th232	Total U	Spec Total U
18Oct021	600	S21018404	2.6	3.0	348.7	489.0
18Oct021	600	S21018404	2.9	2.9	315.8	489.0
18Oct021	600	S21018405	2.1	2.1	266.1	396.0
18Oct021	600	S21018406	1.3	1.2	453.9	2661.0
18Oct021	600	S21018407	1.2	0.9	128.8	171.9
21Oct021	600	S21021403	1.5	1.9	322.6	278.0
21Oct021	600	S21021404	2.0	1.9	376.3	192.5
21Oct021	600	S21021405	1.7	1.8	280.2	109.5
21Oct021	600	S21021406	2.0	1.9	981.8	524.0
21Oct021	600	S21021407	2.3	2.4	624.9	376.0
21Oct021	600	S21021408	1.5	2.1	1051.8	1243.0
28Oct021	300	S21029405	0.6	0.9	-9.7	11.1
29Oct021	300	S21029406	2.5	2.7	-40.6	6.0
29Oct021	300	S21029407	5.7	8.2	-30.9	8.2
29Oct021	300	S21029408	1.0	1.2	90.9	216.0
29Oct021	600	S21029408	1.0	1.2	90.8	216.0
29Oct021	600	S21029409	1.2	1.2	100.5	260.0

Table 5.1 RSS Total Uranium Estimates and Discrete Sample Results

would have missed it, and the soil sample would underestimate the average activity concentration for the field of view of the RSS.

5.7 Logistical and Implementation Issues

The deployment of the RSS system at the AEMP did raise several logistical and implementation issues if the RSS or similar mobile NaI scanning is to be deployed again at the site.

5.7.1 Locational Control Issues

Location control for the RSS system was provided by a Trimble differentially-corrected GPS system. The Trimble system's fundamental units are latitude and longitude. To map data produced by the RSS scans requires transforming the latitude and longitude of a set of measurements to local coordinates used for the site. In the case of the AEMP, the site civil survey has been done in Ohio State Plane North feet, NAD27. The software used by the RSS has built-in routines that transform latitude and longitude to the appropriate local coordinate system. Adjustments were made to the software by Idaho National Engineering and Environmental Laboratory (INEEL) to accommodate the local coordinate system used by the AEMP. However, in practice this resulted in RSS data being displaced approximately 30 feet north and 45 feet east relative to other

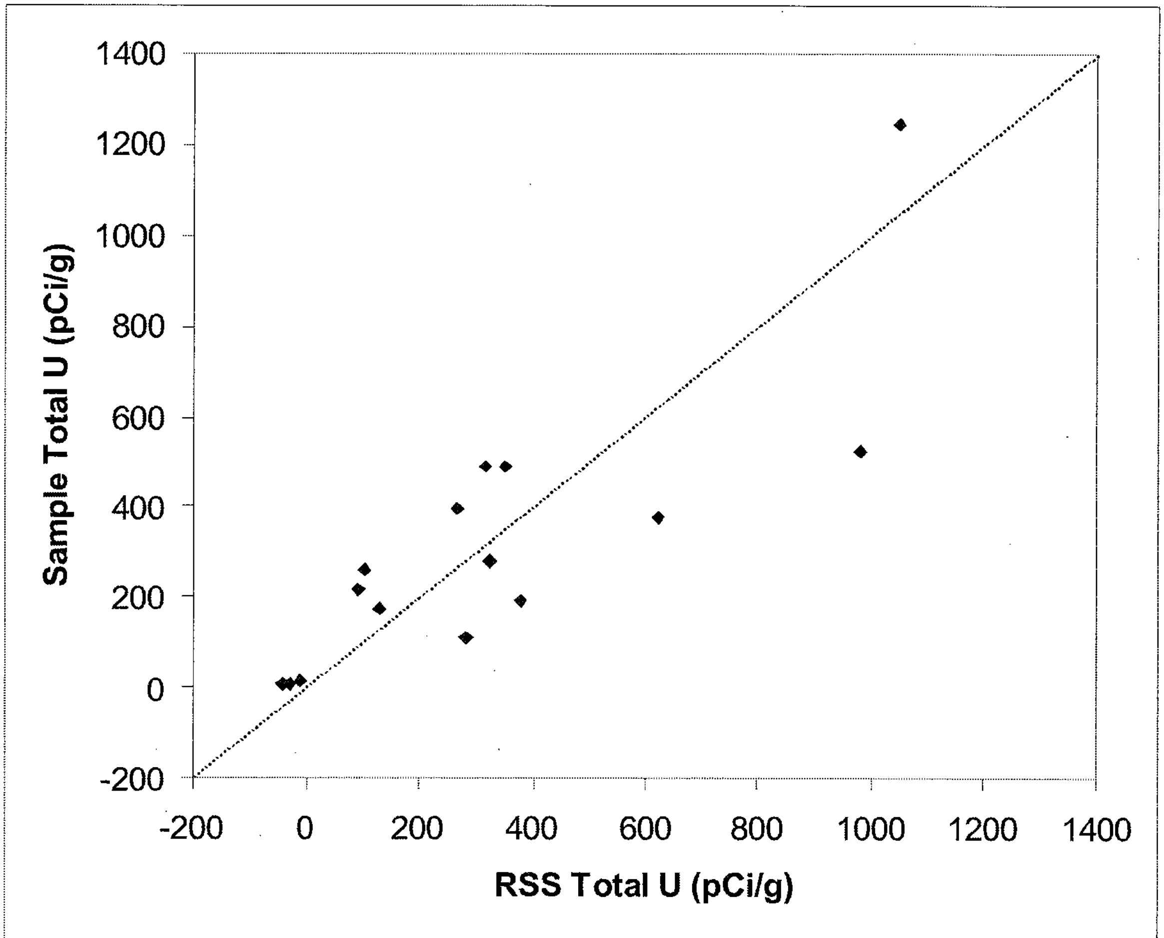

Figure 5.9 RSS Total U versus Gamma Spectrometry Results

features at the site. This displacement was corrected post-data collection, but further deployments of the RSS or its sister platforms would require additional adjustments to the coordinate transformations used by the RSS software.

Reliance on differentially-corrected GPS can also pose problems for scans conducted below grade in excavations or adjacent to standing buildings or other features that might interfere with satellite lock. Most of the remaining required soil excavation work will be conducted after buildings have been removed from the site, so building and structure interference effects will be reduced during future excavations. The degree to which excavation support scans may have GPS problems is difficult to predict since the deployment of the RSS at the AEMP did not include scans in this type of setting. However, there are several mitigating strategies that can be used to correct for potential satellite loss problems. These include replacing the GPS system with a laser-based positioning system, or raising GPS antennae high enough above the scanning platform to ensure that satellite locks are achieved (e.g., above surface grade).

5.7.2 Accessibility Issues

At Ashtabula, the RSS covered areas that were largely flat and readily accessible by the wheeled platform. As remediation moves forward at the site, however, there will be an increasing need to survey areas that have been, or are being, excavated. These surfaces will pose two accessibility issues for the RSS. The first is that they are unlikely to represent smooth surfaces amenable to coverage by a wheeled vehicle. The second is that they are likely to be at depth, and may at times represent angles or geometries that are not appropriate for the RSS platform. The FEMP will be faced with similar issues as excavation there moves to deeper contamination. To address the problem at the FEMP, an alternative platform, the EMS, was deployed. The EMS uses the same sensor, computer and software components as the RSS, but is deployed on a platform that can be attached to the end of an excavator arm. The primary issue associated with the deployment of an EMS-type of system at the AEMP is whether the costs of another specialized platform are justified given the volume of soil that will need to be excavated.

5.7.3 "Shine" Issues

As deployed at the FEMP, the RSS and its sister NaI systems are not shielded. Because of their physical shape, the systems are susceptible to "shine" effects. Shine refers to gamma photons that are captured by the system, but whose source originates from areas other than the area of interest being measured. Common examples of shine sources are buildings with radiological contamination in the walls, or that store gamma-emitting radionuclides, contaminated soil piles, or the walls of excavation areas. In these cases, the presence of shine can make the interpretation of RSS results more difficult. In extreme cases, the existence of shine may prevent the use of a system like the RSS for specific areas.

In the case of the AEMP, since most, if not all, buildings will be down by the time additional soil remediation is undertaken, the primary concern for shine effects would be excavation walls, particularly when those walls might contain embedded contamination. To deploy the RSS at the site in this instance would either require side shielding for the sensor, exclusion zones for sensor use, or design of excavation work so as to minimize wall effects (e.g., sloped layback versus abrupt dig walls as might be produced by a backhoe). If side shielding were used, calibration work would need to be revisited and detection sensitivities for the instrument would need to be recalculated.

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6.0 Conclusions and Recommendations

Based on the RSS deployment at the AEMP and subsequent analysis of the data it produced, the following conclusions can be drawn regarding the first two objectives of the deployment, detector sensitivity and deployment issues:

- The RSS proved to be effective at efficiently covering large areas (approximately eight acres in the case of the AEMP) with complete scanning coverage. The scans at the AEMP identified and documented a few previously unknown elevated areas (e.g., residual contamination in portions of Area C).

- As deployed at the AEMP, for individual four-second measurements the total uranium sensitivity for activity concentration estimates from the RSS was 221 pCi/g based on calibration data, and 171 pCi/g, as observed in field results.

- As deployed at the AEMP, for individual four-second measurements the total uranium sensitivity for gross activity was between 30 and 42 pCi/g, depending on the area and associated background gross activity variability.

- The RSS total uranium activity concentration estimates exhibited a negative bias of around 30 pCi/g for low values of total uranium. While this bias does not affect system sensitivity, it does affect data interpretation, and would have to be corrected if the RSS were to be used to support closure decisions.

- As one would expect, gross activity background levels varied across the site depending on surface cover. Variations in background levels were large enough that they would "mask" variations in total uranium activity if not accounted for correctly.

- The detection sensitivity for the RSS total uranium activity concentration estimates can be reduced to less than 30 pCi/g through spatial averaging. Spatially averaging over a 15 m^2 area results in a sensitivity less than 90 pCi/g. Spatially averaging over a 100 m^2 area results in a sensitivity less than 30 pCi/g.

- The detection sensitivity for total uranium using RSS gross activity data can be improved only marginally by spatial averaging. This is because counting errors are dominated by natural spatial variability in gross activity levels.

- The RSS is capable of supporting closure decisions at the 30 pCi/g level using either total uranium activity concentration estimates or gross activity data. This assumes that the bias observed in total uranium activity concentrations is corrected, and that appropriate area-specific background levels are determined in the case of gross activity.

- False positive issues associated with systems such as the RSS can be addressed through subsequent stationary readings for longer acquisition times over locations flagged by a scan as being of concern.

- The locational control portion of the RSS exhibited a systematic bias in locational accuracy of about 30 feet north-south, and 45 feet east-west.

- The RSS will likely be prone to access and "shine" issues if used to support deeper excavation scans. The former is due to the current platform used, and the latter to NaI crystal geometry.

The RSS established that real-time scans of the AEMP site can be efficiently done, producing data that can be used to support decision-making at the 30 pCi/g level (averaged over 100 square meters). This support could be accomplished by using either the total uranium activity concentration estimates produced by the RSS, or by its measured gross activity combined with an appropriate investigation level. Deployment of the RSS to support excavation work poses accessibility and possible shine issues. Accessibility concerns could be addressed with the use of an alternative platform such as the EMS that is used at the Fernald site. Potential shine issues are more difficult to address.

An alternative to the RSS is the use of a FIDLER (Field Instrument for Detecting Low Energy Radiation). FIDLER systems make use of thin NaI crystals. Unlike the RSS, a FIDLER system would produce only gross activity data. Detection sensitivity for total uranium based on gross activity would likely be comparable to the RSS. While some loss of sensitivity would be associated with a smaller crystal, this would be offset by the fact that the FIDLER's geometry is more appropriate for the relatively low energy gamma photons produced by uranium and its daughter products. A real-time FIDLER-based scanning system would look much like the RSS, with some form of locational control (e.g., a differential GPS connection) and data logging capability. The primary advantages would be that as a hand-carried device it would have much better accessibility for dig-face characterization, it would be much less sensitive to the shine that would potentially be associated with dig face walls, and it would be a lower cost item to procure and maintain. The primary advantage of the RSS, its ability to provide radionuclide-specific activity concentration estimates, is not of great importance at the AEMP where soil concerns are driven solely by elevated uranium concentrations.

Based on the above, the following recommendations are made:

- The AEMP procure FIDLER systems to support upcoming soil removal and closure actions.

- Through appropriate field data collection (similar to what has been done for the RSS but on a smaller and more focused scale), the site establish detection sensitivities for the FIDLER systems and document system performance at the 30 pCi/g level.

- The AEMP develop soil excavation and data collection protocols that allow the deployment of the FIDLER as a means for segregating soils while excavation is underway.

- The AEMP develop closure protocols for exposed soil surfaces that incorporate the use of the FIDLER.

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