NOTICE

All drawings located at the end of the document.

KAISER•HILL
COMPANY

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

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Rocky Flats Environmental Technology Site

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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

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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).

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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

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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.

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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.,

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

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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).

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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°C[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

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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.

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Oenothera biennis	Common Evening Primrose	2
Opuntia humifusa	Prickly Pear Cactus	5
Poa pratensis	Kentucky Bluegrass	1,2,3,4
Psoralea tenuiflora	Wild alfalfa	3
Slasola iberica	Russian Thistle	5
Taraxicum officinale	Dandelion	1
Trapopogon dubius	Goatsbeard	1
Verbascum blattaria	Moth Mullien	1
Verbascum thapsus	Common Mullien	1,2,3,4,5

Table 8.1

Vegetation in Lysimeter	
Species Name	Common Name
Agropyron smithii	Western Wheatgrass
Alyssum minus	Alyssum
Bromus japonicus	Japanese Brome
Bromus tectorum	Cheatgrass
Carduus nutans	Musk Thistle
Cirsium arvense	Canada Thistle
Convolvulus arvensis	Field Bindweed
Poa pratensis	Kentucky Bluegrass
Tragopogon dubius	Goatsbeard

Table 8.2

The dominant species in the lysimeter plot are Western Wheatgrass, Cheatgrass, Alyssum, and Kentucky Bluegrass.

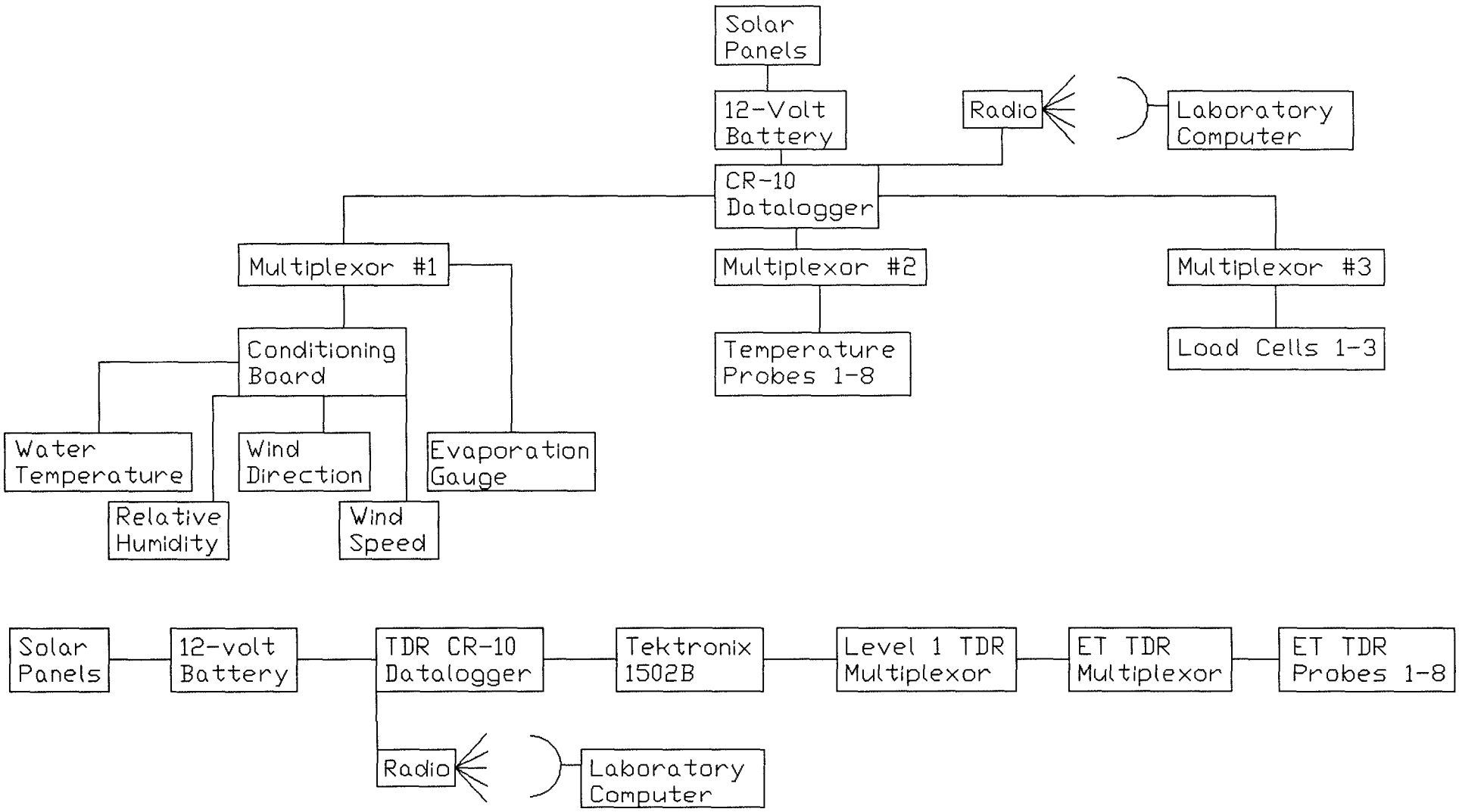
8.4.4 Evapotranspiration Control Station

Evapotranspiration data is collected hourly by a Campbell Scientific CR-10 datalogger which controls the instruments through multiplexors and a conditioning board. The schematic detailing the ET datacollection logic is shown in Figure 8.9. The ET control station is shown in Figure 8.10.

The datalogger collects data for pan water temperature, air temperature, relative humidity, wind speed, and wind direction every minute. The data is stored within the datalogger and averaged over a one hour period. This helps smooth any fluctuations that may occur from power surges and instrument anomalies. Further, any data that lies outside of an acceptable range is

Figure 8.9

EVAPOTRANSPIRATION DATA COLLECTION SCHEMATIC



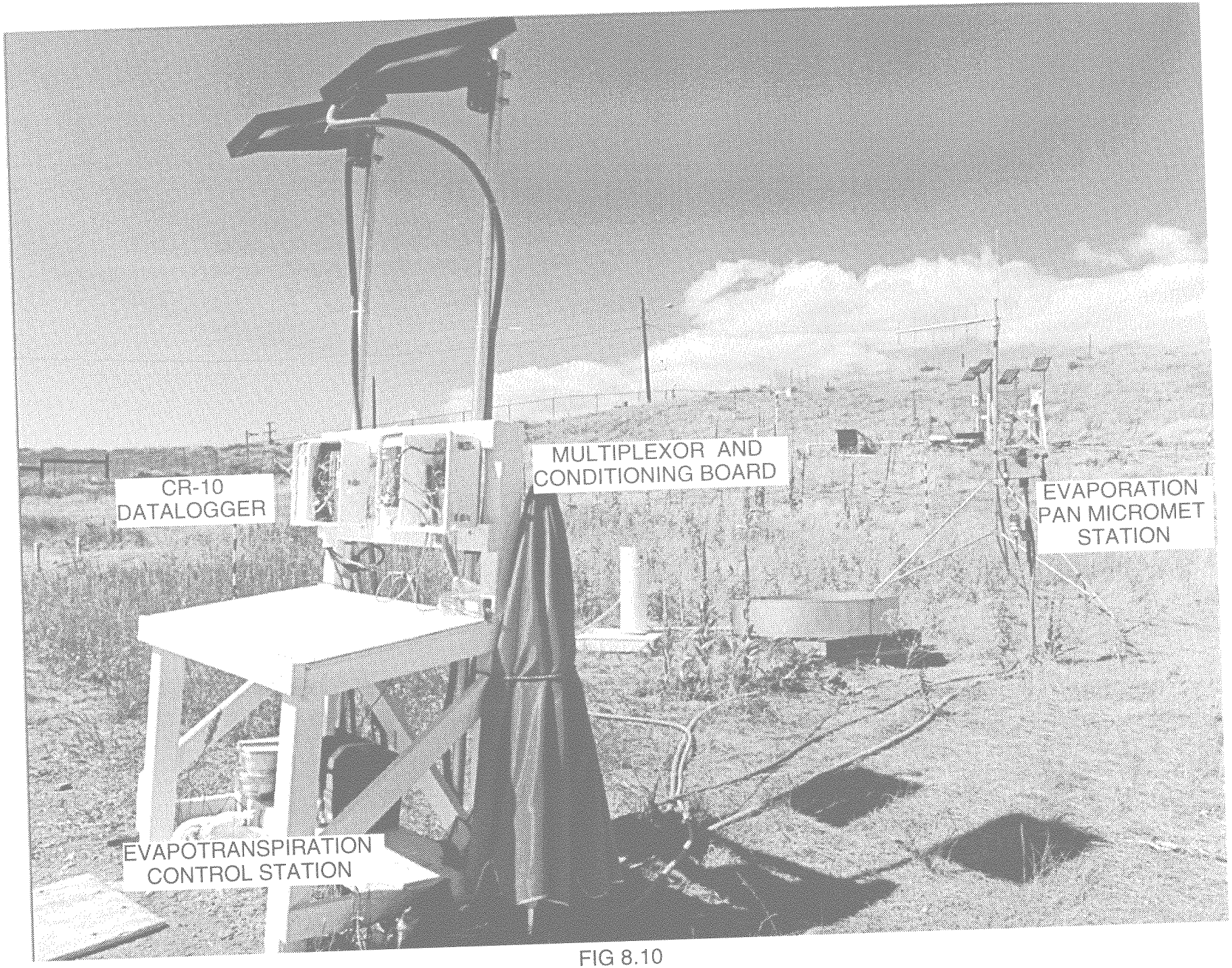

CR-10
DATALOGGER
MULTIPLEXOR AND
CONDITIONING BOARD
EVAPORATION
PAN MICROMET
STATION
EVAPOTRANSPIRATION
CONTROL STATION

FIG 8.10

discarded. For example, if relative humidity data is greater than 100% or less than 0% it is ignored. Also, if air temperature exceeds 150° F or falls below -40° F or if water temperature fall outside of the liquid range the data is omitted from the averaging scheme. The evaporation pan water level is measured at the 59th and 60th minute of every hour and then averaged to give a good, smooth indicator of the rate of water evaporation.

See the snowmelt section for information on micromet data collection.

The lysimeter has not been completed at the time of writing. When operational, soil temperature, soil moisture, and load cell data will be collected at one hour intervals.

8.5 EVAPOTRANSPIRATION DATA

The datalogger program controlling the evaporation pan, the evaporation pan micrometeorological station, the lysimeter load cells, and temperature probes is titled EVAPAN04. The programs used prior to EVAPAN04 are EVAPAN03, EVAPAN02, and EVAPAN and can be found in Appendix 8.

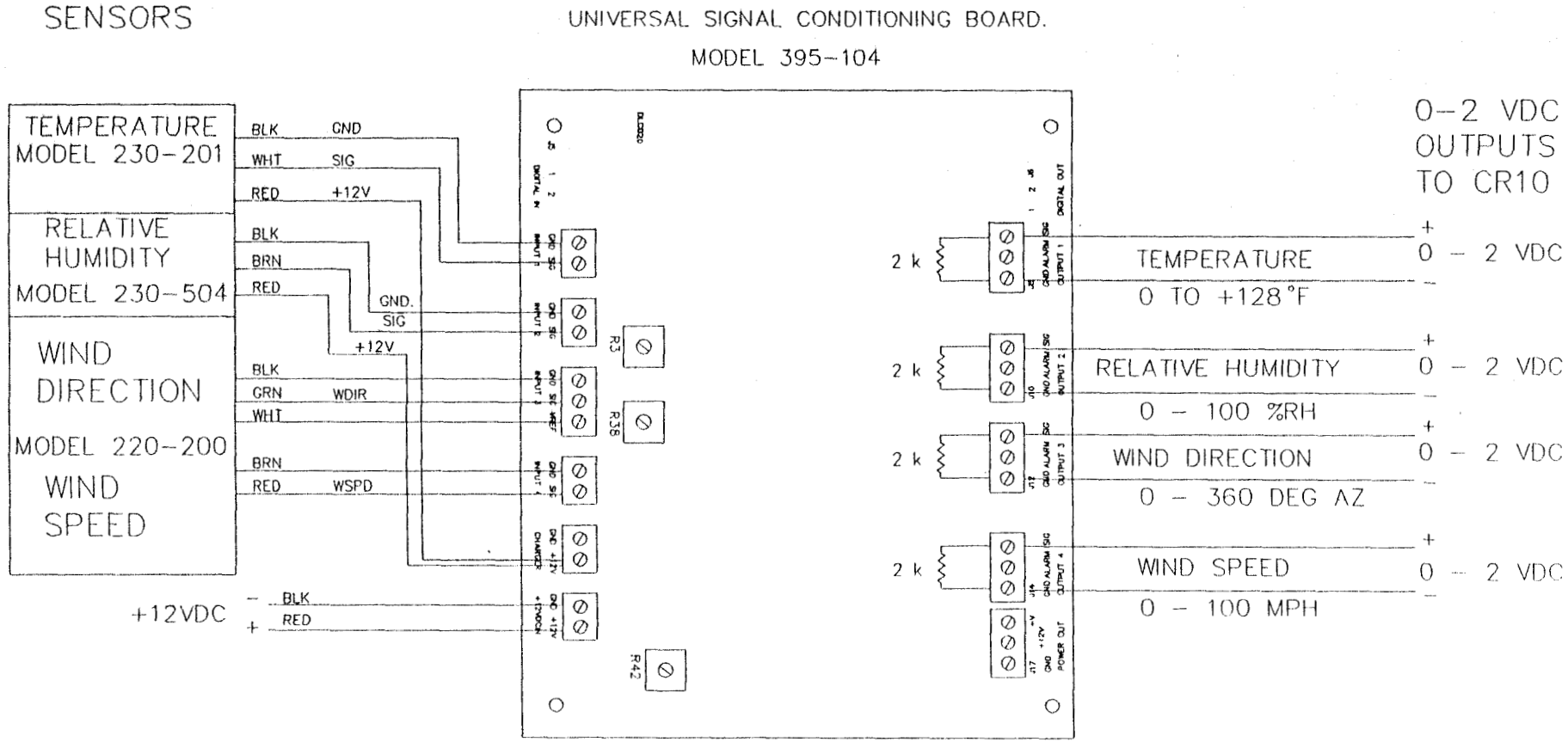
8.6 EVAPOTRANSPIRATION PROBLEMS AND SOLUTIONS

All instruments used in the evapotranspiration study are calibrated by the manufacturer before they are shipped. However, before installation in the field, the instruments are tested and, when possible, calibrated in the laboratory. Results of load cell calibration and temperature probe testing are in Appendix 10. Testing of wind speed, wind direction, and relative humidity were informally tested on a comparison basis with similar existing equipment in the field. Time Domain Reflectometry cables were tested to ensure that cable performance is within acceptable range; the results are in Appendix 10.

The evaporation pan instruments output data over a range of 0 - 12 volts direct current (VDC). However, the CR-10 datalogger can only accommodate signals between zero and two VDC. To compensate for the difference between instrument voltage output and CR-10 datalogger requirements, a universal signal conditioning board was designed as shown in Figure 8.11. All outputs are between zero and one milliamps with a 2000 ohm load resistor and hence produce an output between zero and two VDC for the CR-10 datalogger.

With the marine battery recharged by the solar panel, the voltage output from the battery would vary, with the greatest voltage occurring during peak sunlight and the lowest voltage

FIGURE 8.11



NOTES: 1. ALL OUTPUTS ARE 0-1 mA WITH A 2K OHM LOAD RESISTOR TO PRODUCE 0-2 VDC OUTPUTS FOR CR10.

TRANSLATOR BOARD MODIFIED FOR SPEED, DIRECTION, TEMPERATURE, & HUMIDITY.

BOARD MODIFIED FOR WOODWARE-CLYDE

VAISALA SYSTEMS INC			C
TITLE SYSTEM WIRING DIAGRAM WSPD, WDIR, TEMP, RH BOARD			
MOD. USAGE 395-104			SHEET 1 OF 1
BY RGN	SCALE NONE	DWG NO. 931129	
DATE 11-23-93			

occurring just before sunrise. Because instrument output is dependent on battery voltage input, a varying voltage will cause varying and erroneous data. The battery voltage varied between 11.4 and 14.4 VDC and the output from the instruments varied a proportional amount around the true value. To remedy this, we used a voltage regulator that clamped voltage at 10.8 VDC which is within the CR-10 operating range between 9.6 and 16.0 VDC. By using an LM317T adjustable three-terminal positive voltage regulator (Radio Shack, Part Number 276-177B), the voltage supplying the air and water temperature probes, relative humidity gauge, and wind speed was stabilized at 10.8 VDC. After the voltage regulator was checked and calibrated in the laboratory, it was installed in the field. The multiplying factors in the CR-10 program, EVAPAN03, were adjusted to reflect the 10.8 VDC input voltage.

Due to bureaucratic problems related to excavating radiologically-contaminated soil, excavation of the monolith was done by hand rather than by machine, adding several weeks to the completion of the project. Because the soil was primarily hardpacked clay, an electric jackhammer with a clay spade attachment was used to break up the soil. The soil was then separated by horizon into two large containers adjacent to the excavation site. The soil will be replaced when the lysimeter is operational.

After the monolith was excavated, it was placed by forklift onto a circular baseplate at a temporary staging area. The monolith shell was designed to fit snugly over the baseplate, but due to irregularities in the soil monolith (e.g. rocks, roots, air pockets), the monolith was slightly oval. The long bisecting axis of the oval was one inch longer than the shorter bisecting axis. To ease the shell over the baseplate, small strips of metal were used like a shoehorn between the shell and the baseplate as the shell was slowly pushed down over the baseplate. Once the shell fully enveloped the baseplate, the metal shoehorn strips were removed and the shell was pushed down into its final position. A half-inch wide band of Band-It was wrapped around the base of the shell, securely holding it to the baseplate.

At the time of this writing, the TDR and temperature probes have not yet been installed into the lysimeter.

Algae growth in the evaporation pan originally presented a problem. It is desirable to have clean water in the evaporation pan to ensure consistent evaporative conditions. This not only ensures consistent conditions throughout the year at the study site, but also throughout other study sites. To inhibit the growth of algae, several options were considered including bleach, copper sulfate, and algaecide. Bleach was dismissed because it could potentially eat away at the stainless steel evaporation pan and could be a danger to animals. Copper sulfate was dismissed because the

distributor said that it may change the color of the pan water. Common algaecide, used for swimming pools and ornamental fish ponds, was used and effectively reduced the amount of algae present in the evaporation pan. Algaecide is also considered safe if animals should drink from the pan.

Another problem was that animals (primarily mule deer) would drink from the evaporation pan. Several remedies were considered including chemicals that foul the taste of the water, screening over the pan, and perimeter fencing. Chemicals were ruled out because it was uncertain how they would affect the pan water color and evaporative rates. Screening over the pan was thoroughly investigated, but a literature review on evaporation pan screens indicated that evaporation rates could decrease by up to 15% per day (Source, date). A perimeter fence around the evaporation pan was deemed the best solution. However, before the fence was installed, a larger fence around the entire perimeter of the study site was erected. No animals were observed drinking from the pan after this larger fence went up.

Future work will include a method to automate the evaporation pan water level at a constant level. The evaporation pan operates best when water is maintained at a constant 8" level. However, it is difficult to constantly maintain this level manually.

9.0 TENSIOMETER AUTOMATION

9.1 INTRODUCTION TO TENSIOMETER AUTOMATION

To capture the dynamics of atmospheric water infiltrating the vadose zone, the Soil Water Measurement System (SWMS) must collect measurements of soil physical properties at a frequency substantially greater than the duration of the infiltration events. While the TDR technology used for monitoring soil moisture is amenable to high frequency measurement, the frequency of matric potential measurements with tensiometers is typically labor intensive and provides only low resolution data series. Automation of a network of tensiometers under field conditions permits high-frequency data acquisition and eliminates time-consuming manual maintenance.

The automated system should be capable of providing data resolution at a higher frequency than the duration of most infiltration events. Because rain simulations in the study area are usually one hour long, measurement intervals of 5 to 15 minutes are desirable. A datalogging system capable of these scan rates and compatible with existing measurement systems in the field area had to be designed, tested, and installed.

The system must be reliable and flexible. Most work in 1994 was focused on meeting these conditions. Specifically, we tried to create a modular measurement system with standardized components which could be easily installed, tested, and repaired. These components included the power supplies, the pressure transducer harnesses, the multiplexing and control assemblies at each pit, and the links between the pits and the datalogger. New tensiometer designs were investigated which could mesh easily with the monitoring network and which were more robust in the field than the existing tensiometer arrays. Integrating field data collection with the GUI is described in the GUI section of this document.

Maintenance of water levels in tensiometers is vital to their performance, especially under dry soil conditions where they drain rapidly. Frequent maintenance also permits elimination of the water column height variable in calculation of matric potential (see SNBK '93). Tensiometer water refilling has so far been a manual procedure which has consumed valuable man hours and equipment, added greatly to the expense of the monitoring system and reduced its flexibility. Field tensiometers were redesigned to speed manual refilling while laboratory work progressed in developing a fully automated water level checking and replenishing system.

9.2 METHODS

9.2.1 Tensiometer Automation System

The purpose of the system is to obtain matric potential values, tensiometer temperatures, and indicators for water refilling at user-selected intervals, to store them in a field datalogger, and to relay the accumulated data via telemetry to a database in the laboratory. The components of this system (Figure 9.1) are described in sections 2.1 and 2.2.

2.1.1 Datalogging system equipment

Separate power supplies were established for field system components at each pit and for the datalogger. In each case, electricity generated by panels of photovoltaic cells was stored in 12 volt batteries. Figure 9.1 lists the power supply parts.

The power supply for the datalogger consists of a 12V deep cycle marine battery connected in parallel with the regulated outputs of 2 12V, 40W solar panels and with the 12 volt power input to the CR7 datalogger. The CR7 also contains internal voltage regulation circuitry. The (-) bias of the power supply is not connected to earth ground. The solar panels are described in CSI manual "MSX5, MSX10, MSX10R, and MSX18R Solar Panel Instruction Manual, Revision 3/92". At pits 2 and 3, two solar panels are connected to three batteries in both series and parallel (Figure

9.2) to provide a 12V and a 24Vdc output. The batteries are housed in weatherproof enclosures fitted with AMP 4-pin panel mounted connectors for rapid connections with the solar panels and other system components. The battery enclosures are connected to AMP 4-pin panel mounts on the multiplexing assemblies by 16AWG 3-wire cables which are terminated at each end by AMP 4-pin weatherproof connectors. The three wires consist of a +12Vdc, a +24Vdc, and a (-) bias lead. The (-) biases are not connected to earth ground but are common with the (-) bias of the datalogger power supply. The solar panel cases and masts are connected by 10AWG wire to 8' deep copper ground stakes adjacent to each supply. Each multiplexing assembly contains a power supply unit which provides a regulated 10V output for transducer excitation as well as 12V terminals to power multiplexers and 24V output for future use in water level monitoring of tensiometers and several (-) bias terminals for connection with pressure transducer (-) bias and multiplexer grounds.

The datalogger power supply performance was satisfactory, maintaining a voltage output greater than 12Vdc at all times (Figure 9.3). At pit 2, the 12Vdc and regulated 10Vdc supplies (Figure 9.4) functioned satisfactorily until Julian day 240 when its output became highly erratic, reaching maxima well beyond 15 volts, the expected maximum voltage output of the batteries and solar panels. The regulated 10Vdc also failed and became very erratic at this time. The nature and cause of this improper behavior has not yet been identified. The power supply at pit 3 performed satisfactorily until Julian day 250 when the battery output slipped below 12Vdc and the voltage regulator was no longer able to maintain a 10Vdc output (Figure 9.5). A preliminary investigation of this failure suggests that the voltage loss was due to the reorientation of a solar panel to make room for the rotating boom of a rain simulator. The panel was not reoriented following the event, causing the battery to drain and become sulfated.

9.2.1.4 Multiplexing Assemblies

The multiplexing assembly parts are listed in Table 9.5. The CSI AM-416 multiplexers are described in CSI manual "AM416 Relay Multiplexer Instruction Manual, Revision 3/92". CSI SDM-CD16 control port multiplexers are described in CSI manual "SDM-CD16 Control Port Expansion Module with Drivers Instruction Manual, revision 1/92."

Multiplexing assemblies are used to activate excitation voltages for pressure transducers and to measure arrays of pressure transducers and temperature probes. They contain components which give them the capability to be used in the future to activate excitation voltages for water level sensing in tensiometers, to scan arrays of tensiometers for the presence of internal water, to provide an indication in the field of water fullness for manual tensiometer maintenance, and to control automated water refilling of tensiometers. To make them part of a weatherproof modular field system, all connections to the assemblies are done with panel mounted AMP pin connectors (see Table 9.5). The temperature probes and the power supply are connected to 4-pin mounts. The pressure transducer harness is connected with 2 55-pin mounts, and the datalogger cable is connected with a 24-pin panel mount. The system layout is shown in Figure 6. Wire pinning assignments are listed in Tables 9.6 and 9.7.

The assembly at pit 2 performed satisfactorily from Julian date 188 until the present. Only the transducer excitation and transducer and temperature probe multiplexing capabilities were used at that time. No component failures occurred during this interval. Even though the power supply voltage to the pit 2 assembly became unregulated, the assembly continued to function correctly. Data from pit 3 is insufficient to evaluate the performance of the multiplexing assembly.

9.2.1.5 Temperature Measurement

Campbell Scientific 107B thermistor temperature probes are used for temperature measurements. They are terminated by environmentally sealed AMP 4-pin connectors (#206430-2) which attach to panel mounted pin connectors on the multiplexer enclosures. Instructions for use

9.2.1.2 Datalogger

A Campbell Scientific Inc. CR7 datalogger was used for measurement and control of the automation network. The features and functions of the CR7 are provided in the CR7 Operators Manual revision 7-2-93 (CSI, 1993). Datalogger components are listed in Table 9.2.

The CR7 datalogger wiring schedule is shown in Table 9.3.

For each measurement cycle, the datalogger program produces two output arrays to its final storage area (Table 9.4). These arrays are in the format required by the SWMS GUI for incorporation into the database. These arrays include either measured values or dummy space holders from pits 1..4. The measurements and dummy variables include year, Julian day, time (hours, minutes), datalogger and pit battery voltages, excitation voltages, water level indicators (dummy for now), tensiometer cluster temperatures, and pressure transducer output voltages (matric potential). The first array contains data from the CR7 and pits 1 and 2 while the second array contains data from pits 3 and 4. The program code was created using the program EDLOG, a component of the PC208 software package described in CSI manual " ". The program code for measuring field instrumentation is included in Appendix 11. The program code for laboratory testing of the pressure transducers and temperature probes is listed in Appendix 12. Wiring of the laboratory datalogger is shown in Table 9.15.

9.2.1.3 Telemetry

The telemetry system is used to transmit data collected in the field back to the SWMS GUI located in T891M on RFETS, where it is stored in a database for retrieval and analysis. The telemetry system is identical to that used for the Snowmelt and Soil Moisture Monitoring components of the SWMS, described in section 6.0.

Each transducer was assigned a unique identification number and tested in the laboratory to ascertain whether its output at 0 differential pressure deviated from one Vdc by more than the manufacturer specified 1% accuracy range of ±.05Vdc. Those which failed this test were culled and returned to the manufacturer for recalibration. The transducers were tested by connecting the excitation lead to a regulated 10Vdc power supply and measuring the output over several days with a CR7 datalogger at 10-minute intervals. A battery operated portable testing unit was also constructed for in-field troubleshooting (Figure 9-9). This box consisted of a 9-pin panel mount connector for attaching to the transducer lead, a 12Vdc battery, a output terminal, and a ground terminal for connection of a voltmeter. With this unit, transducers could be individually excited in the field and measured on the spot. Before the transducers were installed in the field, the entire field system was run in the lab for several days to identify problems and to obtain data for calculation of the zero-offsets of the pressure transducers (Figures 9-10...9-19). The offsets were calculated by averaging the transducer outputs over several days and subtracting this output from 1 volt, the ideal output (9.8). Figure 9-12 reflects the correction of a wiring mistake in the Pit 2 harness. The out-of-range value of ~8.5 volts falls into line with the rest of the transducer outputs at time ~89.6 after a day of testing. Diurnal fluctuations in the data from the calibration run are exaggerated in Figures 9-10, 9-11, 9-13, and 9-14 which are plotted at a much finer scale. These fluctuations are actually within the transducers' specified error of ±0.05 volts and imperceptible when the data is plotted using a y-axis whose scale is the transducer F.S.O. of five volts.

An initial examination of data collected from pit 2 indicates that the transducers were sufficiently robust to continue functioning following a degradation of the power supply on Julian day 240 (Figure 9-20). However, several of the transducer outputs fell below their specified minimum output of 1 volt. The source of these failures has not yet been identified. It may be due either to the failure of the transducer electronics or to a poor connection somewhere between the transducers and the data logger, either within or between one or more of the other system components. The data from pit 3 is insufficient to evaluate the performance of the pressure

down the length of the transducer signal cable to the pigtail. These leads are for future application in a water level sensing system for tensiometer maintenance. A bead of hot glue was placed around the junction where the signal cable entered the transducer case. A segment of 0.75" heat shrink tubing was shrunk over the case-to-cable glue-filled junction as a precaution against water leakage. Heat shrink tubing was then shrunk over the rest of the transducer lead, the attached leads, and the previously placed heat shrink tubing at the case junction. The pigtail was then pinned-out to 9-pin male AMP connector with a strain-relief which clamped to the transducer cable. A bead of hot glue was placed around the strain relief connector, then a segment of 0.75" shrink tubing was slid over the strain relief, the glue, and the adjacent heat shrink-coated transducer cable. This segment was then shrunk. After shrinking, a small amount of hot glue was injected into the open end portion which had not shrunk completely flush with the transducer lead and a section of 0.5" shrink tube was slid over the shrunken tube and the glue. This was then shrunk and secured with two plastic wire ties to make a waterproof seal between the cable and the end connector.

To provide a hermetic seal with the tensiometer, the process end of the transducer was fitted with a Delrin plastic male CPC quick connect fitting (#PMC24-02) which uses a buna o-ring and was joined to the transducer case with a brass female-female 1/8" NPT fitting (Figure 9-8). The CPC fitting attached to a complimentary female receiver permanently affixed to the tensiometer. These fittings were used to make the system modular and to simplify and speed field installation and maintenance. All connections were sealed with Loctite #425 Surface Curing Threadlocker. Originally, teflon tape was used as a thread-sealant. However, this practice was abandoned and all fittings resealed when it was found that the tape can occasionally cover the pressure sensor diaphragm.

The transducers were configured to be modular so that they could be applied in a variety of system configurations and so that they could easily be installed and replaced. They provide a one-Vdc output at 0 differential pressure, and 5 Vdc at -14.7 PSI. To convert the voltage output to kiloPascals (kPa) use the formula x kPa=-((V_{out}-1)*25.3384).

of 107B temperature probes and a description of their design is provided in CSI manual "Model 107B Temperature Probe Instruction Manual, revision 3/92".

Current system design calls for one temperature probe to monitor the air temperature at the surface of one tensiometer in each tensiometer cluster at each trench. To date, temperature is being measured at clusters 2 and 4 of pit 2 and cluster 1..5 of pit 3. Zeros are being entered into the database in place of real data for cluster 1,3, and 5 of pit 2. Temperature is measured for each measurement cycle to accompany matric potential data. Temperature data is used for post-processing of matric potential data to remove diurnal temperature effects.

Temperatures were collected from pit 2 without difficulty. Data is shown in Figure 9-7. Due to an as yet unidentified flaw in the pit 3 monitoring system, values of approximately -53°C were obtained from all probes.

9.2.1.6 Pressure measurement

Pressure transducers are used to measure the differential internal pressure of tensiometers, relative to ambient atmospheric pressure. The pressure, usually less than atmospheric pressure, is a function of the matric potential of the soil and other environmental parameters.

Pressure is measured with Ashcroft Model K1 (part #ASH-K1-G-100-3-MO1-15-F2-VAC0) internally regulated and amplified 1-5 VDC output pressure transducers with a 0 to -14.7 PSI measurement range. Their design, specifications, and application instructions are described in Dresser Industries Instrument Division Bulletin PT-1: Model K1 Thin Film Pressure Transmitter. The transducer leads are terminated with 9 pin weather proof connectors (AMP #206704-2) using AMP #66105 pins, 0.5" o-rings and AMP #206704-2 strain reliefs. Pinning is shown in Table 9.11-1

The transducers were weatherproofed prior to field installation. A 22AWG ground lead was connected to the transducer case with a ring terminal connector around one of the case screws and run down the length of the cable to the pigtail. Two additional 22AWG leads were also run

transducers. During an upcoming system overhaul, all transducers shall returned to the laboratory for recalibration.

Earlier applications of the pressure transducers had several failings. Their connection via a single D-connector for each cluster to the main wiring harness was cumbersome and often suffered from poor connections (Figure 9-21). At first, the transducer cases were not grounded because the manufacturer instructions did not suggest that case grounding was necessary. An inquiry to the factory revealed that case grounding was desirable for proper operation and optimal signal quality.

9.2.1.7 System connections

The datalogger-to-multiplexing assembly connections and the multiplexing assembly-to-pressure transducer connections are made with modular wiring harnesses. The harnesses are designed to be weatherproof and to be easily and rapidly installed and replaced. See Table 9.9 for a list of the system connection parts.

The datalogger-to-multiplexing assembly cables consist of 24-strand 22AWG twisted-pair shielded cable run through 0.5" steel reinforced UV-proof conduit and terminated with AMP 24-pin connectors. The wiring schedules for each cable are shown in Table 9.10.

The multiplexing assembly-to-pressure transducer harnesses consist of 104-strand 22AWG twisted-pair shielded cable run through reinforced steel UV-proof flexible conduit (Figure 24). Breakouts to each of 5 transducer clusters leave the main harness through shielded metal junction boxes attached to the conduit with watertight compression fittings. Wiring schedules for each harness are shown in tables 12, 13. Five to seven 6" long leads which are terminated by 9-pin AMP connectors come from each breakout. The leads are bundled in shrink tubing sealed with hot glue where they leave the breakout boxes. The hole by which the leave the breakout box is lined by a rubber grommet to which they are sealed with hot glue. A pressure transducer can be plugged into each of these leads. The harnesses are each terminated by two 55-pin AMP connectors for attachment to panel mounts on the multiplexing assemblies. The segment between the end of the

conduit and the 55-pin connector strain reliefs is sealed with a combination of hot glue and shrink tubing to prevent entry of moisture into the system.

Earlier wiring harness designs had a number of failings. The conduit used was not UV resistant and thus became brittle and broke apart after one or two years in the field. The end connections for the datalogger-multiplexer cables were hard-wired into those units, making installation, repair, and replacement cumbersome and time consuming. A later modification which terminated the harness with D-connectors (Figure 25) also suffered from poor electrical connections. The transducer harness at pit 2 was housed in a split conduit sealed with a latex coating (Figure 26). The harness was not weatherproof. The pressure transducers from each cluster were connected to a D-connector at each breakout point along the harness (Figure 21). The connectors were difficult to connect and disconnect, were difficult to weatherproof, and the pins were constantly pulling out, causing bad connections. An improvement in weatherproofing wherein the main harness cable passed through the junction boxes (Figure 27, 28) was an improvement but did not solve the main problem of poor electrical connection in the D-connectors. This problem was solved by using the new AMP connectors. The transducer harness was originally hard wired into the multiplexer assembly, making installation, maintenance and replacement time consuming and difficult. Replacement with D-connectors was not satisfactory.

9.2.2 Tensiometers

9.2.2.1 Original design

The first tensiometers to be installed in the field were manufactured by Soil Measurement Systems (Figure 9-22a). Their design, installation and performance are discussed in the 1993 Scientific Notebook. Their locations are listed in Table 9.13.

9.2.2.2 Design Modification 1

The first design modification made use of the existing field tensiometers. They were sawn down so that only 6" extended above the ground surface. Sawing was accomplished with a hand-held jigsaw. During sawing, the tensiometer shaft was immobilized with a custom fabricated jig (Figure 9-29) to prevent vibration of the tensiometer shaft and possible breakage of the tensiometer cup. Once the shafts were cut down, pressure transducers could be attached with a removable fitting which screwed onto the transducer and plugged into the tensiometer shaft (Figure 9-22b, 9-23). These fittings were machined by Fiero Fluid Power from PVC and contained 2 o-rings which were coated with a silicone lubricant prior to installation. They did not provide an airtight seal in many instances. The o-rings deteriorated rapidly and failed to provide an adequate seal.

9.2.2.3 Design Modification 2

This modification also used the existing tensiometers in the field, sawn down so that only 6" extended above the ground surface. To these were attached fittings shown in Figure 8. The Delrin plastic fitting bodies were custom manufactured by Fiero Fluid Power. The fittings were affixed to the tensiometer shafts with Loctite cyanoacrilate gel for an airtight seal.

The intent of this design was to provide a rapid solution for monitoring of matric potential during rain simulations in the 1994 field season. Concurrent with their application, a more advanced design, described in section 2.2.4, was being tested. The two steel tubes which penetrate the top of the fitting are used for water refilling. To refill the tensiometer, the airtight caps are removed from both tubes. The caps are constructed from short segments of vinyl tubing which have been plugged with hot glue and which are sealed to the steel tubes with silicone vacuum grease. Water is forced into the larger tube with a hand-held 1-liter squirt bottle until all the air is flushed from the tensiometer and water streams continuously out of the smaller tube. To ensure complete flushing of the tensiometer, a plastic tube extends from the bottom of the steel tube

to the bottom of the tensiometer. This tube extension will also facilitate replacement of the tensiometer water with antifreeze solutions to protect the tensiometers during cold periods.

Pressure transducers are connected to the fittings with leakproof quick-connect fittings for rapid field installation, to make the system modular, and to permit simple, non-destructive exchange of malfunctioning pressure transducers for servicing.

The fitting design (Figure 9-8) was tested for leakage prior to field installation. The fitting prototype was connected to a vacuum tank whose internal pressure was monitored with a pressure transducer connected to a datalogger. The tank was pumped down with a vacuum pump ported directly to the tank. Measurements were taken at one minute intervals. First, the tank system integrity was tested by pumping down the tank with only the pump and pressure transducer ported to the tank (Figure 9-30, run 1). Pressure drained quickly because the pump leaked. A solenoid valve was then connected between the tank and the pump. This valve only remained open during pumping. Measurements taken over a 1300 minute span showed that the revised apparatus was leakproof. The fitting was attached to a port in the tank for run 3. A decline in vacuum pressure indicated leakage through the fitting. For run 4, silicone lubricant was applied to the o-rings in the CPC quick-connect fitting. The measured vacuum increased during approximately the first 500 minutes, possibly due to a temperature decrease in the system. Vacuum pressure then began an abrupt drop at about minute 1100, stabilizing at about minute 1300. The behavior of the fitting was comparable to that of the sealed system. This suggested that the fitting, when lubricated with a silicon vacuum-grade lubricant, would not leak significantly in the field. The fitting remained stable and held vacuum for a period longer than the interval between field maintenance of the tensiometers. During field maintenance the vacuum would be released and fittings re-lubricated. The minor leakage which did occur was at vacuum pressures (>500kPa) higher than those expected in the field during periods of water flow in the vadose zone.

Examples of raw data collected during the 1994 field season are shown in Figures 9- 31 and 9-32. The data from Pit 2 tensiometer clusters 3 and 4 illustrate the behavior of the tensiometers over time.

Figure 9-34 shows the pressure transducer output from tensiometer 02TN34 from Julian day 188 (JD188) until JD340 of 1994. The data are consistent with proper behavior of the tensiometer. Increasing values indicate drying while downward spikes (also marked by arrows) followed by new drying trends indicate precipitation events. Diurnal fluctuations were probably caused by temperature variations. Figure 9-33 compares the behavior of tensiometer 02TN43 and 02TN45. Tensiometer 02TN45 shows behavior comparable to 02TN43 until approximately JD218 when a leak developed. The leak caused the gradual reduction in transducer voltage output (vacuum) followed by an abrupt drop to 1 volt (0 vacuum) on ~JD222. The drop in output of 02tn43 on ~JD243 to 1 volt represents the draining of all field tensiometers in anticipation of winter freezing temperatures. Decreases in transducer outputs below 1 volt or to 0 volts indicates either failure of the pressure transducers or damage to or deterioration of the datalogging system. These failures have not been identified as yet. The data gap on ~JD237 was caused by field maintenance of the power supply at pit 2.

9.2.2.4 New Tensiometer Design

Parts for the new tensiometer design are shown in Figure 9-36.

Tensiometer designs used so far have the common problem of being vulnerable to diurnal fluctuations in their vacuum pressure. While this problem is not evident when tensiometers are measured once daily or less frequently, automated monitoring at intervals of one hour or less reveals diurnal fluctuations which can mask real changes in matric potential (for example Figure 9-34). Tensiometer vacuum usually increases at night and decreases during the day, superficially indicating that matric potential is higher at night than during the day. A multivariate analysis of variance in the pressure data which takes into account parameters such as time of day, air

the valve manifold and the tensiometer. Attempts to seal these leaks met with success but it was concluded that the integrity of the design could not be assured, especially not in the field.

Different flow paths were tested using the first iteration designs to optimize refilling time and completeness. Under the first path design, the input valves and output valves were connected in two parallel circuits (Figure 9-38a). The valves were activated with a SDM-CD16 multiplexer with instructions from a datalogger. To economize the number of terminals used on the multiplexer, all the valves were opened simultaneously and a vacuum applied to the output side to draw water through the tensiometers from a supply tank. This configuration did not work because the resistance to flow of the different tensiometers could not be equalized. Water would only flush through a few of the tensiometers with the least flow resistance while the rest would not completely flush. The flow paths were then rearranged so that the tensiometers were in a series circuit (Figure 9- 38b). The output of one tensiometer was connected to the input of the next. Again, a vacuum was used to pull water through the system. In this case, the flow resistance was so great that refilling took too long and the vacuum necessary was too high. It was felt that a high vacuum might overly strain the airtight seals in the system. At this point testing was halted while a new valve configuration was investigated.

The second valve configuration prototype was used in conjunction with the fittings described in section 2.2.3.2. Twelve tensiometers with these fittings were installed in a sandbox in the laboratory. This setup is described in more detail in section 2.4.3.3. The valves were arranged in 3 clusters of 8 each adjacent to each of 3 clusters of 4 tensiometers each (Figure 9-39,40). The input valves were connected to steel tubes on the fittings with 3/16" i.d. #6406-66 teflon tubing supplied by Cole-Parmer (Figure 9- 41a). The exhaust valves were connected to steel tubes on the fittings with 1/16" i.d. #6406-62 teflon tubing supplied by Cole-Parmer. Connections to the steel tubes were sealed with surface insensitive gel instant adhesive Loctite #454. Connections to the valves were made with modified single-barb plastic fittings of appropriate size made by Value Plastics, Ft. Collins, CO. To ease attachment of the tubing to the fittings, the tube

9.2.3 Water Refilling System

Automated water refilling of tensiometers is desirable to save labor time in the field, to assure that the tensiometers are always full of water and free of air, and consequently to eliminate the water level variable in calculation of matric potential from tensiometer vacuum data. Manual water refilling also compromised the reliability of the tensiometer because ease of access to the tensiometer shaft for refilling also provided a potential source of vacuum leakage. Manual water refilling entailed some unwanted but unavoidable of the tensiometer shaft which could possibly damage the tensiometer ceramic cup or break the contact between the soil and the cup, and also create a void between the tensiometer shaft and the soil, providing a preferential flow path downward.

The basic concept of an automated water refilling system that lies behind all subsequent design iterations is the use of solenoid valves to control the flow of water through the tensiometer and to provide a leakproof seal between the interior of the tensiometer and the atmosphere between refillings. The first configuration made use of existing field tensiometers which were modified to accept solenoid valves for water refilling. The valves used in all of the refilling system configurations are microminiature 7000-series Skinner valves made by Honeywell #BBT3J1C1-12V. The are rated bubble-proof at 90 PSI, well beyond the maximum possible differential pressure of 15 PSI.

In the first iteration, a two valve manifold was attached to the top of the tensiometer (Figure 9-35a). A tube ran from the port of the input valve to the bottom of the tensiometer shaft to ensure complete circulation of the refilling fluid. Complete recirculation would help to flush any air bubbles from the system. When antifreeze would be used during freezing weather, one could be reasonably certain that a known concentration of antifreeze was entirely replacing the water and the concentration could be subsequently controlled. Several prototypes of this design were constructed and tested in the laboratory. They tended to leak around the attachment point between

temperature, soil temperature, water table level, and excitation voltage, shows that vacuum pressure fluctuations are largely dependent on air temperature. That is, variance in the transducer output was mostly correlable to variance in air temperature.

Changing water vapor pressure in the air pocket at the top of the tensiometer shaft is the probable mechanism for the apparent fluctuations in matric potential. Higher daytime temperatures increase the vapor pressure inside the tensiometer. The vapor pressure increase reduces the vacuum pressure inside the tensiometer, causing an apparent decrease in matric potential. The opposite mechanism works at night, resulting in higher apparent matric potential readings. These problems can be eliminated by shielding the tensiometer from diurnal temperature fluctuations and by reducing or eliminating the air pocket inside the tensiometer.

To shield the tensiometers from air temperature variations, research has been conducted toward developing a tensiometer which is fully buried underground where it is shielded from atmospheric temperature fluctuations.

The first design of an underground tensiometer is shown in Figures 9-35 and 9-38.

Sufficient data is not yet available to evaluate the performance of the new underground tensiometer design.

ends were first heated and then slipped over the barbs. No sealant was necessary. During testing the gel adhesive was determined to form an inadequate seal. Visual inspection revealed air leakage in some cases. However, this arrangement was retained while development of a control system for the solenoid valves was investigated. Water was pumped through a single line of 3/16" i.d. teflon tubing to a pair of manifolds which split the line out to each of the input valves. The water was pumped with an in-line #E80125 12 volt automotive pump manufactured by Master Parts. Exhaust water flowed back through another pair of splitter manifolds and into the water supply tank.

Several attempts were made to develop a valve control system which made economic use of the ports on the SDM-CD16 and which could turn on each tensiometer valve-pair individually. This would solve the preferential flow-path problem encountered earlier by only refilling one tensiometer at a time (Figure 9- 38c). Four switches on the SDM-CD16 were used in conjunction with a bank of relays arranged as a truth table. This arrangement did not work because voltage would bleed through other coils, turning on other valves. To fix this problem, each pair of solenoids were wired in parallel. The (+) biases were connected to a constant 12V supply while the (-) biases were connected to 12 ports of the SDM-CD16, one for each tensiometer. An additional port was used to control the in-line pump. This concession tripled the number of ports necessary to control the tensiometer array. However, the water sequential openings and closings of each valve-pair could now be done to accomplish complete refilling of each tensiometer. At this point, flow rate was deemed to be insufficient to refill the tensiometers in a timely manner. Investigation revealed that the barb fittings on the valves screwed too far into the 1/8" NPT port on the valves, inhibiting flow. Shortening the thread length on the fittings solved this problem.

Observation of water flow through the clear teflon tubing during refilling revealed the presence of air bubbles in the lines which were not being flushed during refilling. It was also hypothesized that air might be getting trapped in the CPC quick-connect fittings attached to the tensiometer automation fitting. To eliminate these problems, the fittings and placement of the valves were changed (Figure 9- 41b). The pressure transducers were screwed directly into the

1/8" NPT port in the fittings where CPC fittings were attached. Before installation, water was injected with a squirt bottle into the void in the process connection of the transducer. Capillary pressure kept the water in place to prevent formation of an air cavity in the transducer. The exhaust solenoid valve was attached directly to the top of the fitting with a 1/8" brass nipple. This vertical flow path was intended to encourage movement of bubbles up and out of the system. The input valve was attached by a 1/8" brass nipple to a 1/8" NPT port machined into the fitting directly opposite the port used for the pressure transducer. All NPT connections were sealed with Loctite #425 surface curing thread locker. A 3/16" i.d. teflon tube sealed to the nipple with silicone caulk ran from this port to the bottom of the tensiometer to ensure complete water recirculation.

When the above design was tested, vacuum leakage was tested in several of the tensiometers. Disassembly of one unit revealed two possible leakage paths, through the sheathing in the water level detection wires (Figure 9- 41) and through gaps in the cyanoacrylate gel which was used to affix the automation fitting to the tensiometer shaft. The system is currently undergoing modification to eliminate these leaks (Figure 9- 41c). All process connections shall be accomplished with NPT threads sealed with Loctite pipe thread sealant. The automation fitting shall be replaced with a 4-way 1/8" NPT female brass fitting. The pressure transducer screws directly in to the fitting while the solenoid valves attach with 1/8" male nipples and the fitting attaches to the tensiometer with a 1/8" to 1/2" NPT male-to-male adapter. The tensiometer shaft is drilled out slightly and tapped to accommodate the adapter. The water level sensing wires (Figure 9- 41b) shall be pulled out and replaced with solid pins pressed into the existing holes and soldered to sensing wires (Figure 9- 41c). A prototype of this latest configuration shall be tested for leakage using a vacuum tank prior to implementation in the sandbox experiment.

All fluid shall be deareated prior to use and stored in zero headspace containers. Deareation should eliminate degassing under vacuum and help prevent formation of bubbles in the system.

9.2.4 Antifreeze Calibration

9.2.4.1 Introduction

Year-round data from tensiometers must be available in a system which monitors and provides warnings of contaminant migration in the vadose zone. Matric potential data are necessary to examine snow-melt events during the winter and spring. Water from melting snow may be an important mechanism for the transport of contaminants from the ground surface down into the soil. Tensiometers must be modified for cold-weather use. The pure-water which normally fills tensiometers must be replaced with a dilute antifreeze solution to prevent freezing down to at least -30°C. Freezing can fracture the tensiometer's ceramic cup and destroy the pressure transducer.

Tests must be performed to assess the affects of various antifreeze solutions on data quality. Solutions of methanol (Wendt, et al., 1978) and propylene glycol (McKim, et al., 1976; Ingersoll, 1981) have been documented as suitable antifreeze solutions in tensiometers. However, they do not provide data to support these claims. The chemical difference between a tensiometer antifreeze solution and soil solutions may well compromise the tensiometer data (Kane, 1975). Calibration curves shall be generated in the SSG's RFP facility which will be used to asses the suitability of various antifreeze solutions.

9.2.4.2 Background

Solutions of methanol (Wendt, et al., 1978) and propylene glycol (McKim, et al., 1976; Ingersoll, 1981) have been documented as suitable antifreeze solutions in tensiometers. A 50% solution of methanol prevents freezing down to -42°C and 25% methanol protects down to -16°C. Wendt (1978) shows that tensiometer data from 30% methanol solution tensiometers parallels pure-water measurements with a slight 10-30mbar (1-3kPa) offset toward lower matric potential. The methanol was not observed to affect the vitality of adjacent foliage.

Ethylene or propylene glycol is reported to be an acceptable antifreeze with little data degradation (McKim, et al., 1976; Ingersoll, 1981). The literature does not provide comparative data between pure water and propylene glycol systems, however. Ingersoll (1981) states that "the effect of

glycol in the soil is not entirely known." McKim (1976) justifies the use of propylene glycol in the soil by demonstrating that the compressibility of water and glycol are the same. He assumes that there is "essentially no mass flow into the soil from the porous ceramic cup", acknowledging that if flow did occur, "the results are difficult to interpret." The need for the periodic refilling of tensiometers in this study negates his assumption and suggests that experimentation is necessary for the interpretation of data from glycol systems.

The chemistry of the water in the tensiometer is assumed to be the same as the soil solution phase in theoretical treatments of matric potential data. In the differential thermodynamic equilibrium equation describing the components of soil-water potential

$$dG = -SdT + VdP + m_w dn_w + S_i m_i dn_i$$

where G = Gibbs free energy
S = entropy
T = temperature
V = volume
P = pressure
m = chemical potential
n = amount (moles or grams)
w = water
i = other chemical species

m_w is the water potential or partial specific free energy ¶G/¶n_w for soil water and the last component on the right side shows the contribution of solutes to the energy state. The differential equation relating m_w to the common variables of interest is

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substitution into equation [ ] and integrating from selected standard conditions (designated by superscript o)[1] results in

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where the negative of the left side of the equation is the soil-water potential. The terms on the right side of equation [ ] are, in order, the temperature, pneumatic, matric, and solute components. If the specific molar volume is assumed constant (Nielson, et al., 1972, p.72) then the pressure term in equation [ ] integrates to become $v_w(P-P^o)$ where $(P-P^o)$ is the gauge pressure as measured by a tensiometer. At equilibria, the energy status of the soil solution phase, which consists of a matric, gravity, and solute potential is assumed to be equal to the energy status of the tensiometer water which

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[1] Standard conditions are defined as T^o=298°K, P^o=atmospheric pressure, n^o_w=water content at saturation, and n^o_i=0 (zero soluble salts).

consists of a pneumatic, gravity, and solute potential. If the solute potentials are assumed equal within and without the tensiometer then

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However, this assumption may be invalid for a fluid with a radically different composition such as antifreeze and the equation becomes

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where $n_i^o = 0$ (zero soluble salts in the tensiometer water) and $n_j^o = 0$ (zero soluble salts in the soil solution phase). When the tensiometer is filled with antifreeze solution the solute component has a constant value while the initial value of the soil-water component (due to antifreeze contamination) is zero. Over time the tensiometer solute component will remain constant due to daily tensiometer-system flushing while the soil-water component may gradually increase. If the soil-water component is small then the equation may be solved by determining values for the partial molar entropy and concentration of the antifreeze in the tensiometer solution or by experimentally determining the offset caused by this additional term.

9.2.4.3 Methods

Preliminary tests have been conducted to evaluate the effects of methanol and glycol on matric potential data. Data was generated in a simple test with daily tension measurements. Two simultaneous test runs were conducted in two 5-gallon buckets containing homogeneous soil. A total

of three tensiometers containing pure water, 50% propylene glycol solution, and 50% methanol solution were placed in each bucket. One liter of water was then poured onto the soil in each bucket. Matric potentials were then monitored with a portable datalogger and pressure transducer periodically over a 20 day span. Initial findings indicated that the antifreeze introduced offsets in data magnitudes and, in the case of propylene glycol, may have reduced tensiometer response to changing matric potential.

Further, more detailed tests under controlled conditions are necessary to assess the characteristics of antifreeze tensiometers systems and to provide calibration curves. Groups of tensiometers with different solutions and tensiometers containing pure water will be monitored simultaneously in the bench test apparatus to develop calibration curves. Trials will be performed for wetting and drying cycles. The degree of infiltration of antifreeze into the soil and its effect on frozen soil may be assessed and perhaps modelled.

9.2.4.4 Parts

The antifreeze calibration experiment makes use of 12 automated tensiometers installed in a sandbox. The sandbox (Figure 9- 39, 40) consists of an inner container with walls of 0.5" Plexiglas and a floor of fine steel mesh. It measures 120.3 cm long by 30.7 cm wide by 47.0 cm deep. It is filled with a 4 cm deep layer of 16 grit silica sand covered by homogeneous 30 grit washed silica sand to the top of the container. The sand was poured in to the box along the longitudinal center line of the box. The sand was poured in gradually, maintaining an even depth distribution throughout the box. This filling procedure was intended to reduce lateral packing heterogeneities. Minor differential packing is still evident in fine, horizontal, cross-stratified layering visible through the side of the box. This layering seems to affect the way the sand absorbs water, with more and less saturated layers evident near the top of the capillary fringe. To prevent this heterogeneity form corrupting the tensiometer, the heterogeneous upper end of the capillary fringe is being kept several centimeters above the tensiometer cups. Initial testing of the

setup with water in all tensiometers should reveal any significant lateral variations in matric potential within the box. The open top of the inner box was covered with a non-airtight sheet of plastic to prevent spillage of fluids onto the sand.

Twelve tensiometers and six CSI 107B temperature probes were installed in the sandbox before filling with sand. The were positioned using three levels of steel lattice to ensure precise 3-dimensional positioning and to prevent shifting during water refilling. Instrument locations are shown in 9.14. The air temperature at each of the 3 4-tensiometer clusters is measured with a CSI 107B temperature probe. The tensiometers are equipped with automated pressure measurement and water refilling apparatii discussed in section 2.4.2. The pressure transducers are connected to a field pressure transducer wiring harness connected to a field multiplexing assembly identical to that used at pit 2, and controlled by a CR7 datalogger. The ultrasonic proximity sensor excitation and outputs are wired in place of the cluster 5/transducer 4 and 5 outputs on MUX1 of the multiplexing assembly. Datalogger code is listed in Appendix 11. Datalogger wiring is shown in 9.15.

The inner container rests on 5 evenly spaced 1x1" timbers inside of a Plexiglas outer tank whose inner dimensions measure 135.0 cm long by 46.0 cm wide by 30.5 cm deep. Water placed in the outer tank will flow through the base of the inner tank into the sand. The degree of saturation around the tensiometer cups in the inner tank can be controlled by varying the water level in the outer tank. To measure water level in the outer tank, an ultrasonic proximity sensor is positioned vertically above a 2 liter flask which is ported to the base of the outer tank. The flask is used to eliminate edge effects on the ultrasonic measurement which would occur if the sensor were to read directly off the water level in the tank.

9.2.4.5 Experimental plan

Matric potential readings from tensiometers containing various antifreeze solutions shall be compared with readings from tensiometers filled with pure water to generate empirical calibration

curves for antifreeze filled tensiometers. Initially, baseline data shall be collected from each of the tensiometers while they are filled with pure water. These data shall be used to ensure that all the tensiometers are functioning properly and to identify any offsets that may exist between the tensiometers. Such offsets may be due to irregularities in the construction of the tensiometers or to lateral heterogeneities in the matric potential of the sand. If the offsets are consistent over time, they can be extracted from the data collected during subsequent antifreeze experiments.

Experiments shall be conducted to evaluate and quantify the behavior of methanol and propylene glycol in solutions with concentrations varying from 40% to 60%. Concentrations are determined using hygrometers to measure specific gravity. Specific gravity measurements for various concentrations of the antifreeze solutions are contained in standardized tables. Each concentration of each solution shall be tested in a separate run. In each 4-tensiometer cluster, pure water will be placed in tensiometer numbers 1 and 3 of each cluster while the antifreeze solution shall be placed in tensiometer numbers 2 and 4. Over a span of two days, matric potentials, air temperatures, sand temperatures, water level, and excitation voltages shall be measured at 10-minute intervals. Water level shall be varied during this time and the tensiometers shall be refilled with a frequency sufficient to keep them flushed with air. If four concentrations of antifreeze are tested for each solution type, the experiments should produce a total of eight sets data, each consisting of approximately 25 individual series. The series can be used to establish whether the correlation between matric potential and other environmental parameters is affected by solution type or concentration and to quantify the effect of antifreeze solution concentration on measured matric potential.

9.2.4.6 Results

The antifreeze calibration experiment is currently in the setup stage, undergoing debugging to eliminate vacuum leaks in the tensiometers. Antifreeze calibration data has not yet been collected.

9.3 DATA

9.3.1 Transducer calibrations

Calibration data collected in the lab for pressure transducers used at pit 2 are contained in file {drive}:\snbk94\appendix\data\lab\ptcal\hrnstst1.dat. Calibration data collected in the field for pressure transducers used at pit 2 are contained in file {drive}:\snbk94\appendix\data\field\pit2\tr2bsln.dat. The lab data is shown graphically in Figures 10...19.

9.3.2 Temperature Data

Temperature data collected at pit 2 are contained in {drive}:\snbk94\appendix\data\field\pit2\pit2temp.xls and shown graphically in Figure 9-7. Temperature data collected at pit 3 are contained in {drive}:\snbk94\appendix\data\field\pit3\pit3temp.xls

9.3.3 Voltage Data

The CR7 datalogger power supply voltage data are contained in {drive}:\snbk94\appendix\data\field\CR7_volt.xls.

Voltage data collected at pit 2 are contained in {drive}:\snbk94\appendix\data\field\pit2\pit2volt.xls. Voltage data collected at pit 3 are contained in {drive}:\snbk94\appendix\data\field\pit3\pit3volt.xls.

9.3.4 Pressure (matric potential) Data

Raw pressure transducer measurements from pit 2 are contained in {drive}:\snbk94\appendix\data\field\pit2\pit2mat1.xls, pit2mat2.xls, pit2mat3.xls, pit2mat4.xls,

and pit2mat5.xls. Raw pressure transducer measurements from pit 3 are contained in {drive}:\snbk94\appendix\data\field\pit3\pit3mat1.xls, pit3mat2.xls, pit3mat3.xls, pit3mat4.xls, and pit3mat5.xls. Data from pit 3 are invalid due to an as yet unidentified flaw in the wiring of the pit 3 component of the tensiometer monitoring system. Data generated during leaktesting of tensiometer fittings discussed in section 2.2.3 are contained in {drive}:\snbk94\appendix\data\leaktst\leaktst.xls.

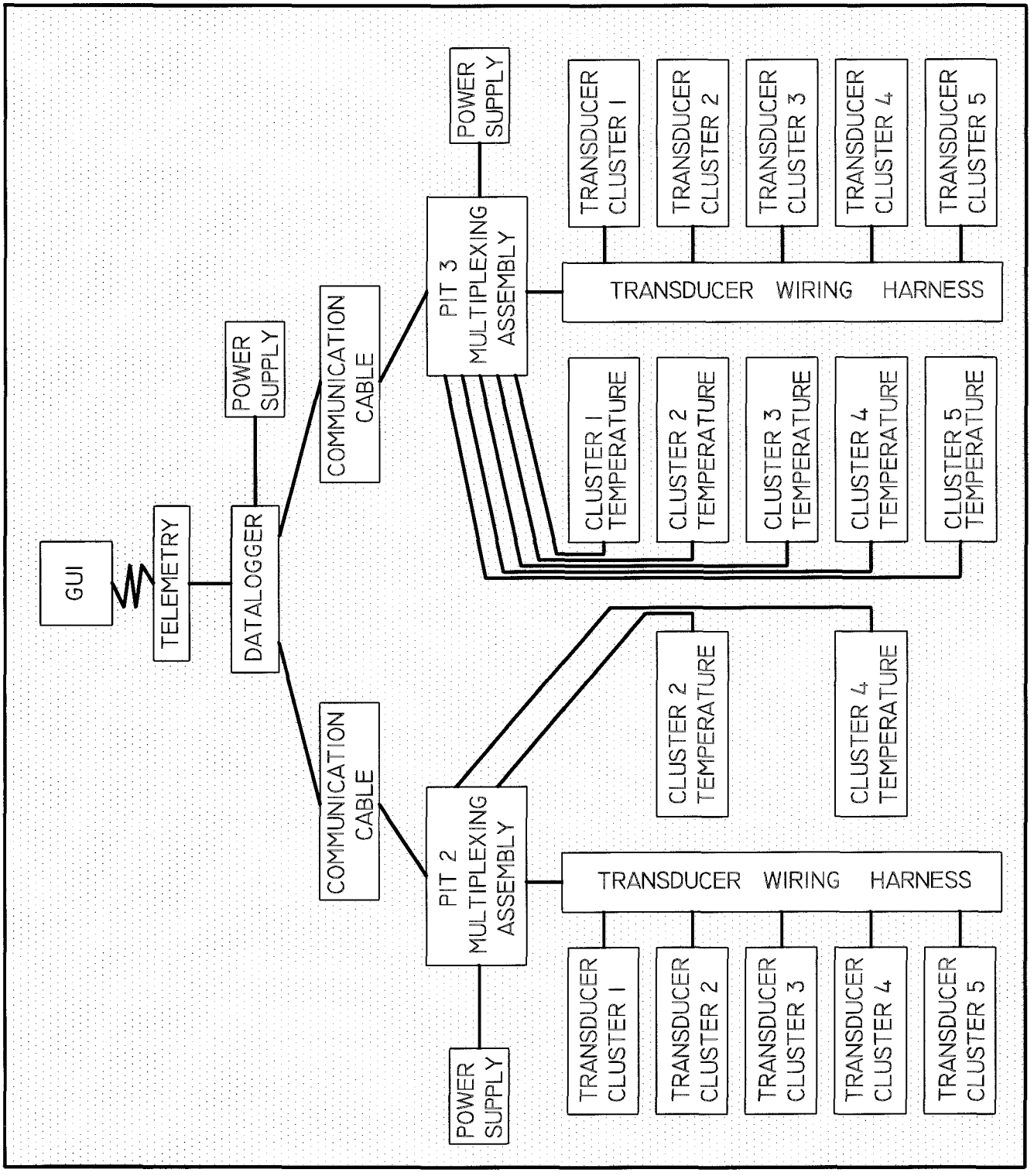
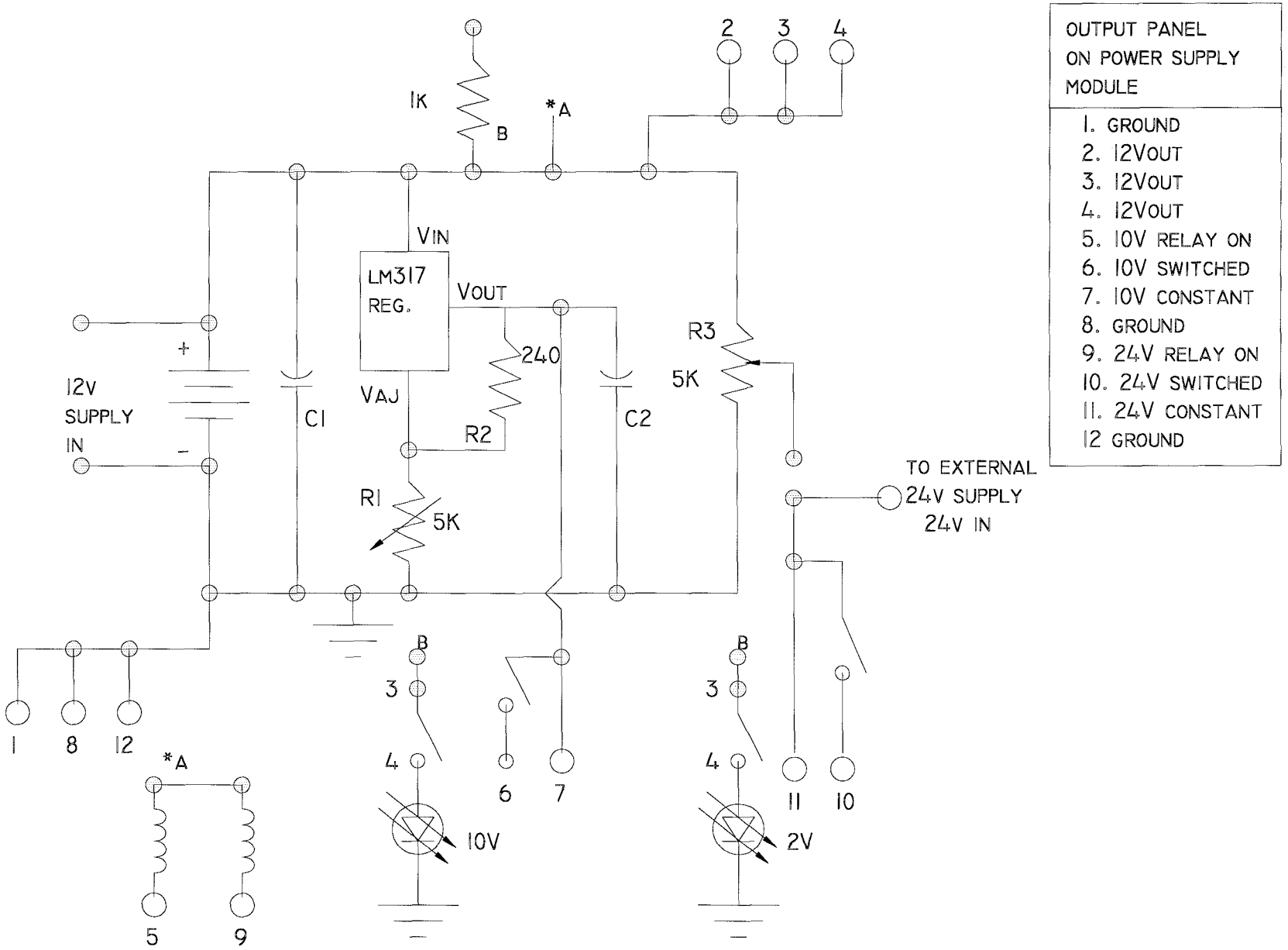

GUI
TELEMETRY
DATALOGGER
POWER SUPPLY
COMMUNICATION CABLE
COMMUNICATION CABLE
PIT 3 MULTIPLEXING ASSEMBLY
PIT 2 MULTIPLEXING ASSEMBLY
POWER SUPPLY
POWER SUPPLY
TRANSDUCER CLUSTER 1
TRANSDUCER CLUSTER 2
TRANSDUCER CLUSTER 3
TRANSDUCER CLUSTER 4
TRANSDUCER CLUSTER 5
TRANSDUCER WIRING HARNESS
CLUSTER 1 TEMPERATURE
CLUSTER 2 TEMPERATURE
CLUSTER 3 TEMPERATURE
CLUSTER 4 TEMPERATURE
CLUSTER 5 TEMPERATURE
CLUSTER 2 TEMPERATURE
CLUSTER 4 TEMPERATURE
TRANSDUCER WIRING HARNESS
TRANSDUCER CLUSTER 1
TRANSDUCER CLUSTER 2
TRANSDUCER CLUSTER 3
TRANSDUCER CLUSTER 4
TRANSDUCER CLUSTER 5

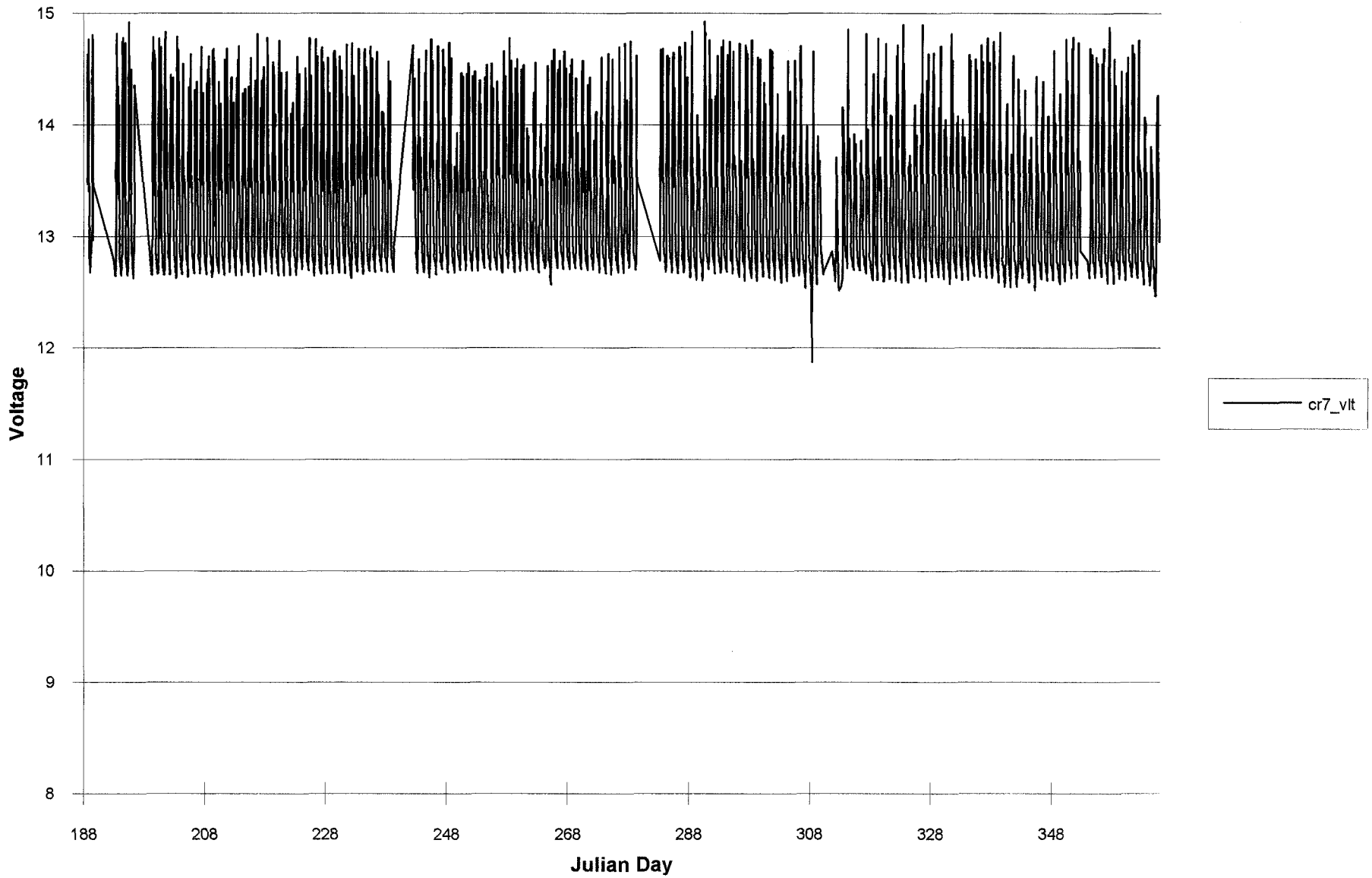
FIG 9.1



OUTPUT PANEL ON POWER SUPPLY MODULE
1. GROUND
2. 12VOUT
3. 12VOUT
4. 12VOUT
5. 10V RELAY ON
6. 10V SWITCHED
7. 10V CONSTANT
8. GROUND
9. 24V RELAY ON
10. 24V SWITCHED
11. 24V CONSTANT
12 GROUND

FIG 9.2

CR7 - Voltage



Date Range: 07/07/94 - 12/31/94

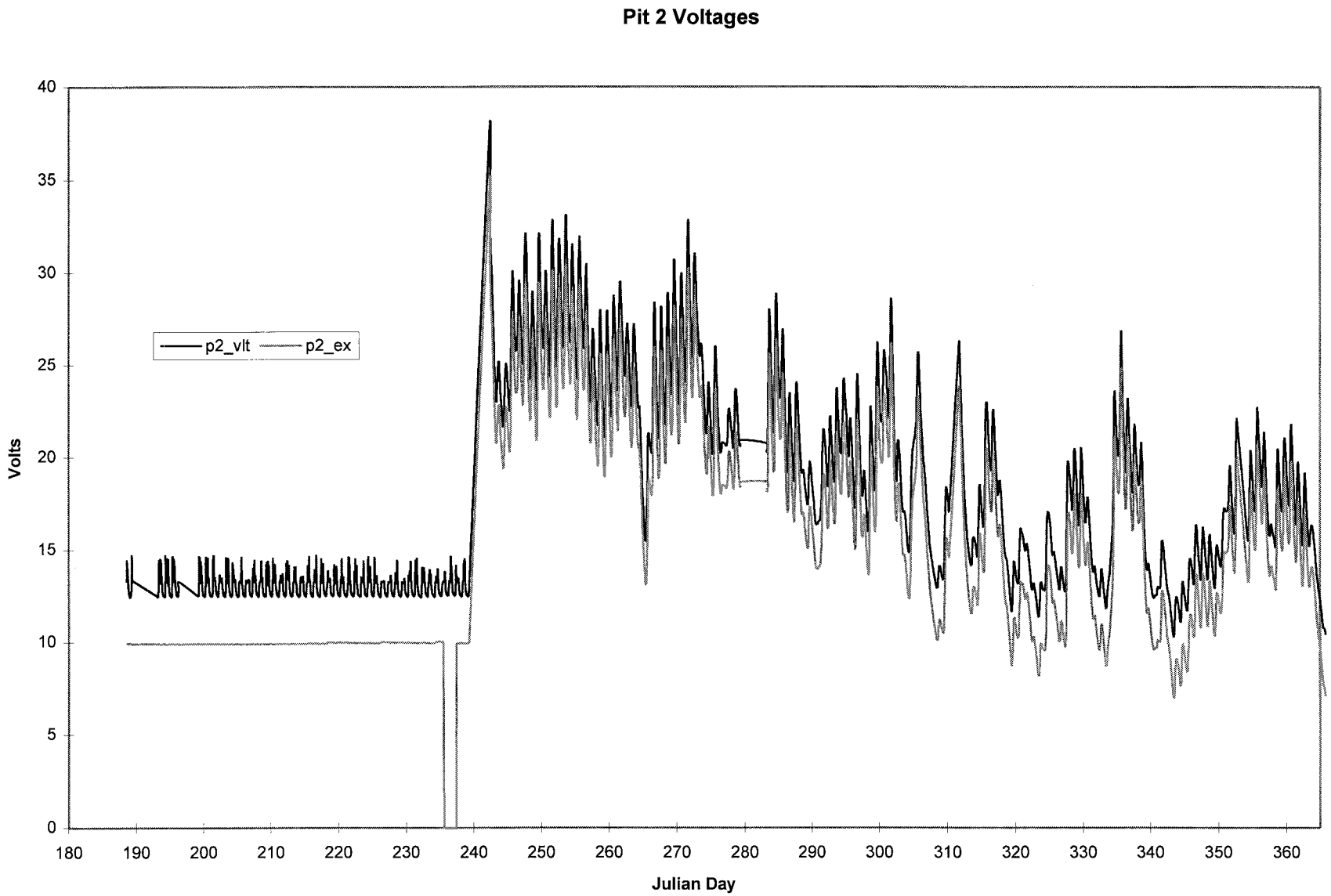

Pit 2 Voltages
p2_vlt
p2_ex
Volts
Julian Day
0
5
10
15
20
25
30
35
40
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360

FIG 9.4

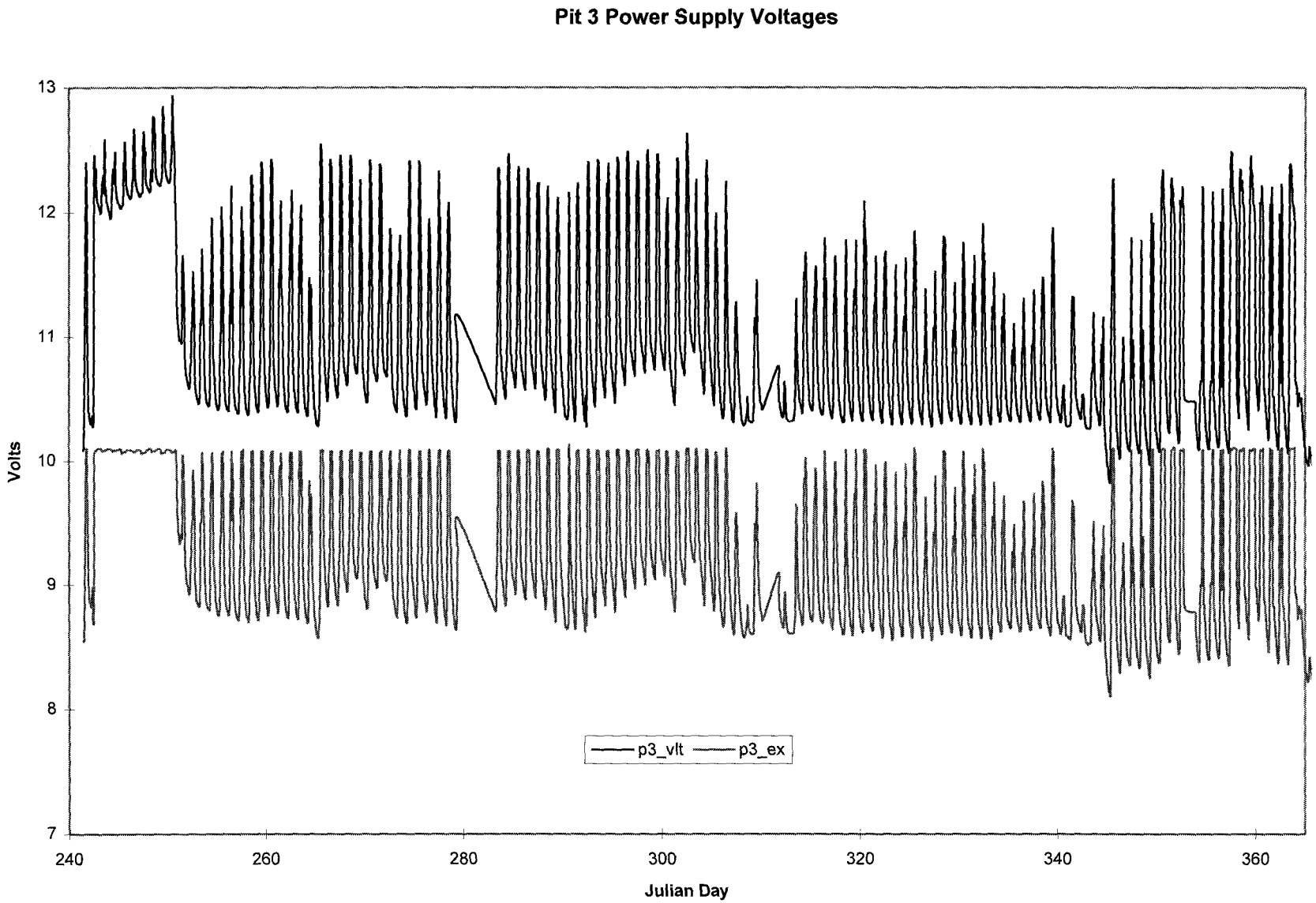

Pit 3 Power Supply Voltages
13
12
11
10
9
8
7
Volts
240
260
280
300
320
340
360
Julian Day
p3_vlt
p3_ex

FIG 9.5

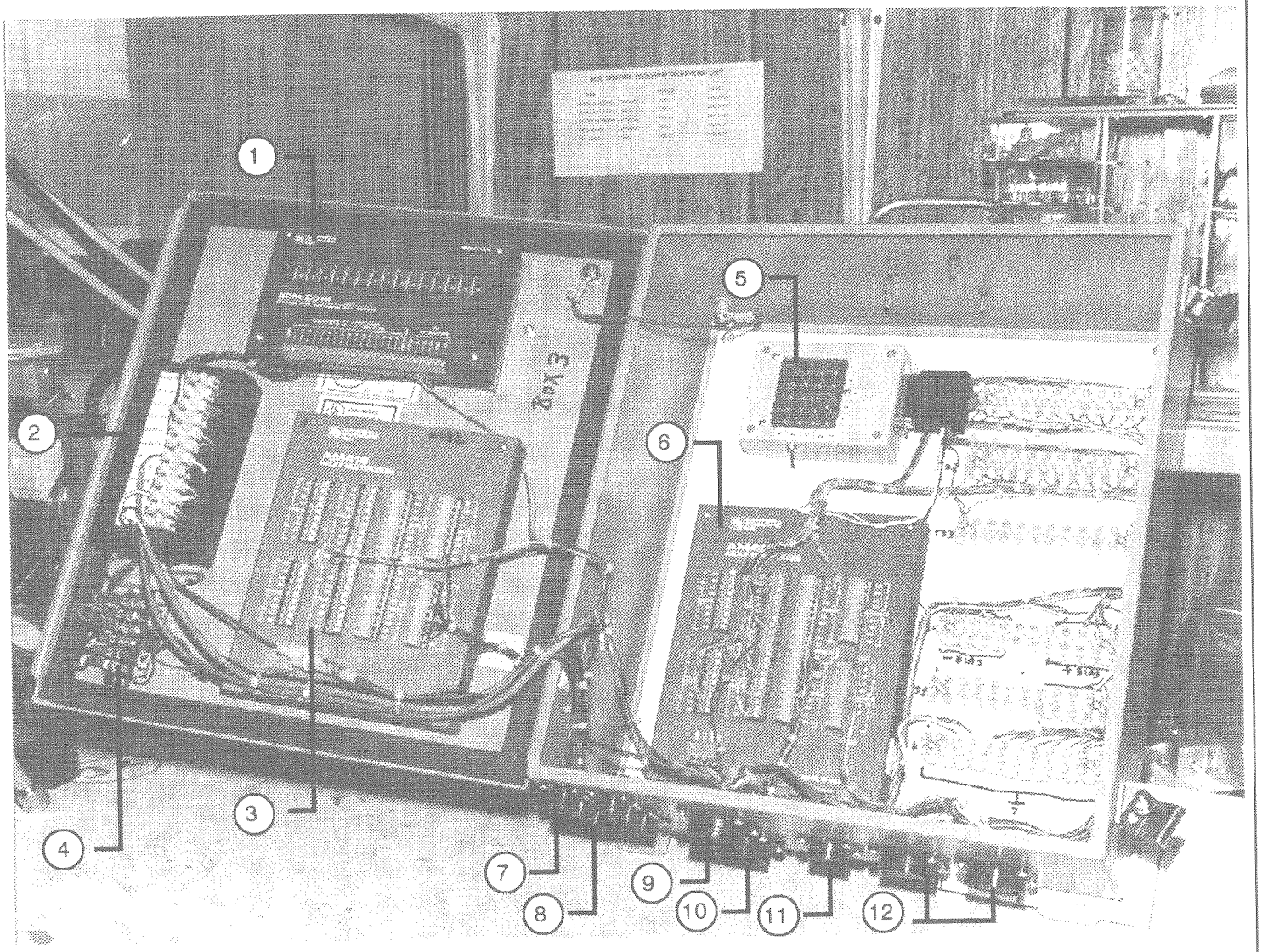


Figure 1 Multiplexing Assembly

Legend:

1. CSI SDM-CD16 Control Port Module
2. Power Supply Switching and Voltage Regulator Module
3. CSI AM416 Relay Multiplexer (MUX) for Measuring Temperature Probes
4. Bus Strip for Connection to External 12V Battery Power Supply
5. LED Indicator Array Module for Field Checking of Tensiometer Water Levels
6. MUX for Measuring Pressure Transducer Outputs, Tensiometer Water Levels, Excitation , and Battery Voltages
7. 4-Pin Panel Mount Connector for External Power Supply
8. 4-Pin Connectors for 5 Temperature Probes
9. 24-Pin Connector for Datalogger Communication Cable
10. Extra 24-Pin Connector
11. Extra 9-Pin Connector
12. 55-Pin Connectors for Transducer Harness Connection

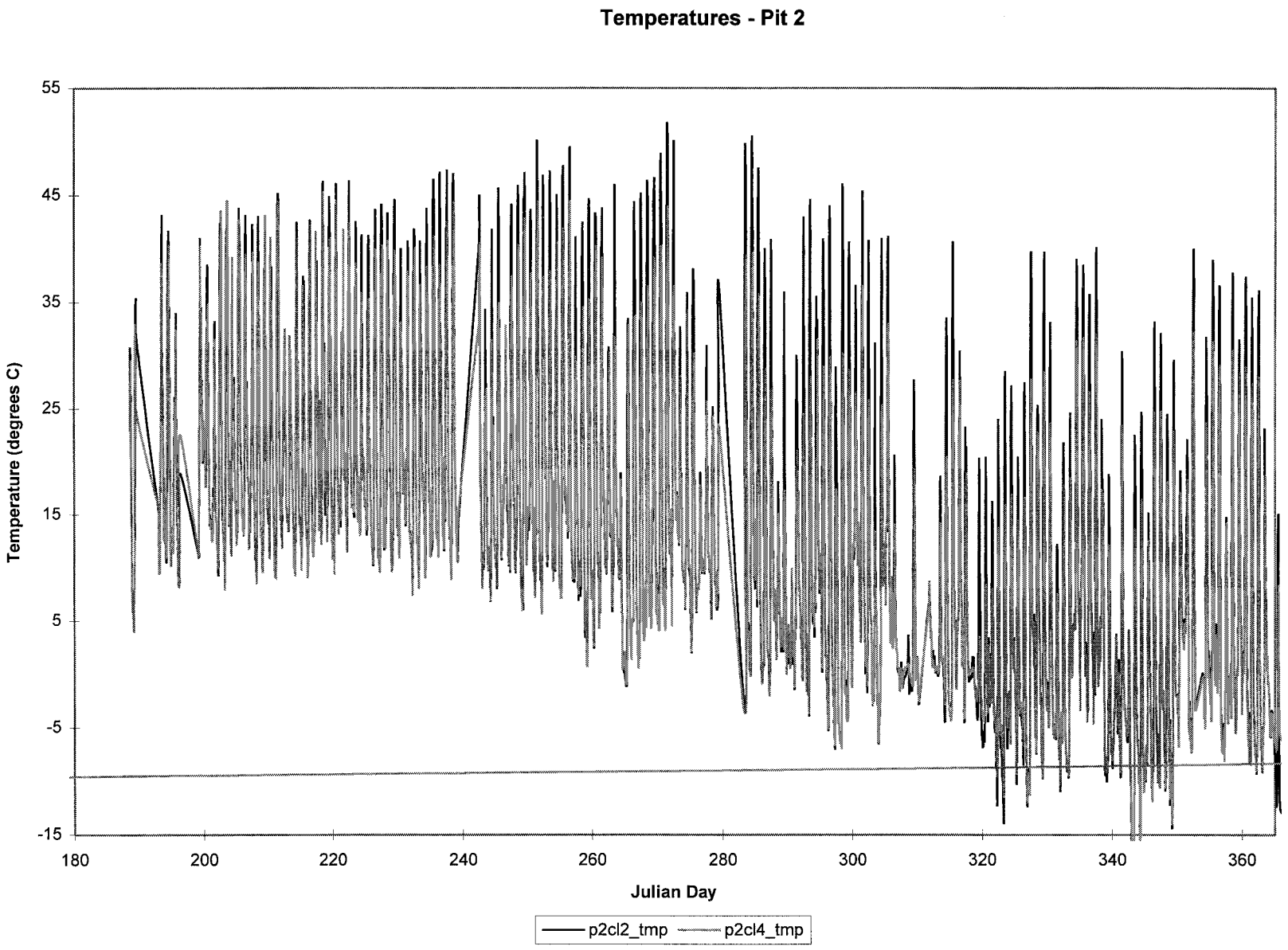
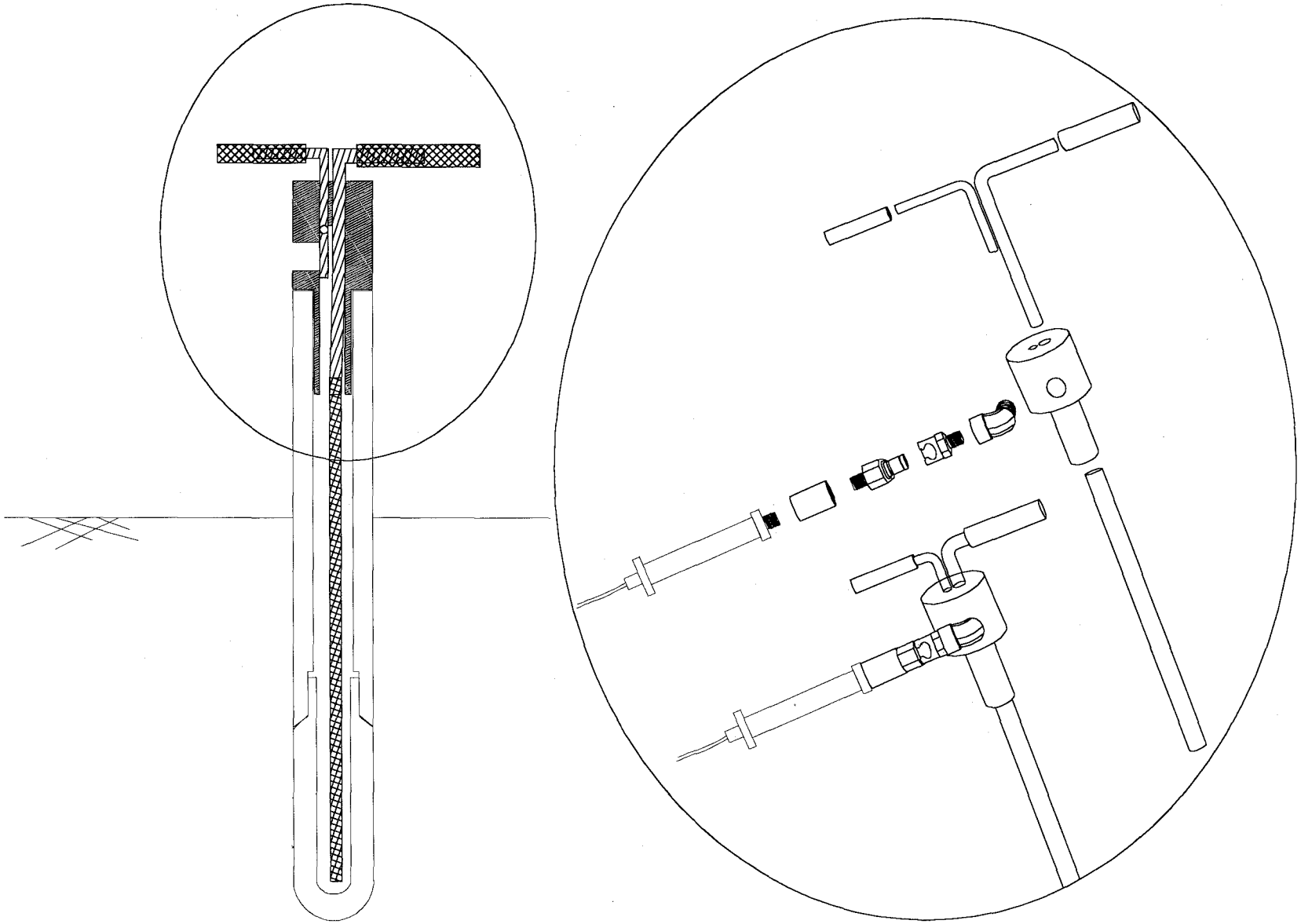

Temperatures - Pit 2
Temperature (degrees C)
55
45
35
25
15
5
-5
-15
180
200
220
240
260
280
300
320
340
360
Julian Day
p2cl2_tmp
p2cl4_tmp

FIG 9.7

SNBK2.DWG



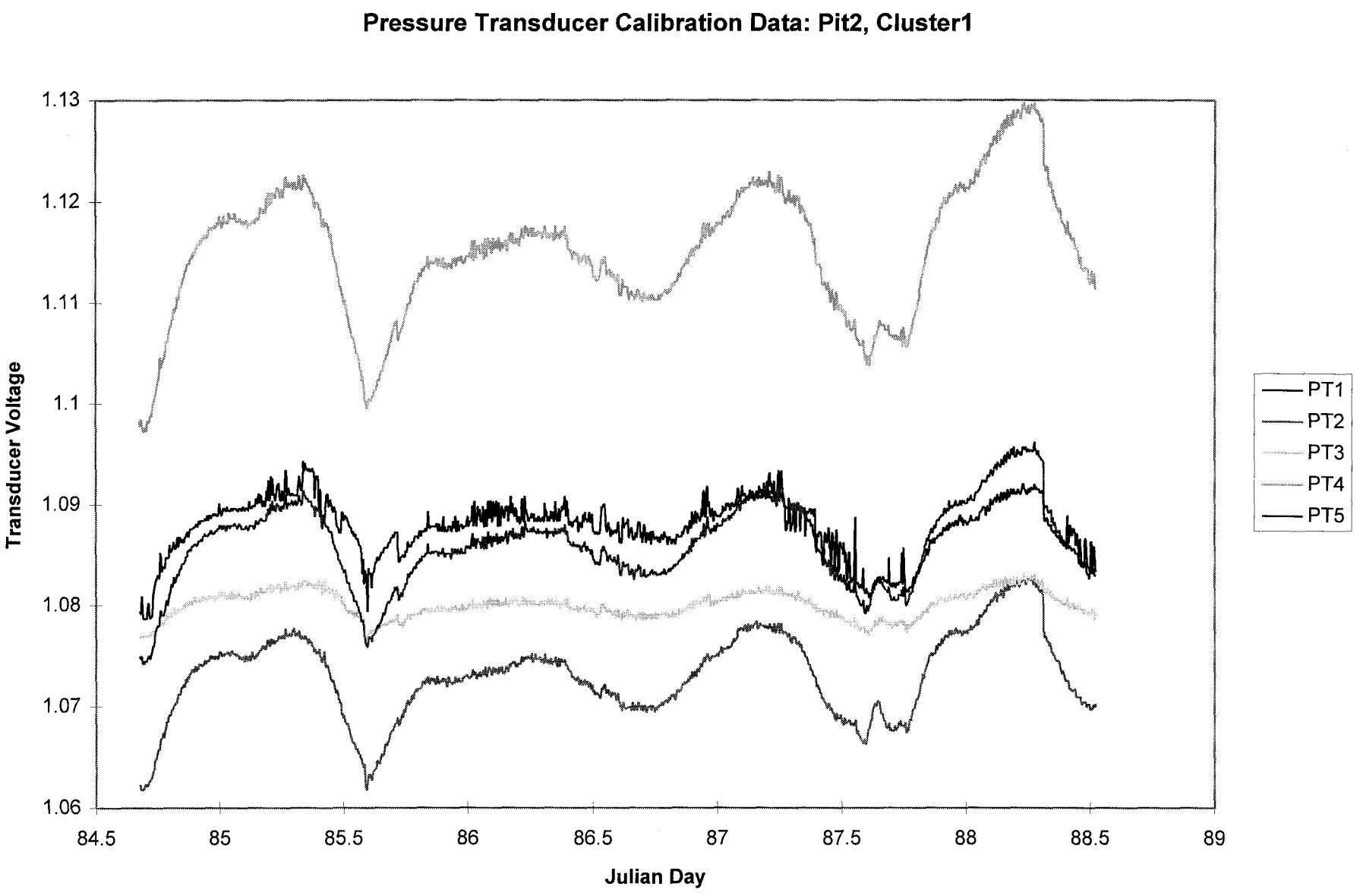

Pressure Transducer Calibration Data: Pit2, Cluster1
Transducer Voltage
1.13
1.12
1.11
1.1
1.09
1.08
1.07
1.06
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT1
PT2
PT3
PT4
PT5

FIG 9.10

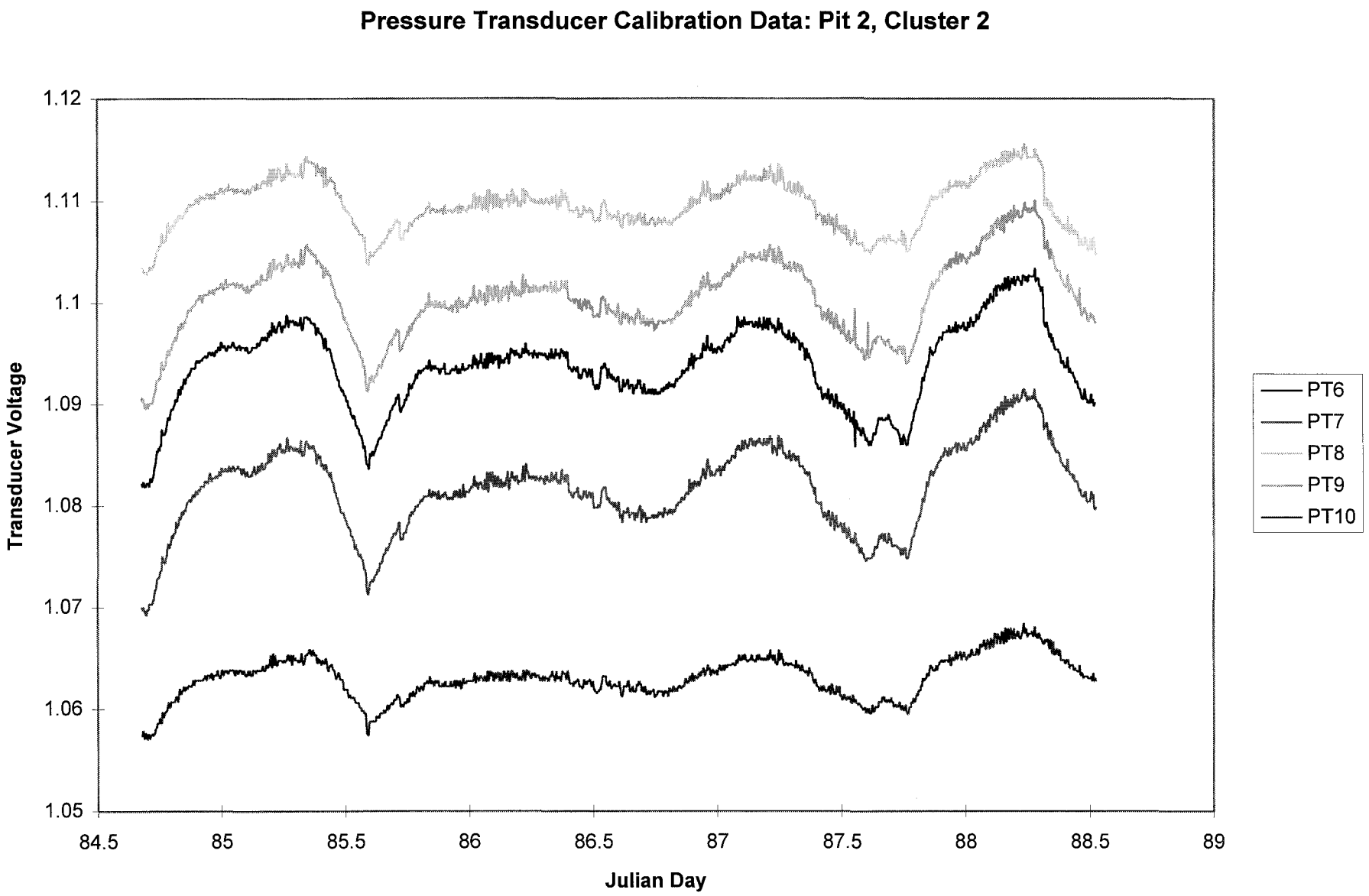

Pressure Transducer Calibration Data: Pit 2, Cluster 2
Transducer Voltage
1.12
1.11
1.1
1.09
1.08
1.07
1.06
1.05
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT6
PT7
PT8
PT9
PT10

FIG 9.11

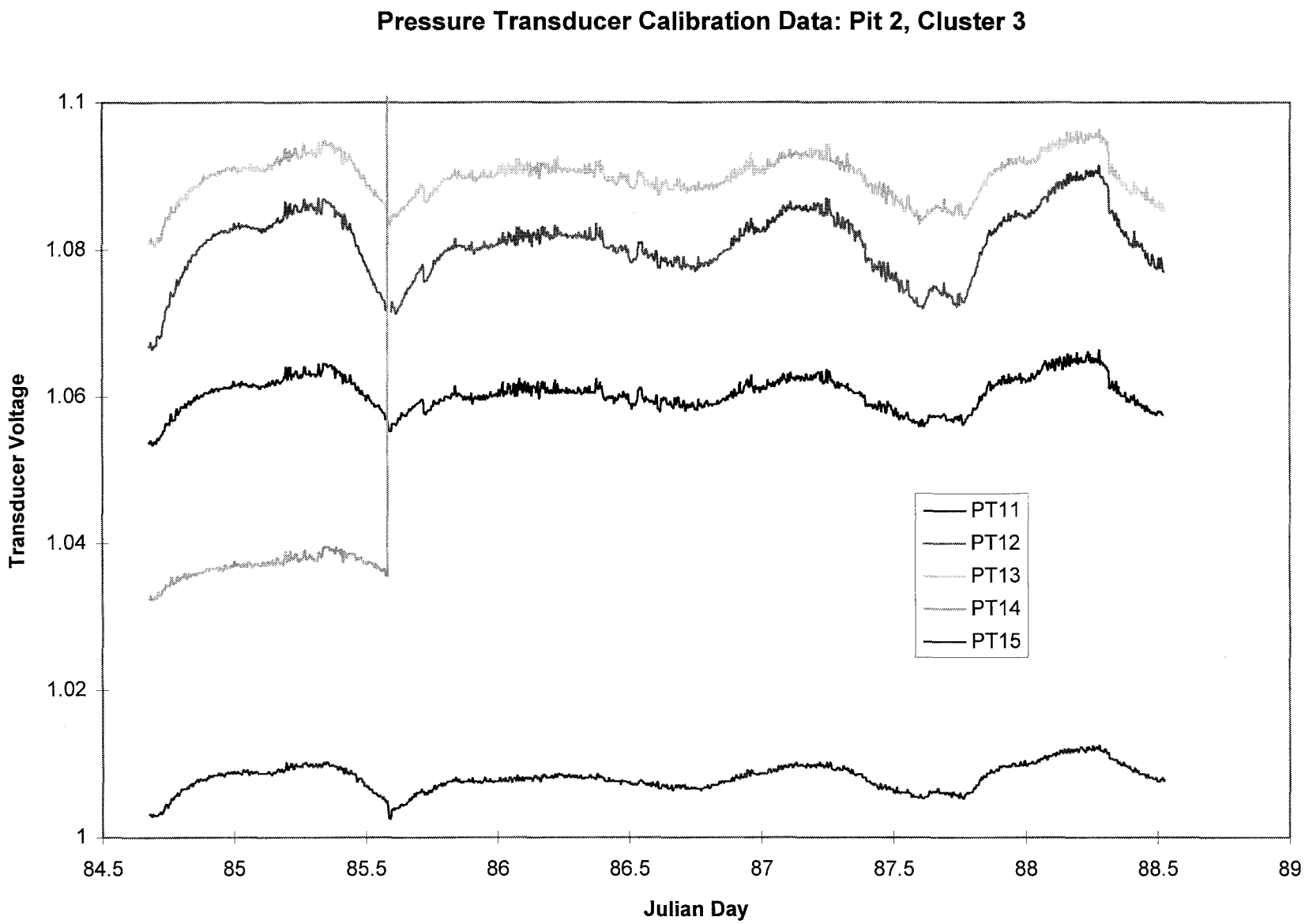
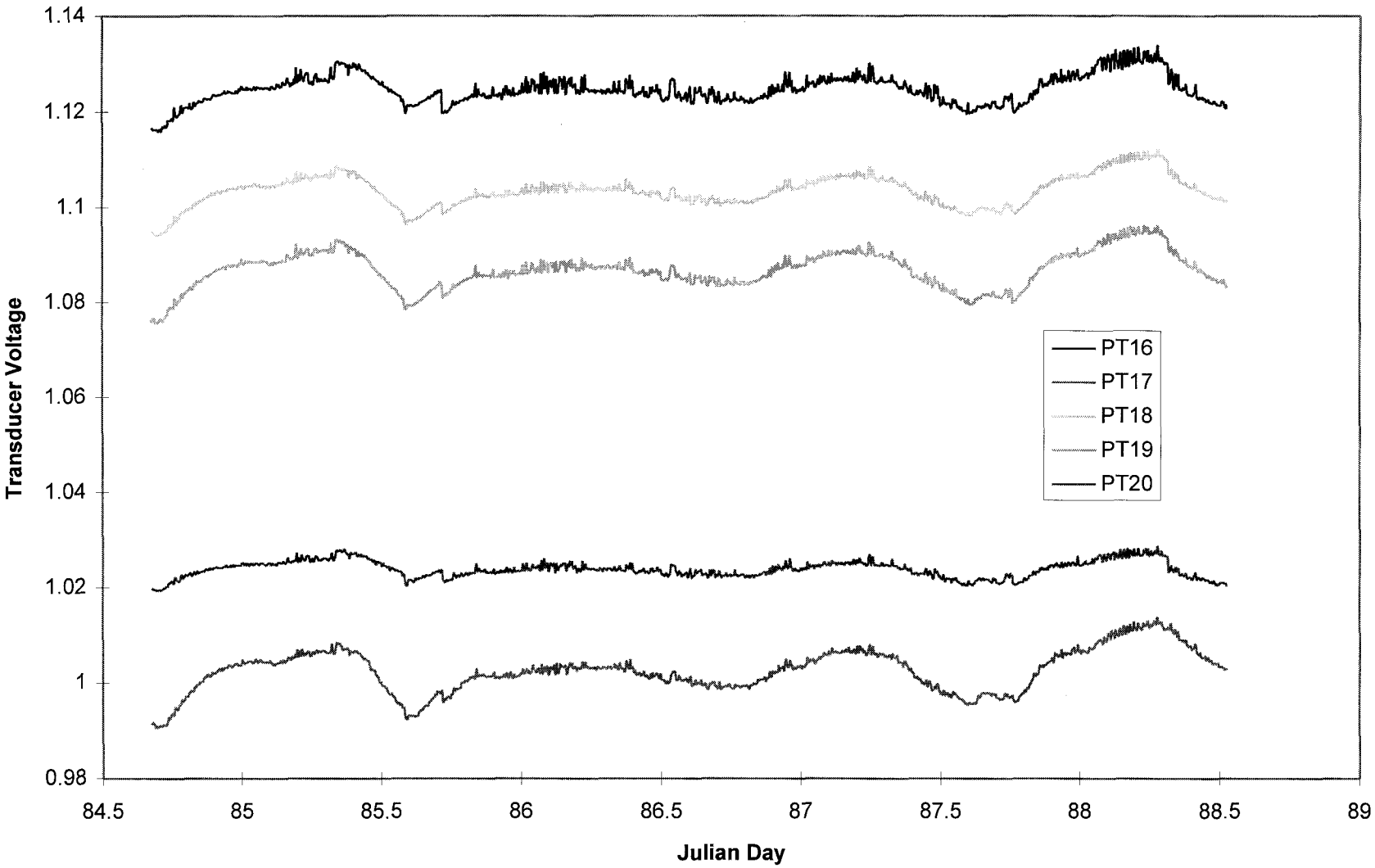

Pressure Transducer Calibration Data: Pit 2, Cluster 3
Transducer Voltage
1.1
1.08
1.06
1.04
1.02
1
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT11
PT12
PT13
PT14
PT15

FIG 9.12

Pressure Transducer Calibration Data: Pit 2, Cluster 4



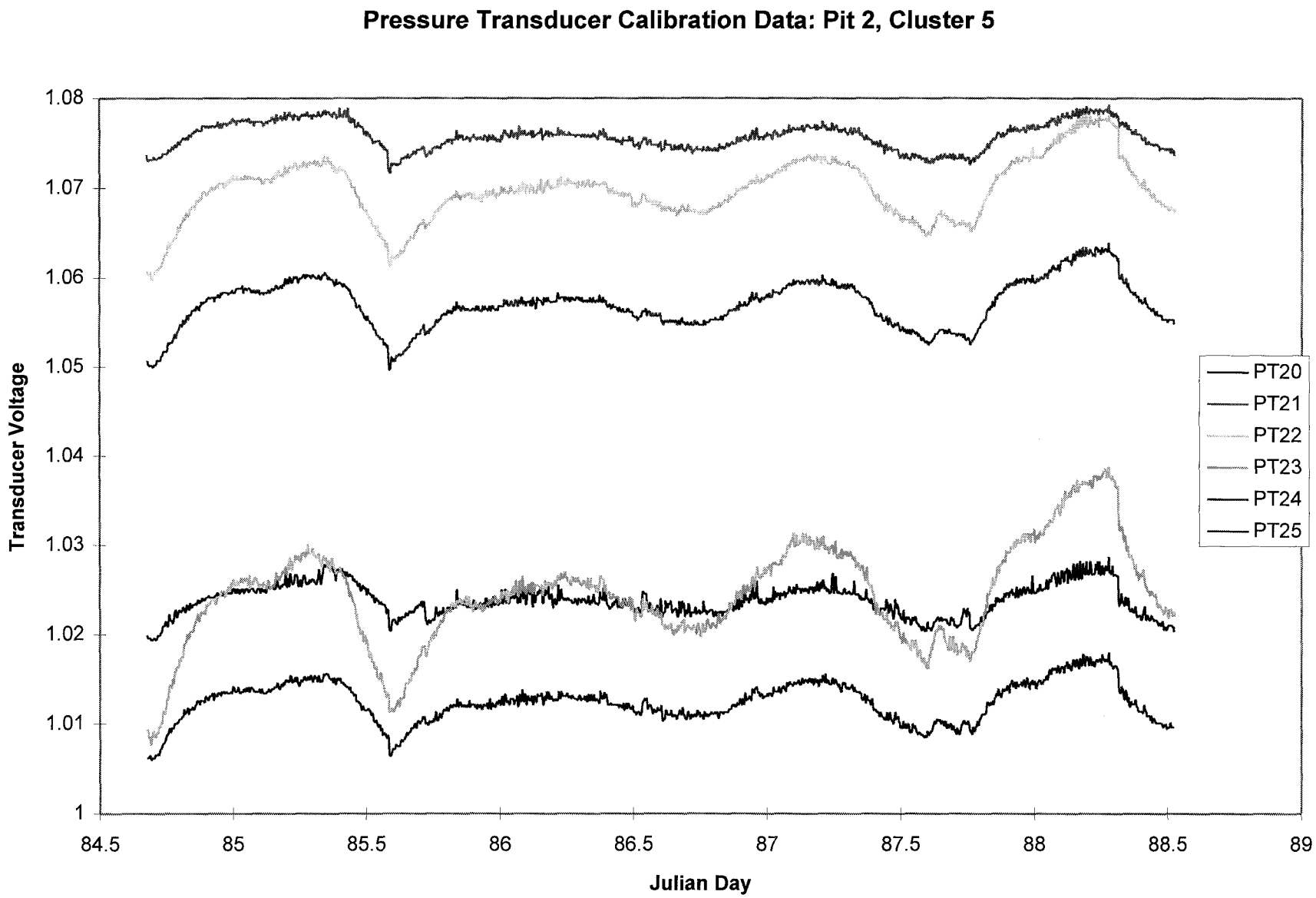

Pressure Transducer Calibration Data: Pit 2, Cluster 5
Transducer Voltage
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT20
PT21
PT22
PT23
PT24
PT25

FIG 9.14

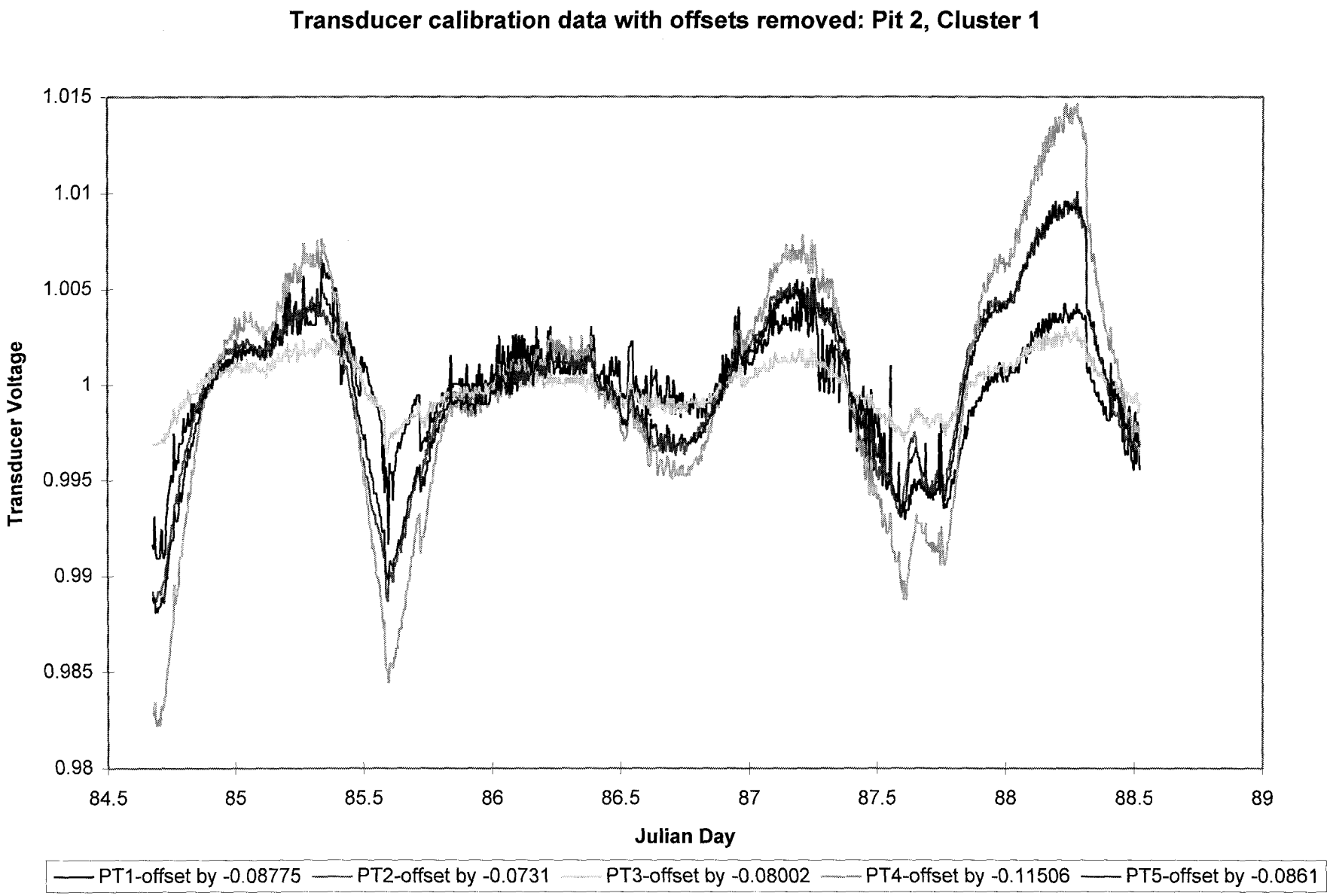

Transducer calibration data with offsets removed: Pit 2, Cluster 1
Transducer Voltage
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT1-offset by -0.08775
PT2-offset by -0.0731
PT3-offset by -0.08002
PT4-offset by -0.11506
PT5-offset by -0.0861

FIG 9.15

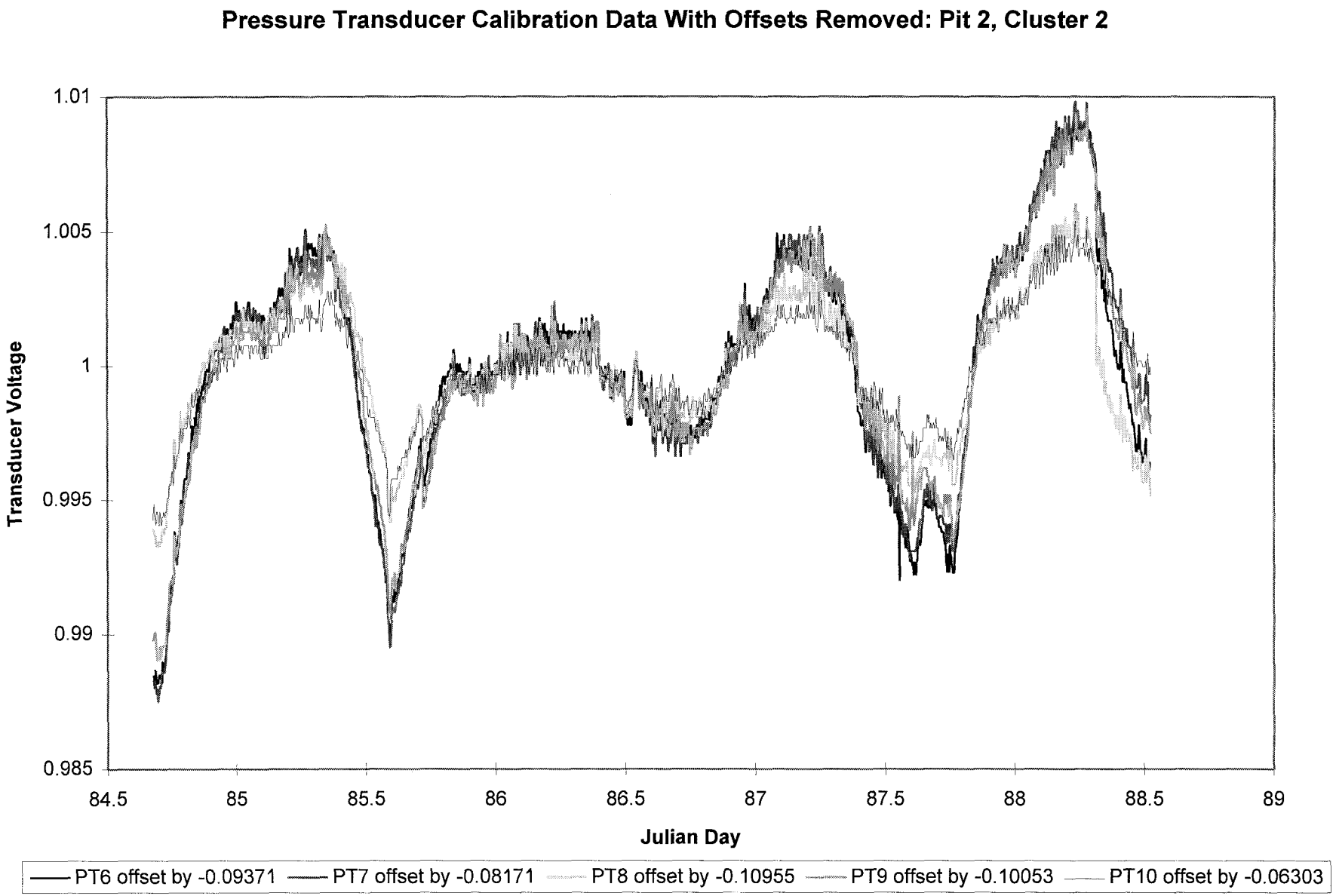

Pressure Transducer Calibration Data With Offsets Removed: Pit 2, Cluster 2
Transducer Voltage
1.01
1.005
1
0.995
0.99
0.985
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT6 offset by -0.09371
PT7 offset by -0.08171
PT8 offset by -0.10955
PT9 offset by -0.10053
PT10 offset by -0.06303

FIG 9.16

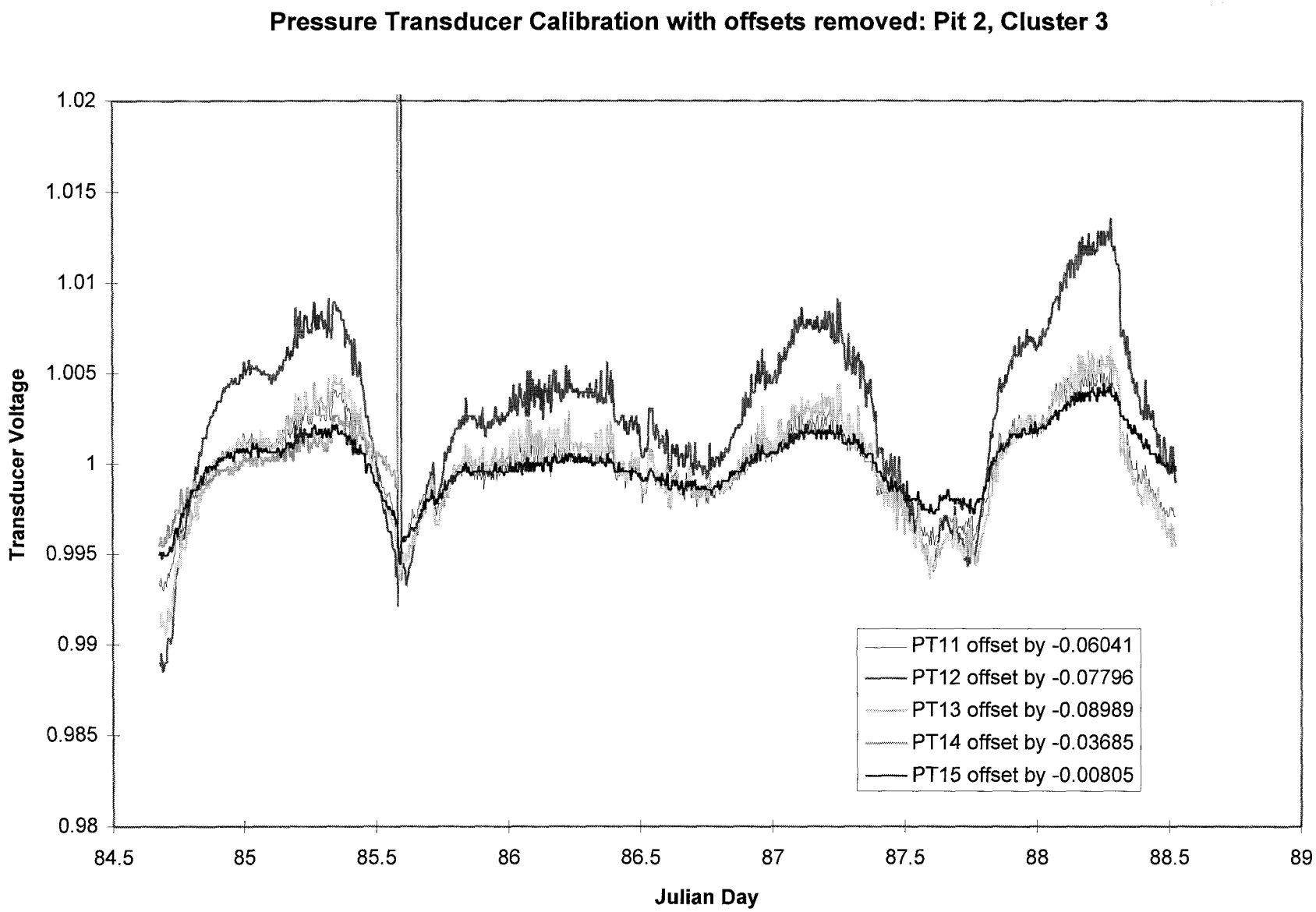

Pressure Transducer Calibration with offsets removed: Pit 2, Cluster 3
Transducer Voltage
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT11 offset by -0.06041
PT12 offset by -0.07796
PT13 offset by -0.08989
PT14 offset by -0.03685
PT15 offset by -0.00805

FIG 9.17

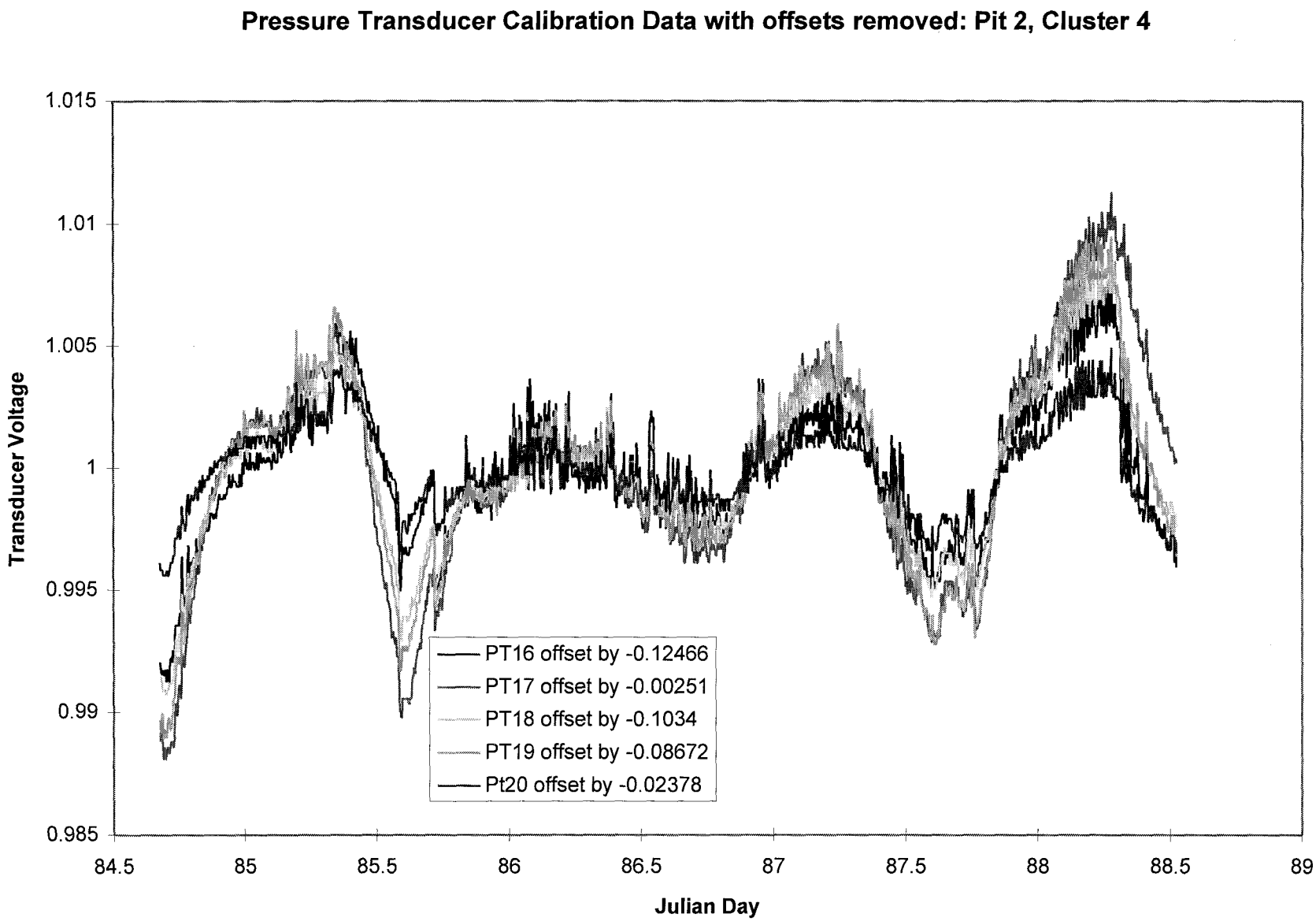

Pressure Transducer Calibration Data with offsets removed: Pit 2, Cluster 4
Transducer Voltage
1.015
1.01
1.005
1
0.995
0.99
0.985
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT16 offset by -0.12466
PT17 offset by -0.00251
PT18 offset by -0.1034
PT19 offset by -0.08672
Pt20 offset by -0.02378

FIG 9.18

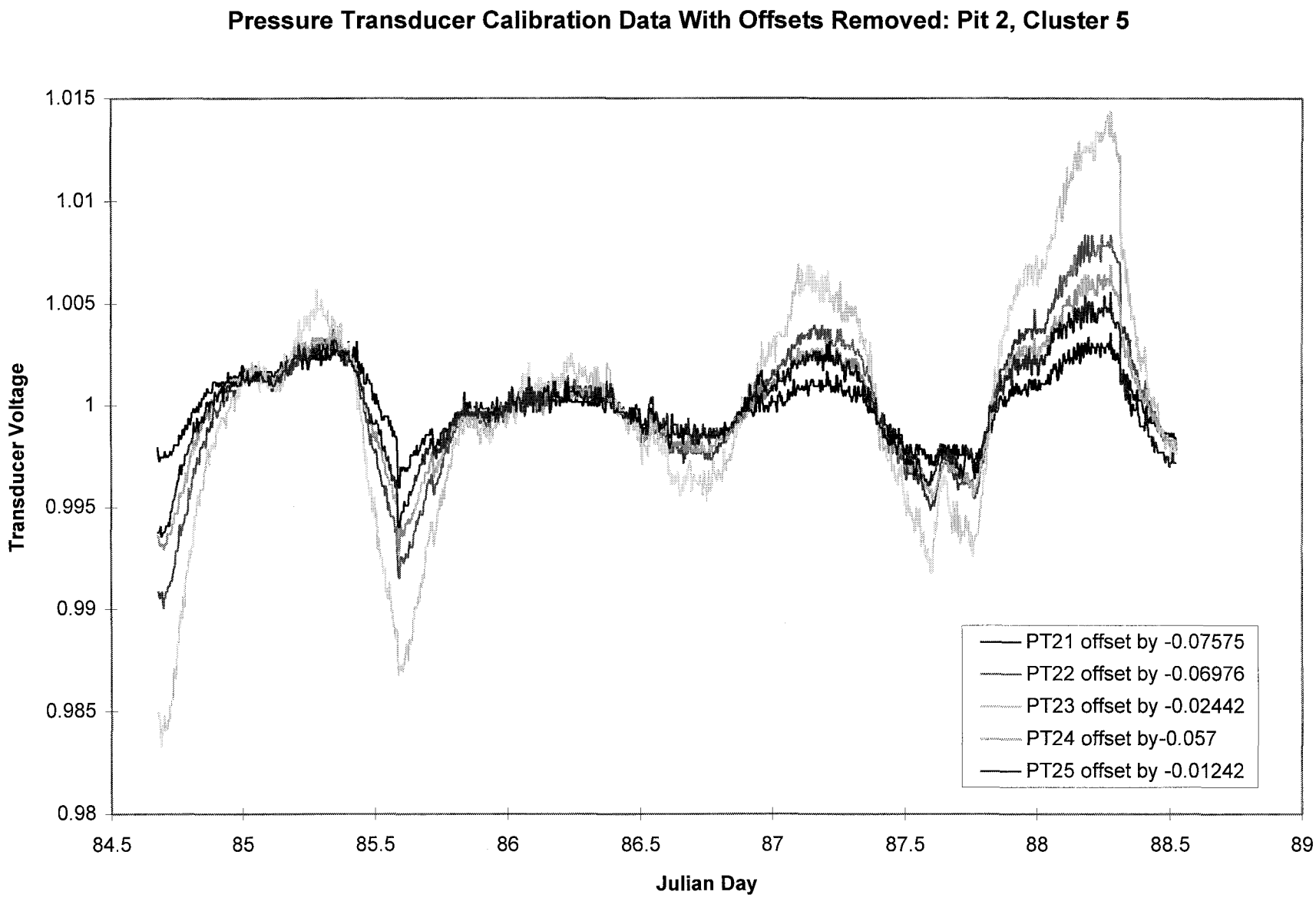

Pressure Transducer Calibration Data With Offsets Removed: Pit 2, Cluster 5
Transducer Voltage
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
84.5
85
85.5
86
86.5
87
87.5
88
88.5
89
Julian Day
PT21 offset by -0.07575
PT22 offset by -0.06976
PT23 offset by -0.02442
PT24 offset by-0.057
PT25 offset by -0.01242

FIG 9.19

PIT2MAT3.XLS Chart 3

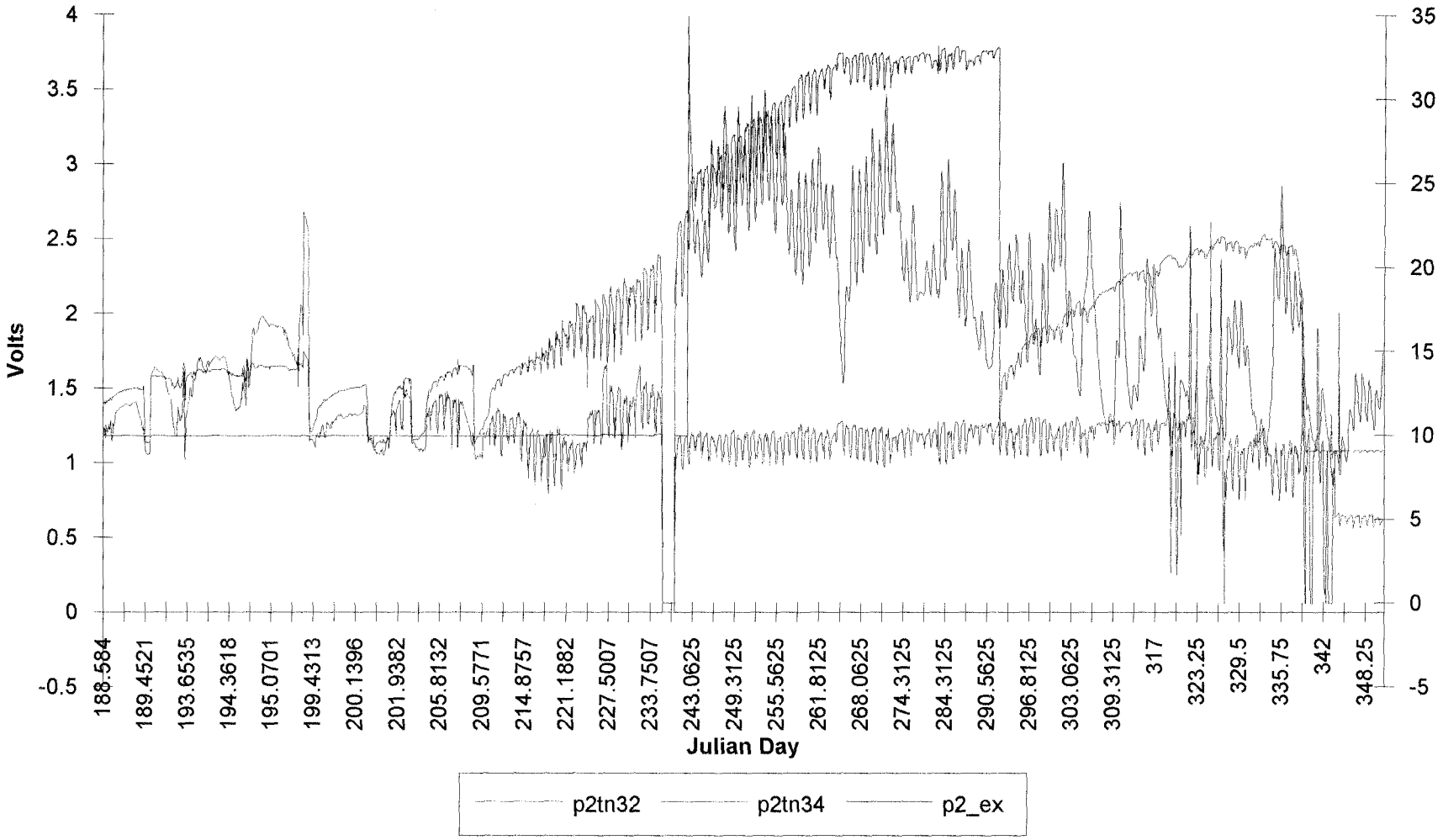


FIG 9.20

SNBKD.XLS

mm (1/4") space between the plates. This space is created by an array of stainless steel nuts and bolts (Figure 6.4).

A fully assembled snow density plate is shown in Figure 6.5. Figure 6.6 is a schematic drawing of an installed snow density plate.

The most important design consideration of the base plate was rigidity. Therefore

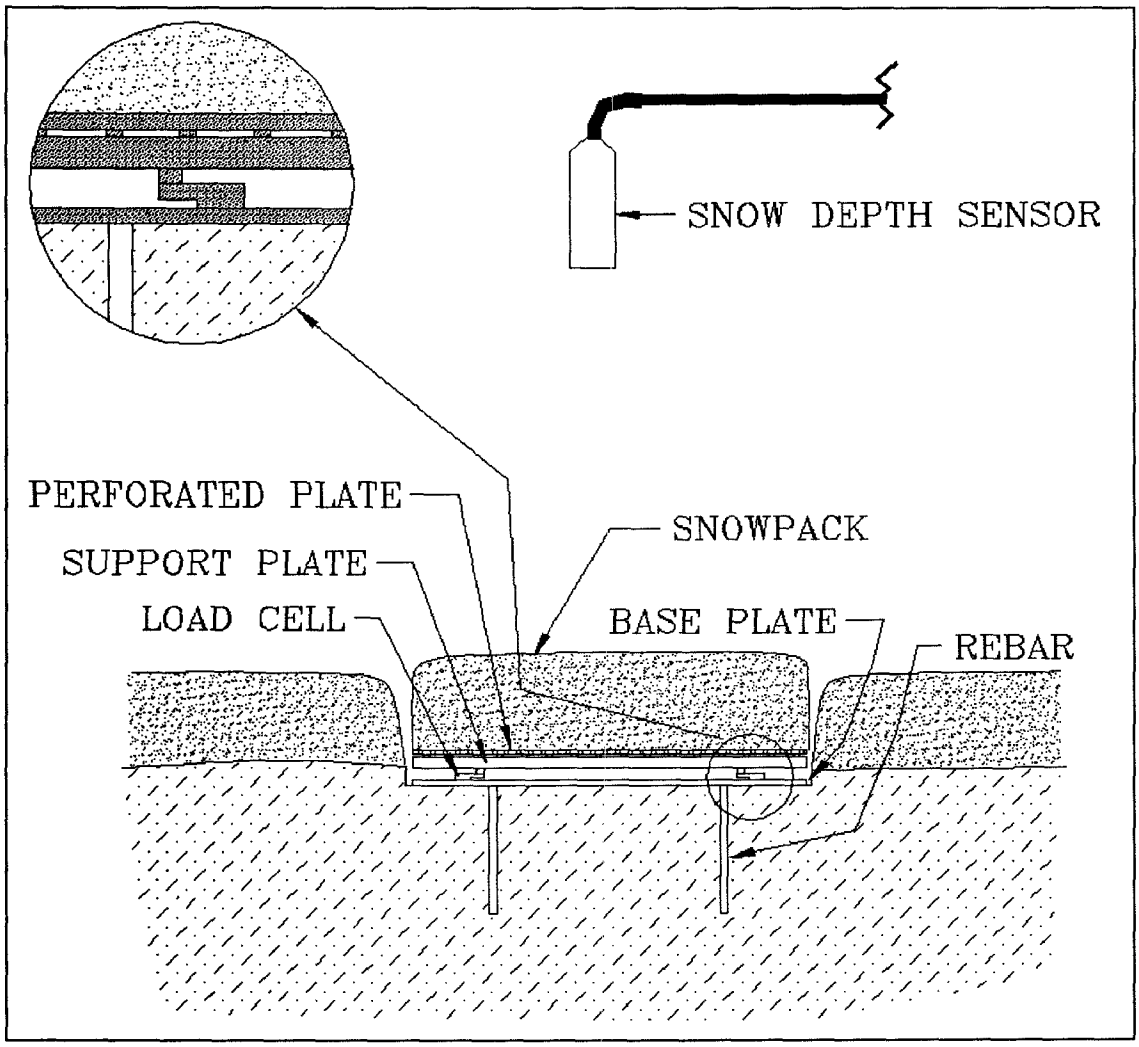


Figure 6.6 - Schematic Drawing of Installed Snow Density Plate

this plate was constructed of steel. To increase the rigidity of this part, rectangular steel bars (1.25 cm x 5 cm) were welded onto the top surface of each plate edge (see Figure 6.1).

These parts were painted white to help reduce thermal conductivity and increase reflectivity. These modifications should help prevent the plates from heating up and accelerating the snowmelt rate. Two coats of zinc chromate primer were applied. White acrylic latex enamel paint was then applied.

The important loadcell specification parameters were the loadcell mass measurement range, compatibility with the current SMS system, and weatherproofing. Interface SSB-MA-250 loadcells met these requirements. This model was specifically designed for outside applications, can measure a maximum of 115 kg (250 lb.), and is compatible with Campbell Scientific Inc. dataloggers, multiplexers and programming language.

6.2.3 Snow Density Plate Calibration

Calibration of the snow density plates was performed by applying known weights to the plates and recording the output of the plate's three loadcells. The loadcell electrical outputs were recorded using a CSI CR10 datalogger and AM416 multiplexer. A millivolt (mV) to kilogram (kg) conversion factor was then determined by dividing the electrical output by the applied weight. The calibration weights used consisted of plastic bottles filled with water. Their masses were confirmed with the Sartorius scale in the Soil Science Laboratory.

A series of five calibration tests were performed on the plates. These tests were designed to assess the loadcell output linearity, the mV-to-kg conversion as a function of applied mass, and the mass resolution of the snow density plates. These tests included mass ranges of 0-25 kg and 0-100 kg. For the 0-25 kg range, increments of 1 kg were used. Above 25 kg, increments of 5 kg were used. A higher mass resolution was used for the 0-25 kg range because this range represents the expected mass of typical snow events at RFETS. Table 1 illustrates the snow mass as a function of snow depth and density. The 25-100 kg range provided calibration information for more extreme snowfall events or for use of the snow density plates in areas of deeper seasonal snow packs.

Hysteresis effects were assessed by recording loadcell output for repeated loading/unloading cycles. The calibration tests ranged from one half to three cycles. Since all recorded snowfall events at RFETS have been isolated events, the primary focus was on single cycle hysteresis.

	Snow depth				
Snow density	1 cm	10 cm	25 cm	50 cm	100 cm
75 kg/m^3	0.75	7.5	18.75	37.5	75
100 kg/m^3	1	10	25	50	100
150 kg/m^3	1.5	15	37.5	75	150
250 kg/m^3	2.5	25	62.5	125	250
500 kg/m^3	5	50	125	250	500
750 kg/m^3	7.5	75	187.5	375	750

Table 6.1 - Snow Mass (kg) as a Function of Snow Depth and Density

6.2.4 Snow Density Plate Calibration Results

Results from one calibration test are presented below. This test consisted of one loading/unloading cycle of 45 kg. Figure 6.7 presents the snow density plate's electrical output versus applied mass. Linear regression of this line results with a slope of 0.0257 mV/kg, with $R^2 = 0.999$, n = 1210. This value of 0.0257 represents the statistical average of the mV-to-kg conversion for this test.

The mV/kg conversion factor versus applied mass is illustrated in Figure 6.8. A trend of decreasing variation with increasing mass can be seen. The conversion factor for loading is more stable than for unloading. The average value for loading was 0.0259, with a standard deviation of 0.000364. For unloading, the average was 0.0267, with a standard deviation of 0.001764.

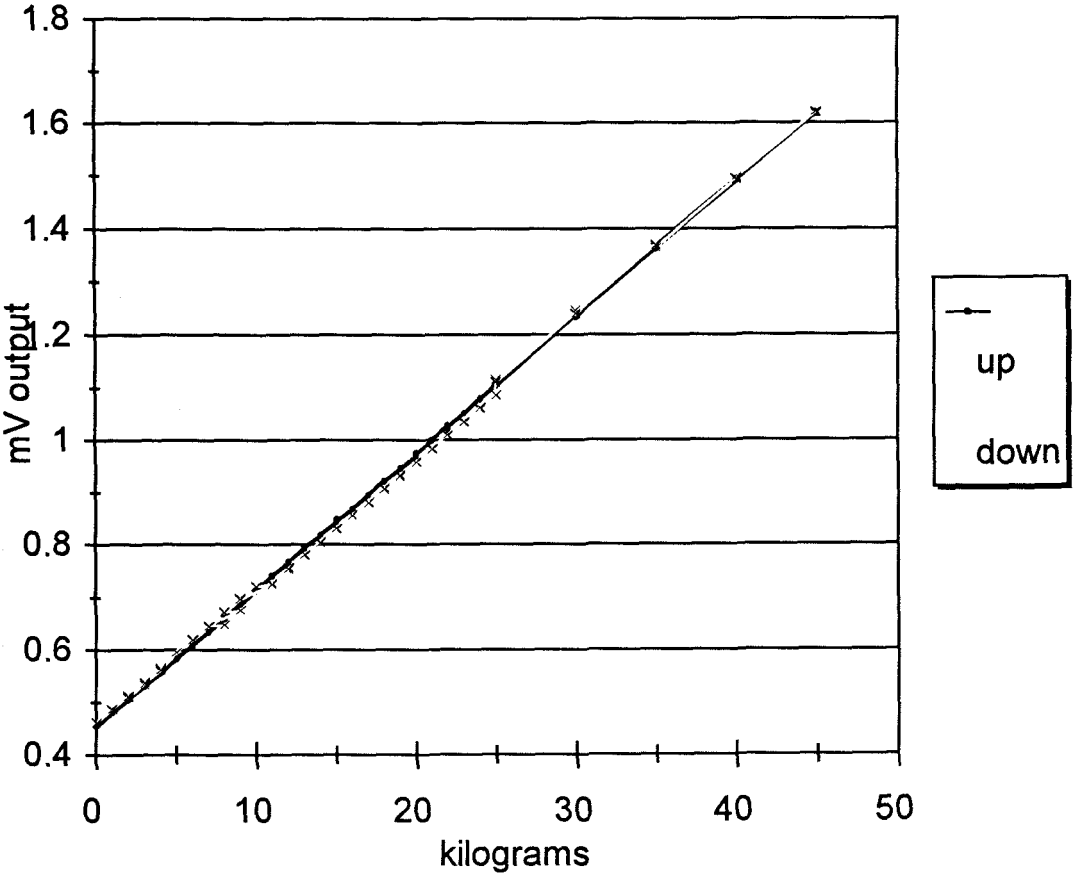


Figure 6.7 - Snow Density Plate mV Output Versus Applied Mass

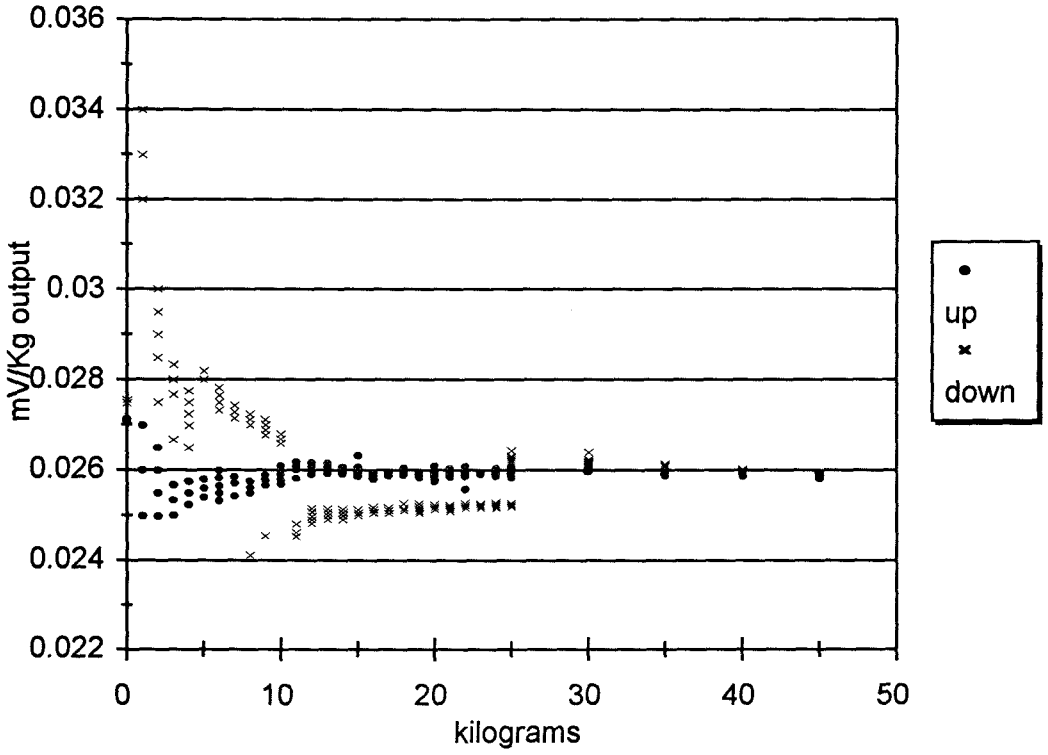


Figure 6.8 - Snow Density Plate mV/kg Conversion Factor Versus Applied Mass

From this calibration data, a mV-to-kg conversion factor of 0.0257 mV/kg was selected. The accuracy of using this constant conversion factor is presented in Figure 6.9. This plot was generated by converting the snow density plate's mV output and comparing it to the actual mass applied. The average error (using absolute values) was 0.284 kg. The maximum error was 0.817 kg.

Based upon these initial calibration results, the snow density plates have a resolution of less than one kilogram. Figure 6.10 illustrates how one kilogram of snow translates to snow depth and density (assuming 1 m^2 of snowcover). One kilogram of

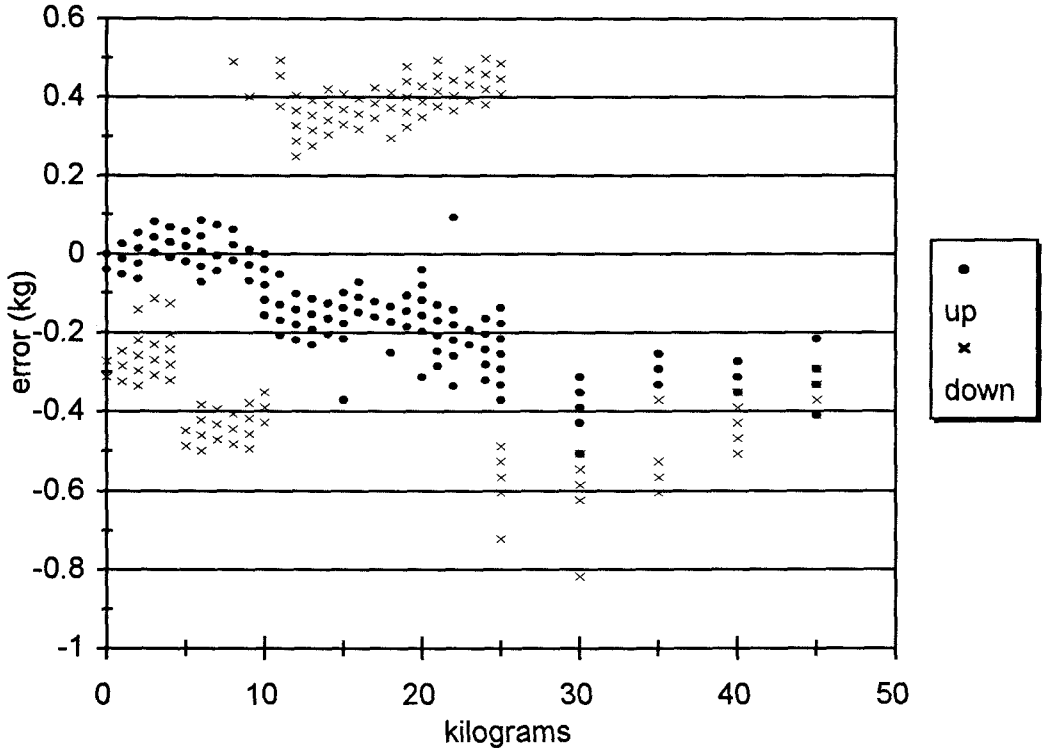


Figure 6.9 - Mass Error (kg) Versus Applied Mass

new snow (10% water content, density of 100 kg/m^3) corresponds to a snow depth of one centimeter. Wet, melting snow (50% water content, density of 500 kg/m^3) corresponds to a snow depth of 0.25 cm. Under ideal field conditions, the resolution of the SDS instruments is approximately one centimeter. These conditions occur when the surface being measured is level and there is no wind or falling snow. Therefore, the

resolution of the snow density plates is greater than the snow depth sensors (SDS) resolution. Improvements in plate mass resolution would not improve snow density calculations.

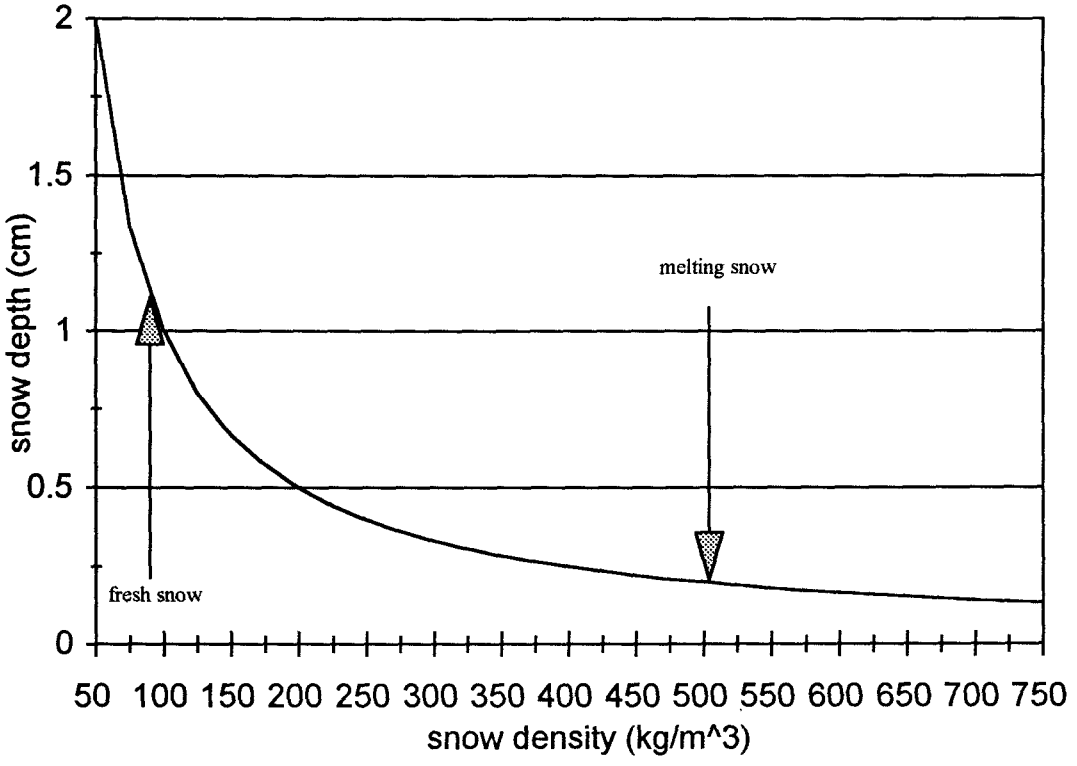


Figure 6.8 - One Kilogram of Snow in Terms of Snow Depth and Density

6.2.5 Snow Density Plate Installation

The two snow density plates will be coupled with the SDS at the meteorological tower and at pit 1. The plates will be installed centered directly under the SDS. The plates provide a level surface, which helps improve the resolution of the SDS.

Currently there is one plate installed in the field. Electrical and wiring problems have prevented the plate from collecting data. Excitation voltage or grounding feedback appears to be the source of the problem. A test CR10 program will be downloaded to test the loadcell/CR10 wiring. This program will use execution delays to allow manual measurements of input/output loadcell voltages.

6.3 SNOWMELT MODELLING

6.3.1 Snowmelt Modelling Tools

To assist with the modelling of the snowmelt data, an array of modelling software tools were developed. While these tools were designed for the snowmelt model *SNTHERM.89* (see the *1994 OU2 Closure Soil Studies Scientific Notebook* for the RFETS, RFP/ERM-94-00021 for *SNTHERM.89* details), the programming concepts and design are general enough to be applied to other environmental models. This application was developed with the widely used software packages, Microsoft Excel 4.0 and Microsoft FoxPro 2.6.

The process of snowmelt modelling involves the repetition of numerous computer tasks. These tasks include preparing and formatting raw data, computer simulations,

plotting of input and output data, and comparing model estimates with measured data. Therefore, the tools developed are based on the simple concept of automating computer tasks. This automation results in significant time savings.

6.3.2 *SNTHERM* Input Files

Two input files are required to run *SNTHERM*. One contains the model parameter settings and a physical description of the snowpack. This file will be referred to as the Model Parameter and Snowpack (MPS) file. Figure 6.11 presents an example of the MPS file format. The comma-delimited lines in the file is where the model parameters are set. These parameters include items such as snow albedo, turbulent transfer coefficients, instrument heights and convergence criteria.

The tab-delimited section of the MPS file contains the snowpack and soil description. Each line describes a snow/soil layer's temperature (°K), thickness (m), water density (Kg/m^3), and snow/soil grain size (m). While the example file contains two layers, a typical file would include ten or more.

```
2,6,1,990.,1,0,0,0,400.,0,0,3600.,0,0.78,0.04,ln, pinv, ifluxout,bp,isolarcalc,
        ircalc,islope,itracks,bext,itm,ioutfiltrate,dtbase,imetcalc,albsnow,ssisnow
5.0,5.0,5.0, height[1..3]
9,3,0.40,.001,999,1.0,1.,1.00,1.00,0.98
14,1,0.0,0.002,999,1.0,0.7,2.00,2.00,1.0 (nn(i), ltype(i),qtz(i), znaught(i), cd(i), rce(i),      rch(i), ck(i), frh(i), i=1, ln)
2,5.,1.,900.,900.,.01,.05,ngood,dtmin,dtsmin,dtmax,dtssmax,dssallowed, errtallowd
40,-105,15,180,7, dlatt,dlongt,elev,azslope,itimezone

  274.5    0.2000    200.0    0.0000
  273.5    0.2000    200.0    0.0000
                to(i),dzo(i),bwo(i),do(i)
```

Figure 6.11 - SNTHERM Model Parameter and Snowpack (MPS) Input File Format

The second required file contains the meteorological data. This file is referred to as the MET file. Figure 6.12 shows the format of the MET file. The first four columns contain the measurement's time stamp (year, Julian day, hour and minute). The following six columns contain meteorological data; air temperature (°K), relative humidity, wind velocity (m/s), incoming short-wave solar radiation (W/m^2), reflected short-wave solar radiation (W/m^2), incoming long-wave solar radiation (W/m^2), and net solar radiation (W/m^2). The remaining columns allow the user to account for new precipitation or specify cloud coverage (when solar measurements are not made). For each time step, SNTHERM reads a new set of meteorological and uses that information to help solve the snow surface energy exchange.

```
87 36 14 0 267.600 28.523 2.400 348.000 273.000 176.000 0.000 0  0.0000 0.00  0 0.00  0 0.00  0
87 36 15 0 267.400 27.967 2.100 239.000 189.000 173.000 0.000 0  0.0000 0.00  0 0.00  0 0.00  0
87 36 16 0 267.000 29.860 1.200 103.000  76.000 178.000 0.000 0  0.0000 0.00  0 0.00  0 0.00  0
87 36 17 0 264.600 47.724 0.800  -3.000  -1.000 174.000 0.000 0  0.0000 0.00  0 0.00  0 0.00  0
87 36 18 0 261.300 55.970 0.400  -6.000  -5.000 176.000 0.000 0  0.0000 0.00  0 0.00  0 0.00  0
```

Figure 6.12 - SNTHERM Meteorological (MET) Input File Format

6.3.3 User Interfaces for SNTHERM Input File Creation

Graphical User Interfaces (GUI) were developed for the creation of the two SNTHERM.89 input files. This software was developed with FoxPro for Windows 2.6. All programming files are named with the *snth*.* convention, and are included on the GUI Bernoulli diskette (see Appendix 19 for file locations and disk directory structure). These GUIs are fully integrated into the SWMS GUI. The following user screens are accessed from the Snow Query Data Main Menu.

Figure 6.13 shows the user screen for creating the MET file. This screen allows the user to specify the desired time period and modelling location. If the tower

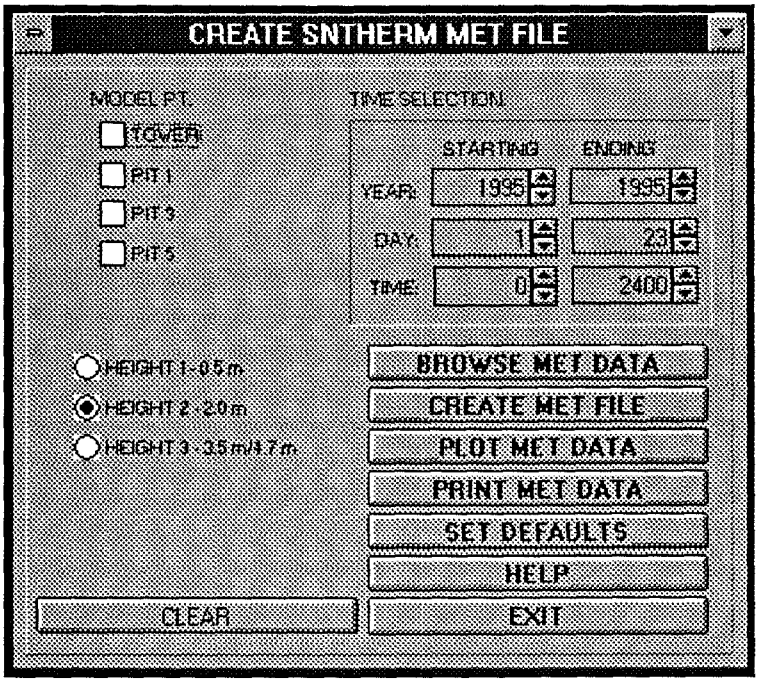


Figure 6.13 - Create SNTHERM MET File Screen

location is selected, the user can select the desired instrument height. All pit locations default to a height of 2 m. Once the time period and instrument location is selected, the corresponding data is extracted from the snow database.

The user option menu is displayed in the lower right-hand portion of Figure 6.13. These options include the following:

Browse MET Data: displays the selected data in its numeric format in the standard FoxPro database browse screen.

Create MET File: creates the SNTHERM.89 MET file. Prompts user for desired file name.

Plot MET Data: plots selected data by executing an Excel plotting macro. This macro give the user the option of printing the plots.

Print MET Data: prints the numeric values of the selected data.

Set Defaults: allows the user to toggle time stamp options and turn on/off filtering of data.

The main menu for MPS input file creation is presented in Figure 6.14. The *SNTHERM.89* modelling parameters have been separated into four different categories and user input screens: model physical parameters, input and output options, numerical convergence criteria settings, and snowpack descriptions. When a category/screen is selected, the current MPS file settings are displayed to the user. Updated values are written to the MPS file when the OK button is pressed. The main menu also allows the of model parameter editing. user to edit the MPS file with a text editor. This feature emulates the traditional method of file editing.

Figures 6.15-6.18 display the four user input screens for updating the *SNTHERM.89* parameters. The physical parameters input screen is shown in Figure 6.15. This screen has been divided into four categories: snow, soil, turbulent energy exchange, and general model parameters. Input values for each parameter are restricted to a appropriate range. For example, the value for snow albedo is constrained to 0-1.00.

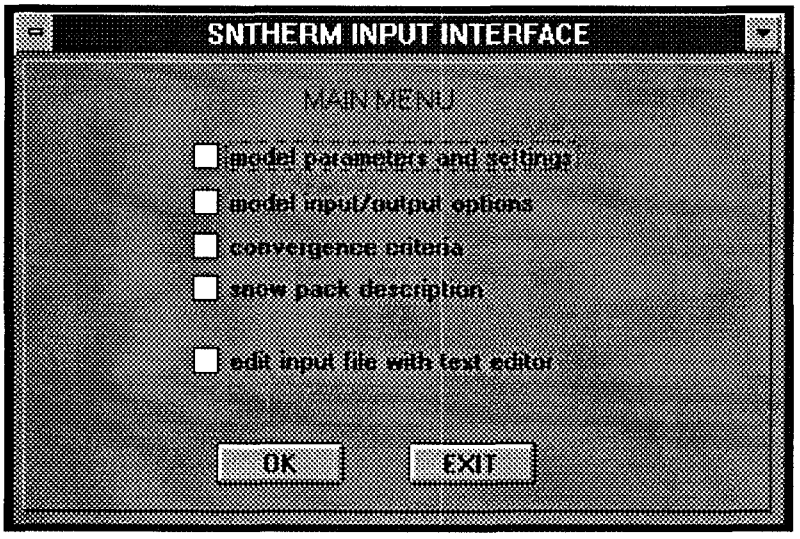


Figure 6.14 - SNTHERM Input Interface Main Menu

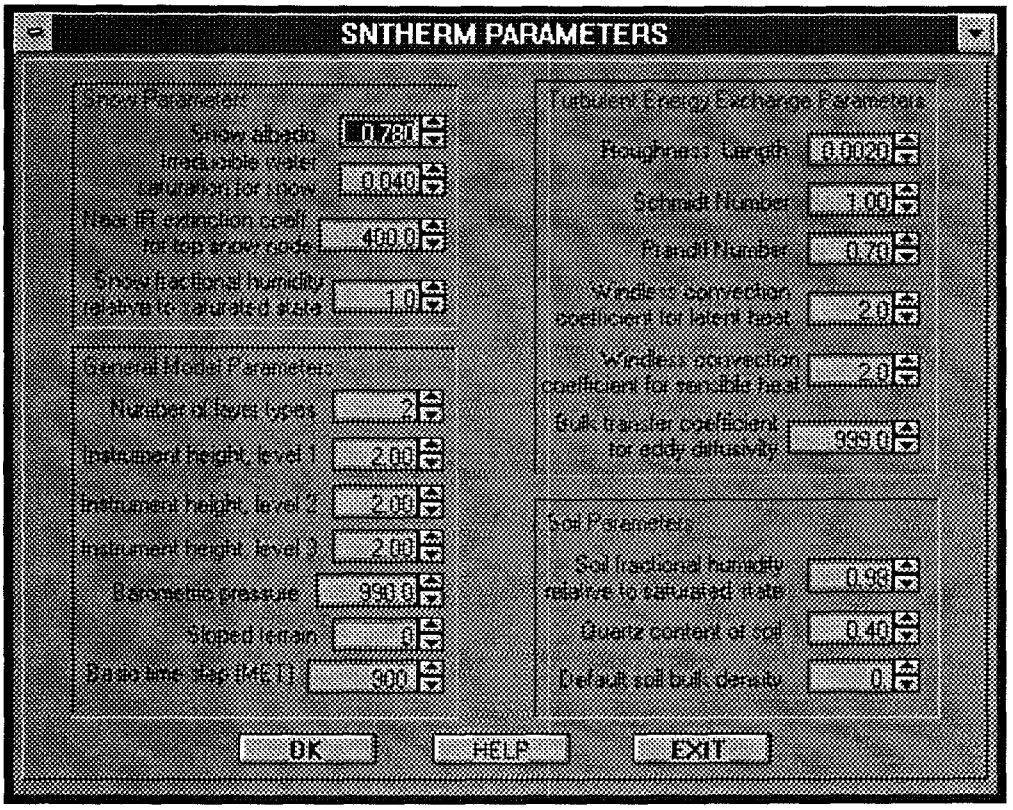


Figure 6.15 - SNTHERM Parameters Screen

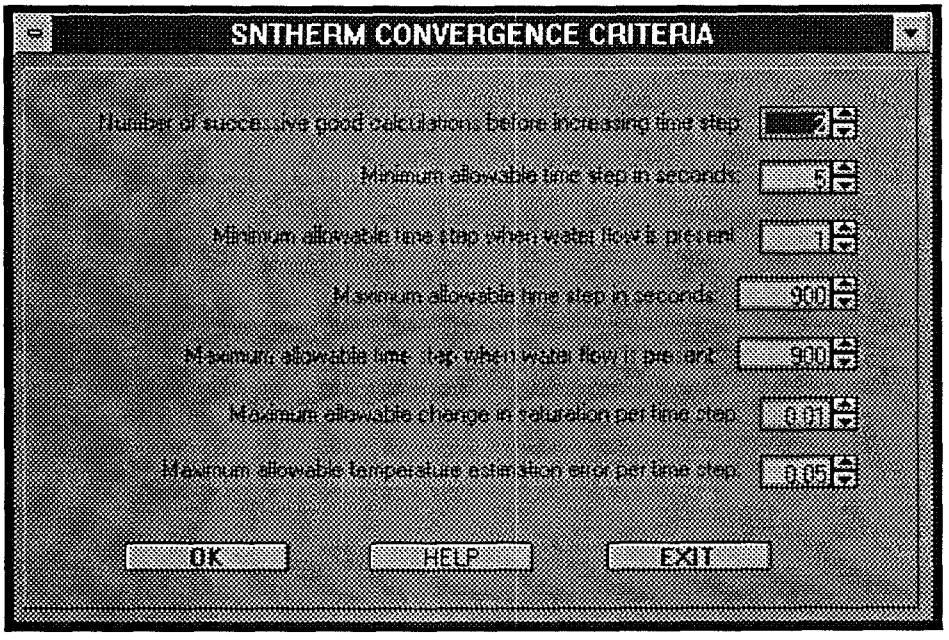


Figure 6.16 - SNTHERM Convergence Criteria Screen

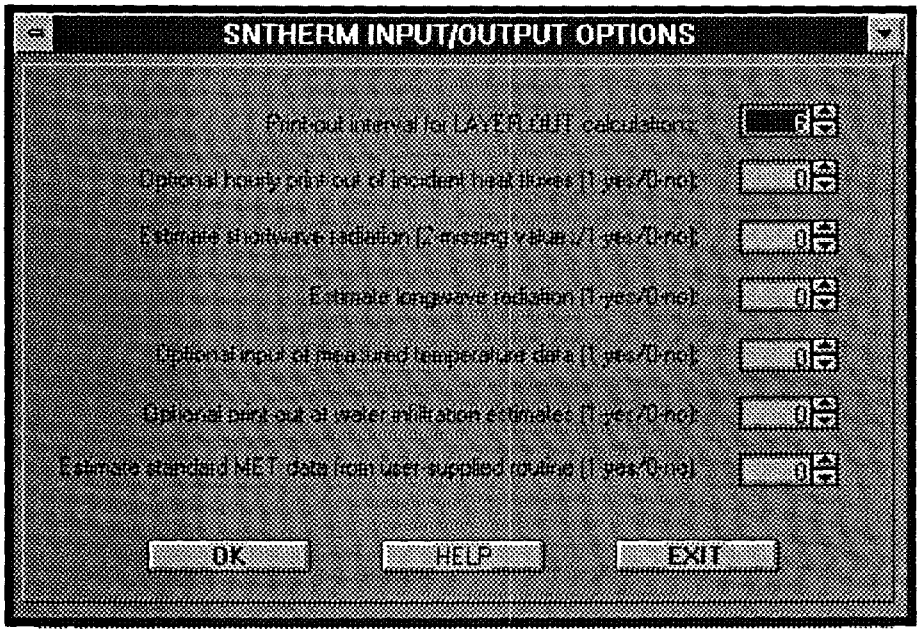


Figure 6.17 - SNTHERM Input/Output Options Screen

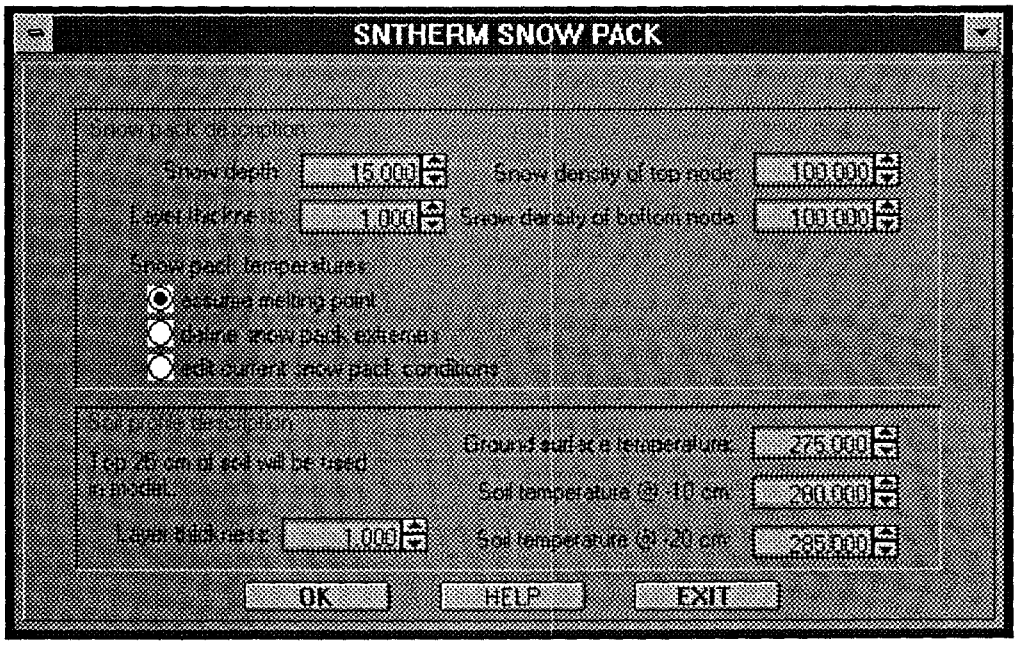


Figure 6.18 - SNTHERM Snow Pack Screen

The screen to update the snow pack description is shown in Figure 6.18. This screen is still in the design and programming stage. It is not yet functional and the snow pack description must be edited using the text editor feature.

7.0 SURFACE RUNOFF

7.1 PRINCIPLES OF SURFACE RUNOFF

Surface runoff is the portion of precipitation which during and immediately following a storm event ultimately appears as flowing water in a watershed (Haan et al. 1982). Runoff occurs when the application rate of water, either through precipitation or snowmelt, exceeds the infiltration capacity of the soil. The infiltration capacity of the soil determines the amount, time, and space distribution of rainfall excess that is available for runoff and surface storage for a given storm (Haan et al. 1982).

Runoff generally is a small component of the hydrologic budget for arid and semi-arid climates such as RFETS (Figure 7.1). However, runoff is an erosive agent that causes soil detachment and transport, providing a potential mechanism for the spread of contamination. Therefore, although it is a small component of the hydrologic budget it can have significant effects on the fate and transport of soil and actinides and should not be overlooked.

Sediment yield, and the corresponding movement of contaminants, is limited by the transport capacity of the runoff. Therefore determining the rate, extent, and magnitude of runoff in the hydrologic budget can provide insight into the soil's erodibility and the potential for the spread of contamination. Rainfall can impart the kinetic energy necessary to detach soil particles and allow for the transport and redistribution of these detached particles by runoff. The slope steepness and the runoff rate determines the sediment delivery rate. Controlled experiments were developed and carried out during the summer of 1994 to determine the state of the system that yields runoff and the likelihood of the system to be in that state.

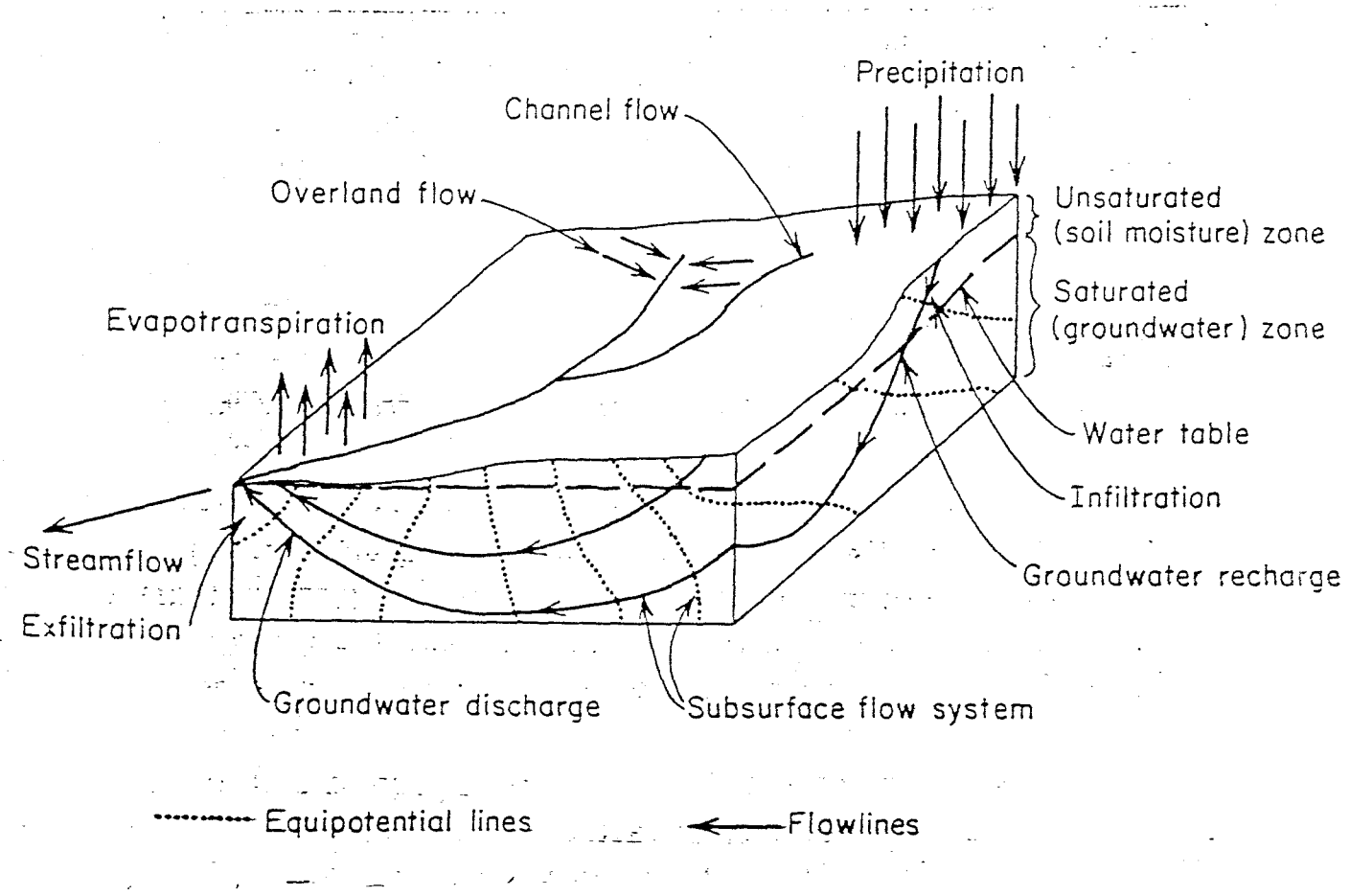


Figure 7.1. Hydrologic Cycle (Freeze et al.)

7.2 RAIN SIMULATION EXPERIMENTAL DESIGN

An overland flow study was designed and conducted during the summer of 1994 to examine the role of runoff and erosion processes in the transport and fate of actinides. The study was designed to meet the two following objectives:

1) To gain understanding of the hydrologic budget in the Americium Zone, characterizing the system response to a large rain event.

2) To determine the state of the system that yields runoff, and the likelihood of the system to be in that state.

A field investigation plan was designed to address the stated objectives during the summer of 1994. Rain simulation was used to stimulate the system to determine the extent, magnitude, and rate of runoff on many different scales. The experiments were designed to push the system to saturation, achieving a constant infiltration and runoff rate (Figure 7.2). Plots of varying sizes were used to measure the resulting runoff. The research study is broken into the following two main components an 1) Application System and a 2) Collection System, and discussed in further detail in these sections.

7.2.1 Application System

Rain simulation techniques were used to stimulate the system in a controlled manner. A rain simulator was used to apply water at a desired intensity, frequency, and duration in a manner similar to natural rainfall. The simulations allowed for the collection of a large amount of data over a relatively short time span. Data of this sort may have taken years to collect if dependent upon natural rain events. The simulations provided the control necessary to begin to reveal the relationship between runoff and rainfall.

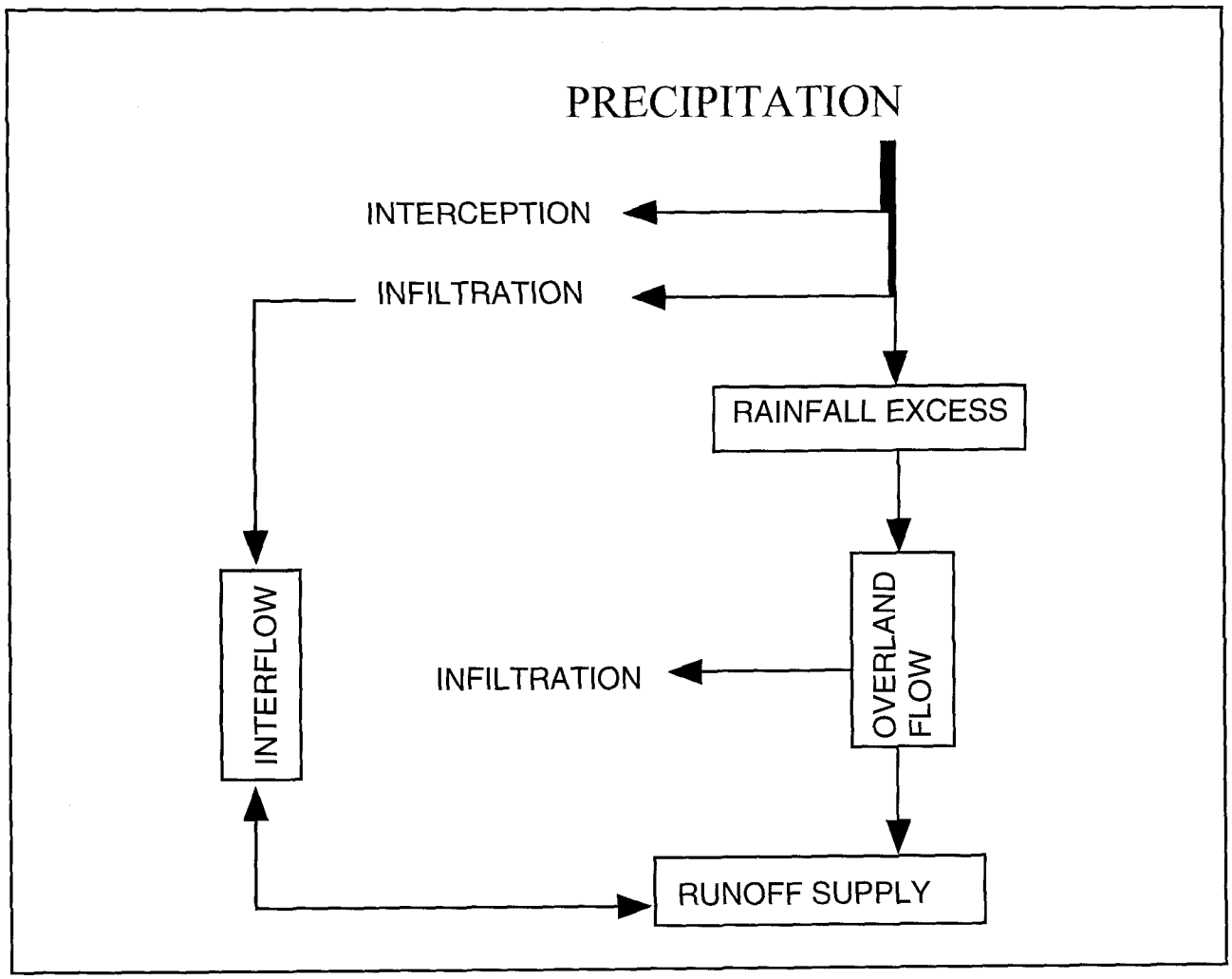


Figure 7.2. Hydrologic Budget. The figure depicts the response of the system to precipitation.

The rain simulator used during the 1994 field season was borrowed from Los Alamos National Lab (LANL). Using this simulator had the following advantages over the simulator used during the 1993 field season (The 1993 simulator is described in detail in OU2 Closure Soil Studies Scientific Notebook for the Rocky Flats Environmental Technology Site 1993):

1) The simulator had been used in many previous studies in climates similar to that existing at RFETS. This commonalty allowed for the integration of a considerable amount of information gained over the last 20 years.

2) The LANL simulator wetted a circular area with a diameter of 50 feet. The large area allowed for runoff to be collected from several plots simultaneously, and reduced the boundary effects felt and measured by the instrumentation.

3) The simulator produced drop-size distributions, impact velocities, and drop sizes similar to those of natural rainfall (Swanson 1979). The simulator produced rainfall energies at about 80% of natural rainfall (Nyhan et al. 1986).

The simulator (Figure 7.3) is trailer mounted with ten arms that extend 7.6 meters from a central rotating stem. Each arm has three nozzles that spray downward from an average height of 2.4 meters. The spatial distribution of rainfall over each plot was reported by LANL to have a coefficient of variation of less than 10 percent (Nyhan et al. 1986).

The three parameters that characterize rain events are duration, frequency, and intensity. Different combinations of these three governing parameters were applied to the system and the response was measured. The different combinations were used to simulate 100 year events or events with higher return periods. The desired combinations and state of each parameter was selected by using knowledge gained through previous studies and equipment limitations.

Intensity is the rate at which water is applied to the ground surface. Rainfall intensities of naturally occurring storms vary widely in time and space during most natural rain events. However even if variations in rainfall intensities during rainfall simulations could have been

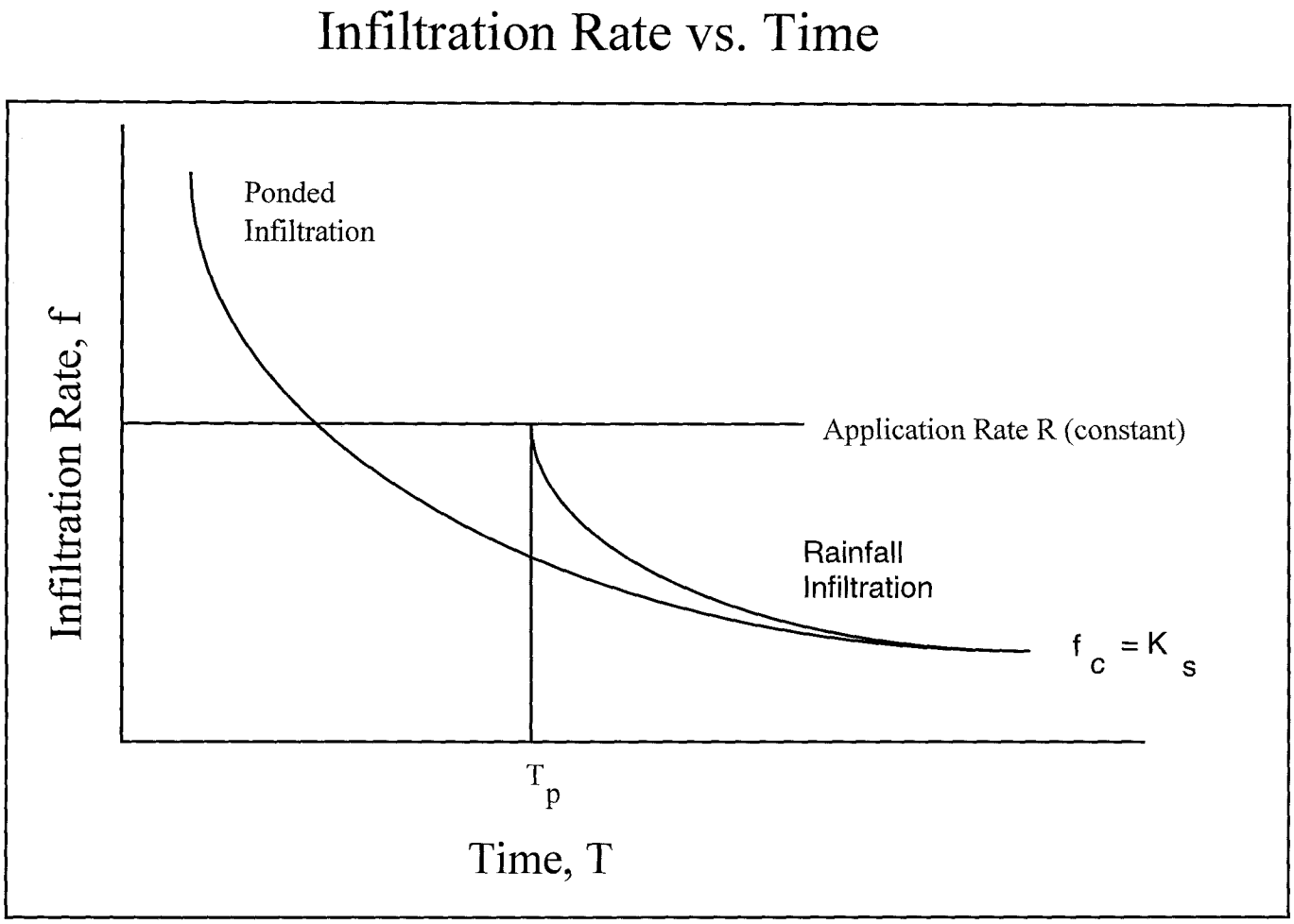


Figure 7.3. Infiltration Rates. The figure shows the theoretical response of the system to a constant rainfall rate. Tp, the time when ponding occurs, indicates when the system will generate runoff. After Tp the runoff rate is equal to the difference between the application rate and the rainfall infiltration rate.

produced, the selection of appropriate combinations of intensities and durations would have been a difficult if not impossible task. Likewise, interpretation and extrapolation of the data obtained from a simulated storm of intensities varying in time and space is arduous task. Also, the LANL rain simulator was only able to apply constant intensities of 60 and 120 mm/hr. For these reasons, a constant rate was applied to the area allowing for greater ease in the interpretation of the collected data.

The frequency of simulations, initially, was guided by the procedure successfully used by the USDA at semi-arid and arid sites. The procedure called for a series of three simulations a dry run, a wet run, and a very wet run. A rainfall of constant intensity was applied when the antecedent moisture conditions were considered "dry" during the dry run. Twenty-four hours after the dry run, a simulation, the wet run, was performed at a constant intensity. Finally a simulation, the very wet run, was performed shortly after the wet run. This series of runs was designed to push the system to saturation during the dry and wet runs. The very wet run was designed to yield constant infiltration and runoff rates.

Mostly dry runs were applied at the end of the field season, after analysis of the system's response to the USDA series of runs. More time was allotted between runs to allow the system to return to a more "natural" state. The goal was to simulate more realistic conditions to determine if the system responded to the single event in the same manner as it had to the series of events. Thereby preventing erroneous extractions and interpretations of the data to be made.

Information obtained during the rain simulation studies conducted during the summer of '93 was used to determine the durations. The durations were selected to force the system to saturation the dry and wet runs so that constant infiltration and runoff rates could be achieved during the very wet run. The durations were modified as the response to the simulations was seen.

7.2.2 Collection system

Plots of four different sizes were used to collect runoff.(Figure 7.4) The plots ranged in size from 1 to 350 sq ft. The differences in runoff rates obtained from these plots were due to scale effects. The four main factors that account for the differences in the rate of runoff collected from the different sized plots are listed below:

1) Vegetation type, season, and cover -

Effects: evapotranspiration and infiltration rates, kinetic energy imparted to the soil surface, and transport capability of runoff.

2) Antecedent moisture conditions -

Effects: Local saturation may allow for ponding and runoff depending on conditions adjacent to saturation area and the slope of the area.

3) Microtopography -

Effects: Runoff development and transport capacity of runoff.

4) Macropore density and distribution -

Effects: Infiltration rates and capacity.

7.2.3 Plot Design

The plots consisted of metal borders on the upslope and sides of the plot and a collection gutter on the downslope side (Figure 7.5). The metal borders were made of 1/8" thick 6" wide steel and were pounded into the ground a few centimeters, to assure that runoff was collected only from the plot area. A collection gutter was placed on the downslope side of plots. The collection gutter, capped at both ends with a 2 1/2 % slope, was inserted into the ground surface (Figure 7.6). Runoff collected in the deep end of the gutter and was collected every five minutes. The runoff was pumped out of the gutter, using a Gast MOA-P125-JH vacuum pump, into a graduated cylinder (Figure 7.6). The volume collected in the graduated cylinder was then recorded.

FIG 7.4

LOS ALAMOS RAINFALL SIMULATOR

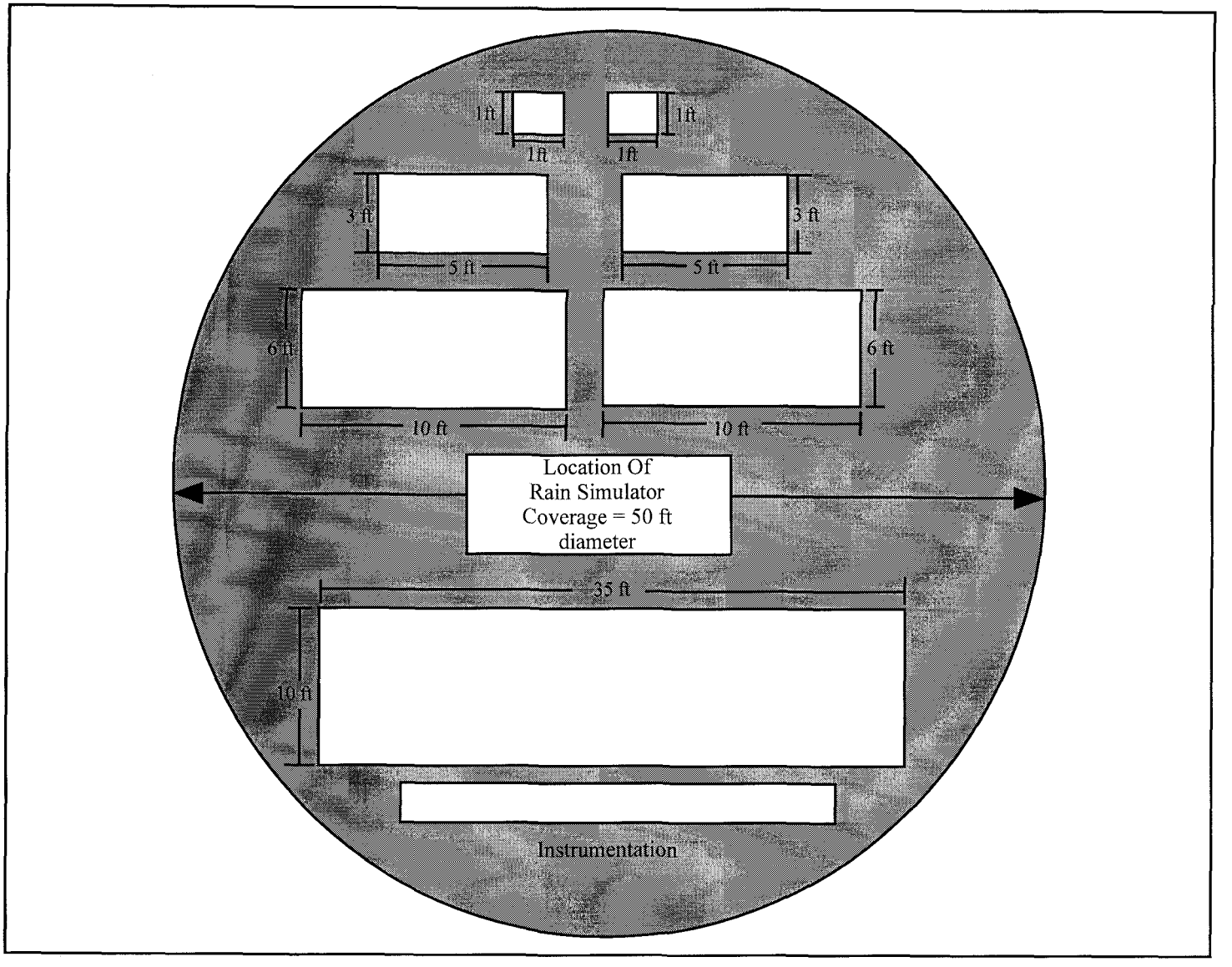
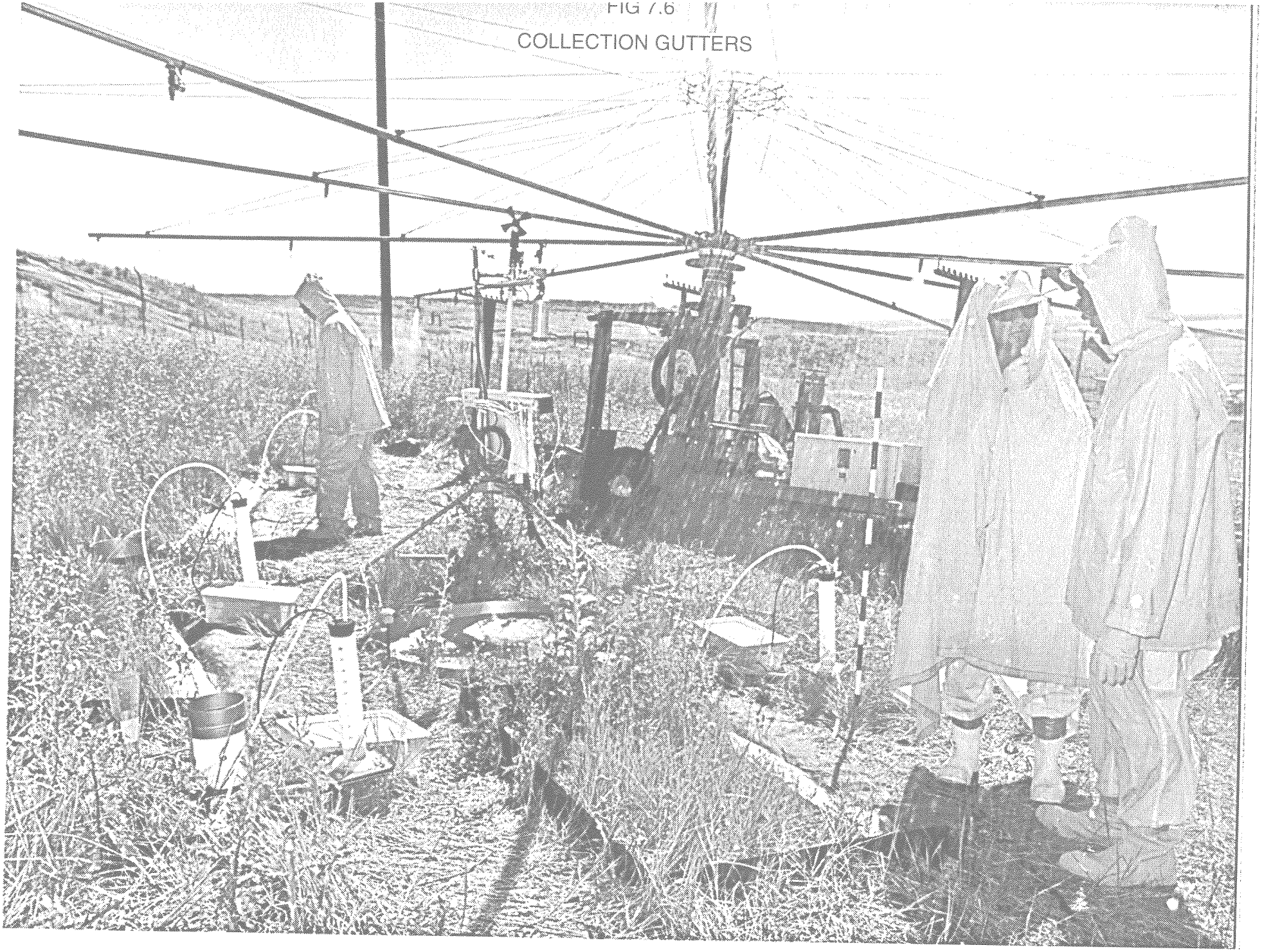


Figure 7.5 Expermintal Setup. The shaded area represents the area to which water was applied at an intensity of 60 mm/hr. The four different plot sizes and their location relative to the instrumented region of Trench 3 are sho in the figure.

FIG 7.6

COLLECTION GUTTERS



Plots of four different sizes were used to collect the runoff simultaneously. A 10 ft x 35 ft plot was located near the instrumentation on both trench 2 and trench 3. This plot size is the standard size used by the USDA in many of their erosion studies. Data collected from the large plot combined the effect of all the erosion processes and conservation measures in a single measurement. The large plot yields a measurement that is representative of the systems response on a field scale. The sizes of the other plots were 10 ft x 6 ft, 3 ft x 5 ft, and 1 ft x 1 ft. These small plots were designed to provide information about infiltration, detachment, and other factors influencing erosion.

The use of a range of sizes of collection plots allowed for a maximum amount of data to be collected. The smaller plots were designed to establish principles and primary factors that effect the infiltration-runoff relationship. The information gained from the small plots greatly assisted in the development of computer models. While the larger plot was used to gain an understanding of the erosion processes on a field scale, furnishing data that could be analyzed and formulated to determine the overall impact of future remedial activities.

7.2.4 Precipitation Monitoring Equipment

Eight TE525 Texas Instruments Tipping Bucket and six manual Tru-Check Rain Gauges recorded the precipitation. The information yielded by the rain gauges was used to determine if the application was uniform over the plot and the total accumulated artificial rainfall received by the ground surface. A tipping bucket rain gauge was placed at each plot. The eighth rain gauge was placed directly in front of the simulator The Tru-check gauges were distributed throughout the wetted area (Figure 7.7).

The automatic rain gauges were connected to a SDM-SW8A multiplexer, and wired to a CR-10 datalogger. The datalogger recorded the Julian day, Hour-minute, battery voltage, and the precipitation received by each of the rain gauges during five minute intervals. Appendix 7 contains

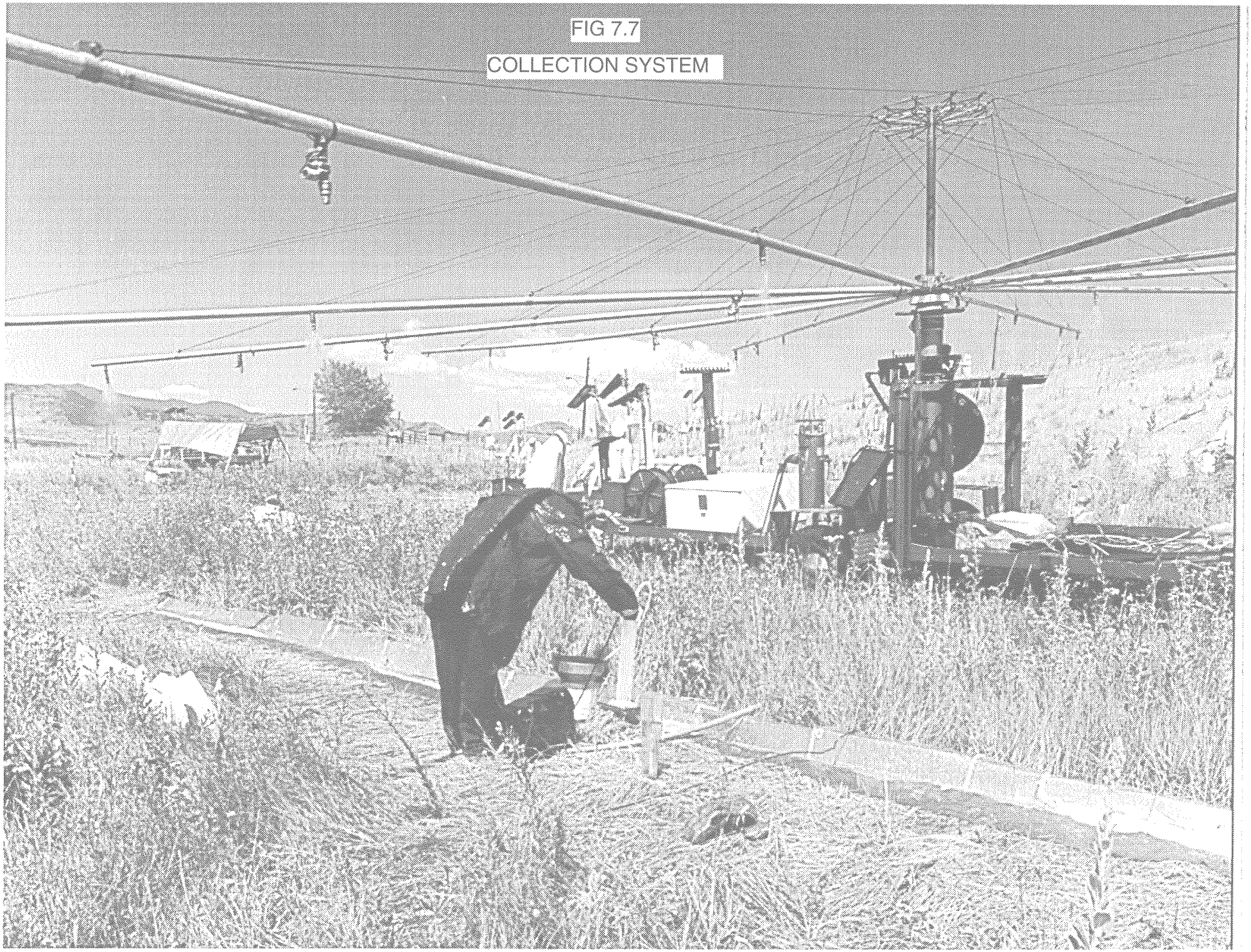


FIG 7.7

COLLECTION SYSTEM

the program written for the CR-10 to obtain and store the desired data. Data from the datalogger was automatically transferred to an SM716 Storage Module. The SM716 was removed from the field and downloaded weekly. The CR-10, SDM-SW8A, and the SM716 were all powered by an 18 Watt CSI Solar Panel.

7.3 SURFACE RUNOFF FIELD EXPERIMENTS

Rain simulations were performed from June 30 to November 11, 1994 During this time fourteen simulations were completed. Table 7.1 summarizes the time, location, and duration of the simulations.

Location	Day	Julian	Start of	Duration	Classification
Trench 2	6/29		8:05	55	Dry
Trench 2	7/1		10:42	55	Wet
Trench 2	7/1		1:00	55	Very Wet
Trench 2	7/7		7:30	60	Dry
Trench 2	7/8		10:00	60	Wet
Trench 2	7/8		12:00	50	Very Wet
Trench 2	7/18		7:50	60	Dry
Trench 2	7/19		7:28	60	Wet
Trench 2	7/19		10:28	60	Very Wet
Trench 2	7/22		10:28	60	Wet
Trench 2	7/28		10:03	60	Dry
Trench 3	11/7		3:13	60	Dry
Trench 3	11/10		2:55	30	Wet
Trench 3	11/11		1:47	60	Very Wet

Table 7.1. Summary of the events and location of the simulations.

The daily tasks performed before, during and after the rain simulations were:

- Preparation of field data sheets
- Four 2000-gallon water tanks were filled using a 1600-gallon water truck
- Collection gutters were cleaned of sediment and debris
- Tensiometers were filled 2 hours previous to simulations
- Piezometer levels were measured (automated later in the summer)
- Tru-check gauges, automated rain gauges, and graduated cylinders were leveled
- Simulator was adjusted to ensure that all the arms were on average eight feet above the ground surface
- Weather conditions were recorded
- Rain simulation was performed at the design intensity and duration
- The vacuum pumps were activated every 5 minutes
- The volume collected in the graduated cylinders was recorded every 5 minutes
- The piezometer levels were recorded
- The depth of water in the six tru-check rain gauges was recorded
- The information from the automated rain gauges was downloaded

Appendix 6 contains the the raw data gathered during the fourteen simulations. The Appendix contains the volume of runoff for each of the plot recorded every five minutes, and the associated runoff intensity. It also contains the depth of rainfall collected during the simulations.

7.4 SURFACE RUNOFF PROBLEMS AND SOLUTIONS

Most of the difficulties experienced during the summer of 1994 pertained to the runoff collection system. Unfortunately, the collection design used by the USDA could not be employed at RFETS. The USDA inserts a 14" metal plated against the end of the collection plot. The collection gutter is attached to this end plate. The gutters slope downward towards the center of the plot and feed into a Parshall flume which records the height water flowing through the flume (Figure 7.9). This setup was unfeasible for the RFETS simulations for the following reasons:

1) The USDA collection system requires a considerable amount of soil to be removed for each plot. The set up of the seven plots for the RFETS would have required an extreme amount of soil removal, unfeasible in a Radiologically Controlled Area.

2) The location of the Parshall flume in the USDA collection system is outside of the area of application. With the use of seven plots most of the flumes would be within the area of application making it extremely difficult to ensure the integrity of the runoff data.

3) The USDA collection system uses a 10 foot long solid metal plate inserted 14" into the ground surface to ensure that the collection gutters are only capturing overland flow. The topography of the Americium Zone varies too greatly to allow for the effective use of a solid metal plate. The plate would not prevent collection of interflow. Also, the solid impermeable plate would not allow for representative data to be collected due to the extreme disturbance in the hydraulic conductivity of the soils.

The USDA collection system was modified to better suit the environment existing at RFETS. The lip of the collection gutter was placed flush against the soil surface. Triple expanding foam was used to achieve good hydraulic connection between the soil surface and the

collection gutter. The foam was also used as an impermeable barrier to prevent interflow from exposed areas. Covers were fabricated to be fastened to the top of the gutter to prevent the simulated rain from entering directly into the gutter and being inaccurately measured as runoff.

Many modifications were made to the system over the course of the 1994 summer to reduce leakage and increase the accuracy of the data collected. The problems encountered and the solutions generated to help correct the deficiencies are summarized below:

1) Problem: Before any simulations were performed it became apparent that there was not good hydraulic conductivity between the collection gutters and soil surface.

Solution: The gutters were lowered allowing the lip of the collection gutter to be inserted into the soil surface instead of being flush with it so that the lip of the runoff from flowing in between the soil and the gutter.

2) Problem: Simulated rain was entering directly into the collection gutters and being measured as runoff.

Solution: The covers on the gutters were extended by 4 - 6 inches.

3) Problem: The vegetation was serving as a direct path for simulated rain to wick down and enter directly into the collection gutters.

Solution: The vegetation close to the gutter was clipped.

4) Problem: When the system became saturated, water was leaking from behind and from the sides into the gutters.

Solution: Approximately eight to twelve inches of clear corrugated plastic was placed over the collection gutters.

5). Problem: The collection gutter collected interflow as well as overland flow. Very difficult to determine the contributions from each of these components.

Solution: Chicken was fastened to the exposed soils. Triple expanding foam was sprayed onto the chicken wire serving as an impermeable barrier.

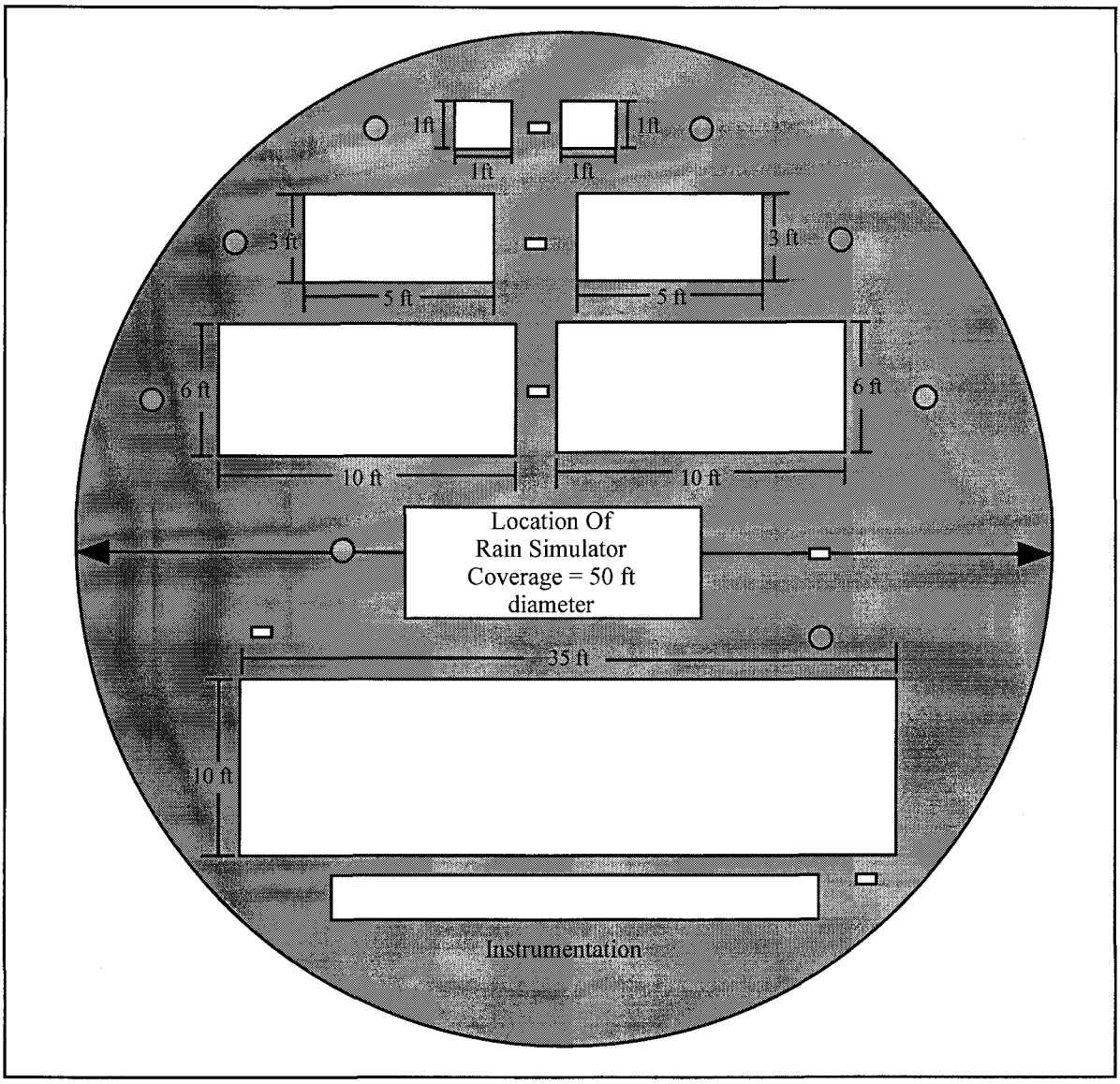


Figure 7.8 Rain Gauge Location. The figure shows the location of the rain gauges used to measure the amount of rainfall at the ground surface. The square synbols show the location of the tru-check manual gauges while the circular symbols show the location of the tipping bucket rain gauges.

8.0 EVAPOTRANSPIRATION

8.1 PRINCIPLES OF EVAPOTRANSPIRATION

Evapotranspiration (ET) is the combination of two water loss processes: evaporation and transpiration. Evaporation is surface water lost to the atmosphere that is converted from liquid or solid state to vapor; transpiration is the vaporization of water through the stomata of living plants. Because these two processes are very difficult to separate in the soil-plant-atmosphere interface, they are lumped together in the term evapotranspiration. Evapotranspiration rates are classified into actual and potential rates. Actual ET, usually referred to simply as evapotranspiration, is the true rate at which ET occurs in the field. According to Granger (1989), potential ET is defined by "the atmospheric conditions and the saturation vapor pressure at the actual surface temperature, and which represents an upper limit to evaporation from a moist surface." Hence, it is an optimum, theoretical rate which is always greater than or equal to actual ET.

In 1801, Dalton showed that the rate of evaporation from a water surface is proportional to the difference between the vapor pressure at the surface and the vapor pressure in the overlying air (Calder, 1990). Evaporation is limited by the rate of diffusion of vapor away from the water surface, and in still air the vapor-pressure difference becomes small. In a turbulent environment caused by wind and thermal convection, the vapor is transported away from the surface allowing evaporation to continue (Linsley and Franzini, 1979). Thus, the rate of evaporation is controlled by the available energy to vaporize the water and wind to carry the vapor away. For a pound of water at 70° F, 1054 Btu (585 cal/g @20° C) are required for evaporation; this is the latent heat of vaporization (Brutsaert, 1984).

In order to understand the importance of ET, one needs to look no further than the hydrological cycle. Water falls to the earth as precipitation which can either percolate into the ground or become surface water that eventually runs into the ocean. Evapotranspiration of water from the ocean and land will resupply the atmosphere with the moisture necessary for precipitation, thus completing the hydrological cycle. In fact, 75% of all water which falls on land is evapotranspired back into the atmosphere (Dick, 1988). By understanding the components that comprise this cycle, soil scientists at RFETS can better determine the fate and transport of contaminants in the soil matrix.

Evapotranspiration occurs in two areas: recharge and discharge areas. In a recharge area, actual ET is typically lower than potential and is limited by water availability. In a discharge area, where upward-rising groundwater provides a continuous moisture supply, actual ET is close to potential and in some cases may even exceed precipitation rates depending on the available water supply (Freeze, 1979). At RFETS, the dominant ecosystem is short grass prairie where actual evapotranspiration typically is below potential rates.

Available water is the range of soil moisture between the wilting point and field capacity (Linsley and Franzini, 1979). The wilting point designates the water content which remains after plants growing in the soil have removed as much water as is possible. It is closely indicated by the moisture retained against a tension of 15 atmospheres (Linsley and Franzini, 1979, Ritchie, 1981). Corey (1990) defines field capacity as the water content in a soil profile after downward drainage has become very slow following a thorough wetting. The ET study will be closely linked with the Time Domain Reflectometry (TDR) soil moisture study to find a correlation between ET rates and soil moisture.

8.2 Objective of Evapotranspiration Study

To fully assess the fate and transport of the actinides in the vadose zone, a complete data set must be collected on all aspects of the hydrologic budget including evapotranspiration. The objectives of the evapotranspiration study are to:

- quantify microclimatic characteristics as they relate to estimating evapotranspiration rates,
- estimate evapotranspiration rates,
- develop a relationship between evapotranspiration and microclimatic characteristics,
- develop a computer model that will calculate evapotranspiration rates from climatic characteristics using the Bowen Ratio Method,
- compare actual evapotranspiration to potential evapotranspiration rates, and
- develop relationships between evapotranspiration and soil moisture.

The data for this study was collected in late 1994 and all of the 1995 growing season in the OU 2 Americium Zone and contributes to a broader study that ultimately will determine the fate and transport of actinides in vadose zone soils at the Rocky Flats Environmental Technology Site.

8.3 METHODS OF DETERMINING EVAPOTRANSPIRATION

In the last twenty years, great advances have been made in determining evapotranspiration rates. These advances, however, are due to improvements in technology and not to refinements in evapotranspirative theory (Dick, 1988). As electronic measuring devices such as load cells and micrometeorological stations improve their accuracy, response time, and energy requirements, the ability to accurately measure evapotranspiration improves dramatically. Further, as prices decrease, more researchers are able to use these instruments in varying experiments leading to an improved refinement in measuring techniques.

In order to understand the relationship between soil moisture and evapotranspiration, one must first understand how ET is measured. By understanding the limitations of the varying ET measurements, one can better assess the validity of experiments done by researchers. Each of the three dominant methods for determining ET is based on the current theories and equations explaining ET and, hence, is only as valid as the theories and instruments used to collect data.

8.3.1 Micrometeorological Station

Micrometeorological (micromet) stations are used to gather the climatic data necessary to calculate evapotranspiration rates. As electronic instruments become less expensive and more reliable, micromet stations are more commonly used by agriculturists interested in irrigation and environmental engineers interested in contaminant fate and transport (Fritschen, 1994). Combination equations (e.g. Penman, Penman-Monteith, etc.) are often used with micromet data to determine potential ET (van Bavel, 1966). Equations such as the Bulk Transfer Method, Eddy Correlation Method, and the Bowen Ratio Method require higher frequency and more advanced instruments to collect data, but can be used to measure actual ET (Fritschen, 1979). The Bowen Ratio Method will be used with the micromet station data to determine ET rates in the OU2 Americium Zone.

The Bowen Ratio Method is based on the surface energy budget as given by,

$$R_n - G - H - L_e = 0 \qquad \text{Equation 8.1}$$

where R_n = net radiation for the surface,

G = the total soil heat flux,

H = the heat flux density, and

L_e = latent heat of vaporization.

The Bowen Ratio, β, is defined as the ratio of sensible to latent hear fluxes at the surface:

$$\beta = Q_H/Q_E = [PC_p(T_1 - T_2)]/[\lambda_\varepsilon (e_1 - e_2)] \qquad \text{Equation 8.2}$$

where PC_p/λ_ε = the psychrometric constant ≈ 0.0004,

Q_H = sensible heat flux,

Q_E = latent heat flux,

T_1 and T_2 = temperature profile at two levels, and

e_1 and e_2 = vapor pressure profile at two levels.

By combining Equations 8.1 and 8.2, one can solve for L_e:

$$L_e = [R_n - G]/[1 + \beta] \qquad \text{Equation 8.3}$$

Measurements of net radiation, soil heat flux, temperature and vapor pressure at two elevations are required to solve for sensible and latent heat flux. Typically, the Bowen Ratio is smaller for moist surfaces where most of the energy goes into evaporation, and larger over dry surfaces where most of the energy goes into sensible heat. For semi-arid regions, β is roughly 5, for grasslands and forests it is 0.5, and for irrigated orchards and grass it is 0.1.

8.3.2 Evaporation Pan

Evaporation pans are used to determine the rate of evaporation from a free water surface. Data from evaporation pans indicate the atmospheric evaporative demand of an area and can be used to estimate potential evapotranspiration rates by combining soil evaporation and plant transpiration rates (Goodridge, 1979). By using appropriate predetermined constants, potential evapotranspiration of vegetation can be estimated (Pruitt, 1966). Snyder (1992) developed an equation that converts evaporation pan data to evapotranspiration rates by incorporating relative humidity, mean daily wind, upwind fetch of low-growing vegetation, and pan evaporation rate. Typically, the rate of evapotranspiration for short vegetation such as short grass prairies, and meadows is exceeded by the pan evaporation rate, but for forests, the ET rate can exceed the pan evaporation rate (Phene, 1975). The major factors that affect the rate of pan evaporation are:

- Type of pan,
- Pan environment,
- Method of operating the pan,
- Exchange of heat between pan and ground,
- Solar radiation,
- Air temperature,
- Wind speed, and
- Temperature of the water surface (Jones, 1991).

The United States National Weather Service (USNWS) uses the Class A evaporation pan as its standard evaporation pan (Doeskin, 1994). It is a galvanized iron cylinder with an inner diameter of 121 cm and a depth of 25.4 cm mounted on a platform at least 5 cm above the ground and is commonly used throughout the United States for irrigation and research purposes (Begg, 1994). The water level in the pan is constantly maintained at 20.3 cm and kept free of algae and other contaminants.

8.3.3 Lysimeter

The most effective and accurate way to directly measure actual evapotranspiration rates is with a lysimeter (Duke, 1994, Schneider, 1994, 1993, Howell, 1991, Marek, 1988). A lysimeter is a large block of soil and vegetation that is isolated from the soil matrix and placed on either a hydraulic weighing device or an electronic load cell. The walls of the lysimeter are typically sealed so that water flux can only occur through the top and bottom of the soil block. The change in weight of the lysimeter corresponds to the water input (from precipitation and irrigation) and output (from evapotranspiration). A larger lysimeter will produce more accurate results by reducing scale and edge effects. The surface area for accurate lysimeters ranges from 1 square meter (van Bavel and Meyers, 1962) to over 29 square meters (Pruitt and Angus, 1960). A truly representative lysimeter will mimic surrounding field conditions including micrometeorological parameters, soil type, hydrologic conditions, and vegetation (Aboukhaled, 1982).

The flux of incoming and outgoing water can be represented in the following water balance equation:

$$P + I \pm R_o = ET + D + \Delta S \qquad \text{Equation 8.4}$$

where P = Precipitation coming in

I = Irrigation coming in

R_o = Surface Runoff resulting in either inflow or outflow

ET = Evapotranspiration going out

D = Drainage going out

ΔS = Change in storage of soil water

8.4 EVAPOTRANSPIRATION INSTRUMENT INSTALLATION

There are three separate instruments used to determine ET: a micromet station, a weighing lysimeter, and a Class-A Evaporation Pan. The locations of these instruments are shown in Figure 8.1, Evapotranspiration Instrument Location.

8.4.1 MICROMET STATION

The micromet station is used to monitor both evapotranspiration and snowmelt, thus saving money and labor. Since the two studies are done at different times of the year, there is little overlap in use of the station.

For a discussion on the components comprising the micromet station, see Section 4.10 of the OU 2 Closure Soil Studies Scientific Notebook for The Rocky Flats Environmental Technology Site, document number RFP/ERM-94-00021. The micromet station is centrally located in the Americium Zone study site and is shown in Figure 8.1.

8.4.2 CLASS-A EVAPORATION PAN

The standard Class-A, National Weather Service evaporation pan system consists of components distributed by NovaLynx Corporation in Grass Valley, California. The evaporation pan (Model 255-200) is coupled with micrometeorological instruments that measure wind speed and direction(Model 220-200), ambient air temperature (CSI, Model 107B), pan water temperature (Model 230-201), and relative humidity (Model 230-504) all within a 3 meter radius. To minimize the effects of solar radiation, the relative humidity gauge is covered with a radiation shield(Model 230-281). Manufacturer specification sheets for the evaporation pan components and the related micrometeorological instruments are in Appendix 9, Evapotranspiration Instrument Manufacturers Specifications.

Figure 8.1
Evapotranspiration Instrument Location

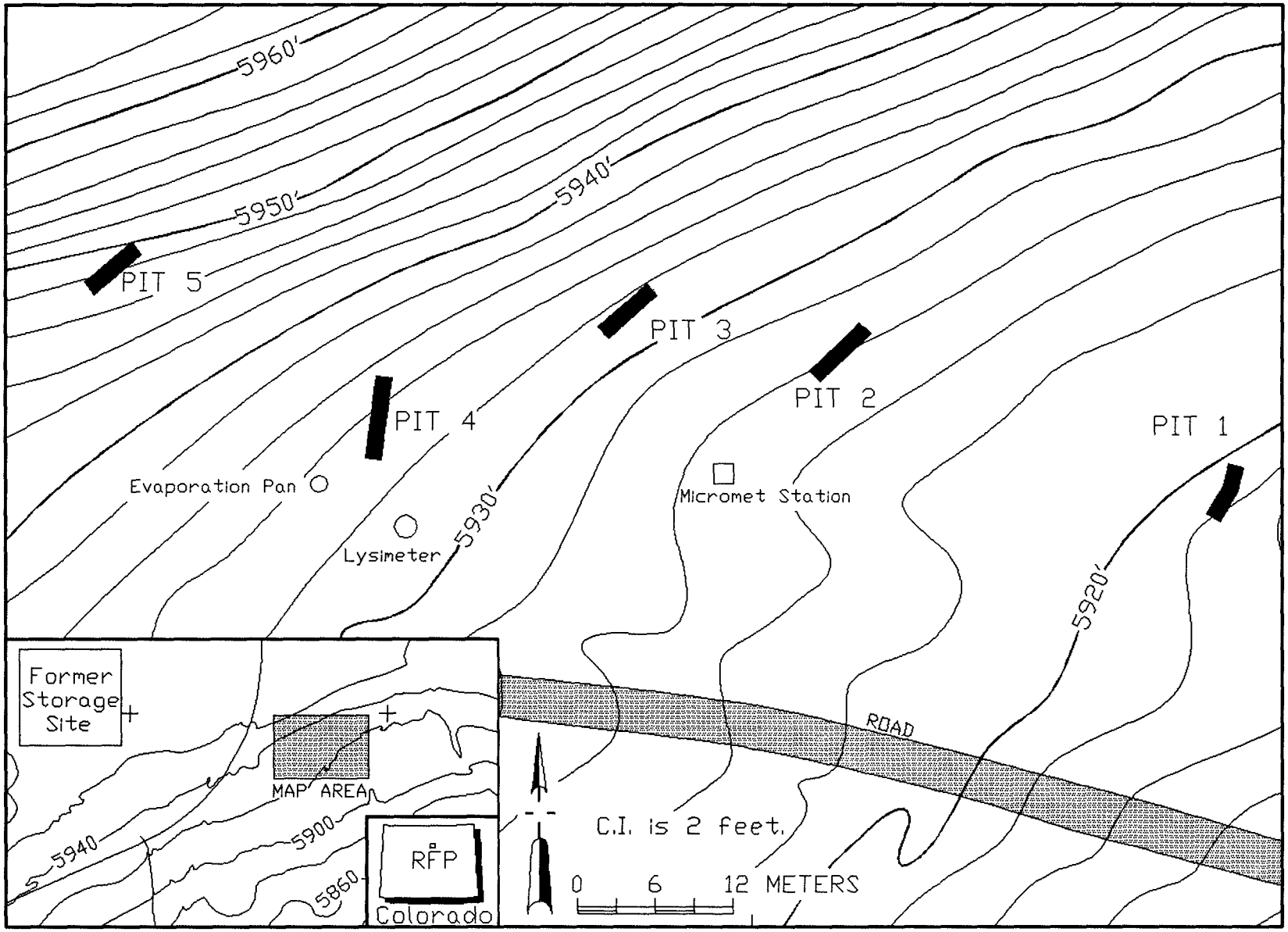


FIG 8.2

CLASS-A EVAPORATION PAN SET-UP

The evaporation pan is south of pits 4 and 5 on a level, grassy area free from shadows and obstructions. It rests on a wooden platform eight inches above the ground to minimize thermal conductance with the surface. The pan is checked at least once a month for leaks and irregularities. Insects and algae are cleaned from the pan as necessary - in the summer months, this is a daily chore. When freezing weather approaches, the pan is drained, cleaned, and secured upside down to the platform.

An automated evaporation gauge is connected to the evaporation pan via a three foot section of 1/2" diameter pipe (Model 255-150). The gauge rests on a customized wooden platform that has telescoping base supports which adapt to the contours of the surface. Once a month, the inside of the evaporation gauge housing is cleaned of insects, algae, and other debris that may accumulate.

8.4.3 WEIGHING LYSIMETER

The monolithic, electronic weighing lysimeter weighs approximately 550 kilograms and is one meter in diameter and 46 centimeters deep – a depth that fully includes the typical root zone of plants found at the site. The lysimeter is designed to allow only vertical water movement through the top and bottom due to precipitation and infiltration. All water that infiltrates through the soil monolith is collected in a 4-liter collecting bottle that can be pumped through a tube connected to the bottom of the bottle. A tube attached to the top of the bottle as shown in Figure 8.3 can be used to apply a negative pressure in the bottle and hence throughout the soil monolith to draw moisture out of soil pores at increased matric potential.

The bottom one inch of the soil monolith is a layer of 30-mesh sand which helps to even soil moisture and matric potential. It also provides a buffer between the lysimeter baseplate and the uneven bottom of the soil monolith. To prevent sand from entering the collecting bottle, a customized screen was designed to hold back the sand while still allowing water to freely flow through the mesh. Four 7" x 1" aluminum slats were used to frame a square layer of thin, medium, and heavy duty screening. The heavy duty screen (6 squares per inch) protected the light (100 squares per inch) and medium screen (35 squares per inch) from protruding rocks and soil chunks. The medium screen served as a buffer between the light and heavy duty screen. Laboratory tests show that the screen effectively blocked out the sand while allowing water to freely flow.

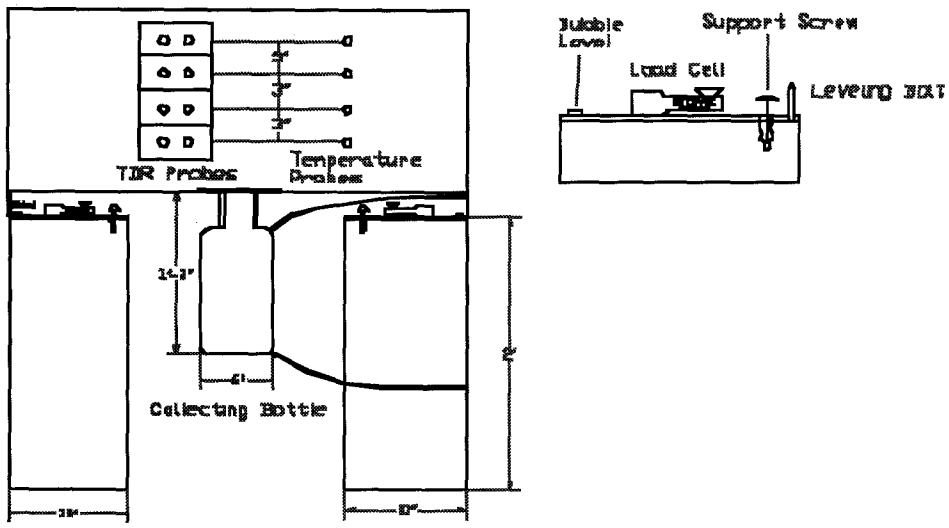


Figure 8.3
Evapotranspiration Lysimeter Detail

A two foot radius around the monolith was excavated by hand to a depth of 44 inches. The soil excavated from around the monolith was placed in one of two 4' x 8' x 2' wooden containers; one container stored soil from the A Horizon and the other container stored soil from the B Horizon. Soil was placed into these containers to aid in the restoration of the site and to prevent the possible spread of radiological contamination due to wind.

As excavation around the monolith continued, a 38" diameter by 18" deep, 18-gauge sheet metal lysimeter shell was snugly pushed around the soil monolith to help keep the soil structure intact. The shell was initially pushed down by hand, but as the depth increased, the shell had to be hammered into place. The shell was pushed down to 14 inches and then the 4'-2" steel channels were inserted under the monlith as shown in Figure 8.4.

Seven steel channels were pushed under the monolith with the aid of a horizontal boring tool and a hydraulic jack. The boring tool drilled 2" diameter holes under the length of the monolith in the hard-packed clay soil. This reduced the amount of soil that the channels had to push through and also provided a "path of least resistance" guide for the channels to follow. Two parallel holes were drilled for each of the seven channels. The channels were pushed through the guide holes with a hydraulic jack that was anchored against the excavation walls. The channels were spaced two inches apart and bolted to a cross channel on each end, forming a frame that was

Figure 8.3

Evapotranspiration Lysimeter Detail

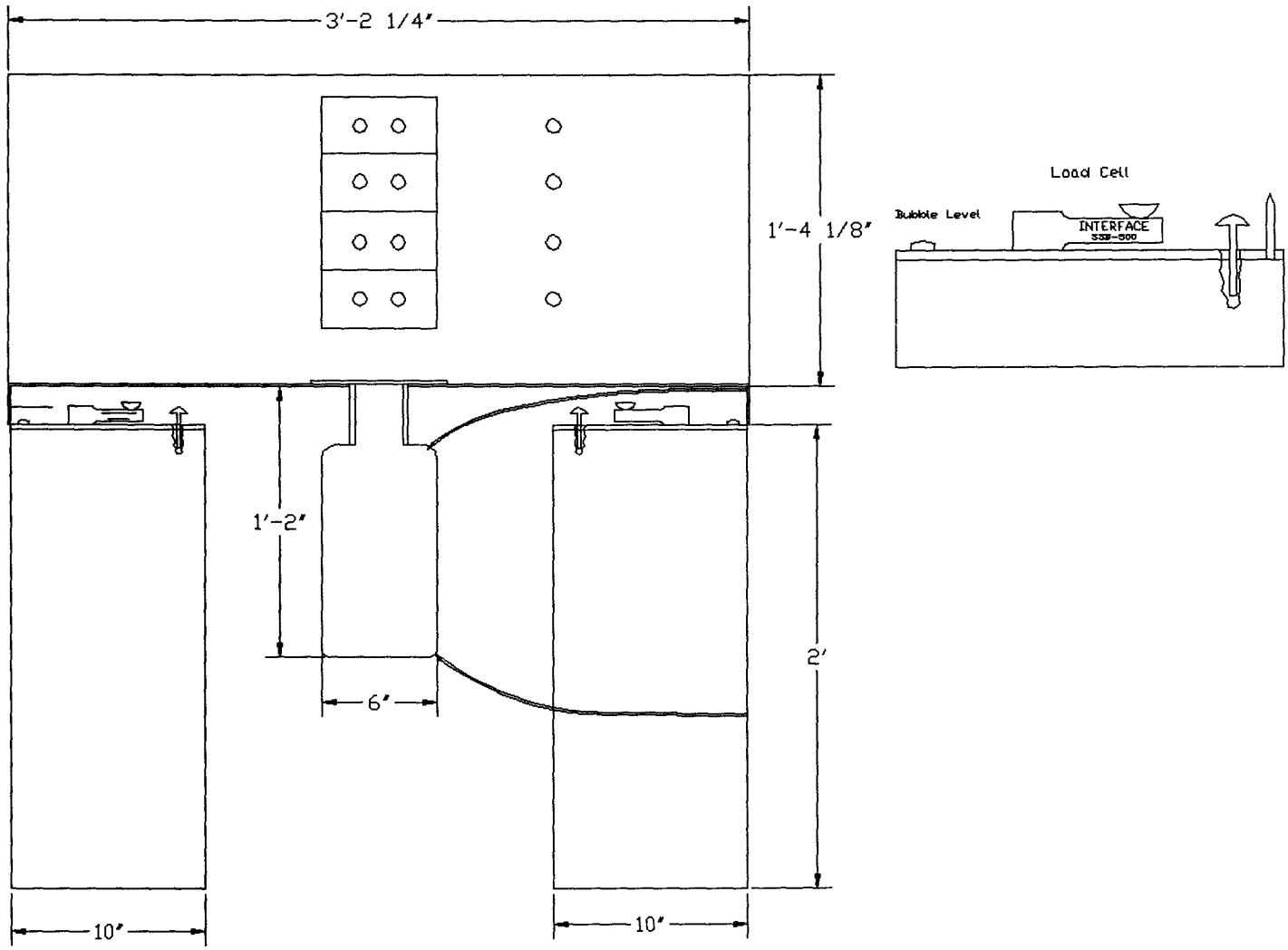


FIG 8.4

used to lift the monolith out of the hole. Two 12,000 pound capacity lifting straps were cleviced onto one inch eyebolts that were fastened to the four corners of the frame.

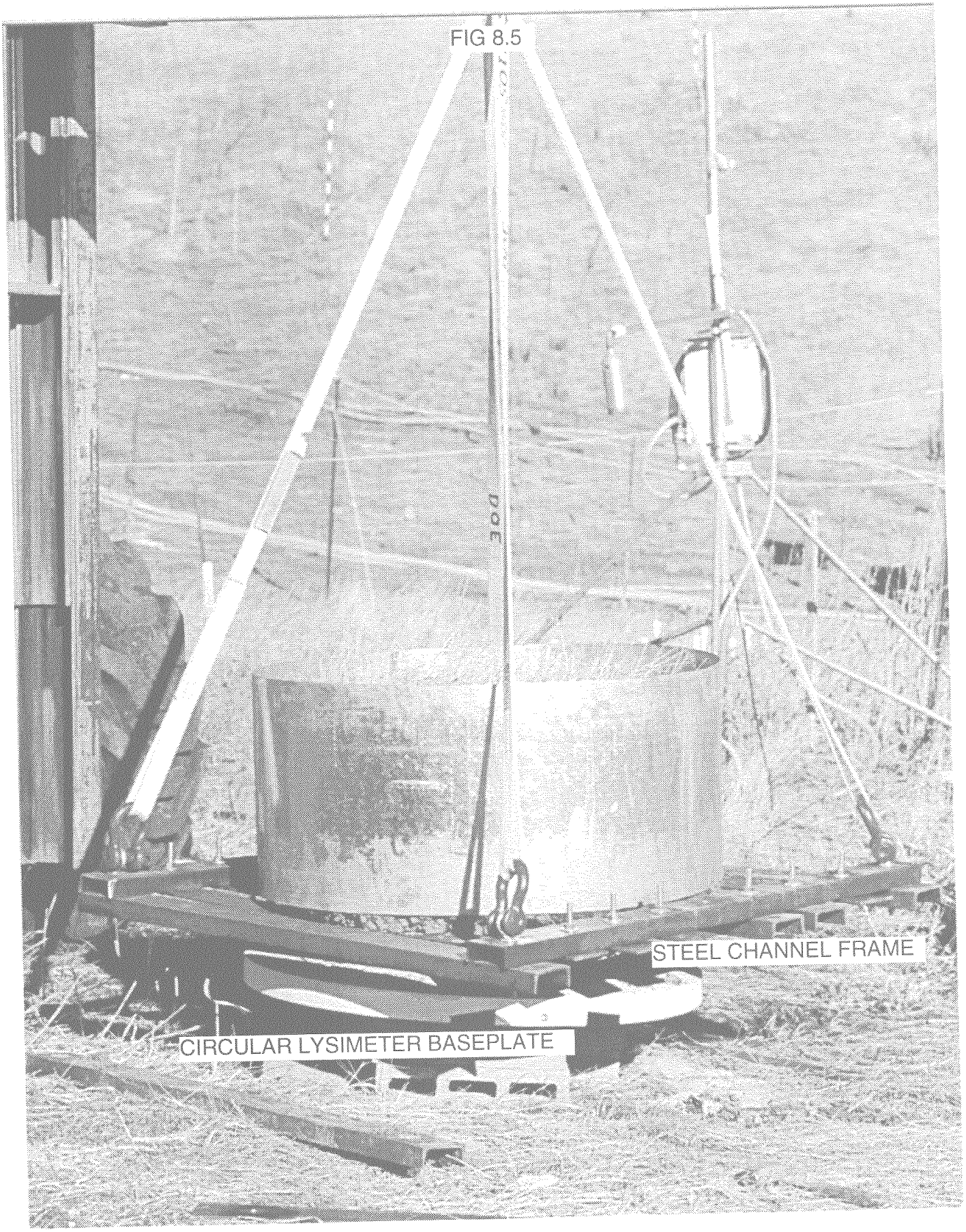
A forklift mounted with a lifting boom hoisted the monolith from the hole onto the circular baseplate at the staging site as shown in Figure 8.5. The baseplate was elevated one foot above the ground with cinder blocks to ensure that the drainage apparatus underneath the monolith would not be damaged. Elevating the baseplate also aided the placement of the lifting straps in the slotted baseplate.

After the monolith was carefully centered over the baseplate, the shell was pushed down over the baseplate lip and tightened with one 1"-wide strip of Band-It. The sections of the metal shell that covered the slots cut in the baseplate lip were cut back and removed to fully expose the openings for the lifting straps. These six openings provide a secure slot for the three lifting straps so that the monolith can be safely hoisted to a new position. Also, the entire metal shell was wrapped with a layer of foil and bubble insulation to reduce thermal variations and hence, to reduce the possibility of soil cracks and fractures.

The lysimeter rests on three Interface SSB-500 load cells capable of measuring up to 500 pounds each. The specifications from the manufacturer and the laboratory calibrations are located in Appendix 9. Each load cell is bolted to a 1/4" thick aluminum plate that is anchor bolted into a 24" concrete support as shown in Figure 8.6. The load cells are designed for outdoor use and can withstand temperature and moisture variations. Although temperature affects the output of the load cells, the offset and multiplier are fully characterized in the manufacturers data sheet. The SSB-500 load cells are accurate to within 0.03% and have the best weight-to-accuracy ratio among commercially available load cells.

Since a plane is determined by three points, the weight of the lysimeter is easier to equally distribute among three supports than four or more. For example, it is easier to build a three-legged stool that balances than a four-legged chair that balances. Because the limiting number of load cells used to measure the weight change of the lysimeter is three and the load cell with the best weight to accuracy ratio is the SSB-500, the total load limit is 1500 pounds (680 kilograms). Further the rhizosphere, or root zone, of the vegetation does not significantly extend deeper than 35 centimeters. With the maximum load of the lysimeter and the depth of the monolith known, it is a simple calculation to determine the area of the monolith. Assuming 30% soil porosity and a specific gravity of solid soil equal to 2.65, the monolith diameter must be one meter. Figure 8.7 shows the plan and elevation views of the lysimeter.

FIG 8.5



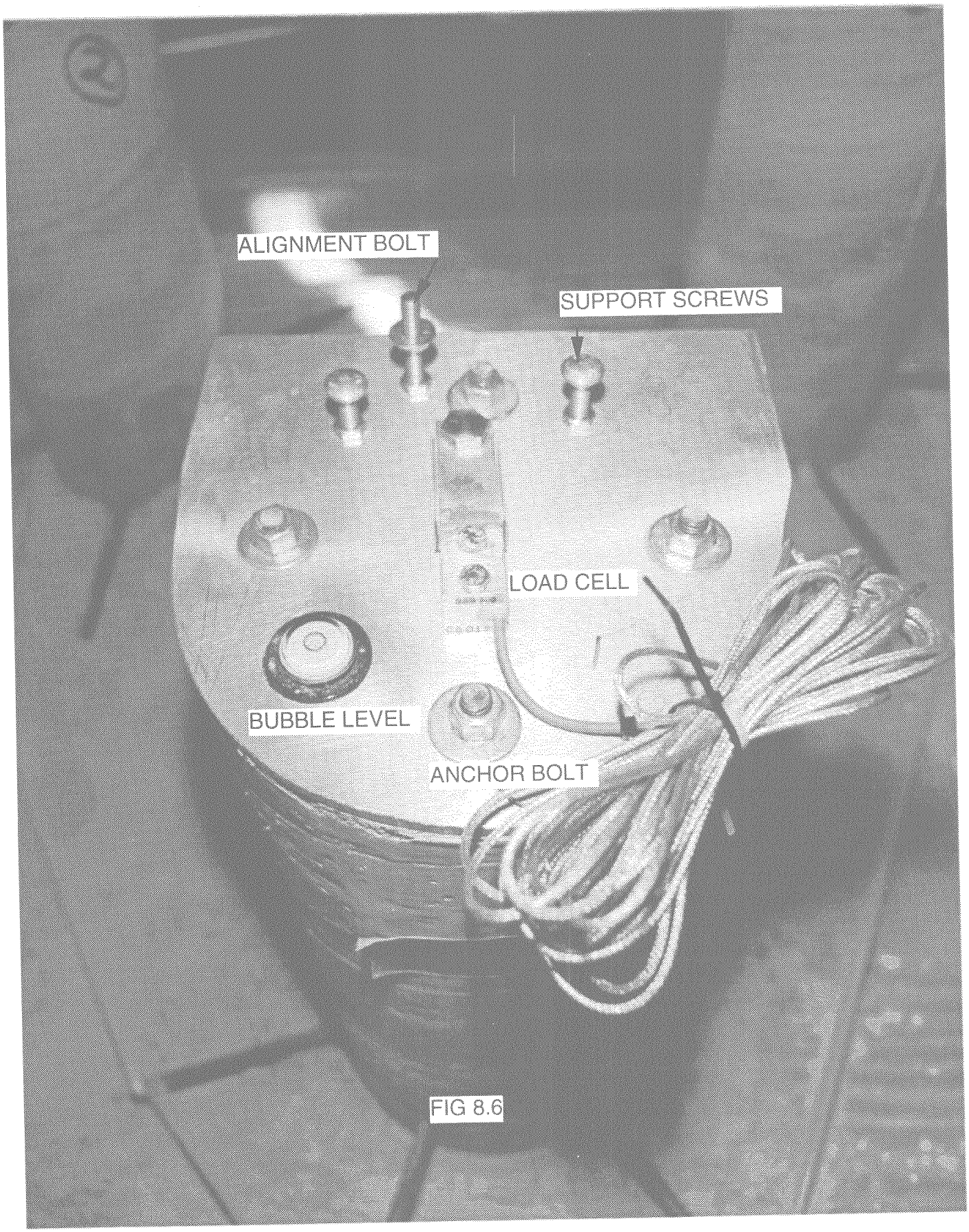
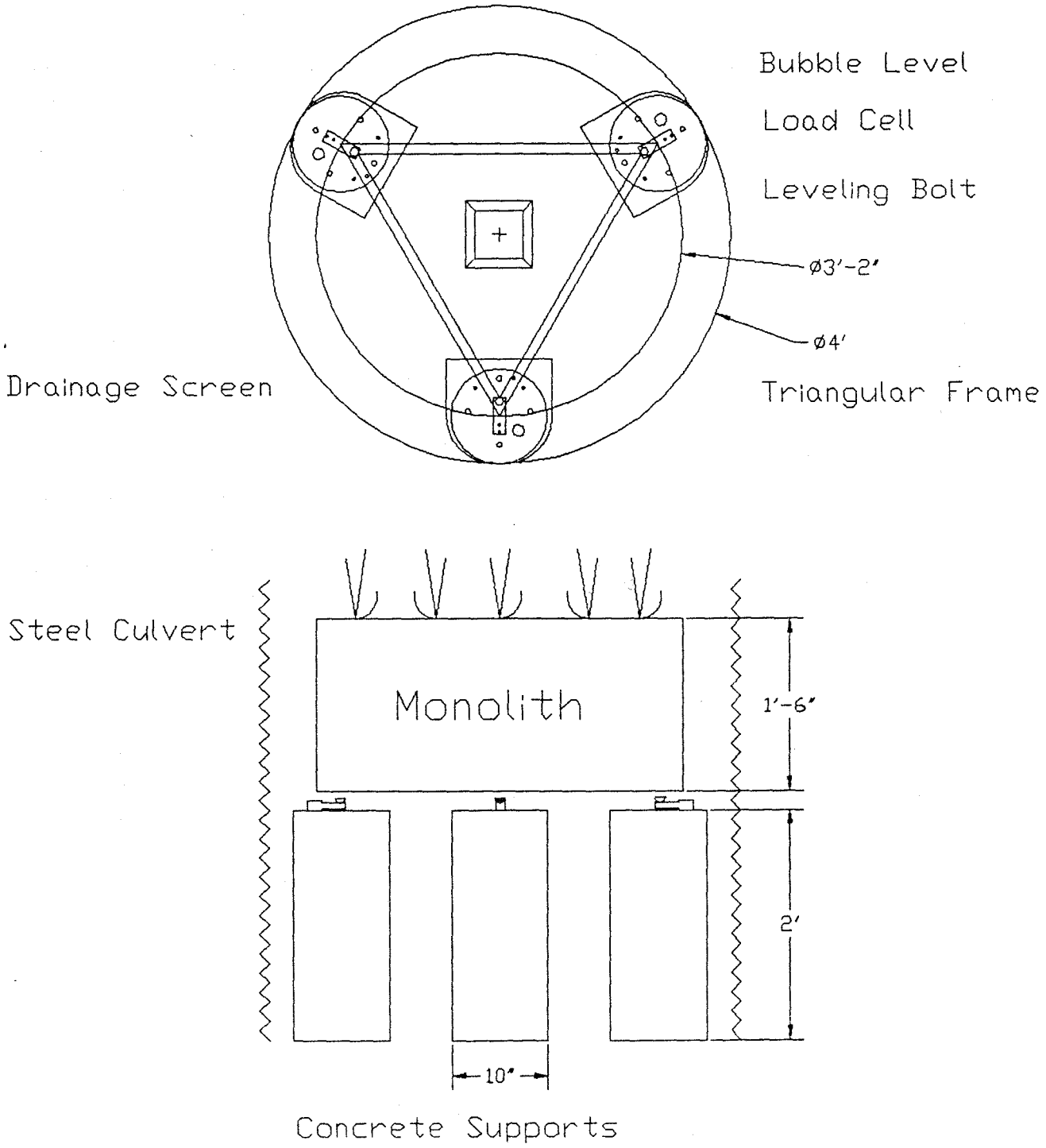

ALIGNMENT BOLT
SUPPORT SCREWS
LOAD CELL
BUBBLE LEVEL
ANCHOR BOLT

FIG 8.6

Figure 8.7
Lysimeter - Top and Plan View



Before the concrete supports and triangular frame were brought out to the field, they were first marked and calibrated in the laboratory. Figure 8.8 shows the sandbox used to align the equipment to ensure that the weight is properly distributed between the load cells. First, each of the concrete supports had to be leveled and then the triangular frame had to be leveled on top of the supports. By using sand, it was easier to move the concrete supports both horizontally and vertically into their final position.

Time domain reflectometry (TDR) probes will measure the change in soil moisture of the lysimeter. The manufacturers specifications for the TDR probes are in Appendix 9. These probes are identical to the type used throughout the rest of the Americium Zone study site. The TDR probes are multiplexed through the existing TDR hierarchy and are detailed in Figure 8.9 (ET Data Collection Schematic). Before installation, the 30 centimeter TDR probes were sheathed in Alpha Brand, Fit 221, Multipurpose Polyolefin 3/16" shrink tube and the cables were tested to ensure that there are no anomalies in the wiring. Appendix 10 gives manufacturer specifications for the shrink tubing and cable calibration results.

The area where the lysimeter is located was carefully chosen by a botanist familiar with the area who assessed the vegetation in the Americium Zone and found a one square meter area that most closely represented the vegetation throughout the site. The vegetation species name, common name, and location is listed in Table 8.1. The vegetation in the lysimeter site is listed in Table 8.2.

VEGETATION AT STUDY PITS		
SPECIES NAME	COMMON NAME	PIT(S)
Agropyron smithii	Western Wheatgrass	1,2,3,4
Alyssum minus	Alyssum	3,4,5
Bromus tectorum	Cheatgrass	3,4,5
Carduus nutans	Musk Thistle	2
Cirsium arvense	Canada Thistle	1,2,3,4,5
Juncus balticus	Baltic Rush	1,2,3,4
Lactuca serriola	Prickly Lettuce	2,3,4,5
Melilotus alba	White Sweet Clover	1,5
Melilotus officinale	Yellow Sweet Clover	1
Melilotus sp.	Sweet Clover	2,3
Nepeta cataria	Catnip	1

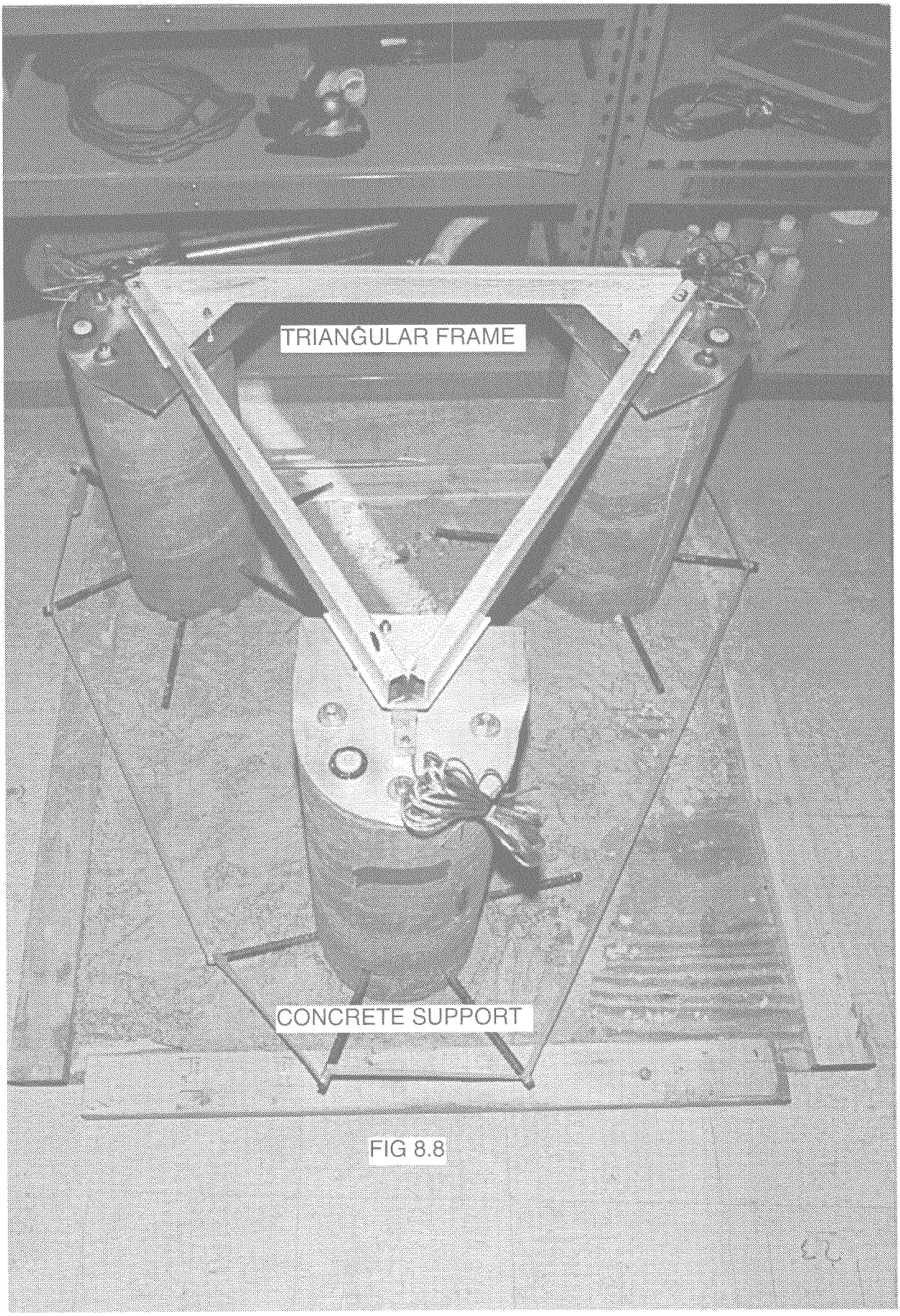


FIG 8.8

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.

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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

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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.

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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			

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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

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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.

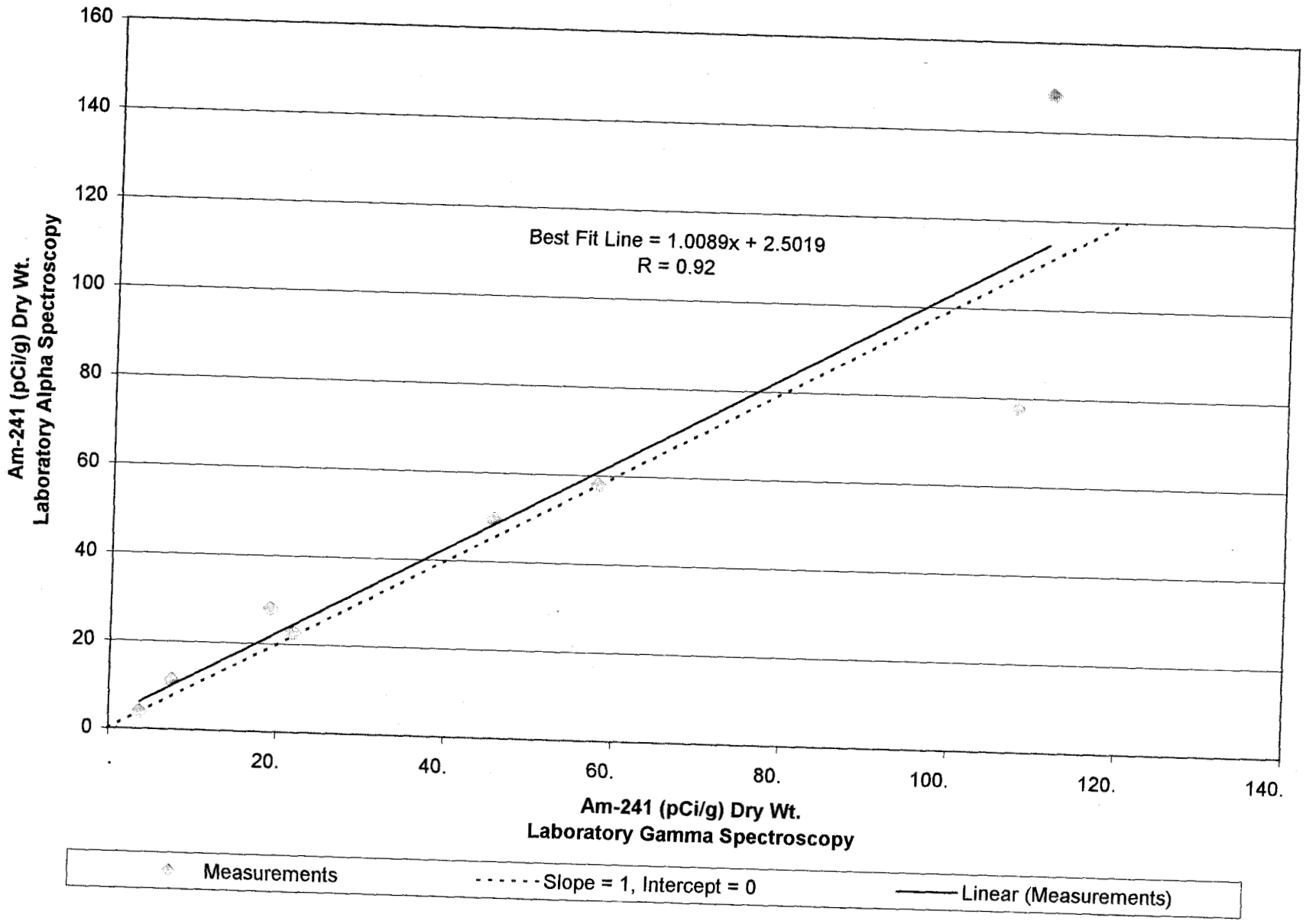
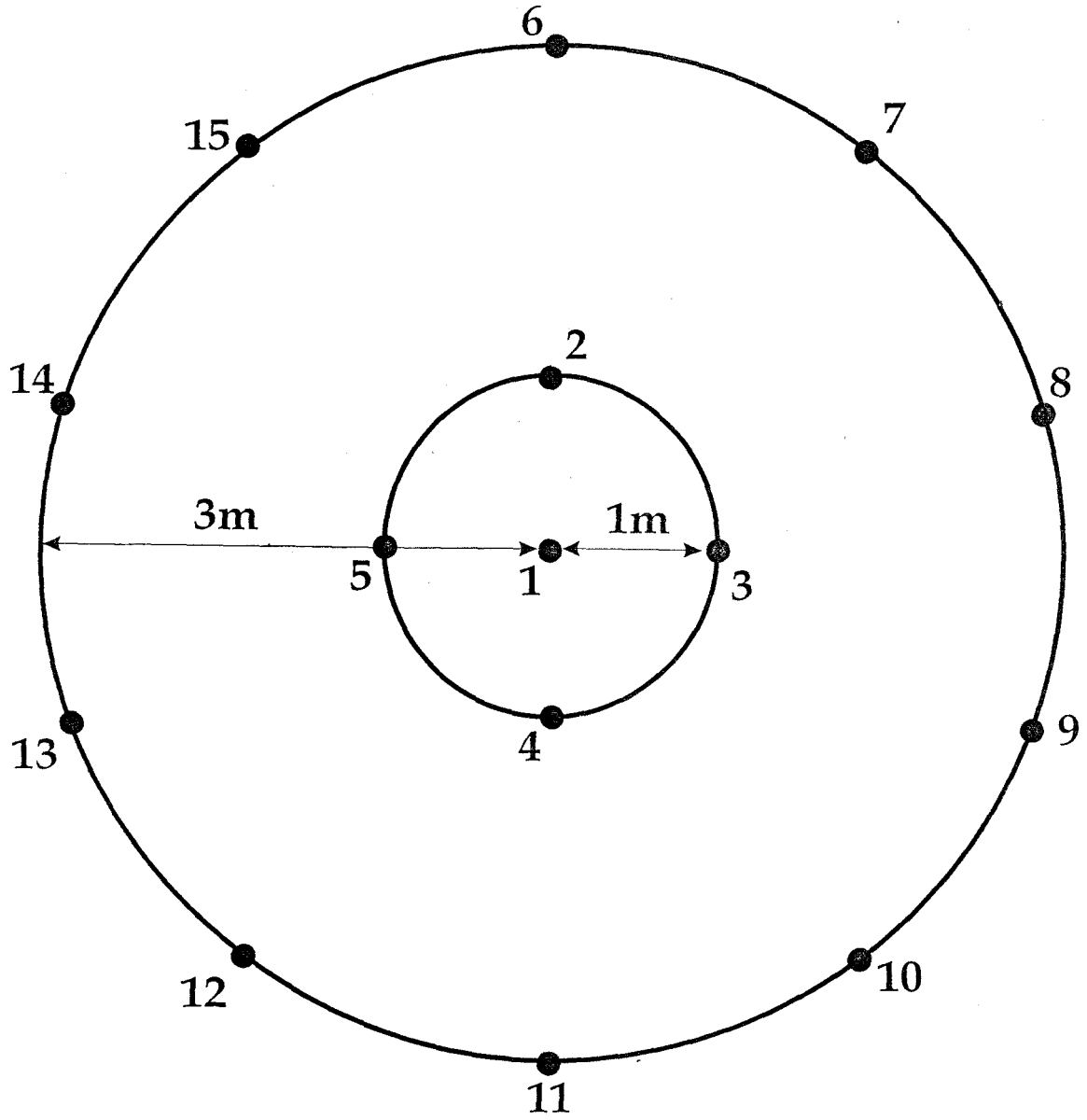


Figure 2-2 Americium-241 Activities in Soil - Laboratory Gamma Spectroscopy vs. Laboratory Alpha Spectroscopy Correlation

4/6



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

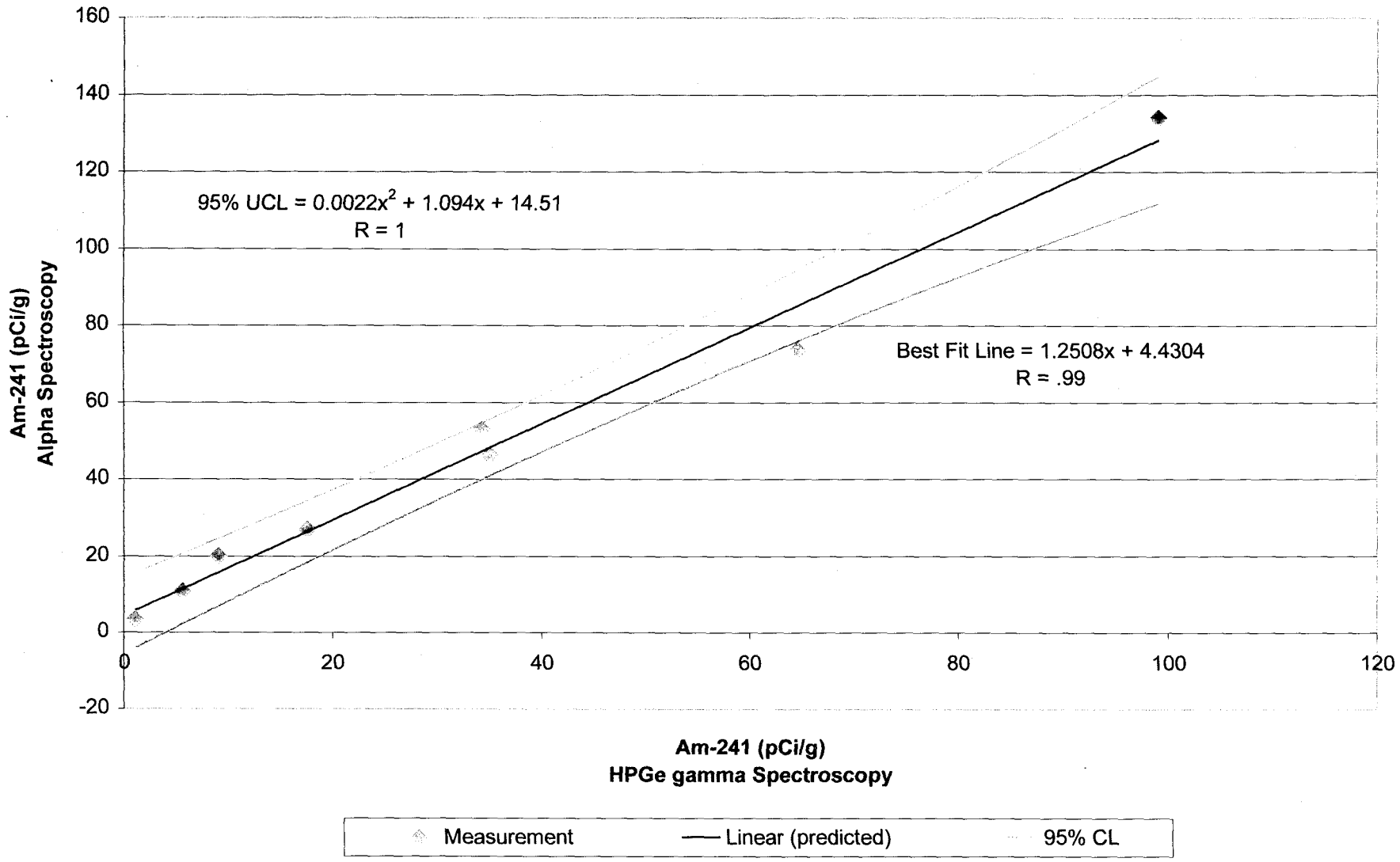


Figure 2-4 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Americium-241 Correlation

Best Available Copy

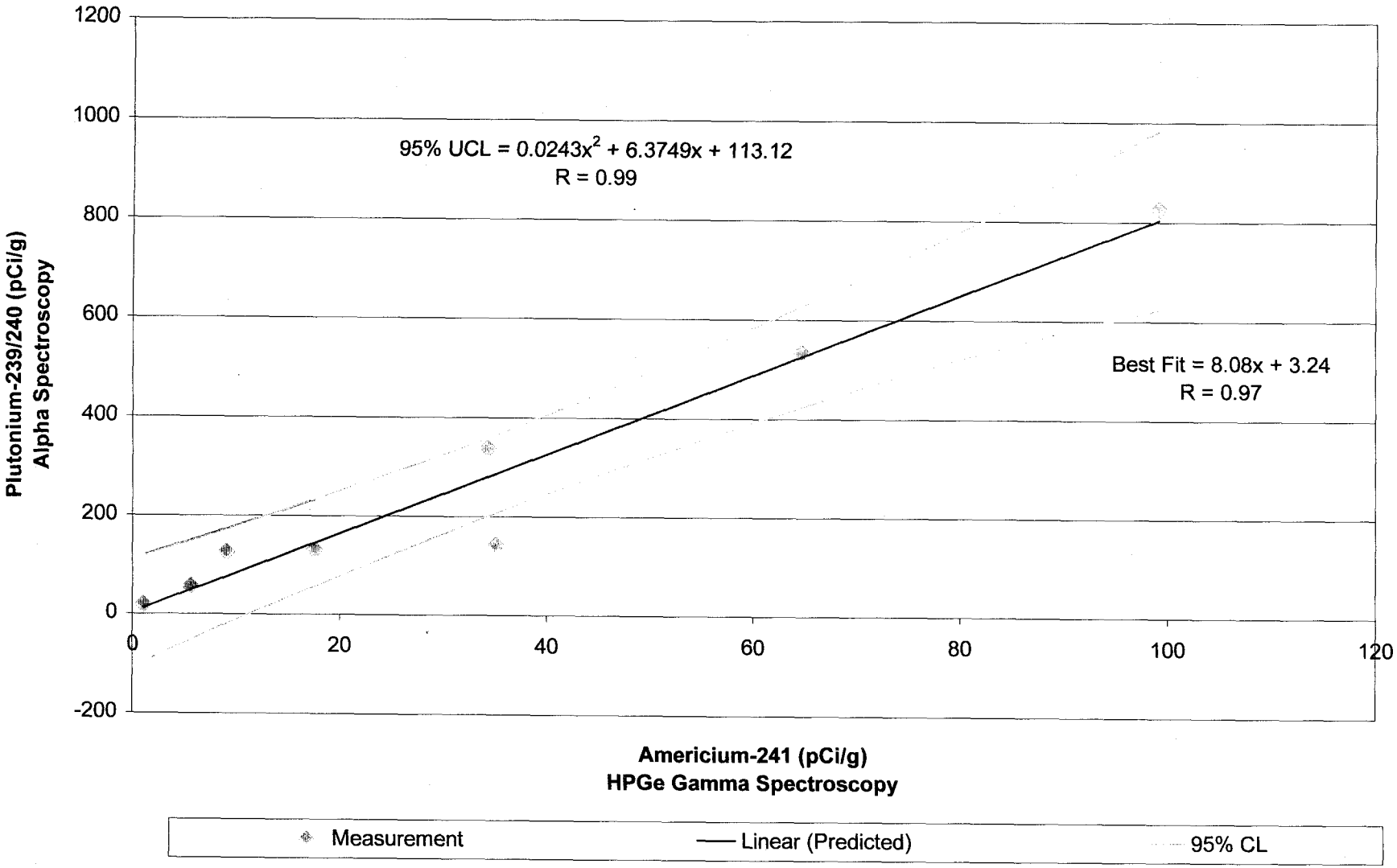


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Figure 2-5 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Americum-241 vs. Plutonium-239/240 Correlation

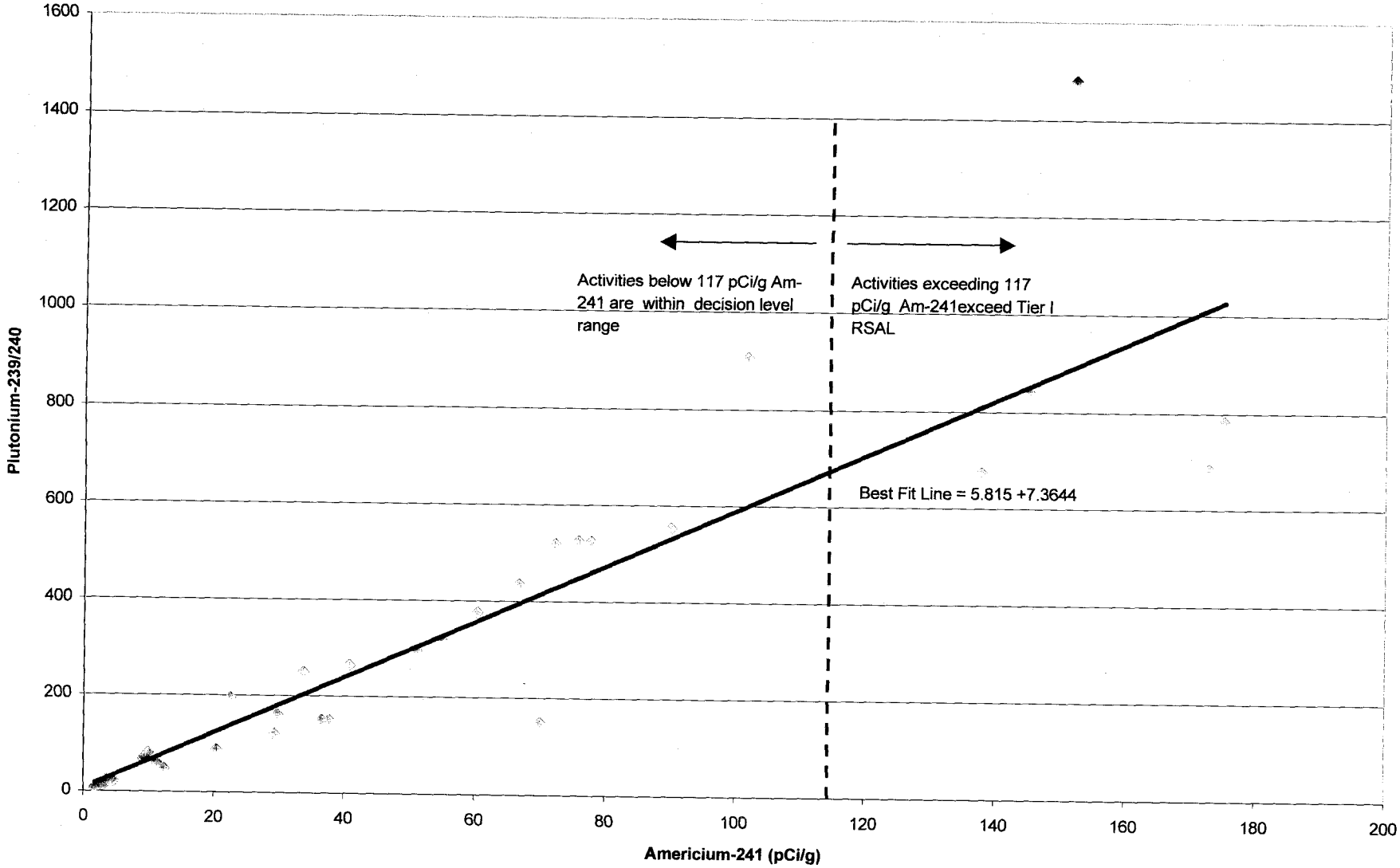

Figure 2-9 Pu/Am Activity Ratio of Soil Samples Collected for HPGe Characterization (Used to Estimate Pu-239/240 and Generate Figure 2-6 RSAL Exceedances in Surface Soils Using HPGe Direct Measurements)

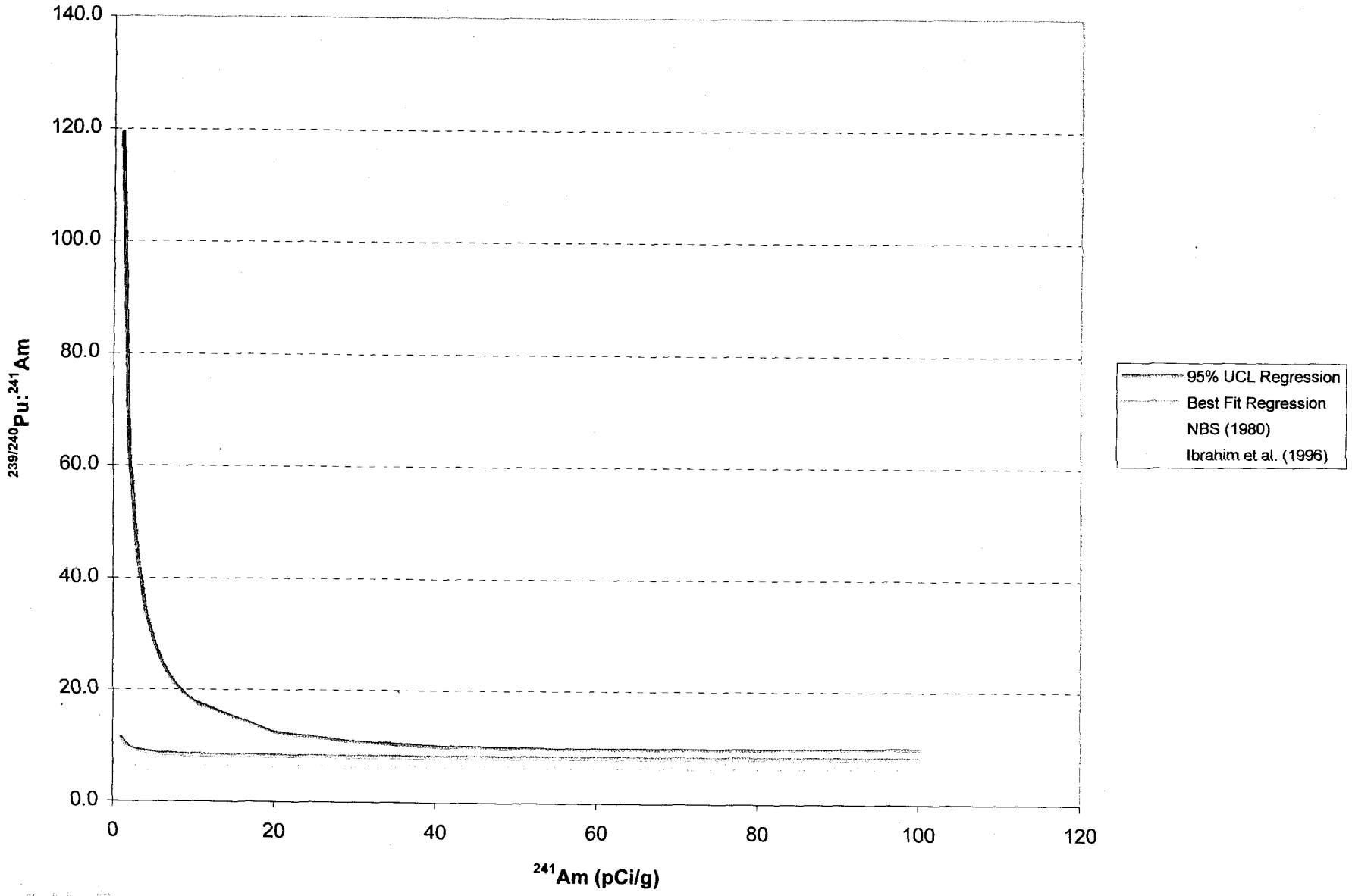

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Figure 2-10 Comparison of $^{239/240}Pu:^{241}Am$ Ratios Derived from "Best Fit" and 95% UCL Regressions to Those of Previous Studies.

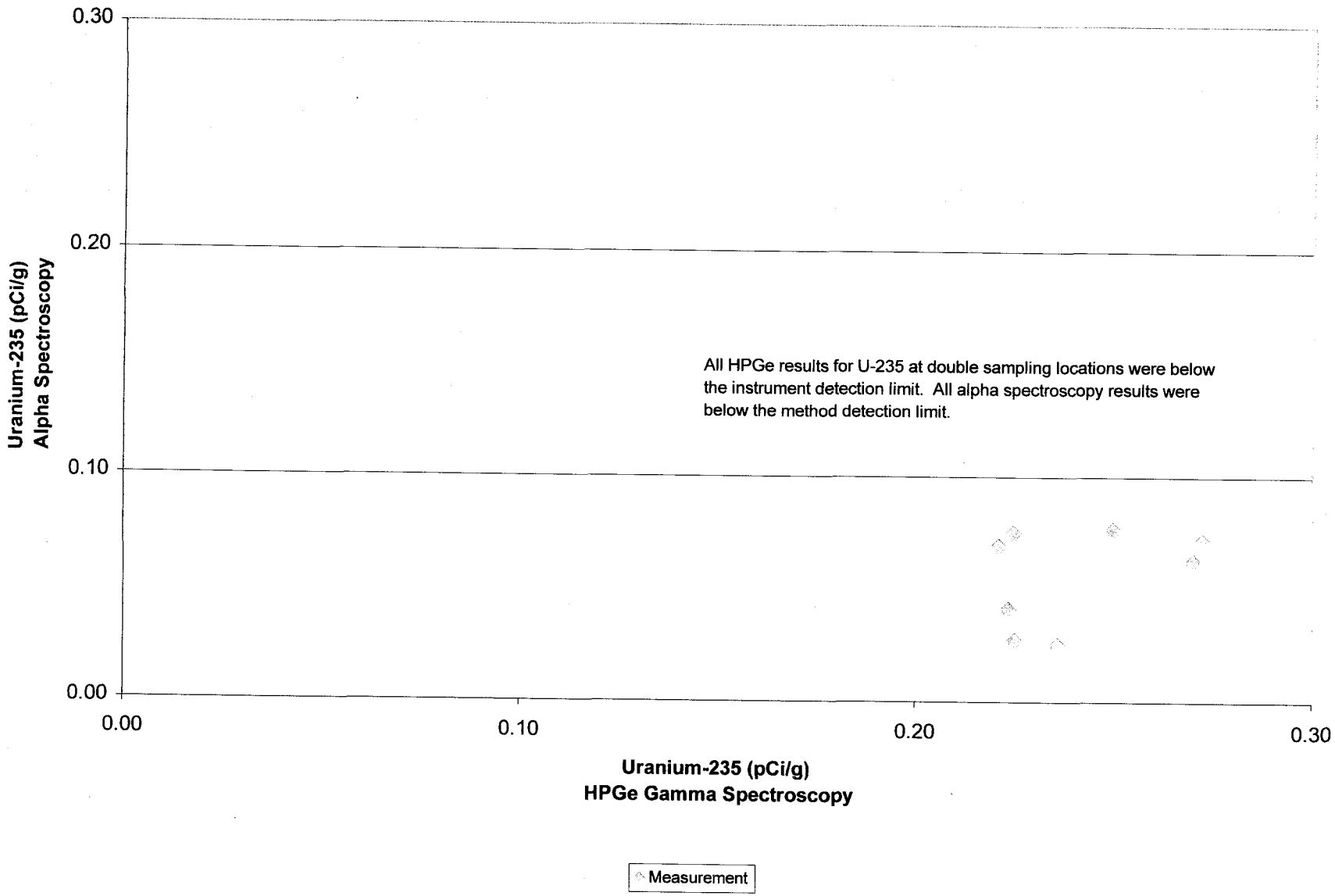

Figure 2-11 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Uranium-235 Correlation

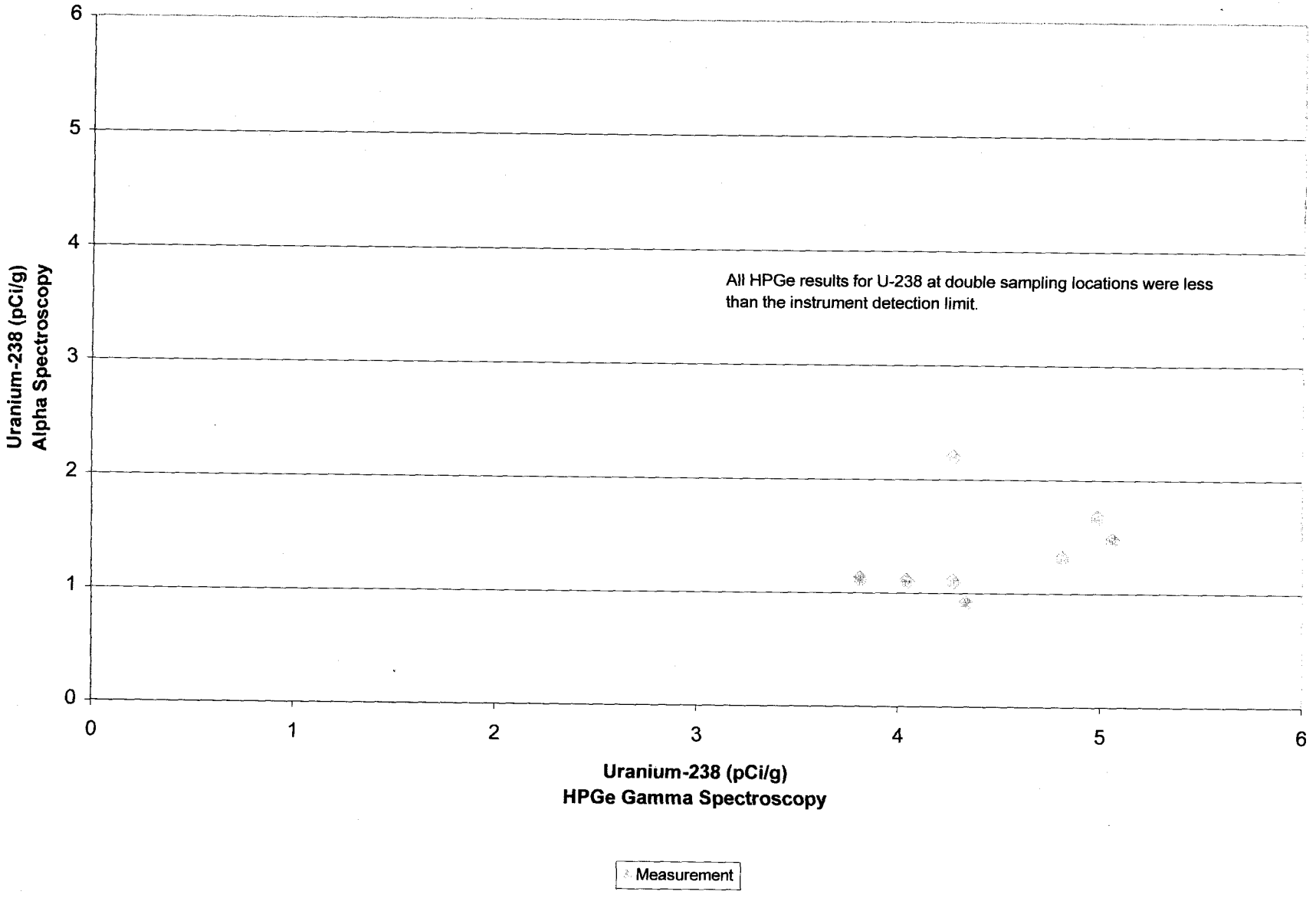

Figure 2-12 Alpha Spectroscopy vs. HPGe Gamma Spectroscopy - Uranium-238 Correlation

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.

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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.

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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

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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

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

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.

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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.

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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.

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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.

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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

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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.

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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**

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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.

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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.

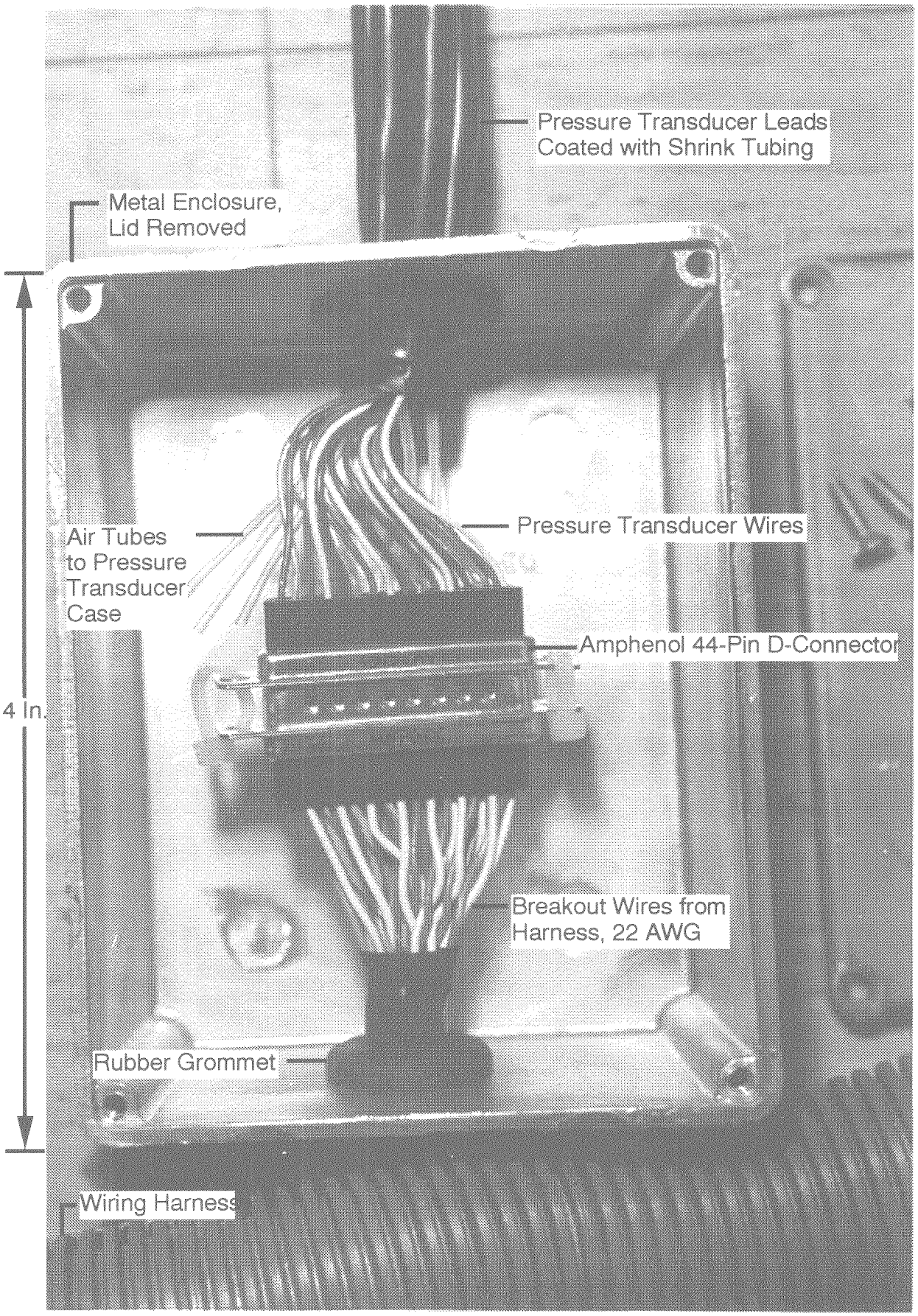

Figure 8 Connection of Pressure Transducer Cluster to Wiring Harness

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

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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.

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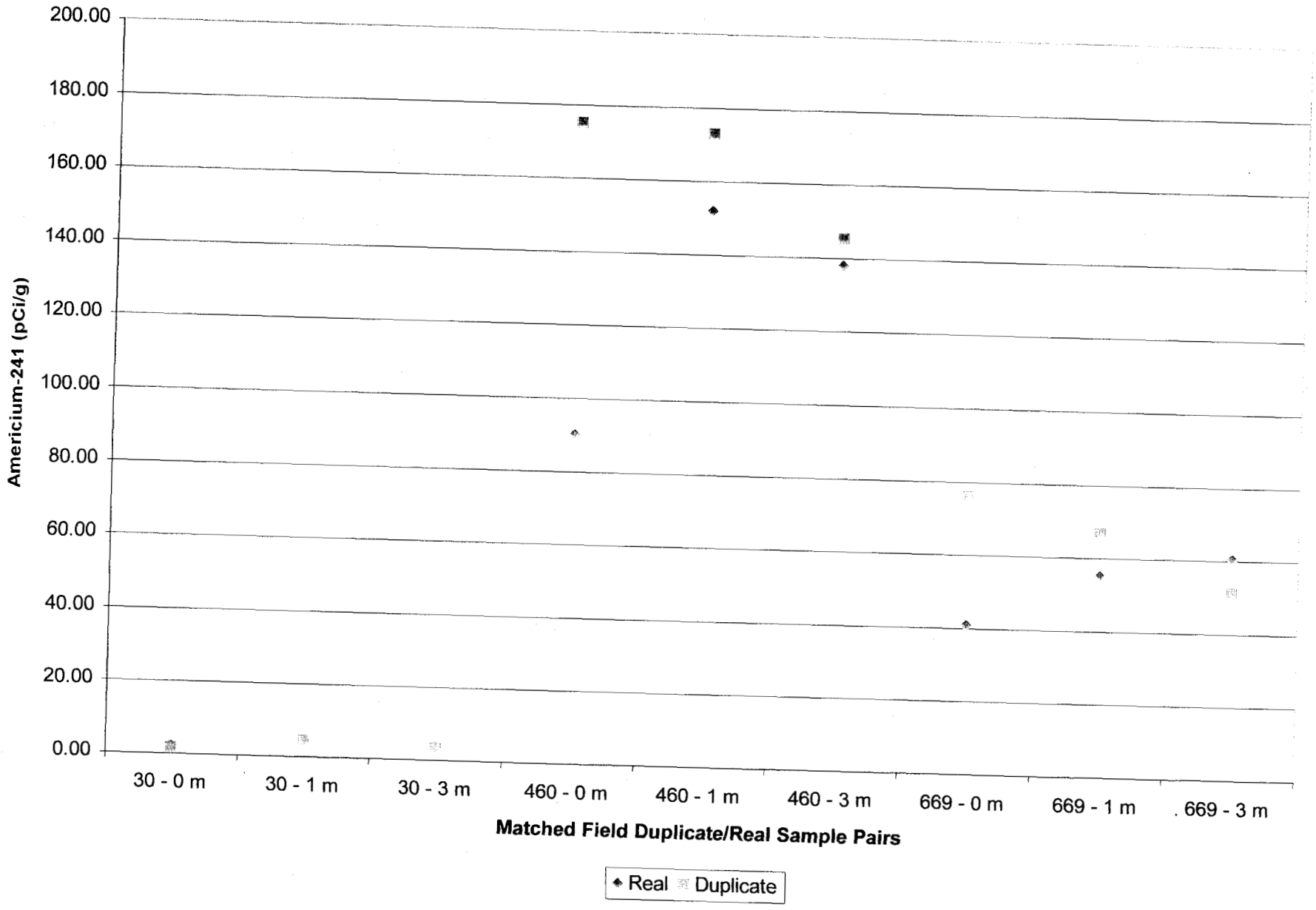

Figure 3-1 Surface Soil Field QA Sample Comparision - Americium-241

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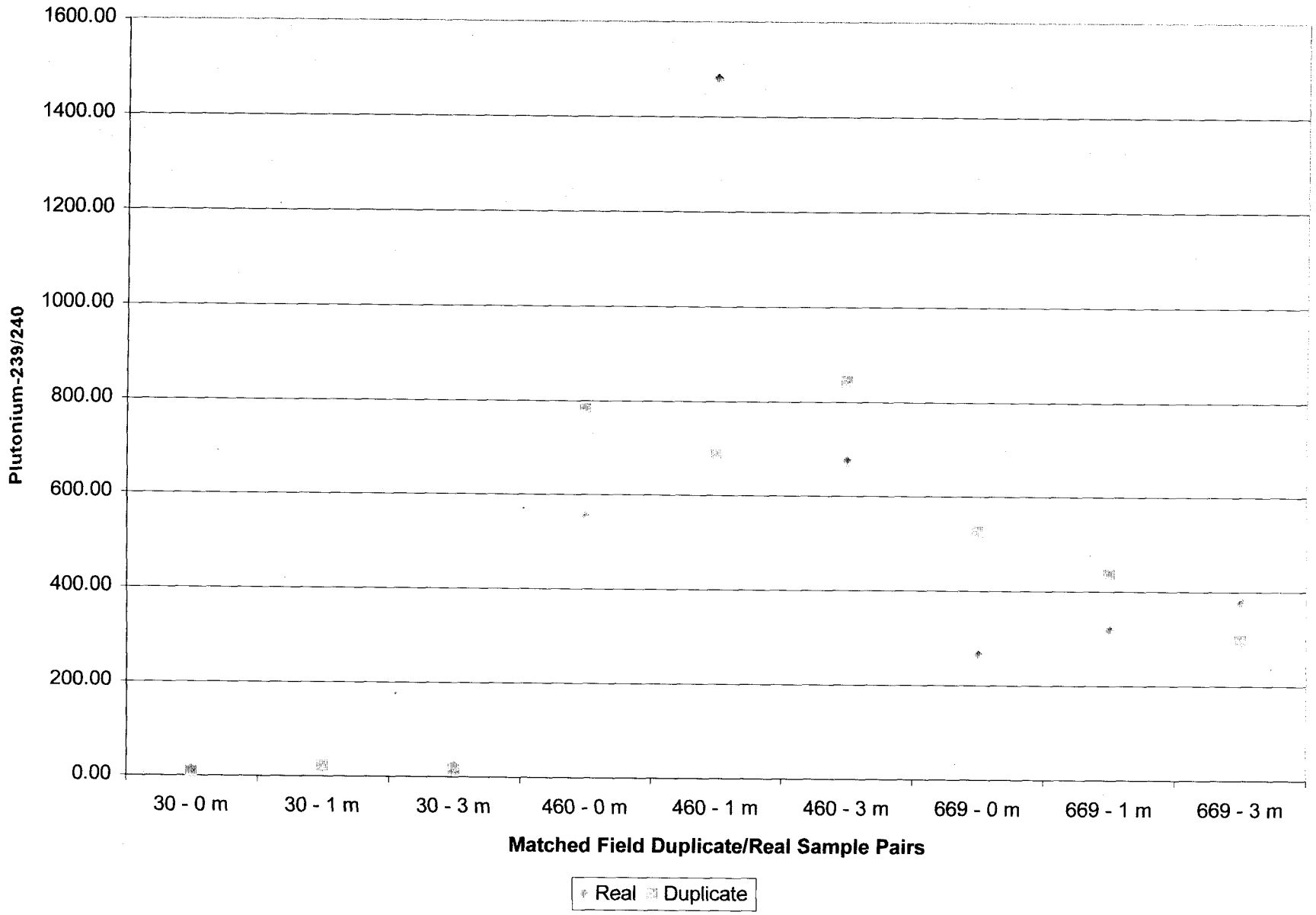

Table 3-2 Surface Soil Field QA Sample Comparison - Plutonium-239/240

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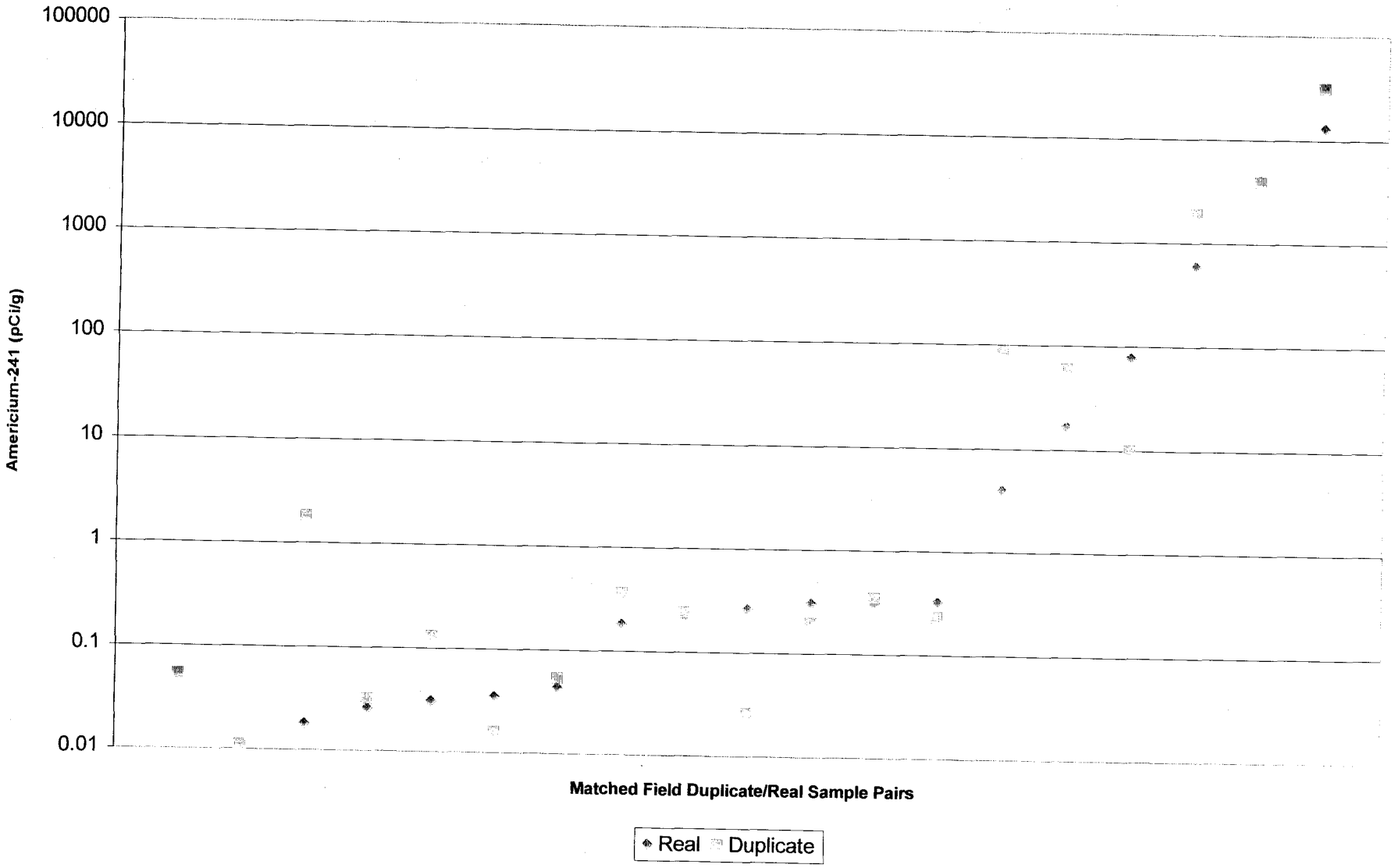

Figure 3-3 Subsurface Soil Field QA Sample Comparison - Americium-241

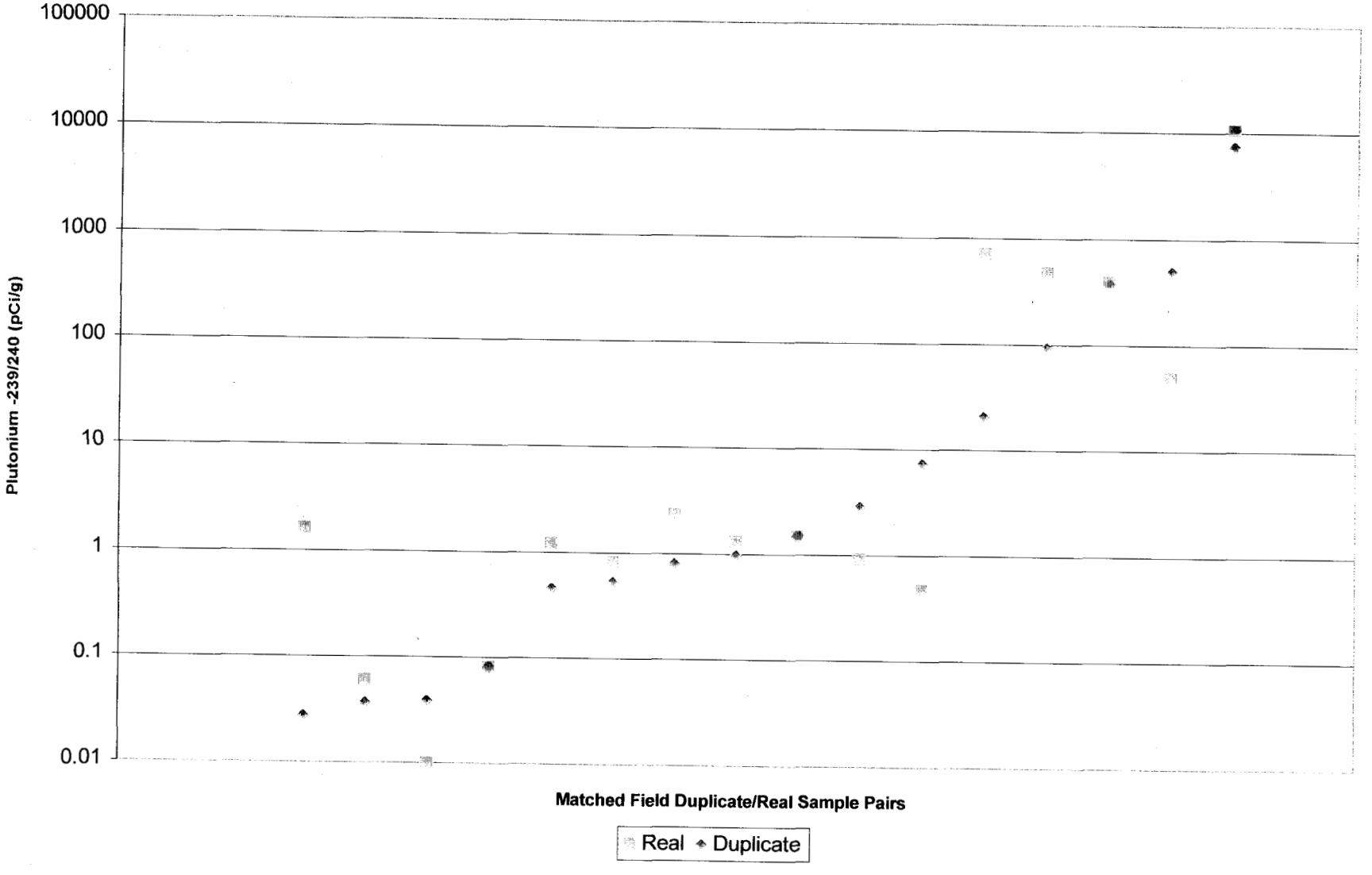

Figure 3-4 Subsurface Soil Field QA Sample Comparison - Plutonium-239/240

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4.0 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of soil contamination related to releases from the 903 Pad has been evaluated by analysis of radionuclide and chemical data obtained as described in Section 2. The primary objective of the investigation is to determine the areal extent and depth of radiological and organic contamination above Tier I RSALs and Tier I SSALs, respectively. Another objective of the investigation is to characterize ^{241}Am in surface soils to 10 pCi/g 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 IM/IRA decision document based on these criteria.

Detailed descriptions of contamination in surface and subsurface soil are presented in this section. Results of the HPGe survey of the Americium Zone are presented in Section 4.1. Sections 4.2 and 4.3, respectively, summarize radionuclide and VOC soil data collected for the 903 Pad and Lip Area. Descriptive summary statistics of the data are presented in Appendix E. Electronic copies of analytical results and Tier I and Tier II RSAL calculations are provided in Appendix F.

4.1 SOIL RADIOLOGICAL CONTAMINATION IN THE AMERICIUM ZONE

Results presented in this section are based on the double sampling technique in which HPGe measurements were correlated to alpha spectroscopy laboratory results. The linear regression between the HPGe results and laboratory results showed a high degree of correlation ($R > 0.97$), and was therefore used to standardize each HPGe measurement to laboratory derived alpha spectroscopy results (see Section 2.2.2). This provided an accurate model for estimating radiological contamination in surface soil relative to Tier I and Tier II RSALs at each survey location.

4.1.1 Comparison of HPGe Measurements to Tier I and Tier II RSALs

Based on 1,110 HPGe measurements in the Americium Zone (Figure 2-1), radiological contamination appears to extend approximately 1,050 feet east of the Lip Area. Surface soil contamination is defined by Tier I and Tier II RSAL exceedances, which are summarized in

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Table 4-1. Using the best-fit regression model, nearly 37 % of the measurement locations exceed the Tier II RSALs. Less than 1% of the measurement locations exceed the Tier I RSALs. HPGe results and RSAL calculations are presented in Appendix F.

Table 4-1 Frequency of RFCA Tier I and Tier II RSAL Exceedances-HPGe Survey Results

HPGe Survey	Number of Measurements	Number Of Exceedances RFCA Tier I RSALs	Number Of Exceedances RFCA Tier II RSALs
Surface Soil	1110	4	416

The range of measured ^{241}Am, $^{239/240}$Pu, ^{235}U, and ^{238}U activities are presented graphically in Figure 4-1. Comparison of radionuclide results to Tier I and Tier II RSALs indicate that RSAL exceedances are due to elevated activities of $^{239/240}$Pu and ^{241}Am. For $^{239/240}$Pu, activities range from 6.32 pCi/g to 938.42 pCi/g with a mean value of 105.05 pCi/g. Approximately 7% of the $^{239/240}$Pu measurements exceed the Tier II RSAL of 252 pCi/g. None of the $^{239/240}$Pu measurements exceed the Tier I RSAL of 1429 pCi/g. ^{241}Am activities range from 4.91 pCi/g to 149.22 pCi/g with a mean value of 20.19 pCi/g. Approximately 10% of the ^{241}Am measurements exceed the Tier II RSAL of 38 pCi/g. Like $^{239/240}$Pu, none of the ^{241}Am measurements exceed the Tier I RSAL of 215 pCi/g. HPGe measurements for ^{235}U and ^{238}U were all below Tier I and Tier II RSALs.

4.1.2 Spatial Distribution of Radiological Contamination in the Americium Zone

Figure 4-2 shows the distribution of Tier I and Tier II RSAL exceedances in surface soil within the Americium Zone. The highest level of contamination as indicated by Tier I RSAL exceedances is 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. Tier II exceedances encompass nearly 37% of the Americium Zone Investigation Area. The HPGe data also define the extent of soil contamination by bounding the area with survey results that are below Tier II RSALs (Figure 4-2). The accuracy of the HPGe survey data is corroborated by historical data as discussed in Section 2.2.2.1. The HPGe data also indicate, as expected, non-contaminated areas where clean fill was used for the road south of the cement and wetland areas, and for the road that borders the western and northern perimeter of the Americium Zone.

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The Tier I and Tier II RSAL exceedances are associated with elevated activities of $^{239/240}$Pu and ^{241}Am. The distribution of ^{241}Am activities is shown in Figure 4-3. The highest activities of ^{241}Am exceed 140 pCi/g near the northwest corner of the Americium Zone. As shown, the distribution of ^{241}Am Tier II RSAL exceedances trend in a northeast-southwest orientation, which extends from the southwest corner of the Lip Area to the north-central portion of the Americium Zone. The distribution of $^{239/240}$Pu activities in surface soil (Figure 4-4) is similar to that of the ^{241}Am activities, with the highest activities exceeding 900 pCi/g near the northwest corner of the Americium Zone. The pattern of Tier I RSAL exceedances is also similar to that observed for ^{241}Am, with a northeast-southwest trend of contamination. This trend is a result of contaminant deposition from the source area. The similar spatial configurations of ^{241}Am and $^{239/240}$Pu are to be expected because ^{241}Am is a daughter product of weapons grade plutonium decay.

4.1.3 FIDLER Surveys

A FIDLER survey was conducted at HPGe measurement location 301 (Figure 2-1) where an isolated HPGe measurement (direct field measurement) exceeded the 10 pCi/g ^{241}Am decision level. The FIDLER survey was used to determine if the result was caused by the presence of a smaller area containing a hot spot. It should be noted that all ^{241}Am activities discussed in this section are presented as direct field measurements. The activity of ^{241}Am from the *in situ* HPGe measurement location 301 was 10.977 pCi/g and the surrounding HPGe measurements were less than 10 pCi/g. FIDLER survey results ranged from 1,224 to 2,841 cpm with a mean of 2,056 cpm. Background measurements of 910 and 1,107 cpm for the two FIDLERs used for the survey were taken at the step-off pad on the north side of the Americium Zone, adjacent to the East Access Road. Because of the low level of ^{241}Am detected in the soil and two FIDLER instruments used for the survey, the results are qualitative at best. However, contamination appears to be homogeneous as would be expected at this distant location from the source where contamination is a result of wind dispersal of plutonium contaminated soil from the 903 Pad and Lip Area.

FIDLER surveys were also conducted at HPGe locations 460 and 462 (Figure 2-1) where surface soils exceeded the RFCA Tier I RSALs. The surveys were conducted to determine whether contamination was homogeneous and widespread as suggested by the conceptual model, or

heterogeneous consisting of numerous individual hot spots. The activities of ^{241}Am from the *in situ* HPGe measurements were 115.74 and 109.04 pCi/g for HPGe measurement locations 460 and 462, respectively, and the surrounding HPGe measurements were less than 100 pCi/g. FIDLER survey results for HPGe measurement location 460 ranged from 2,928 to 17,039 cpm with a mean of 8,293 cpm. FIDLER survey results for FOV 462 ranged from 3,466 to 15,331 cpm with a mean of 8,729 cpm. Background measurements of 1,430 and 2,127 cpm for the two FIDLERs were taken at the step-off pad on the southwest corner of the Americium Zone, adjacent to the access road for the old firing range. Because two FIDLER instruments were used for the surveys, the results are qualitative. However, contamination appears to be heterogeneous and consists of numerous individual hot spots as might be expected from soil disturbance, localized erosional paths, or depositional areas near the source of contamination.

4.2 SOIL RADIOLOGICAL CONTAMINATION IN THE 903 PAD AND LIP AREA

Surface and subsurface soil samples were analyzed for ^{241}Am, $^{239/240}$Pu, $^{233/234}$U, ^{235}U, and ^{238}U using alpha spectroscopy methods. Surface and subsurface soil samples were aggregated into four native soil horizons (Native 1 [0-6 in], Native 2 [6-12 in], Native 3 [12-18 in], Native 4 [18-24 in]), bedrock soil, and artificial fill under the 903 Pad. Artificial fill in the Lip Area was classified as Native 1 soil because native soil and artificial fill could not be differentiated in the field.

Based on the radiological results, contamination appears to be confined to the top 1.5 feet of native soil, and is most extensive in the Native 1 soil horizon. Table 4.2 summarizes the Tier I and Tier II RSAL exceedances. The frequency of Tier I and II exceedances decreases with increasing depth. No samples collected beneath the Native 3-soil horizon exceeded Tier I and Tier II RSALs.[3] Radiological data and RSAL SOR calculations for surface and subsurface soil are presented in Appendix F.

[3] Radiological sample results from the subsurface VOC investigation indicate no contamination above Tier II RSALs. Activities of all measured radionuclides from the VOC investigation were below 3 pCi/g.

Table 4-2 Frequency of RFCA Tier I and Tier II RSAL Exceedances-Native Soil Results

Geologic/Fill Material	Number of Measurements	Frequency Of Exceedances RFCA Tier I RSALs	Frequency Of Exceedances RFCA Tier II RSALs
Asphalt	9	N/A	N/A
Bedrock	12	0	0
Fill	12	0	1
Native	72	0	0
Native 1	62	17	34
Native 2	62	5	11
Native 3	62	0	3
Native 4	58	0	0

N/A Not Applicable; Asphalt samples were not comparable to RSALs

4.2.1 Radionuclide Activities in Native Soils

The range of activities for ^{241}Am, $^{239/240}$Pu, $^{233/234}$U, ^{235}U, and ^{238}U in Native 1, Native 2, and Native 3 soil types are shown graphically in Figure 4-5. As discussed in the following subsections, the amount of contamination decreases significantly with depth.

4.2.1.1 Native 1 Surface Soil Contamination

The Native 1 soil has the most extensive contamination as indicated by activities of ^{241}Am, $^{239/240}$Pu and ^{231}U that exceed Tier I and Tier II RSALs (Table 4-2 and Figure 4-5). ^{238}Uranium activities range from 0.49 pCi/g to 780 pCi/g with a geometric mean value of 1.99 pCi/g[4]. The high activity of 780 pCi/g is the only exceedance above Tier I and Tier II RSALs of 586 pCi/g and 103 pCi/g, respectively. Approximately 44 percent of the $^{239/240}$Pu and ^{241}Am results exceed Tier II RSALs.

$^{239/240}$ Pu activities range from 0.82 pCi/g to 152,260 pCi/g with a geometric mean value of 146.69 pCi/g. For $^{239/240}$Pu, 15% of the samples exceed the Tier I RSAL of 1,429 pCi/g and 44% of the samples exceed the Tier II RSAL of 252 pCi/g. ^{241}Am activities in Native 1 soil appear more extensive than that of ^{239}Pu with activities ranging from 0.15 pCi/g to 31,670 pCi/g. For

[4]The data appear to have a lognormal distribution, and therefore, a geometric mean is a better measure of the central tendency of the distribution.

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^{241}Am activities, 19.1% of the samples exceed the Tier I (215 pCi/g) RSAL and 47.1% exceed the Tier II (38 pCi/g) RSAL.

4.2.1.2 Native 2 Subsurface Soil Contamination

The Native 2 soil horizon is substantially less contaminated than the Native 1 soil horizon but still contains activities above Tier I and Tier II RSALs for ^{241}Am and $^{239/240}$Pu (Figure 4-5). $^{239/240}$Pu activities range from 0.14 pCi/g to 1,820 pCi/g with a geometric mean of 8.65 pCi/g. For $^{239/240}$Pu, 0.03% of the samples exceed the Tier I RSAL (1,429 pCi/g) and 11% of the samples exceed the Tier II RSAL (252 pCi/g). ^{241}Am activities range from non-detectable (0.03 pCi/g) to 406 pCi/g with a geometric mean value of 1.79 pCi/g. ^{241}Am contamination is similar to that of $^{239/240}$Pu contamination as indicated by frequency of exceedances of 0.03% and 11% above Tier I (215 pCi/g) and Tier II (38 pCi/g) RSALs, respectively.

4.2.1.3 Native 3 Subsurface Soil Contamination

The amount of contamination in the Native 3 soil is minimal relative to the Tier II RSALs (Figure 4-5). Only one sample for ^{241}Am exceeds the corresponding Tier II RSAL of 38 pCi/g. ^{241}Am in the Native 3 soil horizon ranges from non-detectable to 54.40 pCi/g with a median value of 0.23 pCi/g.[5] Activities of $^{239/240}$Pu in the Native 3 soil horizon were below the respective Tier I and Tier II RSALs.

4.2.2 Spatial Distribution of Contamination

Examination of the spatial distribution of contamination is useful for evaluating potential sources and contaminant migration pathways. This section discusses the spatial distribution of Tier I and Tier II RSALs for Native 1, Native 2, and Native 3 soil horizons. Also presented are the spatial distributions of $^{239/240}$Pu and ^{241}Am activities because of their exceedance of Tier I and Tier II RSALs.

[5] Due to the negative activities in the data set, the median value was used as a measure of the central tendency of the distribution instead of the geometric mean.

4.2.2.1 Spatial Distribution of Radionuclides in the Native 1 Soil Horizon

As shown in Figure 4-6, Tier I and Tier II RSAL exceedances (>1 for the sum of ratios) in Native 1 soil are located throughout the 903 Pad and Lip Area. There is no distinct pattern to the Tier I and Tier II exceedances at the 903 Pad. Most of the southern boundary and portions of the northern boundary do not exceed Tier II RSALs. For the Lip Area, Tier I exceedances are most prevalent in the center area due east of the 903 Pad, with Tier II exceedances surrounding this area. Relatively "clean" areas as indicated by RSALs less than Tier II are located further to the east and south of the 903 Pad. Apparent spatial gaps in contamination may be explained by past remedial activities. For example, the soil in the Lip Area was graded back toward the 903 Pad during past remedial actions, and therefore the soil closest to the Pad is not as contaminated as the soil near the central portion of the Lip Area. Similar remedial activities in 1984 removed contaminated soil in the western portion of the Lip Area.

The RSAL exceedances are associated with elevated levels of $^{239/240}$Pu and ^{241}Am. Figure 4-7 shows the distribution of ^{241}Am in the Native 1 surface soil. The highest ^{241}Am activities exceed 30,000 pCi/g and are centered near boring 91598 (Figure 4-7). However, as shown in Figure 4-7, the majority of the Native 1 soils in the 903 Pad (approximately half of the Native 1 soil) and Lip Area exceed the Tier II RSAL for ^{241}Am of 38 pCi/g. The distribution of the $^{239/240}$Pu activities is similar to that of the ^{241}Am activities, with the highest activities exceeding 150,000 pCi/g at boring 91598 (Figure 4-8). Like ^{241}Am, the $^{239/240}$Pu activities are elevated with respect to the Tier II RSAL (252 pCi/g) in most of the Native 1 soil within the 903 Pad and approximately half of the Native 1 soil in the Lip Area.

4.2.2.2 Spatial Distribution of Radionuclides in the Native 2 Soil Horizon

Figure 4-9 shows the distribution of the Tier I and Tier II RSAL exceedances (>1 for the sum of ratios) in the Native 2 soil horizon. The RSAL exceedances are not as ubiquitous as in the Native 1 soil horizon. RSAL exceedances are isolated to an area around boreholes 91398, 91598, 91898, and 91998 at the 903 Pad and around several boreholes throughout the Lip Area (boreholes 94898, 94998, 95198, 95398, 95498, 95598, and 97598). Like the Native 1 soil horizon, RSAL exceedances in the Native 2 soil horizon are associated with elevated levels of ^{241} Am and ^{239}Pu.

^{241}Am activities exceed 400 pCi/g in the 903 Lip Area with the highest activity observed at boring 95198 (Figure 4-10). The distribution of Pu-239 in the Native 2 soil horizon is very similar to that of ^{241}Am (Figure 4-11). ^{239}Pu exceeds 18,000 pCi/g (above the Tier I RSAL) at boring 95198. $^{239/240}$Pu activities exceeding the Tier II RSAL (252 pCi/g) are distributed like the ^{241}Am activities (Figure 4-11). The $^{239/240}$Pu and ^{241}Am activities in the Native 2 soil horizon are generally one to two orders of magnitude less than those observed in the Native 1 soil horizon.

Historical grading activity at the 903 Pad likely explains the somewhat different $^{239/240}$Pu and ^{241}Am distributions between Native 1 and Native 2 soils. For example, grading activities at boring 91998 may have redistributed contamination in Native 1 soil leaving higher contaminated soils in the Native 2 soil horizon. In the Lip Area, the amount of artificial fill in the Native 1 soil horizon would explain higher activities in Native 2 soil relative to the Native 1 soil.

4.2.2.3 Spatial Distribution of Radionuclides in the Native 3 Soil Horizon

Figure 4-12 shows the distribution of the Tier II RSAL exceedances (>1 for the sum of ratios) in the Native 3 soil horizon.[6] The amount of radionuclide contamination in the Native 3 soil horizon is significantly less than that in the Native 1 and Native 2 soil horizons. Tier II RSAL exceedances are isolated along the northern boundary of the Lip Area at borings 94898 and 95198. One other isolated Tier II RSAL exceedance is observed east of the 903 Pad at boring 95498. Like the Native 1 and Native 2 soil horizons, the RSAL exceedances within the Native 3 soil horizon are associated with elevated levels of ^{241}Am and $^{239/240}$Pu.

As shown in Figure 4-13, elevated levels of ^{241}Am with respect to the Tier II RSAL (38 pCi/g) are observed along the northern boundary of the Lip Area at boring 94898. Another area east of the 903 Pad near boring 95498 shows relatively high activities of ^{241}Am (up to 26 pCi/g) but these activities are slightly less than the Tier II RSALs.[7] The spatial distribution of ^{239}Pu in the Native 3 soil horizon is similar to that of ^{241}Am (Figure 4-14). Although none of the $^{239/240}$Pu samples exceed Tier I or Tier II RSALs, the relatively high activities near borings 94898 and 95498 contribute to the Tier II RSAL exceedances at these locations.

[6] Tier I RSAL exceedances were not observed in the Native 3 Soil horizon.
[7] Tier I RSAL exceedances for ^{241}Am were not observed in the Native 3 Soil horizon.

Overall, the area of ^{241}Am and $^{239/240}$Pu contamination decreases significantly with depth. Despite nearly identical spatial trends, the ^{241}Am and ^{239}Pu activities within the Native 3 soil horizon are an order of magnitude less than those within the Native 2 soil horizon.

4.2.3 Radionuclide Activities in 903 Pad Asphalt and 903 Pad Artificial Fill

Asphalt samples from the 903 Pad were collected to obtain preliminary estimates of the sample variance and mean for waste characterization purposes.[8] Random sampling techniques were used as an appropriate method to estimate the population mean and to determine the total amount of contamination. Nine asphalt samples were collected from sample locations randomly selected from the twenty-five 903 Pad subsurface soil sampling locations as shown in Figure 4-15. Asphalt thickness ranged from 0.4 to 0.7 feet with an average thickness of 0.5 feet.
Twelve artificial fill samples were collected from locations randomly selected from the twenty-five 903 Pad subsurface soil sampling locations as shown in Figure 4-16. Artificial fill thickness ranged from 0.3 to 0.9 feet with an average thickness of 0.5 feet beneath the 903 Pad. Artificial fill results were compared to RFCA Tier I and Tier II RSALs. Samples were analyzed for ^{241}Am, $^{239/240}$Pu $^{233/234}$U, ^{235}U, and ^{238}U, using alpha spectroscopy methods. The descriptive summary statistics are provided in Appendix E.

4.2.3.1 Radionuclide Distribution in Asphalt

The radionuclide activities in asphalt were low relative to the activities observed in the Native 1 soil horizon. As shown in Figures 4-15 and 4-17, the activities for ^{241}Am, $^{239/240}$Pu, $^{233/234}$U, ^{235}U, and ^{238}U are all below 1.5 pCi/g. The mean, standard deviation, and other descriptive statistics are summarized in Table 4-3.

Figure 4-15 shows the distribution of radionuclides in asphalt. With the exception of ^{238}U, the highest radionuclide activities in asphalt are present at boring 91898 ($^{233/234}$U [1.13 pCi/g], ^{235}U [0.133 pCi/g], ^{241}Am [0.341 pCi/g], and $^{239/240}$Pu [1.22 pCi/g]). The highest ^{238}U (0.919 pCi/g) activity in asphalt was reported at boring 90198.

[8] Asphalt samples were not comparable to RSALs, which are based the physical and chemical properties of soil. Instead, waste disposal WAC requirements for asphalt will be based on the mean and variance.

Table 4-3 Descriptive Summary Statistics for 903 Pad Asphalt

Descriptive Statistic	$^{233/234}U$ (pCi/g)	^{235}U (pCi/g)	^{238}U (pCi/g)	$^{239/240}Pu$ (pCi/g)	^{241}Am (pCi/g)
Mean	0.81	0.05	0.75	0.16	0.07
Geometric Mean	0.80	0.04	0.74	N/A	0.04
Standard Error	0.05	0.01	0.04	0.13	0.03
Median	0.78	0.04	0.75	0.03	0.04
Standard Deviation	0.15	0.03	0.13	0.40	0.10
Sample Variance	0.02	0.00	0.02	0.16	0.01
Kurtosis	1.70	7.01	-1.60	8.85	8.28
Skewness	1.22	2.46	-0.08	2.97	2.84
Coefficient of Variation	0.19	0.72	0.17	2.42	1.46
Range	0.47	0.12	0.32	1.22	0.33
Minimum	0.66	0.01	0.60	0.00	0.02
Maximum	1.13	0.13	0.92	1.22	0.34
Sum	7.27	0.42	6.74	1.48	0.63
Count	9	9	9	9	9
Confidence Level (90.0%)	0.08	0.02	0.07	0.22	0.06

N/A Not Applicable.

4.2.3.2 Radionuclide Distribution in 903 Pad Artificial Fill

The ranges of activities for the measured isotopes in artificial fill are presented in Figure 4-17. Overall, the radionuclide activities in artificial fill are low relative to the activities observed in the Native 1, Native 2, and Native 3 soil horizons. However, one Tier II RSAL exceedance is observed within the 903 Pad Area at boring 91898 (Figure 4-16). The Tier II RSAL exceedance is associated with elevated levels of ^{241}Am (126 pCi/g) and $^{239/240}Pu$ (558 pCi/g), which both exceed the respective Tier II RSALs of 38 pCi/g and 252 pCi/g. ^{241}Am activities in artificial fill range from 0.02 pCi/g to 126 pCi/g with a geometric mean value of 1.18 pCi/g. Elevated activities within the artificial fill appear to be isolated around this single boring considering that the highest $^{233/234}U$ (2.02 pCi/g), ^{235}U (0.49 pCi/g), $^{233/234}U$ (2.77 pCi/g), and $^{239/240}Pu$ (558 pCi/g) activities were also observed at boring 91898 (Figure 4-17). Descriptive summary statistics for the 903 Pad artificial fill are presented in Table 4-4.

Table 4-4 Descriptive Summary Statistics for 903 Pad Artificial Fill

Descriptive Statistic	$^{233/234}U$ (pCi/g)	^{235}U (pCi/g)	^{238}U (pCi/g)	$^{239/240}Pu$ (pCi/g)	^{241}Am (pCi/g)
Mean	1.06	0.09	1.15	53.75	12.01
Geometric Mean	1.02	0.06	1.00	5.78	1.18
Standard Error	0.11	0.04	0.18	45.95	10.38
Median	0.98	0.06	1.13	4.48	0.85
Mode	0.84	0.07	1.24	N/A	N/A
Standard Deviation	0.38	0.13	0.61	159.19	35.97
Sample Variance	0.14	0.02	0.37	25340.90	1294.08
Kurtosis	4.79	11.19	5.53	11.88	11.90
Skewness	1.51	3.30	1.72	3.44	3.44
Coefficient of Variation	0.36	1.43	0.53	2.96	2.99
Range	1.61	0.49	2.60	557.99	125.98
Minimum	0.41	0.00	0.17	0.01	0.02
Maximum	2.02	0.49	2.77	558.00	126.00
Sum	12.25	1.00	13.33	642.14	143.51
Count	12	12	12	12	12
Confidence Level (90.0%)	0.18	0.06	0.29	75.59	17.08
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	1	1

N/A Not Applicable

4.3 SUBSURFACE SOIL VOC INVESTIGATION

Seventeen boreholes were completed during the recent 903 Pad Investigation to characterize organic contamination at the 903 Pad and Lip Area, which included the planned 13 boreholes and four "step-out" boreholes (Figure 4-18). Subsurface soil organic COCs include CCL_4, PCE, TCE, 1,2-DCE, methylene chloride, and Aroclor-1248.[9]

Despite the absence of observed DNAPLs during the recent 903 Pad Investigation, VOCs were detected at several boring locations. Figure 4-18 summarizes the results of the VOC subsurface

[9] Screened from historical OU2 RI/RFI data (DOE, 1993).

soil investigation. As shown, detections of methylene chloride ranged from 0.59 ug/kg in borehole 97098 (8.4 to 8.8 ft) up to 1700 ug/kg in borehole in 92598 (16 to 16.75 ft). Detections of CCl_4 ranged from 2.3 ug/kg in borehole 96698 (22.4 to 22.8 ft) up to 5.3 ug/kg in borehole 96798 (20.4 to 20.8 ft). Detections of PCE ranged from 1.1 ug/kg in borehole 97698 (8.2 to 8.6 ft) up to 6,100 ug/kg in borehole 90998 (3.8 to 4.0 ft). Detections of TCE ranged from 0.89 ug/kg in borehole 96698 (20.4 to 20.8 ft) up to 290 ug/kg in borehole 90998 (3.8 to 4.0 ft). Detections of 1,2-DCE ranged from 1.1 ug/kg in boreholes 96798 (12.5 to 12.9 ft) and 97698 (8.2 to 8.6 ft) up to 4,400 ug/kg in borehole 90998 (3.8 to 4.0 ft). Review of historical data also indicate the presence of Arochlor-1248 and TCE above proposed SSALs (Figure 4-19). As shown, Aroclor-1248 was detected at 7200 ug/kg at boring 33291(0 to 6 ft) and TCE was detected at 5700 ug/kg at boring 21893 (23.1 to 23.4 ft). In general, the majority of the VOC detections were observed in the northeastern quadrant of the 903 Pad at borings 90998, 95998, 96498, 96698, 96798, and 97698. VOC detections were also observed in the 903 Lip Area at boring 97298 and within the central portion of the 903 Pad at boring 96898. The ranges of VOC concentrations are presented in Figure 4-20.

No VOC detections exceeded the current Tier I Subsurface SALs (Table 4-5). However, proposed Subsurface SALs are 1 to 4 orders of magnitude less than the current Tier I Subsurface SALs (Table 1-2). In general, the majority of the VOC detections above proposed RFCA Subsurface SALs were observed beneath the 903 Pad (Figure 4-19). The VOCs that exceed the proposed Tier II SSALs include PCE, TCE, and methylene chloride (Table 4-5). Methylene chloride was the most ubiquitous of the contaminants, exceeding the proposed Tier I Subsurface SAL at borings 90998, 91198, and 92598. PCE was detected once above the proposed Tier I Subsurface SAL at boring 90998. TCE was detected once above the proposed Tier I Subsurface SAL at boring 21893, which is located approximately 320 feet south of the 903 Pad.

The depth of contamination (relative to the proposed Tier I Subsurface SAL) beneath the 903 Pad varies from 3.8 feet at boring 90998 to 19.8 feet at boring 91198. Methylene chloride concentrations at boreholes 92598 and 91198 generally increase with depth, suggesting that the parent contaminant was released from the surface. However, TCE contamination south of the 903 Pad at boring 21893 appears to be isolated at a depth of 23.1 to 23.4 feet bgs. Given that the

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average depth to water in this location is approximately 10 feet bgs (EG&G, 1995), TCE soil contamination is likely associated with the local ground water plume.

Organic compounds that exceed the proposed Tier II Subsurface SALs include PCE, TCE, 1,2-DCE, methylene chloride, and Aroclor-1248. As shown in Figure 4-19, the proposed Tier II exceedances are observed at boreholes 97698 (methylene chloride, PCE), 96498 (PCE), 90998 (methylene chloride, PCE, TCE, and 1,2-DCE), 95998 (PCE), 96798 (PCE), 12991 (methylene chloride), 91198 (methylene chloride), 92598 (methylene chloride), 96398 (methylene chloride), 97198 (methylene chloride), and 33291 (Aroclor-1248). The majority of the proposed Tier II Subsurface SAL exceedances occur beneath the 903 Pad. Methylene chloride occurs at 7 of the borings, followed by PCE, which occurs at five of the borings. The depth of contamination (relative to the proposed Tier II Subsurface SALs) varies from 0.0 feet bgs at boring 33291 to 26.9 feet bgs at boring 12991.

Some of the deeper borehole samples may reflect solute (dissolved) concentrations in ground water rather than concentrations in soil. Ground water beneath the 903 Pad is relatively shallow with depth to water averaging approximately 19 feet bgs. Depth to water in the Lip Area, located south of the 903 Pad, is much shallower as indicated by an average depth to water of 10 feet bgs. During high flow regimes, depth to water may decrease to 12 feet bgs beneath the 903 Pad and to 8 feet bgs in the Lip Area. Therefore, it is likely that detections of CCL_4, PCE , methylene chloride and TCE observed at depths greater than 19 feet at boreholes 97698, 95998, 91198, 12991, 97198, 96798, 21893 may represent partitioning of VOCs between the aqueous and solid phases.

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Table 4-5 Frequency of VOC SSAL Exceedances in Subsurface Soil.

VOC	Number of Measurements	Number of Detections	Number Of Exceedances Current Tier I SSAL	Number Of Exceedances Proposed Tier I SSAL	Number Of Exceedances Proposed Tier II SSAL
Carbon Tetrachloride	86	3	0	0	0
PCE	86	19	0	1	7
TCE[1]	87	7	0	1	2
1,2-DCE	32	1	0	0	1
Methylene Chloride[1]	87	43	0	10	23
Aroclor-1248[2]	N/A	1	0	0	1

[1] Includes historical OU2 data.
[2] Based on screening of historical OU2 data only.

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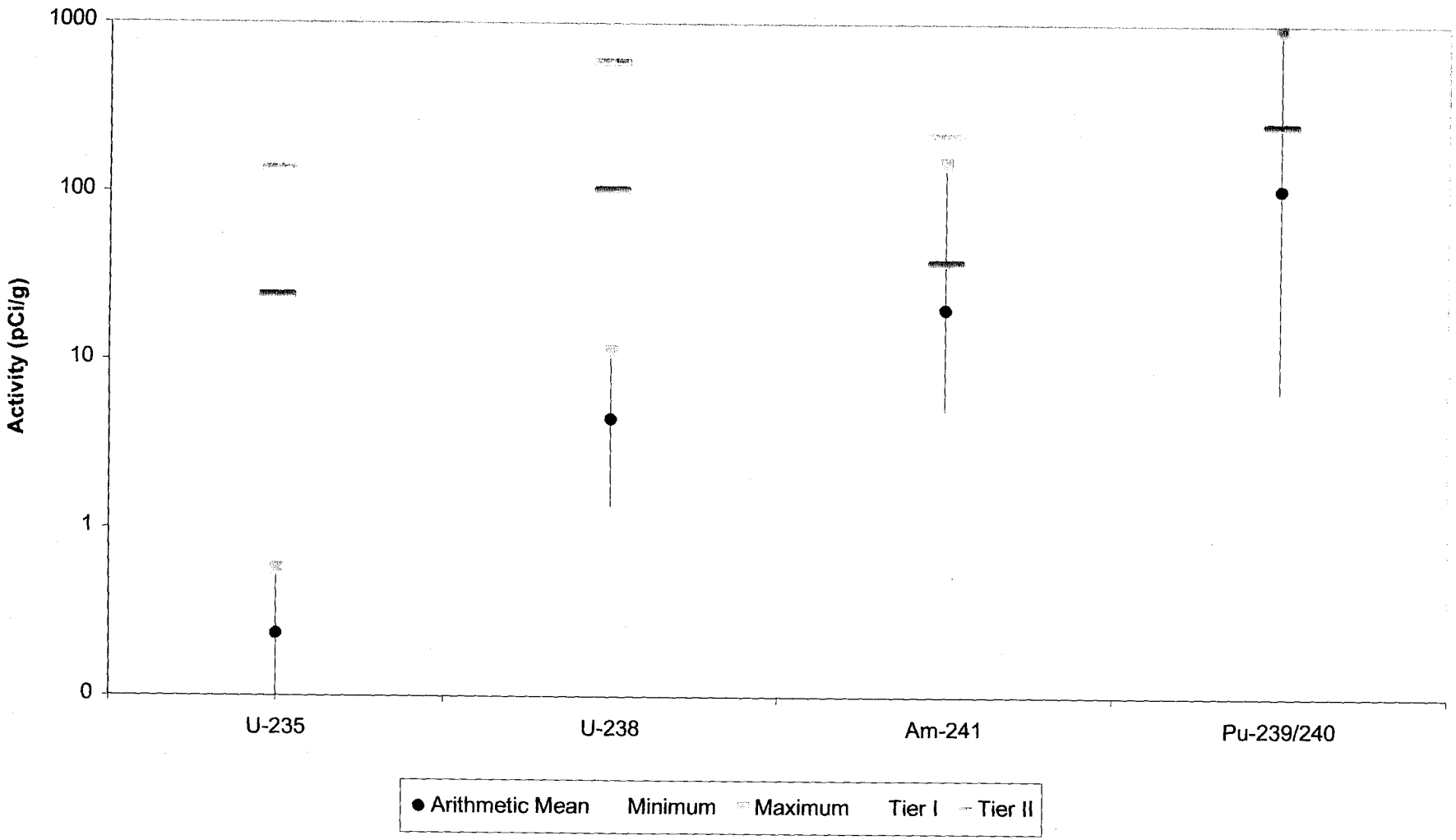
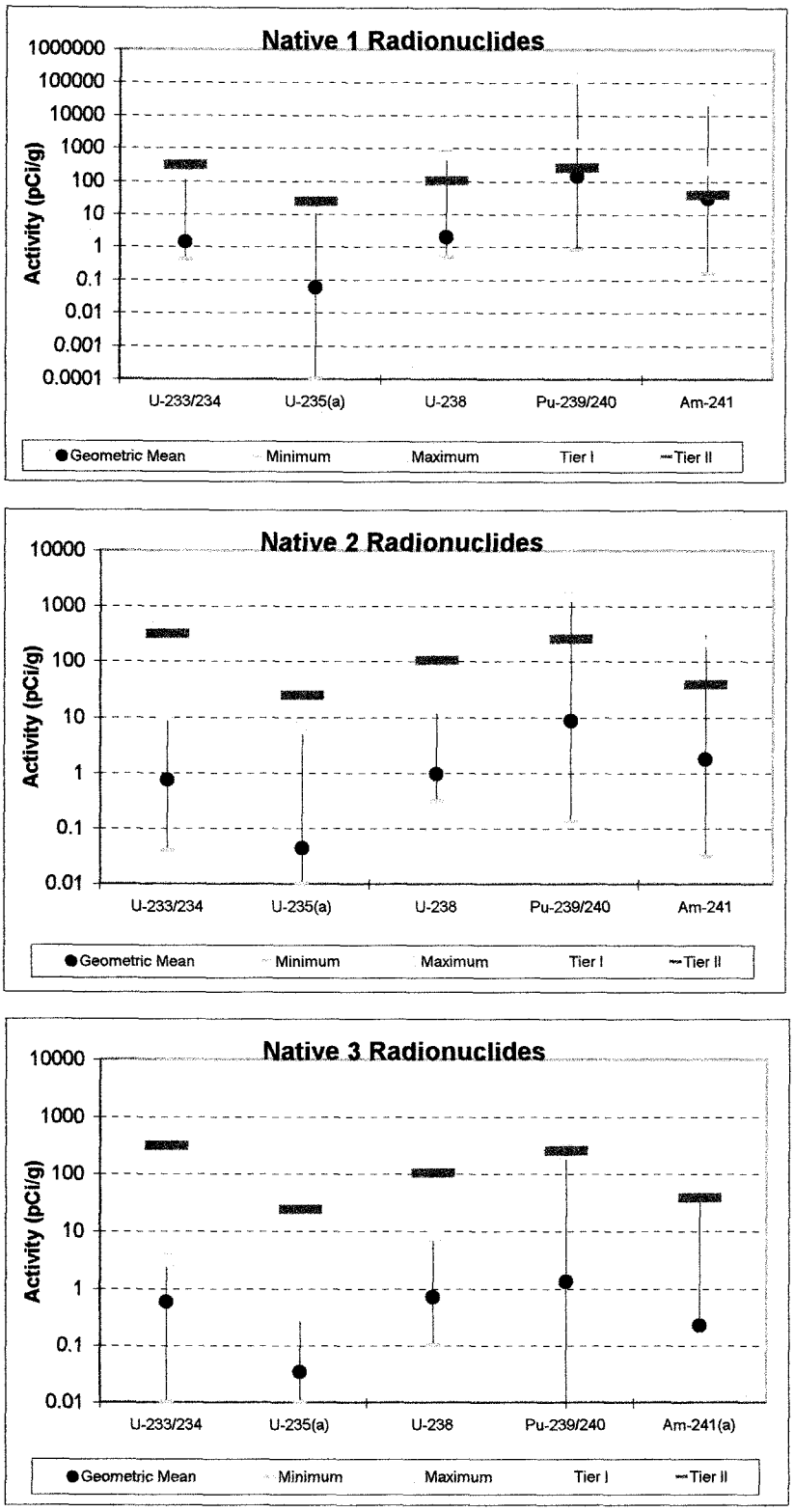


Figure 4-1 Range of Radionuclide Activities in Surface Soil - HPGe Survey



(a) Denotes median used instead of geometric mean

Figure 4-5. Range of Radionuclide Activities in Native 1, Native 2, and Native 3 Soils Horizons.

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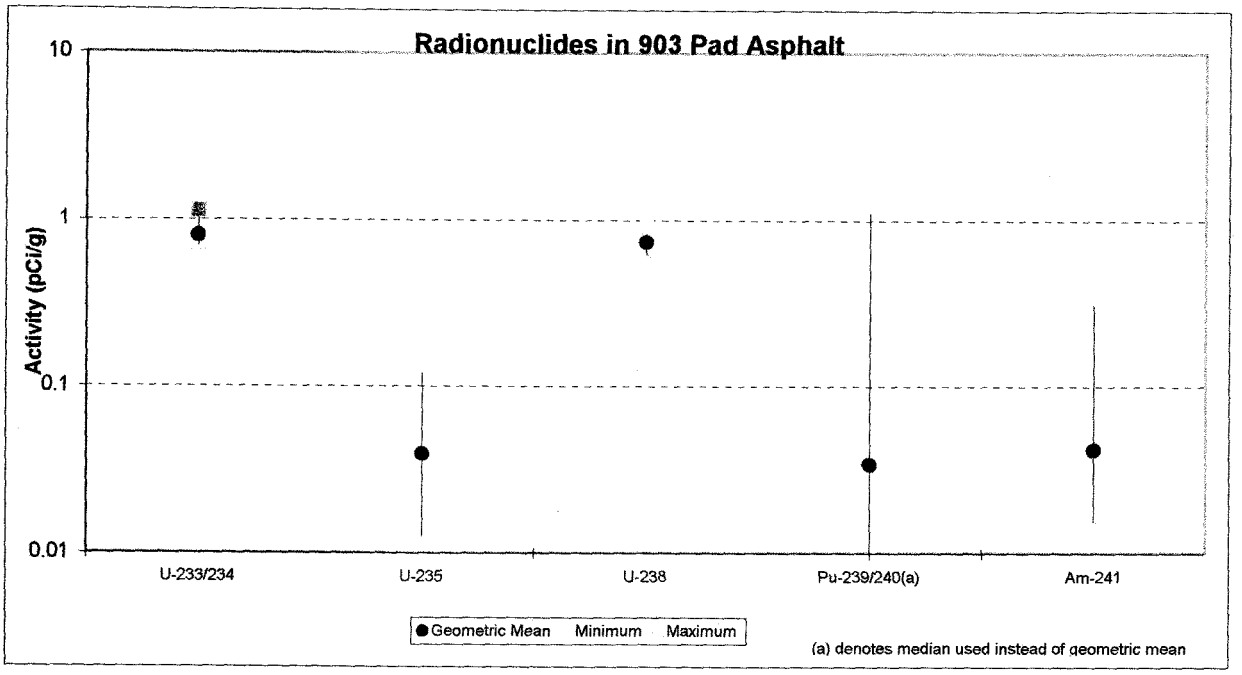

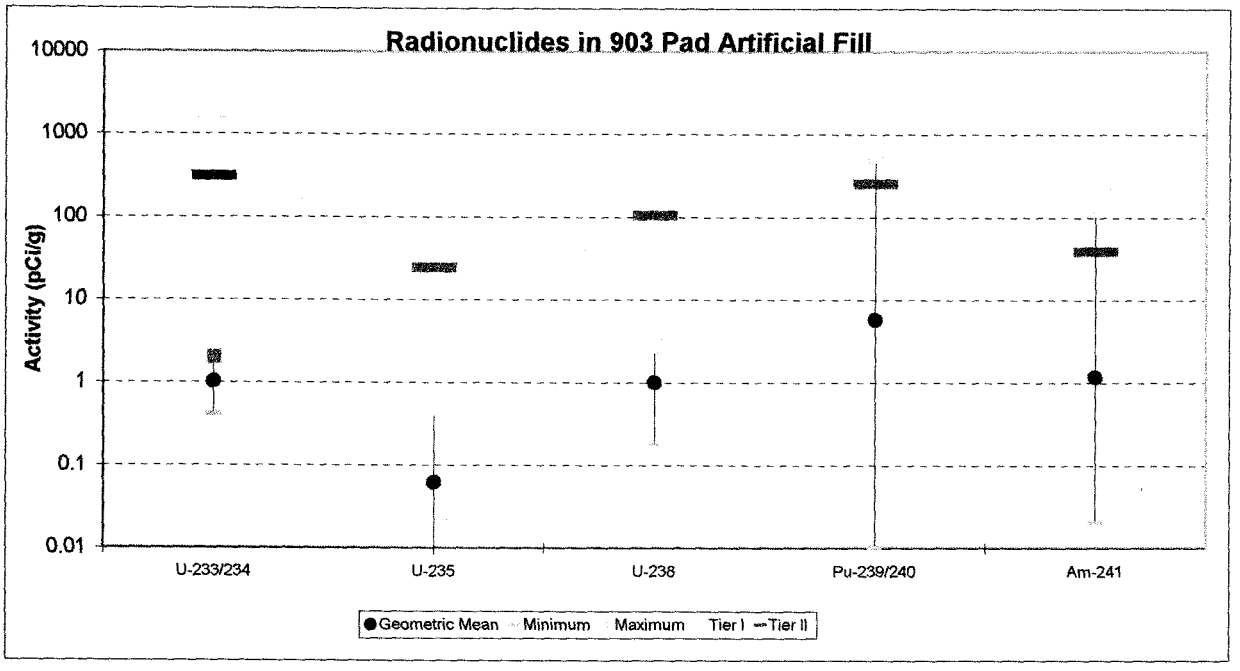

Figure 4-17. Range of Radionuclide Activities in Asphalt and Artificial Fill

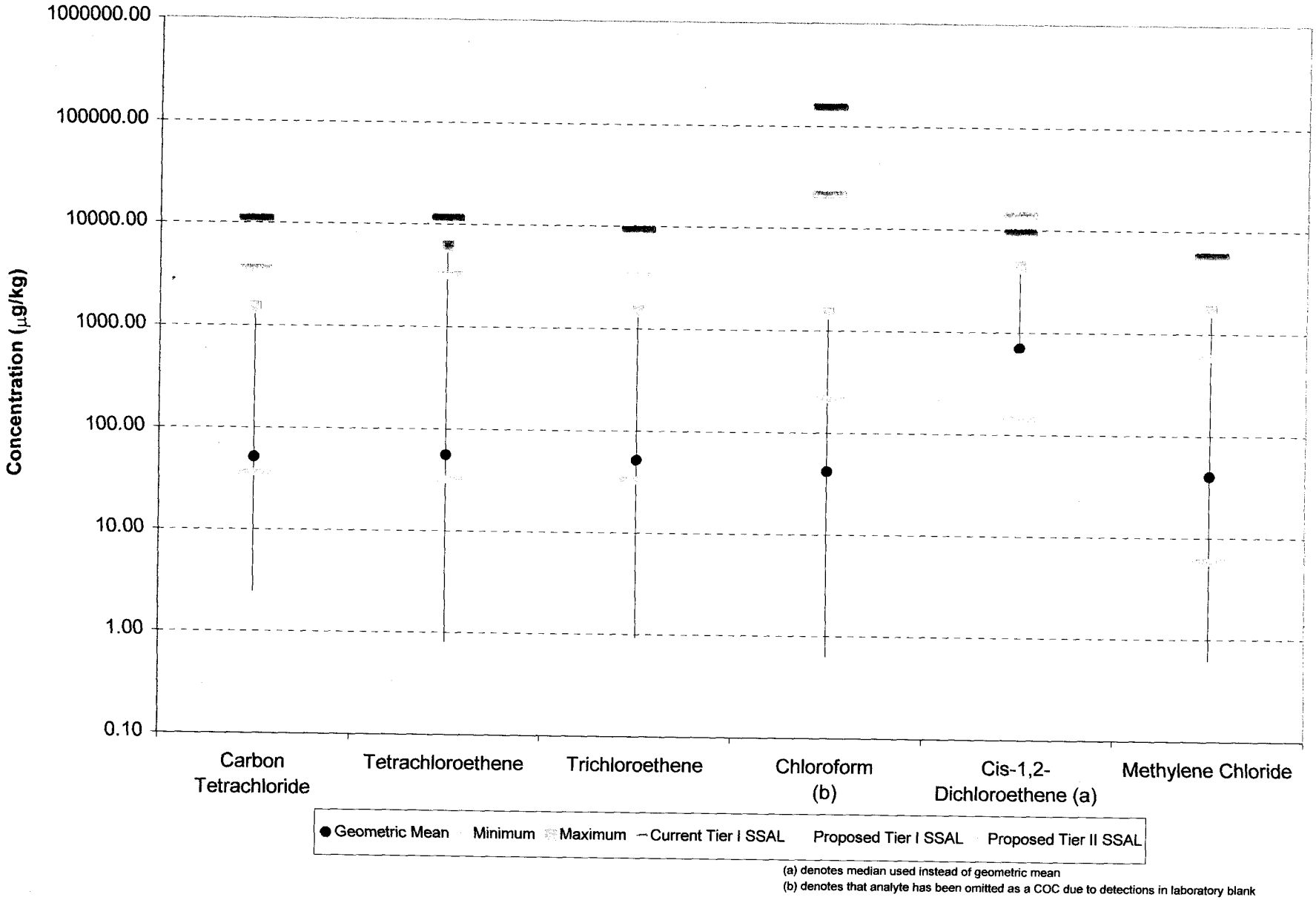

Figure 4-20. Range of VOC Concentrations in Subsurface Soil

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5.0 CONTAMINATED MEDIA VOLUME ESTIMATES

Volume estimates of radiological and VOC contaminated surface and subsurface soil are based on the areal and vertical extent of contamination above Tier I and Tier II RSALs and proposed SSALs. An ArcInfo, version 7.2.2, Thiessen polygon command (ESRI, 1999) was used to determine areas exceeding action levels for subsequent in-place volume calculations. Remedial alternatives will be evaluated in the IM/IRA Decision Document based on these volume estimates. In-place volume estimates for the 903 Pad asphalt and artificial fill are also presented.

5.1 903 PAD ASPHALT AND ARTIFICIAL FILL VOLUME ESTIMATES

Characterization data for the asphalt comprising the 903 Pad were collected only for waste characterization profiling. A comparison to these data to Tier I or Tier II RSALs is not relevant because RSALs are derived for soil cleanup. The estimated in-place volume of asphalt is 2,743 yd^3. The estimated in-place volume of artificial fill is 2,743 yd^3. The amount of radiologically contaminated artificial fill, relative to Tier II RSALs, beneath the 903 Pad is estimated at 104 yd^3. The 104 yd^3 estimate is based on a 75 ft by 75 ft area surrounding boring 91898 and a 6 inch thickness of artificial fill. Table 5-1 summarizes the estimated areal extent, depth, and in-place volumes of asphalt and artificial fill for the 903 Pad.

Table 5-1 Summary of 903 Pad Asphalt and Artificial Fill Volumes

903 Pad	Depth (ft)	Area (ft^2)	Volume[1] (ft^3)	Volume[1] (yd^3)	Volume[1] (m^3)
Asphalt	0.5	148,104	74,052	2,743	2,097
Artificial Fill less than Tier II RSALs	0.5	142,479	71,239	2,639	2,017
Artificial Fill greater than Tier II RSALs	0.5	5,625	2,813	104	80
Total	------	**296,208**	**148,104**	**5,485**	**4,194**

[1]Volume represents materials in-place

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5.2 TIER I RSAL EXCEEDANCE SOIL VOLUME ESTMATES

A composite map of the areal extent of Tier I RSAL exceedances in soil is presented in Figure 5-1. As shown, soil with radionuclides exceeding the Tier I RSALs is located beneath the 903 Pad, east of the 903 Pad in the Lip Area, and sporadically in the southern portion of the Lip Area and western portion of the Americium Zone. Table 5-2 summarizes the estimated areal extent, depth, and in-place volumes of soils exceeding Tier I RSALs by IHSS. The areal extent of Native 1 radiologically contaminated surface soil (relative to Tier I RSALs) is 120,359 ft^2. Depth of contamination varies from 0 to 6 inches to 0 to 12 inches throughout the investigation area. Based on the areal and vertical extent of Tier I RSAL exceedances, the total volume of in-place radiologically contaminated soil is 2,925 yd^3. The in-place volumes of contaminated soil by IHSS are as follows: 1,268 yd^3 for the 903 Pad; 1,580 yd^3 for the Lip Area; and 76 yd^3 for the Americium Zone.

Table 5-2 Summary of Radiologically Contaminated Soil Volumes-Tier I RSAL Exceedances

903 Pad	Depth (ft)	Area (ft^2)	Volume[1] (ft^3)	Volume[1] (yd^3)
Native 1	0.5	62,953	31,477	1,166
Native 2	0.5	5,532	2,766	102
Total	--------	----------	**34,243**	**1,268**
Lip Area				
Native 1	0.5	53,295	26,648	987
Native 2	0.5	32,044	16,022	593
Total	--------	----------	**42,670**	**1,580**
Americium Zone				
Native 1	0.5	4,111	**2,056**	**76**
Grand Total	--------	----------	**78,473**	**2,925**

[1] Volume represents materials in-place

5.3 TIER II RSAL EXCEEDANCE SOIL VOLUME ESTIMATES

A composite map of the areal extent of Tier II RSAL exceedances in soil is presented in Figure 5-2. As expected, contamination above the Tier II RSALs is much more extensive than that of the Tier I RSAL exceedances. In general, Tier II RSAL exceedances encompass most of the 903

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Pad, the Lip Area, and the Americium Zone. Tier II RSAL exceedances in two portions of the Lip Area extend down to the Native 3 soil horizon, a depth of 1.5 feet. Figure 5-2 shows the areal extent of the Tier II RSAL exceedances for the Native 1 (0 to 6-inch), Native 2 (6 to 12-inch), and Native 3 (12 to 18-inch) soil horizons. Table 5-3 summarizes the estimated areal extent, depth, and in-place volumes of soils exceeding Tier II RSALs by IHSS.

The areal extent of Native 1 radiologically contaminated surface soil (relative to Tier II RSALs) is 654,793 ft^2. Depth of contamination varies from 0 to 6 inches to 0 to 18 inches within the investigation area. Based on the areal and vertical extent of Tier II RSAL exceedances, the total volume of in-place radiologically contaminated soil is 14,307 yd^3. A depth of 6 inches was used to estimate volumes of soil in the Americium Zone. Radiologically contaminated soil volumes based on Tier II RSAL exceedances are summarized in Table 5-3. The in-place volumes of contaminated soil by IHSS are as follows: 2,471 yd^3 for the 903 Pad; 4,811 yd^3 for the Lip Area; and 7,025 yd^3 for the Americium Zone.

Table 5-3 Summary of Radiologically Contaminated Soil Volumes-Tier II RSAL Exceedances

903 Pad	Depth (ft)	Area (ft^2)	Volume[1] (ft^3)	Volume[1] (yd^3)
Native 1	0.5	111,676	55,838	2,068
Native 2	0.5	21,738	10,869	403
Total	--------	----------	**66,707**	**2,471**
Lip Area				
Native 1	0.5	163,784	81,892	3,033
Native 2	0.5	74,065	37,033	1,372
Native 3	0.5	21,941	10,971	406
Total	--------	----------	**129,896**	**4,811**
Americium Zone				
Native 1	0.5	**379,333**	**189,667**	**7,025**
Grand Total	--------	----------	**386,270**	**14,307**

[1] Volume represents materials in-place

5.4 SSAL EXCEEDANCE SOIL VOLUME ESTIMATES

Organic contaminants of concern (methylene chloride, CCl_4, PCE, 1,2-DCE, TCE, and Aroclor-1248) did not exceed the current Tier I SSALs. However, as discussed in Section 4.3, PCE, TCE, and methylene chloride exceed the proposed Tier I SSAL in borings 90998, 91198, 21893 and 92598 (Figures 4-18 and 4-19). Tier I SSAL exceedances below the water table were excluded from further consideration. For example, TCE and methylene chloride were detected above the Tier I SSALs at borings 21893 and 12991, respectively (Figure 4-19) but were observed below the water table (depth to water varies from 10 to 20 feet bgs in the Lip Area). VOC contamination below the water table will be addressed under the RFETS sitewide ground water program.

Soil concentrations between proposed Tier I and Tier II SSALs occur at borings 33291, 21893, 96398, 97198, 92598, 97698, 95998, 90998, 96498, 96798, 91198, and 12991. Methylene chloride is the most ubiquitous of the organic compounds, occurring at 7 boring locations at or near the 903 Pad followed by PCE, which was observed in five borings, and 1,2-DCE which exceeded the proposed Tier II SSAL in boring 90998. The depth of contamination between proposed Tier I and Tier II SSALs varies from 0 to 6 feet bgs at boring 33291 to 1 to 19.8 feet at boring 97698.

At the 903 Pad, the depth of organic concentrations between proposed Tier I and Tier II SSALs is assumed to extend from the natural soil surface below the top of the asphalt to the deepest extent of observed contamination above the water table. This is a conservative assumption given that organic samples were not collected above the Native 1 soil horizon. The areal extent of contamination was bounded one-half the distance between adjacent borings where VOC results were below their respective SSALs, and by the edge of the 903 Pad to the east. Several proposed Tier II SSAL exceedances were observed below the water table (average depth to water is 19 feet bgs) at boreholes 95998, 96798, and 97698. Similar to Tier I SSAL exceedances, VOC contamination below the water table will be addressed under the sitewide groundwater program.

5.4.1 Tier I SSAL Exceedance Soil Volume Estimates

A composite map showing the areal extent of contamination as defined by the proposed Tier I SSALs is presented in Figure 5-3. The depth of VOC contamination varies beneath the 903 Pad. For example, at boring 92598, the depth of contamination occurs between 0 and 16.75 feet bgs, at boring 91198 contamination extends from 7.75 to the water table (19.0 feet bgs), and from 1.0 to 4 feet bgs at boring 90998. Based on the areal and vertical extent of the proposed Tier I SSAL exceedances, the total in-place volume of contaminated soil is 4,237 yd^3 (Table 5-4). This amount also includes 174 yd^3 of radiologically contaminated soil relative to proposed Tier I and Tier II RSAL exceedances (Figures 5-1 and 5-2).

Table 5-4 Summary of Radiologically Contaminated Soil Volumes – SSAL Exceedances

Area/Material	Volume Estimate (yd^3)
Soil > Proposed Tier I SSALs	
Soil Mixed With Radionuclides: > Tier I RSALs	93
Soil Mixed With Radionuclides: > Tier II RSALs	81
Soil > Tier I SSALs	4,063
Total	**4,237**
Soil Between Proposed Tier I and Tier II SSALs	
Soil Mixed With Radionuclides: > Tier I RSALs	143
Soil > Tier II SSALs	6,670
Total	**6,813**

[1] Volume represents materials in-place volume.

5.4.2 Tier II SSAL Exceedance Soil Volume Estimates

A composite map showing the areal extent of contamination as defined by the proposed Tier II SSALs is presented in Figure 5-3. Soil concentrations between proposed Tier I and Tier II SSALs occur at borings 97698, 95998,33291, and 97198. The depth of contamination between proposed Tier I and Tier II SSALs varies from 0 to 6 feet bgs at boring 33291 to 1 foot bgs to the water table (19.0 feet bgs) near boring 97698.

Based on the aerial extent and depth of contamination, the amount of soil characterized between proposed Tier I and Tier II SSALs is 6,813 yd^3 (Table 5-4). This amount also includes 143 yd^3 of radiologically contaminated soil above Tier 1 RSALs (Figure 5-1).

5.5 RSAL AND SSAL EXCEEDANCE SOIL VOLUME ESTIMATES

Four areas within the 903 Pad contain surface soil with elevated levels of both radionuclides (RSALs) and VOCs (SSALs). Soil exceeding proposed SSALs occur in the areas shown in Figure 5-3. Soil exceeding Tier I and Tier II RSALs are provided in Figures 5-1 and 5-2, respectively. Comparing these figures with Figure 5-3 shows that there are areas where both RSALs and SSALs exceedances overlap. Soil containing both RSAL and SSAL exceedances occurs to a depth of 6 inches in these areas. An estimated total of 93 yd^3 ([5,017 ft^2 x 0.5 ft]/27 ft^3/yd^3) of soil exceed both Tier I RSALs and proposed Tier I SSALs at boring 90998.
At boring 91198, an estimated total of 81 yd^3 ([4,400 ft^2 x 0.5 ft]/27 ft^3/yd^3) of soils exceed both proposed Tier I SSALs and Tier II RSALs (Table 5-4).

Proposed Tier II SSAL exceedances in natural soils occur to depths of 19.8 feet near boring 97698 and 16.4 feet at boring 96398. Tier I (and consequently Tier II) RSAL exceedances in natural soils are present to a depth of 6 inches near these borings. Therefore, an estimated total of 143 yd^3 ([7,718 ft^2 x 0.5 ft]/27 ft^3/yd^3) of soils exceed both Tier I RSALs and proposed Tier II SSALs (Table 5-4).

5.6 SSAL EXCEEDANCE SOIL VOLUME ESTIMATES (NON-RADIOLOGICALLY CONTAMINTED)

This section provides volume estimates of VOC contaminated soil (relative to SSALs) below the Native 1 soil horizon where radiologically contaminated soil (relative to RSALs) is not present. The total in-place soil volume estimates, therefore, excludes the radiologically contaminated Native 1 soil addressed in Sections 5.2 and 5.3.

Soil exceeding Tier I SSALs occur in two areas within the 903 Pad (Figure 5-3). Proposed Tier I SSAL exceedances in natural soils occur to depths of 16.75 bgs at 92598 and 19 feet bgs at

91198. Therefore, excluding the upper 1.5 feet of radiologically contaminated soil, the artificial fill and the asphalt, a total of 4,063 yd^3 of soil is estimated to exceed Tier I SSALs.

The depth of contamination between proposed Tier I and Tier II SSALs varies from 0 to 6 feet bgs at boring 33291 to 1 foot bgs to the water table (19.0 feet bgs) near boring 97698. . Excluding the upper 1.5 feet of radiologically contaminated soil, artificial fill and asphalt, a total of 6,670 yd^3 of soil is estimated to exceed Tier II SSALs.

5.7 SUMMARY OF MEDIA VOLUME ESTIMATES

This section summarizes volume estimates of soils exceeding Tier I and Tier II RSALs and SSALs, and includes 903 Pad asphalt and artificial fill volume estimates. Tables 5-5 and 5-6 present volumes of asphalt, artificial fill and soil exceeding Tier I SALs and Tier II SALs, respectively.

Table 5-5 Volumes of Asphalt, Artificial Fill and Soils Exceeding Tier I RSALs and SSALs

Area/Material	Exceedance	Volume[1] (ft^3)	Volume[1] (yd^3)
903 Pad Soil	RSAL	34,243	1,268
903 Pad Soil	SSAL	109,701	4,063
Lip Area Soil	RSAL	42,670	1,580
Americium Zone Soil	RSAL	2,056	76
Total		**188,670**	**6,987**
903 Pad Asphalt	NA	74,052	2,743
903 Pad Artificial Fill	None	74,052	2,743
Grand Total		**336,774**	**12,473**

[1]Volume represents materials in-place
NA = Not Applicable.

Table 5-6 Volumes of Asphalt, Artificial Fill, and Soils Exceeding Tier II RSALs and SSALs

Area/Material	Exceedance	Volume[1] (ft^3)	Volume[1] (yd^3)
903 Pad Artificial Fill	RSAL	2,813	104
903 Pad Soil	RSAL	66,707	2,471
903 Pad Soil	SSAL	180,090	6,670
Lip Area Soil	RSAL	129,896	4,811
Americium Zone Soil	RSAL	189,667	7,025
Total		**569,173**	**21,081**
903 Pad Asphalt	NA	74,052	2,743
903 Pad Artificial Fill[2]	None	71,239	2,639
Grand Total		**714,464**	**26,463**

[1]Volume represents materials in-place
[2] Excludes 104 yd^3 exceeding RSALs

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Appendix A

Proposed Subsurface SAL Screening Results

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Proposed Subsurface SAL Screening Results

LOCATION	SAMPLE NO.	PROJECT	CAS No.	COMPOUND	RESULT (µg/kg)	TIER I SSAL (µg/kg)	TIER II SSAL (µg/kg)	LAB QUALIFIER	DEPTH START (ft)	DEPTH END (ft)	COMMENTS
90998	98A2015-001.010	903 Pad	75-35-4	CIS-1,2-DICHLOROETHENE	4400	14000	140		3.8	4	Approximate Average Depth of Water = 19 ft bgs
33291	BH00284EBU1	OU2	12672-29-6	AROCLOR-1248	7200	531000	5310		0	6	Assumed Depth Interval of 0 to 6 ft.
0168	GT0012IT	OU2	7440-38-2	ARSENIC	5	299	2.99		0	5	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
0171	BP00031IT	OU2	7440-38-2	ARSENIC	3	299	2.99		0	31	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
0271	BP00032IT	OU2	7440-38-2	ARSENIC	5	299	2.99		0	32	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
0368	GT0014IT	OU2	7440-38-2	ARSENIC	4	299	2.99	B	0	5	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
0468	GT0015IT	OU2	7440-38-2	ARSENIC	5	299	2.99		0	5	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
10391	BH00373WCU2	OU2	7440-38-2	ARSENIC	7	299	2.99	B	2.2	8.1	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
21793	BH20319WC	OU2	7440-38-2	ARSENIC	4	299	2.99		20.7	26.7	Mound Area. Background above Tier II level, value < BSL (13.2 mg/Kg)
21793	BH20321WC	OU2	7440-38-2	ARSENIC	4	299	2.99		31.9	37.4	Mound Area. Background above Tier II level, value < BSL (13.2 mg/Kg)
21793	BH20320WC	OU2	7440-38-2	ARSENIC	5	299	2.99		26.7	31.9	Mound Area. Background above Tier II level, value < BSL (13.2 mg/Kg)
21793	BH20319WC	OU2	7440-38-2	ARSENIC	10	299	2.99		20.7	26.7	Mound Area. Background above Tier II level, value < BSL (13.2 mg/Kg)
21893	BH20277WC	OU2	7440-38-2	ARSENIC	4	299	2.99		44.6	50	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
21893	BH20263WC	OU2	7440-38-2	ARSENIC	6	299	2.99		38	44.6	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
21893	BH20260WC	OU2	7440-38-2	ARSENIC	6	299	2.99		20.2	26	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
32691	BH00249EBU1	OU2	7440-38-2	ARSENIC	9	299	2.99		0	6	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
32691	BH00251EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		6	8	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
32891	BH00257EBU1	OU2	7440-38-2	ARSENIC	3	299	2.99		0	6	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
32991	BH00266EBU1	OU2	7440-38-2	ARSENIC	3	299	2.99		6	8	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33291	BH00284EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		0	6	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33591	BH00299EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		12	16	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33591	BH00297EBU1	OU2	7440-38-2	ARSENIC	5	299	2.99		6	12	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33591	BH00297EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		6	12	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33591	BH00294EBU1	OU2	7440-38-2	ARSENIC	5	299	2.99		0	6	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33791	BH00355EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		6	12	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33791	BH00359EBU1	OU2	7440-38-2	ARSENIC	3	299	2.99		12	18	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
33791	BH00360EBU1	OU2	7440-38-2	ARSENIC	4	299	2.99		18	20	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46692	BH30323IT	OU2	7440-38-2	ARSENIC	6	299	2.99		59	90	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46692	BH30379IT	OU2	7440-38-2	ARSENIC	5	299	2.99		0	15	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46692	BH30321IT	OU2	7440-38-2	ARSENIC	9	299	2.99	B			Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30301IT	OU2	7440-38-2	ARSENIC	4	299	2.99		0	5	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30303IT	OU2	7440-38-2	ARSENIC	15	299	2.99		10	15	NE Trenches Area. Value < BSL (13.2 mg/Kg)
46792	BH30304IT	OU2	7440-38-2	ARSENIC	3	299	2.99		16	18.5	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30302IT	OU2	7440-38-2	ARSENIC	5	299	2.99		5	10	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30328IT	OU2	7440-38-2	ARSENIC	4	299	2.99	B			Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30327IT.	OU2	7440-38-2	ARSENIC	5	299	2.99	B			Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46792	BH30328IT	OU2	7440-38-2	ARSENIC	5	299	2.99	B			Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46892	BH30380IT	OU2	7440-38-2	ARSENIC	4	299	2.99		0	10	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
46892	BH30380IT	OU2	7440-38-2	ARSENIC	4	299	2.99		0	10	Background > Tier II Level. Value < BSL (13.2 mg/Kg)
SS200193	SS20001WC	OU2	7440-38-2	ARSENIC	5	299	2.99	N	0	2	Background > Tier II level. Value < BSL (10.09 mg/Kg)
32691	BH00251EBU1	OU2	7440-41-7	BERYLLIUM	2	104	1.04		6	8	Not Identified as PCOC in OU2 RI Report (DOE, 1995). Value< Background
32891	BH00259EBU1	OU2	7440-41-7	BERYLLIUM	2	104	1.04		6	8	Not Identified as PCOC in OU2 RI Report (DOE, 1995). Value< Background
32891	BH00257EBU1	OU2	7440-41-7	BERYLLIUM	2	104	1.04		0	6	Not Identified as PCOC in OU2 RI Report (DOE, 1995). Value< Background
32991	BH00264EBU1	OU2	7440-41-7	BERYLLIUM	2	104	1.04		0	6	Not Identified as PCOC in OU2 RI Report (DOE, 1995). Value< Background
33291	BH00288EBU1	OU2	7440-41-7	BERYLLIUM	2	104	1.04		12	14	Not Identified as PCOC in OU2 RI Report (DOE, 1995). Value< Background
91198	98A1091-001.033	903 Pad	74-83-9	Bromomethane	690	5980	59.8	JB	3.1	3.4	Approximate Average Depth of Water = 19 ft bgs
21493	BH20147WC	OU2	56-23-5	CARBON TETRACHLORIDE	230	3560	35.6		0	43	Drum Sample for IDM Characterization. Drum # 3528WC
22493	BH20105WC	OU2	56-23-5	CARBON TETRACHLORIDE	200	3560	35.6	D	15.5	15.8	Remediated. NE Trenches Area
22493	BH20105WC	OU2	56-23-5	CARBON TETRACHLORIDE	650	3560	35.6	E	15.5	15.8	Remediated. NE Trenches Area

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Table A1
Proposed Subsurface SAL Screening Results

LOCATION	SAMPLE NO.	PROJECT	CAS No.	COMPOUND	RESULT (µg/kg)	TIER I SSAL (µg/kg)	TIER II SSAL (µg/kg)	LAB QUALIFIER	DEPTH START (ft)	DEPTH END (ft)	COMMENTS
00891	BH00032WCU2	OU2	75-09-2	METHYLENE CHLORIDE	10	578	5.78	B	16.9	18.9	Probable contaminant in 903 Pad Area.
03391	BH00107WCU2	OU2	75-09-2	METHYLENE CHLORIDE	11	578	5.78	B	13	13.2	Probable contaminant in 903 Pad Area.
03391	BH00109WCU2	OU2	75-09-2	METHYLENE CHLORIDE	7	578	5.78	B	22.6	22.8	Probable contaminant in 903 Pad Area. Below Water Table.
12991	BH00568WCU2	OU2	75-09-2	METHYLENE CHLORIDE	6	578	5.78		26.7	26.9	Probable contaminant in 903 Pad Area. Below Water Table.
21293	BH20292WC	OU2	75-09-2	METHYLENE CHLORIDE	34	578	5.78	BD	26	149	Drum Sample for IDM Characterization.
21393	BH20110WC	OU2	75-09-2	METHYLENE CHLORIDE	72	578	5.78		45	209	Drum Sample for IDM Characterization.
21393	BH20102WC	OU2	75-09-2	METHYLENE CHLORIDE	53	578	5.78		45	209	Drum Sample for IDM Characterization.
21593	BH20089WC	OU2	75-09-2	METHYLENE CHLORIDE	16	578	5.78		0	24.3	Mound Area. Drum Sample for IDM Characterization
21693	BH20088WC	OU2	75-09-2	METHYLENE CHLORIDE	7	578	5.78		32.7	33	NE Trenches Area Remediated
21693	BH20074WC	OU2	75-09-2	METHYLENE CHLORIDE	9	578	5.78		30.7	31	NE Trenches Area Remediated
21693	BH20073WC	OU2	75-09-2	METHYLENE CHLORIDE	7	578	5.78		28.7	29	NE Trenches Area Remediated
21693	BH20072WC	OU2	75-09-2	METHYLENE CHLORIDE	6	578	5.78		26.7	27	NE Trenches Area Remediated
21693	BH20071WC	OU2	75-09-2	METHYLENE CHLORIDE	11	578	5.78		24.7	25	NE Trenches Area Remediated
21693	BH20069WC	OU2	75-09-2	METHYLENE CHLORIDE	7	578	5.78		22.7	23	NE Trenches Area Remediated
21693	BH20070WC	OU2	75-09-2	METHYLENE CHLORIDE	6	578	5.78		0	25	NE Trenches Area Remediated
21693	BH20098WC	OU2	75-09-2	METHYLENE CHLORIDE	16	578	5.78	BJ	0	47	NE Trenches Area Remediated
22293	BH20343WC	OU2	75-09-2	METHYLENE CHLORIDE	48	578	5.78	BJ	51	85	Mound Area. Drum Sample for IDM Characterization
22493	BH20105WC	OU2	75-09-2	METHYLENE CHLORIDE	40	578	5.78	BD	15.5	15.8	NE Trenches Area Remediated
24093	BH20611WC	OU2	75-09-2	METHYLENE CHLORIDE	12	578	5.78		1.6	1.8	Remediated. NE Trenches Area
24093	BH20614WC	OU2	75-09-2	METHYLENE CHLORIDE	13	578	5.78		15.1	15.3	Remediated. NE Trenches Area
24193	BH20626WC	OU2	75-09-2	METHYLENE CHLORIDE	10	578	5.78	J	35.6	35.9	Remediated. NE Trenches Area
24593	BH20608WC	OU2	75-09-2	METHYLENE CHLORIDE	20	578	5.78		7.5	7.8	Remediated. NE Trenches Area
25694	BH20656WC	OU2	75-09-2	METHYLENE CHLORIDE	500	578	5.78	BJ	11.8	12	NE Trenches Area Remediated
91198	98A1091-001.033	903 Pad	75-09-2	METHYLENE CHLORIDE	470	578	5.78	JB	3.1	3.4	Probable Contaminant In 903 Pad Area
92598	98A1092-001.033	903 Pad	75-09-2	METHYLENE CHLORIDE	1400	578	5.78	B	3.5	4	Probable Contaminant In 903 Pad Area
90998	98A2015-001.010	903 Pad	75-09-2	METHYLENE CHLORIDE	830	578	5.78	B	3.8	4	Probable Contaminant In 903 Pad Area
92598	98A1092-001.034	903 Pad	75-09-2	METHYLENE CHLORIDE	1500	578	5.78	B	7.5	8	Probable Contaminant In 903 Pad Area
91198	98A1091-001.034	903 Pad	75-09-2	METHYLENE CHLORIDE	910	578	5.78	B	7.7	8	Probable Contaminant In 903 Pad Area
91198	98A1091-001.035	903 Pad	75-09-2	METHYLENE CHLORIDE	960	578	5.78	B	11.6	11.9	Probable Contaminant In 903 Pad Area
92598	98A1092-001.035	903 Pad	75-09-2	METHYLENE CHLORIDE	1700	578	5.78	B	12	12.5	Probable Contaminant In 903 Pad Area
91198	98A1091-001.036	903 Pad	75-09-2	METHYLENE CHLORIDE	980	578	5.78	B	15.5	15.8	Probable Contaminant In 903 Pad Area
92598	98A1092-001.036	903 Pad	75-09-2	METHYLENE CHLORIDE	1700	578	5.78	B	16	16.75	Probable Contaminant In 903 Pad Area
91198	98A1091-001.037	903 Pad	75-09-2	METHYLENE CHLORIDE	1500	578	5.78	B	19.1	19.5	Probable Contaminant In 903 Pad Area
91198	98A1091-001.038	903 Pad	75-09-2	METHYLENE CHLORIDE	1200	578	5.78	B	19.5	19.8	Probable Contaminant In 903 Pad Area
97698	99A8275-003.002	903 Pad	75-09-2	METHYLENE CHLORIDE	28.6	578	5.78	B	11.2	11.6	Probable Contaminant In 903 Pad Area
96398	99A4102-001.009	903 Pad	75-09-2	METHYLENE CHLORIDE	410	578	5.78	J	12.4	12.7	Probable Contaminant In 903 Pad Area
97698	99A8275-004.002	903 Pad	75-09-2	METHYLENE CHLORIDE	35.4	578	5.78	B	13.5	13.9	Probable Contaminant In 903 Pad Area
96398	99A4102-001.012	903 Pad	75-09-2	METHYLENE CHLORIDE	390	578	5.78	J	16.2	16.4	Probable Contaminant In 903 Pad Area
97698	99A8275-005.002	903 Pad	75-09-2	METHYLENE CHLORIDE	29.9	578	5.78	B	16.3	16.7	Probable Contaminant In 903 Pad Area
97698	99A8275-008.002	903 Pad	75-09-2	METHYLENE CHLORIDE	21.6	578	5.78	B	18.2	18.8	Probable Contaminant In 903 Pad Area
97198	99A4102-002.018	903 Pad	75-09-2	METHYLENE CHLORIDE	460	578	5.78	BJ	24.4	24.8	Probable Contaminant In 903 Pad Area
96398	99A4102-001.003	903 Pad	75-09-2	METHYLENE CHLORIDE	380	578	5.78	J	4.3	4.8	Probable Contaminant In 903 Pad Area
97198	99A4102-002.006	903 Pad	75-09-2	METHYLENE CHLORIDE	200	578	5.78	J	4.4	4.8	Probable Contaminant In 903 Pad Area
97198	99A4102-002.003	903 Pad	75-09-2	METHYLENE CHLORIDE	380	578	5.78	J	7.3	7.6	Probable Contaminant In 903 Pad Area
96398	99A4102-001.006	903 Pad	75-09-2	METHYLENE CHLORIDE	350	578	5.78	J	8.4	8.9	Probable Contaminant In 903 Pad Area
24793	BH20601WC	OU2	127-18-4	TETRACHLOROETHENE	260000	3150	31.5		7.7	8	Remediated; Northeast Trenches Area
24793	BH20600WC	OU2	127-18-4	TETRACHLOROETHENE	1100000	3150	31.5		7.7	8	Remediated; Northeast Trenches Area
25594	BH20658WC	OU2	127-18-4	TETRACHLOROETHENE	730000	3150	31.5		15.8	16	Remediated; Northeast Trenches Area
25594	BH20660WC	OU2	127-18-4	TETRACHLOROETHENE	510000	3150	31.5		9.8	10	Remediated; Northeast Trenches Area

Table A1
Proposed Subsurface SAL Screening Results

LOCATION	SAMPLE NO.	PROJECT	CAS No.	COMPOUND	RESULT (µg/kg)	TIER I SSAL (µg/kg)	TIER II SSAL (µg/kg)	LAB QUALIFIER	DEPTH START (ft)	DEPTH END (ft)	COMMENTS
25694	BH20656WC	OU2	127-18-4	TETRACHLOROETHENE	27000	3150	31.5		11.8	12	Remediated; Northeast Trenches Area
25694	BH20656WC	OU2	127-18-4	TETRACHLOROETHENE	38000	3150	31.5	E	11.8	12	Remediated; Northeast Trenches Area
21693	BH20085WC	OU2	127-18-4	TETRACHLOROETHENE	59	3150	31.5		0	47	Remediated. NE Trenches Area
21793	BH20317WC	OU2	127-18-4	TETRACHLOROETHENE	32	3150	31.5		35.1	35.4	Mound Area
21793	BH20285WC	OU2	127-18-4	TETRACHLOROETHENE	130	3150	31.5		23.1	23.4	Mound Area
21793	BH20316WC	OU2	127-18-4	TETRACHLOROETHENE	100	3150	31.5		31.6	31.9	Mound Area
21793	BH20315WC	OU2	127-18-4	TETRACHLOROETHENE	170	3150	31.5		27.5	27.8	Mound Area
22493	BH20137WC	OU2	127-18-4	TETRACHLOROETHENE	42	3150	31.5		0	52	Remediated. NE Trenches Area
22493	BH20157WC	OU2	127-18-4	TETRACHLOROETHENE	57	3150	31.5		0	52	Remediated. NE Trenches Area
22493	BH20136WC	OU2	127-18-4	TETRACHLOROETHENE	93	3150	31.5		0	52	Remediated. NE Trenches Area
24793	BH20600WC	OU2	127-18-4	TETRACHLOROETHENE	1100000	3150	31.5		7.7	8	Remediated. NE Trenches Area
24793	BH20601WC	OU2	127-18-4	TETRACHLOROETHENE	260000	3150	31.5		7.7	8	Remediated. NE Trenches Area
25294	BH20654WC	OU2	127-18-4	TETRACHLOROETHENE	190	3150	31.5		6.75	7	Remediated. NE Trenches Area
25594	BH20660WC	OU2	127-18-4	TETRACHLOROETHENE	510000	3150	31.5		9.8	10	NE Trenches Area Remediated
25594	BH20658WC	OU2	127-18-4	TETRACHLOROETHENE	730000	3150	31.5		15.8	16	NE Trenches Area Remediated
25694	BH20656WC	OU2	127-18-4	TETRACHLOROETHENE	27000	3150	31.5		11.8	12	NE Trenches Area Remediated
25694	BH20656WC	OU2	127-18-4	TETRACHLOROETHENE	38000	3150	31.5	E	11.8	12	NE Trenches Area Remediated
90998	98A2015-001.010	903 Pad	127-18-4	TETRACHLOROETHENE	6100	3150	31.5		3.8	4	Approximate Average Depth of Water = 19 ft bgs
97698	99A8275-004.002	903 Pad	127-18-4	TETRACHLOROETHENE	40.5	3150	31.5		13.5	13.9	Approximate Average Depth of Water = 19 ft bgs
97698	99A8275-009.002	903 Pad	127-18-4	TETRACHLOROETHENE	76.3	3150	31.5		19.4	19.8	Approximate Average Depth of Water = 19 ft bgs
96798	99A6650-005.002	903 Pad	127-18-4	TETRACHLOROETHENE	72.2	3150	31.5		20.4	20.8	Approximate Average Depth of Water = 19 ft bgs
95998	99A7799-006.002	903 Pad	127-18-4	TETRACHLOROETHENE	343	3150	31.5	E	24.6	25	Approximate Average Depth of Water = 19 ft bgs
96498	99A3210-001.013	903 Pad	127-18-4	TETRACHLOROETHENE	800	3150	31.5	J	4.8	5.2	Approximate Average Depth of Water = 19 ft bgs
95998	99A7799-001.002	903 Pad	127-18-4	TETRACHLOROETHENE	1540	3150	31.5	E	5	5.6	Approximate Average Depth of Water = 19 ft bgs
24793	BH20600WC	OU2	108-88-3	TOLUENE	7600	707000	7070	J	7.7	8	Remediated. NE Trenches Area
21893	BH20256WC	OU2	79-01-6	TRICHLOROETHENE	5700	3280	32.8		23.1	23.4	Variably Saturated Area. Groundwater The Likely Contaminant Pathway
24793	BH20600WC	OU2	79-01-6	TRICHLOROETHENE	8100	3280	32.8	J	7.7	8	Remediated; Northeast Trenches Area
21493	BH20147WC	OU2	79-01-6	TRICHLOROETHENE	130	3280	32.8		0	43	Drum Sample for IDM Characterization. Drum # 3528WC
21893	BH20244WC	OU2	79-01-6	TRICHLOROETHENE	39	3280	32.8		0	18.6	Drum Sample for IDM Characterization. Drum #'s 2824WC, 2825WC
21893	BH20256WC	OU2	79-01-6	TRICHLOROETHENE	5700	3280	32.8		23.1	23.4	Probabale Contaminant
21893	BH20225WC	OU2	79-01-6	TRICHLOROETHENE	56	3280	32.8		0	26	Drum Sample for IDM Characterization. Drum #'s 3651WC-3654WC
24793	BH20600WC	OU2	79-01-6	TRICHLOROETHENE	8100	3280	32.8	J	7.7	8	Remediated. NE Trenches Area
25694	BH20656WC	OU2	79-01-6	TRICHLOROETHENE	280	3280	32.8	J	11.8	12	NE Trenches Area Remediated
90998	98A2015-001.010	903 Pad	79-01-6	TRICHLOROETHENE	290	3280	32.8	J	3.8	4	Approximate Average Depth of Water = 19 ft bgs

BSL=Background Screening Level (mean + two standard deviations)
SSAL=Subsurface Soil Action Level

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Table A-2
Summary of Tier I and Tier II Contaminants of Concern

Compound	Tier I Exceedance	Tier II Exceedance	Final COC	Comments
Aroclor-1248		X	X	Contamination located near Ryans Pit
Arsenic		X		SAL exceeds mean background concentration but < BSL
Beryllium		X		SAL exceeds mean background concentration but < BSL
Bromomethane		X		Laboratory Contaminant. Concentration < 5 x Blank Concentration
Carbon Tetrachloride		X	X	Drum sample for IDM characterization at 21493
1,2 DCE		X	X	Contamination located beneath the 903 Pad.
Methylene Chloride	X	X	X	Natural Decay Product of Carbon Tetrachloride. Associated Contamination In Ground Water Beneath the 903 Pad.
PCE	X	X	X	Contamination located beneath the 903 Pad.
Toluene		X		Remediated. Northeast Trenches Area.
TCE	X	X	X	Contamination located beneath the 903 Pad and near Ryans Pit.
^{241}Am	X	X	X	Contamination located beneath the 903 Pad, Lip Area, and Americium Zone
$^{239/240}Pu$	X	X	X	Contamination located beneath the 903 Pad, Lip Area, and Americium Zone
^{234}U			X	Contamination located beneath the 903 Pad, Lip Area, and Americium Zone
^{235}U			X	Contamination located beneath the 903 Pad, Lip Area, and Americium Zone
^{238}U	X	X	X	Contamination located beneath the 903 Pad, Lip Area, and Americium Zone

BSL=Background Screening Level (mean + two standard deviations)

SAL=Soil Action Level

All radionuclides listed were retained as COCs.

Appendix B

Boring Logs

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH90098
Location - North: 749212 East: 2085611
Date: 3/27/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE

Surface Elevation: 5978 ft.
Area: 903 PAD/LAP ~~mw 8/25/98~~
Total Depth: 3.5ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.5ft	Run #1 0.0-3.5ft	Recovery 3.1 ft.	1.001 1.002	12:32				0.5		0.0-0.6 Asphalt, black, fractured, with geotextile at base.
			1.003 1.004	0.6 12:37 1.0			GP	1.0		0.6-1.0ft. Fill; Sand and Gravel, yellowish brown (10YR 5/4) rounded gravel up to 1.5cm, fine to crs sand, non-calcareous, moist
			1.005 1.006	12:36 1.5			GC	1.5		1.0-3.1 ft; Soil; Clay, sand, gravel, mostly clay/gravel; mottled dark reddish brn (2.5YR 3/4) with spots of very dark grayish brn (10YR 3/2) and yellowish brown (10YR 5/6), gravel up to 3cm, fractured, gravel concentrated at top and near base (clayey middle), gravel commonly rotten - composed of igneous rock frags, clay firm, plastic, moist.
			1.007 1.008	12:38 2.0				2.0		
			1.009 1.010	12:31 2.5				2.5		
			1.011 1.012	12:30 3.0				3.0		
								3.1		No Recovery 3.1-3.5
								3.5		T.D. = 3.5ft.
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH90198
Location - North: 749214 East: 2085686
Date: 4/21/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE

Surface Elevation: 5977
Area: 903 PAD/LIP 8/25/98
Total Depth: 4.0ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0ft	Run #1 0.0-4.0ft	Recovery 2.9ft.	001 002	0.95	10:38		NA	0.5	NA	0.0-0.5ft, Asphalt, black, fractured, gravel to 1.5cm rounded, membrane present.
			003 004	0.9	10:40		GM	0.9		0.5-0.9ft, FILL, sand and gravel, light olive brown (2.5Y 5/6), gravel up to 1.5cm, rounded and fractured, ↑unconsolidated, moist.↑
			005 006 014	1.4 Dupe	10:51 RI		GC	1.0 1.4 1.5		0.9-2.9ft., soil, clay sand gravel; 0.9-1.5 very dark gray (5YR 3/1) 1.5-2.9 yellowish red (5YR 5/8) gravel up to 3cm, fractured, granite and quartzite, well graded, firm but crumbly, slightly moist.
			007 008	1.9	10:48			1.9 2.0		
			009 010	2.4	10:44			2.4 2.5		
			011 012	2.9	10:42			2.9 3.5		2.9-4.0ft No Recovery
								3.5		
								4.0		T.D. = 4.0ft.

NOTES General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 90293
Location - North: 749211 East: 2085761
Date: 02-13-98
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5977 ft
Area: 903 Pad
Total Depth: 3.6 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Word DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (Cores/Bottle)	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	0.0				PT?	0.0		Asphalt - dry, chippy, crumbly. Contains fibrous geomembrane.
			0.5					0.5		
	RUN 1: 0.0-3.6	3.0	001/001 RS 001/002 R 0.8 001/003 RS 001/004 R 1.1 001/005 RS 001/006 R				SM SM	0.8 1.0		Sand fill - sl. moist. Traces gravel (fine). Dark brown (10YR 3/3). Bottom contact blurred. Gravelly, sandy silt w/ clay to sand-silt-clay mixture w/ gravel - Very dark brown (10YR 2/2), to dark brown (7.5YR 3/2, 3/3) below 1.8'. Increasing caliche below 2.6 brings color to v. pale brown (10YR 7/4). Sl. moist throughout. Elevated α activity (FIDLER) @ 0.8-1.1'
BOX 1 OF 1 0.0 - 3.6		1.7	001/007 RS 001/008 R					2.0		
		2.4	2.4 001/009 RS 001/010 R ~~001/011 RS~~ ~~001/012 R~~							
			3.0 N/A					3.0		NO RECOVERY 3.0-3.6'
3.6	3.6	3.6						3.6		
								4.0		TD = 3.6'
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								10.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

RS = rad screen
R = rads

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH90398
Location - North: 749215 East: 2085835
Date: 4/21/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE / MACROCORE

Surface Elevation: 5976 ft.
Area: 903 PAD / ~~LIP~~ 6/25/98
Total Depth: 4.0 ft.
Company: TIERRA Project No. GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 6/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft	Run #1 0.0-4.0 ft	Recovery 3.2 ft.	011 012	13:30 0.4	4/20/98		NA	0.0 0.4	NA	0.0-0.4 Asphalt, black, fractured=brittle, gravel up to 1cm, rounded, membrane present.
			013 014	13:33 0.8			GM	0.5 0.8		0.4-0.8, FILL, Olive Brown (2.5Y 4/4), sand and gravel olive brown (2.5Y 4/4), gravel to 1.5cm rounded, crs sand, unconsolidated, moist.
			001 002	13:11 1.3			GC	1.0 1.3		0.8-3.2, Soil, clay, sand, gravel, 0.8-1.4ft Very dark grayish brown (10YR 3/2), 1.4-3.2 ft brownish yellow (10YR 6/6), gravel up to 3cm fractured, gravel composed of quartzites and metamorphic rock frags, gravel and sand micaceous in part, fine to medium sands, well graded, generally firm ~~and~~ but unconsolidated, moist.
			003 004	13:08 1.8	4/21/98			1.5 1.8		
			005 006	13:06 2.3				2.0 2.3		
			007 008	13:04 2.8				2.5 2.8		
								3.0 3.2		
								3.5		No Recovery 3.2-4.0 ft.
								4.0		
			009	RS — Rns	40ml		13:18			T.D. = 4.0 ft
			010	R — Rns	1 gall		13:18			

NOTES: General: USCS is modified for this log as follows.
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: B490498
Location - North: 749216 East: 2085910
Date: 5/5/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5975 ft
Area: 903 PAD / ~~LIP~~ 8/25/98
Total Depth: 4.0 ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE INDEX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.8 ft.					NA	0.5		0.0-0.5; Asphalt, black, brittle, fractured, gravel up to 2 cm, rounded, membrane at 0.1 ft.
							GM	0.7		0.5-0.7: Fill; Sand and Gravel; Brownish yellow (10YR 6/6)
			001	0.7			GC	1.0		0.7-2.8: Soil; Clay, sand, gravel; top is dark brown to very dark grayish brown (10YR 3/3 to 3/2); bottom 0.5 ft is dark brown (10YR 4/3), gravel up to 3 cm, fractured, quartz (crystalline) and rotten granite, fine sand, firm, unconsolidated, moist. gravel up to 1.5 cm, rounded, granitic and metamorphic rock fragments, Coarse sand: partly granitic, unconsolidated, moist.
			002	12:51				1.2		
			003	1.2				1.5		
			004	12:49				1.7		
			005	1.7				2.0		
			006	12:46				2.2		
			007	2.2				2.5		
			008	12:44				2.7		
				2.7				2.8		
								3.0		No Recovery 2.8-4.0 ft.
								3.5		
								4.0		
								4.5		T.D. = 4.0 ft.
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible

142

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH90598
Location - North: 749137 East: 2085610
Date: 3/27/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE

Surface Elevation: 5979 ft.
Area: 903 PAD/HP mw 8/25/98
Total Depth: 3.5 ft
Company: TIERRA Project No. GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.5 ft.	Run #1 0.0-3.5 ft.	Recovery 2.7 ft.								0.0-0.7 ft. Asphalt, black, brittle fractured
								0.5		
								0.7		
							GP	1.0		0.7-1.1 ft. Fill: Sand and Gravel, gravel up to 1cm, sub-rounded, igneous rock frags, fine to coarse sand, angular
								1.1		1.1-2.7 ft. Clay, sand, gravel; dominantly dark reddish brown (5YR 3/3) one patch (1.3-1.5 ft) very dark gray (5YR 3/1), gravel up to 3cm, igneous rock frags (granitic), commonly rotten, clay - firm, plastic, moist.
			1.001	1.1			GC			
			1.002	10:30						
			1.003	1.6				1.5		
			1.004	10:38						
			1.005	2.1				2.0		
			1.006	10:26						
			1.007	2.6				2.5		
			1.008	10:23				2.7		
				3.1				3.0		No Recovery 2.7-3.5 ft.
								3.5		
								4.0		T.D. = 3.5 ft.
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		

uncoated
Lt. olive b.
2.5Y 5/6

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH901698
Location - North: 749139 East: 2085685
Date: 021298
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5978 ft.
Area: 903 Pad
Total Depth: 3.5 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	003/025 RS 003/031 R 0.5				PT?	0.0		Asphalt – dry, chippy, crumbly; contains fibrous glomembrane.
	RUN 1: 0.0-3.5	2.8	003/026 RS 003/032 R 0.8 003/027 RS 003/033 R 003/036 RD 1.5				SM SM/GM	0.5 0.8 1.0		Sand fill – dark yellowish brown (10YR 4/4), sl. moist, trace gravel. Elevated FIDLER activities (to 15,000 cpm) @ 0.35' – see notes below. Gravelly silt-sand mixture – v. dark brown (10YR 2/2) sl. moist. elevated FIDLER @ top – see notes below. To dark brown (10YR 3/3) below 1.3'.
Box 1 of 1 0.0-3.5			003/028 RS 003/034 R 2.1 003/029 RS 003/035 R 2.8 N.R. 3.0				GM	1.7 2.0 2.8 3.0 3.5		Silty sand-gravel-caliche mixture – mottled colors w/most caliche @ 1.7–2.1', decreasing gradually below that. sl. moist. Colors are v. pale brown (10YR 8/4) in upper portion, dominantly, and darkens to pals of strong brown (7.5YR 5/6) @ bottom. NO RECOVERY 2.8-3.5'
								4.0 5.0 6.0 7.0 8.0 9.0 10.0		TD = 3.5 (most core included in samples)

RS = rad screen
R = rads

NOTES: General: USCS is modified for this log as follows:
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Except for [illegible] elevated FIDLER readings [illegible] @ FIDLER [illegible] Best estimate either [illegible] or both. First [illegible]

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 90798
Location - North: 749137 East: 2085760
Date: ~~BH90798~~ 2/11/98
Geologist: ~~J. Baylor~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5977 ft
Area: 903 Pad
Total Depth: 3.6 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Ward DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	even if broken BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	0.0					0.0		
0.0 – 3.6 ft.	0.0 – 3.6 ft.	Recovery 3.1 ft.	0.4	RS R Dup	2.013 2.019 2.029		PT	0.4		Asphalt Black (10YR 2/1), gravel, sand, organic binder, gravel to 1.5cm, rounded/fracture, dry, Membrane at bottom
			0.8	RS R	2.024 2.022		GM	0.8		Sand Gravel mix, pale yellow (2.5Y 7/4), gravel to 1.5cm, subround to round, unconsolidated, moist,
			1.5	RS R	2.015 2.023		GC	1.0 1.5		Clay Sand Gravel, mottled – (top) very dark grayish brown (10YR 3/2), (middle) very pale brown (10YR 8/4), (bottom) reddish yellow (5YR 6/6), gravel to 4cm, much gravel fractured, unconsolidated, slightly moist. Clay tends to occur in clots.
			2.0	RS R	2.016 2.025			2.0		
			2.5	RS R	2.017 2.024			2.5		
			3.1	RS R	2.018 2.021			3.0 3.1		
			No Sample							No Recovery, 3.1–3.6 ft.
3.6								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								0.0		

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Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
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RS = rad screen
R = rads

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH90898
Location - North: 749140 East: 2085835
Date: 4/22/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE / MACROCORE

Surface Elevation: 5977 ft
Area: 903 PAD ~~/ LTP~~ ~~8/25/98~~
Total Depth: 4.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.4 ft.					NA	0.4		0.0-0.4 Asphalt, black, fractured, membrane at 0.2 ft, gravel up to 1 cm - rounded
							GM	0.5		0.4-0.9, fill, sand and gravel, light olive brown (2.5Y 5/2) gravel to 1.5 cm, rounded, med to coarse sand, unconsolidated, slightly micaceous, moist.
			001	0.9			GC	0.9		0.9-1.4, soil, clay sand gravel, very dark grayish brown (2.5Y 3/2), gravel to 3 cm, fractured, igneous rock frags - granitic in part, fine to medium sand, firm, unconsolidated, moist. well graded
			002	11:18 1.4				1.0		
			003					1.4		
			004	11:16 1.9				1.5		
			005					1.9		1.4-2.4 soil, clay sand, gravel, yellow (10YR 7/6), gravel to 1.5 cm, rounded, mixed lithology - some granitic, medium to coarse sand, unconsolidated, firm, moist,
			006	11:15 2.4				2.0		
			007					2.4		
			008	11:14 2.9				2.5		No Recovery 2.4-4.0 ft.
								2.9		Some of gravel "rotten" or weathered.
								3.0		
								3.5		
								4.0		
										T.D. = 4.0 ft.
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH90998
Location - North: 5 RPK 5/8/98 East: 2085910 → NORTH 749141
Date: 5/4/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft
Area: 903 PAD / UP 8/25/98
Total Depth: 4.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 3.1 ft.	001 002 003 004 005 006 007 008	0.8 p:27 1.3 p:29 1.8 10:21 2.3 10:18 2.8				0.4 0.5 0.8 1.0 1.3 1.5 1.8 2.0 2.3 2.5 2.8 3.0		0.0-0.4; Asphalt, black, brittle, rounded gravel up to 1cm, membrane at about 0.2 ft.
										0.4-0.8; Fill; Sand and Gravel; brown to dark brown (10YR 4/3), gravel up to 1.5cm, granitic and metamorphic rock fragments, coarse sand, unconsolidated, moist.
										0.8-3.1: Soil; Clay-Gravel with minor sand, very dark grayish brown (10YR 3/2) gravel up to 3cm, fractured, granitic and quartzite(?) rock fragments, granitics rotten, coarse sand granitic in part, firm, unconsolidated, moist.
			009 010	3.8	10:06 09:52			3.5 3.8 4.0		No Recovery 3.1-4.0 ft.
			4.0							T.D. = 4.0 ft
			009 - Red Seven - 125ml gl. 3.8-4.0 ft. - 10:06					4.5		
			010 - VOA - 125ml gl. 3.8-4.0 ft. - 09:52					5.0		Note: Up to 15 ppm Foxboro TVA and 16 ppm Mini Rae VOC's measured. Some VOC's present throughout core. Maximum between 1.3 and 1.8 ft.
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

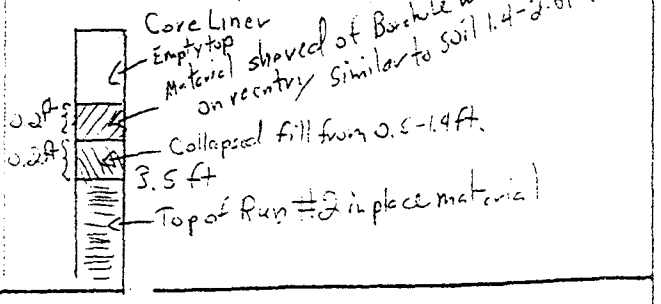
Borehole Number: B#91598
Location - North: 749062 East: 2085610
Date: 3/25/98
Geologist: ~~J Barton~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5979 ft
Area: 903 PAD/~~HP~~ ~~8/25/98~~
Total Depth: 6.5 ft.
Company: Tierra Project No.: GE600000
Sample Type: ~~Continuous core~~ MACROCORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FINAL TIME ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-6.5 ft.	Run #1 0.0-3.5 ft.	Recovery 2.8 ft.	1.001, 1.002, 1.003, 1.004, 1.005, 1.006, 1.007, 1.008	1.4 11:52, 1.9 11:50, 2.4 11:48, 2.9 11:47, 3.4		3.5	Asphalt, GM, GC, GM, GC, GM, GC	0.0, 0.5, 1.4, 1.9, 2.4, 2.6, 2.9, 3.4, 3.5, 3.9, 4.5, 5.0, 5.5, 5.9, 6.0, 6.5		0.0-0.5 Asphalt, black, fractured/brittle. 0.5-1.4 (FILL) Sand and Gravel, olive brown (2.5Y 4/3) Gravel fractured to rounded, up to 1.5 cm, fine to medium sand, poorly graded, unconsolidated, moist. 1.4-2.6 (Soil) Clay Sand Gravel, dark reddish brown (5YR 3/3), Gravel fractured to rounded up to 3cm, Igneous Rock Fragments (IRF's), fine sand, matrix firm breaks into blocks, slightly plastic, moist, less gravel than B#91598, moist. No Recovery 2.8-3.5 ft. Clay Sand 2.6-2.8 ft olive sand (2.5Y 6/8) in yellow brown (10YR 4/3) Clay, fine sand, slightly consolidated to crumbly, poor gradin, moist. 3.5-3.9 ft As Above 2.6-2.8 ft. 3.9-5.9 ft. Clay/Sand/Gravel mottled light olive brown (2.5Y 5/6) dominant, gravel much greater than clay or sand, fractured, granitic, up to 3cm, fine sand, ~~well~~ poorly graded (RPK), massive, moist. 5.9-6.5 No Recovery
	Run #2 3.5-6.5 ft.	Recovery 2.8 ft. including 2.4 ft of slough.								
			1.009	40 ml RS	Rinse			6.5, 7.0, 8.0, 9.0		TD = 6.5 ft.
			1.010	1 gallon R	Rinse					

Diagram: Run #2



NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH91198
Location - North: 749064 East: 2085685
Date: 021798, 021898
Geologist: J. Baylan
Drilling Equip.: Geoprobe - Dual Wall

Surface Elevation: 5979 ft
Area: 903 Pad
Total Depth: 21.4 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (Event/Bottle#)	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	0.0 001/001 RS 001/017 R 0.4				PT?	0.0		Asphalt - dry, chippy. Contains fibrous membrane.
			001/002 RS 001/018 R 0.9				SM	0.4		Fill - sand w/fine gravel. Sl. moist. Dk brown (10YR 3/3) to dk. yellowish brn. (10YR 4/4).
	RUN 1: 0.0-4.0	3.4	001/003 RS 001/019 R 1.3				SM/GM	0.9 1.0		Sand-silt mixture w/gravel to gravelly, sandy silt - pods of caliche common below ~ 1.8'. Sl. moist. V dk brown (10YR 2/2) above 1.8, then mottled below w/dk brown (10YR 3/3), caliche (v. pale brn, 10YR 8/3), and other colors. To 8000 cpm on FIXER @ 1.0'.
			001/004 RS 001/020 R 1.9							
			001/005 RS 001/021 R 2.5					2.0		
			001/006 RS 001/022 R							
			3.1 001/033-V					3.0		
			3.4 N/A					3.4		NO RECOVERY 3.4 - 4.0
	4.0 4.0	4.0 4.0					GM	4.0		Sandy, silty gravel - strong brown (7.5YR 5/6 to 4/6), sl. moist, scattered clay pockets. Abundant shattered gravels. No "hits." Color is mottled, but dominantly strong brown.
	RUN 2: 4.0-8.0	4.0	N/A					5.0		
								6.0		
								7.0		
			7.4 001/007 RS 001/023 R 7.7 001/034-V 8.0							
	8.0 8.0	8.0 8.0						8.0		Same as above, 4.0-8.0', w/more rotting gravels. Color ~~mostly light~~ mainly very mottled due to some to abundant rock flour, shattered gravels, rotting gravels. Sl. moist.
9.0 9.0	RUN 3: 8.0-10.0	4.0 (incl. 2.0' sluff)	N/A					9.0		
								10.0		

Box 1 of 3 : 0.0-9.0

021798 - 021898

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

In sample info: RS = rad screen
R = rads
V = VOCs

149

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B1491198
Location - North: 749064 East: 2085685
Date: 021898
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5979 ft
Area: 903 Pad
Total Depth: 21.4 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 2 of 3: 9.0-17.5'	10.0 RUN 4: 10.0-12.0'	10.0 3.1'	N/A; 11.1 001/024 R; 001/008 RS; 11.6; 001/035 V; 11.9				GM	10.0		Same as above, 8.0-10.0'. ~~Zone of fine grained material @ 11.1-12.0 composed of clayey rotten gravels. Most consumed by samples~~
	12.0	12.0	12.0 N/A				SC	11.0; 11.1		~~Sandy clay~~ Clayey sand w/ gravel — sl. moist. Several altered or clayey rotten gravels. Mottled colors, but mainly strong brown (7.5YR4/6) w/ streaks of light olive brown (2.5Y5/3). Some zones to sandy clay w/ gravel. Abrupt bottom contact, fairly sharp upper.
	RUN 5: 12.0-14.0	3.0						12.0; 13.0		
	14.0	14.0					GM	13.5; 14.0		Same as above, 8.0-10.0'.
	RUN 6: 14.0-16.0	2.8	15.0; 15.1 001/009 RS; 001/025 R; 15.5; 001/036 - V				SC/GC	14.2		Same as above, 11.1-13.5, w/increased gravel (to GC) @ 14.2-14.7. Then SC to 15.7, GC to 16.0.
	16.0	16.0	15.7 N/A; 16.0					15.0; 16.0		Same as above, 11.1-13.5. Sl. moist.
Box 2 of 3: 17.5-21.4'	RUN 7: 16.0-18.0	2.5	N/A				CL/SC	17.0; 17.2		Sandy clay to clay sand mixture, w/ trace gravel. Sl. moist. Same colors as noted for 11.1-13.5.
17.5	17.5							18.0		Same as above but more SC. Sl. moist. Tr. gravel. SC portion @ base of recovery.
Box 3 of 3: 17.5-21.4'	RUN 8: 18.0-20.0	15' (liner has 1.4' core missing bottom)	18.0; 001/040 RS; 001/036 R; 19.1; 001/037 V; 19.5; 001/038 V; 19.9; 001/041 RS; 001/067 R					19.0; 19.5; 20.0		Replace "No Recovery" pattern w/ clay stone pattern. TOP OF BEDROCK = 19.5. ~~NO RECOVERY 19.5-20.0~~ See next page for description.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B4491198
Location - North: 749064 East: 2085685
Date: 021998
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5979 ft
Area: 903 Pad
Total Depth: 21.4 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 3 of 3 (17.5-21.4') → 21.4	Run 9: 20.0-21.4 / 21.4	8.1 / 21.4	see p. 2 of 3 20-2 / N/A / 21.4					20.0 / 21.0 / 21.4		Claystone to claystone w/silt - grayish brown (2.5Y 5/2). Sl. moist. Traces carbonaceous flecks in some zones. Sand & gravel streamers @ ~0.7-1.1' below top of core remaining after sampling probably due to gravels @ contact falling into hole when core was lost in previous run. No hits. (Expect sands & gravels noted above to be out of place, not in original setting.) See logbook for more detailed explanation of lost core recovered core, imported sands & gravels.
										~~No RECOVERY 21.3-21.4~~
										TD = 21.4'
								22.0		
								23.0		
								24.0		
								25.0		
								26.0		
								27.0		
								28.0		
								29.0		
								30.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH91298
Location - North: 749062 East: 2085760
Date: 021098
Geologist: J. Boylan
Drilling Equip.: Geoprobe

Surface Elevation: 5978 ft
Area: 903 Pad
Total Depth: 3.5 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Ward DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	0.0 Bottle 001 (RS) 007 (R) 0.5				PT?	0.0		Asphalt - dry, crumbly, schippy. Containing fibrous geomembrane or other fibrous material - single cut disc ~~in radscreen sample~~. Both samples contain paint from hole marking point.
	RUN 1: 0.0-3.5	2.6	Bottle 002 (RS) 008 (R) 1.0				SM	0.5		Fill - sand w/ silt & gravel. Lower contact not as clear as locations 917, 922. Sl. moist. Dk. yellowish brown (10YR 4/4).
			Bottle 003 (RS) 009 (R) 1.5				GM	1.0		Silty gravel to silt-sand-gravel-caliche mixture - caliche minor, then sharply increases below 1.3' to become dominant to major component. Very dark brown (10YR 2/2) above 1.3', mottled w/ very pale brown (10YR 8/4) to 1.7, then mainly v. pale brown (10YR 8/4). The pale color is caliche. Sl. moist. Some pods of clay present. Lowest 0.1' shows strong brown (7.5YR 5/3) pod which may become dominant color below 2.5'.
			Bottle 4 (RS) 10 (R, red) 2.0 11 (R, dup)					2.0		
			Bottle 5 (RS) 12 (R) 2.6					2.6		NO RECOVERY 2.6-3.5'
3.5			N/A					3.0		
								3.5		TD = 3.5' Measured TD = 3.6'
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								10.0		

Box 1 of 1 0.0-3.5'

NOTES: General: USCS is modified for this log as follows:
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(2) Core breaks cannot be matched, accurate footage measurements not possible.

RS = rad screen
R = rad

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: B#91398
Location - North: 749065 East: 2085834
Date: 4/27/98 (Cont 4/22/98)
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/Macrocore

Surface Elevation: 5977 ft
Area: 903 PAD/LIP
Total Depth: 4.0 ft 8/25/98
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Ward DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.4 ft.				NA		0.4		0.0-0.4; Asphalt, black, membrane about 0.3 ft, ductile breaks into slabs, rounded gravel up to 1 cm.
						GM		0.5		0.4-0.8; Fill: sand and gravel; dark yellowish brown (10YR4/2) gravel up to 2 cm, rounded, mixed lithologies, coarse sand, poorly graded, unconsolidated, moist.
				0.8				0.8		
			001	11:12		GC		1.0		0.8-1.3 ft; Soil, clay, sand, gravel; dark grayish brown (10YR4/2), minor gravel content up to 2 cm, fractured, granitic igneous rock frags, fine to medium sand, well graded,
			002	1.3				1.3		
			003	11:10				1.5		1.3-1.5 ft Transition firm, unconsolidated, moist.
			004	1.8				1.8		1.5-2.4 ft Soil, clay sand gravel, yellow (10YR7/6), gravel up to 3 cm, rounded and fractured, granitic igneous rock fragments, quartzite, fine to medium sand, firm, sticky, moist.
			005	11:08				2.0		
			006	2.3				2.3		
			007	11:26				2.4		2.4-4.0 ft; No Recovery
			008	2.8				2.5		
								2.8		
								3.0		
								3.5		
								4.0		T.D. = 4.0 ft.

NOTES General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH91498
Location - North: 749066 East: 2085909
Date: 5/4/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft
Area: 903 PAD/LIP 8/25/98
Total Depth: 4.0
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 3.2 ft.	001 002 003 004 005 006 007 008	0.8 11:29 1.3 11:25 1.8 11:23 2.3 11:21 2.8			NA	0.5		0.0-0.4; Asphalt black gravel up to 1.5cm, rounded, membrane about 0.2 ft, brittle/fractured.
							GM	0.8		0.4-0.8; Fill; Sand and gravel; brown to dark brown (10YR 4/3), rounded granitic (and quartzite.) Igneous Rock fragments up to 1.5cm, med. to coarse sand
							GC	1.0 1.3 1.5 1.8		0.8-1.8; Soil; clay/sand/gravel, very dark grayish brown at top gets lighter colored towards bottom, gravel up to 3cm, fractured granitic fragments and quartzites, sand minor-fine grained, unconsolidated, firm, moist; (unconsolidated, crumbly, moist)
							SC	2.0 2.3 2.5 2.8 3.0 3.2		1.8-3.2; Soil; largely clay and sand with trace gravel, pink (7.5YR 7/4), fine sand (silty?), gravel up to 3cm-fractured, sticky-firm, moist.
								3.5 4.0		No Recovery 3.2-4.0 ft.
								5.0 6.0 7.0 8.0 9.0		T.D. = 4.0 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#91598
Location - North: 748987 East: 2085610
Date: 3/25/98
Geologist: ~~J Baylan~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5980 ft
Area: 903 PAD ~~Lot~~ ~~Mw~~ Hist 8
Total Depth: 3.5 ft
Company: Tierra Project No. GE600000
Sample Type: Continuous core MACROCORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENTS)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.5 ft.	Run #1 0.0-3.5 ft.	Recovery 2.5 ft.					Asphalt	0.0		0.0-0.8 ft, Asphalt, black, consolidated at top fractured in lower half.
								0.5		
								0.8		
							GM	1.0		0.8-1.5 ft. (Fill) sand and Gravel, olive brown (2.5Y4/3) subangular gravel, granitic and metamorphic, up to 1.5cm, fine to coarse sand, well graded, unconsolidated, friable, moist.
				1.5	12:58			1.5		
			1.001 RS 1.002 R 1.010 R-Dup	2 3	12:58		GC			1.5-2.5 ft (Soil) Clay Sand Gravel, very dark brown (10YR 2/2) in top half, brown (7.5 YR 4/3) in bottom half, Gravel, fractured, up to 3cm, granitic and quartzite, ~~and~~ fine sands, top half more clayey, bottom more sandy, clays plastic, crumbles to blocks, well graded, moist.
				2.8				2.0		
			1.003 RS 1.004 R		12:55					
				2.5				2.5		2.5-3.5 No recovery
			1.005 RS 1.006 R		12:53					
				3.0				3.0		
			1.007 RS 1.008 R		12:52					
								3.5		TD = 3.5 ft.
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								0.0		

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Materials amounts are estimated by % volume instead of % weight.
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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: B1191698
Location - North: 748989 East: 2085684
Date: 5/6/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5979 ft
Area: 903 PAD/~~LIP~~ mw 8/25/98
Total Depth: 4.0 ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 3.4 ft.					NA	0.5		0.0-0.5: Asphalt, black/gray, fractured-unusually powdery, fractured Gravel up to 1cm, granitic and metamorphic rocks
							GM	0.9		0.5-0.9: F, M, Sand and Gravel, light yellowish brown (10YR 6/4), rounded granitic and metamorphic rock frags, ~~rounded~~ RPK 5/6/98
			001	0.9			GC	1.0		0.9-3.4: Unconsolidated, dry, Coarse Sand
			002	11:43						Soil; clay, sand, gravel; very dark grayish brown (10YR 3/2) at top grades to dark reddish brown (5YR 3/2) at bottom; gravel to 3 cm, fractured, rotten granitic rock fragments and quartzites, fine sand rare coarse sand, firm to hard, unconsolidated, slightly moist to dry.
			012	1.4				1.4		
			003	11:38				1.5		
			004	1.9				1.9		
			005	11:35				2.0		
			006	2.4				2.4		
			007	11:32				2.5		
			008	2.9				2.9		
								3.0		
								3.4		
								3.5		No Recovery 3.4-4.0 ft.
								4.0		
			009 - Red Screen - 40ml/gl. Rinse - 11:51					4.5		T.D. = 4.0 ft.
			010 - Red Isotope - 1gal poly Rinse - 11:51					5.0		Note: Sample interval 0.9-1.4 had high α and γ-ray readings γ = 28,000 counts per minute with fiddler.
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH91799
Location - North: 748989 East: 2085759
Date: 02/09/98
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5978 ft
Area: 903 Pad
Total Depth: 3.0 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0	0.0	N/A					0.0		NO RECOVERY 0.0-0.3
	0.3	0.3	0.3				PT?	0.3		Asphalt - crumbly, dry chips.
	RUN 2: 0.3-3.0	2.1	BOTTLE 1.1	001-RS 002-R			SM	0.5		Sand w/silt & gravel - dry to sl. moist. vf-med sand fine gravel mainly. Brown (10YR 5/3). Looks like artificial fill.
BOX 1 OF 1: 0.0-3.0			BOTTLE 1.6	003-RS 004-R			GC	1.0 1.1		Gravel w/sand & clay to clayey silty gravel. Dry to sl. moist. To 14,000+ ppm @ 1.9-2.5'. Also silty zones. Matrix to v. dark brown (10YR 2/2). Abundant caliche (as discrete pods) below 2.0', where gravel is decreased relative to fines. Almost entirely interval consisted by samples. Some portions especially below 2.0', to GM.
			BOTTLE 2.0	005-RS 006-R				2.0		
			BOTTLE 2.4	007-RS 008-R				2.4		NO RECOVERY 2.4-3.0'
3.0	3.0	3.0	N/A					3.0		TD = 3.0' (measured TD = 2.95')
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								10.0		

NOTES: General: USCS is modified for this log as follows:
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(1) Badly broken core, accurate footage measurements not possible.
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Sample types: RS = rad screen
R = rads

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH91898
Location - North: 748990 East: 2085834
Date: 4/28/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE / MACROCORE

Surface Elevation: 5977 ft
Area: 903 PAD/LIP MW 8/25/98
Total Depth: 4.0ft
Company: TIERRA Project No.: GE60000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.7 ft.	001 002	10:07			NA	0.5		0.0-0.6 Asphalt, black, fractured, membrane at approx 0.3ft., gravel to 1cm, rounded and fractured.
			003 004	0.6 10:09			GM	1.0		0.6-1.1 Fill, Sand and Gravel, light yellowish brown (10YR 6/4), medium to coarse sand dominant in top half, gravel to 1.5cm dominant in bottom half, gravel fractured, granitic,
			005 006	1.1 10:12			GC	1.5		1.1-2.0 Soil, clay sand gravel, Unconsolidated, dry to slightly moist. Very dark greyish brown (10YR 3/2), gravel to 2.5cm, fractured, granitic igneous rock frag., medium to coarse sand, firm, dry to slightly moist.
			007 008	1.6 10:06				2.0		
			009 010	2.1 10:04			SC	2.5		2.0-2.7, Soil, clay sand, yellow (10YR 7/6), fine to med. sand, caliche?, crumbly, slightly moist.
			011 012	2.6 10:03				3.0		No Recovery 2.7-4.0 ft.
				3.1				3.5		
								4.0		T.D. = 4.0ft.
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#91998
Location - North: 748990 East: 2085909
Date: 4/29/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft.
Area: 903 PAD/LLP
Total Depth: 4.0 ft.
Company: TIERRA
Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR,
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.7 ft.	001 002	13:06			NA	0.0		0.0-0.5 Asphalt, black, brittle, gravel to 1cm-rounded and fractured, membrane at 0.3 ft. RPK 4/29/98
			003 004	0.5 13:08			GM	0.5		0.5-0.9 Fill, sand and gravel, brown to dark brown (10YR4/3), minor rounded lang gravel, med. to coarse sand,
			005 006	0.9 13:16			GC	0.9 1.0		0.9-2.5 Soil, clay sand gravel, very dark grayish brown (10YR 3/2) with dark reddish brown (5YR 3/2) from 2.0-2.5 ft, fractured granitic and quartzite rock frags to 3cm, fine to medium sand, firm, generally moist to very moist 0.9-1.9. unconsolidated, moist
			007 008	1.4 13:13				1.4 1.5		
			009 010	1.9 13:03				1.9 2.0		
			011 012	2.4 13:01			SC	2.4 2.5		2.5-2.9 Clay Sand-TRACE Gravel, yellow (10YR 8/6) fractured gravel to 1cm, fine sand, firm, sticky, moist.
				2.9				2.7 2.9 3.0		
								3.5		No Recovery 2.7-4.0 ft.
								4.0		T.D. = 4.0 ft.
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B492098
Location - North: 748913 East: 2085609
Date: 5/7/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5980 ft
Area: 903 PAD/~~LIP~~ mw 8/25/98
Total Depth: 4.0ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

LOCATION OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FIRST TIME ARRIVE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0ft.	Run #1 0.0-4.0ft.	Recovery 3.1 ft.					NA			0.0-0.5: Asphalt, black, brittle, top in coin shaped pieces, gravel less than 1.0cm, rounded, no obvious membrane.
							GM	0.5		0.5-0.9: Fill, Sand and Gravel; dark yellowish brown (10YR4/4) rounded gravel up to 1cm, coarse sand, unconsolidated, moist
			001	0.9			GC	0.9		0.9-3.1: Soil, clay, sand, gravel, top is dark reddish brown (5YR3/7) grading down to white (10YR8/2) at bottom, gravel up to 3cm, larger pieces fractured, smaller pieces rounded, metamorphic and rotten granitic clasts, medium grained sand, granitic in part, crumbly, slightly moist, caliche heavy in lower 1.5ft. ↑ gravel lithology mixed metamorphics and granitic rock fragments
			002	13:37				1.0		
				1.4				1.4		
			003	13:34						
			004							
				1.9				1.9		
			005	13:32				2.0		
			006							
				2.4				2.4		
			007	13:30				2.5		
			008	2.9				2.9		
								3.0		
								3.1		
								3.5		No Recovery 3.1-4.0ft.
								4.0		
								4.5		T.D. = 4.0ft.
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#92198
Location - North: 748914 East: 2085684
Date: 5/7/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5979 ft
Area: 903 PAD/~~LIP~~ 8/25/98
Total Depth: 4.0ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0ft.	Run #1 0.0-4.0ft.	Recovery 3.4 ft.					NA			0.0-0.4: Asphalt, black, brittle, fractured, rounded gravel up to 1cm, membrane at 0.2ft.
							GM	0.5 0.4		0.4-0.7 ft: Fill; Sand and Gravel; dark grayish brown (10YR4/2), rounded gravel up to 1cm, gravel granitic in part, coarse sand, unconsolidated, moist
			001 002	0.7 11:14			GC	1.0		RPK/5/8/98
			003 004	1.2 11:12				1.2 1.5		0.7-3.4ft Soil; clay, Sand and gravel; dark reddish brown (5YR3/2-3/3), gravel up to 3cm, fractured, rotten granitic and micaceous metamorphic rock fragments, medium sized sand-micaceous, unconsolidated, firm, well graded, slightly moist.
			005 006	1.7 11:08				1.7 2.0		
			007 008	2.2 11:06				2.2 2.5		
				2.7				2.7 3.0		
								3.5 3.4		No Recovery 3.4-4.0 ft.
								4.0		
								4.5		T.D. = 4.0 ft.
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES. General: USCS is modified for this log as follows.
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

161

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B.H 92298
Location - North: 778914 East: 2085760
Date: 020498
Geologist: J. Baylan
Drilling Equip.: Geoprobe

Surface Elevation: 5977 ft
Area: 903 Pad
Total Depth: 3.0 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 2/23/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENTS)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0	0.0 RUN 1 0.3	0.0 0.0'	ALARE RIN 98A0899, EVENT 001				Asphalt	0.0		NO RECOVERY 0.0-0.3 (Solid point bit)
	0.3	0.3	0.5				PT	0.3 0.5		Asphalt - crumbly black.
			BOTTLE 7 = rads				SM	0.9		Fill - sand w/silt, fine gravel. Light yellowish brown (2.5Y 6/3). Dry.
			BOTTLE 8 = rad screen							
			0.9					1.0		Sandy silty gravel. Consumed by samples. Dry. Some to abundant rock flour, abundant shattered gravels.
Box 1 of 1: 0.0 - 3.0	RUN 2: 0.3 - 3.0	2.0	BOTTLE 5 = rads							
			BOTTLE 6 = r.s.							
			1.6							
			BOTTLE 3 = rads				GM	2.0		
			BOTTLE 4 = r.s.							
			2.6							
			BOTTLE 1 = rads 2 = r.s.				GC	2.3		Clayey gravel to gravelly clay. Yellowish red, 5YR 4/6. W/silt, sand traces. Moderately stiff. Sl. moist.
			2.3							
			N/A							NO RECOVERY 2.3-3.0
3.0	3.0	3.0	3.0					3.0		

TD = 3.0'

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#92398
Location - North: 748915 East: 2085834
Date: 4/28/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft.
Area: 903 PAD/LLP ~~8/25/98~~
Total Depth: 4.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Ward DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft	Recovery 2.9 ft.					NA	0.5		0.0-0.7 Asphalt, black, brittle-fractured, gravel to 1cm, rounded, membrane at about 0.2 ft, dry
							GM	0.7, 1.0, 1.3		0.7-1.3 Fill, sand and gravel, light yellowish brown (10YR 6/4), minor gravel to 1cm-rounded, med-coarse sand, unconsolidated, dry.
			001, 002	1.3, 13:04			GC	1.5, 1.8, 2.0, 2.3, 2.5, 2.8, 2.9		1.3-2.9 Soil, clay, sand, gravel, brown to dark brown (10YR 4/3), fractured gravel to 3cm, granitic rock frag, quartzite too, minor sand-fine to medium, firm, unconsolidated, slightly moist.
			003, 004	1.8, 13:02						
			005, 006	2.3, 13:00						
			007, 008	2.8, 12:58						
				3.3				3.0, 3.3, 3.5		No Recovery 2.9-4.0 ft.
								4.0		T.D. = 4.0 ft.
								5.0, 6.0, 7.0, 8.0, 9.0		

NOTES. General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH92498
Location - North: 748915 East: 2085909
Date: 4/29/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft.
Area: 903 PAD/LIP mw 8/25/98
Total Depth: 4.0
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR,
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FINAL TIME ARRIVE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-4.0 ft.	Run #1 0.0-4.0 ft.	Recovery 2.9 ft.					NA	0.5		0.0-0.5 Asphalt, black, brittle, 1cm rounded gravel,
							GM	1.0		0.5-1.1 Fill, sand and gravel, yellowish brown (10YR 5/4), minor rounded gravel up to 1.5cm, medium to coarse sand, unconsolidated, slightly moist.
			001	1.1 10:27			GC	1.5		1.1-2.1 Soil, gravel dominant with minor clay and sand, very dark grayish brown (10YR 3/2), fractured granitic rock fragments up to 3cm, crumbly, slightly moist.
			002					2.0		
			010	DUPE				2.5		2.1-2.9 Soil, clay sand gravel, 2.1-2.6 very dark grayish brown (10YR 3/2) grades to yellow (2.6-2.9) (10YR 7/6), much less gravel than 1.1-2.1, fractured granitic fragments to 3cm, fine sand, caliche?, firm, slightly moist.
			003	1.6 10:23				3.0		
			004					3.5		No Recovery 2.9-4.0 ft.
			005	2.1 10:20				4.0		
			006							
			007	2.6 10:19						
			008	3.1						
			011	Rad Screen Rinse 40ml						T.D = 4.0 ft.
			012	Rad Isotope Rinse 1 gallon						
				both 10:33				5.0		
								6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92598
Location - North: ~~74864~~ 74865 East: ~~2085909~~ 2085560 (mw 7/6/97)
Date: 2/23/98 2/24/98 3/2/98
Geologist: ~~J. Barber~~ R. KOEHLER
Drilling Equip.: Geoprobe - Dual Wall
Surface Elevation: 5978 ft
Area: 903 PAD/LIP Area
Total Depth: 18.5 ft
Company: Tierra
Project No.: GE600000
Sample Type: Continuous core Dual Wall

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 2 0.0-10.0 ft	Run #1 0.0-4.0 ft (46.5 inches)	Recovery 2.6 ft.	0.2 RS/R	1.001	1.017		GM	0.0–0.2		0.0-0.2 ft: Sand and Gravel, light yellowish brown (2.5Y 6/4); medium sand, quartz and granitic grains, angular, unconsolidated, gravel up 1.5 cm, rounded, quartzite and igneous rock fragments, unconsolidated, dry, fibrous membrane with adhering caliche at base.
			RS R	1.009	1.018		GC	0.2–0.6		0.2-0.6 ft: Rock flour with sand and gravel; pale yellowish brown (10YR/6/2); med sand A.A., gravel to 2.5 cm, fractured, unconsolidated, dry
		1.0	RS R	1.003	1.019			0.6–1.0		0.6-2.6 ft. Clay, sand, gravel; fine dark yellowish brown (10YR 3/4) rare yellow (10YR 8/6); medium angular sand, quartz and rock frags, gravel up to 2.5 cm, angular to fractured composed of ig rock frags and quartzite; clay/sand adhere to gravel but crumble if ~~touch~~ touched generally unconsolidated. fines slightly moist.
		1.5 ft	RS R	1.001	1.020			1.0–1.5		
				2.0 ft				1.5–2.0		
								2.0–2.6		
								2.6–3.0		No Recovery 2.6-4.0 ft.
			3.5 VOA RS R	1.033	1.025/1.021			3.0–4.0		
	4.0		4.0					4.0		TD as of 2/23/98
	Run #2 4.0-7.0 ft.	Recovery 3.0 ft.		Sample #5			GM	4.0–7.0		4.0-7.0 ft; sand and gravel, minor clay; grayish orange (10YR 7/4) to moderate reddish orange (10R 6/6), medium angular quartz and granitic(?) sand, gravel up to 2 cm, fractured and angular composed of granitic and quartzite rock fragments, unconsolidated, dry to slightly moist. White "crust" on some gravel may indicate caliche but no caliche layers observed.
	7.0							7.0		7.0-7.5 As Above
	Run #3 7.0-10.0 ft.	Recovery 2.6 ft.	7.5 VOA RS R	1.034	1.006/1.022		GC	7.5–9.0		7.5-9.0 Clay, sand, gravel; moderate reddish orange (10R 6/6), medium angular quartz and igneous rock fragment sand, less gravel than above amount of gravel decreases downward, gravel mostly quartzite w/ a few granitic pieces - 2 cm most fractured trace rounded, unconsolidated, moist.
			8.0					9.0		
							SC	9.6		9.0-9.6 Clay sand, sand dominant, moderate reddish orange, medium angular, quartz and ig rock frags, unconsolidated, moist. No Recovery 9.6-10.0 ft.
	10.0							10.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92598
Location - North: 749064 East: 2085560
Date: 03/02/98
Geologist: ~~J Baylor~~ R. KOEHLER
Drilling Equip.: Geoprobe - Dual Wall

Surface Elevation: 5978 ft
Area: 903 PAD/LIP Area
Total Depth: 18.5 ft.
Company: Tierra Project No.: GE600000
Sample Type: Continuous core Dual Wall

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 2 of 2 10.0-8.5 ft.	Run #4 10.0-13.0 ft 13.0	Recovery 3.6 ft	12.0 Rs R VOA 12.5	1.007 1.023 1.035			SC	10.0 11.0 12.0 13.0		10.0-13.0 Clayey Sand, yellowish red (5YR 5/6), medium to coarse grained, granitic and quartz grains, well graded, firm, plastic? (forms sausage like extrusion on coring), moist. - 0.1 ft gravel lense, fractured pieces up to 2cm. possibly quartzite, no fines. - 0.1 ft gravel lense as above. RPK
	Run #5 13.0-16.0 ft 16.0	Recovery 2.5 ft	16.0				GC	14.0 15.0 15.5		13.0-15.5 ft, Similar to above but with gravel ~~appears to be more quartzitic than granitic~~ (quartzitic) throughout. Gravel fragments up to 2cm. RPK; 15.5-16.0 No Recovery
	Run #6 16.0-18.5 ft 18.5	Recovery 4.0 ft	Rs R VOA VOA-DUP 16.75	1.003 1.023 1.036 1.037			Sand stone	16.0 16.75 17.0 18.0		16.00 = Bedrock Contact. 16.0-18.5 ft, Fine to Medium grained "sandstone", probably clayey, yellowish brown (10YR 5/6) is dominant, some light gray (10YR 7/1) at top, well sorted, unconsolidated to lightly indurated (crumbles easily), dry to slightly moist. massive
								19.0 20.0		Total Depth = 18.5 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92698
Location - North: 748977 East: 2085551
Date: 5/19/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5979 ft
Area: 903 PAD / LIP Area
Total Depth: 3.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.0 ft	Run #1 0.0-3.0 ft.	Recovery 2.5 ft.	001 002	12:05 0.4			GM	0.5		0.0-0.4 ft: Fill: Sand & Gravel; brown (7.5YR5/3) rounded gravel to 2.5cm, medium grained sand, well graded,
			003 004 010	12:03 0.9			GC	1.0 1.4 1.5 1.9 2.0		0.4-2.5 ft: Soil clay, sand, gravel, dark reddish brown (5YR3/3), with speckled reddish yellow (5YR7/6) between 1.5 and 2.2 ft, gravel up to 3cm, fractured, mostly quartzite minor medium (to coarse?) sand, poorly graded, firm, unconsolidated, slightly moist. gravel includes granitic and metamorphic rock frags, unconsolidated dry, trace root hairs.
			005 006	12:00 1.4						
			007 008	11:58 1.9				2.5		No Recovery 2.5-3.0 ft.
								3.0		
			011	12:15	Rns	40ml Ash	Water	3.5		T.D. = 3.0 ft.
			012	12:15	Rns	1 gall Poly	Water	4.0		
								4.5		
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92798
Location - North: 74882 East: 2085553
Date: 5/18/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5980 ft
Area: 903 PAD / LIP Area
Total Depth: 3.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Ward DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.0 ft.	Run #1 0.0-3.0 ft.	Recovery 2.6 ft.	001 002	0.4			GM	0.4		0.0-0.4 ft; Fill; sand and gravel, brown (10YR 5/3) granitic gravel broken rounded fragments, medium to coarse sand, unconsolidated - friable, dry, root holes.
			003 004	0.9			GC	0.5, 0.9, 1.0		0.4-2.6 ft; Soil; dark reddish brown (5YR 3/2) grades to reddish gray (5YR 5/2) at 1.5 ft., 1.5-2.6 ft yellowish red (5YR 5/6); gravel, sand, clay; fractured gravel up to 2.5 cm, looks like mostly quartzite; medium to coarse sand, not abundant; caliche - 0.2 ft intervals at 1.2 and 2.3 ft; firm, unconsolidated, well graded, slightly moist to dry.
			005 006	1.4				1.4, 1.5		
			007 008	1.9				1.9, 2.0 RPK, 2.3, 2.4		
										2.6-3.0 ft No Recovery
								3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5		

NOTES: General: USCS is modified for this log as follows.
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92898
Location - North: 748830 East: 2085703
Date: 5/12/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5978 ft
Area: 903 PAD/LIP Area
Total Depth: 3.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.0 ft.	Run #1 0.0-3.0 ft.	Recovery 2.4 ft.				GC RPK 5/12/98	~~NA~~ GC	0.5	Continue log RPK 5/14/98	0.0-0.5 ft: Fill, Clay Sand Gravel, dark grayish brown (10YR 4/2), gravel up to 3 cm, fractured, granitic in part, medium to coarse sand, well graded, friable, unconsolidated, slightly moist to moist
			001 002	0.5 11:46				1.0		0.5-2.4 ft: Soil clay, sand, gravel, dark reddish brown (2.5 YR 2.5/4), gravel to 3 cm, fractured, granitic and micaceous metamorphic fragments, poorly graded, medium micaceous sand, trace coarse, firm to hard, possible caliche in lower 1 ft, slightly moist.
			003 004	1.0 11:44				1.5		
			005 006	1.5 11:42				2.0		
			007 008	2.0 11:39				2.5		
				2.5				2.4		No Recovery 2.4-3.0 ft.
								3.0		
								3.5		T.D. = 3.0 ft.
								4.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH92998
Location - North: 748830 East: 2085853
Date: 3/23/98
Geologist: ~~J Bajan~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5976 ft
Area: 903 PAD/LIP Area
Total Depth: 2.5 ft.
Company: Tierra
Project No.: GE600000
Sample Type: Continuous core MACROCORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5	Run #1 0.0-2.5 ft	Recovery 2.2 ft	1.001 1.002 1.003 1.004 1.005 1.006 1.007 1.008	11:06 0.5 11:04 1.0 11:03 1.5 11:01 2.0			GC	0.0 0.5 1.0 1.5 2.0 2.5		0.0-2.2 ft; Clay/Sand/Gravel, dark reddish brown (2.5YR 2.5/4) with mottling of Yellow (10YR 8/8) at base. Gravel fractured to ø 3cm, ~~weathered~~ fine angular sand, granitic and quartzite grains, well graded, massive, clayey parts plastic form clumps, moist. (RPK) No Recovery 2.2-2.5 ft.
								3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0		TD = 2.5 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH93098
Location - North: 748817 East: 2086005
Date: 7-12-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5958 Ft
Area: 903 PAD Lip Area
Total Depth: 3.6
Company: TERRA
Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7/2/99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.6'	Run #1 0.0-4.0'	Recovery 3.6'	001	RS ISO	001 002			1.5		0.0-2.1 Gravelly Silt 2.5YR 2/2 very dark brown, very fine to medium angular sand up to 3.5 cm broken lithic gravel, trace to some clay, some organic material, moist. Locally grading to Gravelly Sand.
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002		GM	1.5		
			004	RS ISO	001 002			2.0		2.1-3.6 Gravelly Sand, 7.5YR 7/1 to 7.5YR 7/6, light gray to brown A/A, silty, very fine to medium angular sand, trace clay dry.
			005	ISO DUP.	~~002~~ 001	DUPLICATE				
			006	RS ISO	001 002	RINSATE		3.0		3.6-4.0 No Recovery
								4.0		
		99A	43	53	001	RS 001	RI (002)	5.0		
					002	001	(002)			
					003	001	(002)			
					004	001	(002)			
					005	001		6.0		
					006	001	(002)			
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-4)0-01 (4-4)0(Form GT.1A)(03/01-V2)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH93199
Location - North: 748839 East: 2086167
Date: 1-13-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ 7/2/99

Surface Elevation: 5956 Ft
Area: 903 PAD Lip Area
Total Depth: 3.7
Company: TIERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC CHG	SAMPLE DESCRIPTION
Box 1 of 1 0.0'-3.7' Run #1 0.0-4.0 Recovery: 3.7'			001	RS ISO	001 002			1.5		0.0-3.7 Silty Sand 3YR3/2 to 3YR3/2 very dark gray to dark brown, very fine, trace medium to coarse, subangular sand, silt, trace broken lithic gravel up to 4 cm, trace clay, trace organics, dry
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002		SM			
			004	RS ISO	001 002			2.0		
								3.0		
								3.7		3.7-4.0 No Recovery
								4.0		
		99A	43	58	001	RS 001(002)	RI	5.0		
					002	001(002)				
					003	001(002)				
					004	001(002)		6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH93298
Location - North: 748671 East: 2085755
Date: 1-12-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ MW 7/2/99

Surface Elevation: 5964 Ft
Area: 903 PAD Lip Area
Total Depth: 2.4
Company: TERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7/2/99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (EVENT)	ANALYTICAL ABBR (ANALYTE)	BLOTTER ABBR	GRAIN SIZE DISTRIBUTION (BOTTLE)	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.4	Run #1 0.0-4.0	Recovery: 2.4	001	RS ISO	001 002	NO	CL	.5		0.0-0.6 Silty Clay 3YR 1/3 very dark gray, with trace sand and up to 3cm lithic gravel, with roots, moist, mod. plasticity
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002		SC	1.5		0.6-2.4 Gravelly Clayey Sand 5YR 6/4 → 4YR 4/3 Light brown to dark brown, very fine to coarse, subangular to angular, poorly graded as above silty, moderately plastic moist
			004	RS ISO	001 002			2.0		
								2.4		
								3.0		2.0-4.0 No Recovery JAL 1-12-99
								4.0		
		99A	4356		001	RS 001	RI (002)	5.0		
			"		002	001	(002)			
			"		003	001	(002)			
			"		004	001	(002)	6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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(4011-4)G-0134-9)0)(Form GT.1A (03/01/92)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 93398
Location - North: 748698 East: 2085857
Date: 1-12-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ mw 7/2/99

Surface Elevation: 5956 Ft
Area: 903 PAD Lip Area
Total Depth: 3.8
Company: TERRA
Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.8	Run #1 0.0-4.0	Recovery: 3.8	001	RS ISO	001 002		CL	.5		a 0-2.0 Silty Clay 2YR 2/2 very dark brown, with organics, very fine to fine sand, trace up to 2.5 cm angular lithic gravel. non to trace plasticity, moist.
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002			1.5		
			004	RS ISO	001 002			2.0		2.0-2.7 Silty Clay 5YR 4/6 dark yellowish brown, A/A, moderate to high plasticity moist
							CL ~~SC~~ mw 7/2/99	2.7 3.0		2.7-3.8 Sandy Clay 5YR 5/2 to 6YR 6/6 reddish gray to reddish yellow very fine to fine angular sand, some med. mod plasticity, gravel A/A, moist
								4.0		3.8-4.0 No Recovery
								5.0		
		99	A4357		001-001 (002) RS RI					
					002-001 (002)					
					003-001 (002)			6.0		
					004-001 (002)					
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH93498
Location - North: 748702 East: 2086198
Date: 1-19-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ mw 7/2/99

Surface Elevation: 5942
Area: 903 PAD Lip Area
Total Depth: 3.2
Company: TERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Ward DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (print)	FRACTURE ANGLE	BEDDING ANGLE (bt)	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC UNIT	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.2	Run #1 0.0-4.0	Recovery 3.2"	001	RS ISO	001 002		CL			0.0-1.0 Silty Clay 6YR 6/2 to 3YR 3/1 pinkish gray to very dark gray, traces sand, traces broken lithic gravel up to 3.5cm, low to mod. plasticity, traces organics moist.
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002					
			004	RS ISO	001 002		SM	2.0		1.0-3.2 Silty Sand, color A/A, pred. very fine to fine, some poorly Subangular, silty, traces clay, trace gravel A/A, trace caliche, dry
								3.0		3.2-4.0 No Recovery
								4.0		
								5.0		
		99A 4850	001		001	RS 001	RI (002)			
			002		001	(002)		6.0		
			003		001	(002)				
			004		001	(002)		7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930X Form GT.1A(03/01/92))

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH93598
Location - North: 748977 East: 2085978
Date: 3/23/98
Geologist: J. Baylor R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5973 ft
Area: 903 PAD/LIP Area
Total Depth: 2.5 ft.
Company: Tierra Project No.: GE600000
Sample Type: Continuous core

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5 ft.	Run #1 0.0-2.5 ft.	Recovery 1.4 ft.	1.001 1.002	10:34 0.4				0.0 0.4		0.0-0.4 Clay Sand, w/abundant root hair, dark brown (10YR 3/3), fine sand, soft clumps, moist to wet.
			1.003 1.004	10:32 ~~1.0~~ 0.8 mw 7/20/99				1.0		0.4-1.4 Clay, Sand, Gravel, dark reddish brown (2.5YR 3/4) fractured granitic IRF up to 3cm in clay sand matrix, angular medium sand, massive, minor root hair, moist, firm.
			1.005 1.006	10:30 1.2				1.4 1.5		1.4-2.5 No Recovery
			1.007 1.008	10:28 ~~2.0~~ 1.4 mw 7/20/99				2.0		
								2.5		
			1.009 1.010	10:42	Rinse 40 ml. 1 gall.			3.0		T.D. = 2.5 ft.
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								10.0		

NOTES. General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#93698
Location - North: 748988 East: 2086153
Date: 3/12/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE

Surface Elevation: 5972 ft
Area: 903 PAD / LIP Area
Total Depth: 2.5 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL M. Wood DATE 4/14/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5 ft.	Run #1 0.0-2.5 ft.	Recovery 2.1 ft.	1.007 RS 1.002 R 1.005 RS 1.004 R 1.010 R-2m 1.003 RS 1.006 R 1.001 RS 1.008 R	0.5 1.0 1.5 2.0			GC	0.5 0.8 1.0 1.5 2.0 2.1 2.5		0.0-0.8 ft; Clay, Sand, Gravel; dark brown (7.5YR 3/2), quartzite gravel up to 3cm, fractured, fine sand, clumpy, plastic, grass shoots and root hair, moist. 0.8-2.1 ft; Clay, Sand with some gravel (1.4 to 2.1 ft), reddish yellow (5YR 7/6) fine sand, crumbly to unconsolidated, gravel is fractured, quartzite, moist. 2.1-2.5 ft. No Recovery
			1.009 RS		RNS	40ml VOA VIAL				T.D. = 2.5 ft.
			1.012 R		RNS	1 gal. poly.				

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH93798
Location - North: 748976 East: 2086300
Date: 3/12/98
Geologist: ~~[illegible]~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5970 ft
Area: 903 Lip Area
Total Depth: 2.5 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core Macrocore

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENTS)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5 ft	Run #1 0.0-2.5 ft.	Recovery 1.8 ft.	1.001	Rs			GC	0.0		0.0-0.4 ft Clay, Sand, Gravel, dark brown (7.5YR 3/2) gray fractured gravel up to 3 cm, quartzite maybe some granitic IRFS, clumpy or clotty, plastic, wet to moist, root hairs,
			1.002	R 0.45				0.4		
			1.003	Rs				0.5		0.4-1.8 ft.; Clay Sand Gravel, yellow (10YR 7/6), gravel concentrated at top (0.4-0.6 ft) 1 piece rounded quartzite rest is fractured quartzite gravel to 3 cm, possibly caliche?, possible clay clasts, wet to moist,
			1.004	R 0.9				1.0		
			1.005	Rs						
			1.006	R 1.35				1.5		
			1.007	Rs						
			1.008	R 1.8				1.8		
								2.0		No Recovery 1.8-2.5 ft
								2.5		T.D. = 2.5 ft.
								3.0		
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								0.0		

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Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 93898
Location - North: 749003 East: 2086406
Date: 2-17-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5968 Ft
Area: 903 PAD Lip Area
Total Depth: 3.9'
Company: TERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark R. Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (event)	FRACTURE ANGLE	BEDDING ANGLE (B+1)	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC CODE	SAMPLE DESCRIPTION (No "Rots" FOR CL SYMBOL)
Box 1 of 1 0.0-3.9' Run #1 0.0-4.0' Recovery: 3.9'			001	RS ISO	001 002		CL	.5		0.0-1.0 Sandy Clay, Dark Reddish Brown 3YR 3/4, slightly plastic, Some, med fine to coarse Sand, angular-Subrounded, trace angular to Subrounded up to 3 cm lithic gravel. Moist
			002	RS ISO	001 002		CL TAL 6-8-99	1.0		
			003	RS ISO	001 002			1.5		
			004	RS ISO	001 002		SC	2.0		1.0-3.7 Clayey Sand color and components same as above. damp
								3.0		3.7-3.9 Gravelly Sand color and components same as above dry
							CW	4.0		3.9-4.0 No Recovery
	99A4852		001		RS 001	RI (002)		5.0		
			002		001	(002)		6.0		
			003		001	(002)				
			004		001	(002)		7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
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(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH93998
Location - North: 749123 East: 2086000
Date: 3/16/17/98 RPK 3/17/98
Geologist: ~~J Baylor~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5973 ft
Area: 903 Lip Area
Total Depth: 2.5 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core Macro Core

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wand DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5 ft	Run #1 0.0-2.5 ft	Recovery 2.2 ft.	1.001	Rs	12:02		GC	0.0		0.0-0.4 ft; Clay Sand Gravel; dark brown (10YR 4/3 to 3/3); rounded spherical gravel up to 3 cm, granitic IRF
			1.002	R				0.4		
			1.003	Rs	12:00			0.5		0.4-1.7 ft; Clay Sand Gravel; yellowish red (5YR 4/6) to dark yellowish brown (10YR 3/4), fractured gravel (granitic IRF) in clay sand matrix, fine sand, gravel to 3 cm, well graded, clumpy or clotty, moist trace roots at top; possibly some quartzite, medium sand, well graded, loose sand at top, more clumpy at bottom, top: dry, bottom: moist, occasional roots.
			1.004	R				1.0		
			1.005	Rs	11:58					
			1.006	R				1.5		
			1.007	Rs	11:56			1.7		
			1.008	R			SC	2.0		1.7-2.2 ft; Clay Sand; yellow brown (10YR 5/4) to very pale brown (10YR 8/4), fine sand, clay clasts (to 1.5 cm), possibly caliche, clumpy, poorly graded, moist
								2.2		2.2-2.5 ft No Recovery.
								2.5		
								3.0		T.D. = 2.5 ft.
								4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								0.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH94098
Location - North: 749117 East: 2086128
Date: 03/03/98
Geologist: ~~J. Barton~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5971 ft
Area: 903 Lip Area
Total Depth: 2.0 ft.
Company: Tierra Project No.: GE600000
Sample Type: Continuous core (MACROCORE)

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
0.0-2.0 ft.	Run #1 0.0-2.0 ft.	Recovery 1.5 ft.	1.001 1.002 1.003 1.004 1.005 1.006 1.007 1.008 2.0 1.010 = Rad Iso Equipment Rinse	4 0.5ft 0.8 1.0ft 1.2 1.5ft 1.5ft	mw 7/20/99 mw 7/20/99 mw 7/20/99		GM GC	0.0 0.5 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 0.0		0.0-0.5; Silt, Sand, Gravel; dark yellowish brown (10YR 4/2), fine to medium sand, well graded, unconsolidated, dry. Abundant Root Hair 0.5-2.0 ft; moderate reddish brown (10R 4/6) Clay, silt, sand, gravel; gravel up to 3cm mostly quartzite - fractured, fine gravel and sand granitic in part, slightly plastic - forms sausages in core barrel moist, root hairs common, not stratified, ~~large~~ gravel lense at top, filled by coarse gravel. No Recovery 1.5-2.0 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH94198
Location - North: 749123 East: 2086298
Date: 3/16/98
Geologist: ~~J. Barton~~ R. KOEHLER
Drilling Equip.: Geoprobe

Surface Elevation: 5969 ft.
Area: 903 Lip Area
Total Depth: 2.5 ft
Company: Tierra Project No.: GE600000
Sample Type: Continuous core Macrocore

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.5 ft	Run #1 0.0-2.5 ft	Recovery 1.6 ft	1.001	Rs			GC	0.0		0.0-0.8 Clay Sand Gravel; dark brown (7.5 YR 3/2) gravel up to 2 cm, rounded, quartz and IRF, well graded, medium grn sand, rounded?, fractured 3cm gravel at base, clumpy, friable, moist root hair abundant
			1.002	R				0.5		
			1.003	Rs						
			1.004	R				1.0		0.8-1.6 Clay Sand Gravel less gravel than above, pink (7.5 YR 8/3) gravel fractured, to 2cm, friable, fine sand, may be massive caliche, clay clasts?, partly cemented "chunks", poorly graded, moist, some root hairs, IRF at bottom.
			1.005	Rs						
			1.006	R				1.5		
			1.007	Rs				1.6		No Recovery 1.6-2.5 ft.
			1.008	R				2.0		
			1.009	Rs-Rinse		40ml		3.0		T.D. = 2.5 ft.
			1.010	R-Rinse		1gall.		4.0		
								5.0		
								6.0		
								7.0		
								8.0		
								9.0		
								10.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: RH94298
Location - North: 749112 East: 2086438
Date: 2-18-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ MW 7/2/99

Surface Elevation: 5968 ft
Area: 903 PAD Lip Area
Total Depth: 3.85
Company: TIERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (TAG EVENT)	FRACTURE ANGLE	SAMPLE DEPTH (BOTTOM OF CORE) OR SAMPLE NUMBER	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC CODE	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 3.85'	Run #1 0.0 - 4.0	Recovery: 3.85'	001	RS 001 ISO 002			SP	.5		0.0-0.7 Gravelly Sand, Dark Reddish Brown, 2YR 2/5 Silty fine coarse Sand, some medium to fine, Subangular to Subrounded, trace to abundant up to 5 cm broken angular lithic gravel, trace clay, trace organics, moist.
			002	RS 001 ISO 002				1.0		
			003	RS 001 ISO 002				1.5		
			004	RS 001 ISO 002			SC	2.0		
			005	ISO 001 DUP						0.7-3.7 Clayey Sand, color and components same as above damp. trace gravel A/A.
			006	RS 001 ISO 002				3.0		
							SP	3.7		3.85-4.0 No Recovery
								4.0		
								5.0		3.7-3.85 Gravelly Sand, color and components same as above day.
			99A4849	001	001(002)			6.0		
				002	001(002)					
				003	001(002)			7.0		
				004	001(002)					
			Dup.	005	001					
			Parents	006	001(002)			8.0		
			Sampled on 2/26/99							
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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140(1)-(430-01 34-9 30)(Form GT.1A x 0 3/01 V2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B#94398
Location - North: 749129 East: 2085550
Date: 5/21/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5978 ft
Area: 903 PAD/LIP Area
Total Depth: 3.0ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1, 0.0-3.0ft.	Run #1 0.0-3.0ft.	Recovery 1.4ft.	001	11:20			GM			0.0-0.3; Fill; sand and gravel, grayish brown (10YR 5/2), gravel to 2cm, round occasionally fractured, granitic and quartzite
			002	0.3				0.3		
			003	11:23			GC	0.5		0.3-1.4; Soil; clay, sand, gravel; rock fragments, medium to fine sand, unconsolidated, dry, root hairs.
			004	0.7				0.7		
			005	11:25						very dark brown (10YR 2/2), gravel to 3.5 cm, angular, fractured, granitic in part, medium sand (Rock), poorly graded,
			006	1.1				1.0 1.1		
			007	11:27						Caliche 1.3-1.4ft, firm, unconsolidated, slightly moist.
			008	1.4				1.4		
								1.5		
								2.0		No Recovery 1.4-3.0ft.
								2.5		
								3.0		
								3.5		T.D = 3.0ft.
								4.0		
								4.5		
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH94498
Location - North: 749264 East: 2085552
Date: 06/08/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE/MACROCORE

Surface Elevation: 5976 ft
Area: 903 PAD/LIP Area
Total Depth: 3.0 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 8/25/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.0 ft.	Run #1 0.0-3.0 ft	Recovery 1.8 ft	001	12:10				0.3		0.0-0.3 fill; clay, sand, gravel; dark brown (7.5YR 3/2), gravel up to 20cm, rounded and fractured, granitic common, subangular clay, sand, medium sand, unconsolidated, moist, root hairs and plant fragments
			002	0.3				0.5		0.3-1.2 ft, soil; clay, sand, gravel; dark brown (7.5YR 3/2), gravel up to 3cm, angular-fractured, quartzite common, firm, caliche(?) in lower half, slightly moist
			003	12:08				0.8		
			004	0.8				1.0		
			005	12:06				1.3		1.2-1.8 ft, Soil; Clay-Sand, trace gravel, yellow to yellowish brown (10YR 8/6 to 10YR 6/6), fine to medium sand, soft unconsolidated, slightly moist, 1cm dia black subround gravel
			006	1.3				1.5		
			007	12:04				1.8		
			008	1.8				2.0		No Recovery 1.8-3.0 ft.
								2.5		
								3.0		
								3.5		
								4.0		T.D. = 3.0 ft.
								4.5		
								5.0		
								5.5		
								6.0		
								6.5		
								7.0		
								7.5		
								8.0		
								8.5		
								9.0		
								9.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: B194598
Location - North: 749265 East: 2085703
Date: Drilled: 9.16.98 sampled: 9.17.98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5976 ft
Area: 903 Lip Area
Total Depth: 3.0 feet
Company: STOLLER Project No.: GE 600000
Sample Type: Continuous Core

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 9/30/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.0 ft.	Run #1 0.0-3.0 ft.	Recovery 2.4 ft.	1.001 1.005	1029 6.5	RS R		GM	0.5		0.0-0.5 Fill, 60% gravel 40% sand, light yellowish brown (2.5y 6/4), 80% medium to coarse sand, gravel minus 0.5 inch subrounded to rounded, dry
			1.002 1.006	1033 40	RS R		GP	1.0		1.0-1.5 Gravel, 90% gravel, 10% sand / Rock fragments, poorly graded 1/8 to 1 inch, pinkish gray (5YR 7/2), subrounded to angular, broken, dry
			1.003 1.007	1022 15	RS R			1.5		
			1.004 1.008 1.009	1036 20	RS R Drp		GC	2.0 2.4		1.5-2.4 Gravel-Clay-Sand, predominant gravel top and bottom, clay sand center, reddish brown (5YR 5/3) gravel subangular moderately graded, mainly sand and clay 2.0-2.3 ft., damp
								2.5 3.0		2.4-3.0 No Recovery
			2.001 2.002	RS R	RNS RNS	40ml 4l	1043 1043			T.D. = 3.0 ft.

NOTES: General: USCS is modified for this log as follows
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible
(2) Core breaks cannot be matched, accurate footage measurements not possible

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH94698
Location - North: 749265 East: 2085852
Date: Drilled: 9-16-98 sampled: 9-17-98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5975 ft
Area: 903 Lip
Total Depth: 2.0 ft.
Company: STOLLER Project No.: GE600000
Sample Type: continuous core

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 9-30-98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.0 ft.	Run 1 of 1 0.0 - 2.0 ft.	Recovery 1.8 ft.	1.001 1.005	1408 0.45	Rs R		GC	0.5		0.0 - 1.8 Clayey Sandy Gravel, 30% clay 50% Sand 20% gravel, Reddish gray (5YR5/2) 80% of sand is medium to coarse grain, gravel is subrounded to angular and broken with fragments less than 0.1 ft. diameter, well graded Loose, dry. 0.2 ft. of caliche @ 1.5 ft.
			1.002 1.006	1409 0.9	Rs R			1.0		
			1.003 1.007	1410 1.35	Rs R			1.5		
			1.004 1.008	1411 1.80	Rs R			1.8		
								2.0		1.8 - 2.0 No Recovery
										T.D. = 2.0 ft. Refusal

NOTES General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible
(2) Core breaks cannot be matched, accurate footage measurements not possible

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH94798
Location - North: 749266 East: 2086000
Date: 3-17-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ mw 7/2/99
Surface Elevation: 5972 Ft
Area: 903 PAD Lip Area
Total Depth: 4.0
Company: TERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER event	FRACTURE ANGLE	BEDDING ANGLE b+l	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1	Run #1 0.0 - 4.0'	Recovery 4.0'	001	RS ISO	001 002		CL	1.0		0.0 - ~~0~~ TAL 1.0 Sandy Silty Clay. very dark ~~clay~~ TAL gray, 3YR N3 medium plasticity, trace up to 3.5 cm broken lithic gravel with organics, trace fine to coarse sand damp.
			002	RS ISO	001 002					
			003	RS ISO	001 002			2.0		1.0-4.0 Clayey Sand, Reddish yellow to 7YR 7/8 to 6YR 6/8 mod very fine to fine, some medium and coarse, subangular to angular, slightly plastic clay blebs locally, trace gravel up to 6 cm A/A, silty damp.
			004	RS ISO	001 002		SC	3.0		
								4.0		
	99A5833		001		RS 001	RI (002)		5.0		
			002		001	(002)				
			003		001	(002)				
			004		001	(002)		6.0		
			Sampled on 3-18-99					7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930)(Form CT.1A)(03/01.92)

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 94898
Location - North: 749243 East: 2086149
Date: drilled: 9.23.98 sampled: 9.25.98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5970 ft
Area: 903 Lip
Total Depth: 2.6 ft.
Company: STOLLER Project No.: GE600000
Sample Type: continuous core

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 9-30-98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.6 ft.	Run #1 0.0 - 2.6 ft.	Recovery 2.0 ft.	1.001 1.005	1412	RS R		GM	0.5		0.0-1.0 Silt, sandy, gravelly 60% silt, 20% sand, 20% gravel, light gray (5YR 6/1) medium to very coarse sand, subrounded gravel, broken quartzite, poorly graded, loose, dry, with abundant roots to 0.2 ft.
			1.002 1.006	0.5 1414	RS R			1.0		
			1.003 1.007	1.0 1410	RS R		GC	1.5		1.0-2.0 Gravel, clayey, silty, 50% gravel, 25% sand, 25% clay; reddish gray (5YR 5/2) to Reddish brown (5YR 4/3) poorly graded coarse sand and gravel; broken rock up to 0.15 ft. diameter; 0.3 ft clay section at 1.7-2.0 ft. Minor to no gravel, loose, dry, clay section damp.
			1.004 1.008	1.5 1406	RS R			2.0		
				2.0				2.5		2.0-2.6 NO RECOVERY
								2.6		T.D. = 2.6 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 94998
Location - North: 749244 East: 2086298
Date: drilled: 9.23.98 sampled: 9.28.98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5968 ft
Area: 903 Lip
Total Depth: 2.0 ft.
Company: STOLLER Project No.: GE-600000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 9-30-98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.0 ft.	Run #1 0.0 - 2.0 ft.	Recovery 1.7 ft.	1.001 1.005 1.002 1.006 1.003 1.007 1.004 1.008	1022 0.4 1021 0.8 1023 1.2 1024 1.7	Rs R Rs R Rs R Rs R		GM GP GC	0.5 0.7 1.0 1.3 1.5 1.7 2.0		0.0 - 0.7 Silty Sand gravel; 60% Sand 35% silt, 5% gravel dark grayish brown (10YR 4/2) low plasticity, 80% medium to coarse sand, subrounded gravel to 0.1 ft. diameter, poorly graded, Loose, dry, Lots of Roots
										0.7 - 1.3 GRAVEL, sandy; 80% gravel, 20% sand, silt; Light brownish gray (10YR 6/2) Low plasticity, sand coarse, gravel subangular and broken, poorly graded, loose, dry
										1.3 - 1.7 Gravel, clayey, Sandy, 55% gravel, 25% clay 20% sand Reddish brown (5YR 4/3) coarse sand, angular gravel, loose, dry
										1.7 - 2.0 No Recovery
										T.D. = 2.0 ft. Refusal

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 95098
Location - North: 749243 East: 2086447
Date: 7-2-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ 7/2/99
Surface Elevation: 5967 Ft
Area: 903 PAD Lip Area
Total Depth: 3.4'
Company: TIERRA
Project No. GE660000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR
APPROVAL Mark Wood
DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER event	FRACTURE ANGLE	BEDDING ANGLE btl	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC CHAR	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.4'	Run #1 0.0-4.0'	Recovery: 3.4'	001	RS ISO	001 002		SC	1.5		0.0-0.5 Clayey Silty Sand, Dark yellowish brown 3YR 3/4 very fine to fine sand, locally medium to coarse, subangular to subrounded Silty, clayey, slightly plastic w/ traces broken lithic gravel up to 3cm some organics, moist.
			002	RS ISO	001 002			1.0		0.5-2.2 Gravelly Silty Clay, Dark Red, 3YR 3/4, trace Sand A/A, traces to some gravel A/A, slightly to moderately plastic moist
			003	RS ISO	001 002		CL	1.5		
			004	RS ISO	001 002			2.0		
								2.2		2.2-3.4 Gravelly Silty Sand, Pink to Light Reddish Brown, Gravel A/A
							GM	3.0		
								3.4		3.4-4.0 No Recovery
								4.0		
	99A4851		001		RS 001 (RI 002)			5.0		Sand same as @ 0.0-0.5 trace clay, dry.
			002		001 (002)					
			003		001 (002)					
			004		001 (002)			6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: B#95198
Location - North: 749188 East: 2086149
Date: drilled: 9.17.98 sampled: 9.24.98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5970 ft
Area: 903 LIP
Total Depth: 2.7 ft.
Company: STOLLER Project No.: GE600000
Sample Type: continuous core

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 9-30-98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.7 ft.	Run #1 0.0 - 2.7 ft.	Recovery 2.4 ft.	1.001 1.005	1433 0.5	Rs R		GM	0.5		0.0 - 0.5 Silty GRAVEL, brown (7.5yR 5/3) TO GRAY (7.5yR 5/0) 60% silt 10% sand 30% gravel, coarse sand, subrounded gravel, well graded, dry, ROOTS
			1.002 1.006	1434 1.0	Rs R		GM	1.0		0.5-1.0 Silty Gravel, 70% gravel 30% silt, brown (7.5yR 5/3) subrounded to angular gravel, 0.1 ft. broken rock fragments, fines are mainly broken Rock, poorly graded, dry
			1.003 1.007	1435 1.5	Rs R		GC	1.5		1.0 - 2.4 Clay, sandy, gravelly; 40% clay, 30% sand, 30% gravel, dark brown (7.5yR 4/3) Low Plasticity, sand grains medium to coarse, Loose, dry; gravel fractured and angular
			1.004 1.008	1436 2.0	Rs R			2.0		
								2.4 2.5 2.7		2.4-2.7 NO Recovery
										T.D.= 2.7 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95298
Location - North: 749123 East: 2086066
Date: Drilled: 9·23·98 sampled: 9·28·98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5972 ft
Area: 903 Lip
Total Depth: 2.95 ft.
Company: STOLLER Project No.: GE606000
Sample Type: CONTINUOUS CORE

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 9/30/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.95 ft.	Run #1 0.0 - 2.95 ft.	Recovery 2.6 ft.	1.001	1108	RS		GM	0.5		0.0-0.9 Silty Sandy Gravel; 40% sand, 40% silt, 20% gravel dark gray (10YR 4/1) medium to coarse sand; gravel is minus 1/2 inch, Rounded, pebbly, loose, dry, abundant Roots to 0.5 ft.
			1.005	0.5	R					
			1.002	1109	RS					
			1.006	1.0	R			0.9 1.0		
			1.003	1325	RS		GP	1.5		0.9-1.5 GRAVEL, SANDY; 90% gravel, 10% sand; light gray (10YR 7/1); sand pebbly; gravel minus 1 inch, angular, broken, poorly graded, loose, dry
			1.007	1.5	R					
			1.004	1327	RS		GC	2.0		1.5-2.2 Gravel, clayey, sandy; 70% gravel 20% clay 10% sand Reddish brown (5YR 4/3) medium to coarse sand, angular gravel, broken, well graded, compact, damp
			1.008		R					
			1.009	2.0	Dup			2.2		
							CL	2.5		2.2-2.6 Caliche, sandy, gravelly; 80% fines 20% gravel pebbles, pinkish white (5YR 8/2) to white (5YR 8/1); Rounded pebbles, friable, compact, dry
								2.6		2.6-2.95 No Recovery
								2.95		
			2.001	R	RNS	4L	1335			T.D = 2.95 ft.
			2.002	RS	RNS	40ml	1337			

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH 95398
Location - North: 749120 East: 2086211
Date: 3-22-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ mw 7/2/99

Surface Elevation: 5970 Ft
Area: 903 PAD Lip Area
Total Depth: ~~4.0~~ TAL 3.8' 7/6/99
Company: TIERRA
Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER EVENT	FRACTURE ANGLE	~~BEDDING ANGLE~~ TAC 7/6/99 BOTTLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 3.2'	Run ~~#~~ 1 0.0 - 3.8'	RECOVERY: 3.2'	001	RS ISO	001 002		SM	.5		0.0-1.0 Silty Sand very dark grayish brown 3YR 3/2 med very fine to fine some medium to coarse, Subangular, Silty, some to trace clay, some up to 6cm, Subangular, dry
			002	RS ISO	001 002			1.0		1.0-3.2 Clayey Sand/Sandy Clay mottled light brownish gray to reddish brown 4YR 4/3 → 6YR 6/2 med. very fine to fine some med + coarse, Subangular, low plasticity clay, trace to some up to 4cm gravel dry
			003	RS ISO	001 002			1.5		
			004	RS ISO	001 002		SC	2.0		
								3.0		3.2-3.8 No RECOVERY
								4.0		
								5.0		
								6.0		
								7.0		
			99A	6157	001	es 001	RI (002)	8.0		
					002	001	(002)			
					003	001	(002)			
					004	001	(002)	9.0		
			SAMPLED ON			3-26-99				

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930X Form GT.1A (03/01/92))

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95498
Location - North: 748987 East: 2086078
Date: Drilled: 9.23.98 sampled: 9.28.98
Geologist: R. Rupp
Drilling Equip.: Geoprobe

Surface Elevation: 5973 ft
Area: 903 Lip
Total Depth: 2.35 ft.
Company: STOLLER Project No.: GE600000
Sample Type: continuous core

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 9/30/98

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
BOX 1 of 1 0.0 - 2.35 ft.	Run #1 0.0 - 2.35 ft.	Recovery 1.75 ft.	1.001 1.005 1.002 1.006 1.003 1.007 1.004 1.008	1429 0.95 1431 0.9 1425 1.35 1427 1.75	RS R RS R RS R RS R		GM GP GC	0.5 0.8 1.0 1.1 1.5 2.0 2.35		0.0-0.8 GRAVEL, SILTY, SANDY; 50% gravel 40% silt 10% sand dark grayish brown (10YR 4/2) sand medium to coarse; gravel subangular, poorly graded, Loose, dry, very heavy ROOTS
										0.8-1.1 GRAVEL, SILTY, SAND; 55% gravel, 30% sand, 15% silt BROWN (10YR 5/3) sand coarse, gravel subrounded minus 0.1 ft poorly graded, Loose, dry
										1.1-1.75 GRAVEL, clayey, sandy; 70% gravel, 20% clay 10% sand Reddish brown (5YR 4/3) angular, broken gravel, compact, dry, grading to light gray (10YR 7/1) pebbly caliche, loose dry
										1.75-2.35 No Recovery
										T.D. = 2.35 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95598
Location - North: 748984 East: 2086229
Date: 3-24-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ 7/2/99

Surface Elevation: 5972 Ft
Area: 903 PAD Lip Area
Total Depth: 4'
Company: TERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (EVENT)	FRACTURE ANGLE	BEDDING ANGLE (TAC) (BOTTLE)	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 2.85	Run #1 0.0 - 4.0	Recovery: 2.85	001	RS ISO	001 002		SM	.5		0.0-0.9 Clayey Silty Sand, dark yellowish brown 3YR 3/4, pred. very fine and fine, some med and coarse, silty, medium plasticity clay with up to 5cm angular lithic gravel, organics, damp at .8, otherwise dry
			002	RS ISO	001 002			1.0 .9		
			003	RS ISO	001 002			1.5		
			004	RS ISO	001 002		GM	2.0		0.9-2.85 Gravelly Silty Sand, very pale brown 2YR 8/3 pred. very fine to silt, some fine to coarse, with up to 4cm subangular lithic gravel 90% of material appears to be Caliche dry
								2.5		
								2.85		
								3.0		
								4.0		
								5.0		
		99A	6158	001	RS 001	RI (002)		6.0		
				002	001	(002)				
				003	001	(002)				
				004	001	(002)		7.0		
								8.0		
	SAMPLED ON 3/26/99									
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930)(Form CT.1A)(03/01/92)

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95698
Location - North: 749248 East: 2086077
Date: 3-18-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ mw 7/2/99

Surface Elevation: 5971 Ft
Area: 903 PAD Lip Area
Total Depth: 4'
Company: TIERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER (event)	FRACTURE ANGLE	~~BEDDING~~ TAL ANGLE (bit)	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1	Run #1 0.0 - 4.0	Recovery: 3.2'	001	RS ISO	001 002		GM	1.0 2.0 3.0 4.0		0.0-3.2 Gravelly Silty Sand, very dusky red to very pale brown 2.5YR to 8YR 8. 0.0-0.9 prod. very fine to fine becoming coarser w/depth, trace to some organics locally clayey, trace to some sub-angular lithic gravel up to 5cm, 0.0-0.9 damp, 0.9-3.2 dry
			002	RS ISO	001 002					
			003	RS ISO	001 002					
			004	RS ISO	001 002					3.2-4.0 No Recovery
99A58	35		001	RS 001	RI (002)			5.0		
			002	001	(002)					
			003	001	(002)					
			004	001	(002)			6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930)(Form GT.1A)(05/01.92)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96798
Location - North: 749108 East: 2085866
Date: 4-28-99 → 5-12-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5977 ft
Area: 903 PAD
Total Depth: 20.8 ft
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
										9.8-11.8
	Run # 4 9.8-11.8	RECOVERY: 2.9'					CL	10.0 11.0 11.8		Sandy Clay with some gravel A/A. damp-dry
	Run # 5 11.8-13.8	RECOVERY: 3.1'	001 003 002 99A6650-003	RS ISO VOA XXX	12.0 12.2 12.5 12.9		~~SC~~ CL	12.0 13.0 13.8		11.8-13.8 Sandy Clay, with some gravel locally grading to Clayey Sand dry - damp A/A 7/6/99
	Run # 6 13.8-15.8	RECOVERY: 2'					CL	14.0 15.0		13.8-15.8 Sandy Clay, with some gravel dry-damp TAL 6-22-99
	Run # 7 15.8-18.8	RECOVERY: 3.95'	002 001 003 99A6650-004-XXX	16.0 16.4 16.6 16.8 XXX	VOA RS ISO		TAL 6-22-99 SCL SC	16.0 17.0 17.5 18.0		15.8-~~18.8~~ 17.5 Clay, locally grading to Gravelly Clay, light Gray 2.5Y 7/2 low to no plasticity, trace to some silt, trace to some fine to coarse sand, angular to subangular with up to 4cm angular to subangular also bedrock, little gravel dry-damp 17.5-18.8 Clayey Sand, olive yellow to light gray 2.5Y 5/6 to 2.5Y 7/2 A/A dry
	18.8-19.8 Run # 8	1.0' RECOVERY:	001	19.8 20.0	RS		SC	19.0 19.8 20.0		18.8-19.8 Clayey Sand A/A with some gravel, damp

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96798
Location - North: 749108 East: 2085866
Date: 4-28-99 → 5-12-99
Geologist: J. LUTHERER
Drilling Equip.: GEOPROBE

Surface Elevation: 5977 Ft
Area: 903 PAD
Total Depth: 20.8 Ft
Company: TIERRA Project No. GE6000
Sample Type:

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC TEXT	SAMPLE DESCRIPTION
	Run #9 19.8-20.8	Recovery: 1.5'	003 003 002 003	20.0 20.4 ISO + DUP 20.8	VOA + DUP		SC	20.0 20.8		19.8-20.8, Clayey Sand with gravel, damp.
			99A 665		↑ -005-XXX					TD = 20.8, Geoprobe drilling, Refusal at 20.8 Ft
			ISO DUP		006-003					
			VOA DUP		006-002					
			VOA RINSE		007-002					
			"		007 003					
			"		007 004					
			ISO RINSE		007 005					
			RS RINSE		007 001					

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH 96898
Location - North: 749095 East: 2085713
Date: 4-12-99 → 4-13-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 18.8 ft
Company: TIERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Ward DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC CHG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8'	Recovery: 2.4'						1.0 2.0 2.4 3.0 3.8		0.0-2.4 See Borehole log for BH91198 2.4 to 3.8; No Recovery
	Run #2 3.8-6.8'	Recovery: 3.8'	001 002 003 99A6307-001-XXX	RS ISO VOA	003 002	TAL 4/21/99	SC SC	4.0 4.2 4.4 4.7 5.0 6.0 6.8		3.8-6.8 Sandy Clay / Clayey Sand; pink to reddish yellow, 5YR 7/4 to 5YR 7/6. fine to coarse subangular Sand moderately plastic clay, some up to 4cm angular to subangular lithic gravel, damp.
	Run #3 6.8-9.8	Recovery 3.5'	001 ~~002~~ ~~003~~ 99A6307-001-XXX	RS ISO VOA	TAL 003 002	4/21/99	SC SC	7.0 8.0 8.2 8.4 8.7 9.0 9.8		6.8-9.8 Clayey Sand, as above. dry, locally grading to Sandy Clay.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 2 OF 2

Borehole Number: BH96898
Location - North: 749095 East: 2085713
Date: 4-12-99 → 4/13/99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 18.8 ft
Company: TIERRA Project No.: 6E6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Ward DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	DEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
4/14/99	Run #4 9.8-12.8	Recovery 3.6'	99A6307-003-XXY				SC	10.0, 11.0, 11.9, 12.0, 12.1, 12.8		9.8 - 12.8 Clayey Sand Same as above
			~~001~~ ~~002~~ ~~003~~	RS ISO VOA	003 002	JAL 4/21/99				
	Run #5 12.8-15.8 JAL	Recovery 2.0'					SC	13.0, 14.0, 15.0, 12.8, 15.8		12.8 - 15.8 Clayey Sand Same as above.
	Run #6 15.8-18.8	Recovery 4.0'	~~001~~ ~~002~~	RS ISO	003		SC	16.0, 17.0, 17.3		15.8 to 17.3 Clayey Sand Same as above
			~~003~~	VOA	JAL 4/21/99 002					
			99A6307-004-XXX	45°			~~BR~~	18.0, 18.8, 19.0		17.3 - 18.8 Claystone, strong brown to light gray 7.5YR 5/8 to 2.5YR 7/1. Highly oxidized near top of interval. Clay highly weathered, locally waxy, dense, becoming silt. Claystone w/ 18. Becoming less weathered and more indurated. 45° bids plane scallopped
										TD = 18.8 Slightly weathered @ 18.8 Top of Bedrock = 17.3 ft

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96998
Location - North: 749038 East: 2085711
Date: 4-20-99 → 4-28-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 18.8 ft
Company: TERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE RUN	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC UNIT	SAMPLE DESCRIPTION
										0.0-2.65
Run #1, 0.0-3.8		Recovery = 2.65'						1.0 2.0 3.0 3.8		See Borehole log for BH91198 2.65 to 3.8 No Recovery
Run #2, 3.8-6.8		Recovery = 3.7'	001 003 002 99A6824-001-XXX	4.2 4.4 4.8	RS ISO VOA		SC SC	4.0 5.0 6.0 6.8		3.8-6.8 Sandy Clay; very pale brown to yellowish red very fine to fine, locally medium to coarse, angular to subangular 5-25-99 low to medium plasticity Silty with some up to 3.5 angular to subangular lithic gravel. damp locally grading to Clayey Sand TAL 5-25-99
Run #3, 6.8-9.8		Recovery = 2.7	001 003 002 99A6824-002-XXX	8.2 8.4 8.8			SC SC	7.0 8.0 9.0		6.8-9.8 Sandy Clay A/A locally grading to Clayey Sand, dry 9.5-9.8 No Recovery

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96998
Location - North: 74903B East: 2085711
Date: 4-20-99 → 4-28-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 18.8 ft
Company: TIERRA Project No.: GE000000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4, 9.8-12.8'	Recovery: 4.0'	99A6824-003-XXX				SC	10.0		9.8-12.8 Sandy Clay; A/A locally clay with some Sand. dry
								11.0		
			001	12.0	RS			12.0		
			003	12.2	ISO					
				12.4						
			002	12.7	VOA			12.8		
	Run #5, 12.8-15.8	Recovery: 3.2'					SC	13.0		12.8-15.8 Sandy Clay; A/A locally grading to Clay with some Sand A/A. dry
								14.0		
								15.0		
								15.8		
	Run #6, 15.8-18.8	Recovery: 3.2'	99A6824-004-XXX				SC	16.0		15.8-17.4 Sandy Clay; A/A locally grading to Clay with some Sand A/A dry → damp
								17.0		17.4-17.8 Gravelly Sand; very pale brown pred fine to very fine, some med. to coarse angular, silty, with up to 4cm angular + broken lithic gravel with several Sandy Clay lithic clasts damp
				17.4				17.8		
			001	17.5						
			003	17.6						
			002	17.5			GC	17.4		
	Run #7	Recovery: 1.1'		45°			BR.	18.0		17.8-18.8 Claystone; gradional (weathered) to 18.2. light gray to moderate yellow 2.5Y 7/4 to N7-10YR 6/6 massive, stiff, trace to some silt very friable, with twinned, 45° scalloped, nonoxidized, non slicken sided, damp
								18.8		
								19.0		TD = 18.8
										Bedrock = 17.8 ft Top of

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH97098
Location - North: 748986 East: 2085611
Date: 3-29-99 → 4-7-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5979 ft
Area: 903 PAD
Total Depth: 18.8
Company: TIERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Word DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC TEXT	SAMPLE DESCRIPTION
	Run #1 0.0'-3.8'	Recovery: 2.7'						1.0 2.0 2.7 3.0 3.8		0.0-3.8 See Borehole Log of BH 91598 2.7-3.8: No Recovery
	Run # 2 3.8'-6.8'	Recovery: 2.35'	4.0 001 RS 4.2 002 ISO 003 VOA 4.7 99A6308-001-XXX				SC	4.0 5.0 6.0 6.15 6.8		3.8-6.8: Sandy Clay, light brown, 6YR 6/4 very fine to medium subangular sand locally coarse, trace to 30% up to 4cm angular and broken pottery gravel locally silty, no plasticity, dry 6.15'-6.8: No Recovery
	Run # 3 6.8'-9.8'	Recovery: 2.9'	99A6308-002-XXX 8.0 001 8.2 RS 002 8.4 ISO 003 8.8 VOA				SC CL	7.0 8.0 9.0 9.7 9.8 10.0		6.8-9.8 Sandy Clay, locally grading to Clayey Sand. Red to 6YR 6/8 reddish yellow. Red = 5YR 5/8 A/A dry. 9.7-9.8: No Recovery

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(40CFR-930-0154-9 90)(Form GT.1A 03/01/92)

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH97098
Location - North: 748986 East: 2085611
Date: 3-29-99 → 4-7-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5979 ft
Area: 903 PAD
Total Depth: 18.8
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run # 4: 9.8-12.8'	Recovery: 3.9'	99A 6308-003-XXX 001 002 003	12.0 12.2 RS 12.4 ISO 12.6 VOA			CL MW 4/1/99 SC CL	10.0 11.0 11.1 12.0 12.8		9.8-11.1 Clay none to low plasticity, trace to some Sand A/A, trace Silt, trace Gravel A/A; dense, massive, dry → damp 11.1-12.8 Sandy Clay, pink to dark brown 7.5YR 7/3 to 7.5YR 3/4, same as @ 3.8-6.8' locally medium plasticity damp locally grading to Clayey Sand
	Run # 5: 12.8-15.8	Recovery: 3.5'	TAL 4/8/99				MW 4/1/99 SC CL	13.0 14.0 15.0 15.8		12.8-15.8 Sandy Clay A/A locally grading to Clayey Sand damp A/A
	Run # 6: 15.8-18.8	Recovery: 3.7'	~~004~~ ~~003~~ 001 003 99A 6308-004-XXX	16.0 16.2 RS 16.5 ISO VOA 17.0				16.0 17.0 18.0 19.0		15.8-16.8 Sandy Clay A/A locally grading to Clayey Sand damp A/A 16.8 to 18.8 Bedrock Clayey Sandstone Light Gray 5YR 7/1, some yellow 7.5YR 6/8 very poorly indurated, slightly weathered, ~~predominantly~~ TAL predominantly very fine to fine subrounded to rounded, quartzose, low to non plastic clay, damp
								19.0		TD = 18.8 ft

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-930-0134-930V Form GT.1A X03/01/92)

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

PAGE 1 OF 3

Borehole Number: BH97198
Location - North: 748911 East: 2085611
Date: 12-14-98 → 1-7-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5980 ft
Area: 903 PAD
Total Depth: 26.5 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	BOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8'	Recovery: 2.3'						1.0, 2.0, 3.0, 3.8		0.0 - 3.8 See Borehole log for BH 92098
										2.3 - 3.8 No Recovery
*	Run #2 3.8-6.5	Recovery: 2.8'	004, 005, 006	RS, ISO, VOA			SC	4.0, 4.2, 4.4, 4.8, 5.0, 6.0		3.8-6.5 Clayey Sand; yellowish red pale to yellow 5YR 5/6 to 2.5Y 7/4, fine to coarse, angular to subrounded, lithic Sand, ~~trace to subangular~~ angular to subrounded, lithic gravel fine to coarse, non to low plastic clay. damp
			99	A4	102.002		xxx			
	Run #3 6.5-9.0'	Recovery: 3.4'	001, 002, 003	RS, ISO, VOA	6.8, 7.0, 7.3, 7.6		SC	7.0, 8.0, 9.0		6.5 - 9.0 Clay w/ some sand grading to Clayey Sand. damp. Clay: non to low plasticity, from 7.0-7.5 possible graphite/carbon black, soft, powdery
			99	A4	102.002		xxy			
*	Run #4	Rec. 3.2'					SC			9.0 - 11.5 Clayey Sand: damp

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

* OFF SET STARTED ON 12-15-98 ORIGINAL BOREHOLE ENCOUNTERED REFUSAL AT 12.0' BGS

207

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH97198
Location - North: 748911 East: 2085611
Date: 12-14-98 → 1-7-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5980 ft
Area: 903 PAD
Total Depth: 26.5 ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run # 4 9.0-11.5	Rec: 3.2'					SC	10.0 11.0		9.0-11.5 Clayey Sand, damp
	Run # 5 11.5-14.0	Rec: 3.8'	TAL 7-7-99 006 007 008	RS ISO VOA	007 008 009		GM SC	12.0 12.2 12.4 12.8 13.0 14.0		11.5-14.0 11.5-12.0 Sandy Gravel. Sand A/A, very silty, Gravel A/A. dry Gravel: Quartzose 12.0-14.0 Clayey Sand: Brown 7.5YR 6/3 damp
			99A4102 002 XXX							
	Run # 6 14.0-16.5	Recovery 3.0	TAL 7-7-99 009 010 011 012	RS ISO VOA	010 011 012		SC CL	15.0 15.3 15.4 16.0 16.1		14.0-16.5 Clayey Sand; A/A grading to Clay w/ Sand towards bottom of interval. 15.6-16.5 Clay: pinkish gray to reddish yellow 7.5YR 6/2 to 7.5YR 6/6, dense, slightly plastic, trace sand, trace gravel. dry.
	Run # 7 16.5-19.0	Recovery 3.7					CL ~~SC~~ SC	17.0 mw 7/7/99 18.0		16.5-17.8 Clay, with sand, A/A damp 17.8-19.0 Clayey Sand. A/A damp
	Run # 8 19.0-21.5	Recovery 2.5					SC	19.0		19.0-21.5 Clayey Sand A/A damp

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

208

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH97198
Location - North: 748911 East: 2085611
Date: 12-14-99 → 1-7-99
Geologist: L. LUTHERER
Drilling Equip.: GEOPROBE

Surface Elevation: 5980 ft
Area: 903 PAD
Total Depth: 26.5 ft
Company: TIERRA Project No.: GE600000
Sample Type: Continuous

RMRS LOGGING SUPERVISOR APPROVAL Mark Ward DATE 7-7-99

TOP-BOTTOM OF CORE IN BOX	TOP-BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ABBR.	BEDDING ABBR.	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGY LOG	SAMPLE DESCRIPTION
	Run #8 19.0-21.5	Recovery 2.5'	012 013 014 TAC 7-7-99	RS 150 013 014; VOA 015			20.2 20.4 20.8 SC	20.0 21.0		Clayey Sand A/A damp.
	Run # 9 21.5-24.0	Recovery 2.2'					SC	22.0 24.0		Clayey Sand A/A moist
	Run # 10 24.0-26.5	Recovery 4.0'	015 TAC 7-7-99	RS 150 016 017; VOA 018			24.2 24.4 24.8	25.0 26.0		24.0-26.5 Sandstone: white to light gray also very pale brown to dark yellow brown. 2.5Y N8/, 2.5Y N7/, 10YR 7/3 to 10YR 4/6, locally very silty, very fine to fine, subrounded, primarily qtz, locally very clayey, locally grading to silty claystone w/sand, friable, poorly indurated, oxidized, locally dense. damp. Bedrock at 24.0 ft TD = 26.5 ft

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

209

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH97298
Location - North: 748844 East: 2085930
Date: 5-26-99 → 6-2-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5974 ft
Area: 903 PAD Lip Area
Total Depth: 18.5 ft
Company: TIERRA Project No.: 6E000000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER / ANALYTE	FRACTURE ANGLE	BEDDING ANGLE / SAMPLE NO.	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8	Recovery: 2.65'					SC	0 1 2 3		0.0-2.65 Gravelly Sand; very dark gray 5YR 3/1 to .5, remaining interval is reddish brown to dark reddish brown, 5YR 4/3 to 5YR 2.5/2 Fine to coarse, subangular to subrounded, lithic, fine to 4 cm subrounded to broken lithic gravel, some silt + clay, damp.
	Run #2 3.8-6.8	Recovery: 2.7	TPL → 002 4.4; 003 4.6; 001 4.8; VOA 002; ISO 003; RS 001; 99A6825 001 xxx				SC	4 5 6		3.8-6.5 Gravelly Sand; reddish brown to dark reddish brown, A/A
	Run #3 6.8-8.8	Recovery: 2.7	99A6825 002 xxx; RS 8.2 001; ISO 8.4 002; VOA 8.8 003				SC	7 8		6.5-8.8 Clayey Sand, light red, 10YR 6/8 to reddish gray 10YR 6/1, with some light yellowish brown 2.5Y 6/6, fine to coarse, subangular to subrounded, up to 4.4 cm angular to lithic gravel, low plasticity, some silt, damp
	Run #4 8.8-11.0	Recovery: 2.2						9 10		8.8-11.0 Clayey Sand A/A

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

210

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: B197298
Location - North: 748844 East: 2085930
Date: 5-26-99
Geologist: I. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5974 ft
Area: 903 PAD Lip Area
Total Depth: 18.5 ft
Company: TIERRA Project No.: GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4 8.8-11.0	Recovery 2.2			NP.		SC	10.0		
	Run #5 11.0-11.4	No Rec.						11.0		USED SOLID POINT TO BREAK THROUGH OBSTRUCTION @ 11.0 - INTERVAL WAS NOT SAMPLED
(3.6)	Run #6 11.4-13.6	Recovery 2.1	RS ISO VOA 99AG825	12.2 12.4 12.8 003	001 002 003 005	XXX	SC	12.0 13.0 13.6		11.4-13.6 Clayey Sand A/A
Run #8, 15.5-16.0	Run #7 13.6-15.5	Recovery 1.3					SC	14.0 15.0		13.6-15.5 Clayey Sand A/A, wet @ 13.8
		Rec. 1.2					SC	16.0		15.5-16.0; Clayey Sand A/A, damp to wet
	Run #9 16.0-17.0	Rec. 1.1	RS ISO 99AG825 VOA	16.2 16.4 17.0	001 002 003	004 XXX	SC	17.0		16.0-17.0; Clayey Sand. A/A, damp to wet
	Run #10 17.0-18.5	Rec. 1.5	99AG825	17.3 17.9 18.1 18.3	002 003 001 005	XXX	SC BR	18.0 19.0		17.0-17.8 Clayey Sand A/A; wet 17.8-18.5 Silty Claystone slightly weathered mostly light gray 7.5 YR N7, some brownish yellow 10 YR 6/6, very poorly indurated locally dense, massive, stiff - damp Top of Bedrock = 17.8 ft TD = 18.5 ft

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH97398
Location - North: 748827 East: 2086090
Date: 6-14-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5956 Ft
Area: 903 PAD Lip Area
Total Depth: 4.0
Company: TIERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	PROJECT/ ANALYTE	BOTTLE/ ANALYSIS NO.	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC TEXT	SAMPLE DESCRIPTION
Box 1 of 1 0.0-3.4'	Run #1 0.0-4.0'	Recovery 3.4'	001	RS ISO	001 002		ML			0.0-2.0 Clayey Silt, very dark gray 2.5 Y N3/, dense, moderate plasticity traces fine to coarse, angular to sub-angular, lithic sand, traces fine to coarse, broken and angular lithic gravel with organic matter, wet → moist.
			002	RS ISO	001 002		CL	1.0		
			003	RS ISO	001 002					
			004	RS ISO	001 002			2.0		2.0-3.4 Clayey Sand, light reddish brown 5YR 6/3, components as above. damp.
							GC	3.0		
								4.0		
										TD: 4.0
								5.0		
		99A	6155	001	001	(002)				
				002	001	(002)				
				003	001	(002)		6.0		
				004	001	(002)				
								7.0		
								8.0		
								9.0		

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Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
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Procedure No. RMRS/OPS-PRO.101
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Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH97498
Location - North: 748770 East: 2086182
Date: 6-14-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5947 Ft.
Area: 903 PAD Lip Area
Total Depth: 4.0
Company: TERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR
APPROVAL _____ DATE _____

TOP/BOTTOM OF CORE INTERVAL	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	REACTIVE ANALYSIS	BEDDING ANALYSIS	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL LITHOLOGY LOG	SAMPLE DESCRIPTION
Box 1 of 1, 0.0-1.8'	Run #1, 0.0-4.0	Recovery: 1.8'	EVENT	ANALYSIS	BOTTLE					
			001	RS	NO 001		ML	.45		0.0-1.3 Clayey Silt; dark reddish brown 5YR 4/3, dense, mod. plasticity, traces fine to coarse, angular to subangular lithic sand, traces fine to coarse, broken and angular lithic gravel, with organic matter, wet to moist.
				ISO	002					
			002	RS	001		CL	.9		
				ISO	002			1.0		
			003	RS	001			1.35		
				ISO	002					
			004	RS	001		SC	1.8		1.3-1.8 Clayey Sand, reddish brown, 5YR 5/3, components as above, damp.
				ISO	002			2.0		
								3.0		
								4.0		
										TD = 4.0
		99A	6156	001	RS 001	RI (002)		5.0		
				002	001	(002)				
				003	001	(002)				
				004	001	(002)		6.0		
								7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH97598
Location - North: 748845 East: 2086247
Date: 6-14-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5954 Ft.
Area: 903 PAD Lip Area
Total Depth: 4.0
Company: TIERRA Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER / EVENT	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1, 0.0-2.7' Run #1 0.0-4.0'		Recovery: 2.7'	001	RS ISO	001 002		ML			0.0-2.7 Clayey Silt: reddish black 10R 2.5/1, dense, mod. plasticity, traces fine to coarse, angular to sub-angular lithic sand, traces fine to coarse, broken and angular lithic gravel with organic matter damp to moist.
			002	RS ISO	001 002			1.0		
			003	RS ISO	001 002		CL			
			004	RS ISO	001 002			2.0		
			005	ISO DUP.	001	DUPLICATE				
			006	RS ISO	001 002	RINSATES				
								3.0		
								4.0		
	99A	79	37	001	RS 001	CI (002)		5.0		
				002	001	(002)				
				003	001	(002)		6.0		
				004	001	(002)				
				005	001					
				006	001	(002)		7.0		
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH97698
Location - North: 749135 East: 2085880
Date: 6-18-99 → 6-23-99
Geologist: J. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: ~~903 PAD~~ TAL 6-29-99 22.8
Company: TIERRA Project No. GE6000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE INTERVAL	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	~~SAMPLE~~ EVENT NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8'	Recovery: 2.5'						1.0 2.0 3.0 3.8		0.0-3.8 See Borehole log of BH 90998
	Run #2 3.8-6.8	Recovery: 3.9'	TAL 6-29-99 ~~001~~ ~~001~~ ~~001~~ ~~006~~ 001 006 99A	4.0 RS 4.2 ISO 4.8 ISO 4.6 5.2 VOA 5.8 VOA 8275	001 003 003 002 002 001 006	DUP DUP	SC	4.0 5.0 6.0		3.8-6.8 Clayey Sand, yellowish brown, 10YR 5/4, very fine to coarse, angular to subangular lithic sand, non plastic clay, silty, locally abundant up to 3.5cm brown to subangular lithic gravel, dry-locally damp.
	Run #3 6.8-9.8	Recovery: 3.5'	BOTTLE No. 001 003 002 99A	RS 8.2 VOA 8.6 ISO 8.8 827	002		SC GC SC	7.0 8.0 9.0 10.0		6.8-9.0 Clayey Sand, dark yellowish brown to yellowish brown 10YR 4/4 to 10YR 5/8. components A/A. damp. 9.0-9.2 Sandy Gravel, color and components as above. damp 9.2-9.8 Clayey Sand A/A damp.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: B497698
Location - North: 749135 East: 2085880
Date: 6-18-99 → 6-23-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 22.8
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4 9.8-12.8	Recovery 3.3'	001 11.0 11.2 RS; 002 11.6 VOA; 003 11.8 ISO; 99A827 003	NATURE		xxx	SC	10.0; 11.0; 12.0		9.8-11.9 Sandy Clay, A/A w/ locally abundant gravel, at times locally grading to Sandy Gravel A/A damp 11.9-12.8 Clayey Sand, Reddish Brown 5YR 5/4 low to mod plasticity, fine to medium, Subangular to Subrounded, lithic sand, damp to moist.
	Run #5 12.8-14.8	Recovery 3.3'	001 13.2 RS; 002 13.4 VOA; 003 13.9 ISO; 14.1; 99A827 004			xxx	SC	13.0; 14.0		12.8-14.8 Clayey Sand; pale yellow to olive yellow 2.5Y 7/4 to 2.5Y 6/8 fine to coarse sand, Subangular to rounded lithic and calcite grains, trace fine angular lithic gravel, low plasticity, locally silty damp
	Run #6 14.8-16.8	Recovery 2.65'	99A827 005; 001 15.9; 003 16.1; 002 16.3; 16.7			xxx	SC	15.0; 16.0		14.8-16.8 Clayey Sand; A/A, locally with abundant gravel, damp wet @
	Run #7 16.8-18.8	Recovery 3.25'	99A827 008; 001 17.8; 003 18.0; 18.2; 002 18.8			xxx	SC	17.0; 18.0; 18.8		16.8-18.8 Clayey Sand with some to abundant gravel A/A brownish yellow 10YR 6/6 to yellowish brown 10YR 5/6 and dark yellowish brown. damp
	Run #8	Recovery 2.4	99A827 009; 001 19.2; 19.4; 002; 003 19.8			xxx	SC	19.0		18.8-20.8 Clayey Sand A/A

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH97698
Location - North: 749135 East: 2085880
Date: 6-18-99 → 6-23-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft.
Area: 903 PAD
Total Depth: 22.8
Company: TIERRA Project No. 6E6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #8	Recovery 2.4					SC	20.0		
	Run #9	Recovery: 1.3'					SC	21.0 22.0		20.8 - 22.8 Clayey Sand, A/A with locally abundant gravel 20.8 - 21.1 Saturated, otherwise damp
		Rinsates:						23.0		TD = 22.8
			99A827 007 001 RS 002 VOA Spares 003 VOA 004 VOA 005 ISO							

NOTES: General: USCS is modified for this log as follows:
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(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95798
Location - North: 749268 East: 2086148
Date: 3-17-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ 7/2/99
Surface Elevation: 5970 ft
Area: 903 PAD Lip Area
Total Depth: 4'
Company: TIERRA Project No. GE6000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0 - 3.3'	Run #1 0.0 - 4.0	Recovery 3.3'	001	RS 001 ISO 002			SC	.8		0.0 - 0.8 Clayey Sand, dark brown 3YR 3/3 pred fine to very fine, some medium to coarse, subangular trace slightly plastic clay, w/trace to some up to 4cm angular to subrounded lithic gravel, damp.
			002	RS 001 ISO 002			CL	1.0		0.8 - 1.2 Silty Clay dark red 3YR 3/6 silty, low to medium plasticity moist @ 1.0 trace sand trace gravel
			003	RS 001 ISO 002				1.2		1.2 - 3.3 Sandy Clay locally grading to Clayey Sand light brown to
			004	RS 001 ISO 002				2.0		
			005	ISO DUP 001						
			006	RS 001 ISO 002			SC	3.0		
								3.3		3.3 - 4.0 No Recovery
								4.0		reddish yellow 6YR 6/3 to 6YR 6/8 pred. fine to very fine, some medium to coarse, subangular, slight to no plasticity, with up to 4cm angular to subrounded lithic gravel dry.
	99A5832		001	RS 001	QI (002)					
			002	001	(002)			5.0		
			003	001	(002)					
			004	001	(002)					
			005	001	~~002~~ VAL			6.0		
			006	001	(002)					
								7.0		
	Sampled on 3-25-99									
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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(4011-430-0134-930)(Form GT.1A)(03/01/92)

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: BH95898
Location - North: 749244 East: 2086219
Date: 3-17-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE ~~DUAL WALL~~ MW 7/2/99

Surface Elevation: 5969 Ft
Area: 903 PAD Lip Area
Total Depth: 4.0'
Company: TERRA
Project No. GE6000 00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-2-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
Box 1 of 1 0.0-2.9	Run #1 0.0'-4.0'	Recovery: 2.9'	001	RS ISO	001 002		CL	1.0		0.0-4.6 Silty Clay, 3YR 3/3 dark Brown, slight to some plasticity, traces fine to coarse Sand, Silty, traces to some up to 6 cm Subrounded to Subangular, dry, ~~damp~~ TAC AT 1.0-1.6 damp to moist.
			002	RS ISO	001 002					
			003	RS ISO	001 002					
			004	RS ISO	001 002		GM	2.0		1.6-29 Gravelly Sand, pinkish white 8YR 8/2, med-very fine, to fine, some mud to coarse, angular to subrounded, locally silty up to 4cm subrounded lithic gravel. dry
								3.0		2.9-4.0 No Recovery
								4.0		
99A5836			001	RS 001	RI (002)			5.0		
			002	001	(002)					
			003	001	(002)					
			004	001	(002)					
								6.0		
								7.0		
	Sampled on 3-25-99									
								8.0		
								9.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98
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(4011-930-0134-930)(Form GT.1A)(03/01.V2)

U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH 90998
Location - North: 749140 East: 2085893
Date: 6-3-99 → 6-7-99
Geologist: T LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 25.0 ft
Company: TIERRA Project No GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP-BOTTOM OF CORE BOX	TOP-BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FIRST TOUCH ARGILE	BLEEDER ARGILE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/BEDROCK LINE	SAMPLE DESCRIPTION
	Run #1: 0.0-3.8'	Recovery: 3.5'						1.0, 2.0, 3.0		0.0-4.0 similar to BH 90998 see log
	Run #2: 3.8-6.8'	Recovery: 3.7'	001, 003, 002, ~~003~~	4.8, 5.0, 5.6	RS, 230, VOA		SC	4.0, 5.0, 6.0		3.8-6.8 Clayey Sand, brown 7.5 YR 5/4 fine to coarse, sub-angular to subrounded, lithic sand, low plastic clay, some silt, with up to 4cm broken to subangular lithic gravel, damp
	Run #3: 6.8-8.8'	Recovery: 1.55'	001, 003				SC	7.0, 8.0		6.8-8.8 Clayey Sand, A/A
	Run #4: 8.8-10.8	Recovery: 2.4'					SC	9.0		8.8-10.8 Clayey Sand A/A

99A7799 001 XXX

99A7799 002 XXX

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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1401 1-930-01 34-930 Form CT 1A x 0.901.V2

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH95998
Location - North: 749140 East: 2085893
Date: 6-3-99 → 6-7-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 25.0 ft
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4 8.8-10.8	Recovery 2.4					SC	10.0		Clayey Sand A/A
								10.8		
	Run #5 10.8-12.8	Recovery 2.8	99A7799 003 XXY				SC	11.0		10.8-12.5 Clayey Sand
			001	12.2	RS			12.0		
			003	12.4	ISO					
			002	12.7	VOA		CL			12.5-12.8 Clay, light-yellowish brown 2.5Y 6/3 to ~~light~~ olive yellow 2.5Y 6/8
	Run #6 12.8-15.8	Recovery 2.9'					SC	13.0		low to no plasticity, dense, trace w/ traces fine to coarse lithic + calcite sand, also w/ traces fine up to 1.5 cm subrounded gravel, damp to moist.
				14.6				14.0		12.8-15.8 Clayey Sand A/A.
			001	14.8	RS					
			002	15.2	VOA			15.0		
			003	15.4	ISO					
			99A7799 004 XXX							
	Run #7 15.8-17.0	Recovery: 2.35					SC	16.0		15.8-17.0 Clayey Sand A/A
								17.0		
	Run #8 17.0-18.8	Recovery 2.45		17.3						17.0-18.8 Clayey Sand A/A
			001	17.5						
			003	17.7						
			002	18.2			SC	18.0		
			99A7799 005 XXY							
	Run #9 18.8-20.0	Recovery: 1.5					SC	19.0		18.8-19.9 Clayey Sand A/A
										TAL 6-27-99
										19.9-20.0 No Recovery

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH95998
Location - North: 749140 East: 2085893
Date: 6-3-99 → 6-7-99
Geologist: T. LITHERER
Drilling Equip. GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 25.0 ft
Company TIERRA Project No GEG00000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

Interval	Feet of Core Recovered (Field Measurement)	Sample Number	Field Test Result	Blow Count	Grain Size Distribution	USCS Symbol	Depth in Feet	Sample Description
Run #10 20.0-21.5	Recovery: 0.6'	001 003 003	20.2 ISO 20.6	RS		SC		20.0-20.5 Clayey Sand. A/A, wet
						BR		20.5-20.6 Claystone, light gray 2.5Y N7/ massive, dense, trace to some silt, mod. plasticity, moist
		99A7799		006	001	RS	21.0	No Recov. 20.6-21.5 Top of Bedrock = 20.5 ft (approximate) TAL 6-29-99
		99A7799		006	003	ISO		
				009	003	ISO	Rep	
Run #11 21.5-22.8	Recovery: 0'						22.0	21.5-22.8' No Recovery
Run #12 22.8-25.0	Recovery: 2.0'	99A7799		007	001	RS	23.0	22.8-24.8' Claystone A/A with some weathering, olive yellow 2.5Y 6/6.
				007	002	VOA		
				009	002	VOA	24.0	
		001	24.4 24.6	RS				
		002 002	VOA 25.0				25.0	
	Rinsates:							TD = 25.0
		99A7799		007	001	RS		
					002	VOA		
					003	VOA		
					004	VOA		
					005	ISO		

NOTES General: USCS is modified for this log as follows.
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS OPS-PRO.101
Revision 0
Date effective: 12-31-98

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH 960 98
Location - North: 749211 TAL East: 2085612
Date: 10/29/98 → 10/30/98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE - Dual Wall

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 17.0 ft
Company: TIERRA Project No.: 6E600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE (PL / ANALYTE)	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0 - 3.8	Recovery: 3.4						1.0, 2.0, 3.0, 3.4, 3.8		0.0-3.8 See Borehole log of BH 90098
										3.4-3.8 No Recovery
	Run #2 3.8 - 7.0	Recovery: 3.0	001 RS, 007 ISO, 013 VOA				SC	4.0, 4.3, 4.5, 4.8, 5.0, 6.0, 7.0		3.8-7.0 Sand; Light Brown to Strong Brown 7.5 YR 6/3 to 7.5 YR 5/6 fine to coarse, Subangular to Subrounded, Some to abundant up to 4cm broken and subangular to angular lithic gravel, some to abundant low plastic clay, locally grading to Clayey Sand. Dry to Damp with some powdery Caliche white; N/8, 5 YR 8/1
	Run #3 7.0-9.0	Recovery: 3.0	002 RS, 008 ISO, 014 VOA				SC	8.0, 8.2, 8.5, 8.8, 9.0		7.0-9.0 Sand; locally grading to Clayey Sand. A/A damp
	Run #4						CL			9.0-12.0 Clay A/A with sand, A/A with traces coarse, rounded Caliche sand. - Lithic subangular fine to coarse Sand

A 993210-002-XXX

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96098
Location - North: 749211 TAL East: 2085612
Date: 10/29/98 → 10/30/98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5978 ft
Area: 903 PAD
Total Depth: 17.0 ft
Company: TIERRA Project No.: GE6000.00
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run#4 9.0-12.0	Recovery: 4.0'					CL	10.0 11.0 12.0		locally grading to Sandy Clay
	Run#5 12.0-15.0	Recovery: 4.0'	003 009 JAL ~~007~~ 015	RS I50 VOA			CL	12.3 12.5 13.0 14.0 15.0		12.0-15.0 Clay; locally grading to Sandy Clay A/A
	Run#6 15.0-16.3	Recovery: 1.25'	004 010 016	RS I50 VOA			CL BR	15.6 15.8 16.0 16.2 16.25		15.0-15.8 Clay; locally grading to Sandy Clay A/A 15.8-17.0 Sandstone; Yellow 10YR 8/8 fine to medium, Subrounded, mostly unconsolidated.
	Run#7 16.3-17.0	Rec: 1.25					7/14/99 BR	16.3 17.0		highly friable, oxidized, quartz sand, saturated trace clay + silt
								18.0 19.0		Bedrock contact: 15.8 TD: 17.0

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96198
Location - North: 749213 East: 2085687
Date: ~~12/03/98~~ 12-2-98 → 12-3-98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE — DUAL WALL

Surface Elevation: 5977 ft
Area: 903 PAD
Total Depth: 18.8 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

Bottom of Core Interval	Top/Bottom of Interval	Feet of Core Interval (Feet Measurement)	Sample Number	Analytical Array	Bedding Angle	Grain Size Distribution	USCS Symbol	Depth in Feet	Soil Lithology Log	Sample Description
BOX 1 of 3 0.0-9.5 ft.	RUN #1 0.0-3.35'	RECOVERY: 2.0'		XXX				1.0, 2.0, 3.0		FOR INTERVAL 0.0-3.35 SEE LOG OF BOREHOLE BH90198
	RUN #2 3.35-6.5	RECOVERY: 3.0'	001, 007, 013	99A3210-003 XXX; 1106, 1107, 1108	Rad S, Iso, VOC	4.0, 4.2, 4.4, 4.7	SC	4.0, 5.0, 6.0		3.35-6.35 Clayey Sand, Strong Brown 7.5 YR 5/6; fine to medium, locally coarse sand, subrounded to subangular, lithic, very slight to non plastic ~~sand~~ clay, trace fine to coarse gravel, damp. 7-7-99
								6.5		6.35-6.50 No Recovery
	RUN #3 6.5-9.0 ft.	RECOVERY 3.6 ft including 0.7 ft slough	09:53, 09:53, 09:53; 002, 008, 014	99A3210-003 XXX	Rad S, Iso, VOC	7.5, 7.7, 8.1, 8.5	GC	7.0, 7.5, 7.7, 8.0, 8.1, 8.5		6.5-9.0 ft; Clayey-sandy gravel; very pale brown (10YR 7/4) grades down to light reddish brown (5YR 6/4); quartzite gravel up to 2 cm, fractured, fine to medium subrounded to subangular sand, firm, not plastic, slightly moist.
9.5	RUN #4 9.0-11.5 ft.						GC	9.0, 9.5		9.0-9.5 As above 6.5-9.0 ft.
							SC			9.5-11.5 ft; Clayey sand (trace gravel); continued next page

NOTES: General USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96198
Location - North: 749213 East: 2085687
Date: 12/03/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE - DUAL WALL

Surface Elevation: 5977 ft.
Area: 903 PAD
Total Depth: 18.8 ft.
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-7-99

Box	Run	Recovery	Sample Number	Field Screening Results	Bedding Angle	Grain Size Distribution	USCS Symbol	Depth in Feet	Soil/Lithologic Log	Sample Description
Box 2 of 3 9.5-17.0 ft.	RUN #4 9.0-11.5 ft.	RECOVERY 4.0 ft.		XXX			SC	11.0 11.5		light reddish brown (5YR 6/4), fine to medium sand, subround to subangular, firm, slightly moist, gravel may be in lenses.
	RUN #5 11.5-14.0 ft.	RECOVERY 4.0 ft.	10:55 003 10:54 009 10:53 015 99A3210-003.XXX		Rad S Iso VOC	11.8 12.0 12.5	SC	11.8 12.0 12.5 13.0 14.0		As above 9.5-11.5 ft. 11.5-14.0 ft
	RUN #6 14.0-16.5 ft	RECOVERY 3.0 ft.	99A3210-003.XXX 13:20 004 13:19 010 13:19 016		Rad S Iso VOC	15.3 15.5 15.8 16.2	GC	15.0 15.3 15.5 15.8 16.0 16.2 16.5		14.0-16.5 Similar to RUN #3 6.5-9.0 ft. Pinkish clayey-sandy gravel, quartzite gravel to 2 cm.
Box 3 of 3 17.0-18.8 ft.	RUN #7 16.5-18.8 ft.	RECOVERY 4.0 ft.						16.6 17.0 18.0 18.8 19.0		Bedrock contact 16.6 ft. 16.6-18.8 ft; Clayey sand, light yellowish brown to yellow (10YR 6/4-10YR 7/6), fine sand, firm to hard, slightly moist. TD 18.8 ft.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96298
Location - North: 749135 East: 2085611
Date: 12/04/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE - DUALWALL

Surface Elevation: 5979 ft
Area: 903 PAD
Total Depth: 16.5 ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR,
APPROVAL Mark Wood DATE 7-6-99

Top/Bottom of Core Hole	Top/Bottom of Interval	Feet of Core Recovered (Field Measurement)	Sample Number	Photoionization Reading	Screening Analysis	Grain Size Distribution	USCS Symbol	Depth in Feet	Soil/Lithologic Log	Sample Description
Box 1 of 2 0.0-10.7 ft.	Run #1 0.0-3.8 ft.	Recovery 3.1 ft.		XXX			GC	0.4, 1.0, 2.0, 3.0, 3.8		0.0-0.4 ft: Asphalt 0.4-3.8 ft; Clayey-sandy gravel; yellowish red (5YR 5/6), quartzite gravel up to 2 cm (most about 0.5 cm), fractured to subround, fine to medium sand - subangular to subround, firm, slightly moist,
	Run #2 3.8-6.5 ft.	Recovery 2.8 ft.	10:46	001	Rad S	4.0	GC	4.0, 4.3, 4.7, 5.0, 6.0, 6.5		As above 0.4-3.8 ft.
			10:46	007	Iso	4.3				
			10:46	013	VOC	4.7				
			99A3210-004.XXX							
	Run #3 6.5-9.0 ft.	Recovery 2.7 ft.	11:16	002	Rad S		GC	6.8, 7.0		As above 0.4-3.8 ft.
			11:15	009	Iso Dup			7.5		
			11:15	008	Iso		SC	8.0		7.5-8.0 ft; Clayey sand; clay-white 10YR 8/2, sand-dark gray 10YR 4/1, weathered cobble?, fine sand, moist, soft
			11:11	015	VOC Dup		GC	8.5		As above 0.4-3.8 ft.
			11:11	014	VOC			9.0		
	Run #4 9.0-11.5 ft.	Recovery 3.1 ft.					GC			As above 0.4-3.8 ft.

NOTES. General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96298
Location - North: 749135 East: 2085611
Date: 12/04/98
Geologist: R. KOEHLER
Drilling Equip.: GEOPROBE - DUAL WALL

Surface Elevation: 5979 ft
Area: 903 PAD
Total Depth: 16.5 ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

BOTTOM OF CORE BARREL	TOP/BOTTOM OF INTERVAL	FEET OF CORE INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FIXATIVE AREA	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
				XXX						See privious page
10.7	Run#4 9.0-11.5	Recovery 3.1 ft.					SC	10.5 / 10.7 / 11.0		10.5-11.5 Clayey sand; yellowish red (5YR 5/6) fine sand, slightly plastic, slightly moist, firm.
RPK 12/4/98 BOX 2 OF 2 10.7 - 14.8 ft	Run #5 11.5-14.8 ft.	Recovery 3.8 ft.* *Looks like 0.3 ft fell back.	11:53 003 11:53 010 11:53 016 99A3210-004.XXX		Rad S Iso VOC	11.6 11.9 12.25 12.75	SC	11.5 / 11.6 / 11.9 / 12.0 / 12.25 / 12.75 / 13.0 / 14.0		11.5-14.0 Clayey sand as above 10.5-11.5 ft. 1cm gravel, subround from 13.5 to 14.0 ft, matrix is clayey sand 14.0 ft. BEDROCK CONTACT
16.5	Run #6 14.0-16.5 ft	Recovery 2.9 ft** **Suspect part of core fell out.	99A3210-004.XXX 12:34 004 12:33 011 12:32 017		Rad S. Iso. VOC	15.7 15.9 16.1		15.0 / 15.7 / 15.9 / 16.0 / 16.1 / 16.5		14.0-16.5 Clayey sand, brownish yellow stone (10YR 6/8), fine sand, firm, slightly moist, friable 16.5 ft. TD.
13:15 Trip Blank 99A3210-006.003 13:15 Rad Screen Rinse 99A3210-006.001 13:15 Isotope Rinse 99A3210-006.002 13:15 VOC Rinse 99A3210-006.004								17.0 / 18.0 / 19.0		** On removing the outer steel core liner from the hole about 1 ft of additional cored material was found. Evidently this material fell out of the plastic core liner, some also from cutting shoe. This material was put into core box.

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96398
Location - North: 749061 East: 2085610
Date: 12-7-98 → 12-8-98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5979 Ft
Area: 903 PAD
Total Depth: 16.5 Ft
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	BOILI LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run#1 0.0-3.8	Recovery: 2.7'						1.0 2.0 2.7 3.0 3.8		0.0-3.8 See Borehole log of BH 91098 2.7-3.8 No Recovery
	Run#2 3.8-6.5	Recovery: 3.0'	001 RS 002 ISO 003 VOA 99A4102-001-XXX				CL	4.0 4.3 4.5 4.8 5.0 6.0 6.5		3.8-6.5 Sandy Clay; light yellowish brown 10YR 6/4, Non to low plasticity with fine to coarse, subangular to subrounded lithic sand, trace gravel damp.
	Run#3 6.5-9.0	Recovery: 3.0'	99A4102-002-XXX 004 RS 005 ISO 006 VOA				SC	7.0 8.0 8.2 8.4 8.5 8.9 9.0		6.5-9.0 Sand; strong brown 7.5YR 5/6 fine to coarse, subrounded to angular, locally silty to TALCOND clayey, also with fine to medium sized gravel, damp Locally grading to Clayey Sand.
	Run#4	Rec: 3.1'					SC			9.0-11.5 Clayey Sand/ locally grading to:

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96398
Location - North: 749061 East: 2085610
Date: 12-7-98 → 12-8-98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5979 ft
Area: 903 PAD
Total Depth: 16.5 ft
Company: TIERRA Project No.: 6E6000 00
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Ward DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4 9.0-11.5	Rec. 3.1'					SC / CL	10.0 / 11.0		Sandy Clay A/A, damp
	Run #5 11.5-14.0'	Recovery 3.3'	007 008 009	RS ISO VOA			CL / GM / SC	12.0 12.2 12.4 12.7 13.0 14.0		12.7 TAV. 11.5 to ~~14.0~~ Sandy Clay; Reddish Brown 5YR 4/3 trace to some plasticity with fine to coarse subangular sand (lithic) locally some fine angular lithic gravel, silty dry 12.7 to 13.8 Gravelly Sand; see above for constituents. 13.8-14.0 Clayey Sand see above for constituents
	Run #6 14.0-16.5	Recovery 3.8'	010 011 012	RS ISO VOA			BR mud 7/6/99	15.0 15.8 16.0 16.2 16.4		14.0-16.5 Claystone, light olive gray 5Y 5/2 locally weathered, Mottled w/ light olive brown 5Y 5/6. Blocky, dense, locally silty, with some light gray N7 very fine sand. Dry - wet @ 14.0-14.2
								17.0 18.0 19.0		Assumed Bedrock contact @ 14.0 Last sample lost from sampler, retrieved with dual wall. TD = 16.5'

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96498
Location - North: 749141 East: 2085910
Date: 10/21/98 → 10/26/98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 23.0 ft
Company: SIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8'	Recovery: 2.25'						1.0, 2.0, 2.25, 3.0, 3.8		0.0-3.8 See Borehole log of BH90998
										2.25-3.8 No Recovery
	Run #2 3.8-7.8'	Recovery: 3.73'	99A32	001	RS	4.0	SC	4.0		3.8-7.53 Clayey Sand
				007	ISO	4.4		4.4		
				013	VOA	4.8		4.8		med. fine some coarse, subangular to subrounded, some medium, feldspar and quartz, clayey, some silt traces, up to 3cm broken lithic gravel, non-low plasticity, well graded, moist
						5.2		5.0, 5.2		
					10-001		XXX			
							SC	6.0, 7.0		
										7.53-7.8 No Recovery
	Run #3 7.5-11.0							8.0		Repositioned Sampler to 7.5 due to soil between liner and shoe
										7.5-11.0 Silty Gravelly Sand
				002	RS		SM	9.0		med very fine to fine, trace med and coarse, subrounded to subangular, locally very silty, some clay, locally sand to abundant broken lithic gravel
				008	ISO					
				014	VOA			10.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96498
Location - North: 749141 East: 2085910
Date: 10/21/98
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 23.0 ft
Company: TIERRA Project No.: 6E6000 00
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #3						GM	10.0 – 11.0		7.5-11.0 Coarse Gravel size A/A, traces Caliche, dry
	Run #4 11.0-14.0	Recovery: 3.6'	003, 009, 015	RS, TSO, VOA			SC	11.0, 12.0, 12.2, 13.0, 13.5, 14.0		11.0-14.0 Clayey Sand Same as @ 3.8-7.53 dry
	Run #5 14.0-17.0	Recovery: 1.9"	004, 010, 016	RS, TSO, VOA			SC	14.0, 14.5		14.0-14.5 Clayey Sand Same as above.
							GM	15.0, 15.9		14.5-15.9 Silty Gravelly Sand Same as @ 7.5-11.0 dry
							CL	16.0, 16.5		15.9-16.5 Sandy Clay size and texture same as @ 3.8-7.53 dry. 16.5-17.0 No Recovery
	Run #6 17.0-20.0	Recovery: 2.6				Rec.: 2.6'	SC Run #6 17.0-18.6	17.0, 18.0, 18.6		17.0-18.6 Clayey Sand Same as @ 11.0-14.5. Obstruction @ 18.6 which required run #7 from 18.6-19.9
						Rec.: 2.3'	SC Run #7 18.6-19.9	19.0, 19.9		18.6-19.9 Clayey Sand as above

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT FORM GT.1A (REV. 2)

ROCKY FLATS PLANT BOREHOLE LOG

Borehole Number: BH96498
Location - North: 749141 East: 2085910
Date: 10-21-98 → 10-26-98
Geologist: LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 Ft
Area: 903 PAD
Total Depth: 23.0 Ft
Company: TERRA Project No.: 6E6000 00
Sample Type: CONTINUOUS

EG&G LOGGING SUPERVISOR
APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #8 19.9-23.0	Recovery: 3.6'						20.0		19.9-22.0 Clayey Sand same as above
							SC	21.0		
			006	RS				21.4		
			012	TSO				22.0		22.0-23.0 Silty Claystone. Top of Bedrock = 22.0 Ft
			018	VOA			BR MW 7/6/99	23.0		slightly weathered, slightly oxidized, generally blocky, dense, mgd. friable, some MnO dendritic patterns, dry
										TD = 23.0'

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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7-7-99

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 23

Borehole Number: BH96598
Location - North: 749147 East: 2085867
Date: 5-17-99
Geologist: J. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 23.8
Company: TIERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8	Recovery: 3.9'						1.0 2.0 3.0 3.8		0.0-3.8' see log for BH90898
	Run #2 3.8-6.8	Recovery: 3.15'	001 003 002 99A6817-001-xxx	4.0 4.2 4.6	RS ISO VOA		SC	4.0 5.0 6.0 6.8		3.6-6.8' Clayey Sand. weak red 2.5YR 5/2, 2.5YR 4/2, pred very fine to fine, some med to coarse, subangular to subrounded, sand, no plasticity, trace to some silt, some up to 3.5cm cobbles and angular lithic gravel dry to damp
	Run #3 6.8-9.8	Recovery: 2.8	001 003 002 99A6817-002-xxx	8.0 8.2 8.4 8.8	RS ISO VOA		SC	7.0 8.0 9.0 9.8		6.8-9.8' Clayey Sand 6.8-8.4 grading to Sandy Clay @ 8.4-9.8 strong Brown 7.5YR 5/6. Components A/A dry to damp

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT — FORM PRO.101A — TAL 7-7-99

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 2 OF 3

Borehole Number: BH965-98
Location - North: 749147 East: 2085867
Date: 5-17-99 → 5-21-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 23.8
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Ward DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4; 9.8-12.0	Recovery: 3.1'	99A	681	7-003-XXX		SC	10.0 11.0 12.0		9.8 - 12.8, Clayey Sand; light brown to dark brown 7.5YR 6/3 to 7.5YR 3/3
			001	11.2 11.4	R6					
			003	11.6	I50					
			002	12.0						
	Run #5 12.0'-15.0'	Recovery: 4.0'	002				SC	12.0 13.0		12.0-12.8 Clayey Sand; with some gravel Reddish Yellow fine to coarse Sand, fine to coarse, subrounded to subangular dense, moist - wet. 12.8-15.0 Sandy Clay with trace fine gravel, fine to coarse Sand, Subrounded slight plasticity, stiff to calcite nodules moist. 12.8-13.5 light olive gray 2.5YR 6/6 13.5-15.0 mottled, dom. red 2.5YR 5/6 to lite olive gray 2.5YR 6/2
			TAL	6-15-99			CL	14.0 15.0		
	Run #6 15.0'-18.0'	Recovery: 4.0'		15.2			CL	16.0		15.0-17.0 Sandy Clay (CL) with some fine gravel fine to coarse Sand Subrounded to Subangular stiff moist mottled light olive gray (2.5YR 6/2) to yellowish red (5YR 4/6)
			002	15.6						
			003	15.8						
			001	16.0						
			99A	681	-004-XXX			17.0		TAL 6-16-99 17.0-18.0 ~~Clayey~~ Sand, Gravel H. gray (5Y 7/ fine to coarse sand, fine to coarse gravel with clay dense moist
							SC	18.0		
	Run #7 18.0-18.6	Rec: .2'					GW			Gravel: Quartzite nubble - broken, angular to ~4 cm, not. 18.2-18.6 No Recovery
	Run #8 18.6-21.1	RECOVERY: 1.3					GC	19.0		18.6-21.1 Gravelly Sand reddish yellow 7.5YR 6/6, fine to coarse, subangular to Subrounded, lithic, broken to Subangular up to 4 cm lithic gravel, silty, locally

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96598
Location - North: 749147 East: 2085867
Date: 5-17-99 → 5-21-99
Geologist: L. LUTHENER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5976 ft
Area: 903 PAD
Total Depth: 23.8
Company: TIERRA Project No.: 6E600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run#8 18.6-21.1	Recovery: 1.3					CL	20.0 – 21.0		abundant low plastic clay, saturated to 18.8 - damp 18.8-19.9
	Run#9 21.1-22.5	UNABLE TO DETERMINE RECOVERY	002	22.3 VOA			CL/SC	22.0		21.1-22.5 21.1-22.4 Gravelly Sand A/A wet. locally grading to Clayey Sand 22.4-22.5 Claystone, BR Contact @ 22.4
	Run#10 *20.8-23.8	Recovery 3.5	003 001	22.7 ISO 22.9 RS 23.1			BR	23.0 – 23.8		22.5-23.8 Claystone 2.5YR 3/3 dark olive brown, 10YR 7/1 light gray, some 10YR 6/8 brownish yellow - oxidized weathered, locally dense + waxy, poorly indurated and friable, w/very fine (gray) sand, silty locally grading to Silty Claystone TD = 23.8

99 068 17.005 XXY

* Hole collapsed to 20.8

Event 005 sampled in interval 20.8-23.8

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96698
Location - North: 749128 East: 2085846
Date: 5-12-99 → 5-13-99 + 6/8/99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5977 ft
Area: 903 PAD
Total Depth: 23.1 ft
Company: TERRA Project No. GE660000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #1 0.0-3.8	Recovery: 2.9'						1.0 2.0 3.0		0.0-3.8 See Borehole log of BH 90898
										2.9-3.8: No Recovery
				3.8				3.8		
	Run #2 3.8-6.8	Recovery: 3.9'	001 003 002	4.0 4.2 4.6	RS ISO VOA		SC	4.0 5.0 6.0		3.8-6.8' Clayey Sand, Strong brown to light brown 7.5YR 5/6 to 7.5YR 6/3 pred. very fine, some medium to coarse angular to subrounded, lithic sand, low plastic clay, silty, with some up to 3cm angular to broken lithic gravel, damp
			99A6649.001.XXX							
								6.8		
	Run #3 6.8-9.8	Recovery: 3.7'	001 003 002	7.8 8.0 8.2 8.6	RS ISO VOA		SC	7.0 8.0 9.0		6.8-9.8' Clayey Sand, with gravel A/A
			99A6649.002.XXX							

NOTES. General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

237

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96798
Location - North: 749108 East: 2085866
Date: 4/28/99 → 5-12-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5977 ft
Area: 903 PAD
Total Depth: 20.8 ft
Company: TERRA Project No. GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-6-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC UNIT	SAMPLE DESCRIPTION
	Run #1 0.0-3.8	Recovery: 3.8'						1.0 2.0 3.0		0.0-3.3 See borehole log for BH90898 or BH91398
										3.3-3.8; No Recovery
			TAL 5-25-99					3.8		
	Run #2 3.8-6.8	Recovery: 3.3'	004 4.0 001 4.2 RS 003 4.4 ISO 002 4.8 VOA 99A6650-001-XXX				SC	4.0 5.0 6.0		3.8-6.8 Clayey Sand; Yellowish Red to pale yellow, 5YR 5/6 to 2.5Y 7/4 some light red 10R 6/6 near top of interval. fine to coarse, angular to subrounded lithic sand, non to low plastic clay, some to abundant, fine to coarse subrounded to broken, lithic gravel. damp.
								6.8		
	Run #3 6.8-9.8	Recovery: 3.4'	001 8.2 RS 003 8.4 ISO 002 8.8 VOA 99A6650-002-XXX				CL	7.0 8.0 9.0		6.8-9.8 Sandy Clay; light gray to yellowish brown, 10YR 7/1 to 10YR 5/6, primarily very fine to fine, some medium to coarse subangular to subrounded lithic + quartz sand, with tuffs up to 4cm broken, tabular lithic gravel, non to low plastic clay dry to damp.
								9.8		

NOTES. General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96698
Location - North: 749128 East: 2085846
Date: 5-12-99→5-13-99 AND 6-8-99→6-9-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE DUAL WALL

Surface Elevation: 5977 ft
Area: 903 PAD
Total Depth: 23.1 ft
Company: TIERRA Project No.: 6E6000.00
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Word DATE 7-7-99

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
	Run #4 9.8-12.8'	Recovery 2.4'	99A664	9 003	xxx		GC/GM	10.0		9.8-12.8 9.8-10.4 Gravelly Sand; very pale brown 10YR 8/4, primarily very fine to fine, some medium to coarse, Subangular to subrounded lithic sand, fine to coarse, subangular lithic gravel, silty, trace to some clay, moist
							CL	11.0		
			001 003 002	12.0 12.2 12.4 12.8	RS ISO VOA			12.0 12.2 12.8		10.4-12.2 Sandy clay grading to Clay, w/ some Sand + gravel, very pale brown to weak red 10YR 7/3 to 10R 4/2 moist, 12.0-12.2 Saturated
	Run #5 12.8-15.8'	Recovery 2.9'					CL	13.0		12.8-15.8 clay with perched water to 10.7' 12.8-14.2 Clay, with some sand, A/A moist.
							CL/SC MW 7/7/99	14.0		14.2-15.7 Sandy clay A/A moist. locally grading to clayey Sand.
								15.0		15.7-15.8; No recovery
								15.8		Borehole abandoned 5/13/99
BH96698 OFFSET on 6/8/99 finished 6/9/99	15.8-17.3' Run #6	Recovery 1.1'					SC	16.0 17.0 17.3		15.8-17.3' Clay: reddish yellow to very pale brown 7.5YR 7/6 to 10YR, slight plasticity, trace to some med. fine to coarse sand, traces to some gravel, moist
	Run #7 17.3-18.3	RECOVERY 1.6'	001 003 002	17.5 17.7 99A	730	001 xxx	SC	18.0		17.3-18.3 Clayey Sand: strong brown to very pale brown 7.5YR 5/8 to 10YR 7/3 fine to coarse. Subangular, lithic sand, low to non plastic clay, gravel A/A wet.
	Run #8 18.3-19.8	RECOVERY 1.5'	001				SC	19.0		18.3-19.8 Clayey Sand: A/A wet @ 18.3-18.9

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: BH96698
Location - North: 749128 East: 2085846
Date: 5-12-99 → 5-13-99
Geologist: T. LUTHERER
Drilling Equip.: GEOPROBE Dual Wall

Surface Elevation: 5977 Ft
Area: 903 PAD
Total Depth: 23.1
Company: TIERRA Project No.: GE600000
Sample Type: CONTINUOUS

RMRS LOGGING SUPERVISOR APPROVAL Mark Wood DATE 7-7-99

TOP-BOTTOM OF CORE IN BOX	TOP-BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC TOPS	SAMPLE DESCRIPTION
	Run #9 19.8-20.6	Recovery 1.3'	003 / 002	99A7930	TAL 7-2-99	2 / 003	SC / XXX	20.0		19.8-20.6 Clayey Sand A/A moist
	Run #10 20.6-21.6	Recovery: 1.4					SC	21.0		20.6-21.6 Clayey Sand A/A moist.
	Run #11 21.6-23.1	Recovery: 1.5	TAL 6/29/99 / 001 / 002 / 003	22.4 / 22.8 / 23.0			SC / BR MW 7/6/99	22.0 / 22.45 / 23.0 / 23.1 / 23.5		21.6-22.45 Clayey Sand A/A moist. 22.45-23.1 Silty Claystone very pale brown 10YR 7/3, dense, locally waxy, mod friable, mod cemented, grading to claystone w/ silt, damp. Top of Bedrock = 22.45' TD = 23.1
			99A7930 003				XXX			

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS OPS-PRO.101
Revision 0
Date effective: 12/31/98

Appendix C

Precision (DER and RPD) Calculations

Surface Soil Charcterization Precision Resuts
HPGe Survey - Americium-241

Measurment Set	Measurement Location	Northing	Easting	Result Identifer	Isotope	Result	Unit	Qualifer	Counting Error	MDA	TPE	DER
1	4	749504.2	2086712.6	REAL	Am-241	3.627	pCi/g		1.4611	1.167	2.549	
				RP	Am-241	2.91	pCi/g		1.3394	1.047	2.212	0.2124
2	34	749488.6	2086940.3	REAL	Am-241	8.113	pCi/g		2.5898	1.325	5.024	
				RP	Am-241	8.698	pCi/g		2.7235	1.312	5.333	0.0798
3	50	749457.1	2086923.4	REAL	Am-241	10.42	pCi/g		3.1812	1.545	6.306	
				RP	Am-241	11.62	pCi/g		3.43	1.411	6.916	0.1286
4	70	749274.8	2086547.4	REAL	Am-241	0.879	pCi/g	U	0	0.879	0	
				RP	Am-241	0.858	pCi/g	U	0	0.858	0	
5	102	748741.8	2086501.7	REAL	Am-241	23.62	pCi/g		6.5632	1.67	13.65	
				RP	Am-241	22.87	pCi/g		6.4112	1.884	13.27	0.0397
6	92	748758.4	2086788.2	REAL	Am-241	12.22	pCi/g		9.2351	1.906	12.9	
				RP	Am-241	13.39	pCi/g		4.0278	1.981	8.045	0.0772
7	103	748762.9	2086525.2	REAL	Am-241	27.61	pCi/g		7.9047	2.422	16.19	
				RP	Am-241	25.32	pCi/g		7.2465	2.148	14.84	0.1042
8	144	748686.7	2086456.2	REAL	Am-241	12.48	pCi/g		3.651	1.553	7.394	
				RP	Am-241	12.76	pCi/g		3.762	1.671	7.59	0.0268
9	143	748712.7	2086475.7	REAL	Am-241	27.69	pCi/g		7.5668	2.517	15.87	
				RP	Am-241	25.6	pCi/g		7.0445	2.158	14.72	0.0965
10	188	748543.5	2086617.9	REAL	Am-241	13.03	pCi/g		3.9436	1.84	7.852	
				RP	Am-241	12.76	pCi/g		3.9288	1.936	7.758	0.0240
11	187	748569.8	2086637.6	REAL	Am-241	11.14	pCi/g		3.3664	1.557	6.707	
				RP	Am-241	10.99	pCi/g		3.4046	1.737	6.702	0.0151
12	224	748530.6	2086328	REAL	Am-241	14.34	pCi/g		4.4282	2.254	8.732	
				RP	Am-241	14.75	pCi/g		4.4725	2.119	8.897	0.0326
13	223	748553.6	2086348.4	REAL	Am-241	18.37	pCi/g		5.1655	1.54	10.68	
				RP	Am-241	18.16	pCi/g		13.326	1.686	18.77	0.0098
14	293	749282.1	2087177.7	REAL	Am-241	17.19	pCi/g		4.9867	1.815	10.14	
				RP	Am-241	14.25	pCi/g		4.0446	1.389	8.32	0.2240
15	292	749308.9	2087156.3	REAL	Am-241	9.506	pCi/g		2.9194	1.391	5.771	
				RP	Am-241	9.568	pCi/g		2.8826	1.388	5.753	0.0076

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Surface Soil Charcterization Precision Resuts
HPGe Survey - Americium-241

Measurment Set	Measurement Location	Northing	Easting	Result Identifer	Isotope	Result	Unit	Qualifer	Counting Error	MDA	TPE	DER
16	328	749360.4	2087307	REAL	Am-241	9.453	pCi/g		3.0676	1.812	5.904	
				RP	Am-241	8.771	pCi/g		2.8074	1.575	5.439	0.0850
17	327	749384.1	2087288.3	REAL	Am-241	10.36	pCi/g		2.9936	1.12	6.1	
				RP	Am-241	9.635	pCi/g		2.9191	1.407	5.81	0.0856
18	347	749466.9	2087225.4	REAL	Am-241	5.972	pCi/g		2.3238	1.765	4.115	
				RP	Am-241	6.221	pCi/g		2.2445	1.553	4.111	0.0428
19	348	749473.4	2087259.1	REAL	Am-241	8.385	pCi/g		2.4629	1.193	4.978	
				RP	Am-241	9.241	pCi/g		2.6696	1.218	5.442	0.1160
20	392	749237.3	2087288.3	REAL	Am-241	17	pCi/g		4.8726	1.488	9.974	
				RP	Am-241	16.44	pCi/g		4.7944	1.73	9.726	0.0405
21	391	749265.7	2087268.3	REAL	Am-241	6.945	pCi/g		2.3826	1.517	4.466	
				RP	Am-241	6.438	pCi/g		2.2561	1.498	4.188	0.0827
22	424	749122.1	2086857.6	REAL	Am-241	1.148	pCi/g	U	0	1.148	0	
				RP	Am-241	1.178	pCi/g	U	0	1.178	0	
23	423	749152.5	2086871.9	REAL	Am-241	4.422	pCi/g		1.5688	1.092	2.895	
				RP	Am-241	4.226	pCi/g		1.5708	1.165	2.839	0.0483
24	466	749030.8	2086645.6	REAL	Am-241	15.33	pCi/g		4.7461	2.335	9.346	
				RP	Am-241	17.95	pCi/g		5.3281	2.178	10.71	0.1841
25	465	749061.8	2086627.6	REAL	Am-241	13.12	pCi/g		4.0085	1.864	7.943	
				RP	Am-241	14.4	pCi/g		4.3058	1.828	8.626	0.1096
26	491	749106.5	2087170.1	REAL	Am-241	14.02	pCi/g		3.9786	1.636	8.185	
				RP	Am-241	9.585	pCi/g		2.7567	1.292	5.632	0.4466
27	493	749103.8	2087136.5	REAL	Am-241	13.09	pCi/g		3.8208	1.552	7.747	
				RP	Am-241	13.44	pCi/g		3.9737	1.776	8.006	0.0319
28	534	748827.7	2086730.2	REAL	Am-241	8.258	pCi/g		3.0181	2.179	5.495	
				RP	Am-241	7.445	pCi/g		2.6872	1.93	4.921	0.1103
29	533	748861.1	2086716.3	REAL	Am-241	18.09	pCi/g		5.1869	1.625	10.62	
				RP	Am-241	18.44	pCi/g		5.1799	1.377	10.71	0.0233
30	562	748943.3	2086803.6	REAL	Am-241	14.25	pCi/g		4.756	2.974	9.03	
				RP	Am-241	15.91	pCi/g		4.8554	2.403	9.629	0.1261

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Surface Soil Charcterization Precision Resuts
HPGe Survey - Americium-241

Measurment Set	Measurement Location	Northing	Easting	Result Identifer	Isotope	Result	Unit	Qualifer	Counting Error	MDA	TPE	DER
31	563	748908.1	2086813.2	REAL	Am-241	18.87	pCi/g		5.436	2.047	11.1	
				RP	Am-241	18.22	pCi/g		5.1838	1.816	10.65	0.0425
32	587	749006.2	2086641.5	REAL	Am-241	34.06	pCi/g		9.2692	1.583	19.49	
				RP	Am-241	32.1	pCi/g		8.8266	2.088	18.46	#REF!
33	624	748997.5	2086833.9	REAL	Am-241	21	pCi/g		5.8026	2.107	12.1	
				RP	Am-241	20.01	pCi/g		5.611	2.467	11.61	0.0590
34	622	748992.1	2086763.2	REAL	Am-241	17.94	pCi/g		5.2004	1.698	10.58	
				RP	Am-241	17.73	pCi/g		5.173	1.834	10.49	0.0147
35	666	748633.6	2085992	REAL	Am-241	2.522	pCi/g		1.6399	1.625	2.397	
				RP	Am-241	2.18	pCi/g		1.3419	1.312	1.996	0.1099
36	665	748662.6	2086013.9	REAL	Am-241	4.508	pCi/g		1.8583	1.51	3.211	
				RP	Am-241	3.562	pCi/g		1.3985	1.079	2.467	0.2336
37	705	748554.4	2085849.5	REAL	Am-241	8.033	pCi/g		2.4323	1.189	4.842	
				RP	Am-241	8.163	pCi/g		2.4687	1.234	4.918	0.0188
38	706	748528.9	2085828	REAL	Am-241	7.134	pCi/g		2.526	1.762	4.666	
				RP	Am-241	7.854	pCi/g		2.5948	1.624	4.951	0.1059
39	770	748550.6	2086926.9	REAL	Am-241	5.353	pCi/g		1.7862	1.131	3.392	
				RP	Am-241	4.531	pCi/g		1.6108	1.127	2.97	0.1824
40	769	748558.5	2086894.8	REAL	Am-241	8.108	pCi/g		2.6069	1.667	5.039	
				RP	Am-241	7.873	pCi/g		2.5173	1.632	4.879	0.0335
41	785	749066.9	2087188.6	REAL	Am-241	8.525	pCi/g		2.5766	1.148	5.134	
				RP	Am-241	7.917	pCi/g		2.4615	1.264	4.837	0.0862
42	786	749053	2087208.3	REAL	Am-241	23.06	pCi/g		6.3291	1.923	13.25	
				RP	Am-241	23.69	pCi/g		6.3199	1.624	13.43	0.0330
43	837	748467.5	2086066.4	REAL	Am-241	5.876	pCi/g		2.1689	1.526	3.932	
				RP	Am-241	4.834	pCi/g		1.6679	1.029	3.118	0.2077
44	836	748458.2	2086097.7	REAL	Am-241	5.479	pCi/g		1.9885	1.401	3.632	
				RP	Am-241	5.652	pCi/g		2.0624	1.469	3.758	0.0332
45	874	748829.3	2087427.7	REAL	Am-241	9.092	pCi/g		2.89	1.63	5.617	
				RP	Am-241	10.74	pCi/g		3.4262	2.017	6.649	0.1896

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Surface Soil Charcterization Precision Resuts
HPGe Survey - Americium-241

Measurment Set	Measurement Location	Northing	Easting	Result Identifer	Isotope	Result	Unit	Qualifer	Counting Error	MDA	TPE	DER
46	873	748800.5	2087445.2	REAL	Am-241	6.727	pCi/g		2.2551	1.402	4.273	
				RP	Am-241	6.694	pCi/g		2.1906	1.295	4.199	0.0055
47	902	749150.1	2087462.7	REAL	Am-241	1.256	pCi/g	U	0	1.256	0	
				RP	Am-241	1.255	pCi/g	U	0	1.255	0	
48	903	749159.1	2087493.4	REAL	Am-241	0.393	pCi/g	J	0.69657	0.755	0.814	
				RP	Am-241	0.676	pCi/g	J	0.70307	0.737	0.906	0.2325
49	946	748935.6	2087258.4	REAL	Am-241	4.619	pCi/g		1.7668	1.296	3.152	
				RP	Am-241	3.791	pCi/g		1.8493	1.635	2.987	0.1906
50	965	748838.4	2086052.2	REAL	Am-241	24.75	pCi/g		6.8179	1.578	14.24	
				RP	Am-241	25.01	pCi/g		6.8798	1.674	14.38	0.0130
51	986	748836.5	2086172.8	REAL	Am-241	20.35	pCi/g		5.627	1.622	11.73	
				RP	Am-241	20.87	pCi/g		5.7331	1.601	11.99	0.0308
52	1003	748566.4	2085682.7	REAL	Am-241	1.14	pCi/g		0.9978	1.031	1.34	
				RP	Am-241	0.93	pCi/g	J	1.065	1.13	1.344	0.1104
53	1002	748594.5	2085666.3	REAL	Am-241	1.095	pCi/g	U	0	1.095	0	
				RP	Am-241	1.132	pCi/g	U	0	1.132	0	
54	1036	748851.9	2087437.9	REAL	Am-241	7.261	pCi/g		2.4047	1.471	4.583	
				RP	Am-241	7.442	pCi/g		2.3804	1.339	4.613	0.0278
55	1055	749317.3	2087419.5	REAL	Am-241	7.141	pCi/g		2.3449	1.483	4.487	
				RP	Am-241	7.622	pCi/g		2.3994	1.446	4.686	0.0742
56	1069	749181.2	2087619.6	REAL	Am-241	0.918	pCi/g	U	0	0.918	0	
				RP	Am-241	0.912	pCi/g	U	0	0.912	0	
57	1107	749240.8	2086516.1	REAL	Am-241	0.992	pCi/g	U	0	0.992	0	
				RP	Am-241	1.042	pCi/g	U	0	1.042	0	
58	1106	749271.9	2086516.4	REAL	Am-241	0.829	pCi/g	U	0	0.829	0	
				RP	Am-241	0.528	pCi/g	J	1.1216	1.222	1.28	0.2354

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Surface Soil Characterization Program
Precision Results
Alpha Spectroscopy

HPGe MEAS. LOCATION	SAMPLE TYPE	LOC	SAMPLE NUMBER	ANALYTE	RESULT	UNIT_ CODE	Q	DET. LIMIT	RC_SIGMA _ERROR
30	Duplicate	1 meter	99A5936-005.001	Am-241	4.4612	PCI/G		0.0675	0.3741
30	Real	1 meter	99A5936-004.001	Am-241	4.6643	PCI/G		0.0618	0.3659
30	Duplicate	3 meter	99A5936-007.001	Am-241	3.1966	PCI/G		0.0216	0.3134
30	Real	3 meter	99A5936-006.001	Am-241	3.574	PCI/G		0.1296	0.4259
30	Duplicate	Center	99A5936-003.001	Am-241	1.7105	PCI/G		0.0948	0.2759
30	Real	Center	99A5936-002.001	Am-241	2.3659	PCI/G		0.1332	0.332
460	Duplicate	1 meter	99A3372-002.008	Am-241	172.9098	PCI/G		.6272	5.4249
460	Real	1 meter	99A3372-002.004	Am-241	151.9866	PCI/G		.8476	5.5795
460	Duplicate	3 meter	99A3372-002.009	Am-241	145.2979	PCI/G		.7359	4.8513
460	Real	3 meter	99A3372-002.006	Am-241	137.9899	PCI/G		1.1001	5.5697
460	Duplicate	Center	99A3372-002.007	Am-241	175.1638	PCI/G		.7965	5.6641
460	Real	Center	99A3372-002.002	Am-241	90.1227	PCI/G		.6611	4.0973
669	Duplicate	1 meter	99A4878-006.001	Am-241	66.7147	PCI/G		0.1048	3.1482
669	Real	1 meter	99A4878-005.001	Am-241	55.0517	PCI/G		0.193	2.8592
669	Duplicate	3 meter	99A4878-008.001	Am-241	51.0332	PCI/G		0.1612	2.5161
669	Real	3 meter	99A4878-007.001	Am-241	60.4235	PCI/G		0.1123	3.1018
669	Duplicate	Center	99A4878-004.001	Am-241	75.9211	PCI/G		0.1046	3.3548
669	Real	Center	99A4878-003.001	Am-241	40.8194	PCI/G		0.1006	2.413
30	Duplicate	1 meter	99A5936-005.001	Pu-239/240	23.1372	PCI/G		0.0209	0.8293
30	Real	1 meter	99A5936-004.001	Pu-239/240	21.7524	PCI/G		0.0217	0.8192
30	Duplicate	3 meter	99A5936-007.001	Pu-239/240	15.5486	PCI/G		0.0659	1.2054
30	Real	3 meter	99A5936-006.001	Pu-239/240	23.8498	PCI/G		0.0769	1.0835
30	Duplicate	Center	99A5936-003.001	Pu-239/240	8.4155	PCI/G		0.1131	0.7811
30	Real	Center	99A5936-002.001	Pu-239/240	12.8235	PCI/G		0.0653	0.6603
460	Duplicate	1 meter	99A3372-002.008	Pu-239/240	684.6637	PCI/G		.2833	12.2161
460	Real	1 meter	99A3372-002.004	Pu-239/240	1481.6998	PCI/G		.1612	18.4008
460	Duplicate	3 meter	99A3372-002.009	Pu-239/240	841.5062	PCI/G		.4739	15.1618
460	Real	3 meter	99A3372-002.006	Pu-239/240	675.0613	PCI/G		.3265	10.7885
460	Duplicate	Center	99A3372-002.007	Pu-239/240	782.3574	PCI/G		.2869	13.1426
460	Real	Center	99A3372-002.002	Pu-239/240	554.3172	PCI/G		.3912	11.1808
669	Duplicate	1 meter	99A4878-006.001	Pu-239/240	435.6164	PCI/G		0.2219	8.6241
669	Real	1 meter	99A4878-005.001	Pu-239/240	318.3239	PCI/G		0.1196	7.3486
669	Duplicate	3 meter	99A4878-008.001	Pu-239/240	297.2583	PCI/G		0.3393	7.2987
669	Real	3 meter	99A4878-007.001	Pu-239/240	376.36	PCI/G		0.2867	8.3559
669	Duplicate	Center	99A4878-004.001	Pu-239/240	525.3358	PCI/G		0.2608	9.415
669	Real	Center	99A4878-003.001	Pu-239/240	265.908	PCI/G		0.1194	6.7098
30	Duplicate	1 meter	99A5936-005.001	U-233,-234	0.7917	PCI/G	J	0.1082	0.1928
30	Real	1 meter	99A5936-004.001	U-233,-234	0.7905	PCI/G	J	0.0798	0.184
30	Duplicate	3 meter	99A5936-007.001	U-233,-234	0.6254	PCI/G	J	0.0767	0.1677
30	Real	3 meter	99A5936-006.001	U-233,-234	0.5568	PCI/G	J	0.1464	0.1997
30	Duplicate	Center	99A5936-003.001	U-233,-234	2.3662	PCI/G		0.3407	0.6882
30	Real	Center	99A5936-002.001	U-233,-234	0.8336	PCI/G	J	0.101	0.2129
460	Duplicate	1 meter	99A3372-002.008	U-233,-234	1.0197	PCI/G		.0331	.1613
460	Real	1 meter	99A3372-002.004	U-233,-234	.8624	PCI/G	J	.0432	.1556
460	Duplicate	3 meter	99A3372-002.009	U-233,-234	1.184	PCI/G		.0794	.2339
460	Real	3 meter	99A3372-002.006	U-233,-234	1.1367	PCI/G		.0403	.1879
460	Duplicate	Center	99A3372-002.007	U-233,-234	.8937	PCI/G	J	.052	.1574
460	Real	Center	99A3372-002.002	U-233,-234	1.1157	PCI/G		.0458	.1721

Surface Soil Characterization Program
Precision Results
Alpha Spectroscopy

HPGe MEAS. LOCATION	SAMPLE TYPE	LOC	SAMPLE NUMBER	ANALYTE	RESULT	UNIT_ CODE	Q	DET. LIMIT	RC_SIGMA _ERROR
669	Duplicate	1 meter	99A4878-006.001	U-233,-234	0.842	PCI/G	J	0.2601	0.3213
669	Real	1 meter	99A4878-005.001	U-233,-234	0.6224	PCI/G	J	0.1497	0.2696
669	Duplicate	3 meter	99A4878-008.001	U-233,-234	0.8276	PCI/G	J	0.2608	0.3128
669	Real	3 meter	99A4878-007.001	U-233,-234	0.9393	PCI/G	J	0.2068	0.326
669	Duplicate	Center	99A4878-004.001	U-233,-234	0.6928	PCI/G	J	0.4855	0.4082
669	Real	Center	99A4878-003.001	U-233,-234	0.7556	PCI/G	J	0.3322	0.3191
30	Duplicate	1 meter	99A5936-005.001	U-235	0.08	PCI/G	J	0.0589	0.0614
30	Real	1 meter	99A5936-004.001	U-235	0.0413	PCI/G	U	0.0547	0.0433
30	Duplicate	3 meter	99A5936-007.001	U-235	0.0434	PCI/G	U	0.0575	0.0454
30	Real	3 meter	99A5936-006.001	U-235	0.1111	PCI/G	U	0.1175	0.0926
30	Duplicate	Center	99A5936-003.001	U-235	0.1025	PCI/G	U	0.1385	0.1417
30	Real	Center	99A5936-002.001	U-235	0.0907	PCI/G	J	0.0824	0.0725
460	Duplicate	1 meter	99A3372-002.008	U-235	.0883	PCI/G	J	.0441	.0489
460	Real	1 meter	99A3372-002.004	U-235	.0729	PCI/G	J	.0197	.045
460	Duplicate	3 meter	99A3372-002.009	U-235	.0837	PCI/G	J	.0323	.0618
460	Real	3 meter	99A3372-002.006	U-235	.0566	PCI/G	J	.0218	.0418
460	Duplicate	Center	99A3372-002.007	U-235	.0986	PCI/G	J	.0356	.0525
460	Real	Center	99A3372-002.002	U-235	.0948	PCI/G	J	.0343	.0505
669	Duplicate	1 meter	99A4878-006.001	U-235	0.0524	PCI/G	U	0.1484	0.0835
669	Real	1 meter	99A4878-005.001	U-235	0.0457	PCI/G	U	0.178	0.0854
669	Duplicate	3 meter	99A4878-008.001	U-235	0.065	PCI/G	U	0.1896	0.0993
669	Real	3 meter	99A4878-007.001	U-235	-0.0205	PCI/G	U	0.1894	0.0231
669	Duplicate	Center	99A4878-004.001	U-235	-0.0382	PCI/G	U	0.3529	0.0431
669	Real	Center	99A4878-003.001	U-235	0.0463	PCI/G	U	0.1803	0.0865
30	Duplicate	1 meter	99A5936-005.001	U-238	0.9948	PCI/G	J	0.0786	0.2135
30	Real	1 meter	99A5936-004.001	U-238	1.1579	PCI/G		0.0651	0.2215
30	Duplicate	3 meter	99A5936-007.001	U-238	1.0056	PCI/G		0.0767	0.212
30	Real	3 meter	99A5936-006.001	U-238	1.024	PCI/G		0.1283	0.2661
30	Duplicate	Center	99A5936-003.001	U-238	2.8263	PCI/G		0.3407	0.751
30	Real	Center	99A5936-002.001	U-238	0.823	PCI/G	J	0.0925	0.211
460	Duplicate	1 meter	99A3372-002.008	U-238	2.5451	PCI/G		.0331	.2547
460	Real	1 meter	99A3372-002.004	U-238	1.9538	PCI/G		.0432	.2339
460	Duplicate	3 meter	99A3372-002.009	U-238	2.442	PCI/G		.0595	.3347
460	Real	3 meter	99A3372-002.006	U-238	2.661	PCI/G		.0479	.2875
460	Duplicate	Center	99A3372-002.007	U-238	2.2426	PCI/G		.0356	.2482
460	Real	Center	99A3372-002.002	U-238	2.4613	PCI/G		.0186	.2549
669	Duplicate	1 meter	99A4878-006.001	U-238	1.4272	PCI/G		0.0805	0.4037
669	Real	1 meter	99A4878-005.001	U-238	1.0122	PCI/G		0.1497	0.3429
669	Duplicate	3 meter	99A4878-008.001	U-238	1.3592	PCI/G		0.1421	0.3867
669	Real	3 meter	99A4878-007.001	U-238	1.0519	PCI/G		0.077	0.3389
669	Duplicate	Center	99A4878-004.001	U-238	1.1399	PCI/G		0.3145	0.4882
669	Real	Center	99A4878-003.001	U-238	1.1541	PCI/G		0.0823	0.3669

Subsurface Soil Characterization Program
Precision Results - Americium-241

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q	Det_Limit	Sigma_Error
90198	Real	98A1496-001.006	AM-241	87	PCI/G		1.09	12.2
	Replicate	98A1496-001.014	AM-241	3.93	PCI/G		0.024	0.51
90698	Real	98A1055-003.033	AM-241	1880	PCI/G		5.13	228
	Replicate	98A1055-003.036	AM-241	590	PCI/G		0.224	69.1
90798	Real	98A1055-002.019	AM-241	0.053	PCI/G	J	0.027	0.043
	Replicate	98A1055-002.020	AM-241	0.043	PCI/G	U	0.086	0.044
91298	Real	98A1055-001.010	AM-241	0.229	PCI/G	J	0.040	0.072
	Replicate	98A1055-001.011	AM-241	0.32	PCI/G		0.038	0.085
91598	Real	98A1296-001.002	AM-241	31670	PCI/G		51.5	3776
	Replicate	98A1296-001.010	AM-241	13010	PCI/G		94.6	1604
91698	Real	98A2017-001.002	AM-241	3930	PCI/G		53.2	526
	Replicate	98A2017-001.012	AM-241	4030	PCI/G		25.6	546
92498	Real	98A1502-001.002	AM-241	59.5	PCI/G		0.118	7.1
	Replicate	98A1502-001.010	AM-241	16.7	PCI/G		0.904	3.38
92698	Real	98A2022-001.004	AM-241	0.345	PCI/G		0.059	0.131
	Replicate	98A2022-001.010	AM-241	0.311	PCI/G		0.099	0.133
93098	Real	99A4353-004.002	AM-241	0.361	PCI/G		0.146	0.184
	Replicate	99A4353-005.001	AM-241	0.181	PCI/G	J	0.115	0.120
93698	Real	98A1289-001.004	AM-241	9.95	PCI/G		0.084	1.31
	Replicate	98A1289-001.010	AM-241	76.8	PCI/G		19.8	23.8
94298	Real	99A4849-004.002	AM-241	0.026	PCI/G	U	0.107	0.065
	Replicate	99A4849-005.002	AM-241	0.26	PCI/G	J	0.123	0.147
94598	Real	98A5489-001.008	AM-241	0.032	PCI/G	U	0.066	0.046
	Replicate	98A5489-001.009	AM-241	0.026	PCI/G	U	0.074	0.048
95298	Real	98A5494-001.008	AM-241	0.238	PCI/G	J	0.083	0.114
	Replicate	98A5494-001.009	AM-241	0.225	PCI/G	J	0.057	0.105
95798	Real	99A5832-004.002	AM-241	0.13	PCI/G	J	0.113	0.103
	Replicate	99A5832-005.002	AM-241	0.031	PCI/G	U	0.123	0.075
95998	Real	99A7799-006.003	AM-241	0.016	PCI/G	U	0.045	0.033
	Replicate	99A7799-009.003	AM-241	0.035	PCI/G	U	0.048	0.050
96298	Real	99A3210-004.008	AM-241	1.8	PCI/G		0.143	0.556
	Replicate	99A3210-004.009	AM-241	0.018	PCI/G	U	0.200	0.110
96798	Real	99A6650-005.003	AM-241	0.053	PCI/G	J	0.048	0.063
	Replicate	99A6650-006.003	AM-241	0	PCI/G	U	0.054	0.000
97598	Real	99A7937-004.002	AM-241	0.194	PCI/G	J	0.041	0.117
	Replicate	99A7937-005.001	AM-241	0.301	PCI/G	B	0.041	0.152
97698	Real	99A8275-001.003	AM-241	0.011	PCI/G	U	0.090	0.041
	Replicate	99A8275-006.003	AM-241	0	PCI/G	U	0.052	0.000

Subsurface Soil Characterization Program
Precision Results - Plutonium-239/240

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q	Det_Limit	Sigma_Error
90198	Real	98A1496-001.006	PU-239	711	PCI/G		6.49	99.3
	Replicate	98A1496-001.014	PU-239	20.6	PCI/G		0.016	2.41
90698	Real	98A1055-003.033	PU-239	10670	PCI/G		1.91	1249
	Replicate	98A1055-003.036	PU-239	7320	PCI/G		3.04	858
90798	Real	98A1055-002.019	PU-239	0.01	PCI/G	U	0.051	0.022
	Replicate	98A1055-002.020	PU-239	0.039	PCI/G	U	0.040	0.032
91298	Real	98A1055-001.010	PU-239	1.49	PCI/G		0.032	0.247
	Replicate	98A1055-001.011	PU-239	1.5	PCI/G		0.034	0.263
91598	Real	98A1296-001.002	PU-239	152260	PCI/G		17.8	17801
	Replicate	98A1296-001.010	PU-239	70030	PCI/G		37	8213
91698	Real	98A2017-001.002	PU-239	389	PCI/G		50.4	106
	Replicate	98A2017-001.012	PU-239	373	PCI/G		42.5	95.9
92498	Real	98A1502-001.002	PU-239	474	PCI/G		0.583	56.6
	Replicate	98A1502-001.010	PU-239	94.8	PCI/G		0.582	12.3
92698	Real	98A2022-001.004	PU-239	1.22	PCI/G		0.061	0.277
	Replicate	98A2022-001.010	PU-239	0.464	PCI/G		0.061	0.156
93098	Real	99A4353-004.002	PU-239/240	2.33	PCI/G	B	0.037	0.654
	Replicate	99A4353-005.001	PU-239/240	0.812	PCI/G		0.083	0.291
93698	Real	98A1289-001.004	PU-239	49.5	PCI/G		0.049	5.91
	Replicate	98A1289-001.010	PU-239	495	PCI/G		15.3	80.7
94298	Real	99A4849-004.002	PU-239/240	0.471	PCI/G		0.033	0.186
	Replicate	99A4849-005.002	PU-239/240	7.35	PCI/G		0.034	1.82
94598	Real	98A5489-001.008	PU-239/240	0.081	PCI/G	J	0.050	0.060
	Replicate	98A5489-001.009	PU-239/240	0.08	PCI/G	J	0.020	0.052
95298	Real	98A5494-001.008	PU-239/240	1.31	PCI/G		0.022	0.376
	Replicate	98A5494-001.009	PU-239/240	0.982	PCI/G		0.037	0.291
95798	Real	99A5832-004.002	PU-239/240	0.816	PCI/G		0.082	0.282
	Replicate	99A5832-005.002	PU-239/240	0.531	PCI/G		0.060	0.205
95998	Real	99A7799-006.003	PU-239/240	-0.019	PCI/G	U	0.102	0.023
	Replicate	99A7799-009.003	PU-239/240	0	PCI/G	U	0.041	0.000
96298	Real	99A3210-004.008	PU-239/240	1.63	PCI/G		0.070	0.492
	Replicate	99A3210-004.009	PU-239/240	0.028	PCI/G	U	0.037	0.040
96798	Real	99A6650-005.003	PU-239/240	0	PCI/G	U	0.052	0.000
	Replicate	99A6650-006.003	PU-239/240	-0.007	PCI/G	U	0.079	0.014
97598	Real	99A7937-004.002	PU-239/240	0.913	PCI/G		0.085	0.339
	Replicate	99A7937-005.001	PU-239/240	2.88	PCI/G		0.048	0.833
97698	Real	99A8275-001.003	PU-239/240	0.06	PCI/G	J	0.054	0.071
	Replicate	99A8275-006.003	PU-239/240	0.037	PCI/G	U	0.049	0.052

Subsurface Soil Characterization Program
Precision Results - Uranium-233/234

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q	Det_Limit	Sigma_Error
90198	Real	98A1496-001.006	U-234	1.58	PCI/G		0.479	0.644
	Replicate	98A1496-001.014	U-234	0.756	PCI/G	J	0.024	0.128
90698	Real	98A1055-003.033	U-234	5.14	PCI/G		2.68	2.56
	Replicate	98A1055-003.036	U-234	1.83	PCI/G	U	2.72	1.75
90798	Real	98A1055-002.019	U-234	0.859	PCI/G	J	0.015	0.121
	Replicate	98A1055-002.020	U-234	0.82	PCI/G	J	0.024	0.118
91298	Real	98A1055-001.010	U-234	0.284	PCI/G	J	0.012	0.052
	Replicate	98A1055-001.011	U-234	0.368	PCI/G	J	0.014	0.062
91598	Real	98A1296-001.002	U-234	19.8	PCI/G	U	30.6	19.1
	Replicate	98A1296-001.010	U-234	31.5	PCI/G		23.6	20.7
91698	Real	98A2017-001.002	U-234	1.83	PCI/G	U	30.1	14.0
	Replicate	98A2017-001.012	U-234	14.2	PCI/G	U	27.6	16.7
92498	Real	98A1502-001.002	U-234	0.758	PCI/G	J	0.043	0.181
	Replicate	98A1502-001.010	U-234	1.47	PCI/G		0.748	0.746
92698	Real	98A2022-001.004	U-234	0.442	PCI/G	J	0.059	0.130
	Replicate	98A2022-001.010	U-234	0.477	PCI/G	J	0.057	0.145
93098	Real	99A4353-004.002	U-233/234	0.773	PCI/G	J	0.040	0.273
	Replicate	99A4353-005.001	U-233/234	0.575	PCI/G	J	0.035	0.212
93698	Real	98A1289-001.004	U-234	0.511	PCI/G	J	0.057	0.124
	Replicate	98A1289-001.010	U-234	0.883	PCI/G	J	0.037	0.156
94298	Real	99A4849-004.002	U-233/234	0.686	PCI/G	J	0.074	0.242
	Replicate	99A4849-005.002	U-233/234	0.549	PCI/G	J	0.088	0.209
94598	Real	98A5489-001.008	U-233/234	0.802	PCI/G	J	0.019	0.232
	Replicate	98A5489-001.009	U-233/234	0.735	PCI/G	J	0.017	0.211
95298	Real	98A5494-001.008	U-233/234	0.562	PCI/G	J	0.017	0.171
	Replicate	98A5494-001.009	U-233/234	0.652	PCI/G	J	0.033	0.196
95798	Real	99A5832-004.002	U-233/234	0.654	PCI/G	J	0.068	0.228
	Replicate	99A5832-005.002	U-233/234	0.783	PCI/G	J	0.095	0.272
95998	Real	99A7799-006.003	U-233/234	0.455	PCI/G	J	0.054	0.215
	Replicate	99A7799-009.003	U-233/234	0.769	PCI/G	J	0.046	0.285
96298	Real	99A3210-004.008	U-233/234	0.656	PCI/G	J	0.038	0.239
	Replicate	99A3210-004.009	U-233/234	0.4	PCI/G	J	0.076	0.172
96798	Real	99A6650-005.003	U-233/234	0.578	PCI/G	J	0.040	0.225
	Replicate	99A6650-006.003	U-233/234	0.591	PCI/G	J	0.039	0.226
97598	Real	99A7937-004.002	U-233/234	0.978	PCI/G	J	0.042	0.327
	Replicate	99A7937-005.001	U-233/234	0.95	PCI/G	J	0.075	0.323
97698	Real	99A8275-001.003	U-233/234	0.519	PCI/G	J	0.079	0.218
	Replicate	99A8275-006.003	U-233/234	0.407	PCI/G	J	0.050	0.196

Subsurface Soil Characterization Program
Precision Results - Uranium-235

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q	Det_Limit	Sigma_Error
90198	Real	98A1496-001.006	U-235	0.384	PCI/G	U	0.514	0.34
	Replicate	98A1496-001.014	U-235	0.038	PCI/G	J	0.022	0.022
90698	Real	98A1055-003.033	U-235	0.577	PCI/G	U	2.42	1.16
	Replicate	98A1055-003.036	U-235	0.412	PCI/G	U	1.94	1.03
90798	Real	98A1055-002.019	U-235	0.035	PCI/G	J	0.009	0.015
	Replicate	98A1055-002.020	U-235	0.045	PCI/G	J	0.014	0.018
91298	Real	98A1055-001.010	U-235	0.007	PCI/G	U	0.016	0.009
	Replicate	98A1055-001.011	U-235	0.018	PCI/G	J	0.013	0.011
91598	Real	98A1296-001.002	U-235	7.2	PCI/G	U	19.8	10.8
	Replicate	98A1296-001.010	U-235	-1.748	PCI/G	U	19.2	10.2
91698	Real	98A2017-001.002	U-235	-0.913	PCI/G	U	23.2	14.0
	Replicate	98A2017-001.012	U-235	3.34	PCI/G	U	21.2	12.8
92498	Real	98A1502-001.002	U-235	0.092	PCI/G	J	0.043	0.057
	Replicate	98A1502-001.010	U-235	0.438	PCI/G	U	0.603	0.413
92698	Real	98A2022-001.004	U-235	0.022	PCI/G	U	0.049	0.029
	Replicate	98A2022-001.010	U-235	0.008	PCI/G	U	0.049	0.029
93098	Real	99A4353-004.002	U-235	0	PCI/G	U	0.050	0.000
	Replicate	99A4353-005.001	U-235	0.072	PCI/G	U	0.076	0.075
93698	Real	98A1289-001.004	U-235	0.032	PCI/G	U	0.039	0.029
	Replicate	98A1289-001.010	U-235	0.05	PCI/G	J	0.027	0.029
94298	Real	99A4849-004.002	U-235	0.034	PCI/G	U	0.091	0.059
	Replicate	99A4849-005.002	U-235	0.056	PCI/G	U	0.076	0.066
94598	Real	98A5489-001.008	U-235	0.043	PCI/G	J	0.024	0.041
	Replicate	98A5489-001.009	U-235	0.031	PCI/G	J	0.021	0.032
95298	Real	98A5494-001.008	U-235	0.023	PCI/G	J	0.021	0.028
	Replicate	98A5494-001.009	U-235	0.038	PCI/G	U	0.040	0.040
95798	Real	99A5832-004.002	U-235	0.017	PCI/G	U	0.084	0.045
	Replicate	99A5832-005.002	U-235	0.01	PCI/G	U	0.081	0.037
95998	Real	99A7799-006.003	U-235	0.21	PCI/G	J	0.117	0.162
	Replicate	99A7799-009.003	U-235	0.084	PCI/G	J	0.057	0.088
96298	Real	99A3210-004.008	U-235	0.113	PCI/G	J	0.083	0.099
	Replicate	99A3210-004.009	U-235	-0.007	PCI/G	U	0.079	0.014
96798	Real	99A6650-005.003	U-235	0.055	PCI/G	J	0.050	0.066
	Replicate	99A6650-006.003	U-235	-0.007	PCI/G	U	0.085	0.014
97598	Real	99A7937-004.002	U-235	0.077	PCI/G	J	0.052	0.080
	Replicate	99A7937-005.001	U-235	0.081	PCI/G	U	0.109	0.093
97698	Real	99A8275-001.003	U-235	0.122	PCI/G	J	0.055	0.106
	Replicate	99A8275-006.003	U-235	0.114	PCI/G	J	0.062	0.108

Subsurface Soil Characterization Project
Precision Results - Uranium-238

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q	Det_Limit	Sigma_Error
90198	Real	98A1496-001.006	U-238	1.9	PCI/G		0.546	0.716
	Replicate	98A1496-001.014	U-238	0.828	PCI/G	J	0.025	0.137
90698	Real	98A1055-003.033	U-238	7.92	PCI/G		2.42	3.1
	Replicate	98A1055-003.036	U-238	2.89	PCI/G	U	3.69	2.37
90798	Real	98A1055-002.019	U-238	0.851	PCI/G	J	0.016	0.121
	Replicate	98A1055-002.020	U-238	0.689	PCI/G	J	0.020	0.102
91298	Real	98A1055-001.010	U-238	0.319	PCI/G	J	0.020	0.057
	Replicate	98A1055-001.011	U-238	0.395	PCI/G	J	0.015	0.065
91598	Real	98A1296-001.002	U-238	28.2	PCI/G		19.8	19.2
	Replicate	98A1296-001.010	U-238	90.9	PCI/G		26.9	35
91698	Real	98A2017-001.002	U-238	0.913	PCI/G	U	32.7	14.0
	Replicate	98A2017-001.012	U-238	4.18	PCI/G	U	31.9	12.8
92498	Real	98A1502-001.002	U-238	1.1	PCI/G		0.056	0.229
	Replicate	98A1502-001.010	U-238	1.31	PCI/G		0.501	0.68
92698	Real	98A2022-001.004	U-238	0.516	PCI/G	J	0.059	0.143
	Replicate	98A2022-001.010	U-238	0.658	PCI/G	J	0.064	0.175
93098	Real	99A4353-004.002	U-238	0.645	PCI/G	J	0.072	0.242
	Replicate	99A4353-005.001	U-238	0.592	PCI/G	J	0.061	0.217
93698	Real	98A1289-001.004	U-238	0.764	PCI/G	J	0.044	0.159
	Replicate	98A1289-001.010	U-238	1.62	PCI/G		0.030	0.246
94298	Real	99A4849-004.002	U-238	0.773	PCI/G	J	0.073	0.263
	Replicate	99A4849-005.002	U-238	0.739	PCI/G	J	0.061	0.253
94598	Real	98A5489-001.008	U-238	0.813	PCI/G	J	0.019	0.235
	Replicate	98A5489-001.009	U-238	0.659	PCI/G	J	0.035	0.193
95298	Real	98A5494-001.008	U-238	0.595	PCI/G	J	0.030	0.179
	Replicate	98A5494-001.009	U-238	0.733	PCI/G	J	0.018	0.214
95798	Real	99A5832-004.002	U-238	0.792	PCI/G	J	0.067	0.260
	Replicate	99A5832-005.002	U-238	0.66	PCI/G	J	0.066	0.240
95998	Real	99A7799-006.003	U-238	1.08	PCI/G		0.094	0.379
	Replicate	99A7799-009.003	U-238	0.854	PCI/G	J	0.096	0.308
96298	Real	99A3210-004.008	U-238	1.06	PCI/G	B	0.038	0.335
	Replicate	99A3210-004.009	U-238	0.353	PCI/G	J	0.084	0.161
96798	Real	99A6650-005.003	U-238	0.52	PCI/G	J	0.083	0.212
	Replicate	99A6650-006.003	U-238	0.798	PCI/G	J	0.069	0.278
97598	Real	99A7937-004.002	U-238	0.89	PCI/G	J	0.074	0.306
	Replicate	99A7937-005.001	U-238	0.828	PCI/G	J	0.042	0.292
97698	Real	99A8275-001.003	U-238	0.5	PCI/G	J	0.078	0.213
	Replicate	99A8275-006.003	U-238	0.472	PCI/G	J	0.088	0.216

Subsurface Soil Characterization Results
QA Sample Results - VOCs

Borehole	Sample Type	RIN/Event/Bottle	Analyte	Result	Unit	Q
92598	Real	98A1092-001.036	Carbon Tetrachloride	720	UG/KG	U
	Dup	98A1092-001.037	Carbon Tetrachloride	740	UG/KG	U
95998	Real	99A7799-006.002	Carbon Tetrachloride	6.3	UG/KG	U
	Dup	99A7799-009.002	Carbon Tetrachloride	6.1	UG/KG	U
96298	Real	99A3210-004.014	Carbon Tetrachloride	670	UG/KG	U
	Dup	99A3210-004.015	Carbon Tetrachloride	700	UG/KG	U
96798	Real	99A6650-005.002	Carbon Tetrachloride	5.3	UG/KG	J
	Dup	99A6650-006.002	Carbon Tetrachloride	0.81	UG/KG	J
97698	Real	99A8275-001.002	Carbon Tetrachloride	5.3	UG/KG	U
	Dup	99A8275-006.002	Carbon Tetrachloride	5.4	UG/KG	U
97698	Real	99A8275-001.002	1,2-Cis-Dichloroethylene	5.3	UG/KG	U
	Dup	99A8275-006.002	1,2-Cis-Dichloroethylene	5.4	UG/KG	U
96798	Real	99A6650-005.002	1,2-Cis-Dichloroethylene	14.9	UG/KG	
	Dup	99A6650-006.002	1,2-Cis-Dichloroethylene	6.8	UG/KG	U
96298	Real	99A3210-004.014	1,2-Cis-Dichloroethylene	670	UG/KG	U
	Dup	99A3210-004.015	1,2-Cis-Dichloroethylene	700	UG/KG	U
95998	Real	99A7799-006.002	1,2-Cis-Dichloroethylene	79.5	UG/KG	
	Dup	99A7799-009.002	1,2-Cis-Dichloroethylene	6.1	UG/KG	U
92598	Real	98A1092-001.036	1,2-Cis-Dichloroethylene	720	UG/KG	U
	Dup	98A1092-001.037	1,2-Cis-Dichloroethylene	740	UG/KG	U
97698	Real	99A8275-001.002	Tetrachloroethene	5.3	UG/KG	U
	Dup	99A8275-006.002	Tetrachloroethene	5.4	UG/KG	U
96798	Real	99A6650-005.002	Tetrachloroethene	72.2	UG/KG	
	Dup	99A6650-006.002	Tetrachloroethene	7.8	UG/KG	
96298	Real	99A3210-004.014	Tetrachloroethene	670	UG/KG	U
	Dup	99A3210-004.015	Tetrachloroethene	700	UG/KG	U
95998	Real	99A7799-006.002	Tetrachloroethene	343	UG/KG	E
	Dup	99A7799-009.002	Tetrachloroethene	6.1	UG/KG	U
92598	Real	98A1092-001.036	Tetrachloroethene	720	UG/KG	U
	Dup	98A1092-001.037	Tetrachloroethene	740	UG/KG	U
97698	Real	99A8275-001.002	Trichloroethene	5.3	UG/KG	U
	Dup	99A8275-006.002	Trichloroethene	5.4	UG/KG	U
96798	Real	99A6650-005.002	Trichloroethene	16.1	UG/KG	
	Dup	99A6650-006.002	Trichloroethene	0.85	UG/KG	J
96298	Real	99A3210-004.014	Trichloroethene	670	UG/KG	U
	Dup	99A3210-004.015	Trichloroethene	700	UG/KG	U
95998	Real	99A7799-006.002	Trichloroethene	12.9	UG/KG	
	Dup	99A7799-009.002	Trichloroethene	6.1	UG/KG	U
92598	Real	98A1092-001.036	Trichloroethene	720	UG/KG	U
	Dup	98A1092-001.037	Trichloroethene	740	UG/KG	U

Appendix D

903 Pad *In-Situ* Models and Uncertainties

903 PAD *IN SITU* MODELS AND UNCERTAINTIES

In Situ Models

The Canberra *in situ* systems used to perform measurements at the RFETS 903 Pad project site employ the Canberra In Situ Object Counting System (ISOCS) software. This software package allows the user to calculate efficiencies for in situ quantification of defined objects using standard templates. One such template has been used to define the in situ measurement of contaminants in soils at the 903 Pad locations. This template requires the entry of various parameters which should accurately represent the actual conditions at the project site.

The template selected for this application is the circular plane source . This template requires the user to define a horizontal source size, a vertical source size, material composition and material density. In addition, the software uses detector specific physical parameters and user definable environmental parameters such as humidity, pressure and temperature. Each of these parameters has been defined in the model to represent actual conditions at 903 Pad, using existing knowledge of the site and project defined parameters. These parameter values, and the basis for selection, are described below.

Use of inappropriate values could lead to errors in *in situ* measurements. The model used for routine measurements contains the values most representative of actual conditions, however it is possible that actual measurement locations may vary from these assumed default conditions. Since it is not possible to verify all parameter values at each measurement location, default values will be used except where it is known that conditions vary significantly. An evaluation of the potential errors associated with deviation from default parameters has been performed and forms the basis of the total propagated measurement uncertainty (TMU) used when reporting *in situ* measurement results. These are also described below.

903 Pad Project ISOCS Model

Horizontal Distribution (Field of View)
As indicated above, the model selected for the 903 Pad Project (and normally used for any *in situ* soil assays) is the circular plane geometry. The circular plane is appropriate since the detector typically views a circular area which is defined by detector height above ground and the collimator employed, if any, to restrict the field of view (FOV). For this project, the field of view was defined in the Statement of Work as a 12 m diameter FOV. However, calculations performed using ISOCS showed that an "infinite field of view" for Am-241 is about 10 meters. This is due to the low energy Am-241 photon (59 keV) which is attenuated by soil, and even air, such that there is little contribution to the detector measurement at distances beyond 5 meters from the detector. Therefore, all efficiencies assumed a FOV of 10 meters diateter. In addition, the collimator used, 5 cm with a 180 degree collimation, effectively limits the FOV to 10 meters at a height of one meter.

Vertical Distribution
The distribution of contaminants vertically will impact the efficiency used. For naturally occurring radionuclides, the distribution is basically uniform throughout the top 20-30 cm of soil. However, man-made contamination will usually have a different distribution, depending on the mode of deposition. At 903 Pad locations, contamination was deposited via airborne and/or surface water releases. This results in a distribution which will tend to have higher concentrations near the surface and decreasing concentrations with depth., which may follow an exponential function. Surface soil sampling has been performed in the 903 Pad areas to determine the vertical distributions. In general, the activities are concentrated in the top 5 cm, which may contain 60-80% of the total contamination. The sampling was generally performed in 2 or 3 cm layers, therefore the distribution in the top 5 cm layer can only be subdivided into two layers, one for the top 3 cm and a second for the next 2 (or 3) 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 is used to be consistent with the soil sampling protocol, which calls for sampling to a depth of two inches. In addition, the contribution from Am-241 below a depth of 5 cm in soil is quite small. This distribution, however, will skew results for naturally occurring radionuclides due to the different distributions.

Soil Composition
The chemical composition of the soils, including moisture content, will impact efficiency determinations. A number of soil samples from the 903 Pad locations have been analyzed and reported for chemical composition. The ISOCS software contains several soil models with varying elemental content. Based on the available data, a soil composition containing measurable amounts of metals, including Fe, and a small amount of H2O (low moisture content) was selected as most representative of RFETS soils. This soil model is termed "dry dirt" and has a composition of: 49O, 27Si, 4Fe, 1.6Mg, 4Ca, 7Al, 0.8Na.

Soil Density
The available soil density data from 903 Pad locations shows densities ranging from 1.0 to 1.3 g/cc. *In Situ* soil densities are typically on the order of 1.6 g/cc, but it is believed that, due to the lower moisture content of RFETS soils, this value may be too high. The ISOCS model uses a value of 1.3 g/cc as a mean value for 903 Pad soils.

Uniformity
The uniformity, or non-uniformity, of contamination, both vertically and horizontally, will impact measurement results. Based on the mode of contamination deposition and on prior survey results (including *in situ* surveys), it is believed that the contamination is relatively uniform within the field of view in the ISOCS systems. This is a reasonable assumption since the in situ measurements integrate the readings over nearly 80 sq m areas. Thus, any individual "hot spots" are averaged over the entire area, or volume, and their impacts are minimized. The ISOCS model is based on uniform distributions.

Environmental Conditions
Environmental temperature, humidity and pressure may impact some measurements. The ISOCS models assume standard environmental conditions; i.e. 20 C, 50 % relative humidity and 760 mm barometric pressure. Normal barometric pressure at RFETS is less, but the impact is negligible, as shown below.

Detector Parameters
An ISOCS efficiency for each detector has been generated, using the specific detector characteristics, which tend to remain constant for long periods of time. The parameter of concern is the detector surface dead layer, which, if it increases could effect detection of low energy photons. This can be monitored by routine check source counts using a source with a low energy photon, such as Am-241. There have been no changes to these parameters over the course of the 903 Pad Project.

The ISOCS template used for the 903 Pad ISOCS efficiency is attached.

ISOCS Model Uncertainties.

As described above, the default ISOCS models are based on assumed mean values for the given set of model parameters. It is recognized that the actual conditions may vary and that it is not possible to characterize each measurement location to use location specific values. Therefore, Canberra has attempted to bound the likely range of parameter values based on existing data, evaluate the potential errors of using mean values when compared to the likely ranges, then assign an error to each parameter and propagate a total measurement uncertainty (TMU). Each parameter has been evaluated, as shown below, and a maximum error estimated for the mean value, based on the likely range of values for a given parameter. The impact of a deviation from the mean value was assessed by entering that value into an ISOCS efficiency, then analyzing a standard count and comparing the Am-241 result to that obtained with the mean value. Each parameter was evaluated independently. The variation from the mean value was considered to be the maximum deviation and equivalent to a 3 sigma boundary.

Horizontal Distribution (Field of View)
The field of view is limited by the 180 degree collimator and the range of Am-241 photons in soil. It is assumed that the horizontal distribution is uniform. There are no likely maximum or minimum ranges for this parameter and no error estimate is provided.

Vertical Distribution
The model distribution was estimated from soil sampling data but is rather coarse. 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 were prepared and the standard acquisition analyzed.

Results:

Default 2 layer 0-3 cm 66%, 3-5 cm 33%	Am-241 = 12,2 pCi/g
Single layer, 0-5 cm uniform	Am-241 = 14.3 pCi/g
3 layers, 0-1.5cm 50%, 1.5-3 cm 30%, 3-5 cm 20%	Am-241 = 11.6 pCi/g
3 layers, default with 1cm grass cover	Am-241 = 13.2 pCi/g
2 layer with 0-3 cm 60%, 3-5 cm 40%	Am-241 = 12.2 pCi/g

The overall impact of a likely range of possible distributions is about +/- 10 %.

Soil Composition
Soil compositions were varied from dirt with little heavy metal component (Dirt 2) to soils with a significant composition of metals (Dirt 4)

Results:

Default soil; Dry Dirt (49O, 27Si, 4Fe, 1.6Mg, 4Ca, 2.7K, 7Al)	Am-241 = 12.2 pCi/g
Dirt 2 (55O, 31Si, 3Fe, 7Al)	Am-241 = 11.6 pCi/g
Dirt 4 (45O, 25Si, 12Fe, 2.5Mg, 4.1Ca, 2Mn, 8.3Al, 0.7Ti)	Am-241 = 15.4 pCi/g

The overall impact of a likely range of compositions is about +/- 25%

Soil Density

Soil densities were varied from the minimum of 1.0 to a maximum of 1,6 g/cc.

Results

Default density 1.3 g/cc	Am-241 = 12.2 pCi/g
Density 1.6 g/cc	Am-241 = 12.0 pCi/g
Density 1.0 g/cc	Am-241 = 13.8 pCi/g

The overall impact of density changes is about +/- 10 %-

Environmental Conditions

The default temperature and relative humidity are close to the ranges at RFETS but the default pressure is 20 % higher than normal barometric pressure at this altitude. However, changing the parameters to the RFETS values had no impact (same Am-241 results).

Detector Parameters

Detector characteristics have been shown to be unchanged since factory calibration by verifying response by counting a standard reference material and obtaining the correct result. There is no error assigned to this.

Propagation of Uncertainties.

All significant sources of error should be included in an assessment of total measurement uncertainty (TMU). The model uncertainties described above for vertical distribution, soil composition, soil density, etc. should be considered random errors and are propagated in quadrature. These are then added to the systematic uncertainty defined below.

Random error components, and the magnitude of the estimated 3 sigma range, excluding counting statistics, are shown as:

Horizontal distribution	negligible
Vertical distribution	+/- 10 %
Soil Composition	+/- 25%
Soil Density	+/- 10%
Environmental conditions	negligible

These are propagated as Total Random Error = (10*2+25*2+10*2)1/2
= 29%

The systematic error is primarily a calibration uncertainty and is estimated to be +/- 5%.

The Total Measurement Uncertainty (excluding counting statistics) is = 29% + 5% = 34% at the 3 sigma level.

Due to reporting requirements, this error is entered into the software as the systematic error, which is then added to the counting error to arrive at a TMU. This method may overestimate the total error slightly (the correct method would be to propagate the counting error with the other random uncertainties, then add the systematic error) but is necessary so that the software can report individual values for the counting error and the TMU.
Typical TMU values for detected Am-241 in natural background locations may range from as high as 70% for low levels (e.g. <10 pCi/g) to 40% for high levels.

Data Quality Objectives for Measurement Data

Data Quality Objectives (DQOs) are qualitative and quantitative statements that describe the *in situ* characterization technical and quality objectives, define the appropriate type of data and specify acceptable levels of decision errors used to establish the quality of data. These data are used to assist RMRS in developing remedial action or management actions for the affected areas. For 903 Pad *in situ* measurements, the DQO is:

- To classify surface soils as exceeding Tier 1 soil action levels. This objective is met by measuring soil concentrations of Am-241, U-235 and U-238. Concentrations of Pu and other U isotopes are derived from these measurements. In order to provide sufficient margin for detection of Tier 1 levels, detection limits for the three nuclides measurable by *in situ* methods have been set at; 1 pCi/g Am-241, 0.5 pCi/g U-235 and 5.0 pCi/g U-238.

Data Quality Objectives used to validate all data generated by *in situ* measurements include the following: precision, accuracy, sensitivity, completeness, comparability and total uncertainty. For the 903 Pad Project, these are defined as follows:

- Precision A quantitative measure of the reproducibility or degree of agreement among replicate or duplicate measurements of a parameter. For the 903 Pad Project, precision shall be demonstrated by performing duplicate counts of specified soil locations on a frequency not to exceed once per 20 measurement locations. The reproducibility shall be calculate using accepted methods for evaluation of duplicate counting.

- Accuracy The degree of agreement between measured concentration values and the true or known values. For *in situ* measurements, true values are difficult to establish and may be estimated from alternate assay methods. For this project. *In situ* results will be compared to laboratory analyses of discrete soil samples. Comparable measurements at the action levels are expected to agree within +/- 50%. Evaluation of accuracy will be performed by RMRS and Canberra technical representativves.

- Sensitivity Sensitivity limits are defined as that level of radioactivity which, if present, will yield a measured value less than the critical limit with 5% probability. The critical limit is defined as that value which measurements of background will exceed with a 5% probability. Sensitivity limits for three detectable radionuclides are specified above.

- Completeness A quantitative measure expressed as a percentage of valid or acceptable data obtained from a measurement system. A goal of 90% has been set for this project.

- Comparability A qualitative measure of the confidence with which a set of data from one assay system can be compared to another from a second system. See the DQO for accuracy.

- Total Uncertainty This includes both random and systematic uncertainties and are propogated to arrive at a total uncertainty at the 95% confidence level. Random uncertainties include counting errors and uncertainties related to non-uniform distribution of contamination. Systematic errors include calibration and positioning. Uncertainties will be obtained from measurements or estimated by *in situ* technical specialists.

Appendix E

Summary Statistics

Appendix E. Summary Statistics
Borehole Radiological Data-903 Pad and Lip Area

Asphalt					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	0.81	0.05	0.75	0.16	0.07
Geometric Mean	0.80	0.04	0.74	#N/A	0.04
Standard Error	0.05	0.01	0.04	0.13	0.03
Median	0.78	0.04	0.75	0.03	0.04
Mode	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0.15	0.03	0.13	0.40	0.10
Sample Variance	0.02	0.00	0.02	0.16	0.01
Kurtosis	1.70	7.01	-1.60	8.85	8.28
Skewness	1.22	2.46	-0.08	2.97	2.84
Coefficient of Variation	0.19	0.72	0.17	2.42	1.46
Range	0.47	0.12	0.32	1.22	0.33
Minimum	0.66	0.01	0.60	0.00	0.02
Maximum	1.13	0.13	0.92	1.22	0.34
Sum	7.27	0.42	6.74	1.48	0.63
Count	9	9	9	9	9
Confidence Level (90.0%)	0.08	0.02	0.07	0.22	0.06

Bedrock					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	0.49	0.04	0.62	0.09	0.04
Geometric Mean	0.45	N/A	0.58	0.05	N/A
Standard Error	0.06	0.01	0.06	0.03	0.02
Median	0.43	0.05	0.69	0.04	0.03
Mode	#N/A	#N/A	#N/A	0.01	0.01
Standard Deviation	0.19	0.03	0.19	0.11	0.06
Sample Variance	0.04	0.00	0.04	0.01	0.00
Kurtosis	1.08	-0.02	0.13	1.89	3.71
Skewness	0.86	0.50	-0.96	1.69	1.51
Coefficient of Variation	0.39	0.81	0.31	1.26	1.54
Range	0.72	0.12	0.63	0.35	0.26
Minimum	0.19	-0.01	0.22	0.01	-0.05
Maximum	0.90	0.11	0.84	0.36	0.21
Sum	5.83	0.51	7.43	1.07	0.50
Count	12	12	12	12	12
Confidence Level (95.0%)	0.11	0.02	0.11	0.06	0.04
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	0	0

Appendix E. Summary Statistics
Borehole Radiological Data-903 Pad and Lip Area

Fill					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	1.06	0.09	1.15	53.75	12.01
Geometric Mean	1.02	0.06	1.00	5.78	1.18
Standard Error	0.11	0.04	0.18	45.95	10.38
Median	0.98	0.06	1.13	4.48	0.85
Mode	0.84	0.07	1.24	#N/A	#N/A
Standard Deviation	0.38	0.13	0.61	159.19	35.97
Sample Variance	0.14	0.02	0.37	25340.90	1294.08
Kurtosis	4.79	11.19	5.53	11.88	11.90
Skewness	1.51	3.30	1.72	3.44	3.44
Coefficient of Variation	0.36	1.43	0.53	2.96	2.99
Range	1.61	0.49	2.60	557.99	125.98
Minimum	0.41	0.00	0.17	0.01	0.02
Maximum	2.02	0.49	2.77	558.00	126.00
Sum	12.25	1.00	13.33	642.14	143.51
Count	12	12	12	12	12
Confidence Level (90.0%)	0.18	0.06	0.29	75.59	17.08
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	1	1

Native					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	0.51	0.04	0.63	0.27	0.11
Geometric Mean	0.49	N/A	0.60	N/A	N/A
Standard Error	0.02	0.01	0.02	0.06	0.03
Median	0.48	0.03	0.59	0.05	0.04
Mode	0.58	0.02	0.66	0.01	0.00
Standard Deviation	0.16	0.05	0.21	0.53	0.25
Sample Variance	0.02	0.00	0.04	0.28	0.06
Kurtosis	13.79	2.25	4.58	9.25	31.76
Skewness	2.74	1.65	1.72	2.94	5.20
Coefficient of Variation	0.31	1.10	0.33	2.00	2.32
Range	1.12	0.22	1.16	2.86	1.81
Minimum	0.28	-0.01	0.30	-0.02	-0.01
Maximum	1.40	0.21	1.46	2.84	1.80
Sum	36.37	3.18	45.03	19.18	7.70
Count	72	72	72	72	72
Confidence Level (95.0%)	0.04	0.01	0.05	0.12	0.06
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	0	0

Appendix E. Summary Statistics
Borehole Radiological Data-903 Pad and Lip Area

Native 1					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	5.31	0.60	16.83	3595.75	775.68
Geometric Mean	1.43	N/A	1.99	146.69	30.48
Standard Error	2.91	0.30	12.58	2462.86	514.23
Median	0.99	0.06	1.32	152.00	34.80
Mode	1.14	0.04	1.54	#N/A	#N/A
Standard Deviation	22.90	2.38	99.08	19392.56	4049.07
Sample Variance	524.52	5.65	9817.55	376071264.13	16394945.59
Kurtosis	55.37	38.00	60.51	59.32	58.16
Skewness	7.30	5.87	7.74	7.63	7.53
Coefficient of Variation	4.31	3.94	5.89	5.39	5.22
Range	177.58	17.81	779.51	152259.18	31669.85
Minimum	0.42	-0.91	0.49	0.82	0.15
Maximum	178.00	16.90	780.00	152260.00	31670.00
Sum	329.51	37.38	1043.61	222936.51	48092.47
Count	62	62	62	62	62
Confidence Level (95.0%)	5.70	0.59	24.66	4827.10	1007.87
Number of Detections Above Tier I	0	0	1	9	12
Number of Detections Above Tier II	0	0	1	27	27

Native 2					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	1.00	0.16	1.50	122.11	25.23
Geometric Mean	0.76	N/A	0.98	8.65	1.79
Standard Error	0.18	0.11	0.29	41.76	8.90
Median	0.73	0.04	0.88	7.62	1.50
Mode	1.63	0.02	0.40	#N/A	#N/A
Standard Deviation	1.42	0.83	2.32	328.85	70.12
Sample Variance	2.00	0.69	5.39	108142.37	4916.12
Kurtosis	49.56	61.25	24.30	15.58	16.02
Skewness	6.73	7.80	4.59	3.81	3.82
Coefficient of Variation	1.41	5.08	1.55	2.69	2.78
Range	11.36	6.58	15.40	1819.87	405.97
Minimum	0.04	-0.01	0.30	0.14	0.03
Maximum	11.40	6.57	15.70	1820.00	406.00
Sum	62.21	10.12	92.74	7571.08	1564.40
Count	62	62	62	62	62
Confidence Level (95.0%)	0.35	0.21	0.58	81.86	17.45
Number of Detections Above Tier I	0	0	0	2	2
Number of Detections Above Tier II	0	0	0	7	8

Appendix E. Summary Statistics
Borehole Radiological Data-903 Pad and Lip Area

Native 3					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	0.70	0.05	0.96	16.24	3.14
Geometric Mean	0.59	N/A	0.71	1.33	N/A
Standard Error	0.06	0.01	0.16	5.09	1.07
Median	0.61	0.03	0.64	0.94	0.23
Mode	0.38	0.02	0.57	0.06	0.25
Standard Deviation	0.44	0.06	1.23	40.12	8.46
Sample Variance	0.19	0.00	1.52	1609.25	71.49
Kurtosis	14.59	16.55	32.01	20.03	23.95
Skewness	3.03	3.70	5.22	4.19	4.60
Coefficient of Variation	0.63	1.23	1.28	2.47	2.69
Range	3.11	0.37	9.00	246.99	54.41
Minimum	0.01	-0.01	0.10	0.01	-0.01
Maximum	3.12	0.36	9.10	247.00	54.40
Sum	43.32	2.92	59.60	1007.14	194.71
Count	62	62	62	62	62
Confidence Level (95.0%)	0.11	0.01	0.31	9.99	2.10
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	0	1

Native 4					
Descriptive Statistic	U233/234 (pCi/g)	U235 (pCi/g)	U238 (pCi/g)	Pu239/240 (pCi/g)	Am241 (pCi/g)
Mean	0.58	0.03	0.64	4.97	0.90
Geometric Mean	0.54	N/A	0.59	N/A	N/A
Standard Error	0.03	0.00	0.04	1.40	0.23
Median	0.55	0.03	0.59	0.80	0.23
Mode	0.76	0.01	0.63	34.50	0.15
Standard Deviation	0.21	0.02	0.29	10.63	1.72
Sample Variance	0.04	0.00	0.08	112.97	2.95
Kurtosis	1.50	2.86	6.66	9.49	6.52
Skewness	1.03	0.19	1.96	3.04	2.67
Coefficient of Variation	0.36	0.74	0.45	2.14	1.92
Range	1.05	0.15	1.78	54.00	7.68
Minimum	0.27	-0.05	0.19	0.00	-0.05
Maximum	1.32	0.10	1.97	54.00	7.63
Sum	33.44	1.79	37.07	288.35	51.98
Count	58	58	58	58	58
Confidence Level (95.0%)	0.05	0.01	0.07	2.74	0.44
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	0	0	1

N/A Not Applicable

Appendix E. Summary Statistics
HPGe Data

HPGe Data					
Descriptive Statistic	^{235}U (pCi/g)	^{238}U (pCi/g)	HPGe ^{241}Am (pCi/g)	Predicted ^{241}Am[1] (pCi/g)	Predicted $^{239/240}Pu$[2] (pCi/g)
Mean	0.24	4.46	12.60	28.43	201.20
Geometric Mean	0.00	N/A	N/A	N/A	N/A
Standard Error	1.37E-03	0.02	0.38	0.45	3.00
Median	0.23	4.37	9.62	24.80	176.67
Mode	0.23	3.63	0.90	15.46	118.91
Standard Deviation	0.05	0.67	12.67	15.02	100.11
Sample Variance	2.07E-03	0.45	160.54	225.69	10021.87
Kurtosis	4.18	10.50	13.05	18.39	22.63
Skewness	-0.12	1.10	2.84	3.36	3.74
Coefficient of Variation	0.19	0.15	1.01	0.53	0.50
Range	0.51	10.04	115.36	150.48	1060.92
Minimum	0.07	1.31	0.38	14.91	115.55
Maximum	0.58	11.35	115.74	165.39	1176.47
Sum	261.72	4946.04	13985.89	31555.57	223330.46
Count	1110	1110	1110	1110	1110
Confidence Level (95.0%)	2.68E-03	0.04	0.75	0.88	5.89
Number of Detections Above Tier I	0	0	0	0	0
Number of Detections Above Tier II	0	0	48	162	183

N/A Not Applicable

[1] Predicted ^{241}Am Based on Regression Equation: $^{241}Am = 0.0022 * {}^{241}Am^2 + 1.049 * {}^{241}Am + 14.509$

[2] Predicted $^{239/240}Pu$ Based on Regression Equation: $^{239/240}Pu = 0.0243 * {}^{241}Am^2 + 6.3749 * {}^{241}Am + 113.12$

Appendix E. Summary Statistics
VOC Borehole Data

Bedrock						
Descriptive Statistic	Carbon Tetrachloride (µg/Kg)	Tetrachloroethene (µg/Kg)	Trichloroethene (µg/Kg)	Chloroform[a] (µg/Kg)	Cis-1,2-Dichloroethene (µg/Kg)	Methylene Chloride (µg/Kg)
Mean	428.37	458.71	428.85	427.25	698.57	493.06
Geometric Mean	71.75	87.43	73.06	45.48	697.70	59.10
Standard Error	117.96	122.44	117.83	118.24	13.88	151.12
Median	620.00	660.00	620.00	620.00	700.00	390.00
Mode	700.00	700.00	700.00	700.00	700.00	700.00
Standard Deviation	456.84	458.13	456.36	457.95	36.71	585.27
Sample Variance	208701.85	209885.96	208265.48	209715.19	1347.62	342541.03
Kurtosis	0.23	0.20	0.23	0.21	4.75	-0.20
Skewness	0.73	0.63	0.73	0.72	-2.05	0.96
Coefficient of Variation	1.07	1.00	1.06	1.07	0.05	1.19
Range	1497.70	1498.40	1499.11	1499.40	110.00	1699.17
Minimum	2.30	1.60	0.89	0.60	620.00	0.83
Maximum	1500.00	1500.00	1500.00	1500.00	730.00	1700.00
Sum	6425.50	6421.90	6432.79	6408.79	4890.00	7395.93
Count	15	14	15	15	7	15
Confidence Level (95.0%)	231.19	239.98	230.95	231.75	27.19	296.18
Number of Detections Above Current Tier I SSAL	0	0	0	0	0	0
Number of Samples at 10% of Current Tier I SSAL	1	1	1	0	0	6
Number of Detections Above Proposed Tier I SSAL	0	0	0	0	0	2
Number of Detections Above Proposed Tier II SSAL	0	0	0	0	0	4
Number of Non Detections	13	12	13	10	7	7
Number of Detections	2	2	2	5	0	8

Appendix E. Summary Statistics
VOC Borehole Data

Descriptive Statistic	Native					
	Carbon Tetrachloride (µg/Kg)	Tetrachloroethene (µg/Kg)	Trichloroethene (µg/Kg)	Chloroform[a] (µg/Kg)	Cis-1,2-Dichloroethene (µg/Kg)	Methylene Chloride (µg/Kg)
Mean	351.59	438.75	344.72	351.36	838.40	385.12
Geometric Mean	47.84	51.01	47.91	40.84	742.11	36.97
Standard Error	50.73	94.02	50.33	50.76	148.57	60.20
Median	6.00	24.80	6.30	6.20	700.00	5.90
Mode	5.30	5.30	5.30	700.00	700.00	5.30
Standard Deviation	427.48	797.76	424.12	427.68	742.86	507.21
Sample Variance	182742.10	636420.43	179878.11	182907.29	551839.00	257264.17
Kurtosis	-0.37	35.93	-0.24	-0.37	24.87	-0.12
Skewness	0.82	5.21	0.87	0.82	4.98	1.06
Coefficient of Variation	1.22	1.82	1.23	1.22	0.89	1.32
Range	1494.90	6099.22	1497.00	1499.36	3790.00	1699.41
Minimum	5.10	0.78	3.00	0.64	610.00	0.59
Maximum	1500.00	6100.00	1500.00	1500.00	4400.00	1700.00
Sum	24962.60	31589.97	24475.40	24946.28	20960.00	27343.80
Count	71	72	71	71	25	71
Confidence Level (95.0%)	99.43	184.27	98.65	99.48	291.19	117.98
Number of Detections Above Current Tier I SSAL	0	0	0	0	0	0
Number of Samples at 10% of Current Tier I SSAL	0	6	5	0	1	25
Number of Detections Above Proposed Tier I SSAL	0	1	0	0	0	8
Number of Detections Above Proposed Tier II SSAL	0	7	1	0	1	18
Number of Non Detections	70	55	66	64	24	36
Number of Detections	1	17	5	7	1	35

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Appendix E. Summary Statistics
VOC Borehole Data

	All					
Descriptive Statistic	Carbon Tetrachloride (µg/Kg)	Tetrachloroethene (µg/Kg)	Trichloroethene (µg/Kg)	Chloroform[a] (µg/Kg)	Cis-1,2-Dichloroethene (µg/Kg)	Methylene Chloride (µg/Kg)
Mean	364.98	442.00	359.40	364.59	807.81	403.95
Geometric Mean	51.34	55.69	51.57	41.62	732.16	40.12
Standard Error	46.47	80.96	46.19	46.51	116.05	56.03
Median	6.25	56.35	6.80	6.25	700.00	13.85
Mode	5.30	700.00	5.30	700.00	700.00	5.30
Standard Deviation	430.96	750.84	428.33	431.29	656.46	519.60
Sample Variance	185726.80	563753.37	183468.61	186010.08	430940.22	269980.52
Kurtosis	-0.33	37.87	-0.23	-0.34	31.79	-0.16
Skewness	0.79	5.21	0.83	0.79	5.63	1.03
Coefficient of Variation	1.18	1.70	1.19	1.18	0.81	1.29
Range	1497.70	6099.22	1499.11	1499.40	3790.00	1699.41
Minimum	2.30	0.78	0.89	0.60	610.00	0.59
Maximum	1500.00	6100.00	1500.00	1500.00	4400.00	1700.00
Sum	31388.10	38011.87	30908.19	31355.07	25850.00	34739.73
Count	86	86	86	86	32	86
Confidence Level (95.0%)	91.08	158.69	90.53	91.15	227.45	109.82
Number of Detections Above Proposed Tier I SSAL	0	1	0	0	0	10
Number of Detections Above Proposed Tier II SSAL	0	7	1	0	1	22
Number of Non Detections	83	67	79	74	31	43
Number of Detections	3	19	7	12	1	43
Number of DLs Above Proposed Tier I[b] SSAL	0	0	0	0	0	21
Number of DLs Above Proposed Tier II[b] SSAL	39	37	38	39	31	24

[a] Denotes that analyte has been omitted as a COC due to detections in the laboratory blanks

[b] Includes only non detections

DL Detection Limit

Appendix F

Electronic Copy of Analytical Database
Electronic Copy of RFCA Tier I and Tier II RSAL Calculation Results

MAINTAINED IN A SEPARATE
FIRE-RATED CABINET

Appendix G

SW053 Wetland Sediment Sampling Results

INTRODUCTION

This appendix summarizes the sediment sampling results from the small wetland area surrounding surface water sampling location 053 (SW053). This document provides the analytical results of sediment samples and field quality assurance samples collected during the investigation in support of the Characterization of 903 Pad Drum Storage Area, 903 Lip Area, and Americium Zone. The wetland is located in the southeast Americium Zone near the East Firing Range. Figure 1 provides the location of the wetland and locations where sediment samples were collected. Samples were collected at three locations: 090100, 090200, and 090300. Two sediment samples were collected at each location from the 0-6 inch and 6-12 inch depth intervals for a total of six sediment samples. Two quality assurance samples were generated in support the sampling program.

FIELD METHODS

The Final Sampling and Analysis Plan (SAP) for the Site Characterization of the 903 Drum Storage Area (IHSS 112), 903 Lip Area (IHSS 155) and Americium Zone, Rev.1 (RMRS, 1998) provided sampling requirements for characterization of the wetland. Operations Order (OO) OO-903-01, Sediment Sample Collection, was followed for the collection of samples. Hand held sampling equipment utilized to obtain sediment samples consisted of a slide hammer and core-barrel. Sediment samples were obtained by driving a core barrel 1.5 feet into the sediment and extracting the recovered material from the core barrel. Samples were generated from 6-inch intervals according to the SAP. Samples were shipped to the laboratory for analytical determination of radionuclides. Sampling equipment was decontaminated prior to sampling and in between the collection of individual samples in accordance with 4-S01-ENV-OPS-FO.03, Field Decontamination Operations.

LABORATORY METHODS

Analytical services were provided through Kaiser-Hill Analytical Services Division (ASD) using Statements Of Work (SOW) which are 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 1.

Table 1. Laboratory Statement of Work Modules

Module Title	Module ID
General Laboratory Requirements	GR01
Electronic Data Deliverables	GR02
Radiochemistry Isotopic Determinations by Alpha Spectrometry	RC01

Radiochemistry Isotopic Determinations by Alpha Spectrometry

Samples collected from the wetland were submitted to laboratories for radiochemical analysis and analyzed in compliance with PSA Module Radiochemistry Isotopic Determinations by Alpha Spectrometry (RC01). The Radiochemistry Isotopic Determinations by Alpha Spectrometry SOW describes the processes by which isotopic analyses using alpha spectrometry 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 spectrometry. These operations and those in the General Laboratory Requirements Module (GR01) are designed to ensure the generation of comparable data from all laboratories contracted by ASD. Module GR02, Electronic Data Deliverables, ensures laboratories report data in a consistent format compatible with the Site's environmental databases.

QUALITY ASSURANCE

Field Quality Assurance

Two QA samples were collected in the field that included a sediment replicate sample and an equipment rinsate sample. The sample replicate was collected to qualitatively evaluate field sampling and measurement precision. The equipment rinsate sample was collected to evaluate whether the field sampling equipment was adequately decontaminated between sampling events.

Replicate Sample

One field replicate sample (00D0686-007.001) was collected from sampling location 090200 from the 0-6 inch depth interval and submitted for radiochemical analysis. The replicate sample was collected as a unique sample. The replicate and real samples were generated for alpha spectroscopy analysis by splitting the recovered core in half lengthwise over the sample interval. The single replicate sample generated met the required frequency of one replicate sample per 20 real samples required in the SAP. Figure 2 provides a comparison between real and replicate radiochemical results. As shown in Figure 2, the relative difference between real and associated replicate sample results for uranium are minimal. The relative difference between sample results is greater for americium-241 (3.8 pCi/g); the largest relative difference was observed for plutonium-239/240 at approximately 17.6 pCi/g.

The variability between field replicate samples and associated real samples is a measure of all variance introduced from sample collection in the field through radiochemical analysis. One source of variance may be attributed to an increased error associated with analyzing only an aliquot of the sample instead of measuring the bulk sample. Another source of variance between field replicates and their associated real samples is contaminant heterogeneity in the soil. Although a variance exists between sample results, the calculated sum of ratios for both real and replicate sample results are significantly below RFCA Tier II soil action levels for this sample interval and does not impact project decisions.

Equipment Rinsate Sample

One equipment rinsate sample (00D0687-001.002) was collected for radiochemical analysis. All radionuclides, with the exception of plutonium-239/240, were below the method detection limit. Plutonium-239/240 was detected at 0.07 pCi/L in the rinsate sample. This indicates that there was a potential for cross-contamination of plutonium-239/240 between samples from field-decontaminated sampling equipment. However, this magnitude of cross-contamination is very small when compared to actual sediment sample results and RFCA action levels and therefore all sample results were evaluated as actual detections in sediments.

Laboratory Quality Assurance

Specific laboratory QA samples analyzed in support of this module include laboratory duplicates and laboratory control samples to access laboratory precision and accuracy, respectively. In addition, sample results were verified and validated. 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.

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 includes examination of raw data and calculations.

Laboratory Data Validation

All sample results generated from the laboratory analysis of sediment samples underwent validation. Section 3.2, Laboratory Data Assessment, Verification, and Validation, provides detailed information on the Site's quality assurance evaluation of analytical data. All data reported from sediment samples were validated as *"no problems with the data were observed at the indicated review level"* ("V").

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 did not meet required criteria to validated as *"estimated"* ("J") or as *"the results could be considered estimated at an elevated level of detection"* ("UJ"). All radiochemical data met the laboratory validation criteria ("V").

Laboratory Accuracy

Accuracy is a measure of how closely an analytical result corresponds to the true concentration or activity in a sample. 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%).

NATURE AND EXTENT OF CONTAMINIATION

Field Sampling Results

The three sediment samples were collected roughly in a triangular grid with location 090100 closest to the seep at SW053 (Figure 1). Samples were collected on December 27, 1999; a thin layer of ice covered the wetland at the time of sampling. Location 090200 was collected directly south of 090100. Sediment sampling location 090300 was collected northeast of 090100 (Figure 1). Actual sediment samples were recovered at two of the sampling locations (090100 and 090200). Approximately 1.15 feet of peat and sandy clay overly the weathered bedrock at sampling location 090100. Borehole logs are provided as an attachment. Clayey sand and silty sand were recovered to 1 foot in depth at sampling location 090200. The boring was completed to 1.5 feet in depth, bedrock was not encountered at this location, Only weathered bedrock was encountered at sampling location 090300; no sediment was present at this location.

Two weathered bedrock samples were generated at this sampling location and submitted to the laboratory for radiochemical determination.

Sediment Sample Analytical Results

This section presents sediment sample results as compared to background surface soil activities, which are defined as the mean plus two standard deviations. Analytical results were also compared to RFCA Tier I and II surface soil action levels (individual radionuclide action levels). Background surface soil activities are provided in the *Geochemical Characterization of Background Surface Soil: Background Soil Characterization Program (EG&G, 1995)*.

Americium-241 results in sediments ranged from 0.188 to 31.3 pCi/g. These results are above background concentrations (0.022 pCi/g) and are slightly less than the Tier II soil action level of 38 pCi/g. Plutonium-239/240 results ranged from 0.298 to 182 pCi/g. These activities are also above background activities but below the Tier II soil action level of 252 pCi/g for plutonium-239/240. Activities of uranium-233/234 in sediments ranged from 0.727 up to 2.44 pCi/g. The maximum activity of uranium-233/234 slightly exceeded the background activity of 2.25 pCi/g. Uranium-235 activities ranged from 0.01 to 0.93 pCi/g, with the maximum detectable activity slightly below the background activity of 0.094 pCi/g. Uranium-238 activities ranged from 0.752 to 2.2 pCi/g. The maximum uranium-238 activity slightly exceeded the background activity of 2.00 pCi/g. Table 2 provides analytical results of sediment and QA samples.

CONTAMINATED MEDIA RESULTS

One sediment sample from the 0-6 inch interval at location 090100 exceeded the Tier II soil action level using the sum of ratios methodology. This sampling location is closest to the seep at SW053 which is also a depositional area for storm generated surface water runoff from the northwest. No samples exceeded Tier I soil action levels (Table 2).

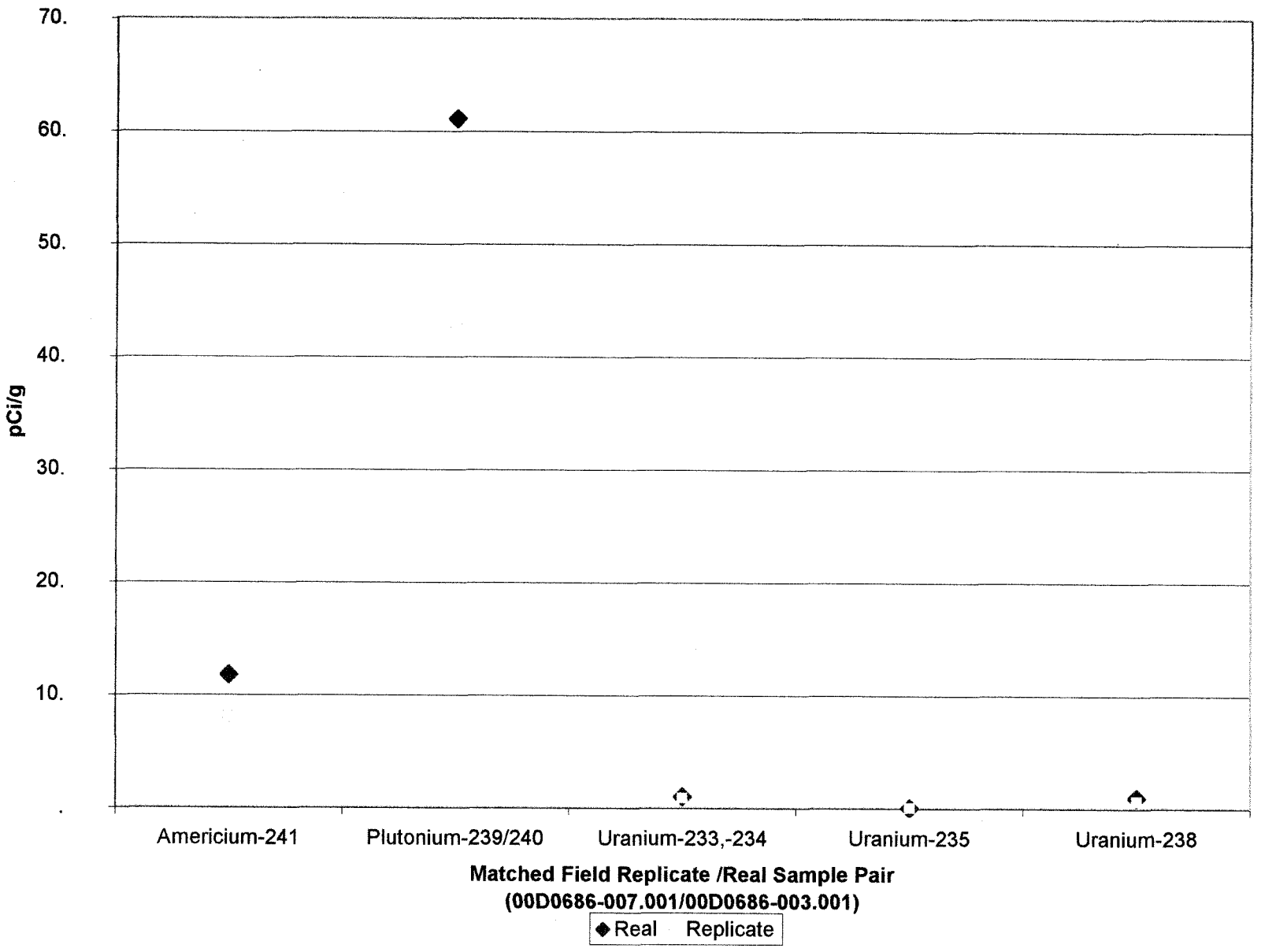

Figure 2 Matched Field Replicate/Real Sample Pair From Location 90200 0-6 Inch Depth

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Table 2. Analytical Results of Sediment Samples Collected at SW053 Wetland

LOCATION	SAMPLE INTERVAL (in.)	SAMPLE TYPE	SRT_BOTTLE_NUM	RESULT TYPE	DESCRIPTION	RESULT	UNIT	Q	V	Tier I SOR	Tier II SOR
090100	0-6	Real	00D0686-001.002	TR1	AMERICIUM-241	31.3	PCI/G		V		
090100	0-6	Real	00D0686-001.002	TR1	PLUTONIUM-239/240	182	PCI/G		V		
090100	0-6	Real	00D0686-001.002	TR1	URANIUM-233,-234	2.44	PCI/G		V		
090100	0-6	Real	00D0686-001.002	TR1	URANIUM-235	0.093	PCI/G	J	V		
090100	0-6	Real	00D0686-001.002	TR1	URANIUM-238	2.2	PCI/G		V	0.28	1.57
090100	6-12	Real	00D0686-002.002	TR1	AMERICIUM-241	0.356	PCI/G		V		
090100	6-12	Real	00D0686-002.002	TR1	PLUTONIUM-239/240	2.66	PCI/G		V		
090100	6-12	Real	00D0686-002.002	TR1	URANIUM-233,-234	0.85	PCI/G	J	V		
090100	6-12	Real	00D0686-002.002	TR1	URANIUM-235	0.07	PCI/G	U	V		
090100	6-12	Real	00D0686-002.002	TR1	URANIUM-238	0.752	PCI/G	J	V	0.01	0.03
090200	0-6	Real	00D0686-003.002	TR1	AMERICIUM-241	11.8	PCI/G		V		
090200	0-6	Real	00D0686-003.002	TR1	PLUTONIUM-239/240	61.1	PCI/G		V		
090200	0-6	Real	00D0686-003.002	TR1	URANIUM-233,-234	1.03	PCI/G	B	V		
090200	0-6	Real	00D0686-003.002	TR1	URANIUM-235	0.035	PCI/G	U	V		
090200	0-6	Real	00D0686-003.002	TR1	URANIUM-238	0.987	PCI/G	J	V	0.10	0.57
090200	0-6	Replicate	00D0686-007.001	TR1	AMERICIUM-241	8	PCI/G		V		
090200	0-6	Replicate	00D0686-007.001	TR1	PLUTONIUM-239/240	42.5	PCI/G		V		
090200	0-6	Replicate	00D0686-007.001	TR1	URANIUM-233,-234	0.882	PCI/G	J	V		
090200	0-6	Replicate	00D0686-007.001	TR1	URANIUM-235	0.034	PCI/G	U	V		
090200	0-6	Replicate	00D0686-007.001	TR1	URANIUM-238	0.688	PCI/G	J	V	0.07	0.39
090200	6-12	Real	00D0686-004.002	TR1	AMERICIUM-241	0.188	PCI/G	J	V		
090200	6-12	Real	00D0686-004.002	TR1	PLUTONIUM-239/240	0.298	PCI/G	J	V		
090200	6-12	Real	00D0686-004.002	TR1	URANIUM-233,-234	0.727	PCI/G	J	V		
090200	6-12	Real	00D0686-004.002	TR1	URANIUM-235	0.068	PCI/G	J	V		
090200	6-12	Real	00D0686-004.002	TR1	URANIUM-238	0.855	PCI/G	J	V	0.00	0.02

Q - Laboratory Qualification
V - Validation/Validated
SOR - Sum of Ratios

Table 2. Analytical Results of Sediment Samples Collected at SW053 Wetland

LOCATION	SAMPLE INTERVAL (in.)	SAMPLE TYPE	SRT_BOTTLE_NUM	RESULT TYPE	DESCRIPTION	RESULT	UNIT	Q	V	Tier I SOR	Tier II SOR
090300	0-6	Real	00D0686-005.002	TR1	AMERICIUM-241	5.06	PCI/G		V		
090300	0-6	Real	00D0686-005.002	TR1	PLUTONIUM-239/240	30	PCI/G		V		
090300	0-6	Real	00D0686-005.002	TR1	URANIUM-233,-234	1.13	PCI/G	B	V		
090300	0-6	Real	00D0686-005.002	TR1	URANIUM-235	0.01	PCI/G	U	V		
090300	0-6	Real	00D0686-005.002	TR1	URANIUM-238	1.29	PCI/G		V	0.05	0.27
090300	6-12	Real	00D0686-006.002	TR1	AMERICIUM-241	0.295	PCI/G	J	V		
090300	6-12	Real	00D0686-006.002	TR1	PLUTONIUM-239/240	1.1	PCI/G		V		
090300	6-12	Real	00D0686-006.002	TR1	URANIUM-233,-234	1.05	PCI/G	B	V		
090300	6-12	Real	00D0686-006.002	TR1	URANIUM-235	0.035	PCI/G	U	V		
090300	6-12	Real	00D0686-006.002	TR1	URANIUM-238	0.964	PCI/G	J	V	0.00	0.02
090300		Rinsate	00D0687-001.002	TR1	AMERICIUM-241	0.008	PCI/L	U	UJ		
090300		Rinsate	00D0687-001.002	TR1	PLUTONIUM-239/240	0.07	PCI/L		V		
090300		Rinsate	00D0687-001.002	TR1	URANIUM-233,-234	0.002	PCI/L	U	V		
090300		Rinsate	00D0687-001.002	TR1	URANIUM-235	-0.001	PCI/L	U	V		
090300		Rinsate	00D0687-001.002	TR1	URANIUM-238	-0.015	PCI/L	U	V	NA	NA

Q - Laboratory Qualification
V - Validation/Validated
SOR - Sum of Ratios

ATTACHMENT

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: 5[illegible]0100 (Rev 4/15/10)
Location - North: _____ East: _____
Date: 12/27/99
Geologist: M. Wood
Drilling Equip.: slide hammer

Surface Elevation: _____
Area: Ann Zone
Total Depth: 1.55
Company: RMRS Project No.: _____
Sample Type: tube

RMRS LOGGING SUPERVISOR APPROVAL _____ DATE 6/26/00

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
R,N 00D0886-			001.001 001.002				Pt			0.0 - 0.45 Peat w/some silt/clay dk gray, v.ly soft, saturated
								0.5		
			002.001 002.002				MH			0.45 - 0.66' Silt, MH, w/some f-m sand dk gray to black (N.) v. soft, saturated
								1.0		0.66 - 1.15 sandy clay Sandy Silt ~ colluvium on bedrock ~ siltstone/claystone highly weathered, some roots firm
							ML/CL	1.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

(4011-933-0134-9308 Form GT 1A x050 V2)

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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

Borehole Number: ~~SED~~ 90200 (MW 6/19/00)
Location - North: East:
Date: 12/27/99
Geologist: M. Weed
Drilling Equip.: Slide Hammer

Surface Elevation:
Area: 903 Lip Area / Am Zone
Total Depth:
Company: RMRS Project No.
Sample Type: tube / grab

RMRS LOGGING SUPERVISOR APPROVAL [signature] DATE 6/26/00

TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/ LITHOLOGIC LOG	SAMPLE DESCRIPTION
LIN	00D0686		003.001				OH			0.0 - 0.3 Sandy Clay (OH) dark gray, very soft, ab roots very plastic, saturated
			003.002							
			007.001							
								0.5		0.3 - 1.0 Sandy Silt (MH) orange brown, loose to soft, plastic, some roots, trace f gravel, thin 1cm sand interbeds, saturated
			004.001							
			004.002				MH			
								1.0		
								1.5		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

(4011-930-0134-930)(Form GT 1A x 03/01 V2)

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U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT

FORM PRO.101A

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE BOREHOLE LOG

PAGE 1 OF 1

Borehole Number: SEB90300
Location - North: _____ East: _____
Date: 12/27/99
Geologist: M. Ward
Drilling Equip. Slide hammer

Surface Elevation:
Area: 903 Lip Area / Am zone
Total Depth: 2.2 ft
Company: RMRS Project No.
Sample Type: tube / grab

RMRS LOGGING SUPERVISOR
APPROVAL _____ DATE 6/26/00

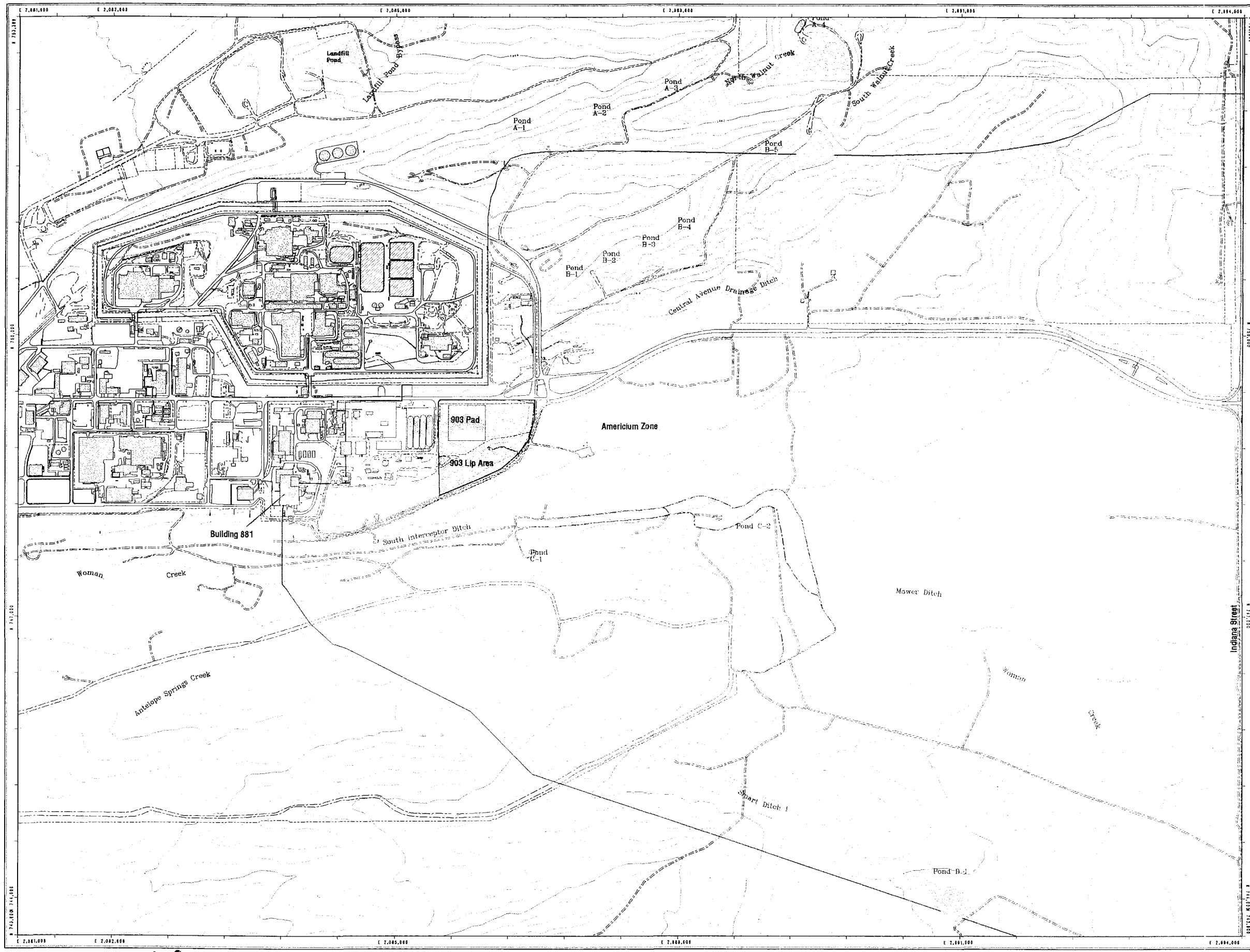
TOP/BOTTOM OF CORE IN BOX	TOP/BOTTOM OF INTERVAL	FEET OF CORE IN INTERVAL (FIELD MEASUREMENT)	SAMPLE NUMBER	FRACTURE ANGLE	BEDDING ANGLE	GRAIN SIZE DISTRIBUTION	USCS SYMBOL	DEPTH IN FEET	SOIL/LITHOLOGIC LOG	SAMPLE DESCRIPTION
2 in			005.001				CL/			0.0 - 0.8 claystone / CL
00D0686			005.002				BR			dark gray - olive gray, crots,
								0.5		soft, friable, plastic, saturated
			006.001							becomes blocky at 0.5 ft,
			006.002				claystone			
								1.0		

NOTES: General: USCS is modified for this log as follows:
Materials amounts are estimated by % volume instead of % weight.
(1) Badly broken core, accurate footage measurements not possible.
(2) Core breaks cannot be matched, accurate footage measurements not possible.

Procedure No. RMRS/OPS-PRO.101
Revision 0
Date effective: 12/31/98

(4011-930-0134-930)(Form CT 1A x 03/01 V2)

286/286



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:
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.

Scale = 1 : 12690
1 inch represents approximately 1058 feet

260 0 500 1000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Prepared by:
RMRS Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

MAP ID: 99-0403 September 20, 1999

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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:
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

Scale = 1 : 3870
1 inch represents approximately 323 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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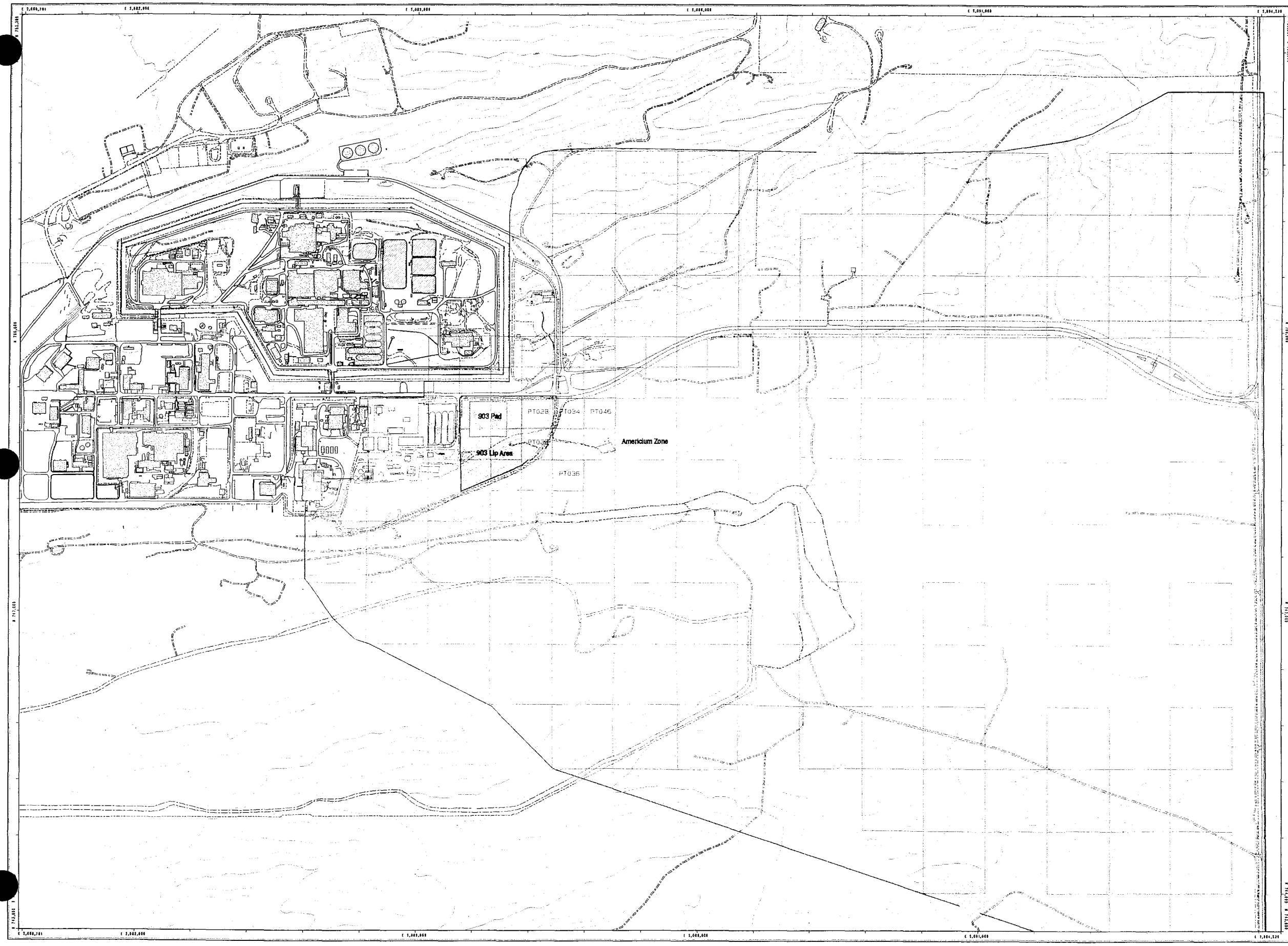

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

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:
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.

Scale = 1 : 12630
1 inch represents approximately 1053 feet

250 0 500 1000 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
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Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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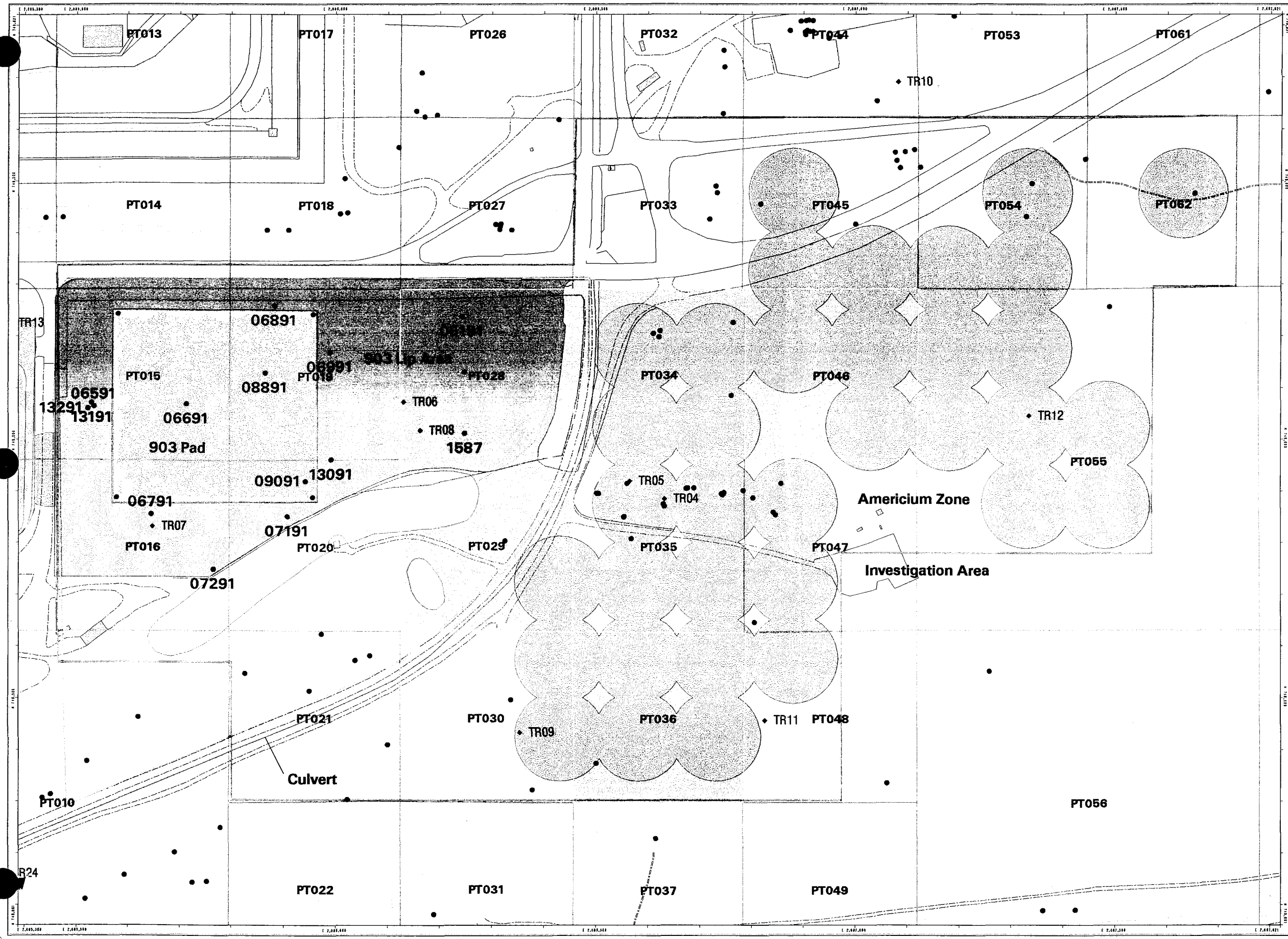

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

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:
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 Reitman, Gamma Survey Group, Safeguard Measurements, EG&G Rocky Flats, Inc. June 1994

Scale = 1 : 2270
1 inch represents approximately 189 feet

50 0 100 200 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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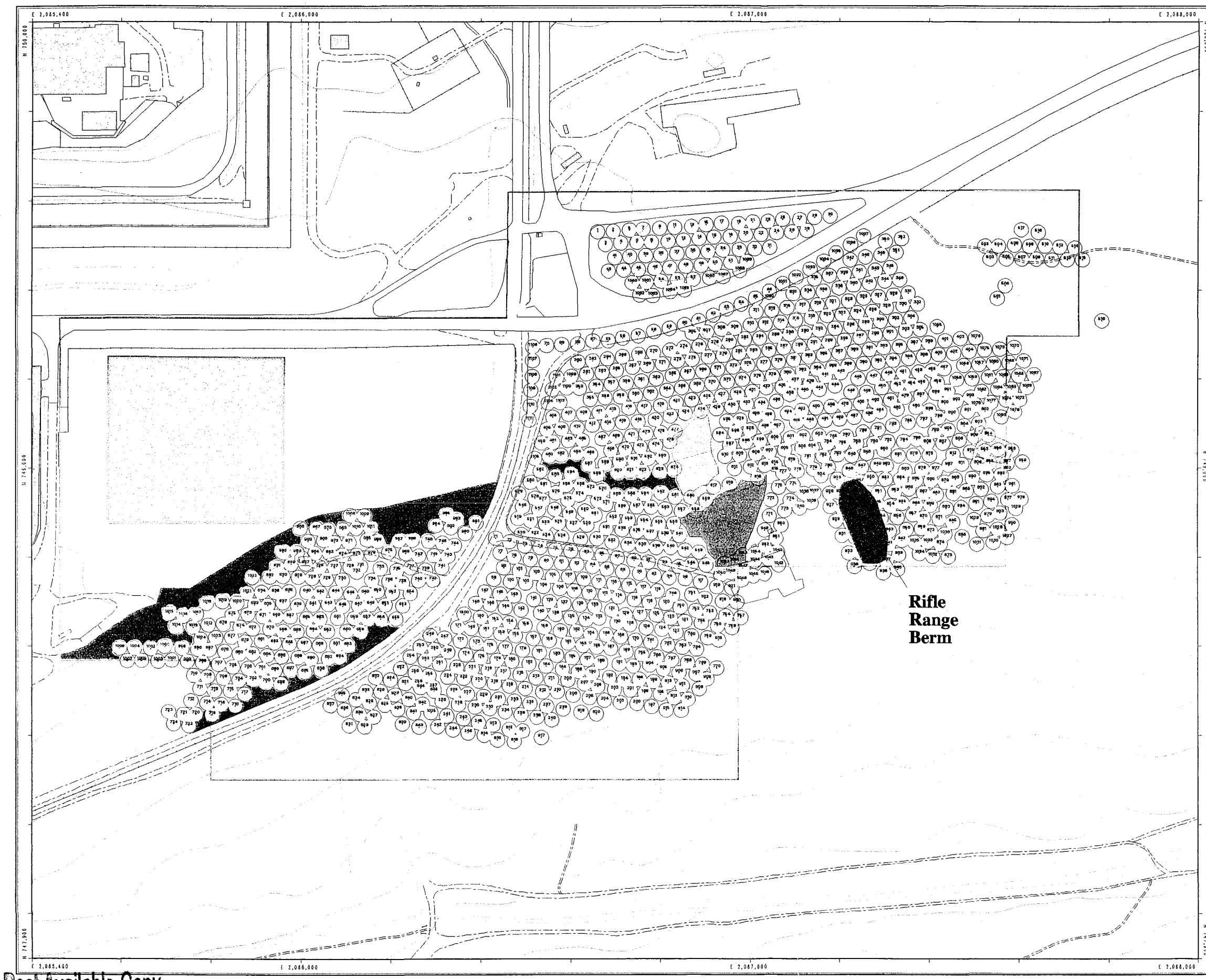

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

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:
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.

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

Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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For more information about GIS
Please Contact Wendell Chavez
at ext. 7707 or page 212-6690
GIS website: http://rfetsfp/gis

MAP ID: 99-0408

March 29, 2000

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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

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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MAP ID: 99-0445

September 15, 1999

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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

30 0 60 120 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

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MAP ID: 99-0445

September 20, 1999

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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
Datum: NAD27

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MAP ID: 99-0446

September 16, 1999

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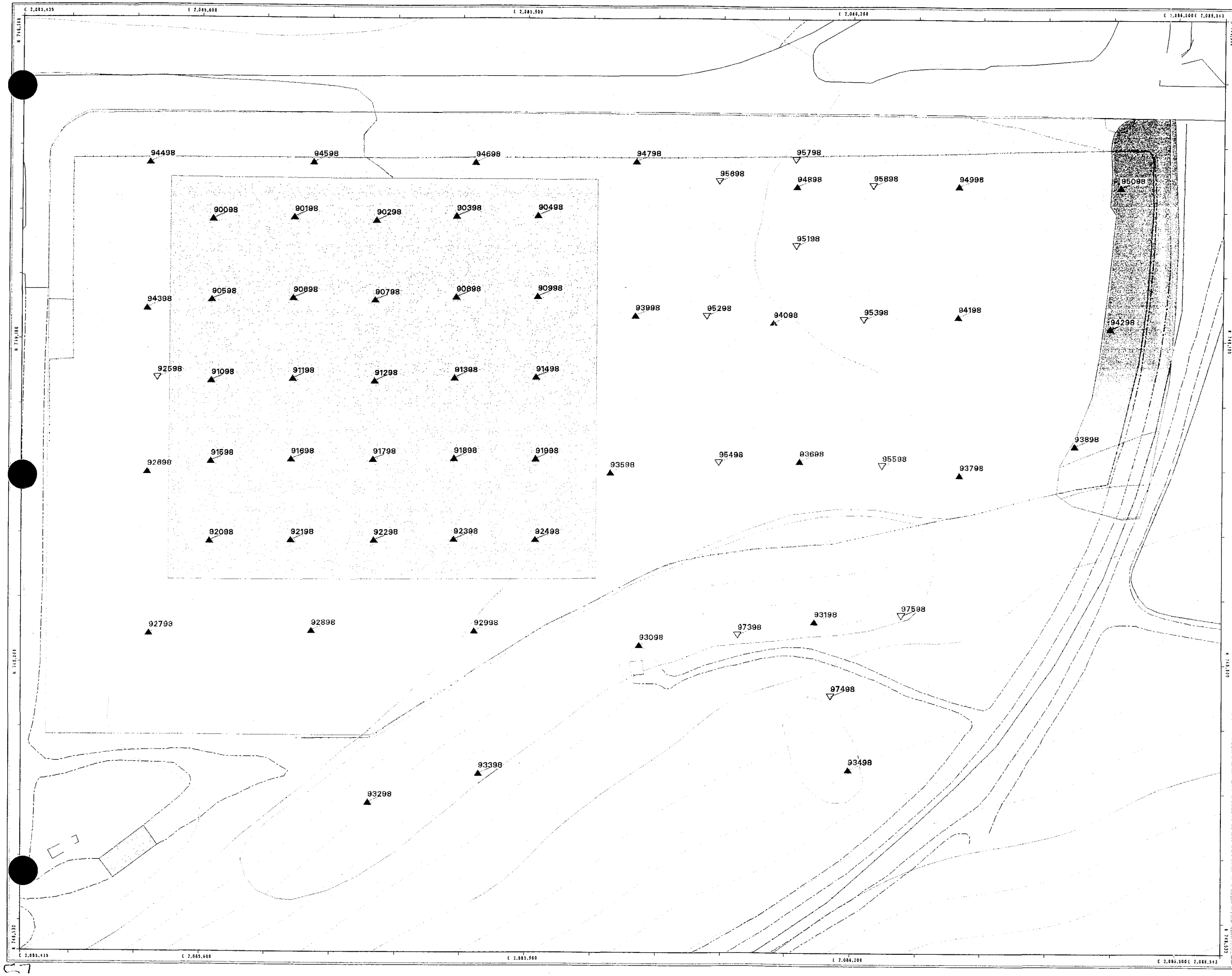

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

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:
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.

Scale = 1 : 1030
1 inch represents approximately 86 feet

25 0 50 100ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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Rocky Flats Environmental Technology Site

Prepared by:

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For more information about GIS Please Contact Wendell Chavez at ext. 7707 or page 212-0000
GIS website: http://rfetsh/gis

MAP ID: 99-0408

March 29, 2000

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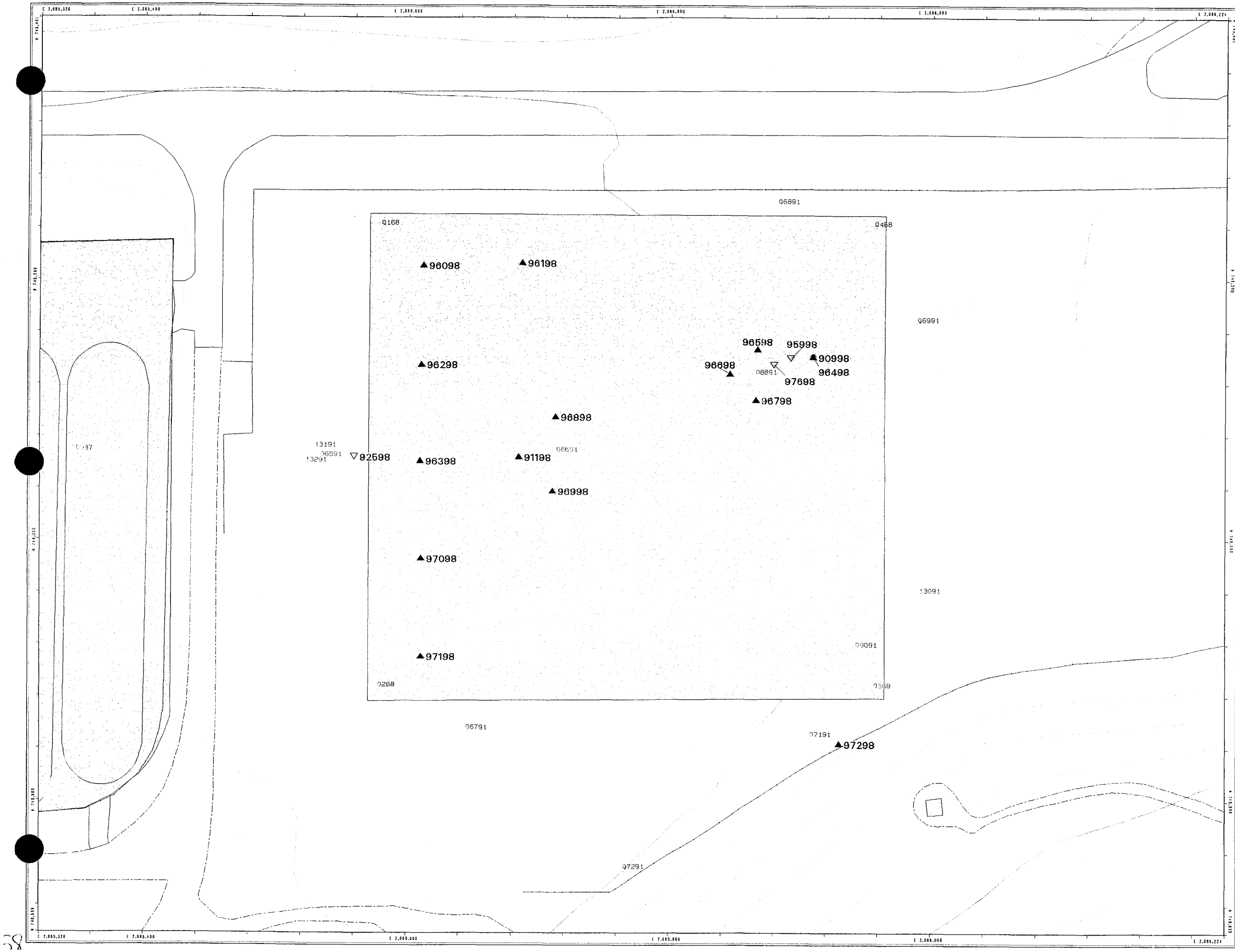

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

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:
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.

Scale = 1 : 830
1 inch represents approximately 69 feet

20 0 40 80ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Prepared by:

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For more information about GIS Please Contact Wendell Choate at ext. 7707 or page 212-4990
GIS website: http://rmrsgis/rgis

MAP ID: 99-0408

March 29, 2000

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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 4-2

EXPLANATION

Gamma Survey Locations

Investigative Area

HPGe Data Ranges

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

25 0 50 100ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Prepared by:

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Golden, CO 80402-0464

MAP ID: 99-0445

September 17, 1999

NT_Svr w:/projects/fy99/99-0445/tier_bestfit-bb.aml

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100

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

Distribution of Am-241 in Surface Soil - HPGe Survey

Figure 4-3

EXPLANATION

- Am-241 Levels and Isoactivity Contour (Contour Interval = 10 pCi/g)
- Extent of RFCA Tier I Exceedances (215 pCi/g)
- Extent of RFCA Tier II Exceedances (38 pCi/g)
- Investigation Area

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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 Montana 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.

Scale = 1 : 2410
1 inch represents approximately 201 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
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Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

MAP ID: 99-0408 September 15, 1999

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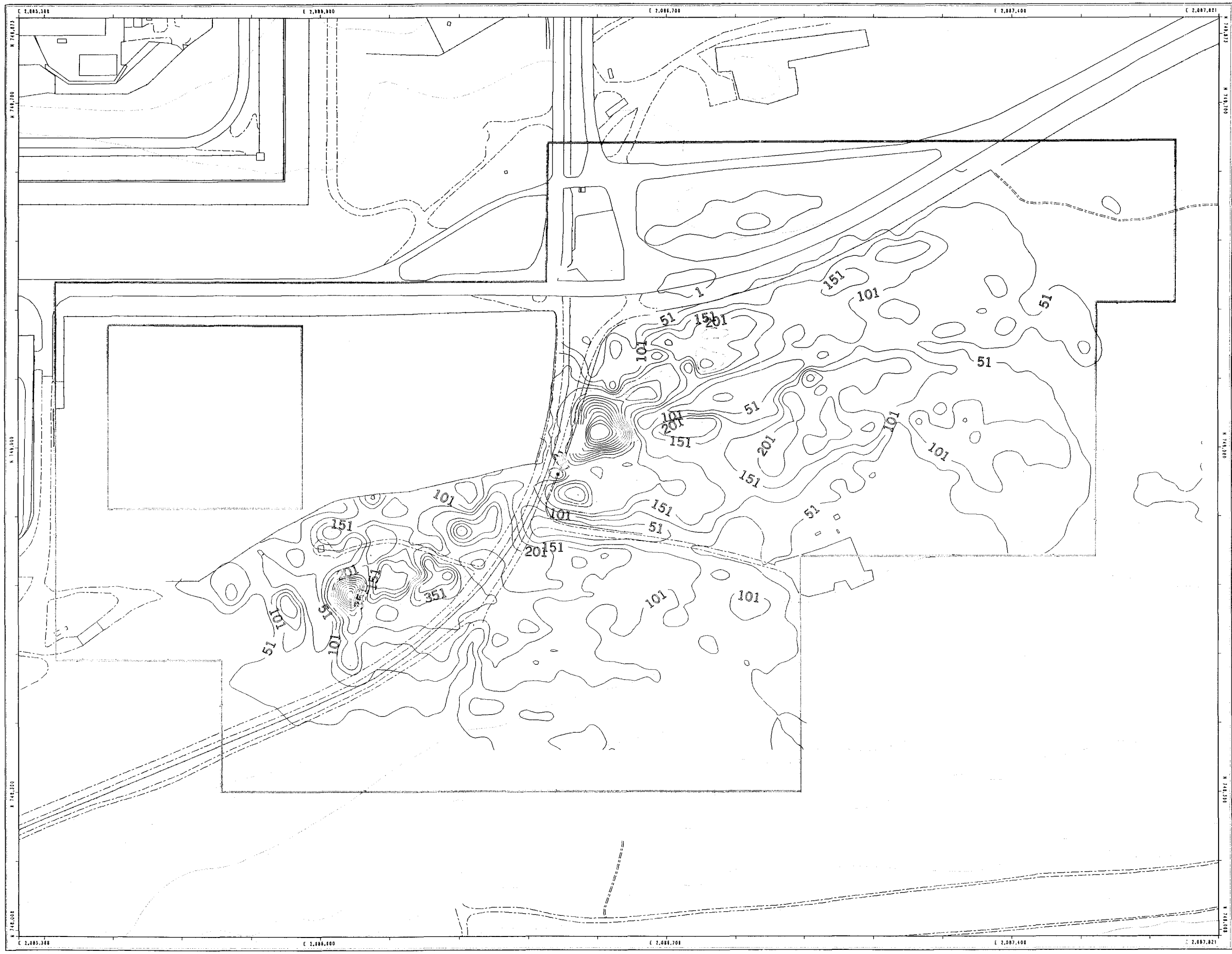

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Distribution of Pu-239/240 in Surface Soil - HPGe Survey

Figure 4-4

EXPLANATION

- Pu-239/240 Levels and Isoactivity Contour (Contour Interval = 100 pCi/g)
- Extent of RFCA Tier I Exceedances (1429 pCi/g)
- Extent of RFCA Tier II Exceedances (252 pCi/g)
- Investigation Area

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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.

Scale = 1 : 2410
1 inch represents approximately 201 feet

60 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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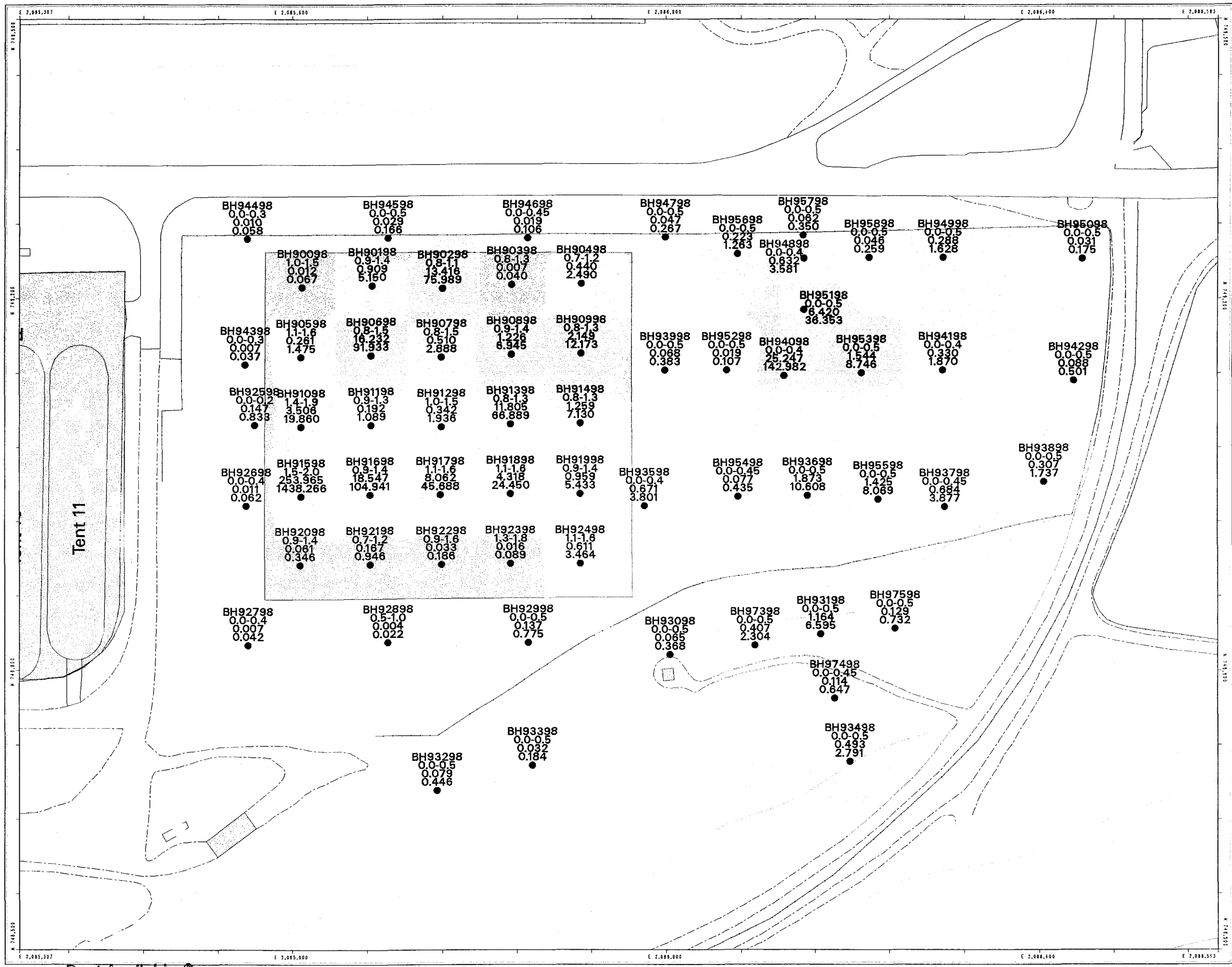

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Native 1 Soil Horizon

Figure 4-6

EXPLANATION

Boreholes locations

- Location
- Sample Depth (ft.)
- Tier I Sum of Ratio
- Tier II Sum of Ratio

Exceed Tier I

Exceed Tier II

Standard Map Features

- 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:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
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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.

Scale = 1 : 1290
1 inch represents approximately 108 feet

25 0 50 100ft

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

Distribution of Am-241 in Native 1 Soil Horizon

Figure 4-7

EXPLANATION

- Am-241 Levels and Isoactivity Contour (Contour Interval = 2000 pCi/g)
- Extent of RFCA Tier I Exceedances (215 pCi/g)
- Extent of RFCA Tier II Exceedances (38 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial flyover 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.

Scale = 1 : 1080
1 inch represents 90 feet

25 0 50 100 ft

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

Distribution of Pu-239/240 in Native 1 Soil Horizon

Figure 4-8

EXPLANATION

- Pu-239/240 Levels and Isoactivity Contour (Contour Interval = 10,000 pCi/g)
- Extent of RFCA Tier I Exceedances (1429 pCi/g)
- Extent of RFCA Tier II Exceedances (252 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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.

Scale = 1 : 1080
1 inch represents 90 feet

25 0 50 100 ft

State Plane Coordinate Projection
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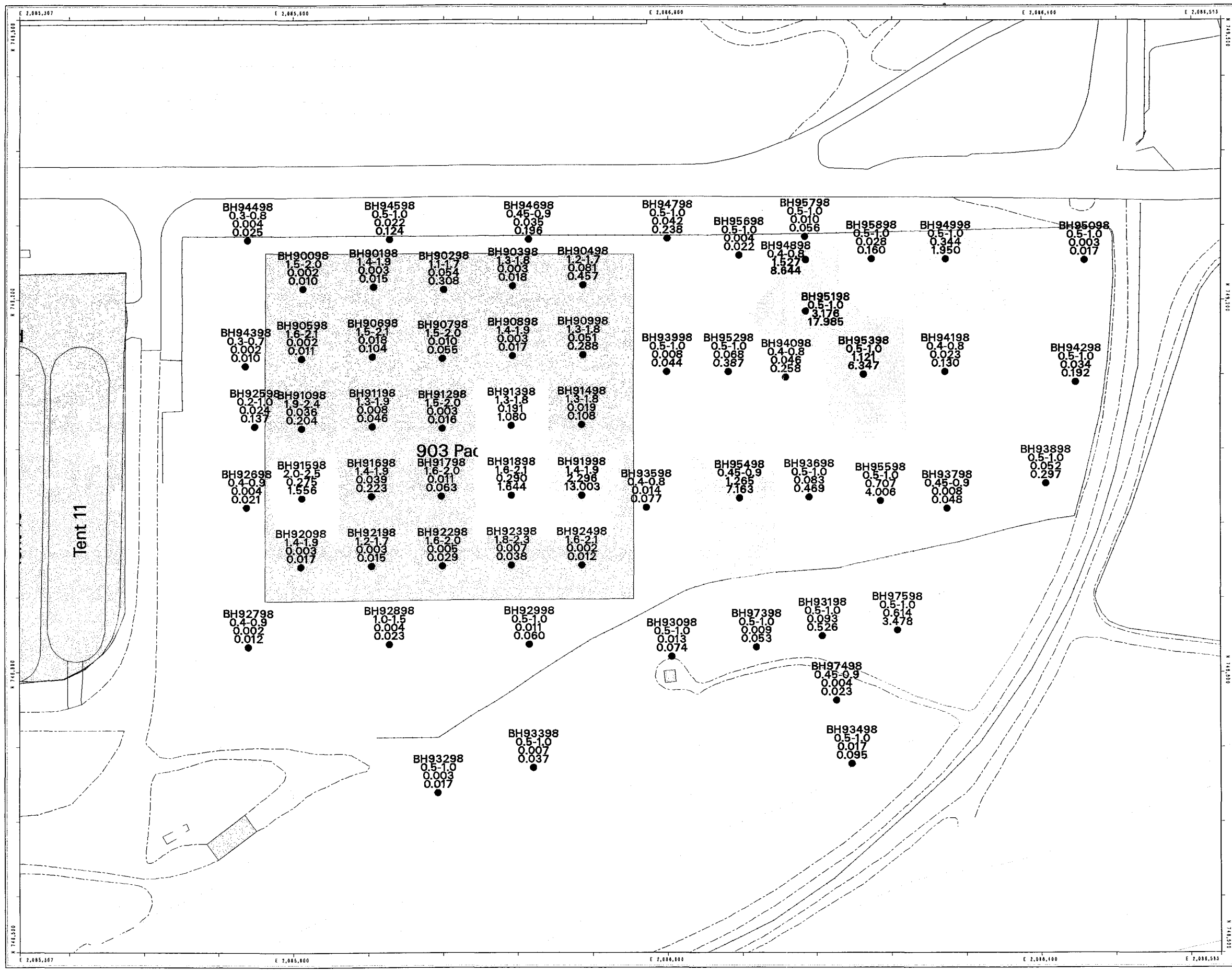

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Native 2 Soil Horizon

Figure 4-9

EXPLANATION

Boreholes locations

- Location
  Sample Depth (ft.)
  Tier I Sum of Ratio
  Tier II Sum of Ratio
- Exceed Tier I
- Exceed Tier II

Standard Map Features

- 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:
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) was 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, Vector 1997.

Scale = 1 : 1290
1 inch represents approximately 108 feet

25 0 50 100ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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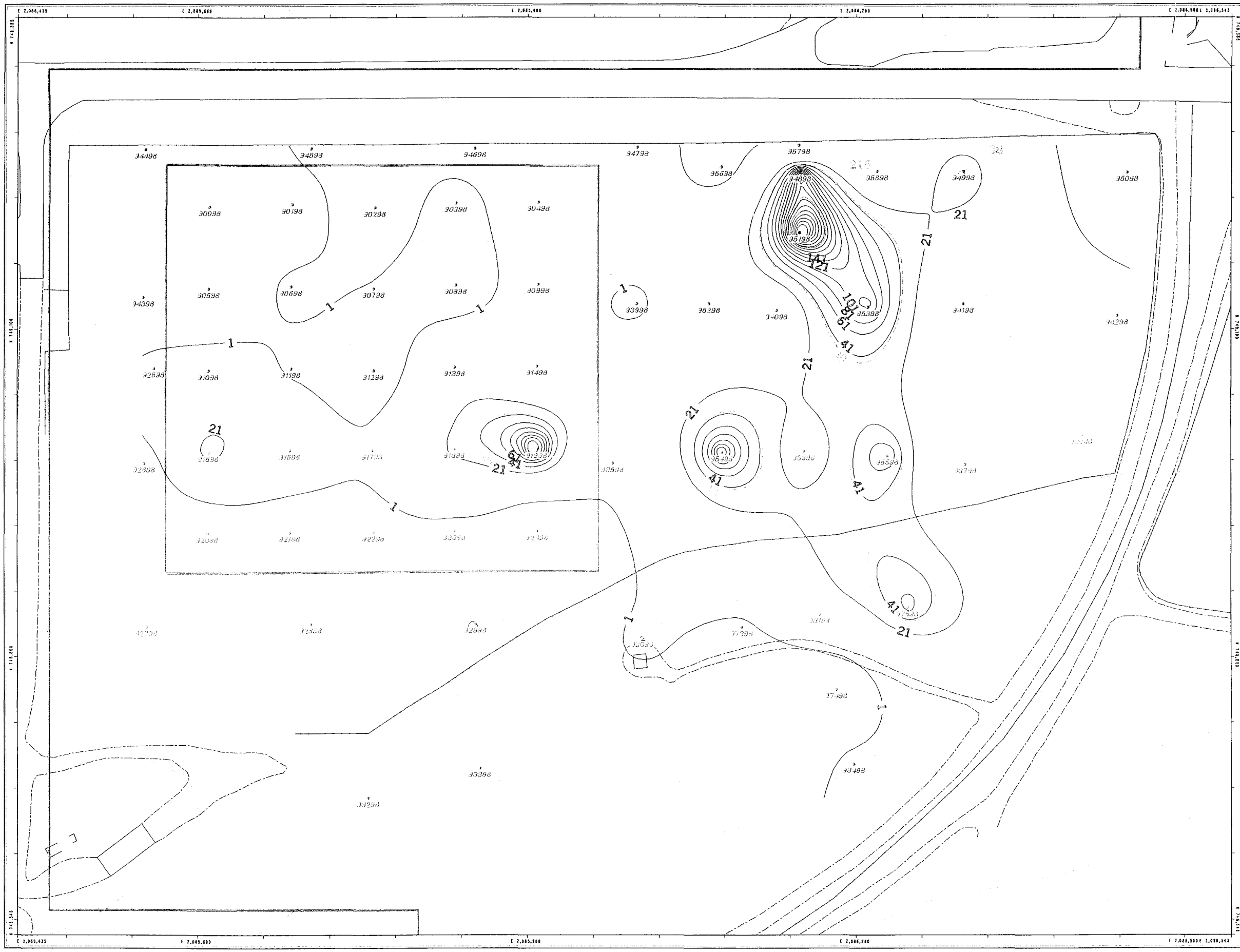

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Distribution of Am-241 in Native 2 Soil Horizon

Figure 4-10

EXPLANATION

- Am-241 Levels and Isoactivity Contour (Contour Interval = 20 pCi/g)
- Extent of RFCA Tier I Exceedances (215 pCi/g)
- Extent of RFCA Tier II Exceedances (38 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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.

Scale = 1 : 1080
1 inch represents 90 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

Distribution of Pu-239/240 in Native 2 Soil Horizon

Figure 4-11

EXPLANATION

- Pu-239/240 Levels and Isoactivity Contour (Contour Interval = 100 pCi/g)
- Extent of RFCA Tier I Exceedances (1429 pCi/g)
- Extent of RFCA Tier II Exceedances (252 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrographs, 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 LATICE 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.

Scale = 1 : 1080
1 inch represents 90 feet

25 0 50 100 ft

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 Native 3 Soil Horizon

Figure 4-12

EXPLANATION

Boreholes locations

- Location
  Sample Depth (ft.)
  Tier I Sum of Ratio
  Tier II Sum of Ratio
- Exceed Tier I
- Exceed Tier II

Standard Map Features

- 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:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. USGS
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.

Scale = 1 : 1290
1 inch represents approximately 108 feet

25 0 50 100ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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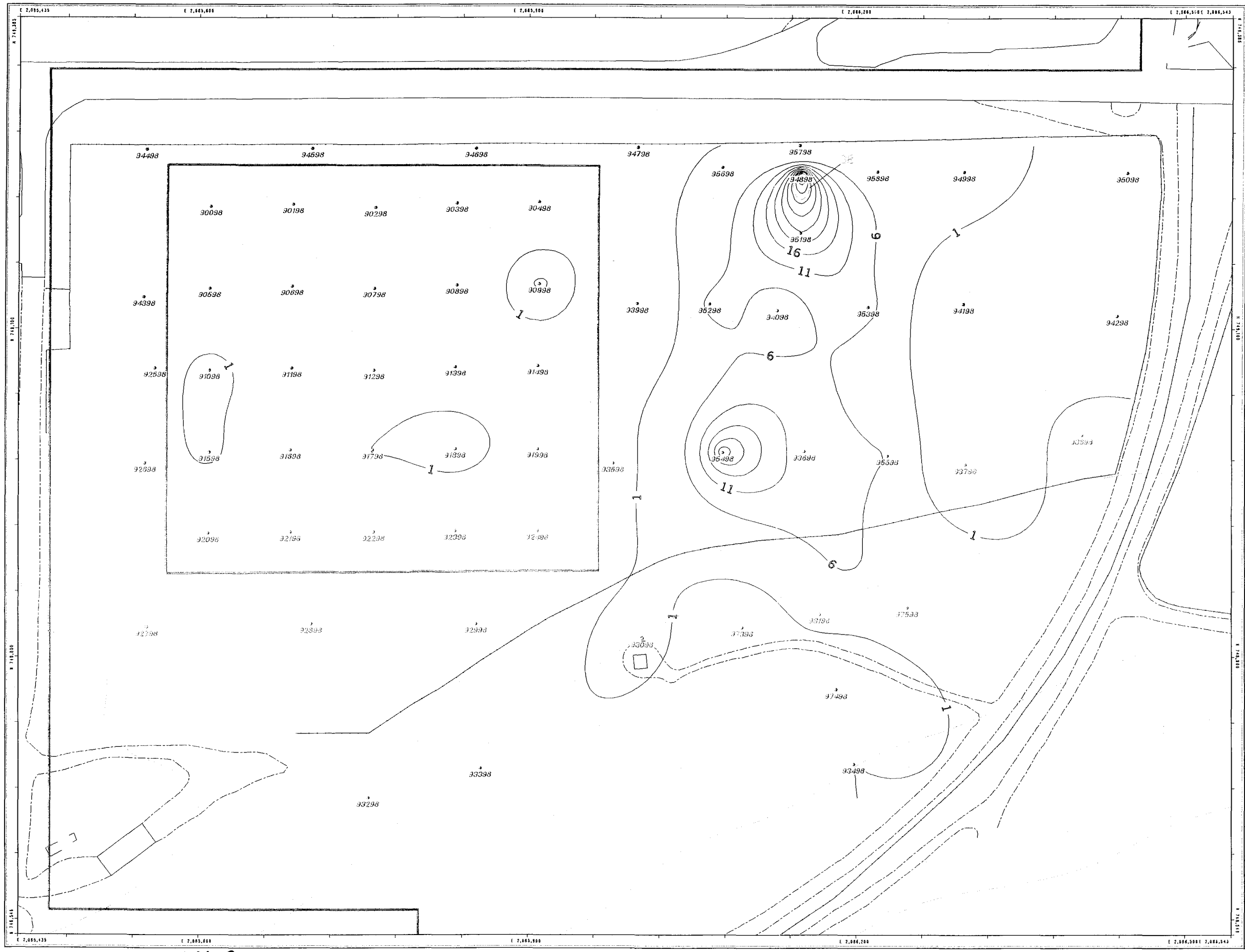

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Distribution of Am-241 in Native 3 Soil Horizon

Figure 4-13

EXPLANATION

- Am-241 Levels and Isoactivity Contour (Contour Interval = 5 pCi/g)
- Extent of RFCA Tier I Exceedances (215 pCi/g)
- Extent of RFCA Tier II Exceedances (38 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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.

Scale = 1 : 1080
1 inch represents 90 feet

25 0 50 100 ft

State Plane Coordinate Projection
Colorado Central Zone
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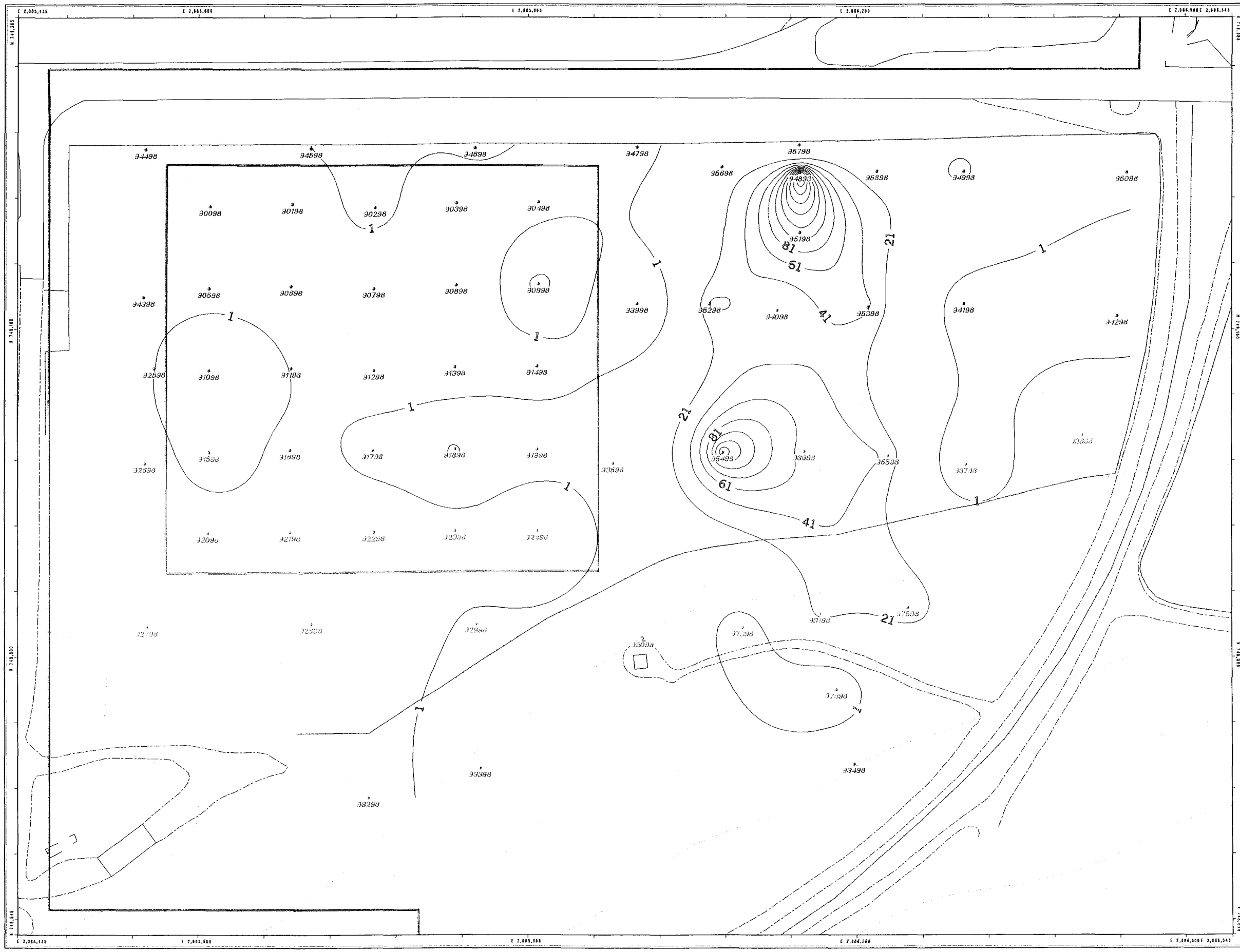

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Distribution of Pu-239/240 in Native 3 Soil Horizon

Figure 4-14

EXPLANATION

- Pu-239/240 Levels and Isoactivity Contour (Contour Interval = 20 pCi/g)
- Extent of RFCA Tier I Exceedances (1429 pCi/g)
- Extent of RFCA Tier II Exceedances (252 pCi/g)
- Investigation Area
- Borehole Locations

Standard Map Features

- Buildings and other structures
- Fences and other barriers
- Contour (20-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
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.

Scale = 1 : 1090
1 inch represents 90 feet

25 0 50 100 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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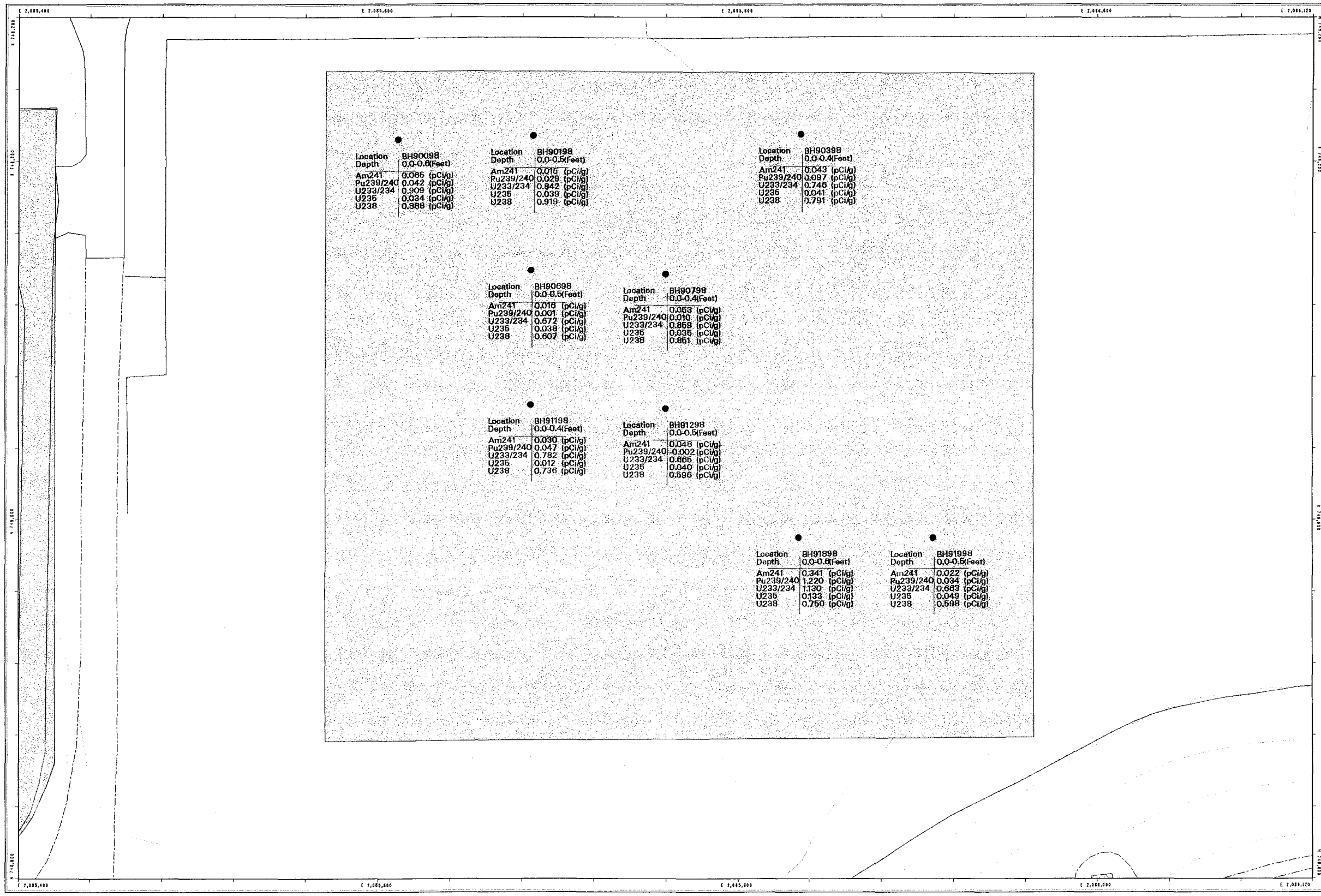

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Radionuclide Distribution in Asphalt

Figure 4-15

EXPLANATION

Boreholes locations

- Location
- Sample Depth (ft.)
- AM241 (pCi/g)
- PU239/240 (pCi/g)
- U233/234 (pCi/g)
- U235 (pCi/g)
- U238 (pCi/g)

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/85
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 w as captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.

Scale = 1 : 700
1 inch represents approximately 58 feet

15 0 30 60 ft

State Plane Coordinate Projection
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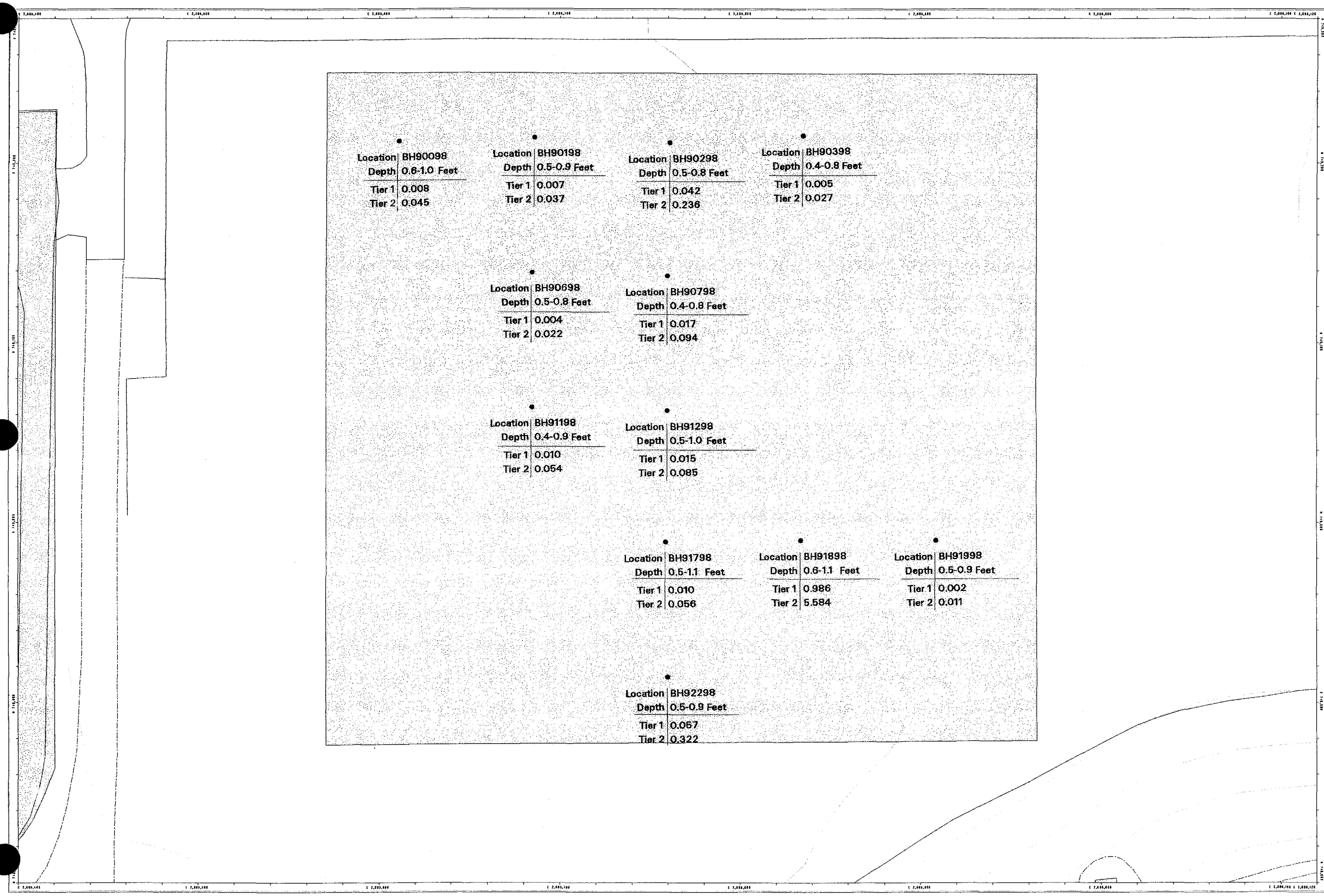

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

RSAL Exceedances in Artificial Fill Beneath the 903 Pad

Figure 4-16

EXPLANATION

Boreholes locations

- Location
  Sample Depth (ft.)
  Tier I Sum of Ratio
  Tier II Sum of Ratio

Standard Map Features

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1995
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.

Scale = 1 : 660
1 inch represents 55 feet

State Plane Coordinate Projection
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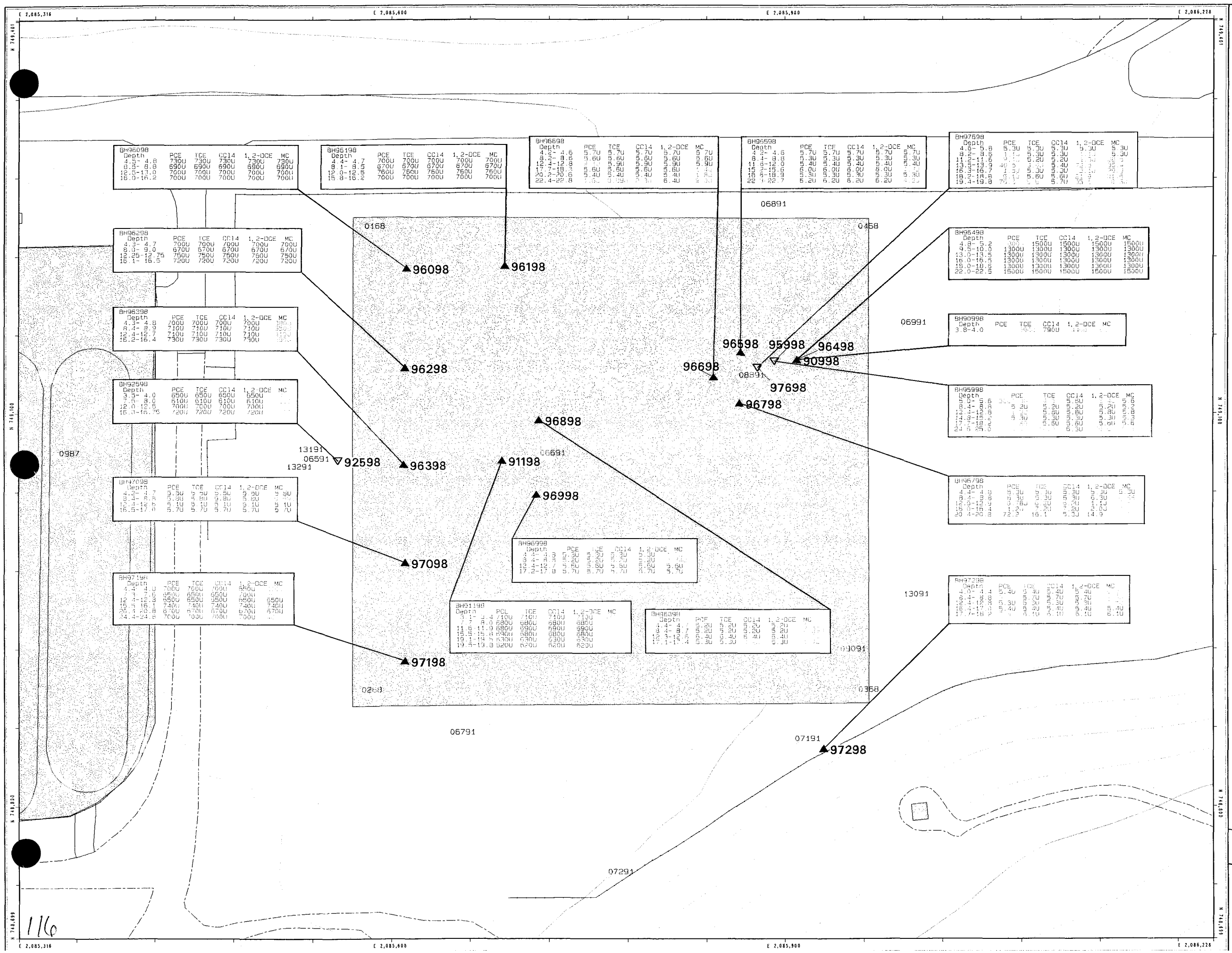

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

VOC Distribution in Soil

Figure 4-18

EXPLANATION

- ▲ VOC Boreholes, Original
- ▽ VOC Boreholes, Stepout
- *Radiological Borehole*
- ● Borehole location
  BoreHole PCE TCE CCL4 1,2-DCE
  Sample Depth Results in Feet
  VOC Compound Results in ug/kg
- Groundwater Well

NOTE:
VOC detections in blue
Proposed Tier I Exceedance in red
Proposed Tier II Exceedance in green
PCE = Tetrachloroethene
TCE = Trichloroethene
CCL4 = Carbon Tetrachloride
1,2-DCE = 1,2-Cis-Dichloroethylene
MC = Methylene Chloride

U = Undetected, Contract Required Quantitative Limit
J = Associated Value is an Estimated Quantity
D = Dilution

Standard Map Features

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

Scale = 1 : 830
1 inch represents approximately 69 feet

25 0 50 100ft

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Colorado Central Zone
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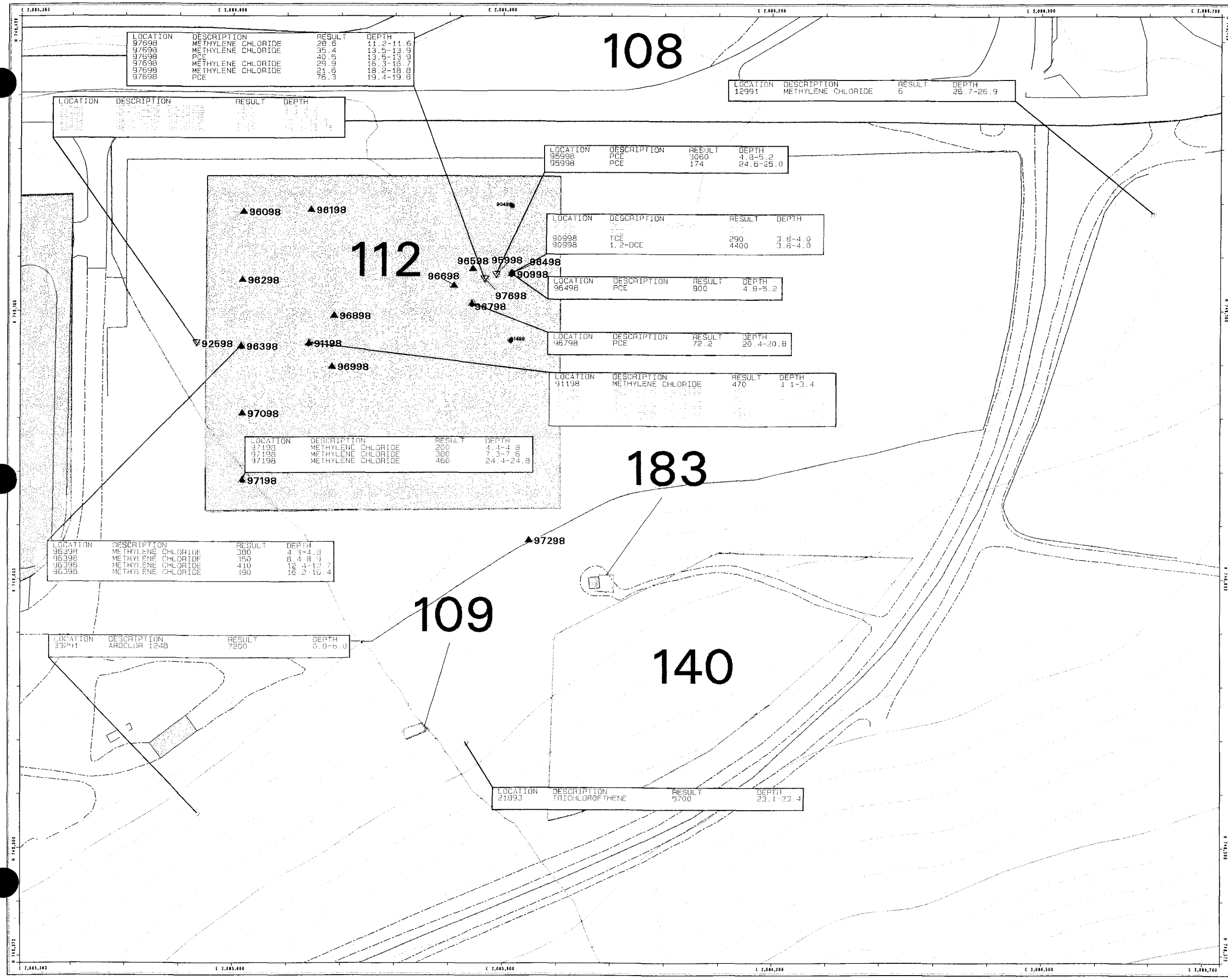

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Extent of Tier I and Tier II Subsurface SAL Contamination Figure 4-19

EXPLANATION

All Wells and Borings

- Monitoring Wells
- Soil Boreholes

Historical Soil Samples

- Monitoring Wells
- Soil Boreholes

903 Pad VOC Boreholes

- ▲ VOC Boreholes, Original
- ▽ VOC Boreholes, Stepout
- Radiological Borehole

Individual Hazardous Substance Sites

- Former OU2, Buffer Zone and Industrial Area IHSS

Standard Map Features

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

Scale = 1 : 1260
1 inch represents 105 feet

25 0 50 100 ft

State Plane Coordinate Projection
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Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Composite Map of Tier I RSAL Exceedances

Figure 5-1

EXPLANATION

- Native 1 (0-6 inches)
- Native 2 (6-12 inches)
- Native 1 and Native 2 (0-12 inches)

Standard Map Features

- 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 : 1290
1 inch represents approximately 108 feet

25 0 50 100 ft

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

Composite Map of Tier II RSAL Exceedances

Figure 5-2

EXPLANATION

- Native 1 (0-6 inches)
- Native 2 (6-12 inches)
- Native 3 (12-18 inches)
- Native 1 and Native 2 (0-12 inches)
- Native 2 and Native 3 (6-18 inches)
- Native 1, Native 2 and Native 2 (0-18 inches)

Standard Map Features

- 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 : 2330
1 inch represents approximately 194 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
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P.O. Box 464
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MAP ID: 2k-0182

March 28, 2000

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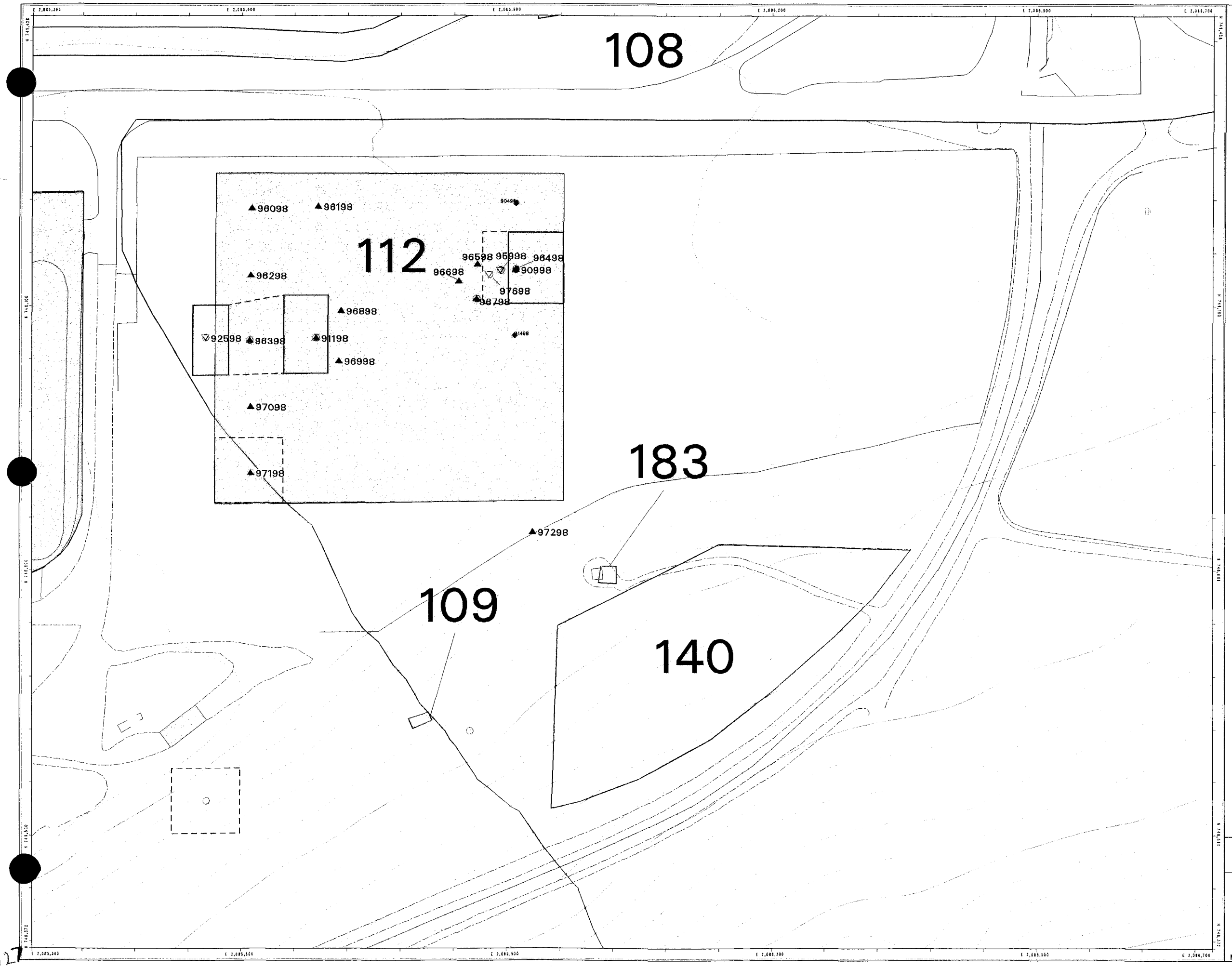

Characterization Report for the 903 Drum Storage Area, 903 Lip Area and Americium Zone

Extent of Tier I and Tier II Subsurface SAL Contamination Figure 5-3

EXPLANATION

All Wells and Borings

- Monitoring Wells
- Soil Boreholes

Historical Soil Samples

- Monitoring Wells
- Soil Boreholes

903 Pad VOC Boreholes

- VOC Boreholes, Original
- VOC Boreholes, Stepout
- Radiological Borehole

903 Pad SSAL Areal Exceedences

- Areal Extent of Proposed Tier I SSAL Exceedences
- Areal Extent of Proposed Tier II SSAL Exceedences

Individual Hazardous Substance Sites

- Former OU2, Buffer Zone and Industrial Area IHSS

Standard Map Features

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

Scale = 1 : 1280
1 inch represents 105 feet

25 0 50 100 ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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

Prepared by:

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MAP ID: 2k-0166 March 06, 2000

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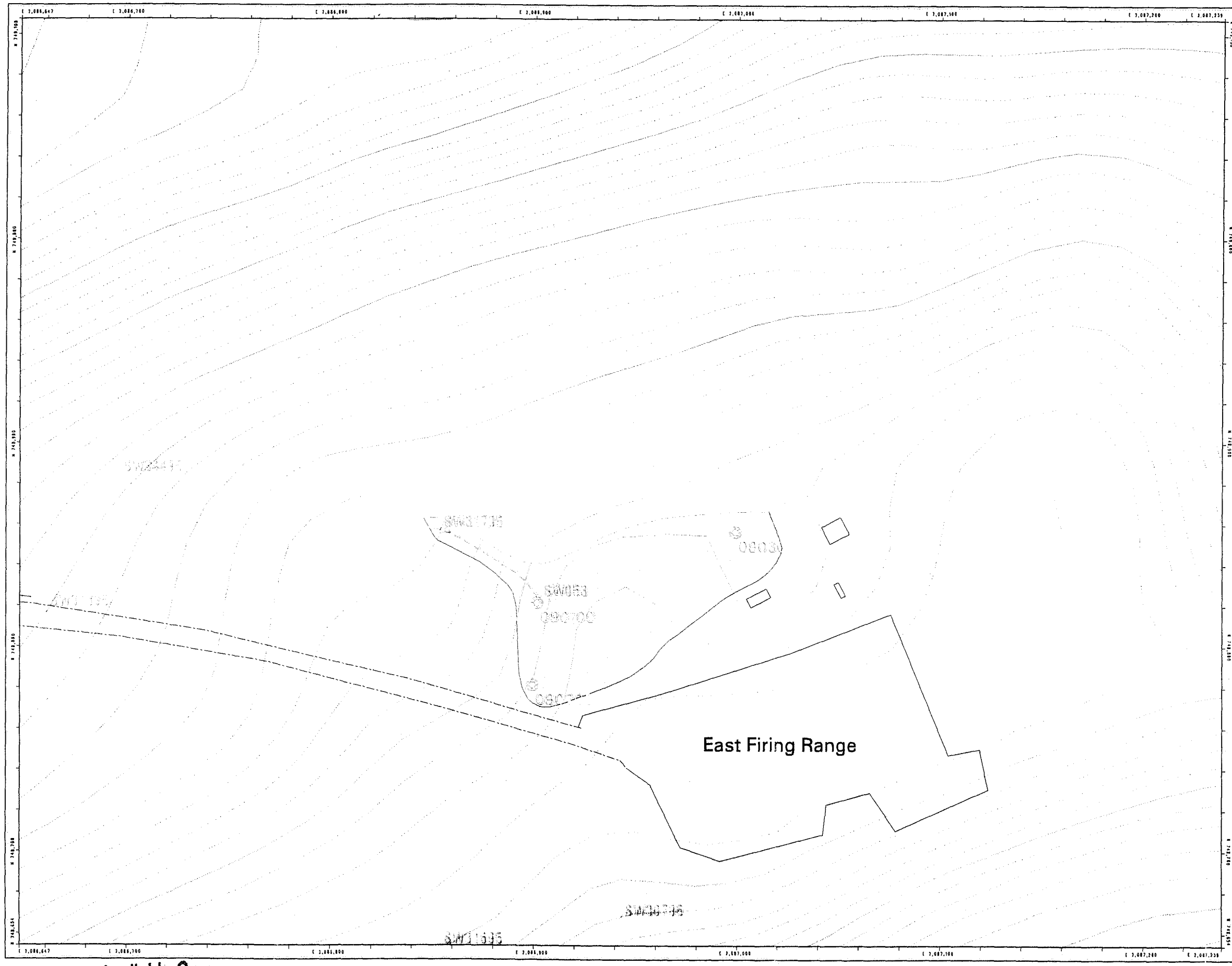

Characterization Report for the
903 Pad Drum Storage Area,903 Lip Area
and Amercium Zone

Wetland Area
Sediment Sampling Locations
Figure 1

EXPLANATION

Surface Water Sampling Location

Approximate Soil Boring Location

Wetland Features

Wetland (Ephemeral Spring)

Hummocky Topography (Landslide)

Drainage

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 (2-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 2-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.

Data Source: Sampling Locations - Approved by RMRS Water Program Group, POC Steve Singer, 303-966-3387.

Data Source: Wetland Features - Approved by RMRS, POC Mark Wood, 303-966-6689.

Source: Dec. 27, 1999 sampling event, visual estimate of locations.

Scale = 1 : 590
1 inch represents approximately 49 feet

10 0 20 40 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

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