Characterization Report for the 903 Drum Storage Area, 903 Lip Area, and Americium Zone

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ACRONYMS

ALF	Action Levels & Standards Framework for Surface Water, Groundwater & Soil
Am	Americium
bgs	below ground surface
C	Carbon
CCL_4	Carbon Tetrachloride
CDH	Colorado Department of Health
CDPHE	Colorado Department of Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cm	centimeter
cpm	counts per minute
COC	Contaminant of Concern
CRQL	Contract Required Quantitation Limit
1,2-DCE	1,2-Cis-Dichloroethylene
DER	Duplicate Error Ratio
DNAPL	Dense Nonaqueous Phase Liquid
DOE	U. S. Department of Energy
DOT	Department of Transportation
DQA	Data Quality Assessment
DQO	Data Quality Objective
EPA	Environmental Protection Agency
Eq	Equation
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FOV	Field of View
g/cc	density (gram/cubic centimeter)
HPGe	High Purity Germanium Detector
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measures/Interim Remedial Action
ISOCS	In Situ Object Counting System
kg	kilogram
K-H	Kaiser-Hill Company, L.L.C.
m	meter
MeV	Value of Energy
mg/L	micrograms per liter
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NIST	National Institute of Standards and Technology
OU	Operable Unit
PARCC	Precision, Accuracy, Representativeness, Completeness, & Comparability
PCE	Tetrachloroethene
pCi/g	picocuries per gram
Pu	Plutonium
QA	Quality Assurance
QAPD	Quality Assurance Program Description
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RFFO	Rocky Flats Field Office

RFI/RI	RCRA Facility Investigation/Remedial Investigation
RIN	Routine Identification Number
RMRS	Rocky Mountain Remediation Services, L.L.C.
RPD	Relative Percent Difference
RSAL	Radionuclide Soil Action Level
RWP	Radiation Work Permit
SAP	Sampling and Analysis Plan
SOR	Sum of Ratios
SSAL	Subsurface Soil Action Level
TCE	Trichloroethene
TMU	Total Measurement Uncertainty
TPU	Total Propagated Uncertainty
U	Uranium
UCL	Upper Confidence Limit
ug/kg	micrograms/kilogram
ug/L	microgram per liter
V&V	Verification/Validation
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria

EXECUTIVE SUMMARY

Investigation of soil contamination at the 903 Drum Storage Area (903 Pad), 903 Lip Area (Lip Area), and Americium Zone was performed to provide characterization data for subsequent evaluation of remedial alternatives for site cleanup. Historically, drums which were stored at the 903 Pad between 1958 and 1967 leaked hydraulic fluids and lathe coolant containing plutonium and depleted uranium. This release contaminated surface and subsurface soil with radionuclides and volatile organic compounds (VOCs). The VOCs have migrated into the shallow groundwater system beneath the 903 Pad.

The primary purpose of this investigation was to estimate the volume of contaminated soil above the Rocky Flats Cleanup Agreement (RFCA) Tier I Radionuclide Soil Action Levels (RSALs) and Subsurface Soil Action Levels (SSALs). Another objective of the investigation was to characterize surface soil to 10 pCi/g americium-241 (^{241}Am) using gamma spectroscopy field instrumentation. This characterization would allow for identification of surface soils exceeding Tier II RSALs. Remedial alternatives will be evaluated in the Interim Measure/Interim Remedial Action (IM/IRA) Decision Document based on these volume estimates.

Delineation of radiologically-contaminated soil in the Americium Zone was performed *insitu* using gamma-ray spectroscopy methods, which employ a high purity germanium detector (HPGe). The HPGe instrument was used to obtain 1110 contiguous gamma ray measurements with a circular field of view of 10 meters in diameter within the investigation area. Given this coverage, nearly the entire Americium Zone within the investigation area was surveyed for radionuclides.

The HPGe measurement results were correlated with alpha spectroscopy measurements of radionuclides in eight co-located surface soil samples. The resulting best-fit regression model was used to standardize each HPGe ^{241}Am measurement to a laboratory-derived ^{241}Am and plutonium-239/240 ($^{239/240}$Pu) alpha spectroscopy measurement. The correlation results for ^{241}Am and $^{239/240}$Pu were input into the Tier I and II RSAL sum of ratios equations to determine HPGe measurements locations exceeding the respective action levels.

Based on the standardized HPGe results, surface soil at approximately 37% of the HPGe measurement locations within the Americium Zone has radionuclides exceeding the Tier II RSALs. HPGe results that exceed Tier I RSAL are isolated at a cluster of three locations near the northwest corner of the Americium Zone and at one location in the south central portion of the Lip Area. The Tier I and Tier II RSAL exceedances are a result of elevated activities of $^{239/240}$Pu and ^{241}Am. Within the Americium Zone, $^{239/240}$Pu activities ranged from 6.32 pCi/g to 938.42 pCi/g and ^{241}Am activities ranged from 4.91 pCi/g to 149.22 pCi/g.

Contamination of surface and subsurface soils at the 903 Pad and Lip Area was delineated with data obtained from borings at evenly spaced grid nodes. Radiological samples from 79 boring locations were analyzed for ^{241}Am, $^{239/240}$Pu, uranium-233/234 ($^{233/234}$U), uranium-235 (^{235}U), and uranium-238 (^{238}U) using alpha spectroscopy. VOC samples were collected from 17 boring locations and were analyzed for VOC contaminants of concern which included carbon tetrachloride (CCL_4), chloroform, cis-1,2-dichloroethene (1,2-DCE), methylene chloride, tetrachloroethene (PCE), and trichloroethene (TCE).

Based on the data obtained from borings in the 903 Pad and Lip Area, most of the surface soil (0 to 6 inches) is contaminated above Tier I and Tier II RSALs. $^{239/240}$Pu and ^{241}Am activities within the 903 Pad and Lip Area ranged from 0.82 pCi/g to 152,260 pCi/g and 0.15 pCi/g to 31,670 pCi/g, respectively. Radiological contamination was also detected in the subsurface soil at depths of 6 to 12 inches and 12 to 18 inches within the 903 Pad and Lip Area; however, $^{239/240}$Pu and ^{241}Am activities decreased by orders of magnitude at progressively deeper soil horizons.

Artificial fill at the 903 Pad is contaminated above the RFCA Tier II RSALs at one location (Boring 91898). Soil at this boring has elevated levels of ^{241}Am (126 pCi/g) and $^{239/240}$Pu (558 pCi/g). Asphalt samples from the 903 Pad were also collected for waste characterization profiling but were not compared to RFCA Tier I and Tier II RSALs.

Contaminated soil volumes are based on the areas and depths of Tier I and Tier II RSAL exceedances. The total volume of contaminated soil exceeding Tier I RSALs is 2,925 yds^3. The total volume of soil exceeding Tier II RSALs is estimated at 14,307 yds^3. Relative to Tier II RSAL exceedances, the amount of radiologically-contaminated soil at the 903 Pad is 2,471 yd^3; 4,811 yd^{3}in the Lip Area; and 7,025 yd^{3}in the Americium Zone.

No VOCs were detected in subsurface soil above the current SSALs within the 903 Pad and Lip Area. However, methylene chloride, PCE, TCE and 1,2-DCE exceeded proposed Tier I and Tier II SSALs in several borings near well 08891. The total volumes of contaminated soil above proposed Tier I and Tier II SSALs are 4,237 yd^3 and 6,813 yd^3, respectively. In addition, 317 yd^3 of contaminated soil containing elevated levels of both radionuclides and VOCs are also present.

1.0 INTRODUCTION

This report summarizes data collected to determine the location, area, and volume of soil potentially requiring evaluation, management, or remedial action at Individual Hazardous Substance Site (IHSS) 112 - 903 Drum Storage Area (903 Pad), IHSS 155 - 903 Lip Area (Lip Area) and Americium Zone, located at the Rocky Flats Environmental Technology Site (RFETS). Figure 1-1 provides the locations of the IHSSs and the Americium Zone. Remedial alternatives will be evaluated in the Interim Measures/Interim Remedial Action (IM/IRA) Decision Document based on these volume estimates.

Previous investigations have been conducted in these areas to evaluate the extent of contamination, and the data collected have been reported in the Operable Unit (OU) No. 2 Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/ Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Remedial Investigation (RFI/RI) Report (DOE, 1995). However, data from these earlier investigations do not provide the resolution necessary to accurately quantify the volume of soils that may require evaluation, management, or remedial action. Furthermore, with respect to VOC contaminated soils, the historical data do not support the presence of a separate phase dense non-aqueous phase liquid (DNAPL) at the 903 Pad, a model convincingly supported by groundwater data collected at this IHSS. Accordingly, the data reported herein were collected to fill these data gaps.

1.1 SITE BACKGROUND

Waste releases at the 903 Pad (IHSS 112) are considered the primary source of radiological contamination in the surficial soil in this part of the RFETS. Drums that contained hydraulic fluids and lathe coolant contaminated with plutonium and uranium were stored at this location from the Summer of 1958 to January 1967. Approximately three fourths of the drums contained liquids contaminated with plutonium while most of the remaining drums contained liquids contaminated with uranium. Of the drums containing plutonium, the liquid was primarily lathe coolant and carbon tetrachloride in varying proportions. Also stored in the drums were vacuum pump oils, trichloroethene (TCE), tetrachloroethene (PCE), silicone oils, and acetone still bottoms (DOE, 1995).

Leaking drums were noted in 1964 during routine handling operations. The contents of the leaking drums were transferred to new drums, and the area was fenced to restrict access. When cleanup operations began in 1967, a total of 5,237 drums were at the drum storage site. Approximately 420 drums leaked to some degree. Of these, an estimated 50 drums leaked their entire contents. The total amount of leaked material was estimated at around 5,000 gallons of contaminated liquid containing approximately 86 grams of plutonium (DOE, 1995).

From 1968 through 1970, some of the radiologically-contaminated material was removed from the 903 Pad and Lip Area, some of the surrounding Lip Area was regraded, and much of the area was covered by an imported base coarse material. An asphalt cap was placed over the most contaminated area resulting in the 903 Pad. However, during drum removal and cleanup activities, wind and rain (stormwater erosion) spread plutonium-contaminated soils to the east and southeast from the 903 Pad area resulting in IHSS 155 (903 Lip Area). Several limited excavations have removed some of the plutonium-contaminated soils from the Lip Area (DOE, 1995; Barker, 1982; and RMRS, 1997a). However, results from the OU2 Phase II RFI/RI sampling and analysis and this investigation confirm that radiologically-contaminated soils remain.

Surface soils to the east and southeast of the Lip Area also exhibit elevated plutonium-239/240 ($^{239/240}$Pu) and americium-241 (^{241}Am) activities. This contamination is primarily attributed to wind dispersion from the 903 Pad with potential contributions from historical fires, stack effluent, and stormwater related surface soil erosion. Areas exhibiting elevated $^{239/240}$Pu and ^{241}Am activities east and southeast of the Lip Area are known as the Americium Zone.

1.2 CONTAMINANTS OF CONCERN

Contaminants of concern (COCs) for the 903 Pad, Lip Area, and Americium Zone were initially identified from previous investigations (DOE, 1995; and RMRS, 1998a) using a phased statistical risk-based approach. However, with the introduction of proposed Soil Action Levels (SALs) (see Section 1.3) data were re-examined to identify analytes that exceed these limits. Specifically, a comprehensive evaluation of the historical data compiled from the OU2 Remedial Investigation (RI) (DOE, 1995) and data acquired for this report was preformed. The evaluation process included comparison of organic and inorganic (metals) data to Tier II SALs (Kaiser-Hill, 1999a). If the maximum concentration of a contaminant was less than the respective Tier II SAL, the compound

was eliminated from further consideration. In addition, non-detect values were automatically eliminated from the screening process. Tables A-1 and A-2 summarize the results of the comprehensive COC screening process (Appendix A). Based on this evaluation the following COCs were identified:

- ^{241}Am;
- $^{239/240}$Pu;
- ^{234}U;
- ^{235}U;
- ^{238}U;
- Aroclor-1248;
- Carbon Tetrachloride (CCl_4);
- Chloroform;
- 1,2-Dichloroethene (Total [1,2-DCE]);
- Methylene Chloride;
- Tetrachloroethene (PCE);
- Trichloroethene (TCE).

Arsenic, beryllium, and bromomethane were identified as potential COCs; however, were eliminated from further consideration. Arsenic and beryllium were eliminated from the final COC list because the corresponding SALs exceeded the respective mean background concentrations and furthermore, these metals were below the background screening levels (DOE, 1995)[1]. Bromomethane was eliminated from further consideration because it was identified as a potential laboratory contaminant (see Section 3.0). Other metals, semivolatile organic compounds, pesticides, and polychlorinated biphenyls not mentioned above were eliminated as potential contaminants of concern based on data evaluation from previous investigations (DOE, 1995).

Although methylene chloride was previously considered a possible laboratory contaminant, data suggest that it is a COC beneath the 903 Pad. Specifically, the rationale for retaining methylene chloride as a COC includes the following:

- Methylene chloride is the most ubiquitous of the organic contaminants, occurring above subsurface SALs at seven borings at or near the 903 Pad. Methylene chloride concentrations at the remaining borings were either non detects or were less than Tier II SALs;

- In general, methylene chloride increases in concentration with depth at four boring locations, not uncommon for a dense chlorinated compound released at the surface;

- Concentrations of methylene chloride have been observed as high as 29,000 µg/L in groundwater beneath the 903 Pad at well 06691;

- The distribution of methylene chloride in soil coincides with the chlorinated solvent plumes identified beneath the 903 Pad (RMRS, 1998e);

- Concentrations of methylene chloride at well 08891 have increased from historical non-detect values to 11,000 µg/L in 1998 while concentrations of carbon tetrachloride have decreased from 5,500 to 5,300 µg/L from 1995 to 1998. These "trends" support the fact that methylene chloride is a natural degradation product of carbon tetrachloride, one of the primary constituents that was released from ruptured drums at the 903 Pad drum storage area.

Although carbon tetrachloride was identified as one of the original constituents released from the drums stored at the 903 Pad Area, it was not detected in soils above proposed SALs. However, carbon tetrachloride likely degraded naturally to methylene chloride, which was detected above Tier I Subsurface SALs at several boring locations and depth intervals. Chlorinated solvents such as carbon tetrachloride can be transformed by chemical and biological processes to form other chlorinated aliphatic hydrocarbons such as methylene chloride (Vogel et al., 1987; McCarty et al., 1992).

1.3 ROCKY FLATS CLEANUP AGREEMENT

The Rocky Flats Cleanup Agreement (RFCA) is a legally binding agreement between the Department of Energy (DOE), the Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE) to accomplish the required cleanup of radioactive and other hazardous substance contamination at the RFETS. Action levels and cleanup levels for interim remedial actions have been established for surface water, ground water, and soils and are presented in Attachment 5 of RFCA; "Action Levels and Standards Framework for Surface Water, Ground Water,

[1] The background screening level (BSL) is equal to the background mean plus two standard deviations.

and Soils (ALF)" (K-H, 1999a). Surface soil is defined in the ALF as shallow soil to a depth of 6 inches (in) (15 cm). Subsurface soil is defined in ALF as soil deeper than 6 in (15 cm). Radionuclide Soil Action Levels (RSALs) for an open space future use scenario are the same for surface soils and subsurface soils.

Revisions to the Subsurface Soil Action Levels (SSALs) have been proposed which has resulted in revised Tier I action levels and the inclusion of new Tier II action levels for organic compounds. For this site characterization, contaminant concentrations in surface and subsurface soils have been compared to both Tier I and II RSALs, current Tier I SSALs, and proposed Tier I and Tier II SSALs (Kaiser-Hill, 1999a) in order to assist in the development of the best management strategy for site cleanup. In addition, an independent review of the soil action levels is currently being conducted by the Rocky Flats Soil Action Level Oversight Panel. Based on this independent review and the results from soil erosion modeling being performed by the Actinide Migration Evaluation Panel additional revisions to the soil action levels may be proposed in the future.

Radionuclides – Table 1-1 provides the Tier I and Tier II RSALs for an open space future use exposure scenario.

Table 1-1 RFCA Tier I and II Radionuclide Soil Action Levels - Surface and Subsurface Soils

RADIONUCLIDE	TIER I RSAL (pCi/g)	TIER II RSAL (pCi/g)
^{241}Am	215	38
$^{239/240}$Pu	1429	252
^{234}U	1738	307
^{235}U	135	24
^{238}U	586	103

If a mixture of radionuclide contaminants a, b, c are present in the soil with activities a_a, a_b, and a_c, and if the applicable RSALs, are A_a, A_b, and A_c respectively, then the activity in the soil shall be considered as exceeding the RSALs if the sum of ratios (SOR) is greater than 1, i.e.,

$$\text{Sum of Ratios (SORs)} = \frac{a_a}{A_a} + \frac{a_b}{A_b} + \frac{a_c}{A_c} > 1 \qquad \text{(Equation 1-1)}$$

Volatile Organic Compounds **-** Table 1-2 provides the current Tier I SSALs and the proposed Tier I and Tier II SSALs for VOC contaminants of concern in soils at the 903 Pad.

Table 1-2 Subsurface Soil Action Levels - VOCs

COMPOUND	Current TIER I SSAL (mg/kg)	Proposed TIER I SSAL (mg/kg)	Proposed TIER II SSAL (mg/kg)
Carbon Tetrachloride	11.00	3.56	0.0356
Chloroform	152.00	21.4	0.214
1,2,-Dichloroethene (Total)	9.51	14.0	0.14
Methylene Chloride	5.77	0.578	0.00578
Tetrachloroethene	11.5	3.15	0.0315
Trichloroethene	9.27	3.28	0.0328

1.4 EXISTING DATA

Numerous investigations to assess the extent of contamination at the 903 Pad, Lip Area, and Americium Zone have been conducted. These investigations are briefly described below.

1.4.1 Surface Soils

High Purity Germanium (HPGe) Surveys - HPGe surveys conducted in 1990 (EG&G, 1991) and 1994 (DOE, 1995; RMRS, 1997b) provide useful information on the activity of ^{241}Am in surface soils over the Americium Zone study area. These data were collected on a 150-foot grid to accommodate the HPGe detector's field of view (FOV) of 150 feet in diameter (17,671 ft^2) (Figure 1-2). Surveys were not conducted over the 903 Pad and Lip Area and soil samples were not collected to supplement the surveys. The results from these surveys were utilized to define the boundaries of this characterization's investigation area.

Surface Soil Radiological Data - Surface soil samples were collected in support of the OU2 Phase II RFI/RI (DOE, 1995). As detailed in the RFI/RI, samples were collected utilizing two sampling methods; the Colorado Department of Health (CDH) sampling method and the Rocky Flats (RF) sampling method. Surface soil sample results were compared with Tier I RSALs. The results of the

comparison indicated that samples collected from five 2.5-acre plots exceed the Tier I RSALs. These plots include two 2.5-acre plots (Plots 28 and 34) sampled using the CDH sampling method and three 2.5-acre plots (Plots 29, 36, and 46) sampled using the RF method (Figure 1-3).

1.4.2 Subsurface Soils

Subsurface Soil Radiological Data - Three data sources were evaluated to determine the depth of radiological contamination within the study area: 1) RFI/RI borehole data (DOE, 1995); 2) RFI/RI soil profile pits (DOE, 1995); and 3) samples collected in support of a 1980 soil decontamination project (Rutherford, 1981). Results from the RFI/RI borehole samples were compared to RSALs and revealed that no samples exceed the Tier I RSALs. However, samples collected from soil profile pit TR08 exceeded Tier I RSALs to a depth of 27 centimeters (cm) (10.6 in). Soil profile pits were sampled at 3 cm (1.2 in) intervals to a total depth of 1 meter (m) (3.28 feet). Samples collected at soil profile pit TR06, located adjacent to pit TR08, were not analyzed because activities exceeded the DOT shipping requirements. It is assumed that radiochemical results from pit TR06 would also exceed Tier I RSALs, if analyzed.

Soil samples collected beneath the 903 Pad in support of the 1980 soil decontamination project exceeded Tier I RSALs to a depth of 66 cm (26-in) (RMRS, 1997b). This depth exceeds the thickness of the asphalt pad and the depth of imported base coarse material and indicates radiological contamination of natural undisturbed soils at the 903 Pad. However, no RFI/RI soil borings detected radiological contamination in excess of Tier I RSALs. As a result, a discrepancy with the depth of radiological contamination between these investigations exists.

Subsurface Soil VOC Data - Three sources of data were evaluated to determine the nature and extent of contamination at the 903 Pad: 1) RFI/RI borehole data (DOE, 1995); 2) IM/IRA soil gas survey results (DOE, 1994); and 3) groundwater monitoring well data.

Borehole sample results from the RFI/RI were compared with current Tier I SSALs revealed that no samples exceeded the current Tier I SSALs for organic contaminants. The soil gas survey indicated that the highest VOC concentrations were located immediately south of the southeast corner of the 903 Pad. Tetrachloroethene was detected at 27,000 micrograms per liter (ug/L) at a depth of 5 feet.

However, at adjacent soil gas locations and boreholes, tetrachloroethene is either not detected or detected at very low concentrations. Soil gas concentrations for the remaining portion of the 903 Pad ranged from 0-500 ug/L with the highest concentrations around and north of monitoring well 08891 (Figure 1-4).

1.4.3 Groundwater

A VOC-contaminated groundwater plume extends from the 903 Pad area to the east. The highest concentrations are found in groundwater samples collected from wells 06691 and 08891, which are located on the asphalt portion of the 903 Pad. Concentrations of contaminants in groundwater decrease rapidly moving eastward from the 903 Pad area. The primary groundwater contaminant in well 06691 is carbon tetrachloride with concentrations ranging from 51 to 100,000 ug/L. Methylene chloride (150 to 29,000 ug/L) and chloroform (92 to 46,000 ug/L) are also observed. Groundwater sample results for well 08891 indicate the primary contaminant as PCE at concentrations ranging from 470 to 27,000 ug/L, along with carbon tetrachloride (290 to 17,000 ug/L), cis-1,2,dichloroethene (94 to 2,900 ug/L) and TCE (210 to 4,600 ug/L). The next highest concentration of carbon tetrachloride in groundwater is found in samples collected from well 13191, which is located west of the well 06691 and off the western edge of the 903 Pad. At this location, observed carbon tetrachloride levels ranged from 122 to 4,800 ug/L.

Concentrations of VOCs in groundwater decrease rapidly eastward from the 903 Pad area (DOE, 1995). For example, during the June 1998 groundwater sampling, well 06991 had 210 ug/L PCE and well 1587 had 880 ug/L PCE which are two orders of magnitude less than the concentration observed in well 08891 with 27,000 ug/L PCE (Figure 1-4).

Because of the complex nature of DNAPL transport and fate, DNAPL may often be undetected by direct methods leading to incomplete site assessments and inadequate remedial designs (EPA, 1992). A guide for estimating the potential for a DNAPL source at a site includes assessing if concentrations of DNAPL-related chemicals in groundwater are greater than 1% of the pure (single) phase solubility of the compound (EPA, 1992).

Table 1-3 provides a comparison of the pure single phase aqueous solubility and concentrations of DNAPL-compounds detected in groundwater at the 903 Pad (wells 06691 and 08891) from a June 1998 sampling event of monitoring wells 06691 and 08891. The comparison indicates that PCE and carbon tetrachloride have been detected in groundwater samples at 13.5% and 10.7% of their aqueous solubilities, respectively. These results and the known historical releases at the 903 Pad indicate there is a potential for pure phase organic contaminants in subsurface soils beneath the 903 Pad.

Table 1-3 Comparison of Pure Single Phase Aqueous Solubilities with VOC Concentrations in Groundwater

Compound	Pure Single Phase Aqueous Solubility at 25^0C[1] (mg/l)	Concentration Detected in Groundwater June 1998 (mg/l)	Ratio Groundwater Concentration/ Aqueous Solubility (%)
Carbon Tetrachloride	793	85.0	10.7
Chloroform	7,920	4.4	0.1
cis-1,2,dichloroethene	3,500	1.3	0.04
Methylene Chloride	13,000	29.0	2.2
PCE	200	27.0	13.5
TCE	1,100	1.3	0.12

[1]EPA, 1996. Soil Screening Guidance: Technical Background Document

1.5 SURFICIAL GEOLOGY

The surficial geology in the study area consists of Quaternary alluvium, colluvium and slump deposits along with artificial fill, soil and debris deposits, and disturbed soil. The surficial deposits overlie bedrock which consists of weathered claystone and minor bedrock sandstones of the Cretaceous Arapahoe and Laramie Formations. Surficial deposits consist of sandy clay and clayey gravel. Soil developed over the alluvium is rocky and sandy in contrast to the clayey soils developed over the claystone bedrock.

For this investigation, the surface and subsurface soils were subdivided into six soil horizons: (1) the Native 1 soil horizon consists of natural soils from 0 to 6 inches (surface soils); (2) the Native 2 soil horizon designates subsurface soils from 6 inches to 1 foot: (3) the Native 3 soil horizon designates

subsurface soil from 1 to 1.5 feet; (4) the Native 4 soil horizon designates subsurface soil from 1.5 to 2.0 feet; (5) the Native group consists of Quaternary alluvium from the bottom of the Native 4 soil horizon (2.0 feet) to the bedrock contact; and (6) the Bedrock group consists of consolidated geologic material from the undifferentiated Laramie/Arapahoe Formations.

Artificial fill is present directly beneath the 903 Pad and in the Lip Area as a result of previous remediation activities. In November 1968 “slightly-contaminated” soil was graded from outside the fence at the 903 Pad into the fenced area to be capped. In September of 1969 a base coarse (artificial fill) material overlay, soil sterilant, and asphalt primer were constructed for the 903 “containment barrier” (Pad). The asphalt pad was constructed in October of 1969 and was reportedly 3 in (7.6 cm) thick. The thickness of the base coarse materials beneath the 903 Pad was assumed to be approximately 8 inches (20 cm). In February 1970, operations were initiated to apply additional fill (base coarse) over the Lip Area due to soil contamination. The thickness of the fill material reportedly ranged from 0.8 in (2 cm) to 5.1 in (13 cm) (DOE, 1995; RMRS, 1997b).

1.6 SITE CONCEPTUAL MODEL

The contaminants present in the surface and subsurface soil are primarily a result of drum storage in the 903 Pad area. Drums containing hydraulic fluids and lathe coolant contaminated with plutonium and uranium leaked onto the surface soil. The liquids from the drums may have moved downward towards the bedrock surface, possibly carrying a fraction of the radionuclides into the subsurface along preferential pathways such as rodent holes, desiccation cracks, and/or along decayed roots. High winds and heavy rains spread the surficial radiological contamination outward from the 903 Pad, depositing it on surface soils in the Lip Area and Americium Zone.

Previous HPGe surveys from the study area and surface soil sample data show that, in general, higher concentrations are present near the 903 Pad, and concentrations decrease with increasing distance from the 903 Pad. Immediately east and south of the 903 Pad and Lip Area, there are areas of higher concentrations which may be the result of wind and surface water dispersion of contaminants (DOE, 1995). Accounting for the surface soil and HPGe sampling already collected from the 903 Pad area to Indiana Street, and the direction of surface water flow from the 903 Pad towards the South

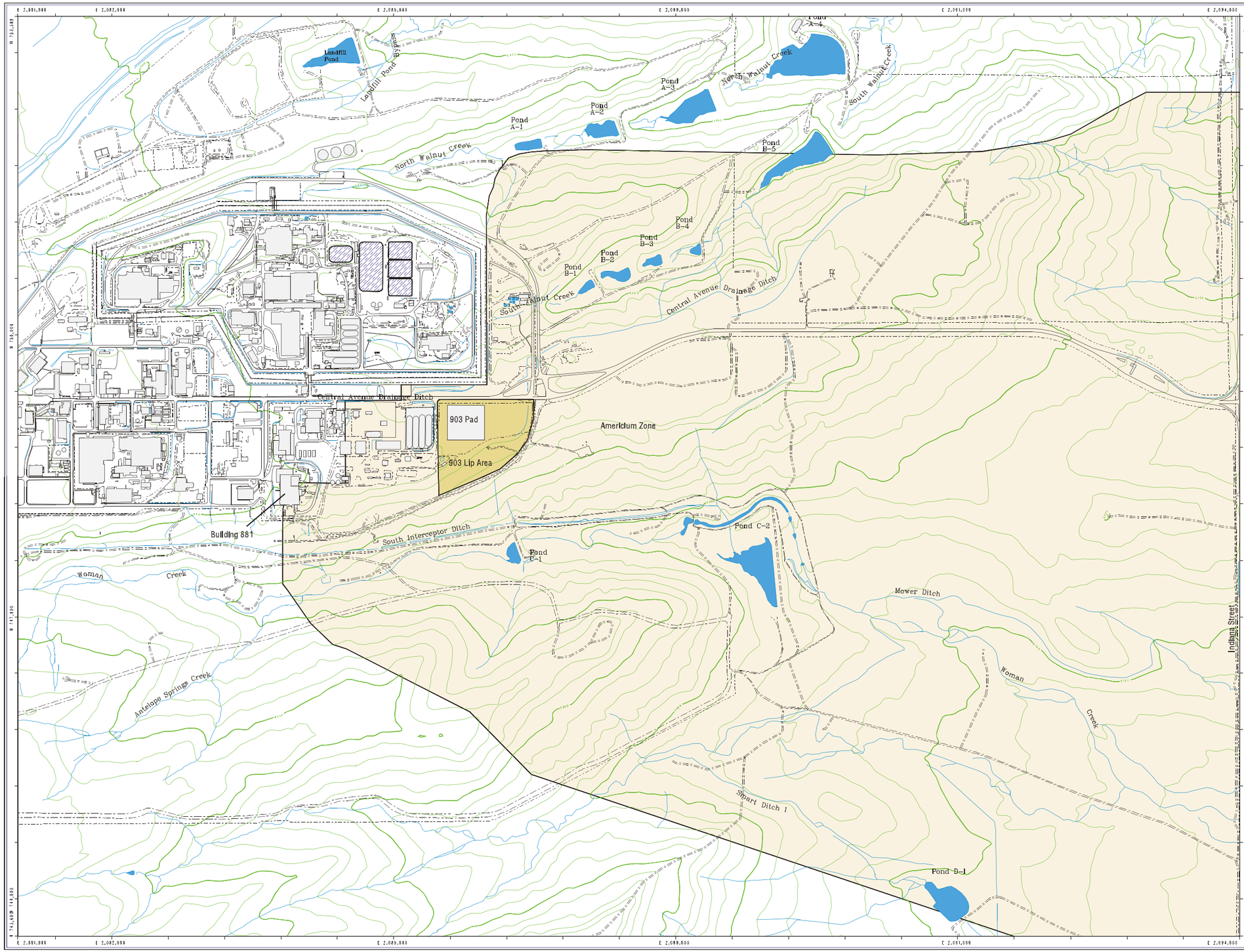
Interceptor Ditch, it was concluded that hot spots are not likely to be present to the east, outside of the Investigation Area (Figure 1-4).

The source of subsurface VOC contamination is suspected to be present directly beneath the area where drums were previously stored (DOE, 1995; RMRS; 1997b). The liquid contained in the drums may have migrated downward towards the bedrock surface. An east-west paleochannel is cut into the bedrock, with the greatest depth to bedrock located toward the middle of the 903 Pad (DOE, 1995; RMRS, 1997b; RMRS, 1997c). Available subsurface and groundwater VOC data (see Section 1.3) indicates that any potential source of DNAPL contamination is limited to the area under the present 903 Pad. The VOC contamination east of the 903 Pad is limited to the dissolved phase in groundwater as supported by groundwater data (see Section 1.3.3) (DOE, 1995; RMRS, 1998e).

1.7 PROJECT INVESTIGATION AREA

Based on the foregoing evaluation of the existing data in the study area, an Investigation Area was defined for this site characterization that represents the area where additional data is required to refine the volume estimate of contaminated soils (Figure 1-4). The Investigation Area represents that portion of the study area which is known, or in which a potential exists, for surface and/or subsurface soils to exceed Tier I RSALs and current Tier I SSALs. These areas include:

- Surface soils exceeding 10 pCi/g ^{241}Am as identified in the 1990 and 1994 HPGe surveys;
- Areas where artificial fill (and asphalt) has been placed over natural soils including the 903 Pad, Lip Area, and areas remedied in 1976, 1978, and 1984;
- Five 2.5-acre plots identified as exceeding Tier I soil action levels based on OU2 RFI/RI surface soil sampling results: and
- The 903 Pad and Lip Area where a subsurface VOC source is suspected as the source of a groundwater contaminant plume.



Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Study Area Location Map

Figure 1-1

EXPLANATION

- 903 Lip Area
- Study Area
- 903 Pad

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs, 1/95

Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

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Scale = 1 : 12690
1 inch represents approximately 1058 feet

250 0 500 1000 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

Prepared for:

MAP ID: 99-0403

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Original map contents are preserved. Logo and date have changed.

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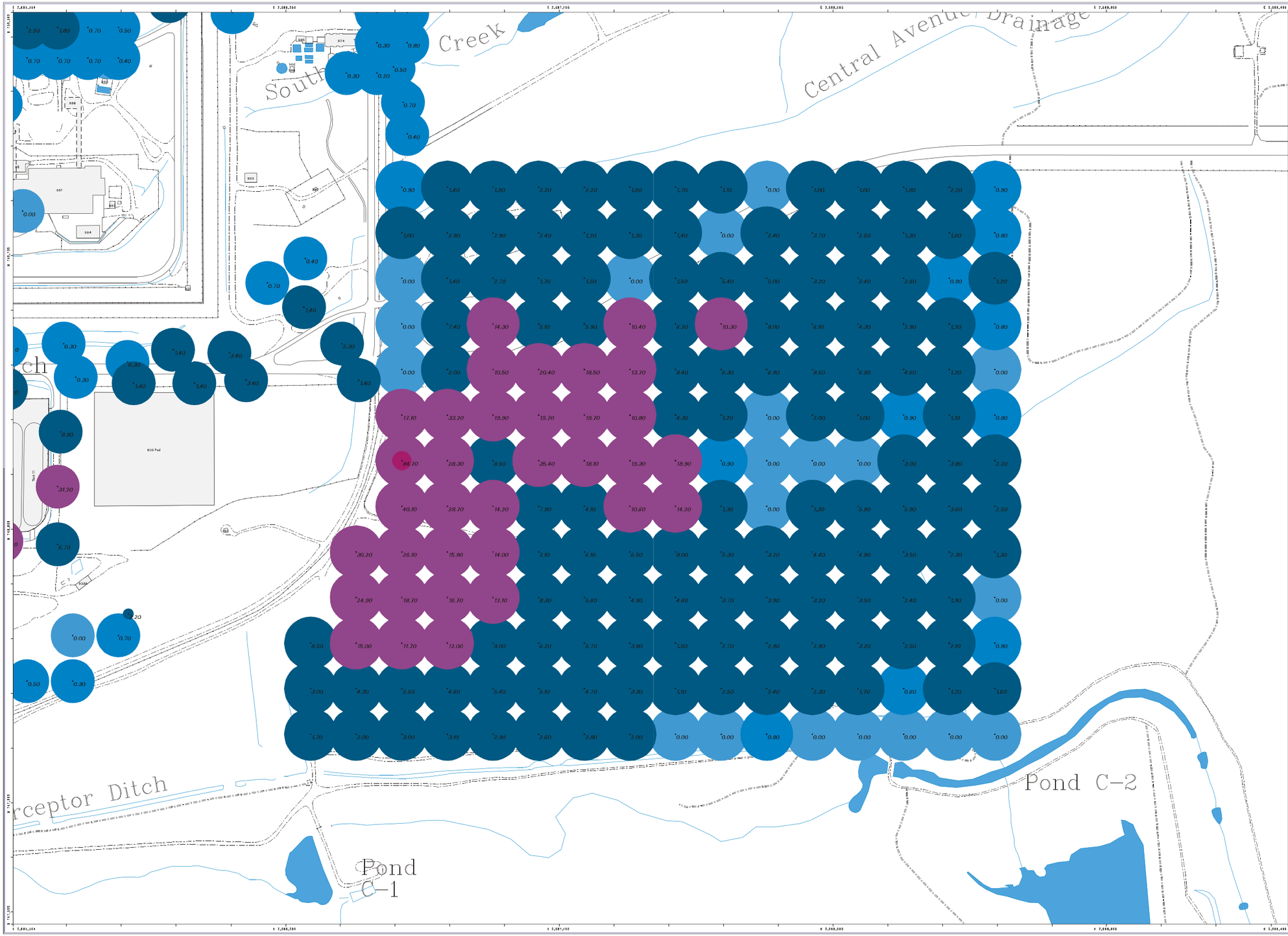

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

1994 HPGe Survey Data for Am-241 in Investigation Area

Figure 1-2

HPGe Data Ranges-- pCi/g for a Field of View of 150 feet (DOE, 1995)

- 0.0 - 0.1
- 0.1 - 1
- 1 - 10
- 10 - 100
- 100 - 1000
- 1000 - 10000

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by: EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

NOTE:
Raw field data which has not been evaluated and may be influenced by building shine.

The HPGe field of view (FOV) or radius of influence, assumes a homogeneous surface distribution. The FOV represents a circle where 90% of the flux originates. The radius, for each HPGe sampling location, is based on the height of the detector above the ground.

The FOV for the maojority of the points is 150 feet however, two of the survey locations have a FOV of less than 150 feet.

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Scale = 1 : 3870
1 inch represents approximately 323 feet

50 0 150 300ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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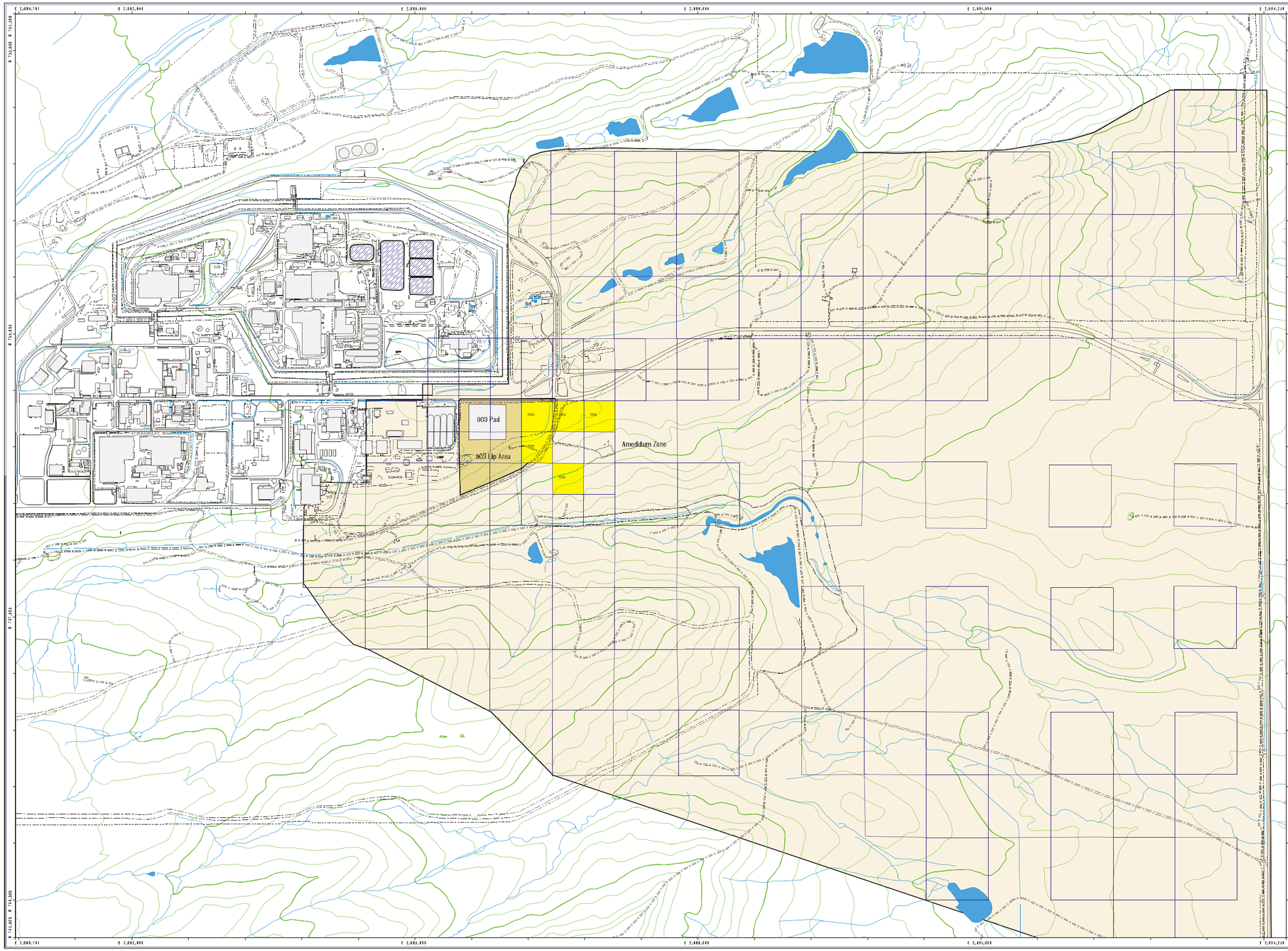

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

OU2 Phase II RFI/RI Surface Soil Sampling Plots Study Area

Figure 1-3

EXPLANATION

- CDH & RF Surface Soil Sampling Plots - (DOE, 1995a)
- Study Area
- 903 Lip Area
- Sampling Plots Exceeding Tier I Soil Actions Levels - Radoinuclides (DOE, 1995a)

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs, 1/95

Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.

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N

Scale = 1 : 12630
1 inch represents approximately 1053 feet

250 0 500 1000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

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Prepared by:
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Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Investigation Area Location Map

Figure 1-4

EXPLANATION

- HPGe 150 foot FOV Circles (above 10pCi/g Am-241)
- Plots above Tier I Action Levels
- Groundwater Well Locations
- Soil profile Sampling Sites
- 1976 Soil Removal Area (approx)
- 1978 Soil Removal Area (approx)
- 1970 Soil Fill Area (approx)
- 1984 Soil Fill Area (approx)

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

HPGe data from Ron Reimer, Gamma Survey Group, Safeguard Measurements, EG&G Rocky Flats, Inc. June 1994

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Scale = 1 : 2270
1 inch represents approximately 189 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

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Prepared by: DynCorp THE ART OF TECHNOLOGY

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MAP ID: 99-0403

July 20, 2000

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2.0 FIELD INVESTIGATION

2.1 OVERVIEW

The lateral and vertical extent of radiological and VOC contamination was assessed within the proposed investigation area. The lateral extent of radiological contamination in the Americium Zone and a portion of the Lip Area were primarily assessed using a non-intrusive HPGe field method. The HPGe method results were "standardized" by correlation to radiochemical data collected by sampling surface soils from selected HPGe measurement locations, and analyzing these samples for radionuclides using alpha spectroscopy. The lateral and vertical extent of contamination at the 903 Pad and a majority of the Lip Area were assessed utilizing sample collection methods employing a Geoprobe®, and analyzing the samples for radionuclides and VOCs in a laboratory. The data were collected pursuant to the Sampling and Analysis Plan for the Site Characterization of the 903 Drum Storage Area (IHSS 112), 903 Lip Area (IHSS 155), and Americium Zone (SAP) (RMRS, 1998a).

2.2 SURFACE SOIL INVESTIGATION

The activities of ^{241}Am, $^{239/240}$Pu, $^{233/234}$U, ^{235}U, and ^{238}U in surface soils within the Americium Zone and a portion of the Lip Area were measured *in situ* using an HPGe survey together with radiochemical analyses of surface soil samples.

2.2.1 HPGe Methodology

The HPGe instrument measures *in situ* activities of ^{241}Am, ^{235}U and ^{238}U. For this investigation, the HPGe measurement had a field of view (FOV) of 10 meters (m) in diameter with the detector placed 1-m over the ground surface. The Compendium of *In Situ* Radiological Methods and Applications at Rocky Flats Plant (EG&G, 1993) provides a detailed discussion on the physics of *in situ* measurement of radionuclides in the environment.

The HPGe survey focused on the Americium Zone (Figure 2-1) and includes all surface soils with elevated concentrations of $^{239/240}$Pu and/or ^{241}Am identified during the OU2 RFI/RI including:

- The 35 HPGe measurements which exhibit elevated (above 10 pCi/g) ^{241}Am activities;
- The area directly below the culvert which drains the 903 Pad and Lip Area where sediments are deposited during surface runoff events; and
- The five 2.5-acre plots where surface soils exceed Tier I RSALs.

The HPGe system used to perform *in situ* measurements for the investigation employs the Canberra *In Situ* Object Counting System (ISOCS) software. In order to estimate counting efficiencies, this software requires the entry of various parameters which should accurately represent the actual field conditions at the site. One important parameter is the distribution of contaminants vertically. In the HPGe investigation area, contamination was deposited via airborne and/or surface water releases. This resulted in a distribution with high activities near the surface and decreasing activities with depth, which may follow an exponential function. Surface soil sampling was previously performed in the study area to determine the vertical distributions. In general, the radionuclides are concentrated in the top 5-cm. Based on available data, the ISOCS model assumes all contamination is contained in the top 5-cm, and it is distributed with 66% in the top 3-cm and 33% in the next 2-cm. This distribution was used to be consistent with the surface soil sampling methodologies (RMRS, 1998a), which specifies sampling surface soil to a depth of two inches (5 cm). In addition, the contribution from ^{241}Am below a depth of 5 cm in soil is quite small. It is possible that the actual distributions in the top 5-cm may be more concentrated near the surface or more uniformly distributed throughout the 5-cm layer. A set of efficiencies with different vertical distributions was prepared and the standard acquisition analyzed.

Results:

Default 2 layer 0-3 cm 66%, 3-5 cm 33%	^{241}Am = 12.2 pCi/g
Single layer, 0-5 cm uniform	^{241}Am = 14.3 pCi/g
3 layers, 0-1.5cm 50%, 1.5-3 cm 30%, 3-5 cm 20%	^{241}Am = 11.6 pCi/g
3 layers, default with 1cm grass cover	^{241}Am = 13.2 pCi/g
2 layer with 0-3 cm 60%, 3-5 cm 40%	^{241}Am = 12.2 pCi/g

As can be seen, the overall error of a likely range of possible distributions is about +/- 10 %.

2.2.2 Double Sampling Correlation Technique

To "standardize" the *in situ* method, a double sampling technique was employed whereby soil samples were collected from select HPGe measurement locations (RMRS, 1998a) and analyzed in the laboratory for ^{241}Am, $^{239/240}$Pu, $^{233/244}$U, ^{235}U, and ^{238}U using alpha spectroscopy, and gamma spectroscopy for ^{241}Am and ^{235}U. The gamma spectroscopy data was collected by the laboratory to simply "validate" the alpha spectroscopy results, and the two sets of results are comparable as indicated by their linear relationship with a slope of one [(Table 2-1) (Figure 2-2)].

Table 2-1 Laboratory Gamma Spectroscopy Results vs. Laboratory Alpha Spectroscopy Results – 241Am

HPGe Measurement Location	Laboratory Gamma Spectroscopy Results ^{241}Am (pCi/g) dry wt	Laboratory Alpha Spectroscopy Results ^{241}Am (pCi/g) dry wt
30*	3.67	3.67
104	19.08	27.80
265	45.46	49.32
266	21.89	22.60
305	7.45	11.05
406	107.86	77.27
460*	111.09	148.23
669*	57.84	57.85

* Real and Duplicate Sample Results Averaged

In order to acquire a good double sampling correlation over the anticipated range of ^{241}Am activities, eight HPGe measurement locations were selected that encompass five ^{241}Am activity intervals; 0-10 (three measurements), 10-20, 20-50 (two measurements), 50-100, and 100-200 pCi/g. These intervals were selected based on detection frequencies of ^{241}Am activities measured in surface soil samples collected in support of the OU2 Phase II RFI/RI (DOE, 1995; RMRS, 1998a).

Multiple HPGe measurements were taken at some of the double sampling locations for quality control. These results are provided in Table 2-2. In these cases, the measurements at each double sampling location were averaged to create the HPGe data set used in the correlation. Table 2-2 also indicates the HPGe measurements at each double sampling location are relatively uniform.

Table 2-2 HPGe ^{241}Am Results at Double Sampling Locations

HPGe Measurement 30		HPGe Measurement 104		HPGe Measurement 265		HPGe Measurement 266		HPGe Measurement 305		HPGe Measurement 406		HPGe Measurement 460		HPGe Measurement 669	
Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)	Count Duration (sec)	^{241}Am (pCi/g)
900	1.1	900	14.5	900	34.3	900	9.1	1200	7.0	900	70.2	900	106.3	900	32.2
		900	17.6	900	39.0			1200	7.5	900	62.9	900	113.2	1200	32.8
		900	20.6	900	39.1			1200	4.7	900	61.7	900	80.2	1200	39.5
		1200	15.5	900	37.3			1200	6.0	900	62.6	900	98.3	1200	35.3
		1200	22.6	900	31.7			1200	4.9	900	65.9	900	115.7	1200	35.2
		1200	17.6	900	29.2			1200	5.7			900	80.8		
		1200	23.0	900	31.3			1200	5.4						
		900	15.1	900	39.3			1200	4.0						
		900	17.6	900	34.4										
		1200	13.0												
		1200	18.6												
		1200	19.4												
		1200	15.8												
		1200	15.8												
Average	**1.1**		**17.6**		**35.1**		**9.1**		**4.7**		**64.7**		**99.1**		**35.0**

Fifteen (15) grab samples were then collected at each double sampling location; one grab sample from the center; four grab samples collected at 1- m radius, and ten grab samples from 3-m radius. Figure 2-3 provides this surface soil sampling geometry which was developed by the DOE (DOE, 1997) at the Fernald Environmental Management Project site in Ohio in order to correlate HPGe results to surface soil results. The 1-m and 3-m radius grab samples were then composited into a 1-m and 3-m sample representative of each individual band. Therefore, three separate alpha (and gamma) spectroscopy analyses were performed at each double sampling location.

Samples were collected in this “bulls eye” pattern to mimic the averaging done by the field HPGe detector over the instrument’s FOV. The HPGe detector receives gamma-ray photons from every point within the circle; however, it receives more gamma rays from soil closer to the detector than from soil further from the detector. If the circle is divided into concentric bands, the relative weighting factor for each band can be calculated based upon the percentage influence of gamma photons at the detector which originates from a given band of soil, assuming a uniform source distribution with depth and a one MeV photon energy. The relative weighting factor is the relative importance of each band with respect to the probability of gamma-rays emitted from within that band being detected by the HPGe (Table 2-3). The sample results were multiplied by the weighting factor per band, then the products were summed to determine the activity of the soils in the FOV area. Tables 2-4 and 2-5 provide the results of these calculations, including adjustment for moisture content in order to report results on a wet weight or "*in situ* moisture" basis. Note that if field duplicate samples were collected at a given double sampling location, the "real" and "duplicate" data were averaged (denoted as "combined"), and the "combined" data were used in the weighted averaging process to develop the data for the correlation.

Table 2-3 Surface Soil Samples, Weighted Average Calculations

Horizontal Distance from Point Under Detector (m)	Weight (per circle)
0	0.1
1	0.36
3	0.54
Total	1.00

Table 2-4 Alpha Spectroscopy Results for ^{241}Am at Double Sampling Locations

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
30	Real	99A5936-002.001	0	2.3659	4.99	0.24	0.2253
	Real	99A5936-004.001	1	4.6643	4.6	1.68	1.6053
	Real	99A5936-006.001	3	3.574	5.18	1.93	1.8349
		Average		3.535		3.85	3.666
30	Duplicate	99A5936-003.001	0	1.7105	4.99	0.17	0.1629
	Duplicate	99A5936-005.001	1	4.4612	4.6	1.61	1.5354
	Duplicate	99A5936-007.001	3	3.1966	5.18	1.73	1.6412
		Average		3.123		3.50	3.339
30	Combined		0	2.0382	4.99	0.2	0.1941
	Combined		1	4.5628	4.6	1.64	1.5704
	Combined		3	3.3853	5.18	1.83	1.738
		Average		3.329		3.67	3.503

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
104	Real	98A5590-001.002	0	11.2017	4.28	1.12	1.0742
	Real	98A5590-001.004	1	29.3735	3.63	10.57	10.2041
	Real	99A5590-004.001	3	29.824	2.56	16.1	15.703
		Average		23.466		27.80	26.981

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
265	Real	98A5590-002.002	0	36.6004	2.34	3.66	3.5764
	Real	98A5590-002.004	1	70.1548	9.99	25.26	22.9618
	Real	98A5590-002.006	3	37.785	2.83	20.4	19.8424
		Average		48.180		49.32	46.381

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
266	Real	98A3372-003.002	0	33.7418	18.91	3.37	2.8376
	Real	98A3372-003.004	1	22.6443	9.6	8.15	7.4379
	Real	98A3372-003.006	3	20.503	12.55	11.07	9.8371
		Average		25.630		22.60	20.113

Table 2-4 Alpha Spectroscopy Results for ^{241}Am at Double Sampling Locations (Cont.)

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
305	Real	98A5590-003.002	0	9.947	5.04	0.99	0.947
	Real	98A5590-003.004	1	9.2659	1.13	3.34	3.2985
	Real	98A5590-003.006	3	12.4345	1.2	6.71	6.635
		Average		10.549		11.05	10.88

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
406	Real	98A3372-001.002	0	101.9353	5.91	10.19	9.6247
	Real	98A3372-001.004	1	77.7979	5.2	28.01	26.6229
	Real	98A3372-001.006	3	72.3595	4.38	39.07	37.4345
		Average		84.031		77.27	73.682

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
460	Real	98A3372-002.002	0	90.1227	11.65	9.01	8.0719
	Real	98A3372-002.004	1	151.9866	12.66	54.72	48.5666
	Real	98A3372-002.006	3	137.9899	8.67	74.51	68.5696
		Average		126.700		138.24	125.208
460	Duplicate	99A3372-002.007	0	175.1638	11.65	17.52	15.6887
	Duplicate	99A3372-002.008	1	172.9098	12.66	62.25	55.2526
	Duplicate	99A3372-002.009	3	145.2979	8.67	78.46	72.201
		Average		164.457		158.22	143.142
460	Combined		0	132.6433	11.65	13.26	11.8803
	Combined		1	162.4482	12.66	58.48	51.9096
	Combined		3	141.6439	8.67	76.49	70.3853
		Average		145.578		148.23	134.175

Table 2-4 Alpha Spectroscopy Results for ^{241}Am at Double Sampling Locations (Cont.)

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Am-241 (pCi/g)	Moisture Content (%)	Am-241 Weighted Average (pCi/g)	Am-241 Weighted Average Corrected for Moisture (pCi/g)
669	Real	99A4878-003.001	0	40.8194	8.62	4.08	3.758
	Real	99A4878-005.001	1	55.0517	10.00	19.82	18.0169
	Real	99A4878-007.001	3	60.4235	7.99	32.63	30.2145
		Average		52.098		56.53	51.989
669	Duplicate	99A4878-004.001	0	75.9211	8.62	7.59	6.9896
	Duplicate	99A4878-006.001	1	66.7147	10.00	24.02	21.8339
	Duplicate	99A4878-008.001	3	51.0332	7.99	27.56	25.519
		Average		64.556		59.17	54.342
669	Combined		0	58.3703	8.62	5.84	5.3738
	Combined		1	60.8832	10.	21.92	19.9254
	Combined		3	55.7284	7.99	30.09	27.8668
		Average		58.327		57.85	53.166

Table 2-5 Alpha Spectroscopy Results for $^{239/240}$Pu at Double Sampling Locations

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu –239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
30	Real	99A5936-002.001	0	12.8235	4.99	1.28	1.2214
	Real	99A5936-004.001	1	21.7524	4.60	7.83	7.4865
	Real	99A5936-006.001	3	23.8498	5.18	12.88	12.2446
		Average		19.475		21.99	20.953
30	Duplicate	99A5936-003.001	0	8.4155	4.99	.84	0.8016
	Duplicate	99A5936-005.001	1	23.1372	4.60	8.33	7.9631
	Duplicate	99A5936-007.001	3	15.5486	5.18	8.4	7.9827
		Average		15.700		17.57	16.747
30	Combined		0	10.6195	4.99	1.06	1.0115
	Combined		1	22.4448	4.60	8.08	7.7248
	Combined		3	19.6992	5.18	10.64	10.1137
		Average		17.588		19.78	18.85

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
104	Real	98A5590-001.002	0	61.0754	4.28	6.11	5.8569
	Real	98A5590-001.004	1	121.7496	3.63	43.83	42.2946
	Real	98A5590-001.006	3	161.424	2.56	87.17	84.9931
		Average		114.750		137.11	133.145

Table 2-5 Alpha Spectroscopy Results for $^{239/240}$Pu at Double Sampling Locations (Cont.)

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
265	Real	98A5590-002.002	0	150.7151	2.34	15.07	14.7269
	Real	98A5590-002.004	1	150.3247	9.99	54.12	49.2016
	Real	98A5590-002.006	3	151.1863	2.83	81.64	79.3938
		Average		150.742		150.83	143.322

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
266	Real	98A3372-003.002	0	250.0412	18.91	25.00	21.0278
	Real	98A3372-003.004	1	194.6868	9.6	70.09	63.9482
	Real	98A3372-003.006	3	87.7801	12.55	47.4	42.1157
		Average		177.503		142.49	127.092

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
305	Real	98A5590-003.002	0	80.7024	5.04	8.07	7.683
	Real	98A5590-003.004	1	67.9077	1.13	24.45	24.1736
	Real	98A5590-003.006	3	48.3793	1.2	26.12	25.815
		Average		65.663		58.64	57.672

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
406	Real	98A3372-001.002	0	906.2229	5.91	90.62	85.5654
	Real	98A3372-001.004	1	524.8652	5.2	188.95	179.6117
	Real	98A3372-001.006	3	519.3453	4.38	280.45	268.6784
		Average		650.144		560.02	533.855

Table 2-5 Alpha Spectroscopy Results for $^{239/240}$Pu at Double Sampling Locations (Cont.)

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
460	Real	98A3372-002.002	0	554.3172	11.65	55.43	49.6478
	Real	98A3372-002.004	1	1,481.6998	12.66	533.41	473.4706
	Real	98A3372-002.006	3	675.0613	8.67	364.53	335.4496
		Average		903.693		953.38	858.568
460	Duplicate	99A5936-002.001	0	782.3574	11.65	78.24	70.0723
	Duplicate	99A5936-004.001	1	684.6637	12.66	246.48	218.7812
	Duplicate	99A5936-006.001	3	841.5062	8.67	454.41	418.159
		Average		769.509		779.13	707.013
460	Combined		0	668.3373	11.65	66.83	59.86
	Combined		1	1,083.1818	12.66	389.95	346.1259
	Combined		3	758.2838	8.67	409.47	376.8043
		Average		836.601		866.25	782.79

HPGe Measurement Location	Sample Type	Sample No.	Radius (m)	Pu-239/240 (pCi/g)	Moisture Content (%)	Pu-239/240 Weighted Average (pCi/g)	Pu-239/240 Weighted Average Corrected for Moisture (pCi/g)
669	Real	99A4878-003.001	0	265.908	8.62	26.59	24.4806
	Real	99A4878-005.001	1	318.3239	10.00	114.6	104.1787
	Real	99A4878-007.001	3	376.36	7.99	203.23	188.1974
		Average		320.197		344.42	316.857
669	Duplicate	99A4878-004.001	0	525.3358	8.62	52.53	48.3646
	Duplicate	99A4878-006.001	1	435.6164	10.00	156.82	142.5654
	Duplicate	99A4878-008.001	3	297.2583	7.99	160.52	148.6429
		Average		419.404		369.87	339.573
669	Combined		0	395.6219	8.62	39.56	36.4226
	Combined		1	376.9702	10.00	135.71	123.372
	Combined		3	336.8092	7.99	181.88	168.4202
		Average		369.800		357.15	328.215

2.2.2.1 Alpha Spectroscopy/HPGe $^{239/240}$ Pu and ^{241}Am Correlations

The linear regressions (using the method of least squares) between the alpha spectrometry data ($^{239/240}$Pu and ^{241}Am) and the HPGe data (^{241}Am) show very high degrees of correlation (Figures 2-4 and 2-5). The correlation coefficients (R) are greater than or equal to 0.97. The ^{241}Am (alpha spectrometry) to ^{241}Am (HPGe) correlation has a slope (1.25) near 1.0 and a small intercept (4.43 pCi/g) near zero as would be expected when correlating the activities of the same radionuclide. The $^{239/240}$Pu (alpha spectrometry) to ^{241}Am (HPGe) correlation has a slope of 8.08 which is

within the expected range of $^{239/240}$Pu to ^{241}Am activity ratios considering the in-growth of ^{241}Am in weapons grade plutonium over 30 to 40 years (elapsed time since the release). The intercept (3.24 pCi/g) is also small in magnitude. These results indicate the regression lines are appropriate models to correlate HPGe data to alpha spectrometry data.

However, according to the SAP (RMRS, 1998a), the 95% upper confidence limits (UCL) of the linear regressions are to provide the equations to calculate the activities of these isotopes in the surface soils at all *in situ* measurement locations (see Figures 2-4 and 2-5). Examination of the results from using the 95% UCL to determine RSAL exceedances strongly suggest this alternative "model" to be overly conservative. Figures 2-6, 2-7, and 2-8 show RSAL exceedances in surface soils in the Americium Zone based on the direct HPGe results[2], the least square regression lines ("best fit" lines), and the 95% UCL equations for the "best fit" lines, respectively. Also plotted on these figures are RSAL comparisons to historical surface soil data (0-2 inches) from the OU2 RFI/RI trenching investigations (DOE, 1995) and a surface soil investigation conducted by the Actinide Migration Evaluation Project (RMRS, 1998f). These figures also provided RSAL comparisons for the alpha spectrometry results of surface soil samples collected at the eight double sampling locations for this investigation. Analytical results and RSAL comparisons for these surface soil samples are provided in Tables 2-6, 2-7, and 2-8.

As would be expected, Figures 2-6, 2-7, and 2-8 indicate progressively higher actinide levels in surface soils, i.e. increasing numbers of Tier I, and in particular, Tier II RSAL exceedances. As can be seen, the "best fit" line results (Figure 2-7) are substantiated by the historical data. For example, unlike the HPGe "direct" results (Figure 2-6), the Tier II exceedances plotted using the "best fit" line (Figure 2-7) extend to the south bordering on location TR09 (a Tier II exceedance),

[2] Because $^{239/240}$Pu is not measured directly by the HPGe instrument at low levels, the $^{239/240}$Pu data used to determine RSAL exceedances was estimated using the $^{239/240}$Pu to ^{241}Am activity ratio of 5.8. Figure 2-9 shows the correlation between the $^{239/240}$Pu and ^{241}Am alpha spectroscopy results from soil samples collected at the eight double sampling locations (using real and duplicate sample results).

Table 2-6 Alpha Spectroscopy Results of Trench Soil Samples – OU2 RFI/RI

Location	Easting	Northing	Sample	Sampling Interval (cm)	QC	Analyte	Result	Units	Qual	Tier I SOR	Tier II SOR
TR04	2086630	748884	TR00422WCU2	0-3	REAL	Am-241	109.9000	pCi/g		0.889	5.036
					REAL	Pu-239/40	535.3000	pCi/g			
					REAL	U-233,-234	1.0080	pCi/g			
					REAL	U-235	0.0819	pCi/g	J		
					REAL	U-238DA	1.3520	pCi/g			
			TR00421WCU2	3-6	REAL	Am-241	63.7300	pCi/g		0.622	3.523
					REAL	Pu-239/40	459.9000	pCi/g			
					REAL	U-233,-234	1.2540	pCi/g			
					REAL	U-235	0.0359	pCi/g	J		
					REAL	U-238DA	1.5680	pCi/g			
TR05	2086570	748918	TR00367WCU2	0-3	REAL	Am-241	71.1800	pCi/g		0.789	4.468
					REAL	Pu-239/40	646.6000	pCi/g			
					REAL	U-233,-234	2.2070	pCi/g			
					REAL	U-235	0.0000	pCi/g	J		
					REAL	U-238DA	2.2070	pCi/g			
			TR00366WCU2	3-6	REAL	Am-241	34.1200	pCi/g		0.429	2.433
					REAL	Pu-239/40	381.3000	pCi/g			
					REAL	U-233,-234	1.4260	pCi/g			
					REAL	U-235	0.0483	pCi/g	J		
					REAL	U-238DA	1.6100	pCi/g			
TR09	2086350	748432	TR00300WCU2	0-3	REAL	Am-241	23.3700	pCi/g		0.251	1.424
					REAL	Pu-239/40	198.7000	pCi/g			
					REAL	U-233,-234	1.1960	pCi/g			
					REAL	U-235	0.0636	pCi/g	J		
					REAL	U-238DA	1.3920	pCi/g			

Table 2-6 Alpha Spectroscopy Results of Trench Soil Samples – OU2 RFI/RI (Cont.)

Location	Easting	Northing	Sample	Sampling Interval (cm)	QC	Analyte	Result	Units	Qual	Tier I SOR	Tier II SOR
TR09	2086350	748432	TR00299WCU2	3-6	REAL	Am-241	22.2800	pCi/g		0.251	1.422
					REAL	Pu-239/40	204.4000	pCi/g			
					REAL	U-233,-234	2.0480	pCi/g			
					REAL	U-235	0.0439	pCi/g	J		
					REAL	U-238DA	1.6620	pCi/g			
TR11	2086830	748455	TR00284WCU2	0-3	REAL	Am-241	15.5600	pCi/g		0.139	0.785
					REAL	Pu-239/40	88.6500	pCi/g			
					REAL	U-233,-234	1.6220	pCi/g			
					REAL	U-235	0.0796	pCi/g	J		
					REAL	U-238DA	1.5400	pCi/g			
			TR00283WCU2	3-6	REAL	Am-241	8.3860	pCi/g		0.081	0.461
					REAL	Pu-239/40	53.9900	pCi/g			
					REAL	U-233,-234	1.4840	pCi/g			
					REAL	U-235	0.0921	pCi/g	J		
					REAL	U-238DA	1.7660	pCi/g			
TR12	2087340	749045	TR00267WCU2	0-3	REAL	Am-241	34.1700	pCi/g		0.577	3.271
					REAL	Pu-239/40	591.2000	pCi/g			
					REAL	U-233,-234	1.0140	pCi/g			
					REAL	U-235	0.1239	pCi/g	J		
					REAL	U-238DA	1.8320	pCi/g			
			TR00266WCU2	3-6	REAL	Am-241	13.5300	pCi/g		0.131	0.743
					REAL	Pu-239/40	93.0900	pCi/g			
					REAL	U-233,-234	0.7726	pCi/g			
					REAL	U-235	0.0323	pCi/g	J		
					REAL	U-238DA	1.3680	pCi/g			

SOR = Sum of ratios. Source: DOE, 1995

Table 2-7 Alpha Spectroscopy Results of Surface Soil Samples – HPGe Double Sampling Locations

HPGe Measurement Location	Easting	Northing	Am-241 (pCi/g)	Pu-239/240 (pCi/g)	U-233/234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Tier I SOR	Tier II SOR
30	2087180.071	749564.78	3.503	18.850	0.784	0.075	1.128	0.03	0.18
104	2086540.732	748734.16	26.981	133.145	0.899	0.072	1.315	0.22	1.26
265	2086703.63	749219.19	46.381	143.322	0.795	0.063	1.472	0.32	1.81
266	2086716.983	749249.52	20.113	127.092	0.684	0.026	0.915	0.18	1.05
305	2087381.285	749310.79	10.880	57.672	0.797	0.041	1.108	0.09	0.53
406	2086548.208	749086.09	73.682	533.855	0.804	0.077	1.671	0.72	4.08
460	2086554.05	749026.53	134.175	782.790	0.967	0.069	2.197	1.18	6.66
669	2085947.078	748667.47	53.166	328.215	0.748	0.028	1.108	0.48	2.72

Radionuclide results reported as the weighted averages over the HPGe measurement's field of view.
SOR = Sum of ratios.

Table 2-8 Alpha Spectroscopy Results of Surface Soil Samples – Actinide Migration Evaluation Project

Sample Number	Easting	Northing	Am-241 (pCi/g)	Pu-239/240 (pCi/g)	U-233/234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Tier I SOR	Tier II SOR
SSSE05398	2087390	749012	20.100	397.000	NA	NA	NA	0.37	2.10
SSSE05498	2087398	748502	0.855	4.770	NA	NA	NA	0.01	0.04

NA = Not analyzed
SOR = Sum of ratios.
Source: RMRS, 1998f

and extend to the east encompassing locations TR12 and AME 5398 (also Tier II exceedances). Also, unlike the 95% UCL results (Figure 2-8), the "best fit" results (Figure 2-7) indicate actinide levels below Tier II to the north at HPGe Measurement Location 30, to the east at HPGe Measurement Location 305, and southeast at TR11.

Using the "best fit" line regression model instead of the 95 % UCL regression model is further justified by comparing the predicted $^{239/240}$Pu to ^{241}Am ratios to those derived from previous studies. The National Bureau of Standards (NBS, 1980) collected soil samples from RFETS for isotopic analyses, which were eventually used as a standard radioactive source reference. The NBS (1980) sampling and analysis of RFETS soil indicated a $^{239/240}$Pu to ^{241}Am ratio of 6.42. A second study performed by Ibrahim et al. (1996) included an isotopic inventory (using alpha spectroscopy) of RFETS soil to determine the activity ratio of ^{239}Pu to ^{241}Am. The regression model between ^{241}Am and $^{239/240}$Pu resulted in a strong correlation (R=0.96) between the two radionuclides, and a $^{239/240}$Pu to ^{241}Am activity ratio of 5.29. Based on their findings, Ibrahim et al. (1996) concluded that $^{239/240}$Pu values could be inferred from gamma spectroscopy results of ^{241}Am. As shown in Figure 2-10, the $^{239/240}$Pu to ^{241}Am ratio (8.08) derived from the "best fit" line regression model compares favorably to the 6.42 and 5.29 ratios derived from the NBS (1980) and Ibrahim et al. (1996) studies, respectively. It is also conservatively high with respect to estimating $^{239/240}$Pu activities from ^{241}Am activities. Conversely, the $^{239/240}$Pu to ^{241}Am ratio derived from the 95% UCL model is not comparable, ranging up to 120 at 1 pCi/g ^{241}Am.

Based on the representativeness of the $^{239/240}$Pu to ^{241}Am ratio and the agreement with the historical alpha spectroscopy data, the best fit regression line (Figure 2-7) is the chosen model to standardize the HPGe results. The 95% UCL regression model would be inappropriate for accurately delineating the extent of radiological contamination within the Americium Zone.

2.2.2.2 Alpha Spectroscopy/HPGe ^{235}U, ^{238}U Correlations

As shown in Figures 2-11 and 2-12, correlations for the alpha spectrometry/HPGe data for ^{235}U and ^{238}U were not performed because in both cases the uranium isotopes were not detected by *in situ* HPGe. The plots show minimum detectable activities when the isotopes were non-detected. Also, alpha spectrometry did not measure detectable levels of ^{235}U, and only in a few instances was ^{238}U detected at estimated activities. Therefore, ^{235}U and ^{238}U results from the HPGe survey

in the Americium Zone were used directly as the surface soil radiological data for these isotopes. The lack of correlation for the uranium data does not impact the findings reported herein because the activities of uranium isotopes are well below the Tier II RSALs throughout the investigation area.

The activity of $^{233/234}U$ was calculated based on the fact that ^{234}U should be in equilibrium with ^{238}U (the activity contribution of ^{233}U is insignificant). The equilibrium between the radioactive parent (^{238}U) and daughter (^{234}U) suggests the activity ratio between these two isotopes should be 1.0. Surface soil data collected in support of the OU2 Phase II RFI/RI supports this relationship with an average activity ratio of 0.97 between the two isotopes. Therefore, the activity of $^{233/234}U$ in surface soil was assigned the value measured by the HPGe survey for ^{238}U.

2.2.3 FIDLER Surveys

A FIDLER survey was conducted in a selected area where an isolated HPGe measurement exceeded the 10 pCi/g ^{241}Am decision level. The FIDLER survey was conducted at HPGe measurement location 301 to determine if the measurement result was caused by the presence of a smaller area containing a hot spot. In addition, two FIDLER surveys were conducted at HPGe measurement locations 460 and 462 where HPGe measurements exceeded the RFCA Tier I RSALs based on preliminary results using the sum-of-ratios methodology. The purpose of the survey was to determine whether contamination was homogeneous and widespread as suggested by the conceptual model, or heterogeneous and consists of numerous individual hot spots.

A grid with four-foot spacings was staked in the field to encompass the circular FOV for the HPGe measurement. A total of 37 FIDLER measurements were collected from each selected HPGe measurement location. FIDLER measurements were taken with the instrument placed on the ground surface at each of the four-foot grid nodes for a one-minute count. FIDLER surveys were conducted in accordance with Radiological Safety Procedure, 3-PRO-112-RSP-2.01, Job Aid: 4-JOB-010-RSP-02.01.07, Bicron FIDLER (Kaiser-Hill, 1999b).

2.3 SUBSURFACE SOIL INVESTIGATION

The subsurface soil investigation consisted of two phases. One phase was the radiological investigation consisting of shallow boreholes. The second phase consisted of the VOC investigation.

2.3.1 Radiological Investigation

Subsurface soil sampling for radiological characterization was conducted at the 903 Pad and Lip Area. The depth of radiological contamination is required to estimate the volume of soil requiring remedial action. Figure 2-13 provides the radiological subsurface sampling locations for the 903 Pad and Lip Area. Samples were analyzed for ^{241}Am, $^{239/240}$Pu, $^{233/244}$U, ^{235}U, and ^{238}U using alpha spectrometry. Boring logs are presented in Appendix B.

903 Pad - Twenty-five shallow boreholes were drilled for the characterization of radionuclide contamination beneath the 903 Pad. Twenty-five boreholes over the 3.4-acre 903 Pad represent a borehole completed at each node of a 23 m by 23 m (75 ft by 75 ft) grid (Figure 2-13). Subsurface soil samples were collected from artificial fill material and natural soils beneath the 903 Pad for radiochemical analysis utilizing a single-tube Geoprobe hydraulic push drilling technique. Soils were continuously cored to a total depth of approximately 1.2 m (4 ft) to ensure core recovery or to a depth where the FIDLER indicated less than 5,000 cpm. Samples were collected at approximately 15 cm (6 in) intervals or as appropriate so that the sample intervals coincide with asphalt, artificial fill material, and natural soils. This was done to prevent potential dilution of the natural soil samples below the artificial fill material. Borings and cores were checked by engineer's tape for total depth and recovery. Samples for radiological screening were collected as a composite sample from the radiological sample. Soil samples were screened for alpha, beta/gamma, and VOCs using portable field instruments. If VOCs were detected above 10 parts per million by field instrumentation at any sampling location, the VOC subsurface soil sampling program, as described in the SAP (RMRS, 1998a), was implemented to characterize VOC contamination at that location.

Subsurface soil samples for radiochemical analysis were also collected during the VOC subsurface investigation as described in Section 2.3.2. Soil samples were collected from 12 original and three "step-out" boreholes on the 903 Pad, one borehole west of the 903 Pad, and one borehole east of well 07191 in the Lip Area (see Figure 2-14).

Lip Area - A total of thirty-seven boreholes were completed over the Lip Area where artificial fill was placed in 1970 and where surface soils were remediated in 1976, 1978, and 1984. Of the 37 boreholes, 25 borings were original and twelve were "step-out" borings (Figure 2-13). Of the 37 boreholes, two boreholes were completed in the 1976 remediation area, six boreholes were completed in the 1978 remediation area, and three boreholes were placed in the 1984 remediation area.

Shallow soil borings located in the 903 Lip Area and soil samples were collected utilizing single-tube Geoprobe hydraulic push drilling technique. Soils were continuously cored to either a total depth of 0.9 m (3 ft) or 1.2 m (4 ft) to ensure core recovery, or to a depth where the FIDLER indicated less than 5,000 cpm. Samples were collected at approximately 15 cm (6 in) intervals or as necessary so that the sample intervals coincided with artificial fill material and natural soils. This was done to prevent potential dilution of the natural soil sample below the artificial fill material. Borings and cores were checked by engineer's tape for total depth and recovery. Samples for radiological screening were collected as a composite sample from the radiological sample. Soil samples were screened for alpha, beta/gamma, and VOCs using portable field instruments. A detailed surface soil characterization using HPGe was not performed in portions of the Lip Area where surface/subsurface soils were collected (RMRS, 1998a).

2.3.2 VOC Investigation Boreholes

Investigation of VOC contamination at the 903 Pad, completed per the SAP (RMRS, 1998a), targeted the highest areas of groundwater contamination as well as the anomalous PCE soil gas results, east of groundwater well 07191. Figure 2-14 shows the borehole locations for the VOC investigation. Samples were analyzed for ^{241}Am, $^{239/240}$Pu, $^{233/244}$U, ^{235}U, and ^{238}U using alpha spectroscopy and for VOCs using EPA Method 8260B (EPA, 1986). Boring logs are presented in Appendix B.

Subsurface soil sampling was conducted near existing groundwater monitoring wells 06691, and 08891 using an upgradient radial placement geometry with the well location serving as the downgradient location. Boreholes were located approximately 20 ft to the north, south, and west of well locations 06691, and 08891. Six boreholes were placed along the west to northwest side of the 903 Pad on the basis of aerial photographs showing drum storage and surface staining. A total of 15 boreholes were required to investigate the VOC contamination at the 903 Pad: the original 12 boreholes; two “step-out” boreholes (95998 and 97698); and one completion of a shallow subsurface radiological borehole (90998) as a VOC borehole (96498) where VOCs were observed with concentrations greater than 10 percent of the respective current Tier I SSALs.

The soil gas anomaly in the Lip Area at the southeast corner of the 903 Pad adjacent to well 07191 was evaluated. One borehole (97298) was located 20 ft east and 10 ft south of well 07191. A surface area with little or no vegetation and FIDLER readings greater than 10,000 cpm was identified 30 feet east of well 6591, adjacent to the west side of the 903 Pad. One borehole (92598) was completed to evaluate this area.

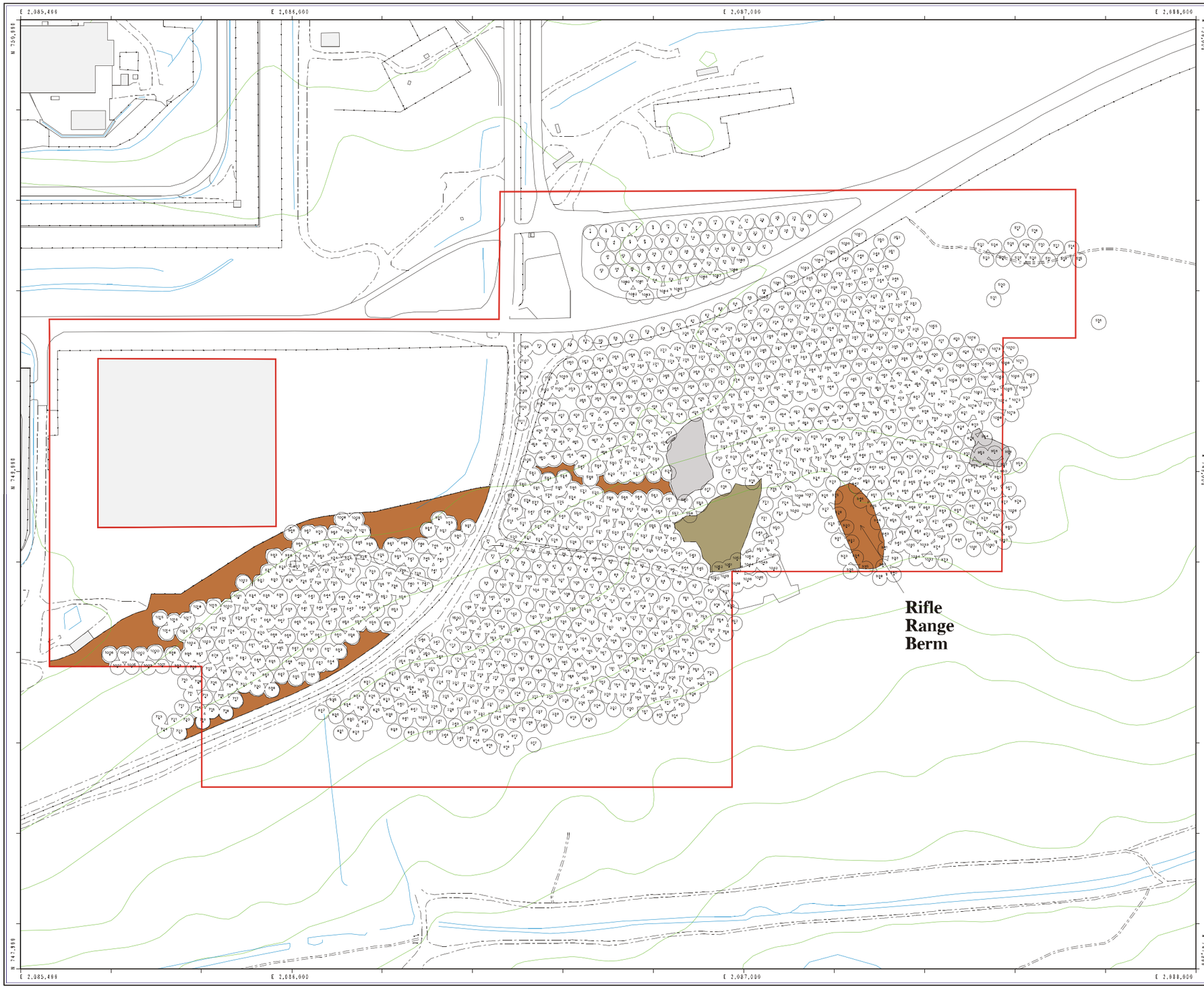
Soil samples were collected from VOC soil borings located in the 903 Pad and Lip Area utilizing a dual-wall Geoprobe hydraulic push drilling technique. Boreholes were advanced from the surface to either a depth of 0.31 to 0.62-m (1 to 2 feet) below the top of bedrock, or to a depth below the vertical extent of VOC contamination (based on field instruments), whichever was greater, provided that refusal of the Geoprobe drilling equipment was not encountered. Samples were collected at approximately 1.22m (4 ft) intervals below ground surface, or at intervals where VOCs were detected with field instrumentation. In general, the VOC samples were collected from approximately the lower 15cm (6 in) interval and the radiological sample was collected from the 15cm (6 in) interval above the VOC sample. Samples for radiological screening were collected from the 15cm (6 in) interval above the radiological sample. Because of the different ionization potential between PCE and CCl_4, two photoionization detectors were used (10.4 and an 11.7 electron volt bulb). If VOCs were detected above 10% of the current Tier I SSALs, then the sampling grid was extended an additional 6.1m (20 ft) in an upgradient direction of that location, and additional samples were collected for laboratory analysis.

2.4 903 PAD ASPHALT SAMPLES

Asphalt samples from the 903 Pad were collected to obtain preliminary waste characterization data for disposal purposes. Nine asphalt samples were collected randomly from the following locations over the 903 Pad: 90098; 90198; 90398; 90698; 90798; 91198; 91298; 91898; and 91998 (Figure 2-13). Random sampling techniques are appropriate methods for estimating the population mean and the standard error of this estimate. Locations were determined randomly based on the 903 Pad subsurface soil sampling grid. Samples were collected using a Geoprobe® and analyzed for ^{241}Am, $^{239/240}$Pu, $^{233/234}$U, ^{235}U, and ^{238}U using alpha spectroscopy.

2.5 WORK CONTROLS

Field activities were conducted in accordance with the procedures detailed in the SAP (RMRS, 1998a), the Task-Specific Health and Safety Plan (RMRS, 1998b) and additional controls summarized herein. Additional work controls implemented for the project included the ALARA Job Review (#903Pad-98-001) for fieldwork performed under job-specific Radiation Work Permits (RWPs). Contamination control included measurement of direct and removable contamination levels on equipment, wind speed monitoring (soil handling activities suspended with two consecutive 15-minute wind speed average of 15 miles per hour), high volume air sampling during soil handling activities, and requirements for personal protective equipment. Fieldwork also could not be performed due to sensitivity of the radiological field instruments when the humidity was greater than 90% and ambient temperatures less than 32 degrees Fahrenheit.



Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

HPGe Measurement Location Map

Figure 2-1

EXPLANATION

Investigation Area

FOV (Field of View) Stake Number

Standard Map Features

- Steep Topography
- Wetland Area
- Cement
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95

Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post processing performed by MK, Winter 1997.

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Scale = 1 : 2710
1 inch represents approximately 226 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

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Prepared for: KH

MAP ID: 99-0408

July 20, 2000

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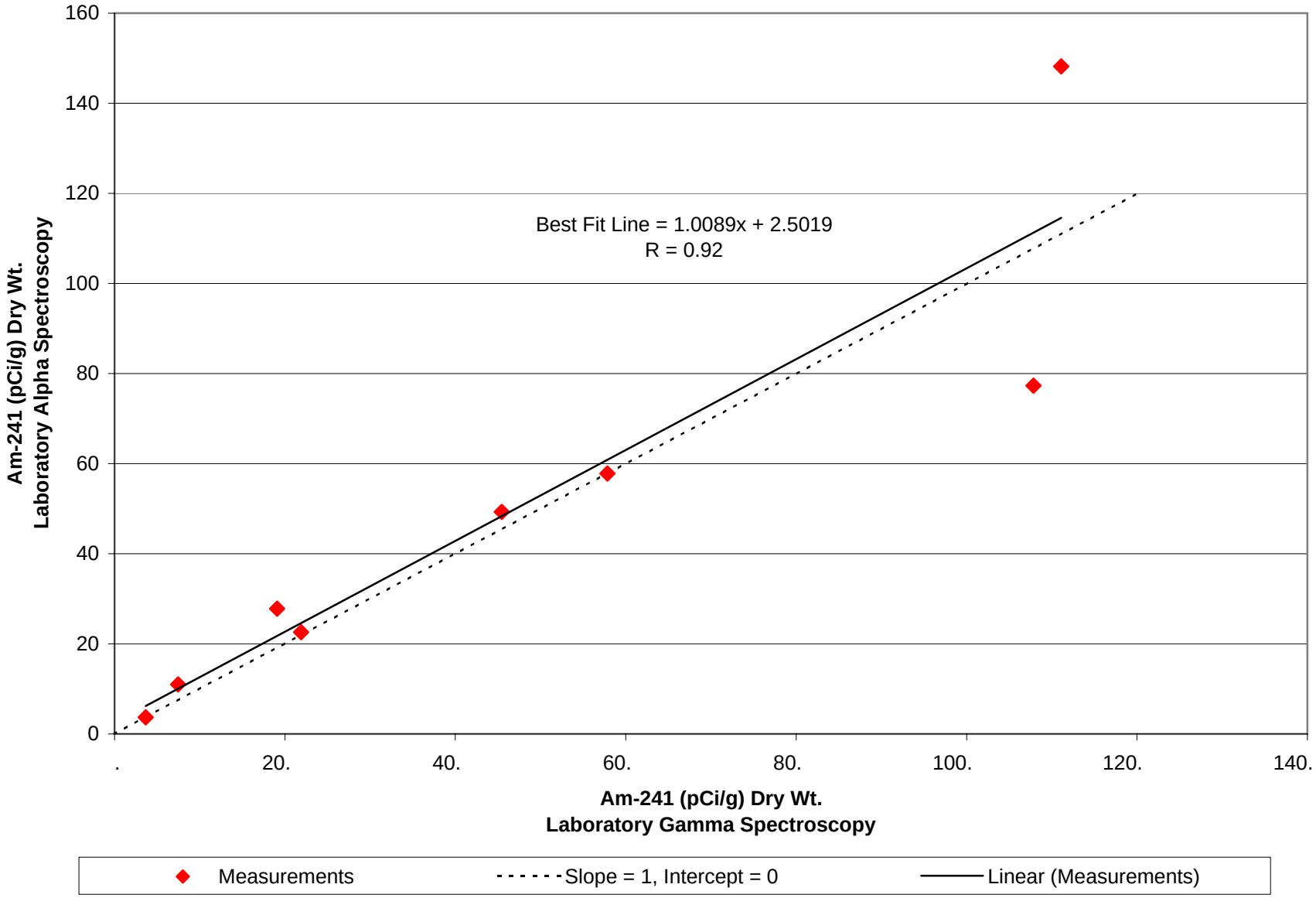
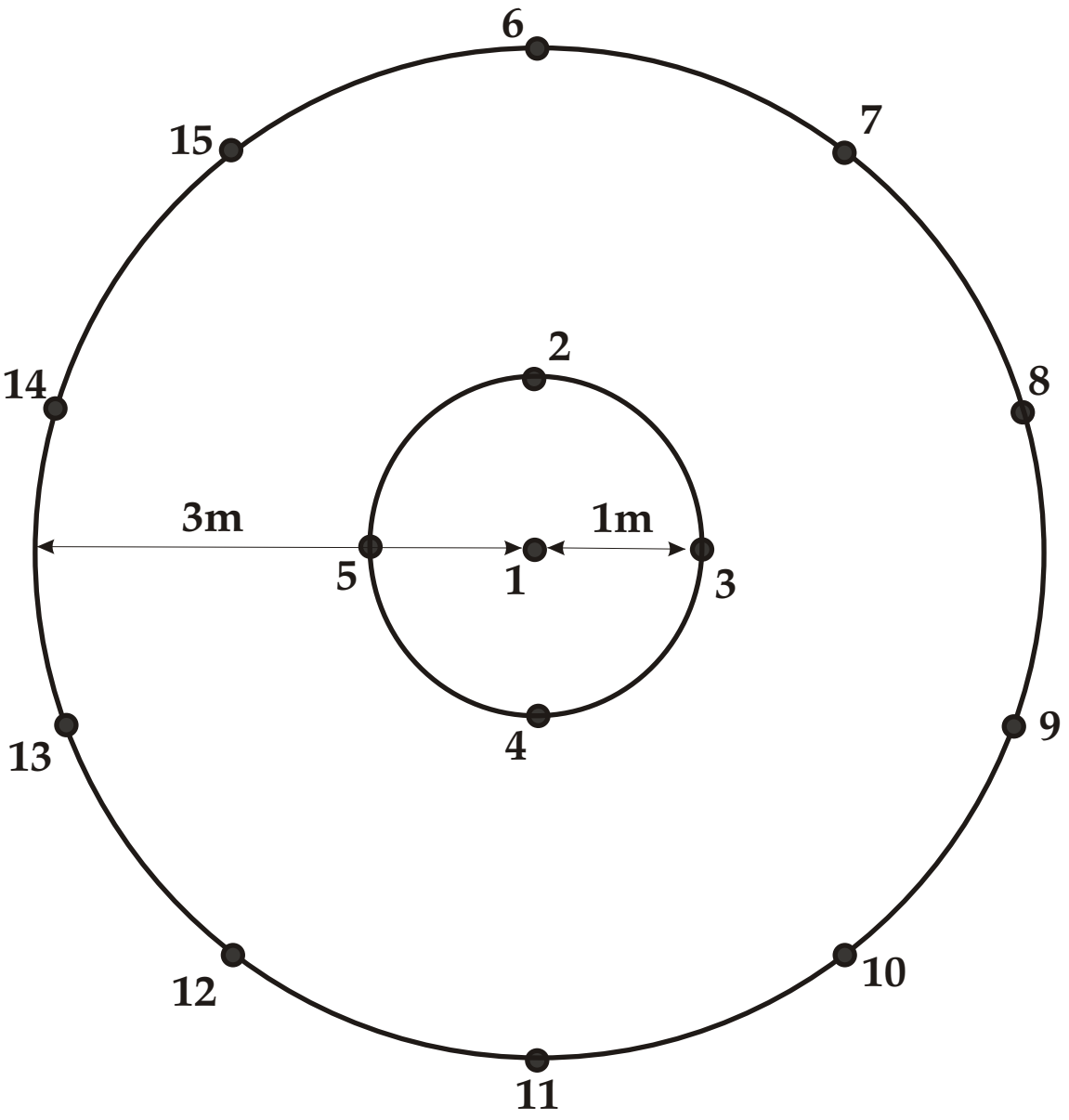


Figure 2-2 Americium-241 Activities in Soil - Laboratory Gamma Spectroscopy vs. Laboratory Alpha Spectroscopy Correlation



15-Point Sampling Pattern

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

HPGe 15-Point Surface Soil Sampling Pattern

Figure 2-3

Explanation:

● **Grab Sampling Location**

98-0421

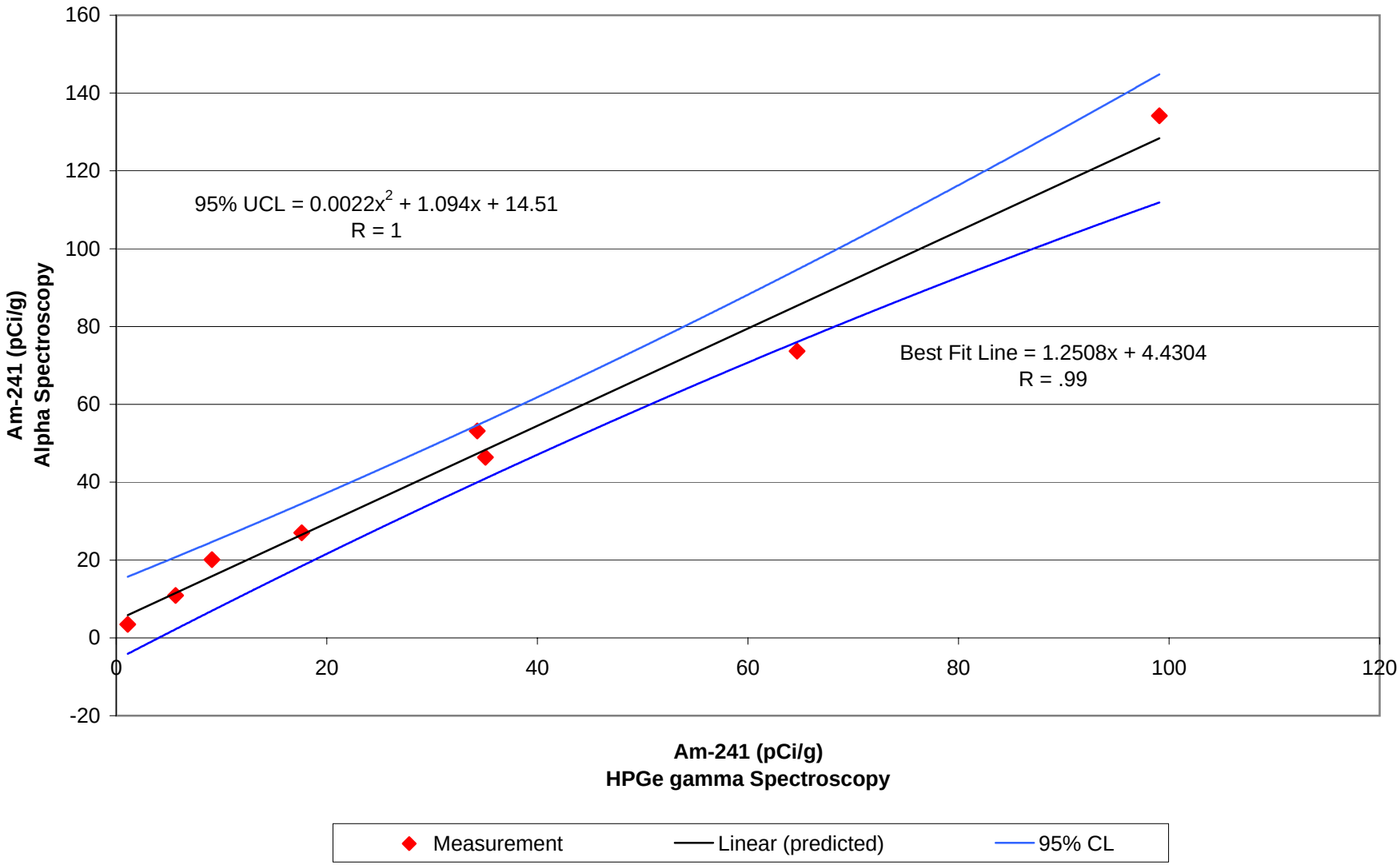


Figure 2-4 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Americium-241 Correlation

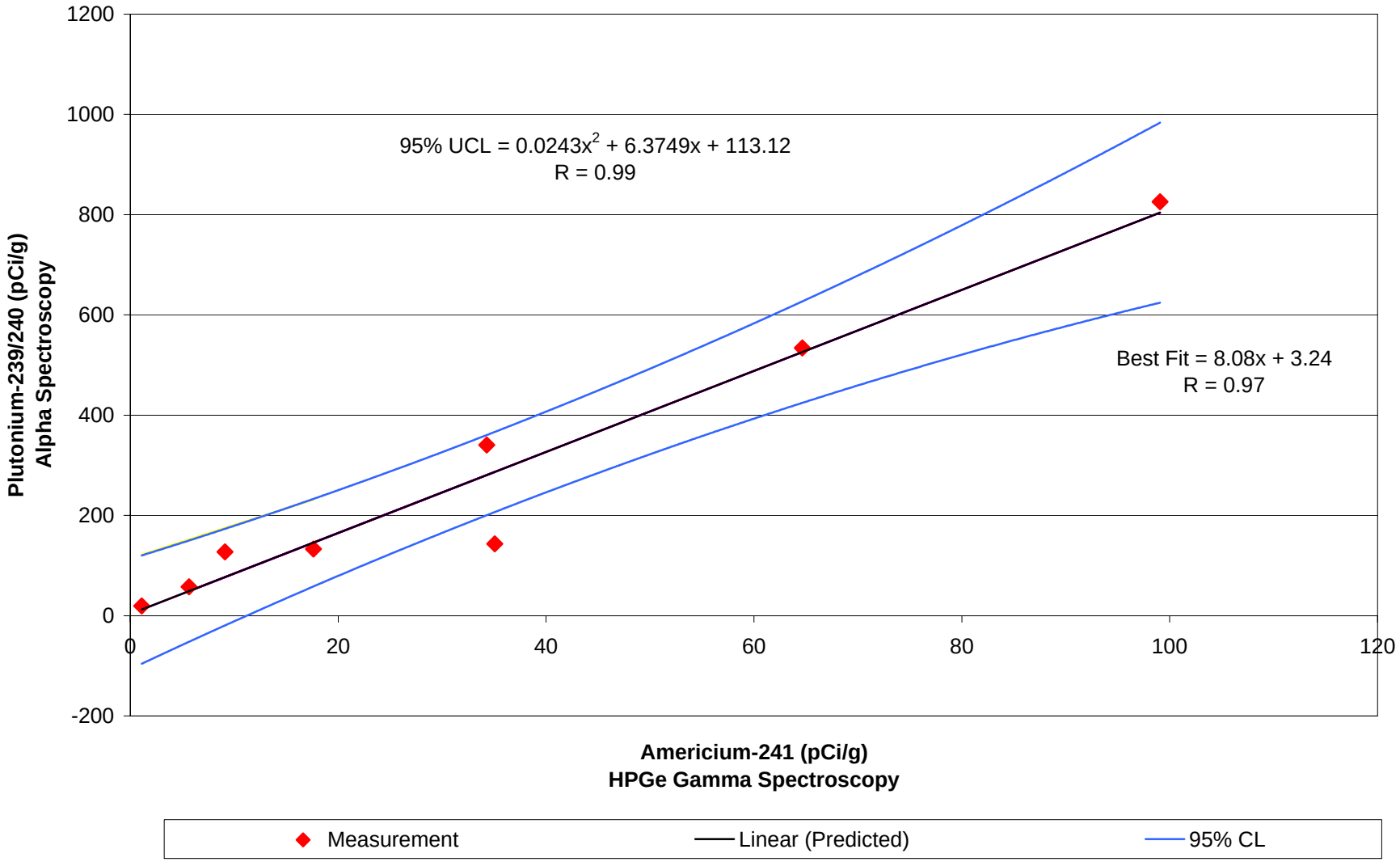
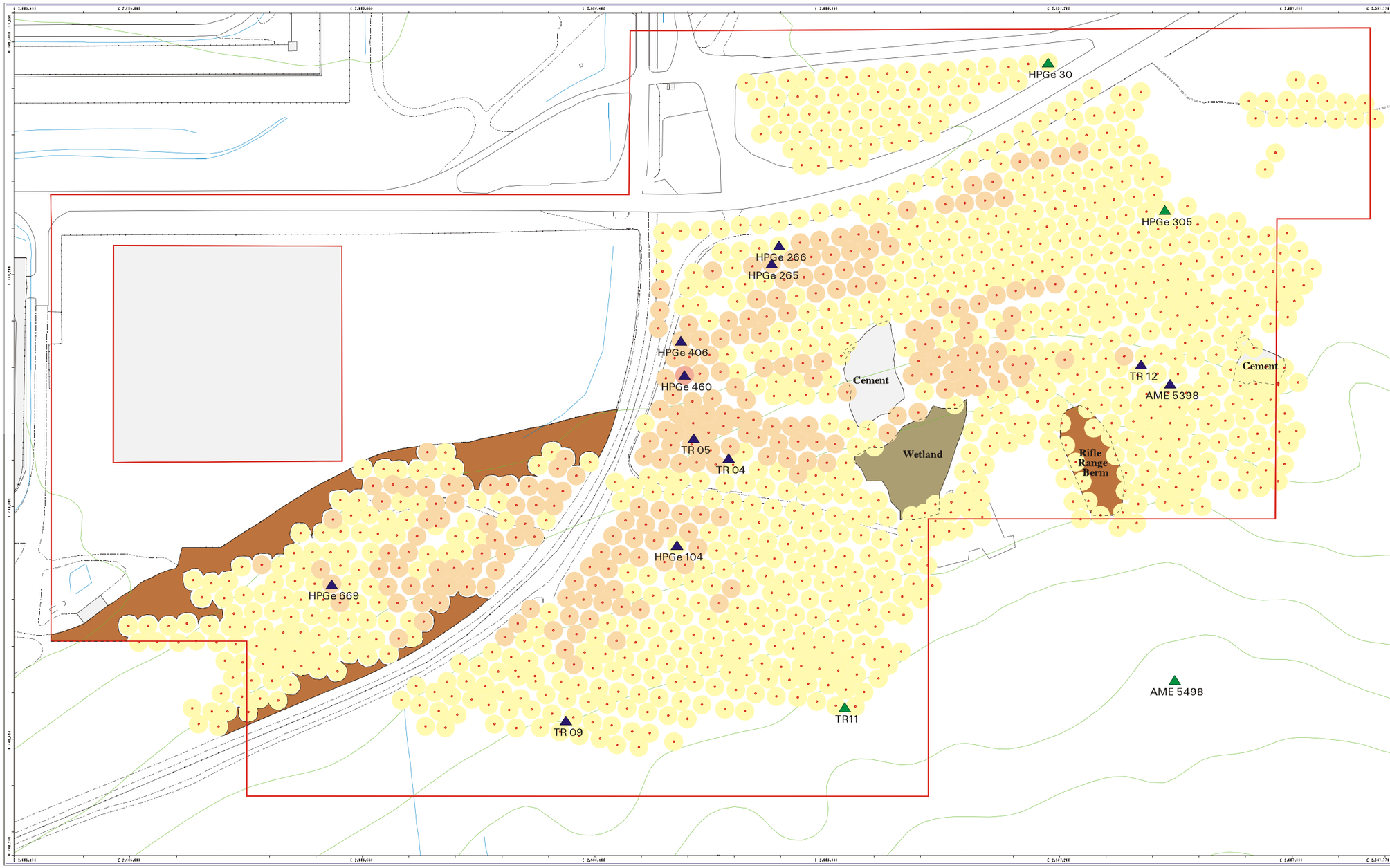


Figure 2-5 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Americum-241 vs. Plutonium-239/240 Correlation



Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Surface Soil using HPGe Results

Figure 2-6

EXPLANATION

- Gamma Survey Locations
- Investigative Area

HPGe Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels
- Exceeds Tier I Action Levels

Surface Soil Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels

TR = Trench

HPGe = HPGe Measurement

AME = Actinide Migration Evaluation

Standard Map Features

- Steep Topography
- Wetland Area
- Cement
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

Scale = 1 : 2160
1 inch represents 180 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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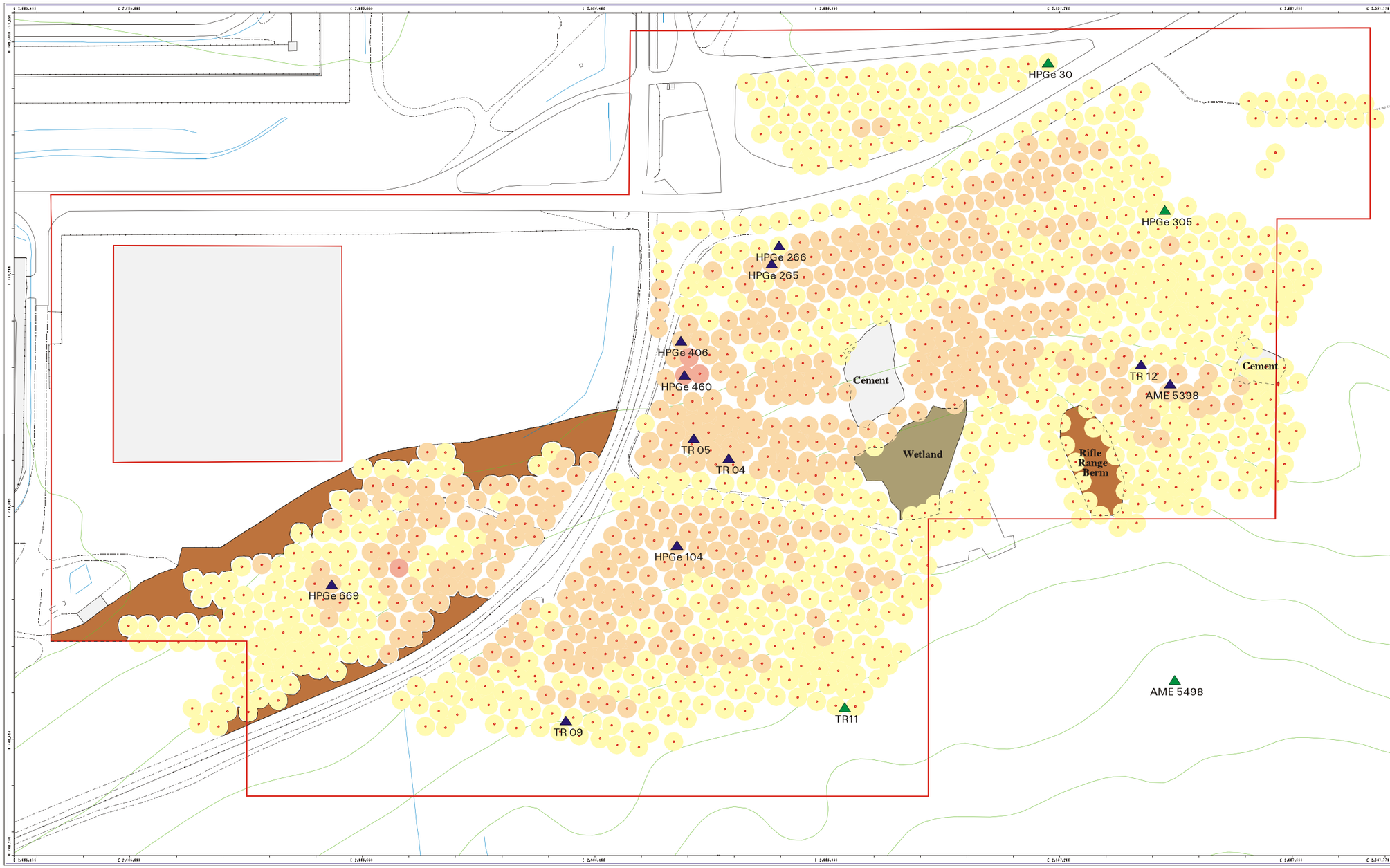

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Surface Soil using Best Fit Line - HPGe Survey

Figure 2-7

EXPLANATION

Gamma Survey Locations

Investigative Area

HPGe Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels
- Exceeds Tier I Action Levels

Surface Soil Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels

TR = Trench

HPGe = HPGe Measurement

AME = Actinide Migration Evaluation

Standard Map Features

- Steep Topography
- Wetland Area
- Cement
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

Scale = 1 : 2160
1 inch represents 180 feet

State Plane Coordinate Projection
Colorado Central Zone
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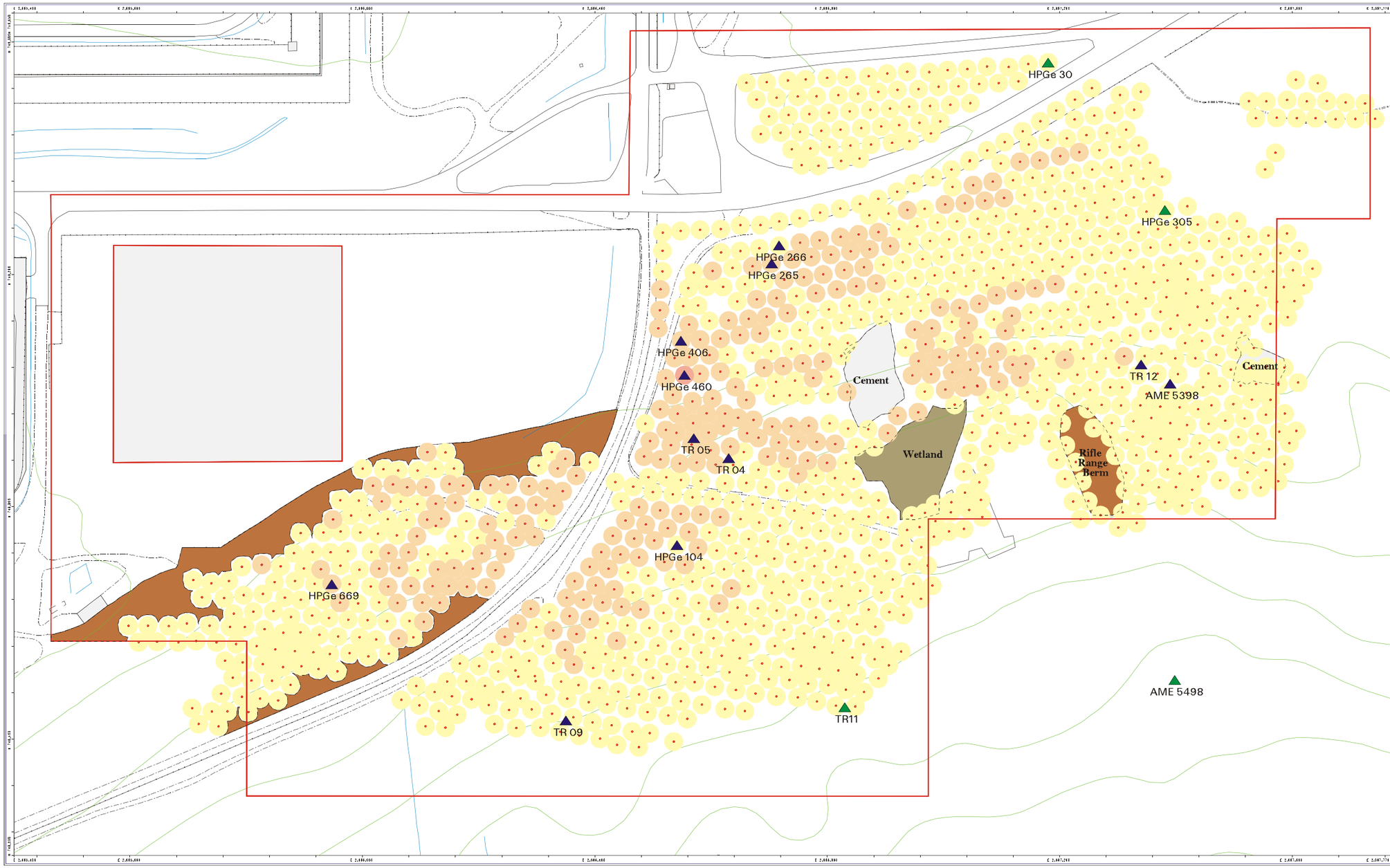

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Surface Soil using 95% UCL - HPGe Survey

Figure 2-8

EXPLANATION

- Gamma Survey Locations
- Investigative Area

HPGe Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels
- Exceeds Tier I Action Levels

Surface Soil Data Ranges

- Below Tier II Action Levels
- Exceeds Tier II Action Levels

TR = Trench

HPGe = HPGe Measurement

AME = Actinide Migration Evaluation

Standard Map Features

- Steep Topography
- Wetland Area
- Cement
- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

Scale = 1 : 2160
1 inch represents 180 feet

State Plane Coordinate Projection
Colorado Central Zone
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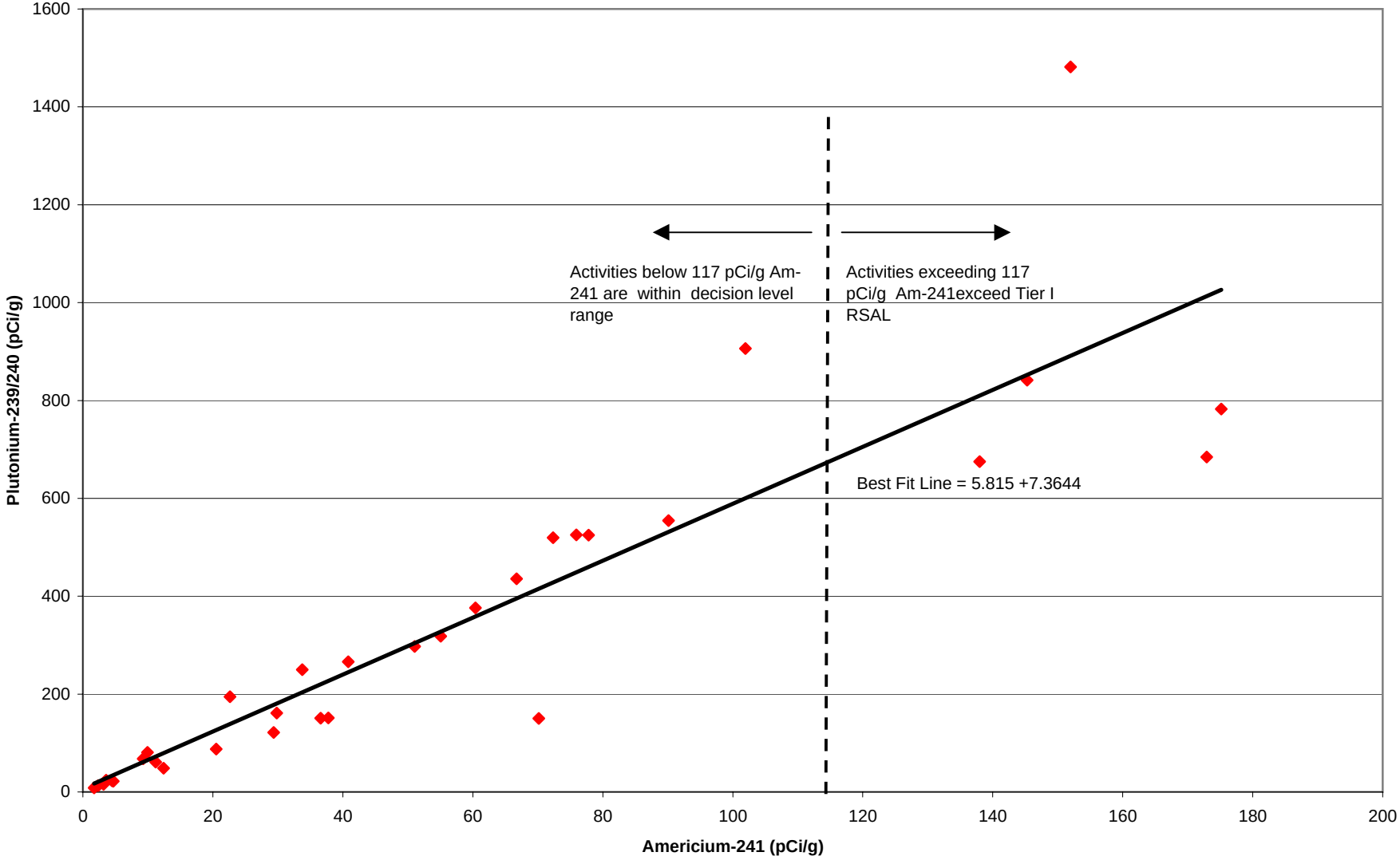


Figure 2-9 Pu/Am Activity Ratio of Soil Samples Collected for HPGe Characterization (Used to Estimate Pu-239/240 and Generate Figure 2-6 RSAL Exceedances in Surface Soils Using HPGe Direct Measurements)

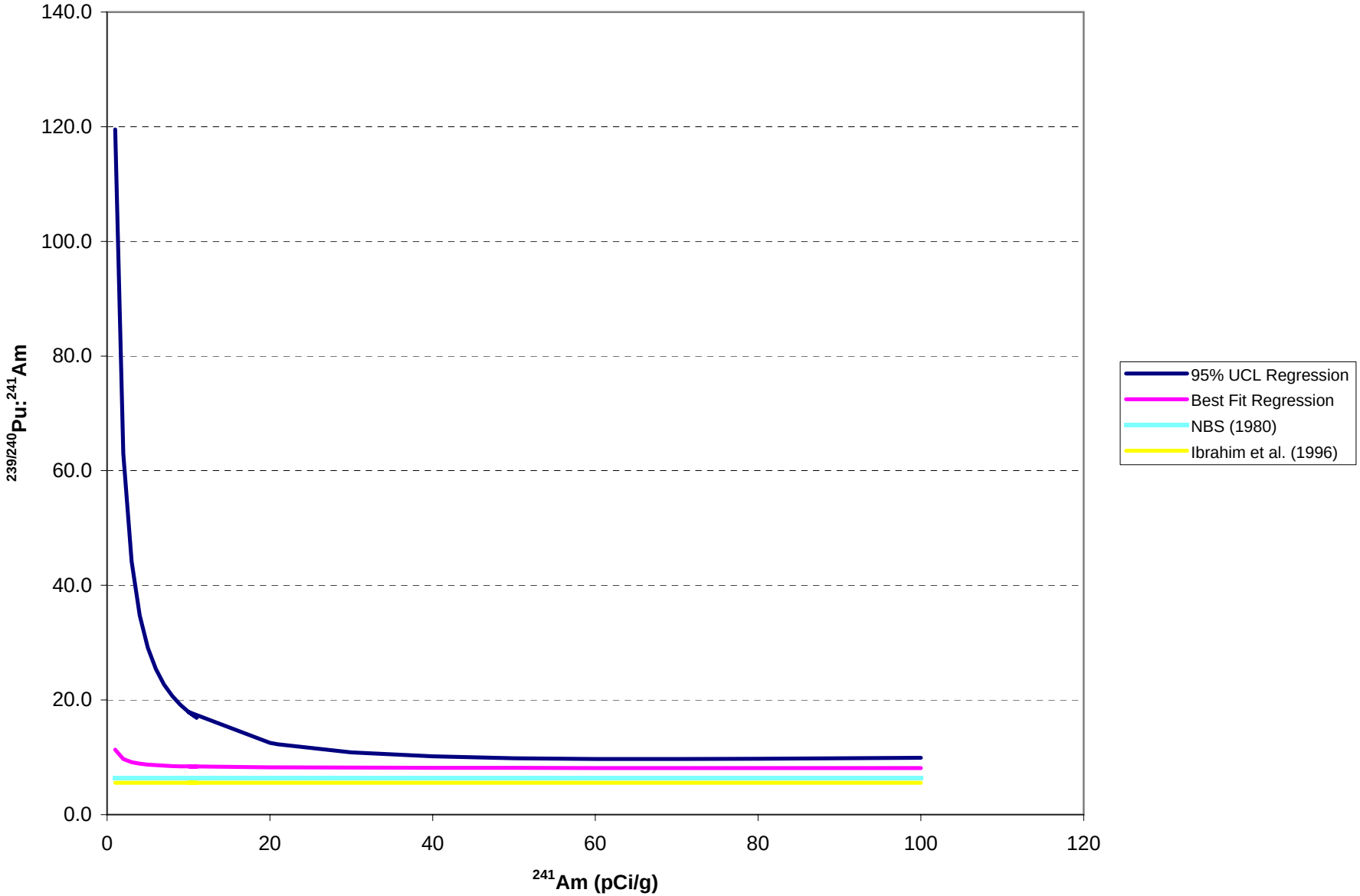


Figure 2-10 Comparison of $^{239/240}$Pu:^{241}Am Ratios Derived from "Best Fit" and 95% UCL Regressions to Those of Previous Studies.

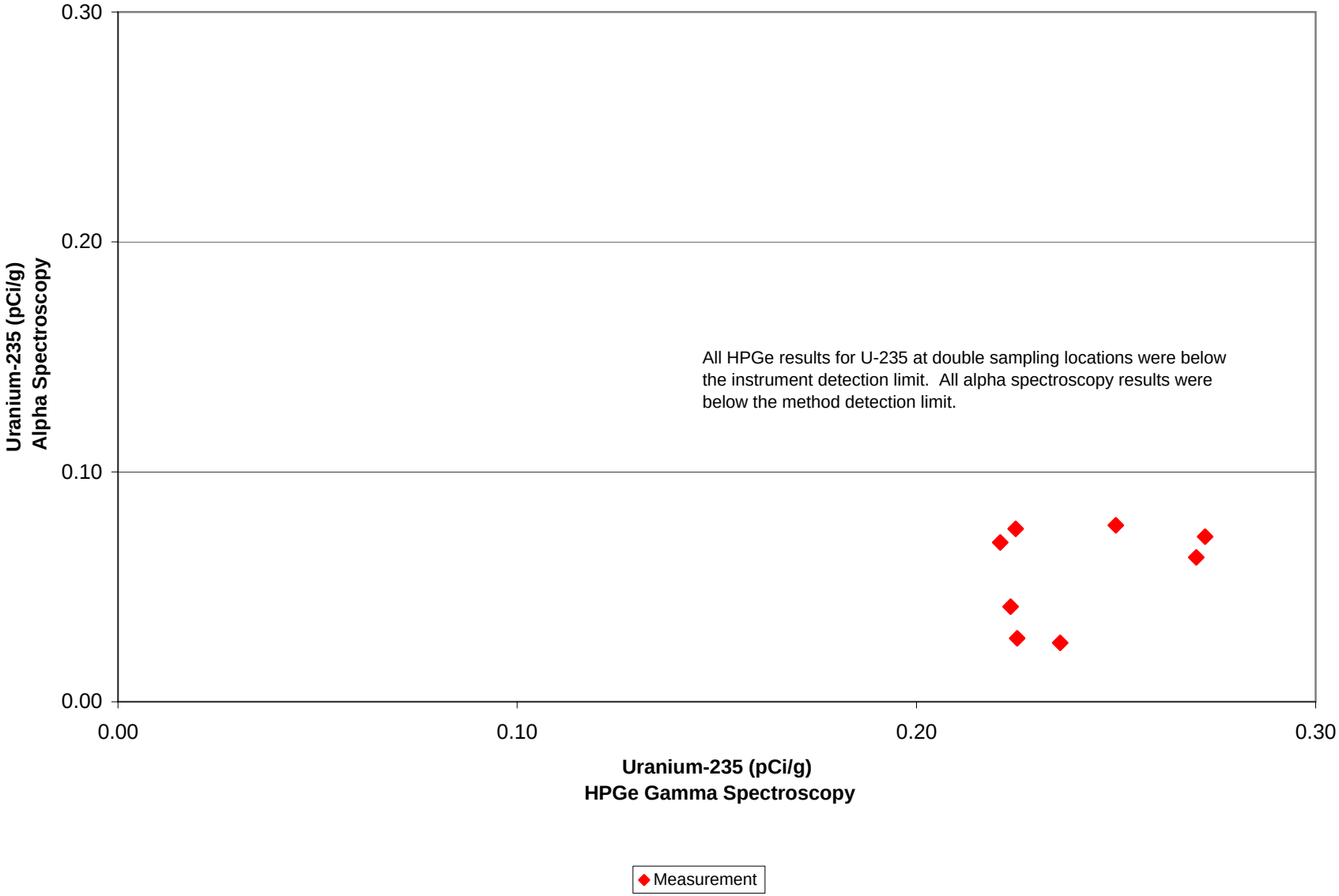


Figure 2-11 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Uranium-235 Correlation

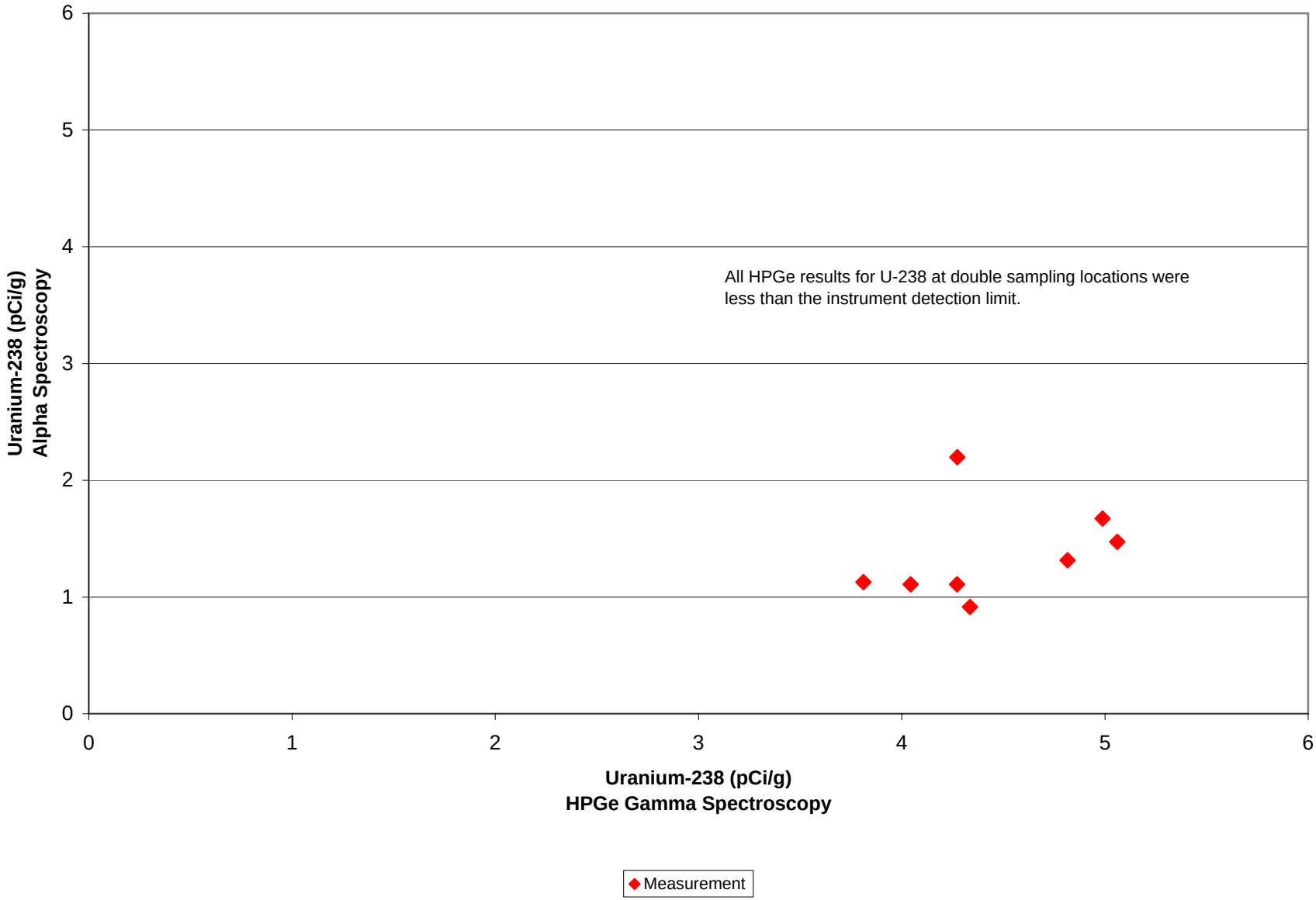
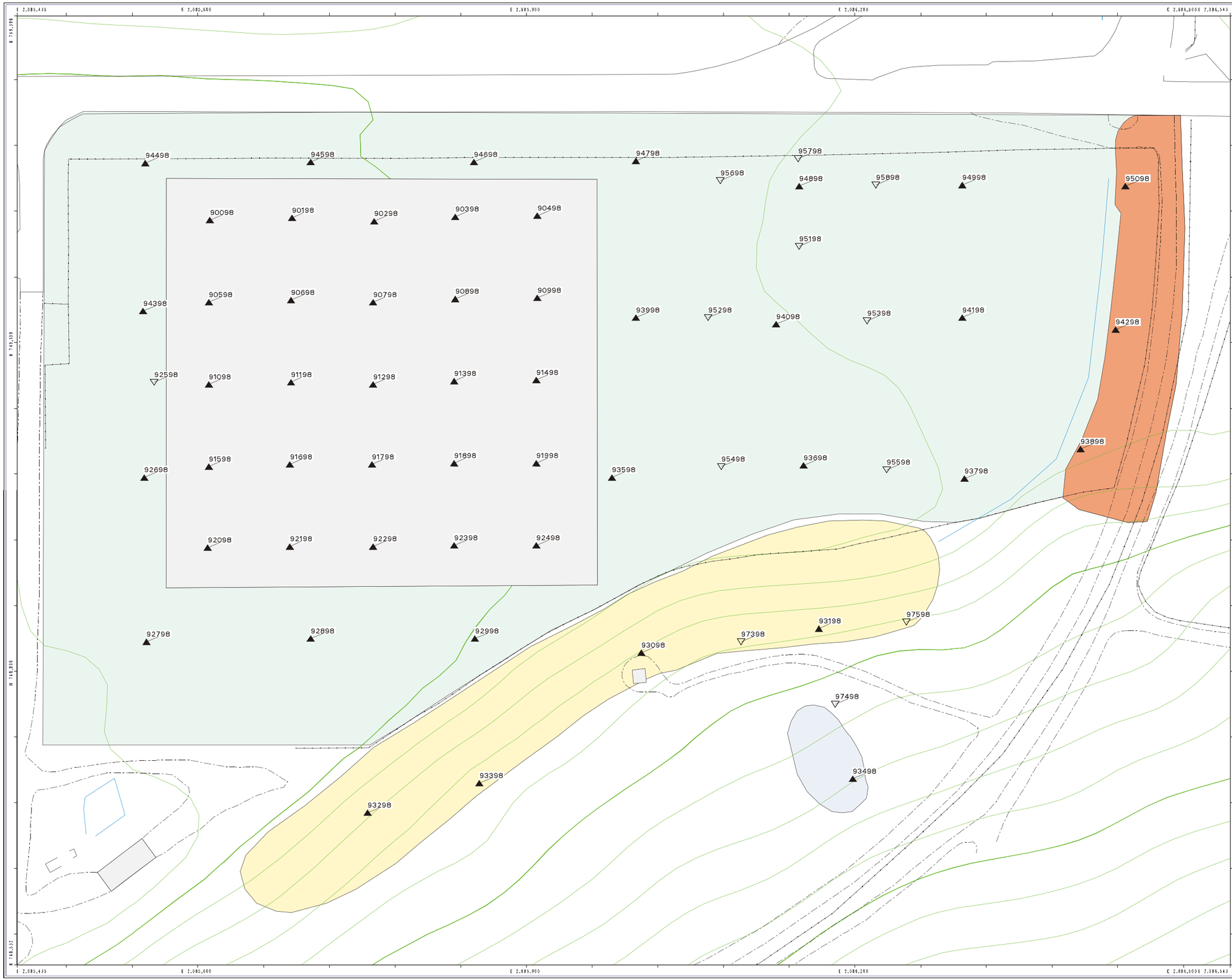


Figure 2-12 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Uranium-238 Correlation



Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Radiological Subsurface Sampling Locations

Figure 2-13

EXPLANATION

- Radiological Boreholes, Original
- Radiological Boreholes, Stepout
- 1970 Soil Fill Area
- 1976 Soil Removal Area (approx)
- 1978 Soil Removal Area (approx)
- 1984 Soil Removal Area (approx)

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.

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Scale = 1 : 1030
1 inch represents approximately 86 feet

25 0 50 100ft

State Plane Coordinate Projection
Colorado Central Zone
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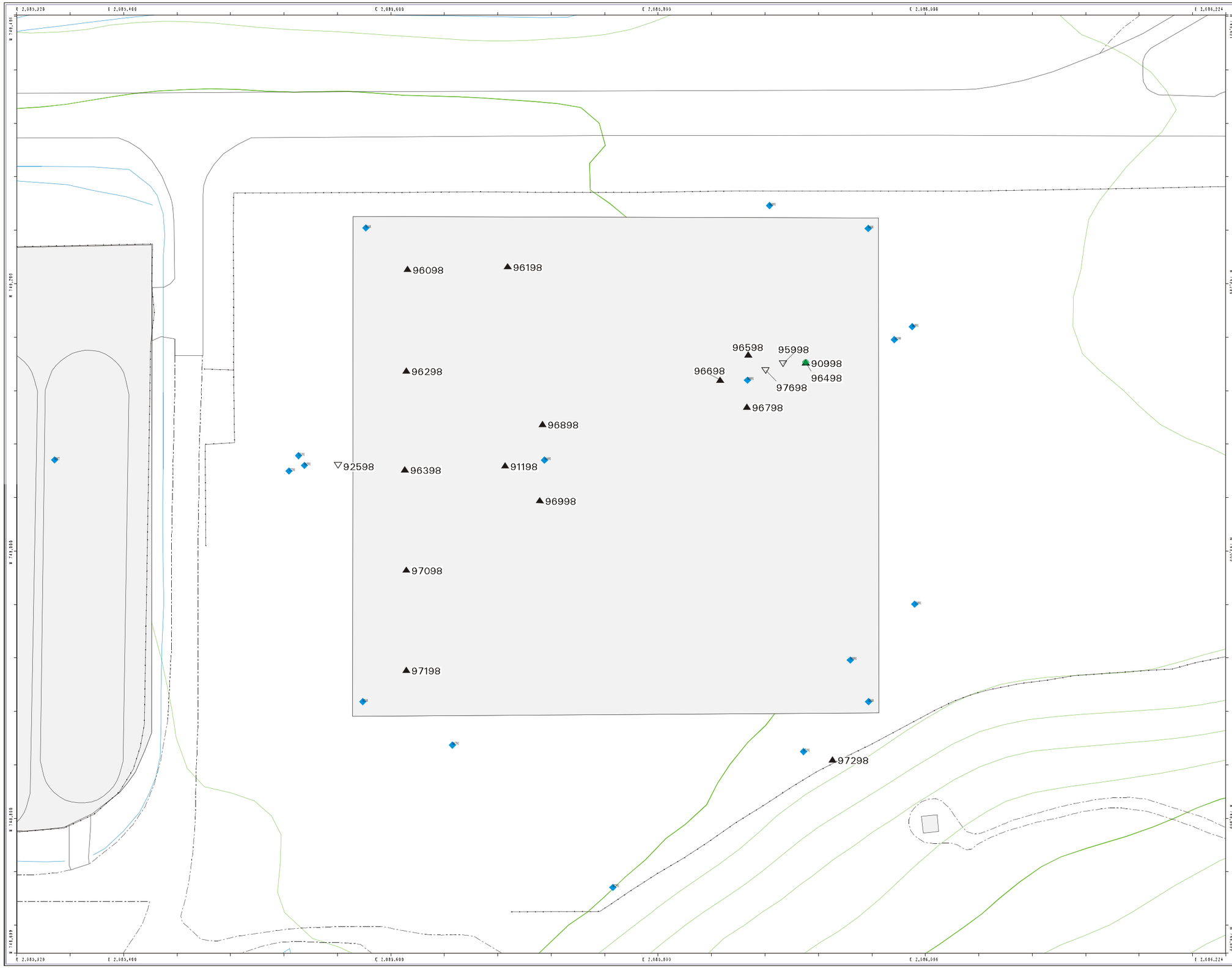

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

VOC Investigation Borehole Location Map

Figure 2-14

EXPLANATION

- VOC Boreholes, Original
- VOC Boreholes, Stepout
- Radiological Borehole where VOC Sample was Collected
- Groundwater Well

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Montson Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

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Scale = 1 : 830
1 inch represents approximately 69 feet

20 0 40 80 ft

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Colorado Central Zone
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NT_Svr w:/projects/fy99/99-0408/voc_borehole.aml

3.0 DATA QUALITY ASSESSMENT

This section provides the results of the data quality assessment that was conducted to ensure that data used in making management decisions are in accordance with the project DQOs. The intended uses of these data include delineation of contaminated soils requiring remedial actions under the IM/IRA.

As discussed herein, Data Quality Objectives for the project were achieved. A summary of project DQOs and the corresponding project decisions is presented in Table 3-1.

Table 3-1 Sample Types & Data Quality Objectives

Sample Type	DQO	Decision
Actinides in Surface Soils using *In Situ* Gamma Spectroscopy.	Quantify spatial distribution of RFETS actinide activities that meet or exceed Tier I RSALs to estimate soil volumes requiring remediation. Quantify spatial distribution of ^{241}Am to 10 pCi/g using HPGe gamma ray survey.	Spatial extent of actinide activities exceeding Tier I RSALs. Volume estimates of soils exceeding Tier I and Tier II RSALs.
VOCs in Subsurface Soils.	Quantify three-dimensional distribution of VOC concentrations that meet or exceed Tier I Soil Action Levels to estimate soil volumes requiring remediation.	Three-dimensional extent of VOC concentrations relative to Tier I soil action levels. Volume estimates of soils exceeding Tier I soil action levels.
Actinides in Subsurface Soils.	Quantify three-dimensional distribution of actinides to estimate soil volumes requiring remediation.	Three-dimensional extent of actinide activities relative to Tier I & II RSALs. Volume estimates of soils exceeding Tier I and II RSALS.

3.1 DATA SOURCES

Data collected to support decision making was generated in both laboratory and field environments. Surface and subsurface soil samples as well as quality control samples generated in the field were provided to analytical laboratory for direct isotopic or compound determinations.

Indirect methods (HPGe) were utilized to collect isotopic determination of radionuclides in undisturbed surface soils.

3.1.1 Laboratory Data

Analytical Services were procured though Kaiser-Hill Analytical Services Division using a Statement Of Work (SOW) which is composed of several modules, a limited number of which are required for performing work in a specific analytical discipline. The SOW for Analytical Measurements, General Laboratory Requirements (GR01), defines requirements for the determination of organic, metal, water quality, radiochemical, geotechnical, industrial hygiene, bioassay, and other parameters in samples collected at or related to the Site. Parameter Specific Analytical (PSA) Modules provide technical requirements, quality control procedures, and analysis structure for obtaining data of known and documented quality. Modules used in support of this characterization are provided in Table 3-2.

Table 3-2 Statement of Work Modules

Module Title	Module ID
General Laboratory Requirements	GR01-B.3
Electronic Data Deliverables	GR02-D
Radiochemistry Isotopic Determinations by Alpha Spectrometry	RC01-B.3
Standard Services Volatile Organics	SS01-B.3

3.1.1.1 Radiochemistry

Samples submitted to laboratories for radiochemical analysis were analyzed in compliance with PSA Module Radiochemistry Isotopic Determinations by Alpha Spectrometry (RC01) and Gamma Spectroscopy under Task Order TR01A058.

3.1.1.2 Radiochemistry Isotopic Determinations by Alpha Spectrometry

Exhibit E of the Radiochemistry Isotopic Determinations by Alpha Spectrometry (Module RC01) describes the processes by which isotopic analyses using alpha spectroscopy meet the defined data quality objectives. This module requires a variety of activities that represent the minimum QA/QC operations necessary to satisfy the analytical requirements associated with the determination of the alpha-emitting radionuclides by alpha spectroscopy. These operations and those in the General Laboratory Requirements Module, GR01, are designed to ensure the generation of comparable data from all laboratories. Specific laboratory QA samples analyzed in support of this module include laboratory duplicates and laboratory control samples to access laboratory precision and accuracy, respectively.

3.1.1.3 Gamma Spectroscopy Analysis (Laboratory)

Gamma Spectroscopy Analysis was conducted under Kaiser-Hill Analytical Services Division Task Order TR01A058. There are no laboratory control samples or laboratory duplicate analysis requirements identified under this task order. A total of 33 surface soil samples collected for alpha spectroscopy analysis in support of the HPGe investigation were also analyzed using gamma spectroscopy. Laboratory gamma spectroscopy results were obtained for comparison purposes only.

3.1.1.4 Volatile Organics

Samples submitted to laboratories for volatile organic analysis were analyzed in compliance with PSA Module Standard Services Volatile Organics (SS01) using SWD-846 Method 8260B. This module provides the technical requirements, quality control procedures, and an analysis structure that generates data of known and documented quality for the identification and quantification of organic parameters. The following modules are required for the analysis of Volatile Organics under this subcontract: The General Laboratory Requirement Module, GR01; the Requirements for Analytical Services Electronic Deliverable Module, GR02; and the Requirements for Volatile Organics Module, SS01. The specifications in SS01 supersede any GR01 specifications in the case of conflicting requirements.

This module requires a variety of activities that represent the minimum QA/QC operations necessary to satisfy the analytical requirements associated with the determination of the volatile organic compounds in soils. These operations and those in the General Laboratory Requirements Module, GR01, are designed to ensure the generation of comparable data from all laboratories. The frequency of analysis of laboratory QA samples met all requirements of SW-846 Method 8260B. QC summary reporting and flagging requirements were performed as stated in CLP-SOW.

3.1.2 Field Data

Four types of QA samples were collected in the field including sample duplicates/replicates, equipment blank, trip blanks, and check source measurements. Sample duplicates/replicates were collected to evaluate sampling and measurement precision. Equipment blanks were collected to determine the effectiveness of the decontamination of reusable equipment and are evaluated under the representativeness section. Trip blanks were evaluated to determine if samples can into contact with contaminants during transport to the laboratory. Check source measurements (continuing calibration checks) were performed during the HPGe investigation and are discussed under accuracy of field measurements.

3.1.2.1 Surface Soil Duplicates

Field duplicate samples collected in support of the HPGe surface soil investigation program were collected as unique samples. The duplicate samples were generated from grab samples of surface soils collected at HPGe measurement locations. The duplicate samples were collected adjacent to the real samples collected over the same HPGe FOV, composited, placed into sample jars and transported to the laboratories for analysis (see Section 2.2.2).

3.1.2.2 *In Situ* Gamma Spectroscopy

Replicate measurements of the individual locations were required at a frequency of one replicate per 20 field measurements set to determine field precision for the HPGe characterization program. Check source measurements were preformed on HPGe detectors at the start of each

measurement set to monitor system stability, alignment and response (accuracy). Spectrum response was required to be within ± 20% relative to the efficiencies, and within 10% of the applicable energy specifications provided by the detector's manufacturer.

3.1.3 Subsurface Soil Replicates

Field replicate samples were collected for radiochemistry in support of the subsurface soil program. Replicate samples were collected as unique samples. Splitting the recovered core in half lengthwise generated replicate and real samples of subsurface soils collected for alpha spectroscopy analysis. VOC quality assurance (QA) samples were also collected and are identified as duplicate samples because the real and QC samples were collected from adjacent depth intervals (i.e. not split).

3.2 LABORATORY DATA ASSESSMENT, VERIFICATION, AND VALIDATION

3.2.1 Laboratory Data Assessment

Data Assessment is a generic term for a quality assurance evaluation of analytical chemistry data. This assessment involves: (1) initial review of the data package by the contracted laboratory performing the analysis; (2) a cursory examination of the data by Analytical Services Division (ASD) Personnel prior to customer release of preliminary data; (3) verification subcontract personnel who range from a cursory completeness check and QC verification of the Data Review Checklist to a more thorough check of the data; and (4) validation by ASD or subcontractor personnel of the data package. The nature of the verification and validation activities are based upon program and customer-specified requirements and requirements of ASD to evaluate contractor laboratory performance against SOW requirements.

3.2.2 Verification and Validation of Laboratory Results

Verification is an assessment process to ensure that data meet certain specified criteria. Verification is a graded process to assess both compliance of the data package with the SOW and

acceptability of the data, using Parameter Specific Analytical (PSA) Module verification and validation guidelines. Verification ranges from a cursory check of the Data Review Checklist to a more thorough review of the data, up to and including the assignment of data qualifiers. Verification may indicate that the data package requires validation. Validation is a more thorough assessment process than verification. Verification and validation criteria are generally based on government-published standards and guidelines, primarily EPA CLP and SW-846 method guidelines for organic and inorganic data evaluation and review. Validation involves the inspection of data package contents for both compliance with the SOW and validity of the data, using PSA Module verification and validation guidelines. Validation usually includes examination of raw data and calculations.

Data generated under PSA Module General Requirements General Laboratory Requirements were verified and validated according to DA-GR01, General Guidelines for Data Verification and Validation DA-GR01-v1. Data generated under the Radiochemistry Isotopic Determinations by Alpha Spectrometry Module was verified and validated according to DA-RC01, Verification and Validation Guidelines for Isotopic Determinations by Alpha Spectrometry. Data generated under Standard Services Volatile Organics (SS01) was assessed by Verification and Validation Guidelines for Volatile Organics (DA-SS01-v1).

K-H Analytical Services Division currently performs validation on a site-wide basis at a 25% frequency. Satisfactory validation at this frequency indicates that the subcontracted labs are operating competently relative to industry-wide standards, and more specifically, that sample custody and analytical procedures are implemented under defined quality controls. Site-wide data validation coupled with annual lab audits provide the inference that all analytical and radiochemical results not specifically validated are represented by the percentage that is validated.

Validation by an independent third party was performed on 37 percent of the alpha spectroscopy data and 32 percent of the VOC data, which exceeded the required 25 percent validation by an independent third party. The remaining alpha spectroscopy and VOC data were verified by an independent third party. Original verification and validation (V&V) packages for the project are managed and filed by the K-H Analytical Services Division, Building 881.

Data Packages are the hard-copy deliverables for results of sample analyses as specified in the SOW. A data package generally includes report-format elements (for example, a cover page, table of contents, data review checklist, chain of custody, and case narrative), sample and QC results, sample-preparation and instrument raw data, and summaries of chemistry standards.

Data Review Checklists are included as an appendix to each PSA Module and are used by the laboratory performing analyses to demonstrate completeness of the data package and compliance of the data to the SOW requirements. This documentation is the first step of the data-assessment process, and the Data Review Checklists provide an initial basis for verification and validation.

3.3 PARCC PARAMETER EVALUATION

Data were evaluated relative to the precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters described in the this section

3.3.1 Precision

Precision is a measure of the reproducibility of results. Precision is evaluated by comparing results from duplicate and/or replicate (duplicate/replicate) samples with results from associated real samples. Precision was evaluated for laboratory samples quantitatively by using two functions, relative percent difference (RPD) for Volatile Organics, and duplicate error ratio (DER) for radiochemistry analysis, where the latter function is used to account for the stochastic nature of error of radioactivity. Equations 3.1 and 3.2 present the RPD and DER equations, respectively;

$$RPD = \frac{|C_1 - C_2|}{|(C_1+C_2)/2|} * 100 \qquad \text{(Eq. 3.1)}$$

where:
C_1=Concentration of the analyte in the real sample
C_2=Concentration of the analyte in the duplicate sample

$$DER = \frac{|C_1 - C_2|}{\sqrt{(TPU^2_{C1} + TPU^2_{C2})}} \qquad \text{(Eq 3.2)}$$

where:
TPU = total propagated uncertainty

For laboratory data, the precision criteria for acceptability is a RPD < 40% and a DER <1.5. The objective of field duplicate samples is provided in the USEPA Contract Laboratory Program National Function Guidelines for Inorganic Data Review (EPA, 1994):

Field duplicate samples may be taken and analyzed as an indicator of overall precision. These analyses measure both field and lab precision; therefore, the results may have more variability than lab duplicates which measure only lab performance.

The EPA guideline also states that:

> *There are no "required" review criteria for field duplicate comparability.*

Therefore, field duplicate/replicate sample results were compared to their associated real samples qualitatively, with the exception of the replicate samples collected in support of the *In Situ* HPGe gamma spectroscopy survey results. The HPGe replicate samples were compared to their respective associated real sample results using the DER methodology.

3.3.1.1 Laboratory Precision Results

Laboratory duplicate samples were analyzed for radiochemical parameters to measure laboratory precision. Laboratory duplicates samples were run at a frequency of one set of QC samples per 10 field samples or a minimum of one set per analytical batch. Verification and validation guidelines require that all data generated in an analytical batch in which the laboratory duplicate was missing to be qualified as estimated "J". No radiochemical data were validated due to missing laboratory control sample results.

QA samples analyzed for volatile organic analysis to measure laboratory precision include matrix spike and matrix spike duplicate samples. These data were generated to determine long-term precision and accuracy of the analytical method on various matrices.

Radiochemistry Isotopic Determinations by Alpha Spectrometry

Laboratory precision for alpha spectroscopy analysis was determined by comparing laboratory duplicate samples with their respective associated real samples. Verification and validation guidelines require that all data generated in an analytical batch in which the laboratory duplicate sample results do not comply with the duplicate equivalency test (DER $\leq$ 1.5) to be validated as estimated "J". Ninety nine percent of the laboratory duplicate pairs passed the duplicate equivalency test. The samples that failed the duplicate equivalency test were qualified as estimated ("J") but were validated as acceptable because the remaining laboratory QA/QC criteria were met. The fifteen estimated results were for samples collected at three HPGe survey locations (Table 3-3).

Table 3-3 Sample Results Qualified as Estimated Due to Duplicate Equivalency Test Failure

Sample Number	HPGe Location	Interval (ft)	Sample Type	Analyte	Result	Unit	Validation Qualifier
99A3372-003.002	266	Center	Real	PU239/240	250	PCI/G	J
99A3372-003.004	266	1 meter	Real	PU239/240	195	PCI/G	J
99A3372-003.006	266	3 meter	Real	PU239/240	88	PCI/G	J
99A3372-001.002	406	Center	Real	PU239/240	906	PCI/G	J
99A3372-001.002	406	Center	Real	AM241	102	PCI/G	J
99A3372-001.004	406	1 meter	Real	PU239/240	525	PCI/G	J
99A3372-001.004	406	1 meter	Real	AM241	78	PCI/G	J
99A3372-001.006	406	3 meter	Real	PU239/240	519	PCI/G	J
99A3372-001.006	406	3 meter	Real	AM241	72	PCI/G	J
99A3372-002.007	460	Center	Dup.	PU239/240	782	PCI/G	J
99A3372-002.008	460	1 meter	Dup.	PU239/240	685	PCI/G	J
99A3372-002.009	460	3 meter	Dup.	PU239/240	842	PCI/G	J
99A3372-002.002	460	Center	Real	PU239/240	554	PCI/G	J
99A3372-002.004	460	1 meter	Real	PU239/240	1482	PCI/G	J
99A3372-002.006	460	3 meter	Real	PU239/240	675	PCI/G	J

Although these results are estimated "J", these data were used to standardize the HPGe results (see Section 2.2) based on the following rationale: (1) the $^{239/240}$Pu:^{241}Am ratios derived from the

estimated results compared favorably to those derived from site specific studies (Ibrahim et al., 1995; NBS, 1980); (2) the best fit regression model used to standardize the HPGe results showed a high degree of correlation (R=0.97); and (3) the standardized HPGe results compared favorably with historical alpha spectroscopy results. In summary, the "J" estimated results did not compromise the accuracy of the best fit regression model used to standardize the HPGe results.

Gamma Spectroscopy Analysis

Gamma spectroscopy was performed on surface soil samples collected in support of the HPGe Program. No laboratory duplicate samples were analyzed because the gamma spectroscopy data were used only for qualitative comparisons to the HPGe measurements.

Volatile Organics

Matrix spike (MS) and matrix spike duplicate (MSD) samples generate data to determine long-term precision and accuracy of the analytical methods for soil samples. MS and MSD samples were performed at the required frequency of one set of QC samples per 10 field samples or a minimum of one set per analytical batch. All percent recoveries and relative percent differences (RPD) for MS and MSD samples were within the required limits.

3.3.1.2 Field Precision Results

Precision of field duplicate samples will be discussed separately from the precision of laboratory duplicate samples in this section due to the different sampling techniques and the effects of contaminant heterogeneity in surface soils. Field precision results were evaluated following laboratory assessment of the analytical data (i.e. post verification and/or validation).

Surface Soils-HPGe Double Sampling

A total of 24 real and nine duplicate surface soil samples were collected from three double sampling HPGe measurement locations and were provided to the laboratory for alpha spectroscopy analysis for ^{241}Am, $^{239/240}$Pu, and uranium isotopes. The frequency for duplicate sample collection for alpha spectroscopy analysis was met for this program. ^{241}Am activities were detected above the method detection limit in all samples.

Figures 3-1 and 3-2 present duplicate and associated real sample results for ^{241}Am and $^{239/240}$Pu. As shown, the three QA samples with lower activity levels compared favorably with results obtained from their associated real samples. The six QA samples collected within the higher activity range showed more variability when compared to the real samples, with at least one matched sample pair at FOV 460 showing significant departure from the associated real sample results.

The variability between field duplicate samples and associated real samples is a measure of all variance introduced from sample collection in the field through radiological analysis. One source of variance may be attributed to an increased error associated with analyzing only an aliquot (0.25 to 2.0 grams) of the sample instead of measuring the bulk sample. Another source of variance between field duplicates and their associated real samples is contaminant heterogeneity in the soil. The heterogeneous distribution of ^{241}Am and $^{239/240}$Pu activities in surface soils is evident at small intersample distances as seen in Table 3-3. Heterogeneity in surface soils is also observed in the FIDLER survey results (Section 4.1.3). Although it is clear that small-scale heterogeneous distributions exist for ^{241}Am and $^{239/240}$Pu activities in surface soil, the high degree of correlation between the alpha spectroscopy results and the HPGe gamma spectroscopy results indicate insignificant impact to the regression “model”.

Borehole Sampling

A total of 349 real and nineteen replicate surface and subsurface soil samples and asphalt samples were collected and analyzed by laboratory alpha spectroscopy analysis for ^{241}Am, $^{239/240}$Pu, and uranium isotopes. The frequency criterion for replicate sample collection (1 in 18.5) for alpha spectroscopy analysis was met for this program.

Figures 3-3 and 3-4 present replicate and associated real sample results for ^{241}Am and $^{239/240}$Pu. As shown, the majority of the QA samples compared favorably with the associated real samples. Slightly higher variances between real and duplicate QA samples are observed at higher activity ranges. The scatter plots shown in Figures 3-3 and 3-4 show no apparent bias in variation between paired real and duplicate samples.

Field Duplicate Samples Analyzed by In Situ Gamma Spectroscopy

The precision of *in situ* gamma spectroscopy is demonstrated by the high degree of agreement between real and duplicate measurements. The gamma spectroscopy unit collected a total of 1,110 *in situ* measurements. The required frequency of duplicate samples was one measurement for each set of 20 real measurements. A total of 58 duplicate measurements were collected (1 in 19.1) meeting the required collection frequency. Precision was quantified by calculating the duplicate error tolerances to demonstrate the laboratory-like precision of the HPGe measurements. All 58 duplicate measurements acquired were within error tolerances (DER $\leq$ 1.96) for ^{241}Am. This excellent performance by the *in situ* system indicates the large-area, physical-averaging is a repeatable method. Appendix C provides the TPU for HPGe measurements used in the DER calculations.

Field Duplicate Samples Analyzed for Volatile Organics

A total of 86 real and five duplicate subsurface soil samples (1 in 17.2) were collected and provided to the laboratory for analysis of VOCs. Therefore, the frequency for duplicate sample collection for VOC analysis was met for this program. Table 3-4 provides the number of samples collected under this program and the results of the RPD for the duplicate assessment. One sample pair detected VOCs in both the duplicate and associated real sample. The four other RPD calculations were conducted on sample pairs that had VOC detections in the real samples but not in the associated duplicate sample.

3.3.2 Accuracy

Accuracy is a measure of how closely an analytical or survey result corresponds to the true concentration or activity in a sample. Systematic uncertainties that affect accuracy, also known as bias, are also discussed in this section. Laboratory control samples (LCS) were analyzed to determine accuracy for radiochemical analyses. Matrix spikes and matrix spike duplicate samples were analyzed to determine accuracy for volatile organic analyses. The purpose of the laboratory control sample is to provide information about the degree of accuracy and precision of the analysis, and to assess the overall process for any inherent biases or trends. Check source measurements (field control samples) were used to evaluate accuracy with the HPGe detectors in the field for the *In Situ* Gamma Spectroscopy Survey.

3.3.2.1 Laboratory Accuracy

Alpha Spectroscopy

Laboratory accuracy for radiochemical analysis was evaluated by analyzing laboratory control samples (LCS). LCSs were analyzed at the required frequency of one per analytical batch. All LCS results were within the control limits (75% - 125%).

Volatile Organics

Quality Control check sample (also known as laboratory fortified blank [LFB]) data were generated to provide information on the accuracy of analytical method and laboratory performance. One LFB is required with each batch of samples processed within a working shift (up to 20 samples). LFBs were analyzed at the required frequency of one per working shift and were within control limits for each compound required to be evaluated.

3.3.2.2 Accuracy of Field Measurements

***In Situ* Gamma Spectroscopy**

The accuracy of *in situ* gamma spectroscopy is confirmed through two methods of validation implemented for the project: systematic validation, and more importantly, performance validation. That is, through the use of HPGe check source measurements and by comparing and correlating these data to results for surface soil samples analyzed by laboratory alpha spectroscopy.

Check source measurements were performed at the start and at the conclusion of each work day, and spot checked during the work day, to monitor system stability, alignment, and response. Calibration verification was performed by checking measurements against a standard reference point source traceable to the National Institute of Standards and Technology (NIST). The measured activity was required to be less than three standard deviations from the known activity of the check source as provided by the source manufacturer prior to collecting field measurements. Additionally, the energy calibration of the system was confirmed for the 59.5 keV peak of ^{241}Am, as well as for the 1173 keV and 1337 keV peaks of ^{60}Co. Required system response criteria were confirmed prior to performing daily field measurements.

As shown in Figure 2-4, the high correlation coefficient (R=0.99) for ^{241}Am, validates the *in situ* gamma spectroscopy measurement system in relation to the laboratory measurements of physical soil samples. However, the HPGe measurements are biased on the low side relative to the laboratory measurements by approximately 25% (Figure 2-4). This low bias was corrected prior to comparison of HPGe measurements to RFCA action levels. The correction was made by using the best fit regression line equation to "standardize" HPGe measurements to laboratory measurements.

The systematic validation of gamma spectroscopy results yielded no significant qualifications to the data. Detailed technical considerations and associated effects on data quality are further detailed in Appendix D under*"903 Pad In-Situ Models and Uncertainties"*.

3.3.3 Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point. The discussion of representativeness will evaluate whether analytical results for field samples are truly representative of environmental concentrations or whether they have been influenced by the introduction of contaminants during collection and handling. Two field QA samples collected to assist in the evaluation of representativeness are equipment rinsate blanks and trip blanks. Equipment blanks are used to determine the effectiveness of the decontamination of reusable sampling equipment. Trip blanks are utilized to determine if contamination is introduced during sampling handling and shipment.

As shown in Table 3-5, the collection frequency of quality control samples was met for all analytical programs with the exception of trip blanks. Detections of VOCs in soil samples shipped without trip blanks are considered actual detections except where qualified as a laboratory contaminant. No analytical results were qualified based on trip blanks analyses performed in support of this project.

Equipment rinsate blanks were performed at a frequency of one blank for every twenty samples collected. Methylene chloride was detected above detection limits in two equipment blank

samples associated with sampling at boreholes 95998 and 96798. However, the detections were estimated at low levels; therefore the results were not qualified due to detected results in the equipment rinsate blanks.

Methylene chloride was detected at estimated (J) concentrations in 16 samples (0.59 J to 410 J ug/Kg) at less than the method reporting limit. However, the maximum detected concentration in a method blank from the entire sample data set is 860 ug/Kg. Using EPA guidance (EPA, 1989), the concentration in the samples does not exceed ten times the maximum amount detected in any blank. However, despite meeting all of the EPA (1989) laboratory contaminant criteria, methylene chloride was retained as a final COC because of recognition of contaminant spatial patterns, association with other contaminants and other media, and knowledge of past chemical releases at the 903 Pad (see Section 4.3). Although bromomethane is not considered a common laboratory contaminant, it was detected in the laboratory blank. EPA (1989) criteria for identifying bromomethane as a non-detect due to laboratory contamination includes the following: a detected concentration of less than 5 times the associated blank concentration; and the absence of other detected organics in the sample.

Acetone was detected in several samples from boring 97698 (99A8275), however the continuing calibration verification criteria were not met and the results were qualified as estimated. Acetone was detected in samples from boring 96398 (99A4102), ranging from 1,200 up to 3,300 ug/Kg. The maximum detected concentration of acetone in a method blank from the entire sample data set is 670 ug/Kg. Using EPA guidance (EPA, 1989) the concentration in the samples does not exceed ten times the maximum amount detected in any blank. Therefore, acetone detections associated with samples from these boreholes are considered a result of laboratory contamination.

The compound trichlorotrifluoroethane was detected in several samples from borehole 97698 (99A8275). Detections of trichlorotrifluoroethane are not considered repeatable as the dilution results for this sample indicated trichlorotrifluoroethane was no longer present. The results were assigned the J148 qualifier, as the associated value is estimated and the linear range of the measurement system was exceeded. Results were then adjusted with the dilution Contract Required Quantitation Limit and given the qualifier UD, the associated value is considered undetected at an elevated level of detection.

PCE was detected in two samples from boring 95998, at 1,540 ug/kg and 343 ug/kg with an E (estimated) qualifier. When re-analyzed by the lab, the PCE results were 3,060 ug/kg and 174 ug/kg, respectively, with a D qualifier (dilution).

Qualifications of VOC data did not affect representativeness or project decision making. VOC samples were analyzed using an expedited turn-around to assist field decisions based on "Form-1's" faxed from the laboratory. Although VOC detection limits varied during the course of the project, the detection limits were lower than the current Tier I soil action levels for VOCs and therefore did not impact decision making based on these action levels.

Representativeness is also evaluated by comparing the number and types of samples identified in the SAP with the number and type of samples actually collected. The number of samples required was based on meeting the DQOs of the characterization. Table 3-4 provides a comparison of planned samples versus actual samples collected in support of the investigation.

As shown in Table 3-4, all areas met or exceeded planned sample requirements with the exception of the HPGe survey in the Lip Area and characterization of the asphalt and fill at the 903 Pad by alpha spectroscopy. Surface soils in the Lip Area were characterized by twenty borings completed during the subsurface radiological program. Sample results collected from the 0-6 inch interval were used to characterize surface soils in this area. Asphalt and fill samples were to be collected at all 25 boring locations within the 903 Pad, which was later determined to be excessive. Therefore, the SAP was revised to include the collection of samples at nine randomly selected locations.

3.3.4 Completeness

Completeness is typically expressed as a percentage, calculated as a ratio of usable results to the number of samples collected. One hundred percent of the data were verified at the project level based on comparing usable data with unusable data, which exceeds the project goal of 90% (RMRS, 1998c). Additional sampling is not required to meet the project objectives of estimating soil volumes exceeding current action levels and characterizing surface soils to 10 pCi/g ^{241}Am.

3.3.4.1 Deviations

Despite weather constraints and field activities conducted non-sequentially among the subsurface investigations of the 903 Pad, Lip Area, and the VOC program, quality control samples were collected at a frequency of one in 20 during the entire subsurface investigation. Trip blank samples for VOC samples were reduced to a frequency of one trip blank for every 20 real VOC samples; detections not associated with a trip blank will be considered actual detects. Two of the required VOC trip blank samples were missed. This deviation from the SAP is justifiable as the analytical data is adequate to characterize subsurface soil and thus is representative of the subsurface soil conditions. Gamma spectroscopy analysis of aqueous samples could not be performed on rinse blank water samples. Two of the VOC investigation boreholes were not completed to bedrock due to refusal of the Geoprobe sampling equipment at boreholes 96798 and 97698. Data collected from these boreholes are adequate and representative of subsurface soil conditions.

Table 3-4 Planned vs. Actual Sample Comparison

Area (Program)	Analysis	Planned No. of Samples (per SAP)	Actual Number of Samples Collected	Deviation	Justification
Lip Area and Americium Zone	*In Situ* Gamma Spectroscopy	1,200	1,110	-90	Borehole samples from 0 – 6 inch interval were used to characterize Lip Area east of the 903 Pad. This deviation from the SAP was approved by the agencies.
Americium Zone Surface Soils	Alpha Spectroscopy and Gamma Spectroscopy	18 from 6 FOVs	24 from 8 FOVs	+6	Collected samples from two additional FOVs for correlation of HPGe samples and field quality control locations.
903 Pad Radiological	Alpha Spectroscopy	150	107	-43	Original estimate erroneously included samples of asphalt and fill for 25 boreholes. Reduced number of fill samples to same frequency as asphalt samples. This deviation from the SAP was approved by the agencies.
903 Pad Asphalt	Alpha Spectroscopy	9	9	0	N/A
903 Pad VOC (Subsurface VOC)	Alpha Spectroscopy	72	76	+4	Collected additional samples as a result of “stepout” borings.
903 Pad VOC	VOC	72	77	+5	Collected additional samples as a result of “stepout” borings.

Table 3-4 Planned vs. Actual Sample Comparison (cont.)

Area (Program)	Analysis	Planned No. of Samples (per SAP)	Actual Number of Samples Collected	Deviation	Justification
903 Lip Area Radiological	Alpha Spectroscopy	100	148	+48	Collected additional samples as a result of "stepout" borings.
903 Lip Area VOC	Alpha Spectroscopy	6	9	+3	Collected additional samples as a result of "stepout" borings.
903 Lip Area VOC	VOC	6	9	+3	Collected additional samples as a result of "stepout" borings.

Table 3-5 QC Sample Type, Quantity

Sample Type (Program)	Analysis	Number of Investigative Samples	Number of Duplicate/ Replicate Samples	Number of Rinse Blank Samples	Number of Trip Blank Samples
Americium Zone Surface Soils (HPGe)	Alpha Spectroscopy	24	9	3	N/A
Americium Zone Surface Soils (HPGe)	Gamma Spectroscopy	24	9	0	N/A
903 Pad Radiological (Subsurface)	Alpha Spectroscopy	107	6	4	N/A
903 Pad Asphalt (Subsurface)	Alpha Spectroscopy	9	1	0	N/A
903 Pad VOC (Subsurface)	Alpha Spectroscopy	76	4	4	N/A
903 Pad VOC (Subsurface)	VOC	77	4	3	2
903 Lip Area Radiological (Subsurface)	Alpha Spectroscopy	148	8	10	N/A
903 Lip Area VOC (Subsurface)	Alpha Spectroscopy	9	0	0	N/A
903 Lip Area VOC (Subsurface)	VOC	9	1	2	1
Project Totals	**Alpha Spectroscopy**	**373**	**28**	**21**	N/A
	Gamma Spectroscopy	**24**	**9**	**0**	N/A
	VOC	**86**	**5**	**5**	**3**

3.3.5 Comparability

All results presented are comparable with historical sampling and analyses results. This comparability is based on standard methods (EPA-approved methods), systematic quality controls, and thorough documentation of the planning, sampling, and analysis process.

The comparability of two samples was questioned during the investigation. One sample from HPGe measurement location 104 at 3 meters (98A5590-001.006) was reanalyzed as sample 98A5590-004.001 because ^{241}Am results from the first analysis were elevated and not comparable to the other sample results collected at this location. However, the reanalysis (98A5590-004.001) was comparable to the other HPGe measurements at location 104. One alpha spectroscopy sample result from boring 94298 (98A2014-001.002) was rejected due to the MDA exceeding the RDL. However, sample results were comparable to other Native 1 soil radiological results and therefore were usable. The remaining soil samples results were comparable because sample collection activities and analysis were performed in accordance with the SAP (RMRS, 1998) and procedures described in Section 2.0.

3.3.6 Sensitivity

Sensitivity was evaluated by comparing actual quantitation limits of the results with the regulatory or project-specific action levels required for decision-making. All analytical and radiological methods achieved adequate sensitivities based on quantitation limits well below regulatory thresholds, typically with a quantitation limit at less than 50% of the threshold.

3.3.6.1 *In Situ* Gamma Spectroscopy

The sensitivity of *in situ* gamma spectroscopy is corroborated through the evaluation of actual measurement detection limits and project goals. Table 3-6 provides a comparison of detection limits for the *In Situ* Gamma Spectroscopy program.

Table 3-6 Comparison of Detection Limits – In Situ Gamma Spectroscopy

Analyte	Required Analytical Method	Required Detection Limit (pCi/g)	Actual Detection Limit (pCi/g)
^{241}Am	*In Situ* Gamma Spectroscopy	1.0	0.38 – 1.43
^{235}U	*In Situ* Gamma Spectroscopy	0.5	0.36 - 0.72
^{238}U	*In Situ* Gamma Spectroscopy	5.0	1.31 – 6.49

As shown in Table 3-6, the lower limit of the actual detection limit was met for all three radionuclides. The required detection limit was exceeded for ^{241}Am and ^{238}U in a limited number of analyses; however, these exceedances do not significantly impact the results of the HPGe survey.

3.3.6.2 Laboratory Alpha Spectroscopy

The sensitivity of laboratory alpha spectroscopy data was evaluated with respect to detection limits. Table 3-7 provides a comparison between required detection limits and actual detection limits.

Table 3-7 Comparison of Detection Limits – Alpha Spectroscopy

Analyte	Required Analytical Method	Required Detection Limit (pCi/g)	Actual Detection Limit (pCi/g)
$^{239/240}$Pu	RC01B001	0.3	0.028 - 0.122
^{241}Am	RC01B001	0.3	0.0061- 0.168
$^{233/234}$U	RC01B001	1.0	0.015 – 0.472
^{235}U	RC01B001	1.0	0.016 – 0.472
^{238}U	RC01B001	1.0	0.008 – 0.643

As shown in Table 3-7, the range of actual detection limits were lower than the required detection limits for all radionuclides. Therefore, the sensitivity relative to detection limits was adequate for all alpha spectroscopy analyses for decision making purposes.

3.3.6.3 Volatile Organic Compound Analysis (EPA 8260B)

The sensitivity of VOC data was evaluated with respect to detection limits. Table 3-8 provides a comparison between required detection limits and actual detection limits.

The method detection limit was revised during the VOC Subsurface Investigation from the mid-level detection limit (740 ug/kg) specified in the SAP (RMRS, 1998b) to a low-level detection limit (5 ug/kg). The required detection limit of 740 ug/kg was exceeded for the target analytes in all samples from boring 96498, and in one sample each from borings 96198 and 96298. The detection limit exceedance in samples from boring 96498 was due to sample analysis using the VOA-CLP, mid-level method. However, the actual detection limit is lower than the current Tier I soil action levels for VOCs and therefore did not impact decision making based on current SSALs.

Table 3-8 Comparison of Detection Limits – Volatile Organic Compound Analysis

Analyte	Required Analytical Method	Required Detection Limit (ug/kg)	Actual Detection Limit (ug/kg)
Carbon Tetrachloride	8260B	740	5.0 – 1500
Chloroform	8260B	740	0.1 – 1500
1,2 DCE	8260B	740	0.1 – 1500
Methylene Chloride	8260B	740	1.4 – 1500
Tetracholorethene	8260B	740	0.41 – 1500
Trichloroethene	8260B	740	0.31 - 1500

3.3.7 Summary

In summary, the data sets acquired and evaluated for the 903 Pad Project were satisfactory for supporting the Data Quality Objectives proposed in the SAP. The following project objectives were achieved:

1) Defining actinide activities that exceed 10 pCi/g ^{241}Am in surficial soils;
2) Defining actinide activities in surface and subsurface soil that exceed Tier I and II RSALs; and

3) Defining VOC concentrations in subsurface soil that exceed current Tier I SSALs.

Although not required by the SAP, an additional evaluation was performed to define VOC concentrations in subsurface soils that exceed proposed Tier I and Tier II SSALs (Kaiser-Hill, 1999b). However, proposed Tier II SSALs are below the required detection limit for VOCs identified in the SAP. Although subsurface soils have been characterized with respect to the proposed Tier I SSALs, not all soils have been characterized with respect to proposed Tier II SSALs. Therefore, areas exceeding proposed Tier II SSALs may be underestimated.

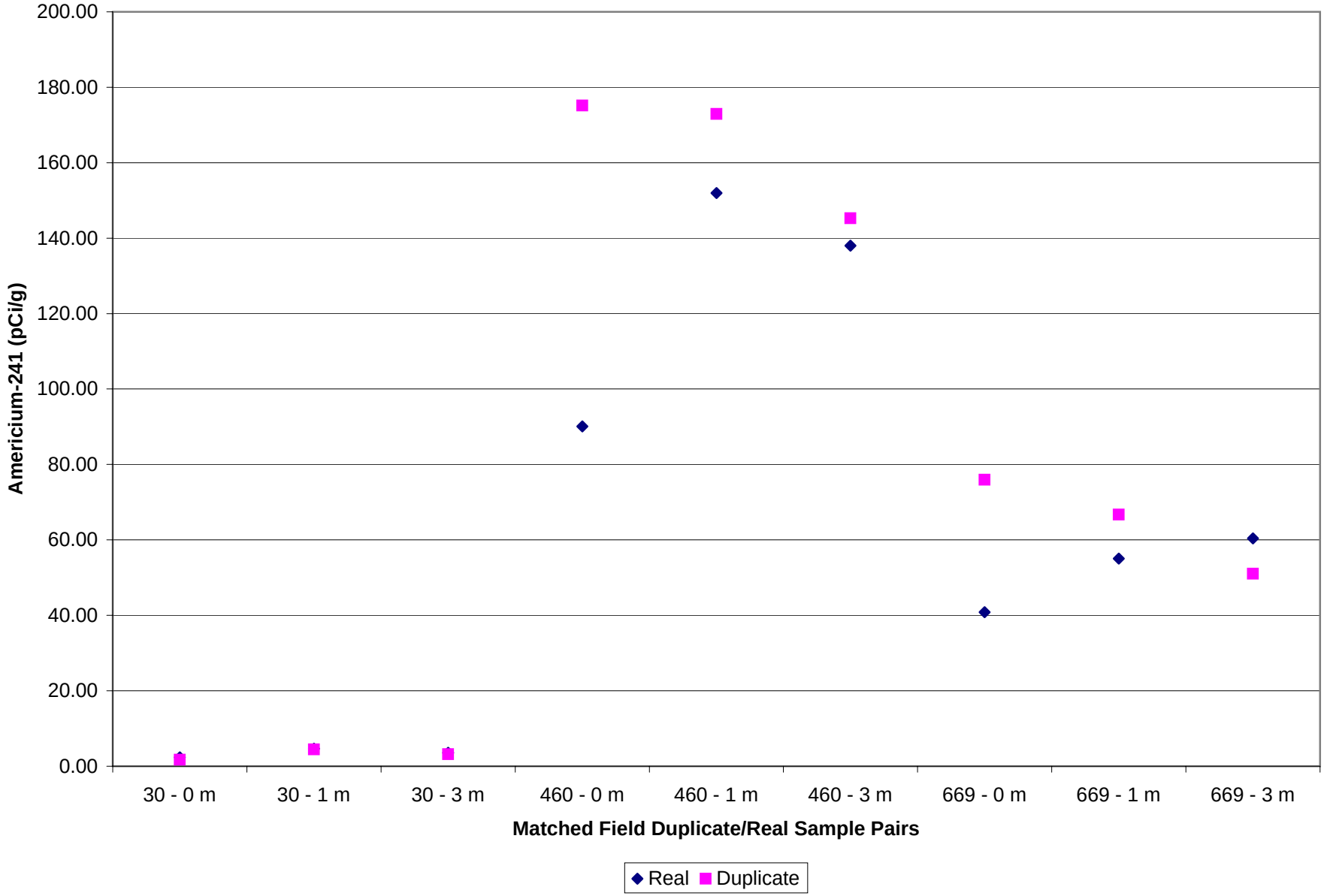

Figure 3-1 Surface Soil Field QA Sample Comparision - Americium-241

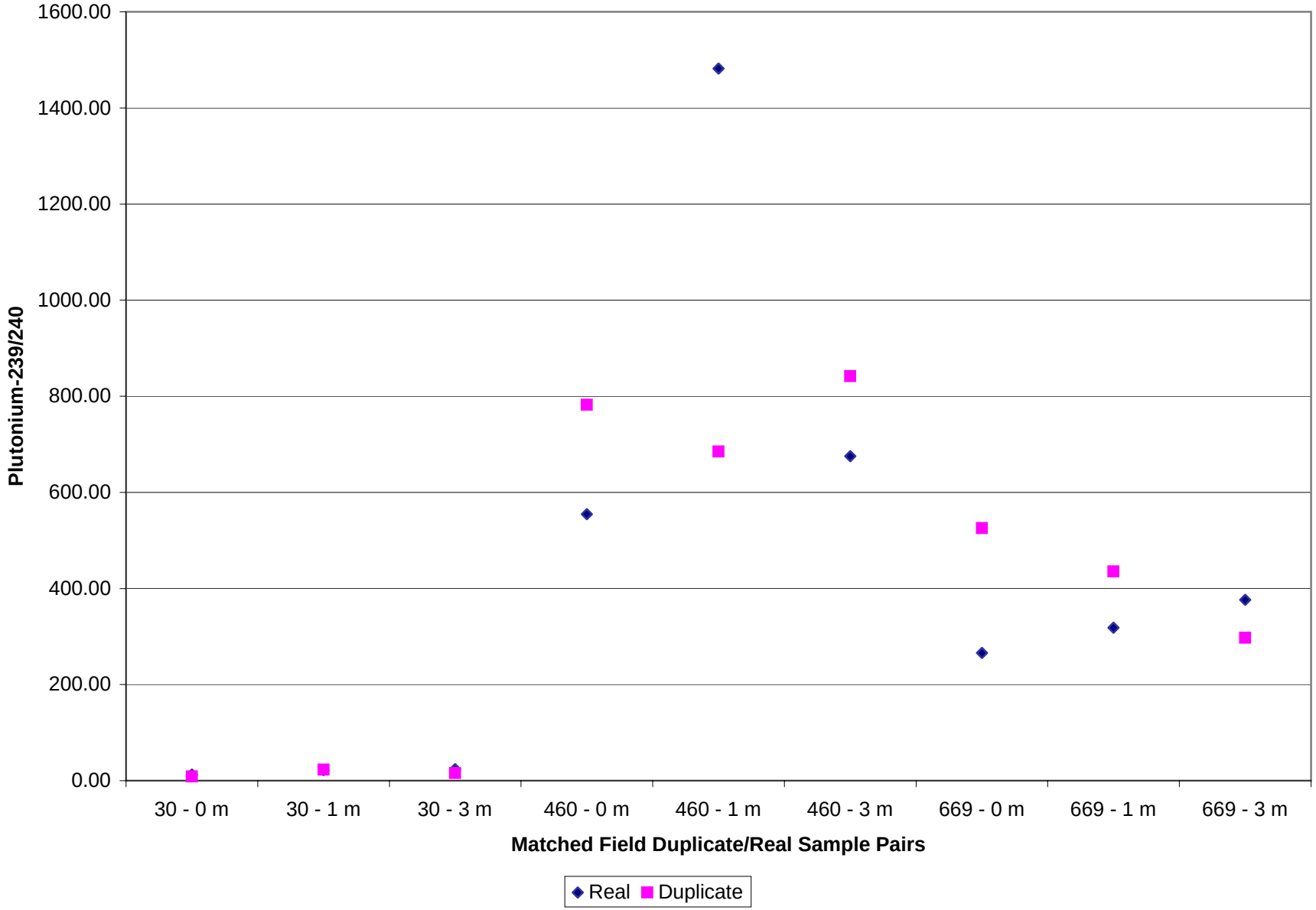

Table 3-2 Surface Soil Field QA Sample Comparison - Plutonium-239/240

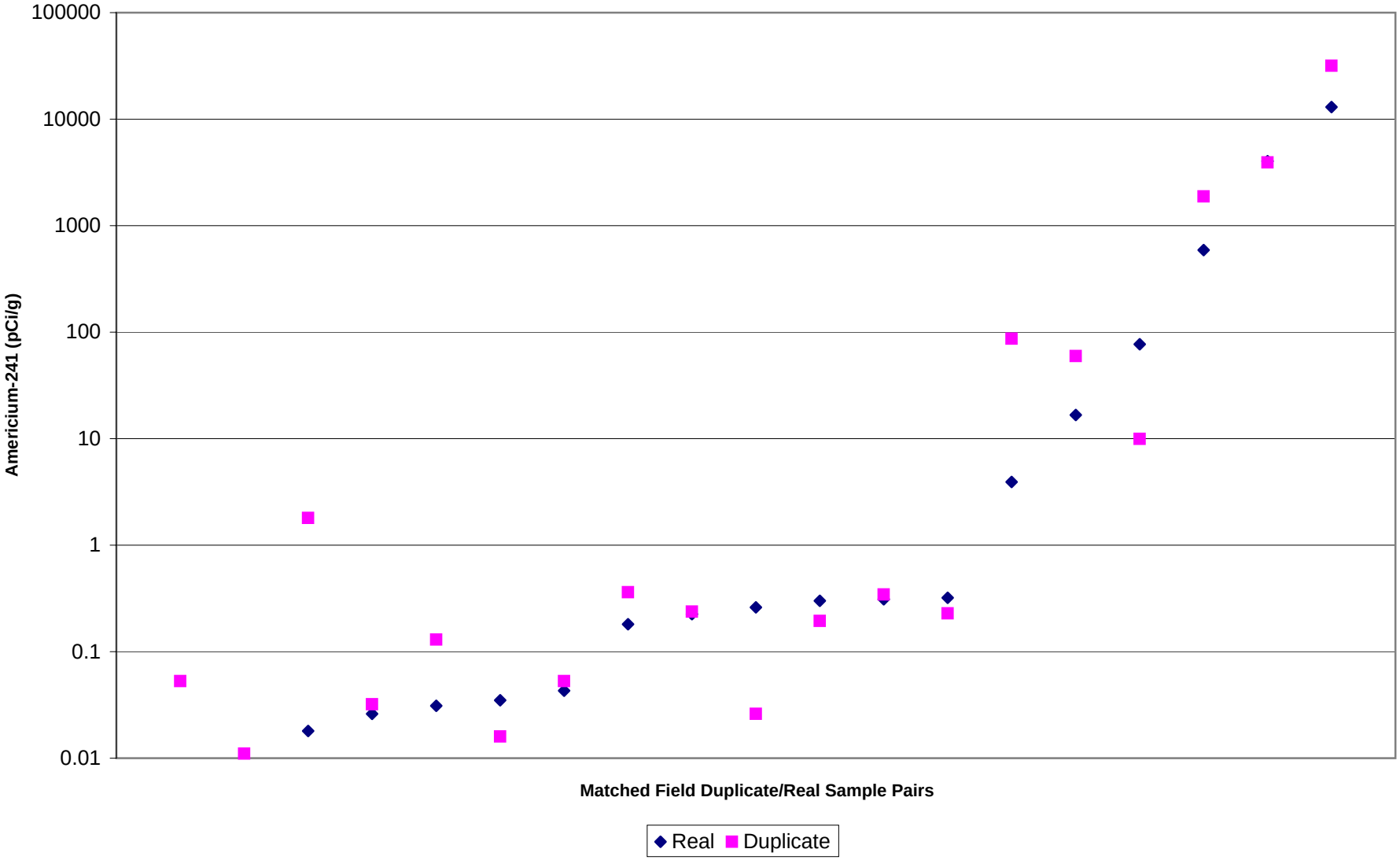

Figure 3-3 Subsurface Soil Field QA Sample Comparison - Americium-241

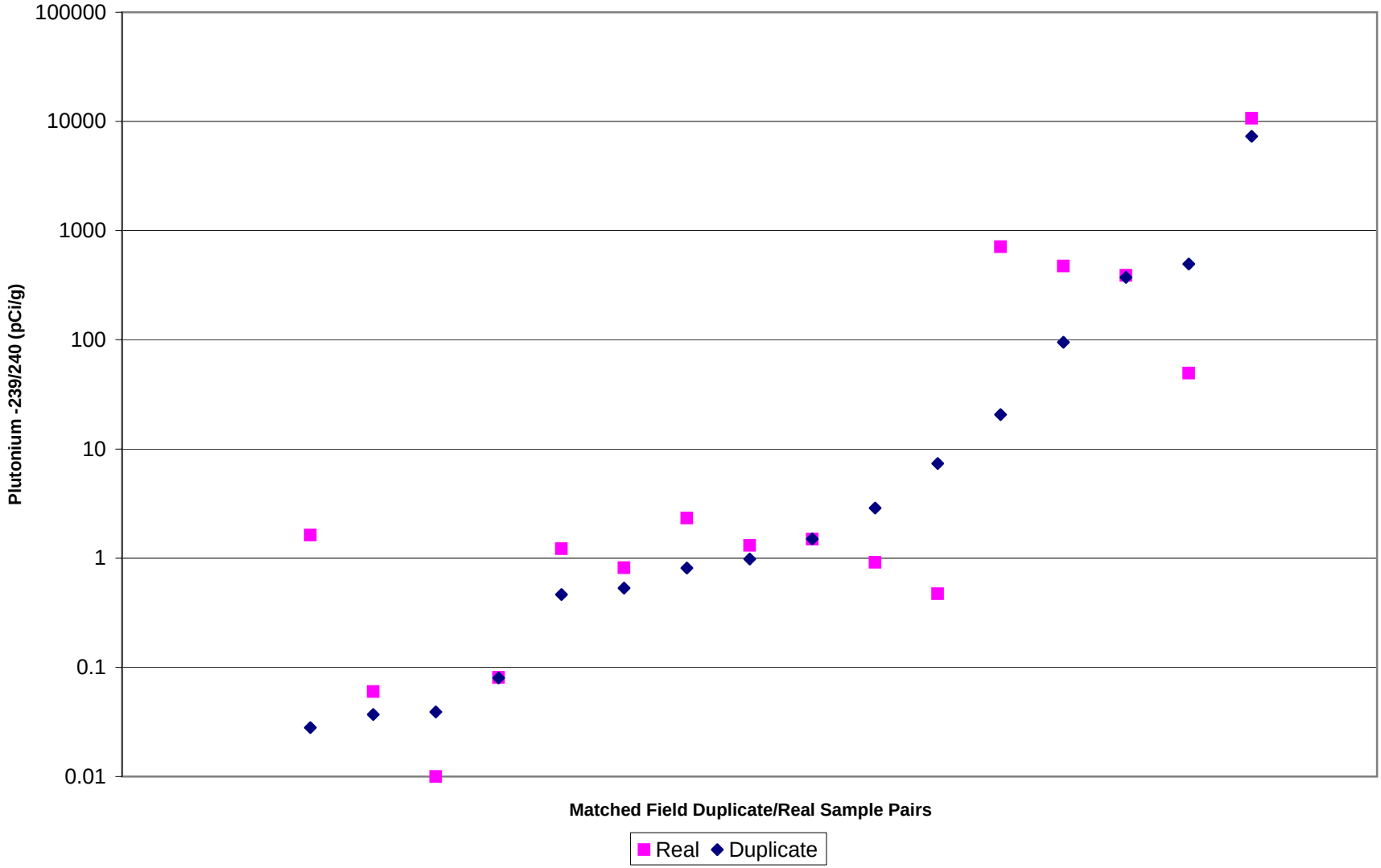

Figure 3-4 Subsurface Soil Field QA Sample Comparison - Plutonium-239/240