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Enclosure 2

Revised Final Status Survey Report
– Redacted Version –
for Survey Units 4, 6, 7, 12, 16, 17, and 18

SUITABLE FOR PUBLIC RELEASE

FINAL STATUS SURVEY REPORT
REDACTED VERSION

SUBSURFACE SOIL CHARACTERIZATION AND FSS PROJECT

NUCLEAR FUEL SERVICES NORTH SITE
Erwin, Tennessee

SURVEY UNITS 4, 6, 7, 12, 16, 17, 18

PREPARED FOR:

NUCLEAR FUEL SERVICES, INC.

PREPARED BY:

AMEC FOSTER WHEELER ENVIRONMENT & INFRASTUCTURE, INC.
AMEC FOSTER WHEELER PROJECT NO. 9120071235

REVISION 1
MAY 2017

WORK PERFORMED UNDER DOE CONTRACT NO. DE-AC12-04SN39427

Summary of Changes FSS Report, Survey Unit 4, 6, 7, 12, 16, 17, 18 Revision 1

Section (# and Title)		Original Page #	Revised Page #	Revision
2	Subsurface Soil Characterization and FSS Design	2-1 to 2-69	2-1 to 2-67	• **Removed** extraneous paragraphs (i.e. "enter" symbols) in header
2.5	Compiling Historical Data	2-13	2-11	• **Added** 2nd paragraph
2.6.1	Survey Unit Description	2-14	2-12	• **Removed** "4" from subheading
2.7.1	Survey Unit Description	2-26	2-24	• **Added** Subheading
2.7.2	Sampling Density Determination	2-27	2-25	• **Added** Subheading • **Added** "The number of corehole locations for Survey Unit 6 was calculated using the method described in Section 2.6.2." in 1st paragraph • **Replaced** "conservative" with "alternative" twice in 2nd paragraph
2.7.3	Confirmation of Selected Sampling Density	2-29	2-27 to 2-28	• **Added** Subheading • **Added** first two paragraphs
2.8.1	Survey Unit Description	2-33	2-31	• **Added** Subheading
2.8.2	Sampling Density Determination	2-34	2-32	• **Added** Subheading
2.9.1	Survey Unit Description	2-41	2-39	• **Added** Subheading
2.9.2	Sampling Density Determination	2-42	2-40	• **Added** Subheading

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2.10.1 Survey Unit Description	2-47	2-45	• **Added** Subheading
2.10.2 Sampling Density Determination	2-48	2-46	• **Added** Subheading
2.11.1 Survey Unit Description	2-55	2-53 to 2-54	• **Added** Subheading • **Removed** "Human activities occurred in areas to the south of the former security zone, the former ponds area in Figure 5-2, resulting in the eventual remediation of the majority of that area." From last paragraph
2.11.2 Sampling Density Determination	2-56	2-54	• **Added** Subheading • **Added** "Similar to Survey Unit 6" in 1st paragraph • **Replaced** "conservative" with "alternative" twice in 2nd paragraph
2.11.3 Confirmation of Selected Sampling Density	2-59	2-56 to 2-57	• **Added** Subheading • **Added** first two paragraphs
2.12.1 Survey Unit Description	2-63	2-60	• **Added** Subheading
2.12.2 Sampling Density Determination	2-64	2-61	• **Added** Subheading • **Added** "Similar to Survey Units 6 and 17" in 1st paragraph • **Replaced** "conservative" with "alternative" twice in 2nd paragraph
2.12.3 Confirmation of Selected Sampling Density	2-66	2-63 to 2-64	• **Added** Subheading • **Added** first two paragraphs

Summary of Changes FSS Report, Survey Unit 4, 6, 7, 12, 16, 17, 18 Revision 1

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2.8.1 Survey Unit Description	2-33	2-31	• **Added** Subheading
2.8.2 Sampling Density Determination	2-34	2-32	• **Added** Subheading
2.9.1 Survey Unit Description	2-41	2-39	• **Added** Subheading
2.9.2 Sampling Density Determination	2-42	2-40	• **Added** Subheading

Section (# and Title)	Original Page #	Revised Page #	Revision
5.12 Assessment of Potential For Intact Original Surface Soils	5-134	5-134	• **Added** Subsection in its entirety
Appendix A.2 Historical Dataset SU 6	A.2	A.2	• **Replaced** Historical Dataset to reflect 2009 post-remediation samples
Appendix A.6 Historical Dataset SU 17	A.6	A.6	• **Replaced** Historical Dataset to reflect 2009 post-remediation samples
Appendix A.7 Historical Dataset SU 18	A.7	A.7	• **Replaced** Historical Dataset to reflect 2009 post-remediation samples
Appendix I Assessment of Potential For Intact Original Surface Soils	NA	NA	• **Added** Appendix in its entirety

FINAL STATUS SURVEY REPORT
REDACTED VERSION

SUBSURFACE SOIL CHARACTERIZATION AND FSS PROJECT

NUCLEAR FUEL SERVICES NORTH SITE
Erwin, Tennessee

SURVEY UNITS 4, 6, 7, 12, 16, 17, 18

PREPARED FOR:

NUCLEAR FUEL SERVICES, INC.

PREPARED BY:

AMEC FOSTER WHEELER ENVIRONMENT & INFRASTUCTURE, INC.
AMEC FOSTER WHEELER PROJECT NO. 9120071235

REVISION 1
MAY 2017

WORK PERFORMED UNDER DOE CONTRACT NO. DE-AC12-04SN39427

amec
foster
wheeler

FINAL STATUS SURVEY REPORT
REDACTED VERSION
SUBSURFACE SOIL CHARACTERIZATION AND FSS PROJECT

SURVEY UNITS 4, 6, 7, 12, 16, 17, 18

NUCLEAR FUEL SERVICES NORTH SITE
Erwin, Tennessee

US NRC SNM License Number 124
Docket Number 70-143

Prepared for:

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Erwin, Tennessee 37650

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Contract No. POO7O3070423
Project No. 9120071235

Revision 1
May 2017

NOTICE

This *Final Status Survey Report* has been created by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), previously Amec Environment and Infrastructure (Amec), previously MACTEC Development Corporation (MACTEC) to disclose the subsurface soil Derived Concentraion Guideline Level (DCGL) method conceived and designed by Amec Foster Wheeler to parties authorized by Amec Foster Wheeler. The method is designed to derive DCGLs for subsurface soils having residual contaminant concentrations (including radioactivity). It is also used to document the mathematical methods employed in the process.

This *Final Status Survey Report* contains intellectual property of a confidential and proprietary nature that Amec Foster Wheeler considers to be a Trade Secret belonging to Amec Foster Wheeler. Its unauthorized use, disclosure, modification, or distribution to the public is prohibited. Users expressly authorized by Amec Foster Wheeler in writing are permitted to obtain this document for the specified purpose only.

Amec Foster Wheeler has been contracted by Nuclear Fuel Services, Inc. (NFS) to develop subsurface soil DCGLs for its North Site Decommissioning Project located in Erwin, Tennessee.

Amec Foster Wheeler hereby authorizes only the official use of this information in connection with its application to the NFS North Site Decommissioning Project. Amec Foster Wheeler stipulates this report be withheld from public disclosure under 10 CFR 2.390.

For information regarding approved use of this document, contact:

Amec Foster Wheeler Environment &
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Grand Junction. CO 81505

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E.0 EXECUTIVE SUMMARY

Nuclear Fuel Services (NFS) contracted Amec Foster Wheeler Environment & Infrastructure Inc. (Amec Foster Wheeler) to assist in the radiological decontamination and decommissioning (D&D) of the NFS North site (the site). The overall objective is to establish the post remedial action radiological conditions at the site such that Survey Units 4, 6, 7, 12, 16, 17, and 18 are in compliance with the NFS site decommissioning plan (DP) (NFS 2006), and meets the radiological release criteria for unrestricted use in accordance with Title 10 Code of Federal Regulations (CFR) Part 20 Subpart E. The site-specific DP establishing the radiological conditions that NFS must satisfy to comply with the Nuclear Regulatory Commission's (NRC) decommissioning criteria has been developed (NFS 2006).

Based upon the requirements and commitments contained in the DP, NFS and Amec Foster Wheeler have completed the specified decommissioning activities and completed a final status radiological survey of the potentially impacted area of the site identified as Survey Units 4, 6, 7, 12, 16, 17, and 18. This survey establishes the final radiological conditions within the subject survey unit(s) at the site. The final status survey also serves to demonstrate that the radiological conditions within the survey unit(s) comply with the criteria and conditions specified in the DP and are protective of human health and the environment. This report documents the final radiological status of Survey Units 4, 6, 7, 12, 16, 17, and 18 at the NFS North site.

The NFS North site is comprised of the former radiological burial grounds and a set of evaporation and settling ponds. Survey Units 4, 6, and 7 are associated with the former radiological burial grounds, and Survey Units 12, 16, 17, and 18 are associated with the settling ponds.

Based on historical use of the land area comprised by Survey Units 4, 6, 7, 12, 16, 17, and 18 and an evaluation of the available relevant historical data from within and immediately surrounding the survey units, Survey Units 4, 6, 7, 12, 16, 17, and 18 were demarcated and a subsurface soil characterization survey was designed. The survey design implemented supports both the characterization of residual radioactivity in the soil and the final status survey.

Quality control (QC) samples were taken during the survey process. Review and analysis of the QC measures indicates that the data collected meet the data quality objectives and are acceptable for their intended use. In addition, no unexpected results or trends are evident in the data.

The design and interpretation of the final radiological status survey in support of the site decommissioning project is based on the proprietary Subsurface Soil derived concentration guideline level (DCGL) methodology developed by Amec Foster Wheeler and approved in the DP. The method is designed to implement the NRC's decommissioning guidance found in NUREG 1757, *Consolidated NMSS Decommissioning Guidance, Volume 2, Characterization, Survey, and Determination of Radiological Criteria* (NRC 2006). The residual radioactivity release criteria have been derived from the basic annual dose criterion applicable to decommissioning sites.

The survey data were compared to the DCGLs both statistically and with non-statistical comparisons using the approved subsurface soil DCGL compliance metrics. The radiological survey data demonstrates that the site meets the DCGLs established. Statistical evaluation of the data indicates that the residual radioactivity DCGLs were met with greater than 95% confidence.

Based upon the evidence provided by the final radiological status survey of the site, NFS concludes that Survey Units 4, 6, 7, 12, 16, 17, and 18 are in compliance with the NFS Site DP and meets the radiological release criteria for unrestricted use in accordance with 10 CFR 20 Subpart E.

1.0 INTRODUCTION

1.1 BACKGROUND

NFS is currently licensed (SNM-124) by the NRC to possess radioactive materials and to engage in remedial activities at the NFS North site in Erwin, Tennessee. NFS is subject to NRC regulation governing the activities at the site, including the decommissioning of this portion of the site. NFS has contracted Amec Foster Wheeler to perform the post remediation characterization of residual radioactivity in soils at the NFS site and to ascertain whether the site meets the radiological conditions required to decommission this portion of the site in accordance with applicable license requirements and regulations. Amec Foster Wheeler was previously Amec Environment and Infrastructure (Amec), and prior to Amec was MACTEC Development Corporation (MACTEC). Any reference in this document to Amec or MACTEC are to be considered a refence to the same company, now Amec Foster Wheeler.

1.2 DECOMMISSIONING OBJECTIVE

NFS' objective is to decommission the portion of the NFS site known as the North site, (hereafter referred to as "the site") such that Survey Units 4, 6, 7, 12, 16, 17, and 18 are in compliance with the NFS site DP, and meets the radiological release criteria for unrestricted use in accordance with 10 CFR 20 Subpart E. NFS has implemented decommissioning activities, including decontamination and soil removal actions, such that radiologically impacted areas within the site are expected to meet the approved criteria for radiological release. This *Final Status Survey Report* (FSS Report) documents the final radiological status of Survey Units 4, 6, 7, 12, 16, 17, and 18 all planned remedial activities in these areas now having been completed. The FSS Report also documents objective evidence supporting NFS' conclusion that the site meets the conditions and commitments identified in the site DP (NFS 2006) as well as the applicable decommissioning standards.

1.3 SITE AND LICENSEE INFORMATION

The NFS facility is located in the Town of Erwin in Unicoi County, Tennessee. The NFS property consists of approximately 64 acres; however, the North site DP addresses only a subset of approximately 24 acres of the NFS property, which comprises the northern portion of the property. The FSS Report addresses only Survey Units 4, 6, 7, 12, 16, 17, and 18, a subset of the approximately 24 acres of the North site.

The name and address of the licensee are:

Nuclear Fuel Services, Inc.
1205 Banner Hill Road
Erwin, Tennessee 37650

The address where licensed material is possessed is:

Nuclear Fuel Services, Inc.
1205 Banner Hill Road
Erwin, Tennessee 37650

1.4 SITE DESCRIPTION

The NFS facility is located in northeast Tennessee in the town of Erwin in Unicoi County, occupying roughly 64 acres (Figure 1-1). The North site decommissioning project addresses roughly 24 acres of the NFS facility. Within these 24 acres were three distinct areas: the north half is the Former Radiological Burial Ground, the southern half is the Former Ponds Areas, and separating the Former Burial Ground from the Former Ponds Areas is the Security Zone (Figure 1-2). During characterization activities the topography across the site fluctuated somewhat with elevations ranging from 1,628-1,675 feet above mean sea level (msl). Various physical features existed across the site including several ponds, two marsh areas, and a wooded region. Significant remedial activities have been conducted across the North site and final grading has been completed to match the NFS Drainage Plan.

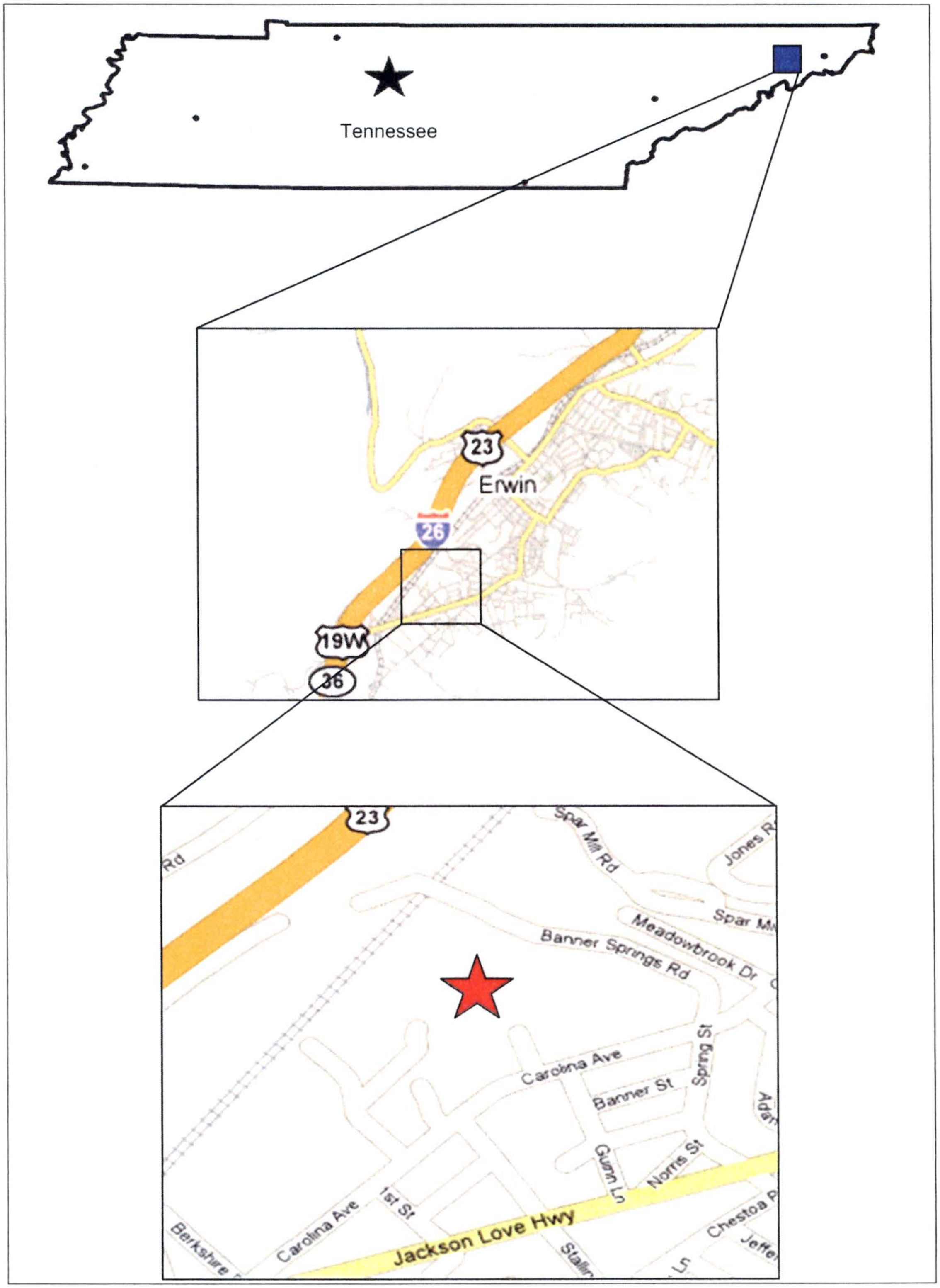

Figure 1-1 Site Location

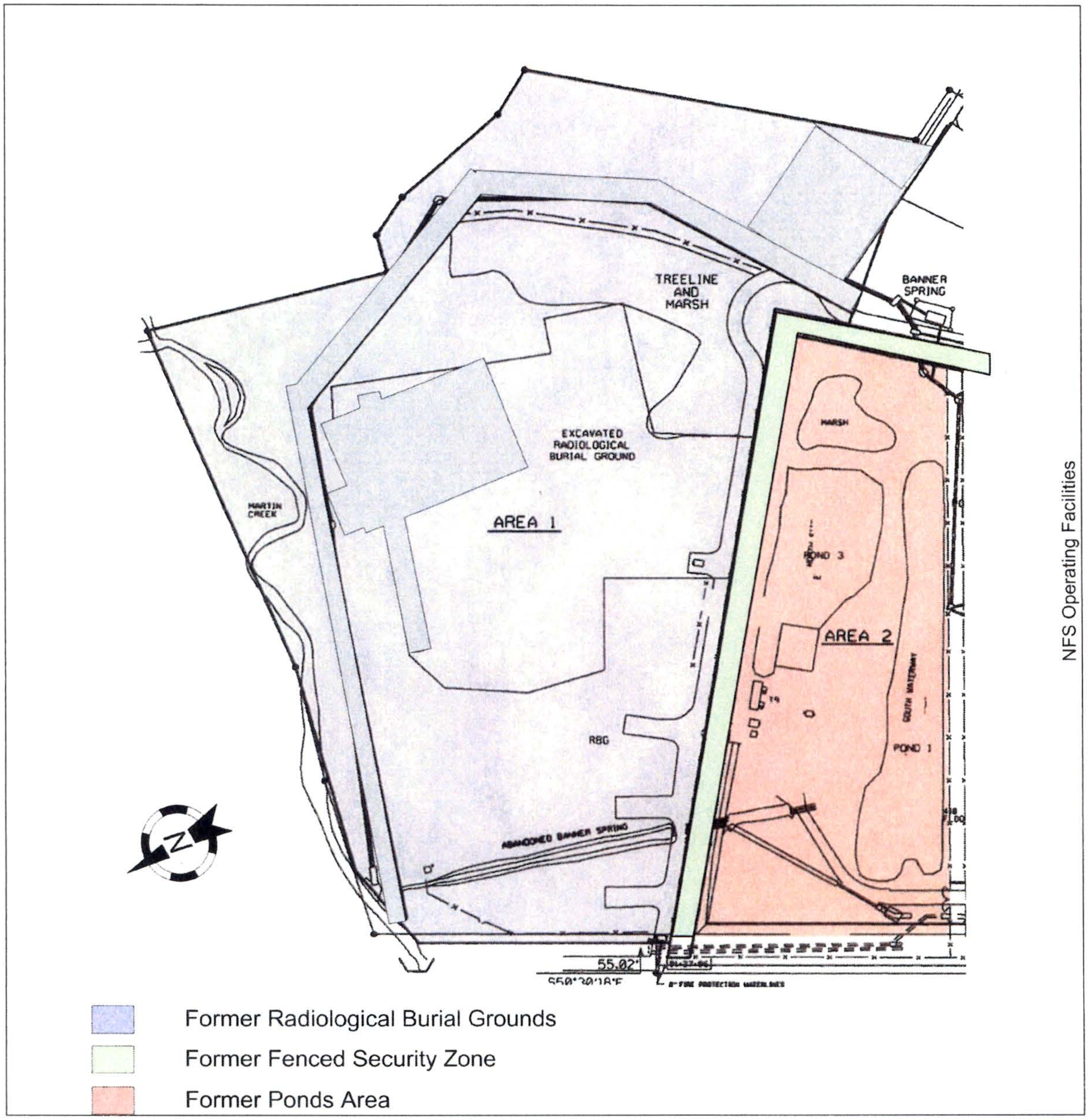

Figure 1-2 NFS North Site Map - Decommissioning Areas

The process leading to license termination has involved a series of steps that includes:

- a historical site assessment;
- radiological site characterization;
- radiological dose assessment and approval of derived concentration guideline levels (DCGLs) for residual radioactivity and applicable to subsurface soils;
- soil remediation (as necessary);
- design and implementation of a radiological survey that assesses the final radiological status of the site; and

- a final status survey report (this report) that evaluates and documents the final status survey and serves as the basis for conclusions and decisions regarding the acceptability of radiological condition of soils at NFS' North site.

Each of these major steps is briefly discussed to provide context for this FSS Report.

1.4.1 Historical Site Assessment

NFS began operations at the Erwin facility in 1957. Operations have primarily involved the processing of uranium-, thorium-, and plutonium-bearing materials as listed below:

- conversion of uranium hexafluoride to uranium oxides;
- conversion of uranium hexafluoride to uranium tetra fluoride and to uranium metal;
- production of fuel containing highly enriched uranium;
- fabrication of fuel pins or rods containing pellets of uranium and/or thorium oxides;
- recovery of thorium, low-enriched uranium, and high-enriched uranium, either generated by NFS or generated at other facilities;
- production of thorium metal, metal powder, and metal pellets; and
- production of plutonium and uranium mixed oxide fuel internally.

These processing activities occurred on portions of the NFS facility other than the North site area; however, the North site area was used in the past for waste storage and disposal activities related to its nuclear work. NFS has excavated and removed buried wastes and debris. Excavated wastes, debris, and contaminated soils have been packaged for shipment to and disposal at an off-site licensed disposal facility.

Three surface impoundments, Ponds 1, 2, and 3 are located within the North site. These impoundments received liquid waste from on-site processing operations from 1957 until 1978. Also low-level, contaminated solid wastes were disposed of in the North site Burial Ground area from 1966 until 1977, as authorized under 10 CFR 20.302. The contents and locations of most disposal pits are well documented. Another area previously used for solid waste disposal is the former Pond 4 area which is located west of the three impoundments. NFS removed waste materials from Ponds 1, 2, and 3 and the Pond 4 area from 1991 through 1996. NFS has also excavated waste and contaminated soil from the North site Burial Ground. Each former disposal area at the site has been identified as a Solid Waste Management Unit (SWMU) in the Hazardous and Solid Waste Amendments (HSWA) permit issued to NFS by the Environmental Protection Agency (EPA 1993a).

1.4.2 Radiological Site Characterization

Previous characterization of the North site involved sampling and analysis of soil, sediment, and surface water, and direct gamma surveys of the grounds and some structures within the North site. Characterization data were available for portions of the North site from previous Resource Conservation and Recovery Act (RCRA) investigations, routine monitoring programs, operational surveys, and radiological surveys of waste disposal areas. NFS has performed remedial actions on select areas of the site by excavating soil and transporting off-site for disposal. By applying the surface soil DCGLs to subsurface soils, several excavated areas were able to meet release criteria and were not included in the characterization. Other areas, where the surface soil release DCGLs were not met, excavation was proceeding to the point of refusal (bedrock was encountered). Post-remediation radiological data indicates residual soil radioactivity exceeds the surface soil release criteria in select areas of the site. Data from previous investigations and routine monitoring were combined with site characterization data and evaluated as a single dataset (NFS 1999). Using this dataset, subsurface DCGLs were developed and incorporated into the characterization and Final Status Survey (FSS) design.

1.4.3 Radiation Dose Assessment & DCGLs

The combined historical survey results dataset, coupled with process and historical knowledge of the activities at the site, provides a reasonably comprehensive understanding of the pre-remediation radiological status and characteristics of the North site.

The primary radioactive contaminants in the North site are uranium (U-233/234, U-235, and U-238), thorium (Th-230 and Th-232), plutonium (Pu-238, Pu-239/240, Pu-241, and Pu-242), americium 241 (Am-241), and technetium 99 (Tc-99). Elevated concentrations of radioactivity in soil and sediment across select areas of the North site exceeded the approved surface soil DCGLs. Elevated concentrations of radioactivity have been measured in subsurface soils in much of the former Protected Area (PA). Only a portion of the northeast corner of the former PA was not found to have radioactivity in soil above the approved surface soil release criteria.

Outside the former PA, concentrations of radioactivity in soil exceeding the approved surface soil DCGLs have been measured in soil/sediment surrounding the former channel of Banner Spring Branch, the burial trenches, and the contaminated soil mound area, with isolated occurrences found between the radiological burial ground trenches and Banner Spring Branch. Generally, elevated concentrations of radioactivity in soil occur near the surface and did not extend beyond a depth of about four feet, except in the area where debris was formerly disposed in burial trenches. There is no indication that radioactive contamination extends off the site to the north and east. The presence of elevated concentrations of residual radioactivity in soils to the west of the site is bounded by the former streambed of Banner Spring Branch.

Elevated concentrations of uranium are present in groundwater of the shallow alluvial aquifer in some locations on the site. The shallow alluvial aquifer at the site contains a number of other contaminants (unassociated with the NFS Site or its operations) and is in hydraulic communication with nearby surface water features, making it susceptible to producing poor water quality (NFS 2000). In acknowledgement of this fact, the NRC has agreed that groundwater from the shallow alluvial aquifer is unsuitable as drinking water, that it is unlikely that such use might be sought in the future, and that the drinking water pathway may be excluded from consideration in the derivation of DCGLs for residual radioactivity in soils at the site (NRC 2001).

The source term in soil at the site consists of relatively insoluble forms of uranium and thorium series radionuclides in soils with trace impurities consisting of actinides and Tc-99. The most limiting isotope among them is Th-232. Prior characterization and remediation efforts at the site have shown that residual radioactivity is present in soils on the site at depths greater than was evaluated in the dose modeling used to derive surface soil DCGLs for the site (NFS 2006).

Residual radioactivity in soils deeper than approximately 0.5 meter produces little radiological dose to a potential receptor provided it remains in the subsurface position. To ascertain the potential dose consequence associated with bringing subsurface-deposited residual radioactivity to the surface where exposure might occur, it is conservatively assumed that subsurface soil brought to the surface is uniformly spread on the ground surface in a 0.5-meter-thick lift. Thus, the physical configuration of each source term modeled and evaluated, regardless of its origin of depth, is defined by the volume distributed over the area corresponding to a 0.5-meter-thick source. RESRAD computer software (Yu 2005) assumes that the source is cylindrical (discus) in shape with the thickness describing the height of the right cylinder. The receptor is assumed to be exposed at the center of the circular ellipse. The receptor to source term geometry was evaluated for a series of 25 source sizes, the largest (55,000 m^2) represents an essentially infinite geometry and served as the baseline against which the dose response for all other source sizes were compared. In addition to its essentially infinite geometry, 55,000 m^2 was the appropriate selection for the baseline case because it corresponds to the source size used to derive the surface soil DCGLs.

The North site DP (NFS 2006) specifies surface soil DCGLs for thirteen radionuclides (Table 1-1). The source term is being defined in support of comparative (or relative) dose modeling using RESRAD. Consequently, it was not an objective of the subsurface soil characterization plan to establish the correlation between annual dose and concentration of any particular isotope in soil. In fact, instead of establishing new correlations, the methodology used in this characterization builds on the already established and approved correlations between annual dose and residual radioactivity concentration described by the surface soil DCGLs.

Table 1-1 Surface Soil DCGLs

Isotope	DCGL (pCi/g)
Am-241	130
Pu-238	155
Pu-239	140
Pu-240	141
Pu-241	4365
Pu-242	148
Tc-99	414
Th-230	17
Th-232	3.7
U-233/234[(a)]	642
U-235	74
U-238	306

[a] DCGL is for the sum of U-233 and U-234

1.5 SUBSURFACE SOIL SURVEY SAMPLING DESIGN

The site characterization sampling was designed to ensure that appropriate and adequate radiological data is acquired such that decision-makers have the information necessary to confidently demonstrate compliance with applicable release criterion or identify areas requiring additional remediation.

The subsurface soil sampling design follows the method approved for subsurface soils in the North site DP (NFS 2006). The design incorporates provisions for assessing each of the thirteen isotopes of concern (Table 1-1) in the measurement protocols employed. It takes into consideration the historical knowledge of the past uses of the various areas of the North site and available historical data that had been collected for a variety of reasons during past sampling activities. In consideration of the historical uses of the facilities at the site and the radiological characterization surveys performed in the past, the site was demarcated into 19 survey units. The characterization survey of the entire site was designed to support the premise that three distinct soil classification areas exist and are present at the site. These soil classification areas are based on the occurrence of past remedial activities and associated radiological data (pre- and post-remediation). The design of the subsurface soil sampling plan is described in detail in Section 2.0.

1.6 MEASUREMENT METHODS SUMMARY

Measurement methods required for this characterization were by laboratory analysis of volumetric soils for U-235, 233/234, and 238; Pu-238, 239/240, 241 and 242; Am-241, Th-230 and 232; and Tc-99. Radioanalysis methods and reporting levels are presented in Table 1-2 below.

Table 1-2 Radioanalysis Methods and Reporting Limits

Radioisotope	Analysis Method	Percent of Samples Analyzed by Method	Reporting Limit (pCi/g)
Am-241, Th-232, U-235	DOE GA-01-R (Gamma Spectroscopy)	100	0.5, 0.9 and 2.0, respectively
U-233/234, 235, 238	Alpha Spectroscopy	10	1.0
Pu-238, 239/240, 242	Alpha Spectroscopy/ Liquid Scintillation	10	1.0
Pu-241	Alpha Spectroscopy/ Liquid Scintillation	10	5.0
Am-241	Alpha Spectroscopy	10	1.0
Th-230, 232	Alpha Spectroscopy	10	1.0
Tc-99	Liquid Scintillation	10	1.0

1.7 FINAL STATUS SURVEY REPORT

This report documents the results of the final radiological status of Survey Units 4, 6, 7, 12, 16, 17, and 18 and the basis for NRC confirmation that these survey units will be suitable for unrestricted release in accordance with 10 Code of Federal Regulations (CFR) 20 Subpart E.

1.8 DATA ANALYSIS FRAMEWORK

NFS and the NRC agreed early in the decontamination and decommissioning process to utilize the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) as the principal guidance for sampling, survey, and data evaluation methods. Thus, the data evaluated in this report is presented principally in the context of the MARSSIM data quality assessment methods. In addition, and where appropriate, conventional guidance from the NRC, the U.S. Environmental Protection Agency (EPA), and accepted practice and methods used in radiological site assessment and characterization are utilized. Principal guidance documents referenced include:

- Multi-Agency Radiation Survey and Site Investigation Manual (NRC 2000)
- Guidance for Data Usability (EPA 1992)
- Data Quality Objectives Process for Superfund (EPA 1993b)

A common theme in these guidance sources is the use of the seven-step data quality objectives (DQO) activity as the foundation for survey design and data evaluation.

The data analysis framework is critical to sample plan development because it establishes the basis for decision and drives the sample size. The evaluation process will use an analysis structure incorporating three possible common statistical procedures as well as conventional qualitative and semi-quantitative comparisons. The test is the Wilcoxon Rank Sum (WRS) Test. The WRS test (sometimes referred to as the Mann-Whitney test) is a general two-sample, non-parametric procedure that can be used to compare means between samples (e.g., concentrations of residual radioactivity measured in the different survey units) when either or both sampling distributions deviate significantly from normal. This test will be used to determine whether there is a statistically significant difference between the mean residual radioactivity in subsurface soils in the Reference Background Area (RBA) and the survey unit.

In addition to the inferential test (WRS test), data analysis will include qualitative visual analysis (e.g., histograms, scatter diagrams, and box and whisker plots). Additional analytical methods (e.g., spatial correlation) as well as spatial analysis (e.g., posting on diagrams, iso-concentration plots) not required to support the decision rule are not explicitly planned for but could be employed on an ad-hoc basis to gain insight.

The data analysis framework will incorporate data quality analysis (DQA) components discussed in MARSSIM (NRC 2000) and EPA guidance (EPA 1992) to assess the overall usability of the data for its intended use. The data evaluation process will be validated, and statistical analysis methods will be used, to assess whether variability and bias in the data are small enough to allow NFS to use the data to support the sampling objective—unrestricted release in accordance with 10 CFR 20 Subpart E. Risk managers will be presented with an ensemble of information, logically interpreted, and supported by rationale to gauge compliance.

The NRC is responsible to determine whether the final status radiological status survey of the survey unit supports a decision to grant unrestricted release in accordance with 10 CFR 20 Subpart E.

1.9 POST-REMEDIATION ACTIVITIES

No post-remediation activities related to the radiological constituents found at the site have been identified and none are anticipated.

1.10 REQUEST TO TERMINATE LICENSE

Amec Foster Wheeler submits this FSS Report for Survey Units 4, 6, 7, 12, 16, 17, and 18 located at the North site. This FSS was conducted in accordance with methods specified in the North site DP (NFS 2006). NFS does not intend to request a partial site release of this area at this time. NFS, does however, request regulatory confirmation that Survey Units 4, 6, 7, 12, 16, 17, and 18 will be suitable for unrestricted use in accordance with 10 CFR 20 Subpart E.

2.0 SUBSURFACE SOIL CHARACTERIZATION & FSS DESIGN

The subsurface soil sampling design for the NFS North site implements the method approved for subsurface soils in the North site DP (NFS 2006). The sampling design was planned to be robust enough to support the premise that the data acquired through its implementation could support a final status survey release decision.

2.1 SURVEY DESIGN OBJECTIVES

The survey design objectives were to:

- Specify a sampling design that complies with the approved design criteria for subsurface soil sampling as approved in the site DP (NFS 2006);
- Provide the decision-makers with subsurface soil sample data of appropriate type and quality and which was collected in sufficient quantity and over an appropriate density;
- Demonstrate, with reasonable confidence, compliance with the applicable release criteria;
- Optimize the survey design such that the sampling resources were focused prevalently in areas where it was known or suspected that higher concentrations of residual radioactivity might be present; and
- Identify and isolate localized areas that would require additional remediation in order to make a radiological release decision.

2.2 ANALYTICAL DESIGN

The North site DP identifies 13 isotopes of concern. Among the 13 isotopes that require assay, 3 isotopes (Am-241, Th-232, and U-235) produce readily discernable gamma radiation signals. The other 10 isotopes of concern require radiochemistry techniques that can only be performed in a specially equipped laboratory. The nature of the sample preparation process (chemical extraction, fusion, etc.) produces larger relative uncertainty in the analytical results. Additionally, such analyses are both time consuming and costly. Based on historical knowledge of operations, previous characterization data, and relative margin between isotopic concentrations and their associated DCGLs, U-235 and Th-232 stand as the most important among the 13 isotopes of concern (Table 2-1). Both of these isotopes can be measured directly using gamma spectroscopy. The analytical design for the subsurface soil characterization and FSS project takes advantage of the fact that the important isotopes can be measured directly.

Still there was a need to account for the residual radioactivity contributed by the remaining isotopes. The *survey design* takes into account the dose contribution from each of the 13 isotopes in every sample. The *analytical design* calls for a surrogate isotope technique in which each of the 3 gamma emitting isotopes for every sample is measured and each of the 13 isotopes from a subset of 10% of the soil samples is measured ("full-suite" analysis).

This technique provides a basis for establishing "consistent" or conservative relationships between the gamma emitting isotopes and those that are more "difficult to measure." The gamma emitting isotopes then serve as surrogates upon which the remaining isotopes' concentrations for all samples can be confidently inferred. After the isotopic relationships were established using alpha spectroscopy and liquid scintillation data, only gamma spectroscopy measurements for U-235, Th-232 (Ac-228) and Am-241 were required for each sample. Am-241, U-235, and Th-232 are the surrogate radionuclides for the North site.

- Am-241 is the surrogate for the Pu isotopes.
- Th-232 is the surrogate for Th-230.
- U-235 is the surrogate for U-233/U-234, U-238, and Tc-99.

For survey design purposes, data collected during previous characterization of the North site (NFS 1999) was used to provide an estimation of the relationships between the measured gamma emitting radionuclides and the inferred radionuclides. The *a posteriori*-determined surrogate ratios for each survey unit were used to infer the unmeasured isotopes, thereby verifying the appropriateness of the survey design and accounting for spatial variability in the surrogate ratios between the survey unit and the historical dataset.

The samples to be analyzed by alpha spectroscopy and liquid scintillation will be collected spatially throughout the survey units. Surrogate ratio relationships for the survey units will be established by conservatively assigning the 95% Upper Confidence Interval of the mean calculated ratio within a specific survey unit to infer the concentrations of isotopes that are not specifically assayed in a given sample. Radioanalysis methods and reporting levels are presented in Table 2-1.

Each volumetric soil sample collected as part of the Subsurface Soil Characterization and FSS Project will be assayed with gamma spectroscopic analysis by NFS' on-site laboratory. Volumetric soil samples selected for full-suite analysis (a subset of 10%) will be submitted for analysis by an independent, off-site, contract laboratory. The selected laboratory, ALS Environmental, Fort Collins, Colorado, has a written laboratory quality program and approved analytical procedures. Standard laboratory quality measurements, including blanks, laboratory control samples, and replicate measurements were required. ALS was formerly Paragon Analytics, Inc. at the time of the analyses discussed in this FSS Report. Any reference to Paragon or ALS in the document are to be considered in reference to the same company, now ALS.

Additionally, the NFS QA Department has performed audits of ALS and approved this laboratory as acceptable.

Table 2-1 Summary of Analytical Design for Radionuclides of Concern

Radioisotope	Analysis Method	DCGL (pCi/g)	Percent of Samples Analyzed by Method	Reporting Limit (pCi/g)
Am-241	**Gamma Spec**	**130**	**100**	**0.5**
Am-241	Alpha Spec	130	10	1
Pu-238	Alpha Spec	155	10	1
Pu-239/240[(a)]	Alpha Spec	140	10	1
Pu-241	Liquid Scint	4365	10	5
Pu-242	Alpha Spec	148	10	1
Th-232	**Gamma Spec**	**3.7**	**100**	**0.9**
Th-230	Alpha Spec	17	10	1
Th-232	Alpha Spec	3.7	10	1
U-235	**Gamma Spec**	**74**	**100**	**2**
U-233/234[(b)]	Alpha Spec	642	10	1
U-235	Alpha Spec	74	10	1
U-238	Alpha Spec	306	10	1
Tc-99	Liquid Scint	414	10	1

[a] DCGL is the limiting DCGL.
b. DCGL is for the sum of U-233 and U-234

2.2.1 Spatial Distribution of Sample Selected for Full-Suite Analysis

There was a need to select samples for full-suite analysis such that the surrogate ratios that result would be spatially representative of the survey unit from which they were chosen. There was also a desire to minimize undue bias in their selection, although it was desired that the samples selected be chosen from among those more likely to have higher concentrations of residual radioactivity in order to improve the confidence interval about the surrogate ratios derived. From historical data and knowledge of the contaminant deposition mechanisms at the North site, it was determined that samples from the existing surface layers would likely yield the highest concentrations of radionuclide contaminants. To accommodate these design considerations, a two-part selection process was adopted to select samples that would be designated for full-suite analysis.

The first selection criterion provided for representative spatial distribution in the lateral dimensions and preferentially placed full-suite samples in the uppermost vertical increment of a corehole. Full-suite samples were identified by selecting the "A" increment from every "X^{th}" corehole in the survey unit. The frequency was chosen such that good spatial representation and a preference for identifying samples from the surface increment was achieved. Typically, the frequency selected was every third or fourth corehole.

The second selection criterion provided for spatial distribution in the vertical dimension and completed the design requirement to select 10% of all samples for full-suite analysis. The running totals of the number of samples collected and the number of samples selected for full-suite analysis from each survey unit were maintained. When the number of samples selected for full-suite analysis (using the first criterion) fell below 10% of the total number of samples, the sample team subsequently selected a sample "on-the-fly" for full-suite analysis. The field sample team distributed their selection of these over a range of depth increments.

An additional selection criterion was introduced in survey units where the NRC collected regulatory confirmation samples. Samples were selected for full-suite analysis by NFS when the NRC selected that sample for confirmatory analysis. This was done so that NFS could provide analytical data from its contract laboratory to the NRC for evaluation in comparison with confirmatory analyses provided by Oak Ridge Institute for Science and Education (ORISE). The NRC selected samples from Survey 4, 12, 16, 17, and 18 for regulatory confirmation sampling. The actual selection of samples for full-suite analysis was implemented in the field and is further described in Section 3.4.2.3.

2.3 SURVEY UNIT DEMARCATION

The first major step in the design of the sampling plan for the North site was to demarcate the site into appropriate survey units. Survey unit demarcation is important because the survey unit serves as the basic unit for data evaluation and decision making. Fundamentally, survey units that are to be evaluated using inferential statistics should not based on an *a priori* metric such as size, area, volume, or count. Rather, decision units (Survey Units) are appropriately demarcated based on an assessment of the properties that are characteristic of the presence of a single population of interest. In this case, the populations of interest are concentrations of residual radioactivity in soil.

Factors that indicate the appropriate demarcation of survey units include:

- Historical knowledge of deposition mechanisms and past practices at the North site,
- Natural or man-made physical "boundaries" that introduce barriers for the contaminant deposition mechanism(s) between neighboring regions,
- Potential or known levels of residual radioactivity and the spatial distribution and variability of the residual radioactivity as assessed with historically available sampling data from across the radiologically impacted area.

To determine the appropriate demarcation of survey units for the North site, Amec Foster Wheeler imported all of the relevant historical sampling data from the North site[1] into the computer software program SADA (Figure 2-1). SADA does not automatically determine appropriate survey unit demarcation. Rather, it is a geospatial modeling tool which can be used to mathematically and visually assess the spatial distribution and variability of residual radioactivity in the North site areas undergoing decommissioning. The software also permits the user to superimpose civil engineering drawing program files (e.g., CADD files, Figure 2-2) over various data views.

1. Some areas of the North site had a considerable amount of prior sampling data available, while some areas had very little relevant historical data. For example, in some areas of the site, most of the historical data that was available was from soils that have since been removed from the site and disposed of as part of NFS' approved soil remediation activities.

Figure 2-1 SADA Screenshot Showing the Placement of Historical Data

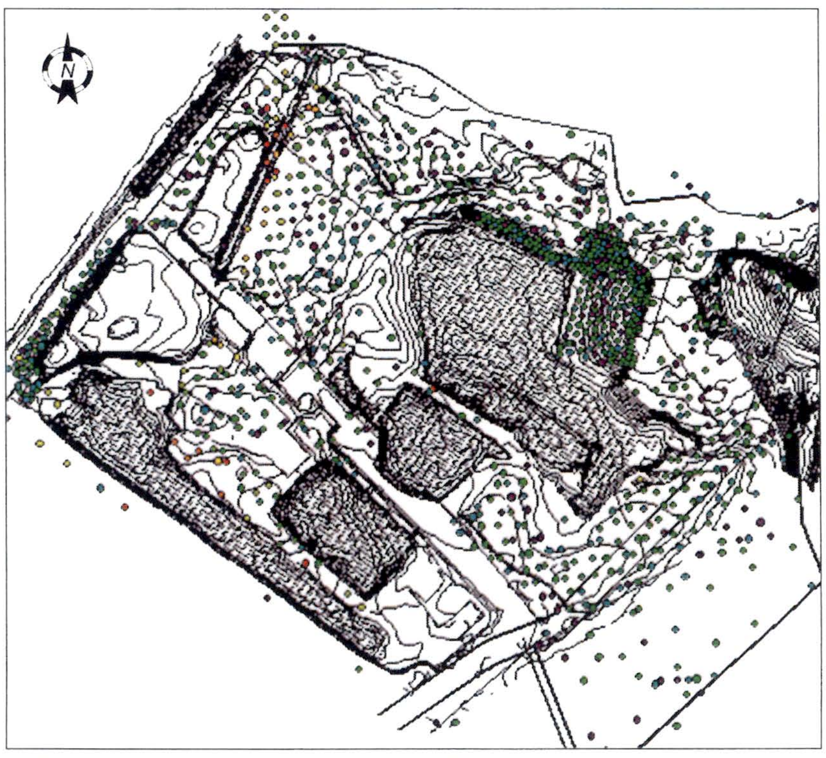

Figure 2-2 Surface Feature Drawing Superimposed on SADA Data

One of the tools available in SADA, and utilized during survey unit demarcation, is an iso-contour graphic generator (Figure 2-3, Figure 2-4, and Figure 2-6), which is based on user-defined input parameters. One of the user-defined input parameters is the search neighborhood radius distance that a particular point can influence. The user-defined search neighborhood radius was set as a relatively large value as compared with the distance between historical data points. Setting the search neighborhood radius as a relatively large value in SADA was necessary to produce an iso-contour map providing high-level (generalized) visualization of the radiological contamination of the entire North site (Figure 2-3). Caution must be exercised when interpreting the iso-contour map generated using a large search neighborhood radius. While this method yields beneficial site-wide visualization, single data points can result in predictions of visually exaggerated spheres of influence over unrealistically large areas, particularly where minimal historical data exists. Iso-contour mapping in SADA was merely used as a tool to help demarcate large, obviously elevated regions. Precise survey unit demarcation was performed by "zooming in" and considering each of the major factors that govern survey unit demarcation.

Using the geo-spatial features of the software, iso-concentration contours were generated and viewed simultaneously with site drawing layers superimposed (Figure 2-4) permitting the visualization of each of the major factors that govern survey unit demarcation.

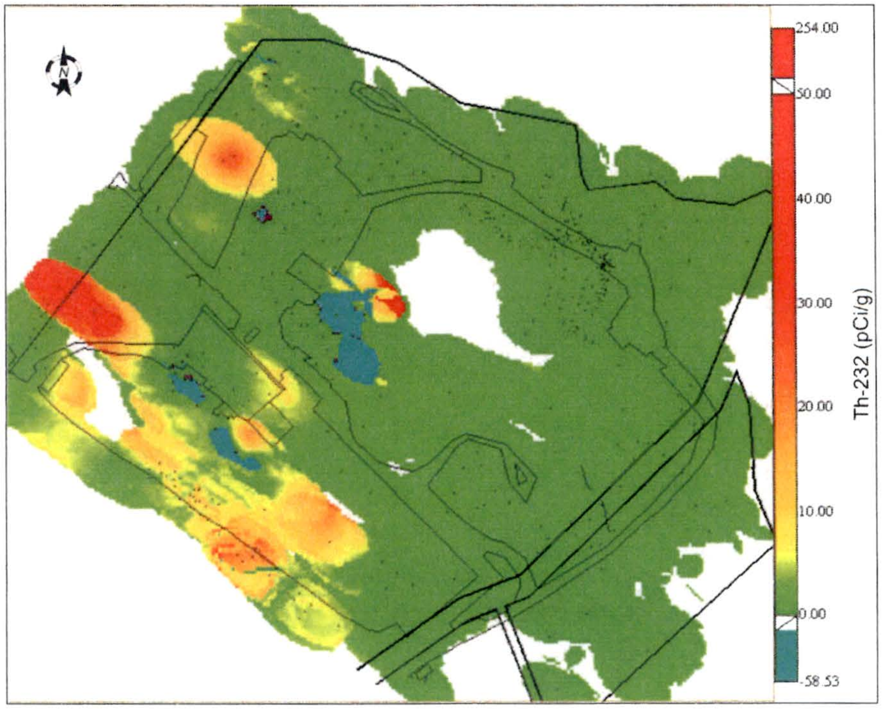

Figure 2-3 Iso-Concentration Contours Based on Historical Data

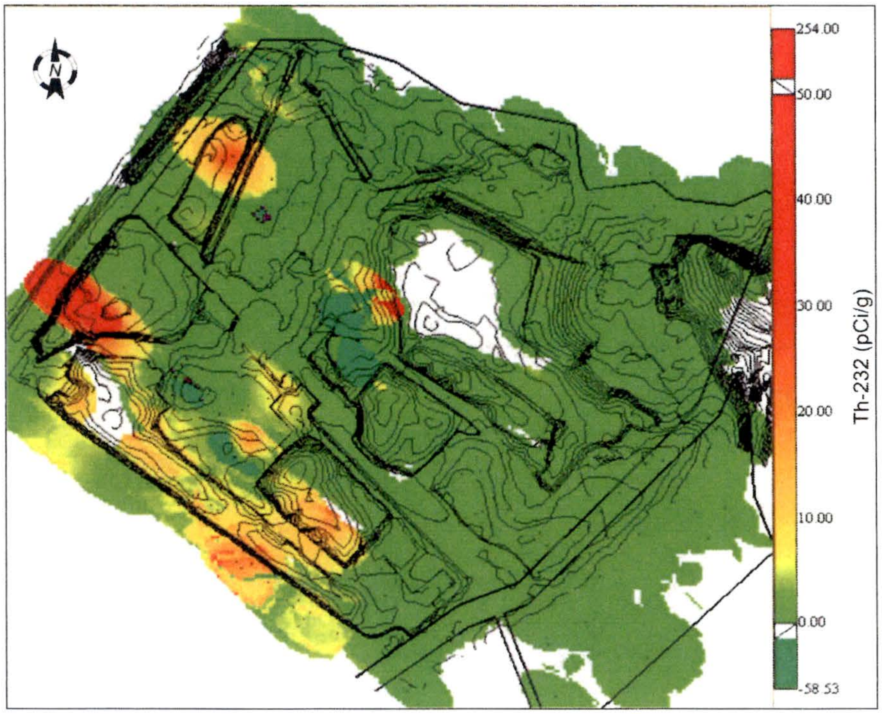

Figure 2-4 *Surface Features Superimposed on Iso-Concentration Contours Map*

The first demarcation determined was based on historical knowledge of the primary contamination deposition mechanisms that impacted the radioactivity on the site. The North site can be divided into two major regions, the "radiological burial grounds" and the "ponds area," based on the known contaminant deposition mechanisms (Figure 2-5). As is implied by their names, a series of liquid impoundments (ponds) located in the ponds area (colored pink in Figure 2-5) received liquid effluent wastes from various discrete plant-origin processing operations from 1957 to 1978. The land area located north of ponds area and outside of the former fenced security zone was used to dispose of low-level contaminated solid wastes (under permit) in shallow pits and trenches. The portion of the North site is known as the radiological burial grounds (RBG; colored light blue in Figure 2-5). The strip of land dedicated to the placement of the former security fence along the northern border of the production plant bisects the North site and creates a physical barrier that serves as a line of demarcation.

The former security zone itself (colored green in Figure 2-5) is not a finite line but rather a strip of land approximately 25 feet wide with a double-wide, high-security fencing system. The security zone was inviolate during the time that contaminant deposition activities were occurring. Therefore, the former zone not only distinguishes the ponds area from the RBG, but is itself a separately demarcated region.

Figure 2-5 First Order Demarcation of Survey Units

The second order of demarcation was accomplished by considering additional natural or physical boundaries that were or are currently present on the site (e.g., roadways, Martin's Creek, areas that have been excavated as part of the remedial action, previously surveyed and released areas) together with the iso-concentration contour map (Figure 2-3 and Figure 2-4). The process of demarcating the survey units was an iterative one in which Amec Foster Wheeler sought to not only circumscribe and isolate localized areas wherein the known or potential concentrations of radioactivity were likely to be confined, but also to optimize the overall design. In consideration of the deposition mechanisms, physical features that form barriers (impediments) to discrete contaminant populations, and the concentration gradients derived from historical radiological data, the site was demarcated into 19 survey units. The final survey unit demarcation relative to the historical contaminant distribution and variability is presented in Figure 2-6. The final survey unit demarcation relative to the physical features that define the site is presented in Figure 2-7. Each of the nineteen survey units were assigned numbers to identify them and distinguish them from one another Figure 2-8).

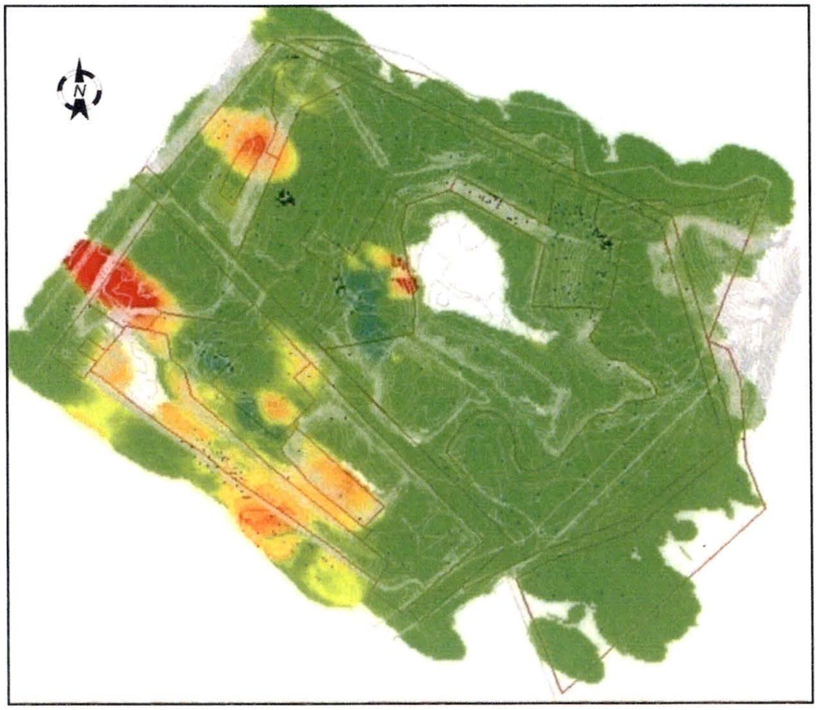

Figure 2-6 Survey Unit Demarcation - Iso-Concentration View

Figure 2-7 Survey Unit Demarcation – Physical Barriers (Features) View

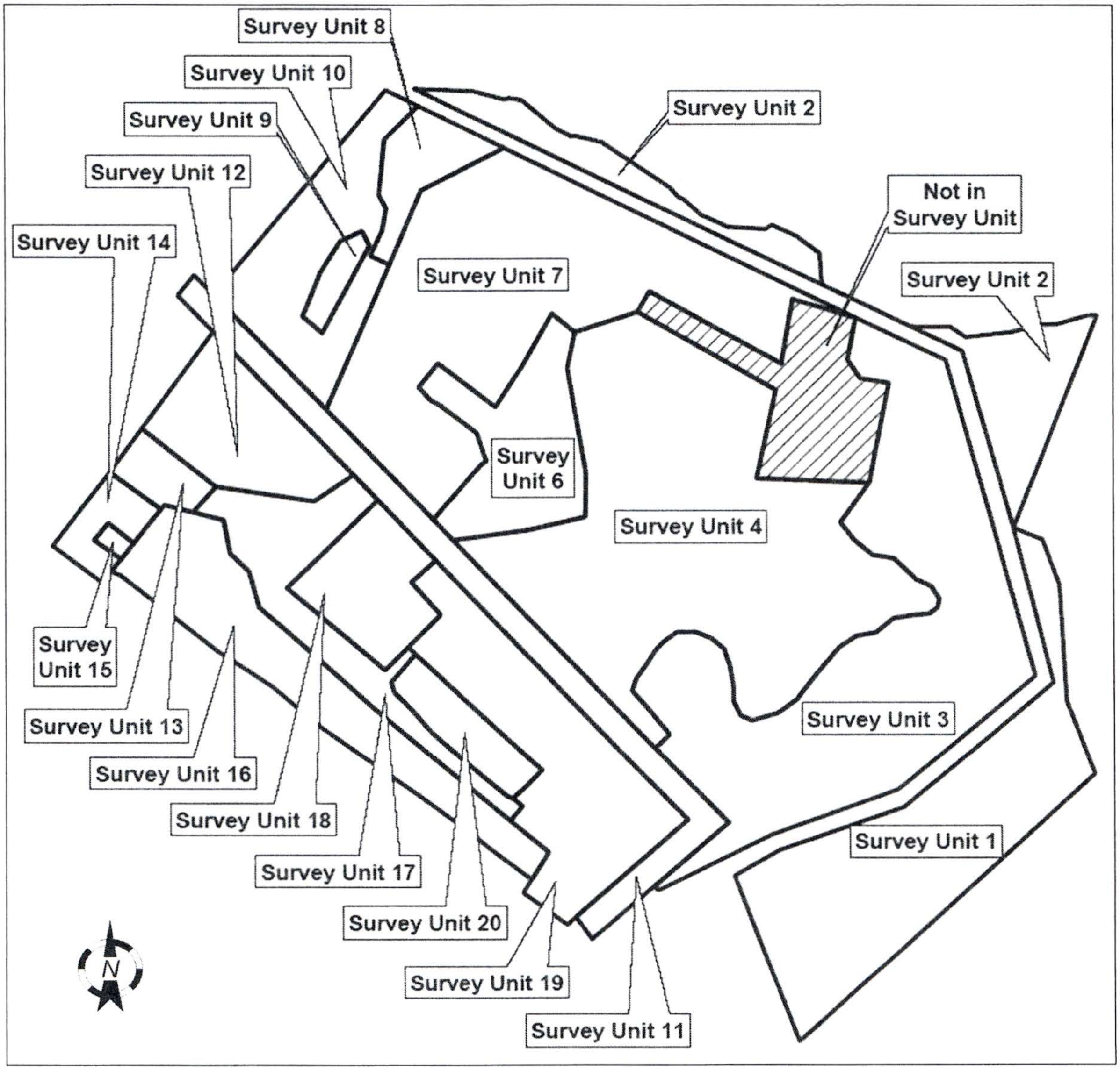

Figure 2-8 Survey Unit Enumeration

2.4 VERTICAL DEMARCATION OF THE SOIL COLUMN

Nominally, the sample core was divided into 1-meter segments. There were situations, however, when a viable sample could not be collected from the entire 1-meter depth layer. For example, when a sample is collected from the bottom of an excavation, part of the interval may have previously been excavated, rendering a sample cell either completely or partially devoid of soil. In such a case, it is understood that a completely void cell will eventually contain radiologically-unimpacted backfill. Partially void cells were sampled over the depth of impacted soil remaining within the sample cell as long as sample refusal (top of bedrock) was not encountered.

2.5 COMPILING HISTORICAL DATA FOR INDIVIDUAL SURVEY UNITS

Historically available data relevant to the characteristics of residual radioactivity in soils at the site were not only used to demarcate survey units, but were also used to establish an appropriate survey design for the survey unit under consideration. NFS provided Amec Foster Wheeler with 23,429 historical analytical sample values from across the entire North site and obtained during previous characterization and remediation activities. Not all historical data provided was relevant to the current radiological characteristics of the North site. For example, in several areas of the site, decommissioning activities performed subsequent to the collection of sample data likely altered the spatial distribution and variation in the concentrations of radionuclides currently present in the soil. The indiscriminant use of historical data may potentially lead to inaccurate calculations of the number of samples required to be collected from each survey unit. Of the 23,429 sample results provided, Amec Foster Wheeler utilized 19,107 sample results, from across the entire site, during the design of the Characterization Plan in 2006 (MACTEC 2007).

Subsequent to the design of the Characterization Plan in 2006, NFS performed additional remedial activities on the North Site. These remedial activities substantially altered (reduced) the radiological concentrations and their variability in Survey Units 6, 17, and 18, as indicated by post-remedial action samples collected in 2009. In light of the newly available data, a revised historical dataset was created for use in assessing and confirming the adequacy of the survey design in Survey Units 6, 17, and 18. Additional details regarding the revised historical dataset and its use are provided within the applicable Survey Unit-specific subsections below.

To assess the historical data in the context of its implication on the design of the sampling plan for individual survey units, Amec Foster Wheeler again made use of the spatial data features found in SADA. Historical sample data from within a "sphere of influence" including and surrounding the demarcated boundaries of each survey unit was extracted from the SADA database. This approach results in certain historical sample results that lie near the boundaries of survey units being included in more than one "sphere-of-influence" data subset. The extracted survey-unit-specific data was then used to calculate representative measures of the population's central tendency, standard deviation, 90^{th} percentile, and maximum values. The survey-unit-specific "sphere-of-influence" data subset is also used to populate the SSDCGL-RME Calculator, which, in turn, provides automatic input to the design of the sampling density for the survey unit. This approach ensures that the most accurate and representative historical information was available to appropriately design the survey unit corehole density.

The following descriptions have been included to provide context for the presentation of this Survey-Unit-specific FSS Report. The subsequent descriptions and details are specific to Survey Units 4, 6, 7, 12, 16, 17, and 18.

2.6 SURVEY UNIT 4 DESIGN

2.6.1 Survey Unit Description

Survey Unit 4 (as shown in Figure 2-9) comprises a portion of the former RBG area of the site. The survey unit encompasses an area of 13,773 m^2.

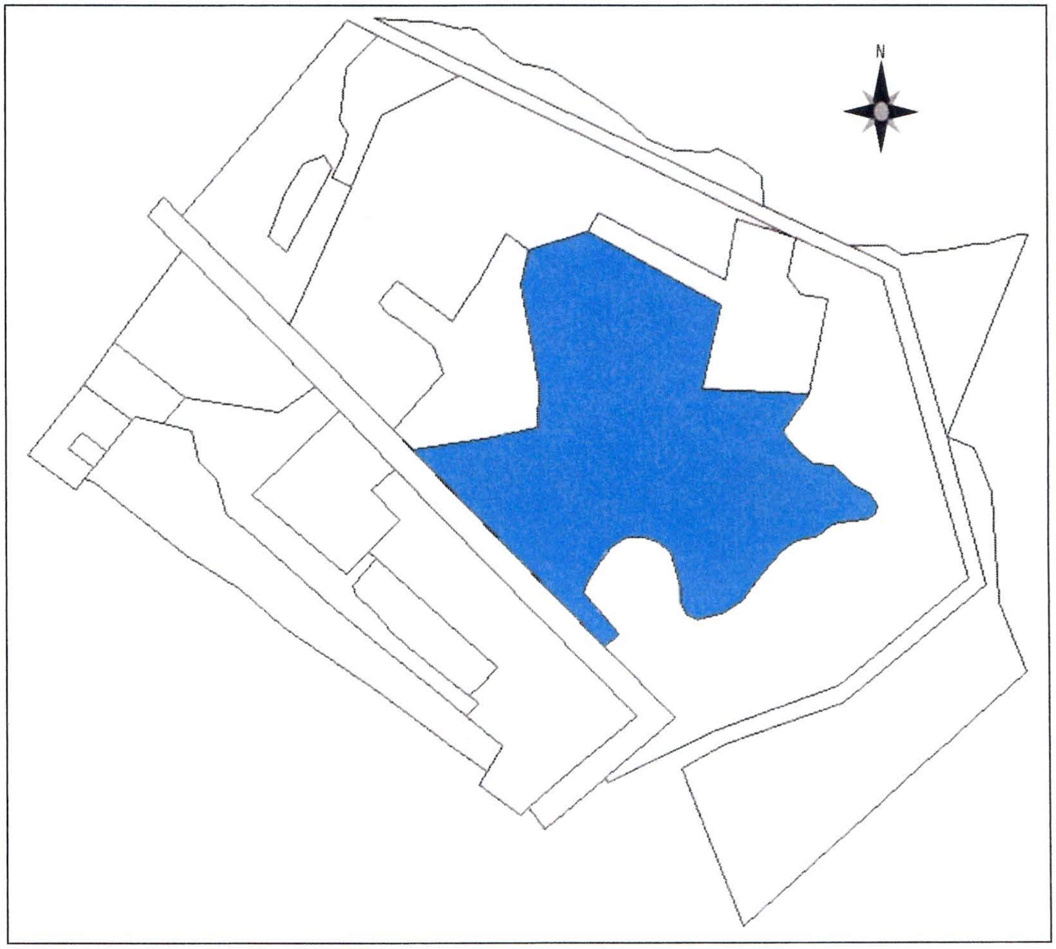

Figure 2-9 Survey Unit 4 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. The majority of Survey Unit 4 lies in a previously excavated area. The southwestern border is bound by Survey Unit 11, the former security zone and the western border approximates the edge of the previously excavated radiological burial ground, and is bound by Survey Unit 6. The eastern and southern border is bound by the edge of the tree and marsh area located in Survey Unit 3, and the northern border is bound by a previously released area.

2.6.2 Sampling Density Determination

The number of corehole locations for Survey Unit 4 was calculated using the method approved in the NFS Site-specific DP, Appendix B, Section 3.2 (NFS 2006) and described in detail in the technical basis document entitled *"Development & Application of Subsurface Soil DCGLs, North site Decommissioning Project, Nuclear Fuel Services Site,"* (MACTEC 2005). This method uses the sum-of-fraction (SOF) values calculated from the historical dataset to determine values for the shift and standard deviation. The number of coreholes and, consequently, the core sampling density within Survey Unit 4 was specified in consideration of the number of cores that would be needed to:

- demonstrate compliance with applicable statistical tests,
- provide a high level of confidence that localized volumes having elevated concentrations radioactivity in subsurface soils would not go undetected, and
- produce favorable subsurface soil DCGLs (SSDCGLs) for comparison with the various compliance metrics.

Historical sample data from within a "sphere of influence" including and surrounding the demarcated boundaries of Survey Unit 4 was extracted from the SADA database and loaded into the SSDCGL-RME Calculator for Survey Unit 4. In turn, the SSDCGL-RME Calculator returns the survey-unit-specific values of central tendency, standard deviation, 90^{th} percentile, and maximum. Historical data from the RME Calculator is linked to the SSDCGL-CALC Calculator where it is cross-checked with the proposed corehole density to ensure that each of the corehole frequency design objectives is satisfied. The historical data used to design the sampling density for Survey Unit 4 can be found in the Survey Unit 4 SSDCGL-RME Calculator and is tabulated in Appendix A.

2.6.2.1 Corehole Density for Demonstrating Compliance with the Statistical Test of the $DCGL_W$

The sample size is important when performing a statistical test to determine compliance where bounds on the acceptable error rate are specified. The power of a statistical test to distinguish a survey unit metric from its associated limit is a function of the sample size, sample variance, and tolerable error probabilities in making the decision. It is important to recognize that the sample size, *N*, estimated to be necessary to satisfy the statistical test for the survey-unit-wide area average, is the number of coreholes advanced into the subsurface soil. In the case of the two-sample WRS test, *N* represents the number of coreholes divided between the background reference area and the survey unit under investigation.

NFS previously collected a substantial subsurface soil background dataset from a reference background area near the North site (data was collected from multiple layers in 85 coreholes; see Table 4-1). Therefore, it was possible to use a two-sample statistical test to assess compliance with the derived concentration guideline level for the average (or median) concentration in the survey unit ($DCGL_W$). Amec Foster Wheeler designed the subsurface soil DCGL process to use the non-parametric, two-sample WRS test for this purpose. The set of equations that determine the minimum sample size (for a given set of decision criteria) using the WRS test are presented in Equations 1 & 2.

In practice, the number of coreholes, *N*, estimated to be needed for Survey Unit 4 to satisfy the WRS test with sufficient statistical power was calculated using Visual Sample Plan (VSP) computer software. VSP implements Equations 1 & 2 within its algorithms. The total number of coreholes, N, determined to satisfy the WRS test with an additional margin of 20% is calculated to be 82, 41 in both the survey unit and the RBA (Figure 2-10).

$$\boxed{N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2}}$$

Equation 1 Sample Size Calculation (WRS Test)

The Z statistic is a percentile score corresponding to the accepted probability of decision error at the DCGL and Lower Bound of the Gray Region (LBGR) ($Z_{1-\alpha}$ and $Z_{1-\beta}$, respectively). The *North site Decommissioning Plan* specifies the α-decision-error at 0.05. The β-decision error rate is at the discretion of NFS and was chosen to be 0.10 for Survey Unit 4.

The "P_r" value is an intermediate statistic used to determine the minimum sample size. The "P_r" is the estimated probability that a random measurement from the survey unit will exceed a random measurement from the reference area by less than the DCGL when the survey unit median is actually at the selected LBGR (above background) value. The value of "P_r" is proportional to the relative shift (Δ/σ). The "P_r" value is contained as an integral component of the commercially available software program used to perform the sample size calculations (BMI 2006).

Relative shift (used to determine the appropriate value of "P_r", was calculated using Equation 2:

$$\boxed{\Delta/\sigma = \frac{(DCGL_{SOF} - LBGR_{SOF})}{\sigma_{SOF}}}$$

Equation 2 Relative Shift

The shift (Δ) is the width of the gray area below and above which uncertainties in discrimination are critical to the decision maker. The shift defines the decision maker's critical window of observation and is based on the decision maker's acceptance of consequences of making Type I and Type II errors in testing the null hypothesis. In this case, the null hypothesis used states that residual radioactivity in the survey unit exceeds the release criterion. The relative shift (Δ/σ) is the ratio of the shift and standard deviation (σ).

Values for the variables $DCGL_{SOF}$, $LBGR_{SOF}$, and standard deviation were calculated from the Historical dataset and used to calculate the relative shift. The $DCGL_{SOF}$ variable in Equation 2, expressed as an SOF value, is always 1.0. The value for the $LBGR_{SOF}$ variable in Equation 2 was calculated using Equation 3:

$$\boxed{\mathrm{LBGR}_{\mathrm{SOF}} = \sum \frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \ldots \frac{C_n}{DCGL_n}}$$

Equation 3 Calculating the Sample Sum-of-Fractions

The DCGL variable in Equation 3 is the isotope-specific surface soil DCGL. The value for the standard deviation variable (σ_{SOF}) in *Equation 2* was calculated using Equation 4:

$$\boxed{\sigma_{SOF} = \sqrt{(\sigma_1 / DCGL_1)^2 + (\sigma_2 / DCGL_2)^2 + \ldots (\sigma_n / DCGL_n)^2}}$$

Equation 4 Standard Deviation Expressed as SOF

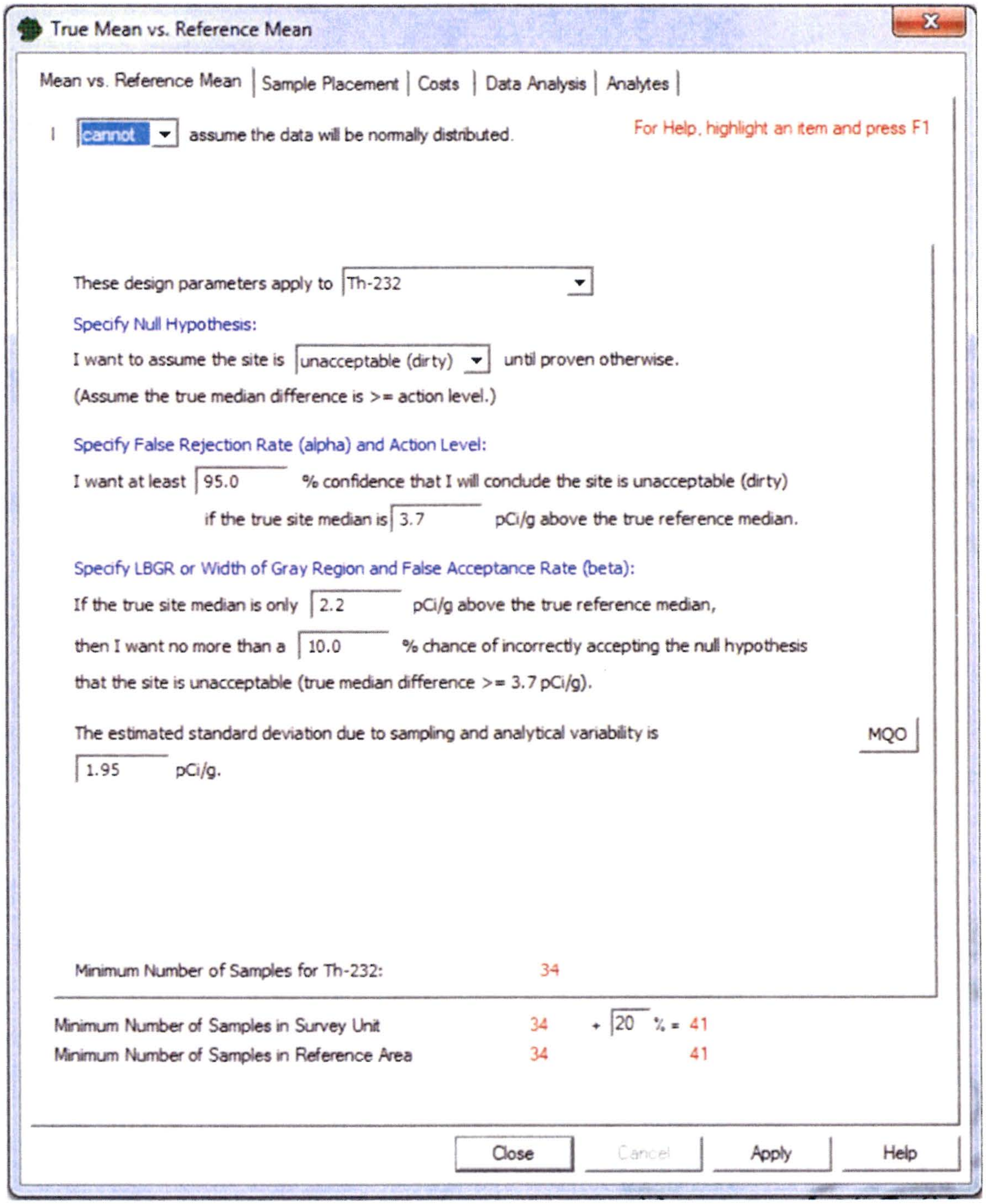

Figure 2-10 Screen Shot, VSP Sample Size Calculation, Survey Unit 4

Once the minimum number of coreholes (41) in the survey unit had been determined, they were distributed over the survey unit, again using VSP, using a random start, systematic square grid. The core sampling density that arises from the distribution of 41 coreholes over the area of Survey Unit 4 (13,773 m^2) is one corehole every 336 m^2.

2.6.2.2 Adjusting Corehole Density to Demonstrate Compliance with Local Area Subsurface Soil DCGLs

Having estimated the required sample size needed to satisfy the statistical test, the next step was to determine the corehole density required to provide reasonable assurance that a local deposit in subsurface soil having a significant amount of radioactivity did not go undetected. For a local deposit of residual radioactivity to be potentially significant as dose producer, it must have both a significant concentration and volume. As the concentration in a localized deposit goes up, the volume necessary for that local deposit to be potentially significant goes down. The inverse relationship between concentration and volume is described by the volume factor curves. Adjusting the corehole spacing varies the unsampled volume and varies the critical relationship between localized concentration and volume. This process is conceptually analogous to the grid spacing adjustment described in MARSSIM for surface soils when it becomes necessary to compensate for inadequate scan detection sensitivity.

The first step in the process was to determine the volume of soil represented by each sample in each subsurface soil layer based upon the thickness of the layer and the grid spacing. The grid spacing for Survey Unit 4 is 18.3 m by 18.3 m (336 m^2), and the thickness of each vertical layer of subsurface soil is 1 m. In this case, each sample is shown to represent a soil volume of 336 m^3.

The next step was to calculate "critical volumes" for localized deposits of residual radioactivity in the subsurface soil based on estimates of the "reasonable maximum concentration" and "expected maximum concentration." It was necessary to consider two critical volumes in order to appropriately regulate the process of corehole density adjustment to account for the potential presence of extreme left-skewness in historical data and to address the likelihood of, and the dose consequences from, potential exposures to small volumes at concentrations higher than the "reasonable maximum concentration."

The "reasonable maximum concentration" is defined as the concentration above which it is estimated that there is a reasonably small likelihood of occurrence in the resulting sample data set. For practical purposes, this value is derived by calculating the 90th percentile concentration considering the pre-existing data that is relevant to conditions in the survey unit at the time the sample design is implemented. The "expected maximum concentration" is defined as the highest concentration that is expected to be observed in the resulting sample data set. For practical purposes, this value is associated with observed maximum concentration considering the pre-existing data that is relevant to conditions in the survey unit at the time the sample design is implemented.

The existing data relevant to conditions in Survey Unit 4 at the time of the survey for Th-232 in layer 1 is distributed, as shown in Figure 2-11. Note that the 90th percentile is calculated to be 1.73 pCi/g. The maximum observed concentration is 8.30 pCi/g.

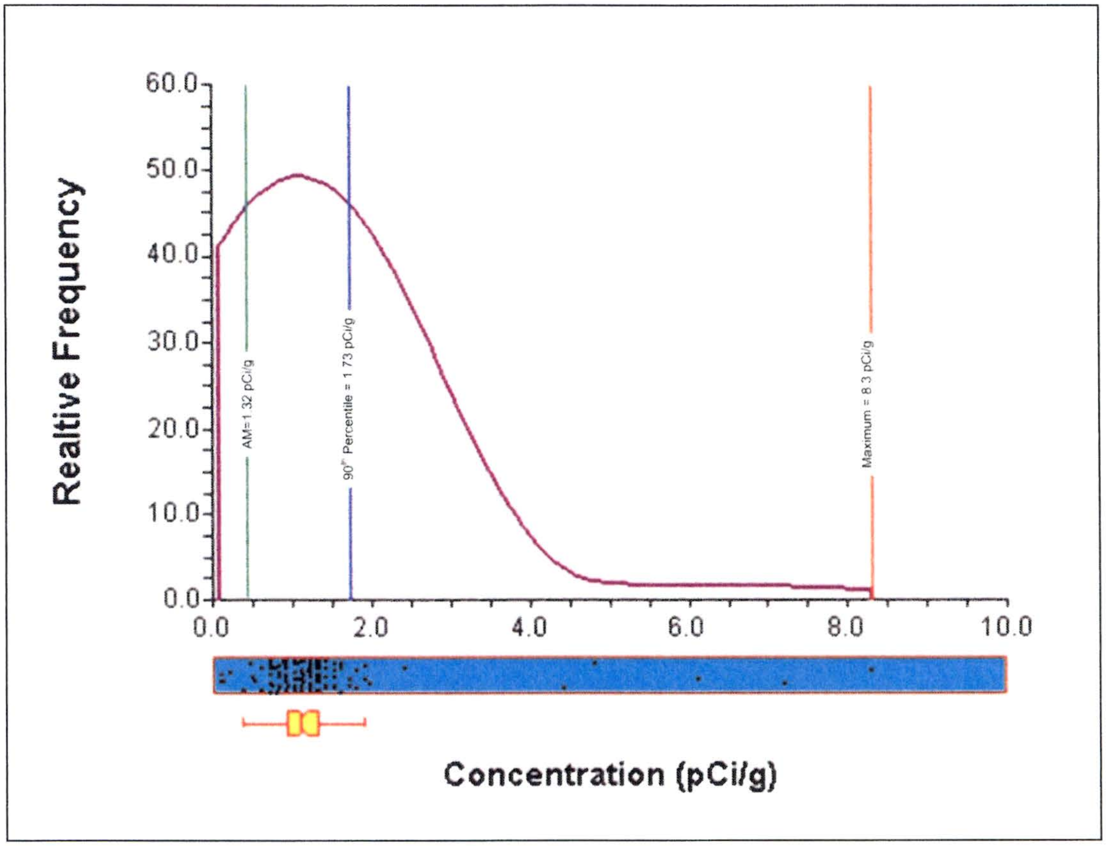

Figure 2-11 Sample Pre-Existing Data Distribution, Th-232, Layer #1, Survey Unit 4

Once the values of "reasonable maximum concentration" and "expected maximum concentration" had been identified, the critical volumes associated with them were derived.

The "reasonable maximum concentration" (for each isotope and depth layer) was compared with their applicable volume factor curves (related to an annual dose of 25 mrem) to arrive at the critical volume corresponding to the 90th percentile. For Survey Unit 4, the highest 90th percentile concentration observed was less than the corresponding permissible surface soil DCGL. Therefore, the "reasonable maximum concentration" value could not intersect the volume factor curve. This indicated that it was not necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil.

In like manner, the "expected maximum concentration" (for each isotope and depth layer) was compared with their applicable volume factor curve (related to an annual dose of 100 mrem) to arrive at the critical volume corresponding to the maximum concentration observed. For Survey Unit 4, the highest concentration observed was less than four times the corresponding permissible surface soil DCGL. Therefore, the "expected maximum concentration" value could not intersect the volume factor curve. This critical volume calculation also indicated that it was not necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil.

If either the 90th percentile critical volume or the volume associated with the expected maximum concentration would have been less than 336 m^3 (volume resulting from the nominal corehole spacing required to satisfy the survey unit wide area statistical test), the corehole density would have been adjusted down such that each sample represented a volume smaller than or equal to the limiting critical volume. Consequently, the final corehole density sampled in Survey Unit 4 is shown in Table 2-2.

Table 2-2 Corehole Density Summary Table, Survey Unit 4

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
4	13,773	336	41

2.6.3 Final Design and Sample Placement

Having determined the appropriate number and spacing of the coreholes for Survey Unit 4, VSP was used to specify the final sampling design. The sampling design template (sampling goal in VSP) used was the MARSSIM version WRS test design in which the 41 coreholes were distributed over the survey unit using a systematic square grid with a random start location (Figure 2-12). A summary table describing the basic aspects of the survey design is presented in Table 2-3. A detailed report describing the sampling design, automatically generated by the VSP software, is provided in Appendix B.

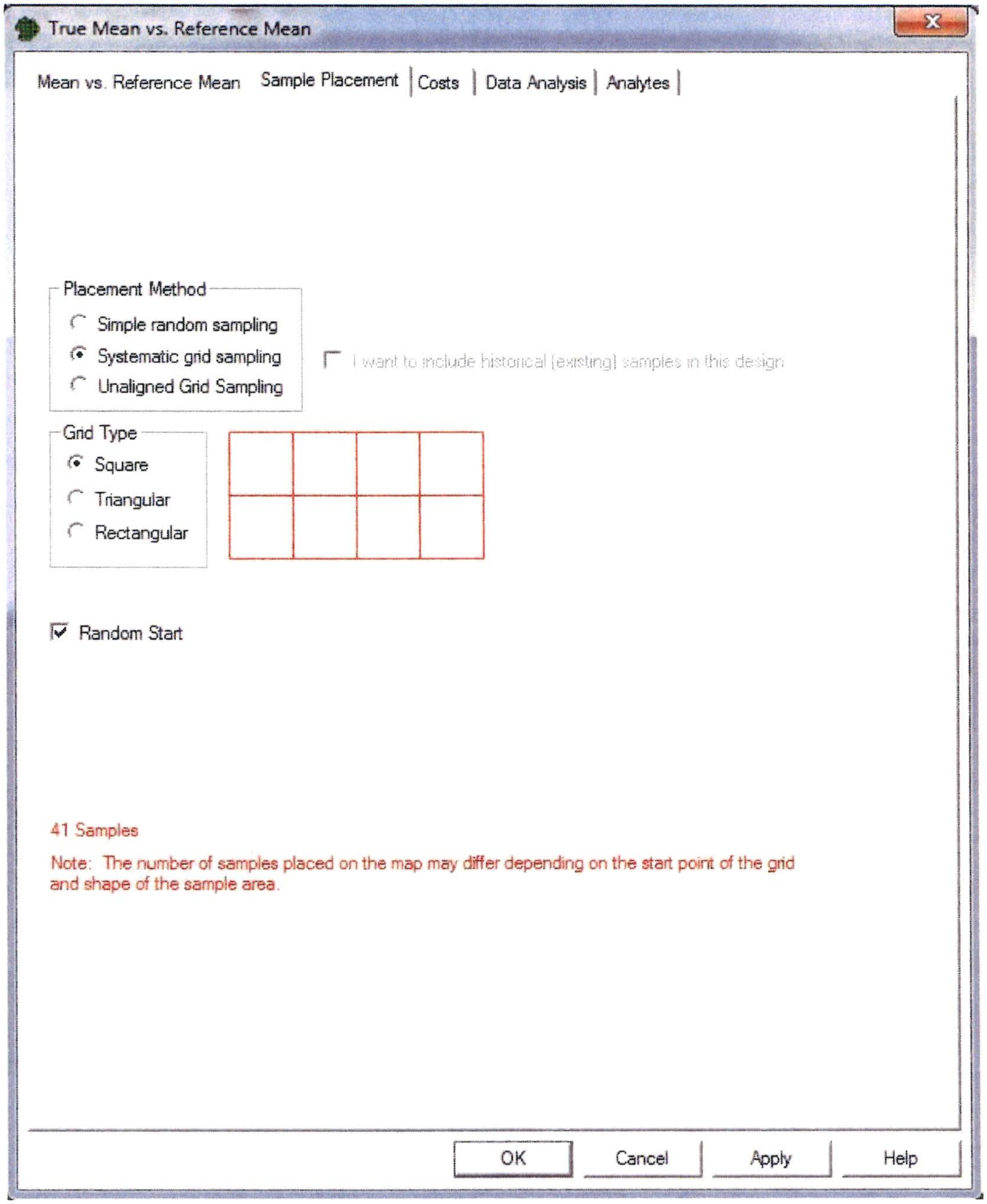

Figure 2-12 Sample Placement Architecture, Survey Unit 4

Table 2-3 Summary of Sampling Design, Survey Unit 4

Survey Unit 4	
Primary Objective of Design	Compare a site mean or median to a reference area mean or median
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Wilcoxon Rank Sum Test - MARSSIM version
Calculated total number of samples for each site and reference area [a]	41
Number of samples on map [b]	41
Number of selected sample areas [c]	1
Specified sampling area [d]	13,773 m^2
Size of grid / Area of grid cell [e]	18.3 m / 336 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

The resulting design placed 41 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 4 (Table 2-4, Figure 2-13). Amec Foster Wheeler assigned a unique number to each corehole.

Table 2-4 Planned Corehole Locations, Survey Unit 4

Sample ID	Easting (X)	Northing (Y)
0050	3022543.34	673734.02
0051	3022483.34	673794.02
0052	3022663.33	673794.02
0053	3022723.33	673794.02
0054	3022423.34	673854.02
0055	3022483.34	673854.02
0056	3022543.34	673854.02
0057	3022603.33	673854.02
0058	3022663.33	673854.02
0059	3022723.33	673854.02
0060	3022783.33	673854.02
0061	3022363.34	673914.02
0062	3022423.34	673914.02
0063	3022483.34	673914.02
0064	3022543.34	673914.02
0065	3022603.33	673914.02
0066	3022663.33	673914.02
0067	3022723.33	673914.02
0068	3022783.33	673914.02
0069	3022843.32	673914.02
0070	3022423.34	673974.01
0071	3022483.34	673974.01
0072	3022543.34	673974.01
0073	3022603.33	673974.01
0074	3022663.33	673974.01
0075	3022723.33	673974.01
0076	3022783.33	673974.01
0077	3022483.34	674034.01
0078	3022543.34	674034.01
0079	3022603.33	674034.01
0080	3022663.33	674034.01
0081	3022483.34	674094.01
0082	3022543.34	674094.01
0083	3022603.33	674094.01
0084	3022663.33	674094.01
0085	3022483.34	674154.01
0086	3022543.34	674154.01
0087	3022603.33	674154.01
0088	3022663.33	674154.01
0089	3022483.34	674214.00
0090	3022543.34	674214.00

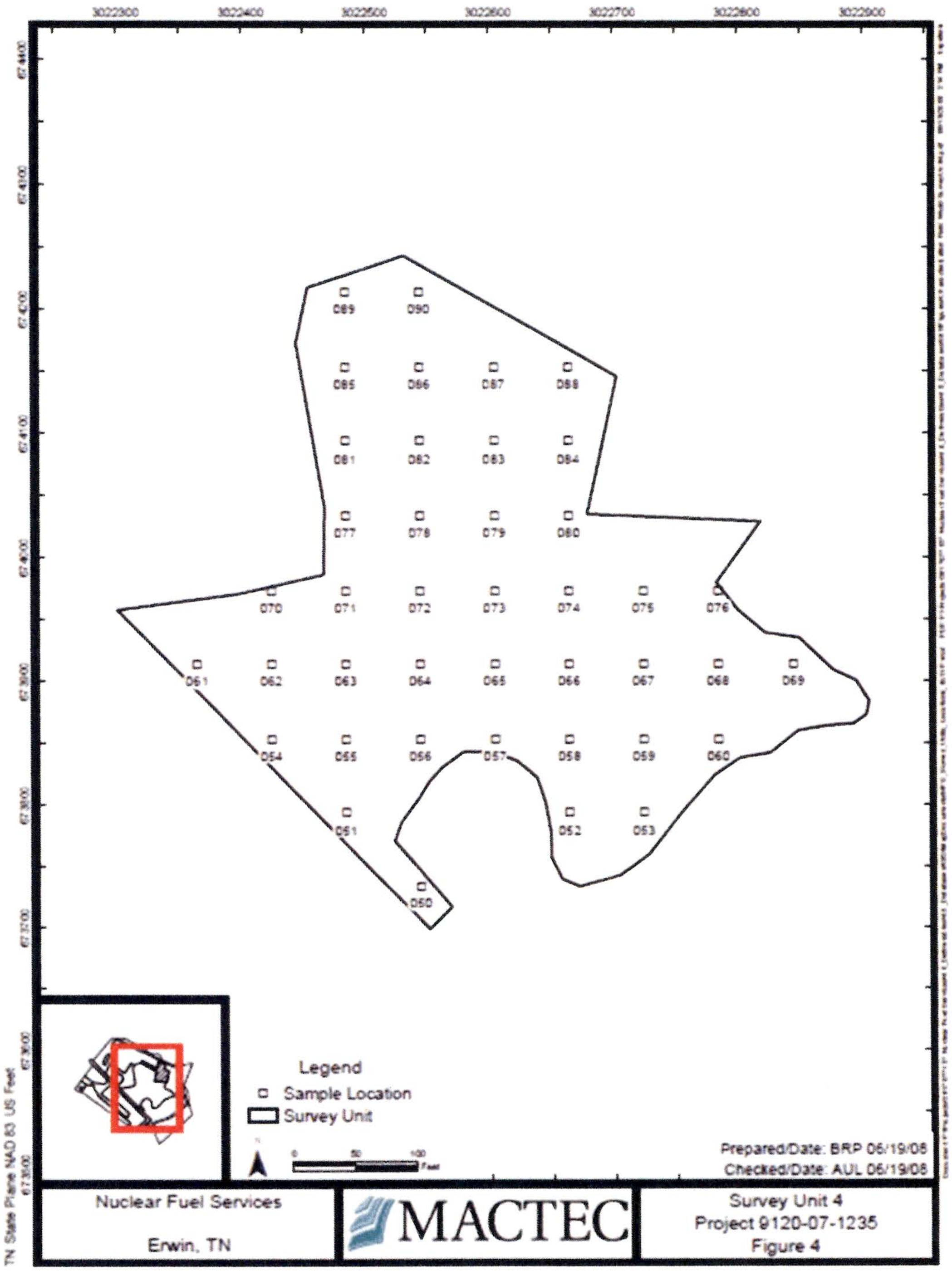

Figure 2-13 Survey Unit 4 Corehole Locations

2.7 SURVEY UNIT 6 DESIGN

2.7.1 Survey Unit Description

Survey Unit 6 (as shown in Figure 2-14) comprises a portion of the former RBG area of the site. Survey Unit 6 encompasses an area of 3,101 m^2.

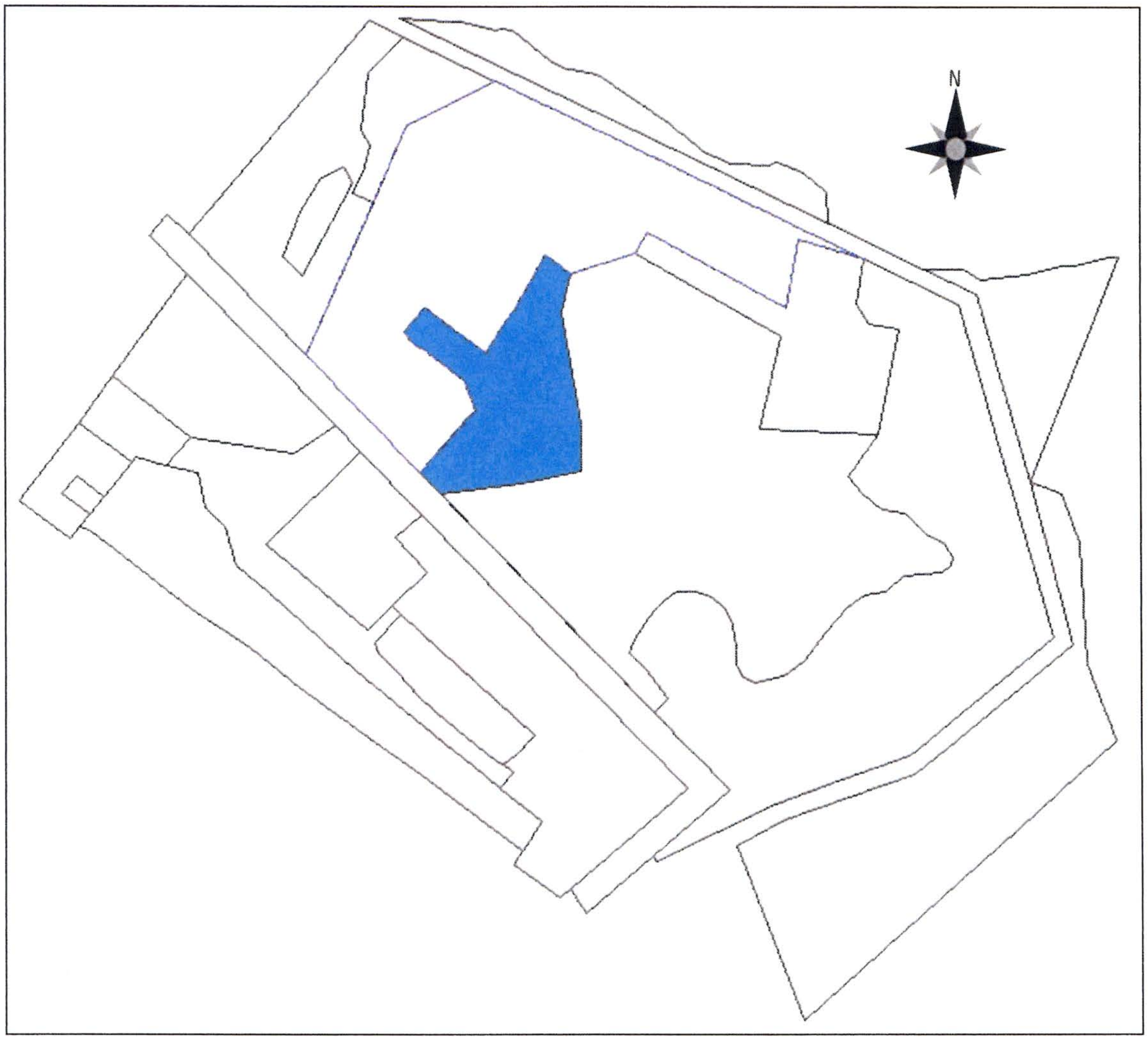

Figure 2-14 Survey Unit 6 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. The eastern and southern borders are bound by the previously excavated radiological burial grounds located in Survey Unit 4. The northern and western borders are bound by Survey Unit 7, the decommissioning operations area, and the southwestern border is bound by Survey Unit 11, the former security zone.

2.7.2 Sampling Density Determination

The number of corehole locations for Survey Unit 6 was calculated using the method described in Section 2.6.2. Contrary to Survey Unit 4, the number of coreholes for Survey Unit 6 was not constrained by the survey unit wide area statistical test. For Survey Unit 6, the highest 90th percentile and maximum concentrations observed were greater than the corresponding permissible surface soil DCGL. Therefore, the "reasonable maximum concentration" value and the "expected maximum concentration" value intersected the respective volume factor curves. This indicates that it was necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil. Both the "reasonable maximum concentration" and "expected maximum concentration" calculations returned a maximum corehole density of 1 m^2, resulting in a total of 3,101 coreholes.

Rather than place a corehole every 1 m^2 as dictated by the "reasonable maximum concentration" and "expected maximum value" calculations, an alternative sampling density was determined. As explained in Section 4.3 of the Characterization Plan (MACTEC 2007), a sampling density of one corehole location every 50 m^2 was selected to obtain current and accurate data for the survey unit. Guidance to determine the corehole density was found in MARSSIM (NRC 2000). MARSSIM recommends, in Section 5.3.3.2, Characterization Surveys, Land Area Surveys, that "A typical reference system spacing for open land areas is 10 meters (100 m^2)". This spacing is somewhat arbitrary and is chosen to facilitate determining survey unit locations and evaluating areas of elevated radioactivity." Because surface scanning is not applicable for subsurface soil characterization and known elevated concentrations of residual radioactivity exist in these areas, an alternative approach is taken here. The reference system spacing area identified in MARSSIM (100 m^2) is reduced by a factor of two, resulting in a reference system spacing surface area of 50 m^2 (approximately every 7 m).

Sampling Survey Unit 6 at a 50 m^2 grid would produce a sufficient number of coreholes to accurately assess the radiological nature of the survey unit. In order to determine the placement of coreholes using VSP, a different statistical parameter was used. Instead of using built-in algorithms needed to satisfy the WRS test, the "Locating a Hotspot" function was utilized. This allows the user to manually set the size and shape of the hotspot to force the sampling density to accommodate. In other words, by setting the diameter of a circular hotspot to 7 meters, VSP placed a corehole every 50 m^2 as desired. Figure 2-15 and Table 2-5 present relevant information used to determine the appropriate number and spacing of the coreholes.

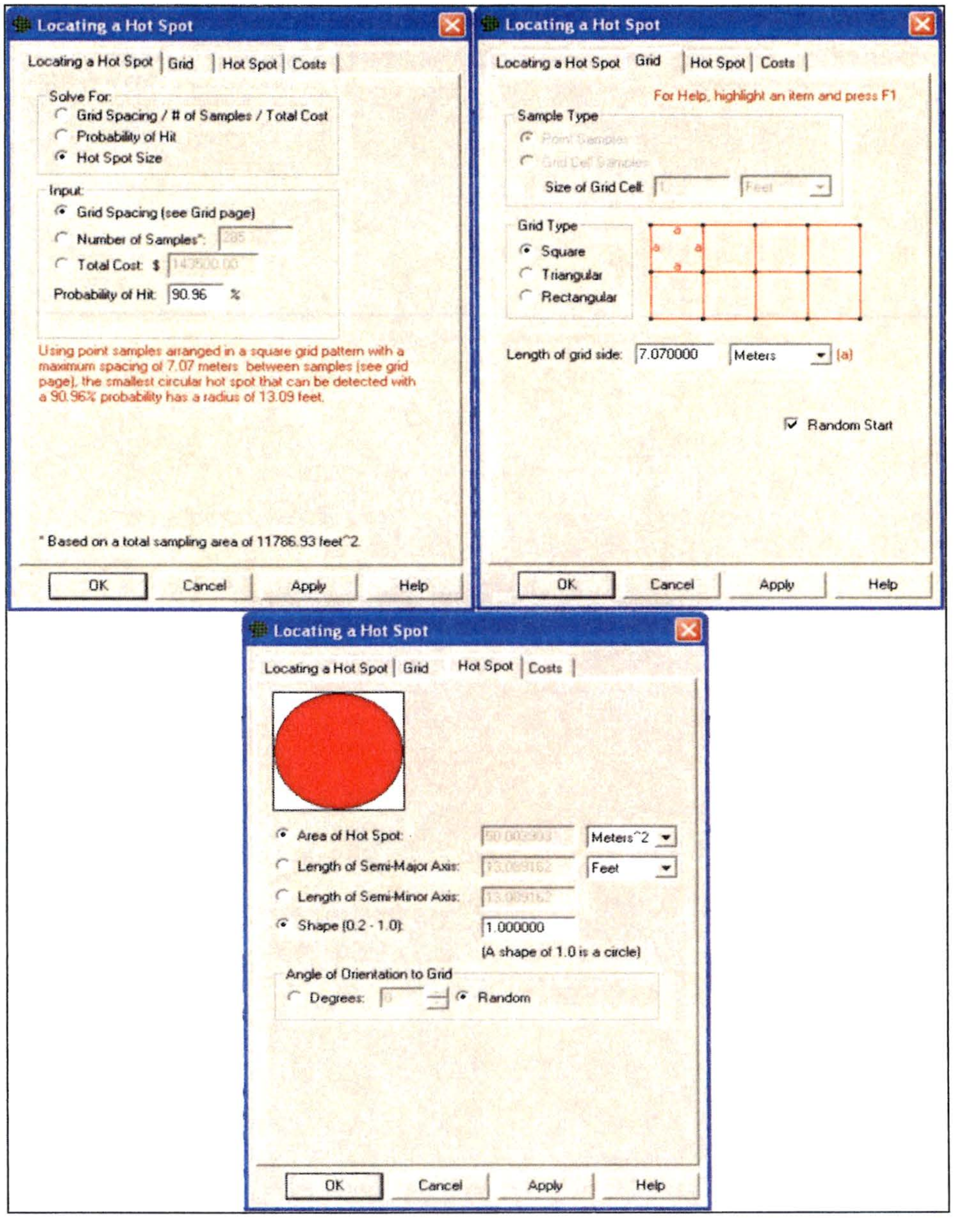

Figure 2-15 Screen Shots, VSP Sample Size Calculation Using "Locating a Hot Spot" Function, Survey Unit 6

Table 2-5 Summary of Sampling Design, Survey Unit 6

Survey Unit 6	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Formula for calculating minimum size of hot spot	Algorithm developed by Singer and Wickman (1969)
Calculated total number of samples	61
Type of samples	Point Samples
Number of samples on map [a]	60
Number of selected sample areas [b]	1
Specified sampling area [c]	32374.40 ft^2
Grid pattern	Square
Size of grid / Area of grid [d]	7.07 meters / 50.0 m^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid gives the linear and square dimensions of the grid spacing used to systematically place samples.

2.7.3 Confirmation of Selected Sampling Density

Survey Unit 6 underwent additional remediation in October of 2009. Field records indicate that the survey unit was excavated down ~0.5 to 2.0 m with volumetric sampling occurring throughout and at the conclusion of the excavation process. The post-remedial action sample results from the 2009 remedial actions were not included in the 2006 dataset. Furthermore, the large majority of the Survey Unit 6 soils represented by the 2006 dataset were excavated during the 2009 remedial activities. Mapping the 2006 pre-remediation samples and plotting them against the post-remediation contour map demonstrates that the soils represented by these samples, except for those represented by Sample ID 09-S6-023, were removed in 2009 and disposed of as part of NFS' approved soil remediation activities. Therefore, Sample ID 09-S6-023 is the only sample from the pre-2006 historical dataset that is considered relevant to the post-remediation radiological conditions. The 2009 post-remediation dataset (including Sample ID 09-S6-023) is representative of the radiological conditions of the site at the time of FSS activities and is considered the relevant historical dataset for use in designing the FSS and demonstrating compliance and acceptability with the sampling density criteria for Survey Unit 6. The historical dataset of Survey Unit 6, Appendix A.2, is the 2009 post-remediation dataset which includes Sample ID 09-S6-023.

The selected corehole spacing (one corehole every 50 m^2) was reevaluated using the 2009 post-remediation dataset for Survey Unit 6. To reevaluate the Survey Unit 6 survey design, the 2009 post-remediation sample results were plotted in SADA to verify their locations within the survey units. Next, the dataset was inputted into the Subsurface Soil DCGL calculators as the appropriate historical dataset, replacing the 2006 dataset (except for Sample ID 09-S6-023) which was no longer considered representative of the radiological condition of Survey Unit 6. This test was performed to determine what the resultant corehole spacing would have been, if the post-remediation data had been available and used during the original survey design. This evaluation confirmed the suitability of the survey design for Survey Unit 6. It affirmed that the corehole spacing prescribed in the survey design (one corehole every 50 m^2) was far more dense than would reasonably be required to assess the radiation dose consequences of locally elevated pockets of residual radioactivity within the survey unit. Using the 2009 dataset, the Subsurface Soil DCGL calculators conclude that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *90th Percentile* is 999 m^2 (the default maximum size of the Subsurface Soil DCGL calculators) and that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *Observed Maximum* is 999 m^2.

The resulting design placed 60 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 6 (Table 2-6, Figure 2-16). Amec Foster Wheeler assigned a unique number to each corehole.

Table 2-6 Planned Corehole Locations, Survey Unit 6

Sample ID	Easting (X)	Northing (Y)
750	3022290.88	673972.48
751	3022314.08	673972.48
752	3022337.28	673972.48
753	3022360.48	673972.48
754	3022383.68	673972.48
755	3022290.88	673995.68
756	3022314.08	673995.68
757	3022337.28	673995.68
758	3022360.48	673995.68
759	3022383.68	673995.68
760	3022406.88	673995.68
761	3022430.08	673995.68
762	3022453.28	673995.68
763	3022314.08	674018.88
764	3022337.28	674018.88
765	3022360.48	674018.88
766	3022383.68	674018.88
767	3022406.88	674018.88
768	3022430.08	674018.88
769	3022453.28	674018.88
770	3022337.28	674042.08
771	3022360.48	674042.08
772	3022383.68	674042.08

Table 2-6 Planned Corehole Locations, Survey Unit 6, Continued

Sample ID	Easting (X)	Northing (Y)
773	3022406.88	674042.08
774	3022430.08	674042.08
775	3022453.28	674042.08
776	3022360.48	674065.27
777	3022383.68	674065.27
778	3022406.88	674065.27
779	3022430.08	674065.27
780	3022453.28	674065.27
781	3022337.28	674088.47
782	3022360.48	674088.47
783	3022383.68	674088.47
784	3022406.88	674088.47
785	3022430.08	674088.47
786	3022453.28	674088.47
787	3022314.08	674111.67
788	3022337.28	674111.67
789	3022360.48	674111.67
790	3022383.68	674111.67
791	3022406.88	674111.67
792	3022430.08	674111.67
793	3022453.28	674111.67
794	3022290.88	674134.87
795	3022314.08	674134.87
796	3022337.28	674134.87
797	3022383.68	674134.87
798	3022406.88	674134.87
799	3022430.08	674134.87
800	3022267.68	674158.07
801	3022290.88	674158.07
802	3022383.68	674158.07
803	3022406.88	674158.07
804	3022430.08	674158.07
805	3022406.88	674181.27
806	3022430.08	674181.27
807	3022406.88	674204.47
808	3022430.08	674204.47
809	3022430.08	674227.67

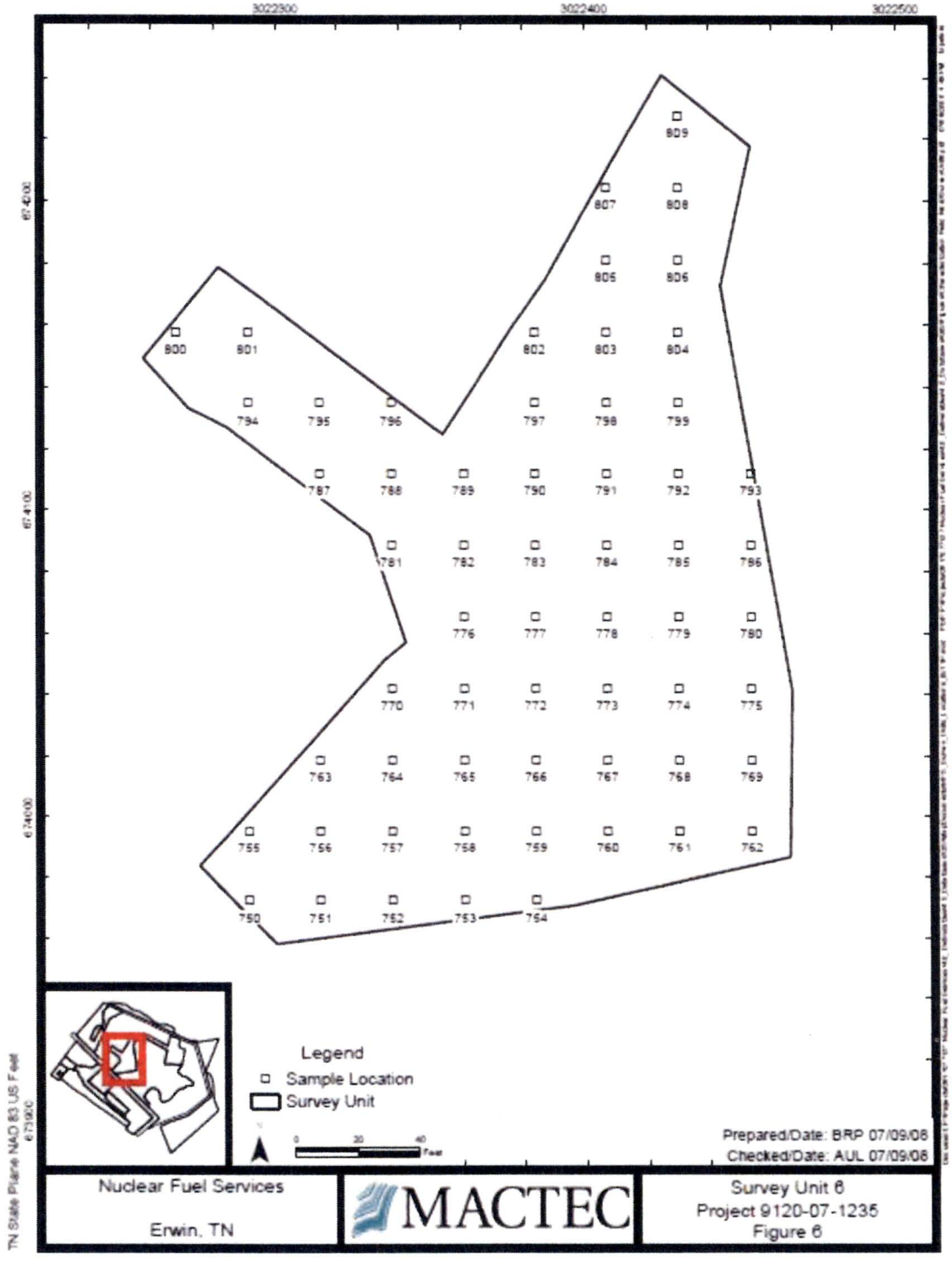

Figure 2-16 Survey Unit 6 Corehole Locations

2.8 SURVEY UNIT 7 DESIGN

2.8.1 Survey Unit Description

Survey Unit 7 (as shown in*Figure 2-17*) comprises a portion of the former burial grounds area of the site. The survey unit encompasses an area of 10,213 m^2.

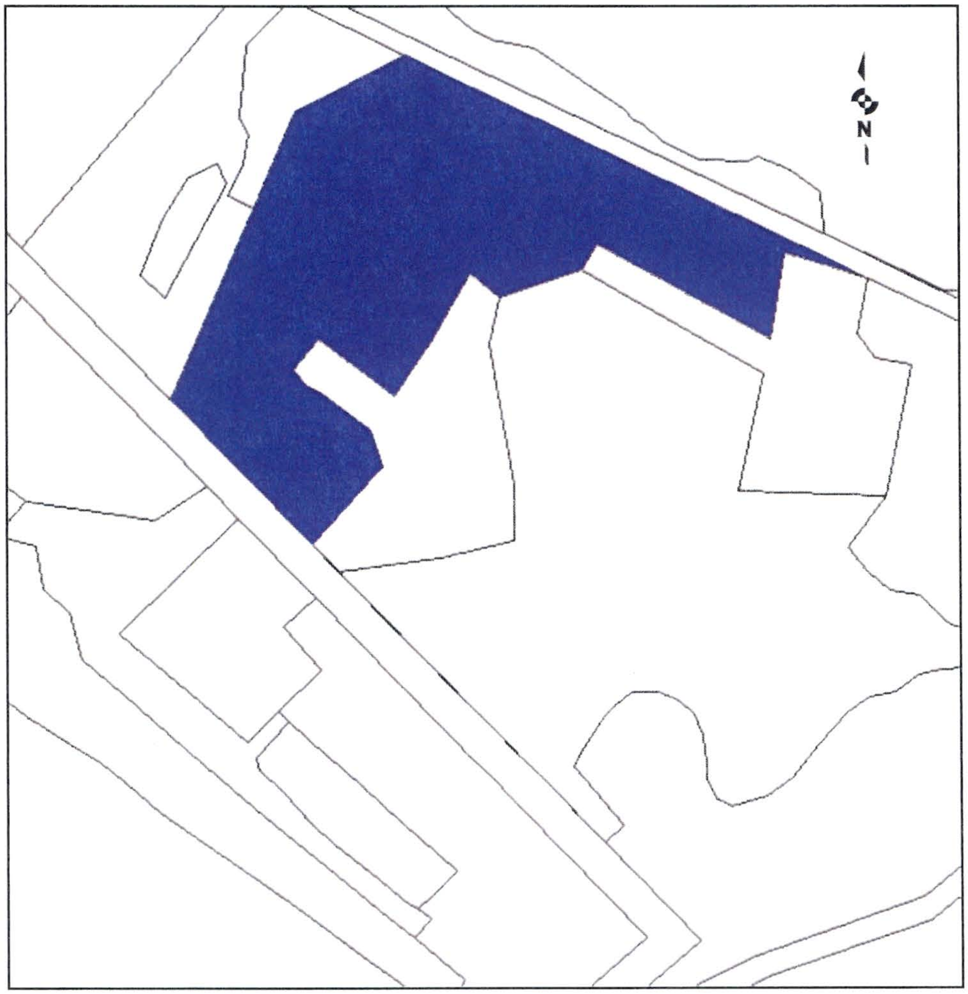

Figure 2-17 Survey Unit 7 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. Survey Unit 7 is bounded to the northwest by Survey Unit 10 and Survey Unit 8. The southeast border of Survey Unit 7 is the former security zone (Survey Unit 11) and the northern border is the access road (Survey Unit 2). Survey Unit 7 is bounded to the east by Survey Units 6 and 4 on the southern and central portions, respectively. The northeasertern arm of Survey Unit 7 is largely bounded by an area that is not included in this characterization project. The entire survey unit lies inside of the security fencing system placing it within NFS secured property.

2.8.2 Sampling Density Determination

Using the same final design criteria as outlined in Sections 2.6.2 and 2.6.3 used during the design of Survey Unit 4, the appropriate number and spacing of the coreholes was determined for Survey Unit 7. Figure 2-18, Figure 2-19, and Table 2-7 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes, presented in Figure 2-20 and Table 2-8.

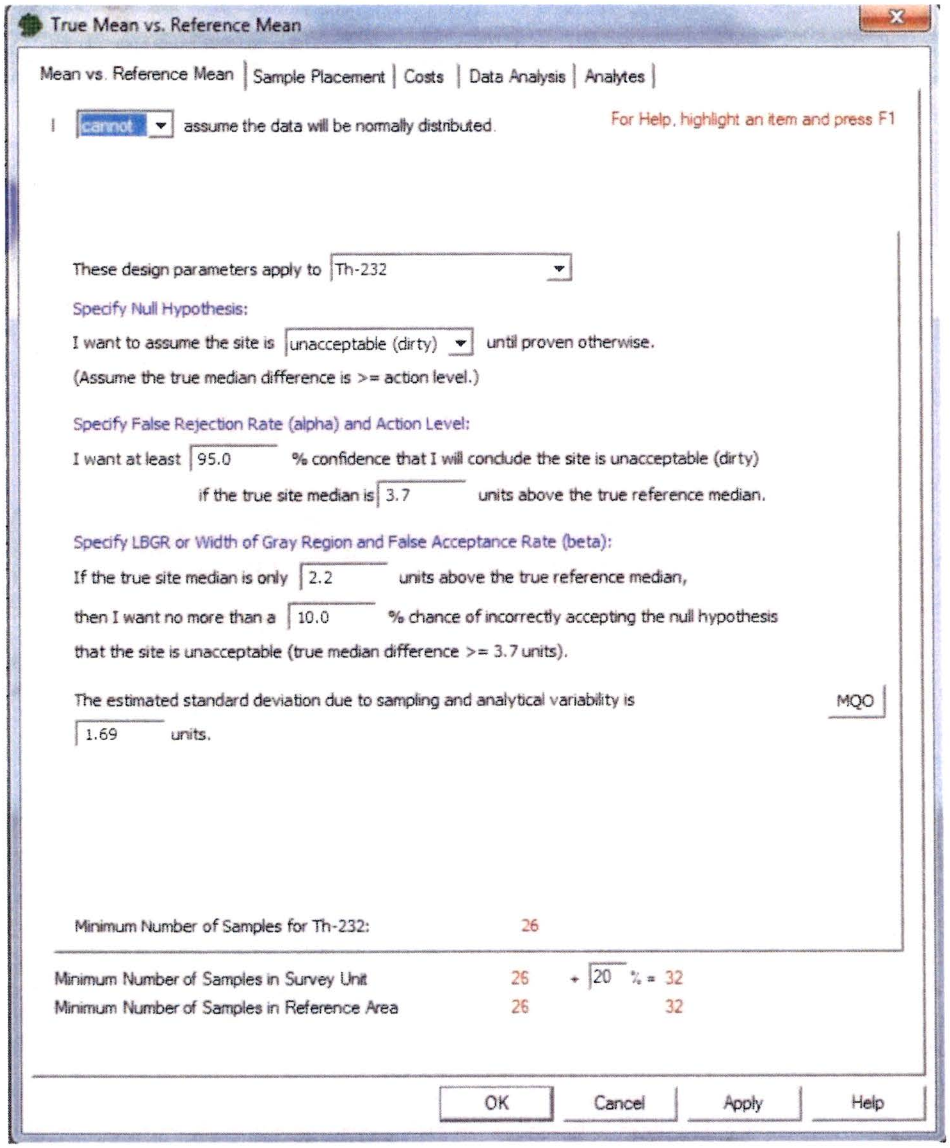

Figure 2-18 Screen Shot, VSP Sample Size Calculation, Survey Unit 7

Once the minimum number of coreholes (32) in the survey unit had been determined, they were distributed over the survey unit, again using VSP, using a random start, systematic square grid. The core sampling density that arises from the distribution of 32 coreholes over the area of Survey Unit 7 (10,213 m^2) is one corehole every 319 m^2.

The existing data relevant to conditions in Survey Unit 7 at the time of the survey for Th-232 is distributed, as shown in Figure 2-19 which presents historical data from Layer #1 (0-1 meter depth). Note that the 90[th] percentile is calculated to be 2.74 pCi/g. The maximum observed concentration is 11.4 pCi/g.

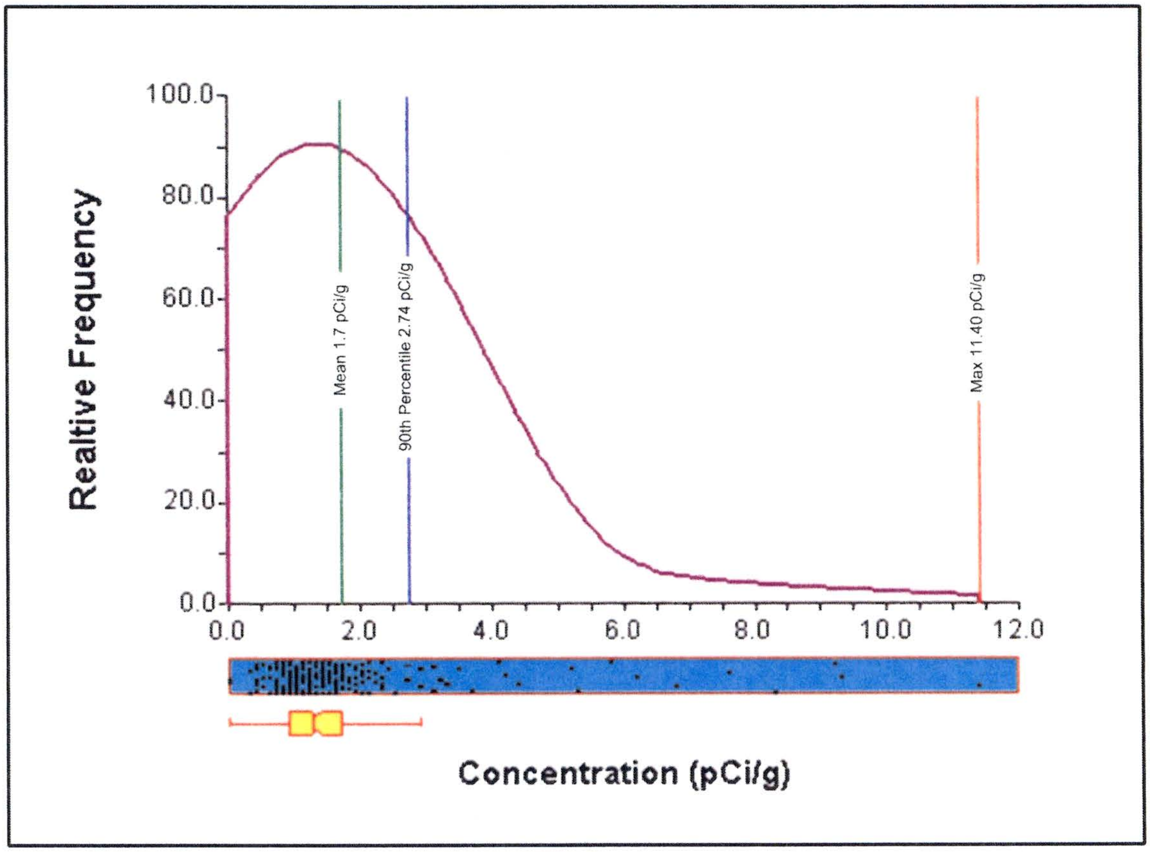

Figure 2-19 Pre-Existing Sample Data Distribution, Th-232, Layer #1, Survey Unit 7

For Survey Unit 7, the highest 90[th] percentile and "expected maximum" concentrations observed were less than the corresponding permissible surface soil DCGL. This indicated that it was not necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil. Consequently, the final corehole density sampled in Survey Unit 7 is shown in Table 2-7.

Table 2-7 Corehole Density Summary Table

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
7	10,213	319	32

Having determined the appropriate number and spacing of the coreholes for Survey Unit 7, VSP was used to specify the final sampling design. The sampling design template (sampling goal in VSP) used was the MARSSIM version WRS test design in which the 32 coreholes were distributed over the survey unit using a systematic square grid with a random start location (Figure 2-20). A summary table describing the basic aspects of the survey design is presented in Table 2-8 A detailed report describing the sampling design, automatically generated by the VSP software, is provided in Appendix B.

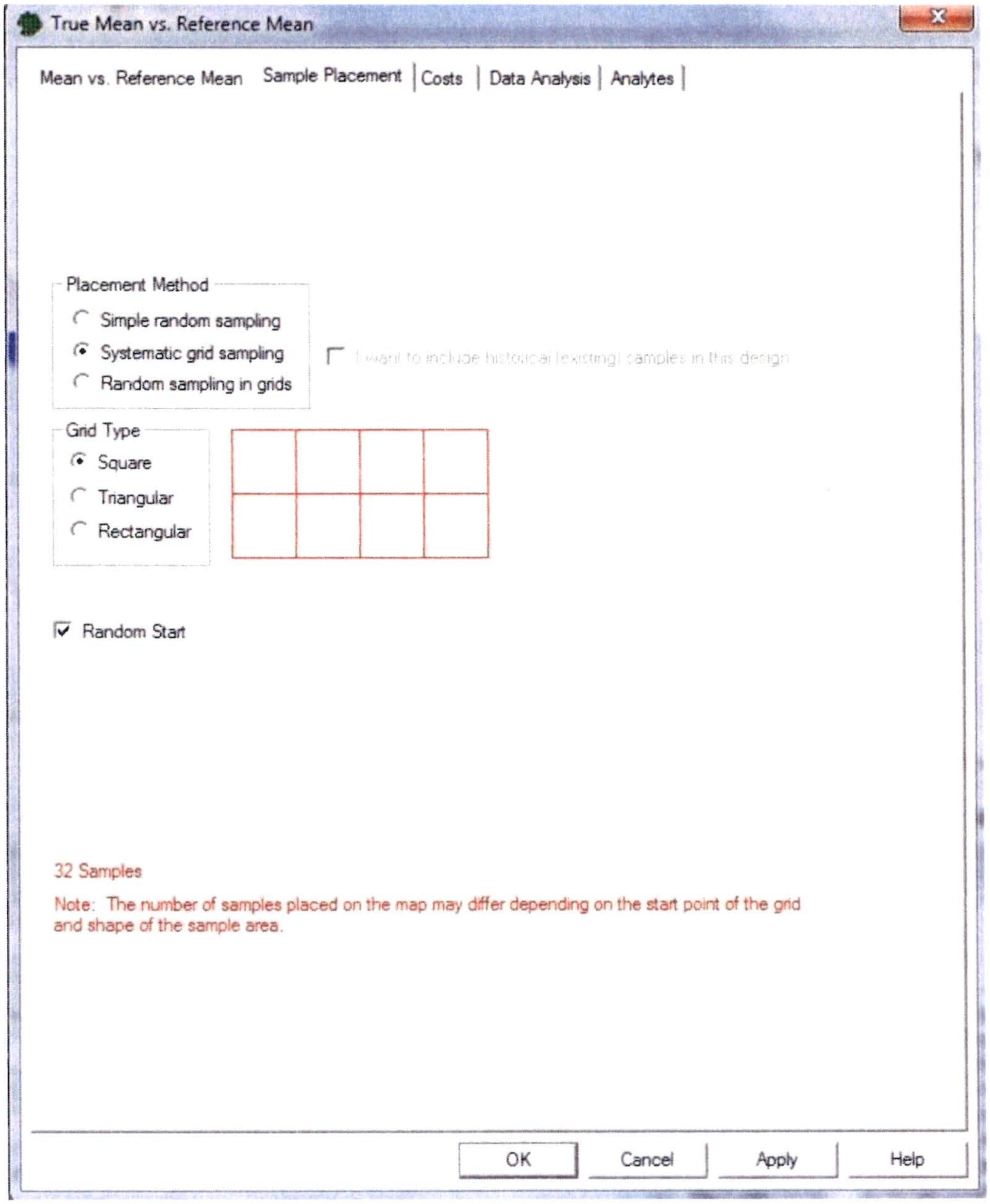

Figure 2-20 Sample Placement Architecture, Survey Unit 7

Table 2-8 Summary of Sampling Design, Survey Unit 7

Survey Unit 7	
Primary Objective of Design	Compare a site mean or median to a reference area mean or median
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Wilcoxon Rank Sum Test - MARSSIM version
Calculated total number of samples for each site and reference area [a]	32
Number of samples on map [b]	32
Number of selected sample areas [c]	1
Specified sampling area [d]	10212.9 m2
Size of grid / Area of grid cell e	17.9 m / 319.1 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

The resulting design placed 32 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 7. Amec Foster Wheeler assigned a unique number to each corehole, listed in Table 2-9 and presented in Figure 2-21.

Table 2-9 Planned Corehole Locations, Survey Unit 7

Sample ID	Easting (X)	Northing (Y)
7001	674039.1564	3022225.356
7002	674039.1564	3022283.968
7003	674097.7681	3022166.745
7004	674097.7681	3022225.356
7005	674097.7681	3022283.968
7006	674156.3799	3022166.745
7007	674156.3799	3022225.356
7008	674156.3799	3022342.58
7009	674214.9916	3022225.356
7010	674214.9916	3022283.968
7011	674214.9916	3022342.58
7012	674214.9916	3022401.192
7013	674214.9916	3022694.25
7014	674273.6034	3022225.356
7015	674273.6034	3022283.968
7016	674273.6034	3022342.58
7017	674273.6034	3022401.192
7018	674273.6034	3022459.803
7019	674273.6034	3022518.415
7020	674273.6034	3022577.027
7021	674273.6034	3022635.638
7022	674273.6034	3022694.25
7023	674332.2151	3022283.968
7024	674332.2151	3022342.58
7025	674332.2151	3022401.192
7026	674332.2151	3022459.803
7027	674332.2151	3022518.415
7028	674332.2151	3022577.027
7029	674390.8268	3022283.968
7030	674390.8268	3022342.58
7031	674390.8268	3022401.192
7032	674390.8268	3022459.803

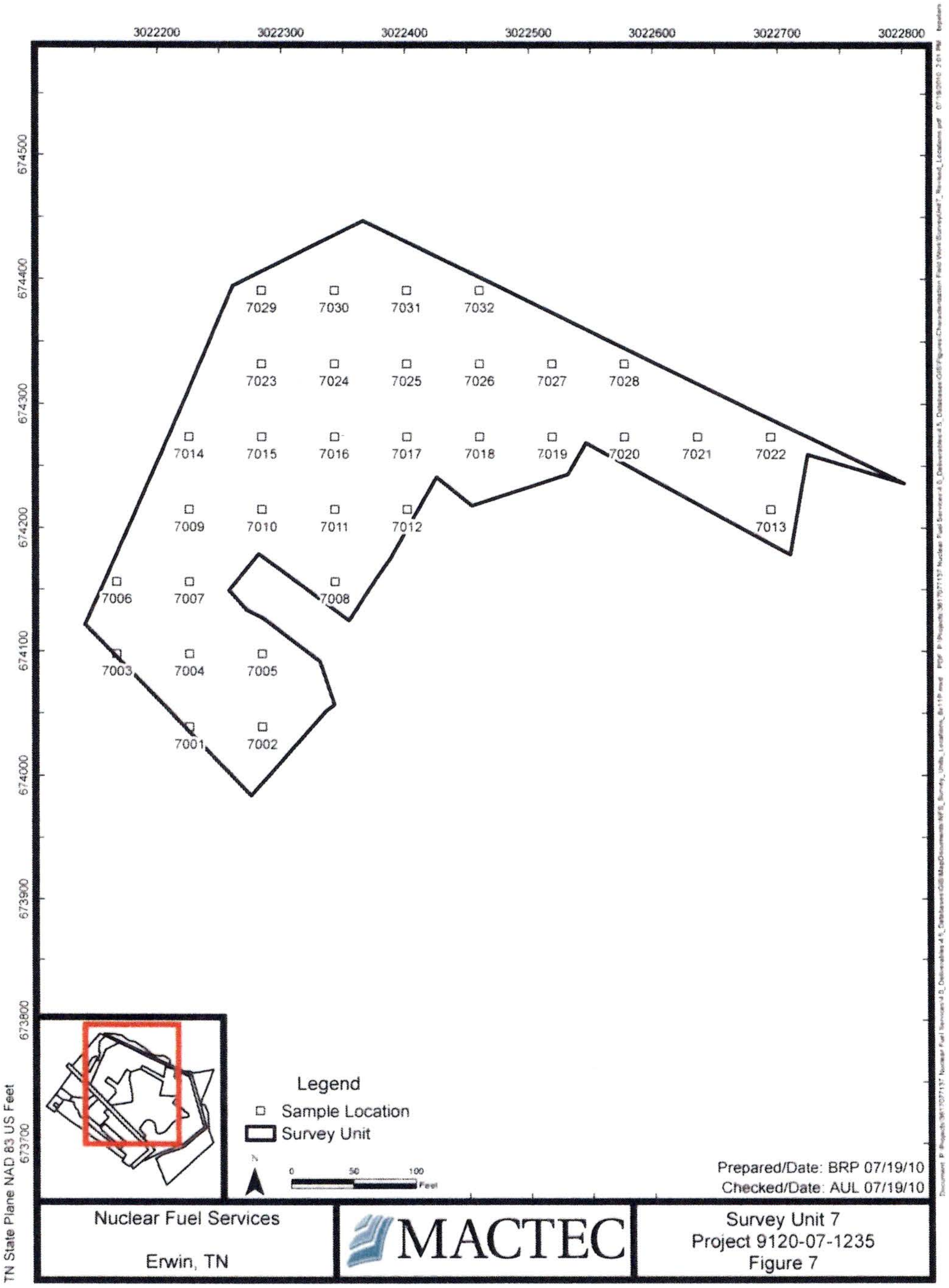

Figure 2-21 Survey Unit 7 Corehole Locations

2.9 SURVEY UNIT 12 DESIGN

2.9.1 Survey Unit Description

Survey Unit 12 (as shown in Figure 2-22) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 2,624 m^2.

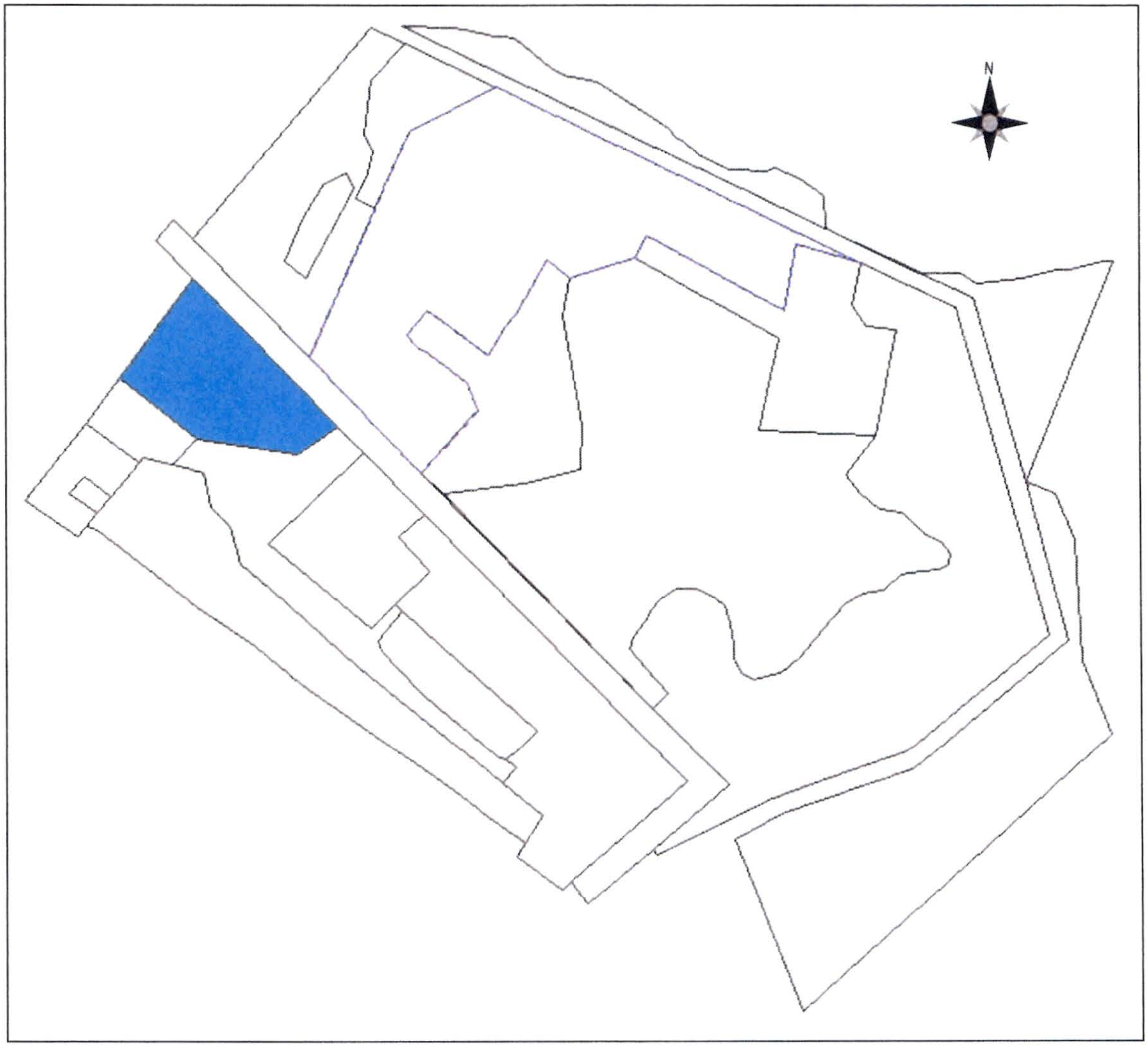

Figure 2-22 Survey Unit 12 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. The northwestern boundary of Survey Unit 12 is a fence which delineates the extent of characterization, and the northeastern boundary is a fence which separates Survey Unit 11, the former security zone. The southern and southwestern borders are bound by Survey Units 17 and 13, respectively.

2.9.2 Sampling Density Determination

Using the same final design criteria as outlined in Sections 2.6.2 and 2.6.3 used during the design of Survey Units 4 and 6, the appropriate number and spacing of the coreholes was determined for Survey Unit 12. Figure 2-23, Figure 2-24 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes, presented in Table 2-11 and Figure 2-25.

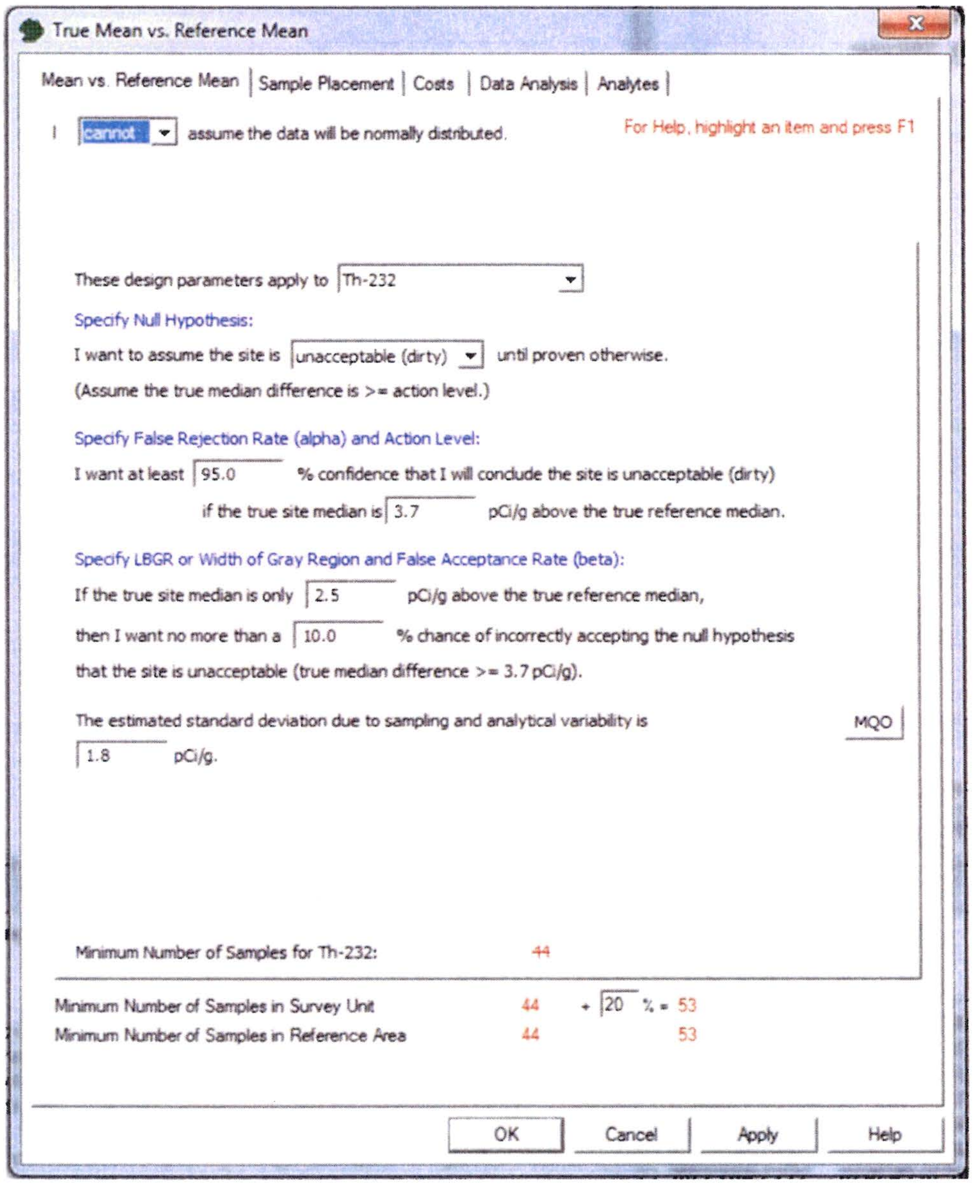

Figure 2-23 Screen Shot, VSP Sample Size Calculation, Survey Unit 12

Once the minimum number of coreholes (53) in the survey unit had been determined, they were distributed over the survey unit, again using VSP, using a random start, systematic square grid. The core sampling density that arises from the distribution of 53 coreholes over the area of Survey Unit 12 (2,624 m^2) is one corehole every 50 m^2.

The maximum elevation of Survey Unit 12 present during survey design was 1,637 feet above msl. The final desired grade of Survey Unit 12 is 1,640 feet above msl; therefore, the analytical value depths from historical data was lowered 3 feet to account for this offset. Historical data collected from Layer #1 (0-1 meter depth) of Survey Unit 12 was consequently assigned to Layer #2 (1-2 meter depth) in Amec Foster Wheeler's SSDCGL calculator in order to determine grid size for the survey unit. Figure 2-24 presents historical data from Layer #2 (1-2 meter depth). Note that the 90th percentile is calculated to be 8.90 pCi/g. The maximum observed concentration is 11.5 pCi/g.

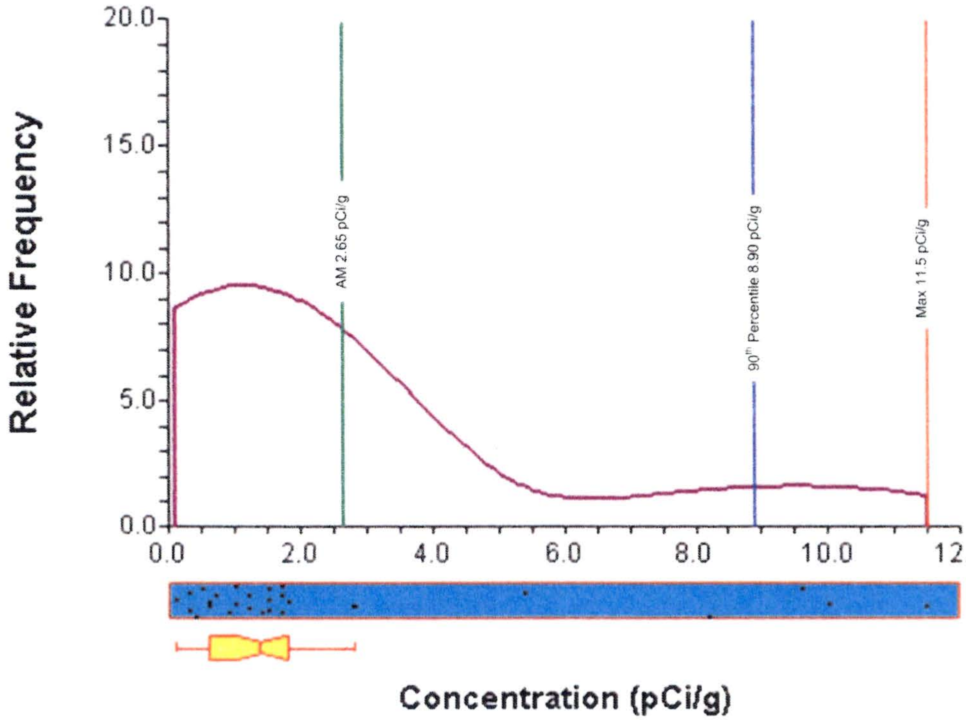

Figure 2-24 Sample Pre-Existing Data Distribution, Th-232, Layer #2, Survey Unit 12

Contrary to Survey Unit 4, the highest 90th percentile concentration observed in Survey Unit 12 (8.90 pCi/g) was greater than the corresponding permissible sub-surface soil DCGL. Therefore, the "reasonable maximum concentration" value intersects the volume factor curve. This indicates that it was necessary to consider adjusting the corehole density to compensate for the potential presence of localize anomalies. The "reasonable maximum concentration" calculation returned a maximum corehole density of 92.0 m^2 resulting in a total of 29 coreholes. Because the WRS calculation performed in VSP returned a corehole density of 50 m^2, the more dense corehole frequency of one every 50 m^2 was selected for Survey Unit 12.

Table 2-10 Summary of Sampling Design, Survey Unit 12

Survey Unit 12	
Primary Objective of Design	Compare a site mean or median to a reference area mean or median
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Wilcoxon Rank Sum Test - MARSSIM version
Calculated total number of samples for each survey and reference area [a]	53
Number of samples on map [b]	53
Number of selected sample areas [c]	1
Specified sampling area [d]	2,624 m^2
Size of grid / Area of grid [e]	7.07 meters / 50.0 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

The resulting design placed 53 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 12 (Table 2-11, Figure 2-25). Amec Foster Wheeler assigned a unique number to each corehole.

Table 2-11 Planned Corehole Locations, Survey Unit 12

Sample ID	Easting (X)	Northing (Y)
292	3022050.00	674017.76
293	3022073.24	674017.76
294	3022096.48	674017.76
295	3022119.72	674017.76
296	3022142.96	674017.76
297	3022003.53	674041.00
298	3022026.76	674041.00
299	3022050.00	674041.00
300	3022073.24	674041.00
301	3022096.48	674041.00
302	3022119.72	674041.00
303	3022142.96	674041.00
304	3022166.20	674041.00
305	3021957.05	674064.24
306	3021980.29	674064.24
307	3022003.53	674064.24
308	3022026.76	674064.24
309	3022050.00	674064.24
310	3022073.24	674064.24
311	3022096.48	674064.24
312	3022119.72	674064.24
313	3022142.96	674064.24
314	3021933.81	674087.48
315	3021957.05	674087.48
316	3021980.29	674087.48
317	3022003.53	674087.48
318	3022026.76	674087.48
319	3022050.00	674087.48
320	3022073.24	674087.48
321	3022096.48	674087.48
322	3022119.72	674087.48
323	3021933.81	674110.72
324	3021957.05	674110.72
325	3021980.29	674110.72
326	3022003.53	674110.72
327	3022026.76	674110.72
328	3022050.00	674110.72
329	3022073.24	674110.72
330	3022096.48	674110.72
331	3021957.05	674133.96
332	3021980.29	674133.96
333	3022003.53	674133.96
334	3022026.76	674133.96
335	3022050.00	674133.96
336	3022073.24	674133.96
337	3021980.29	674157.20
338	3022003.53	674157.20
339	3022026.76	674157.20
340	3022050.00	674157.20
341	3021980.29	674180.44
342	3022003.53	674180.44
343	3022026.76	674180.44
344	3022003.53	674203.67

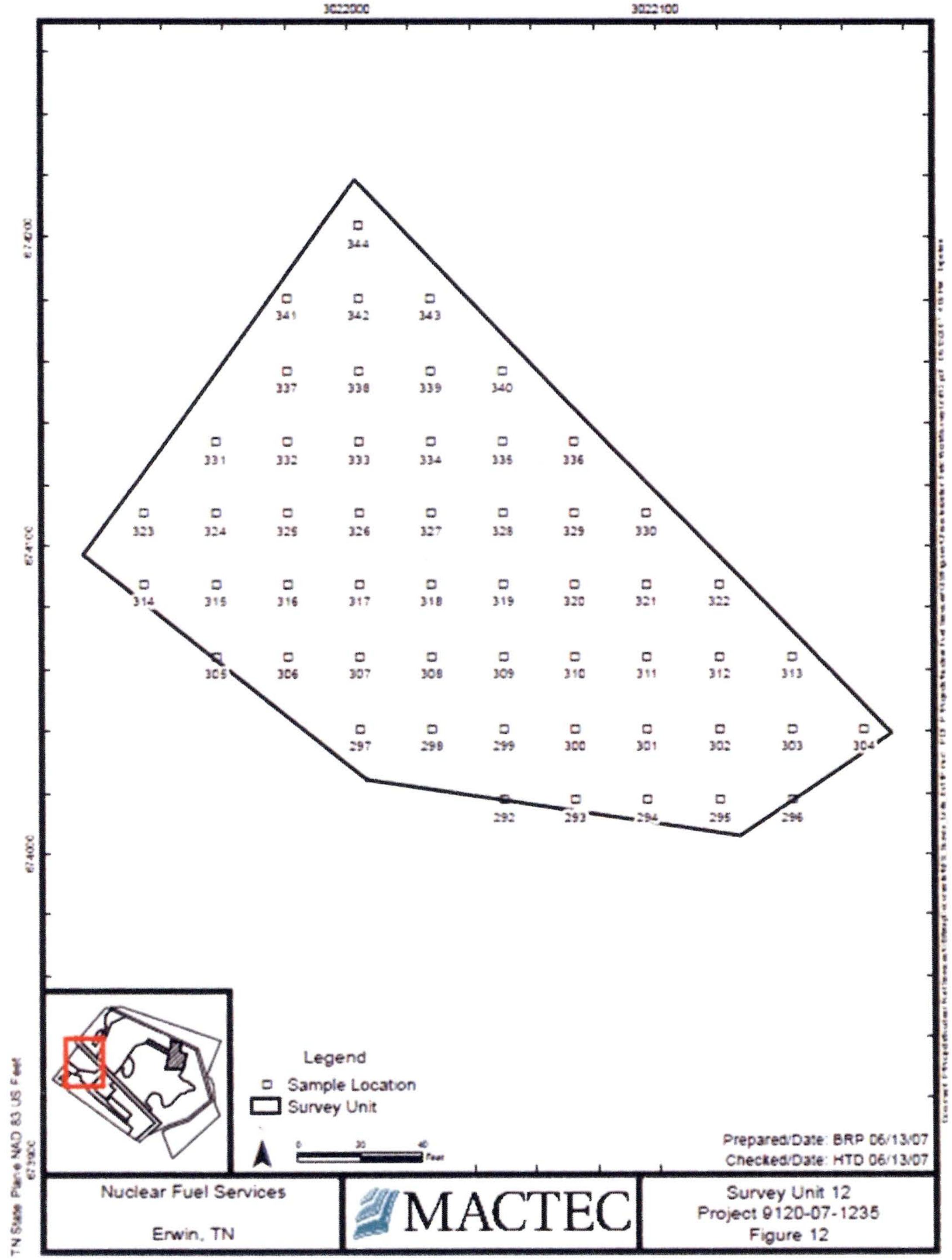

Figure 2-25 Survey Unit 12 Corehole Locations

2.10 SURVEY UNIT 16 DESIGN

2.10.1 Survey Unit Description

Survey Unit 16 (as shown in Figure 2-26) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 4,112 m^2.

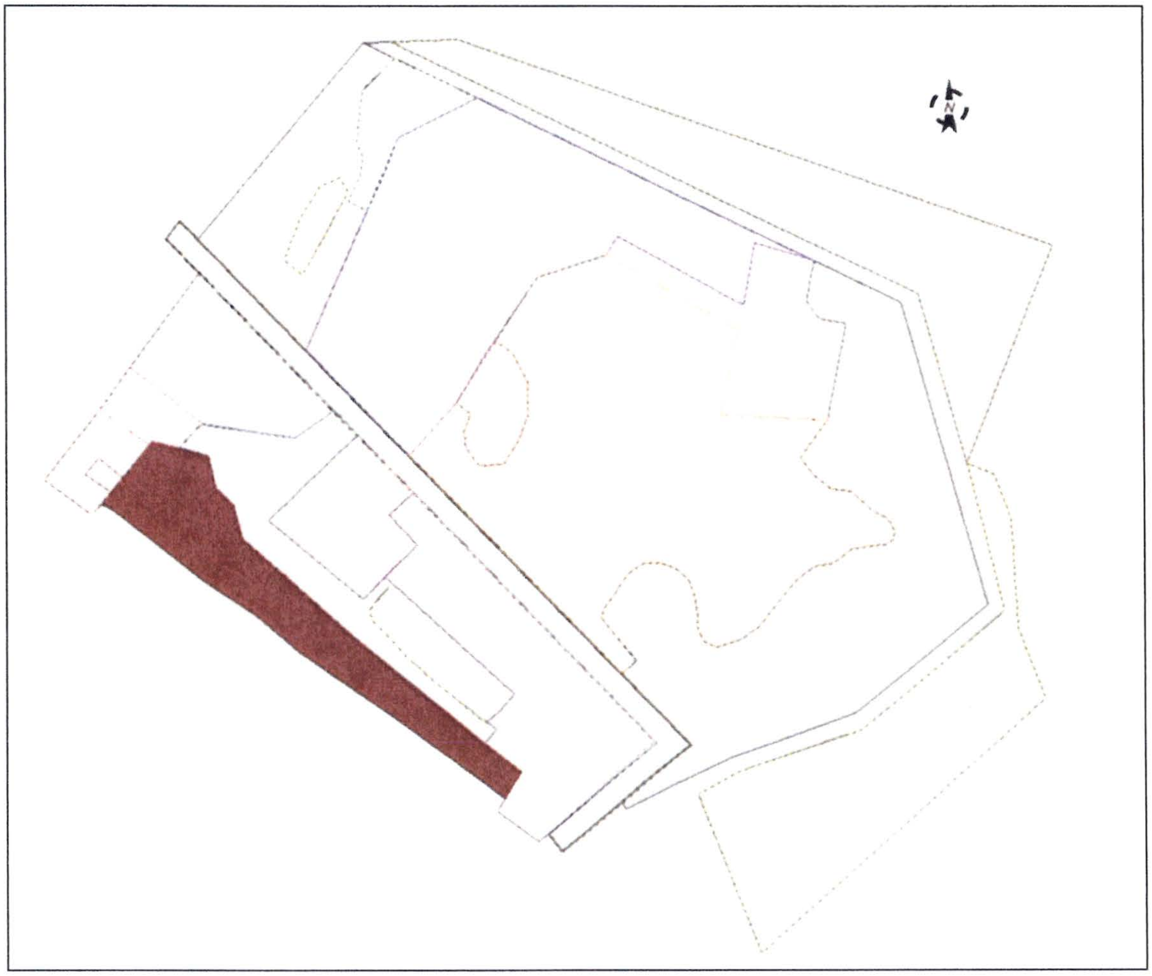

Figure 2-26 Survey Unit 16 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. The southwest border of Survey Unit 16 lies at the extent of the North site characterization, and all remaining borders are bound by Survey Units 13, 14, 15, 17, and 19. Part of the area encompassed by Survey Unit 16 was a former pond. The entire survey unit lies inside of the security fencing system placing it within NFS secured property.

Visualization of the historical data using iso-contour graphics generated in SADA indicates that elevated readings may still be present in Survey Unit 16 and the area immediately surrounding the survey unit (Figure 2-6). It was necessary, therefore, to demarcate exact survey unit borders by "zooming in" on the historical dataset. Elevated data points causing an exaggerated area of influence were grouped together as a single data population, bound into the survey unit, and taken into account in the design of Survey Unit 16.

All of Survey Unit 16 has been previously remediated, resulting in steep excavation banks demarcating the southwest border. Survey Unit 16 was originally designed to encompass an area of 5,255 m^2; however, the steep excavation grade rendered a narrow strip of the survey unit adjacent to the security fencing unsuitable for safe drilling operations. This strip was removed from Survey Unit 16 (Figure 2-27) resulting in an area of 4,112 m^2.

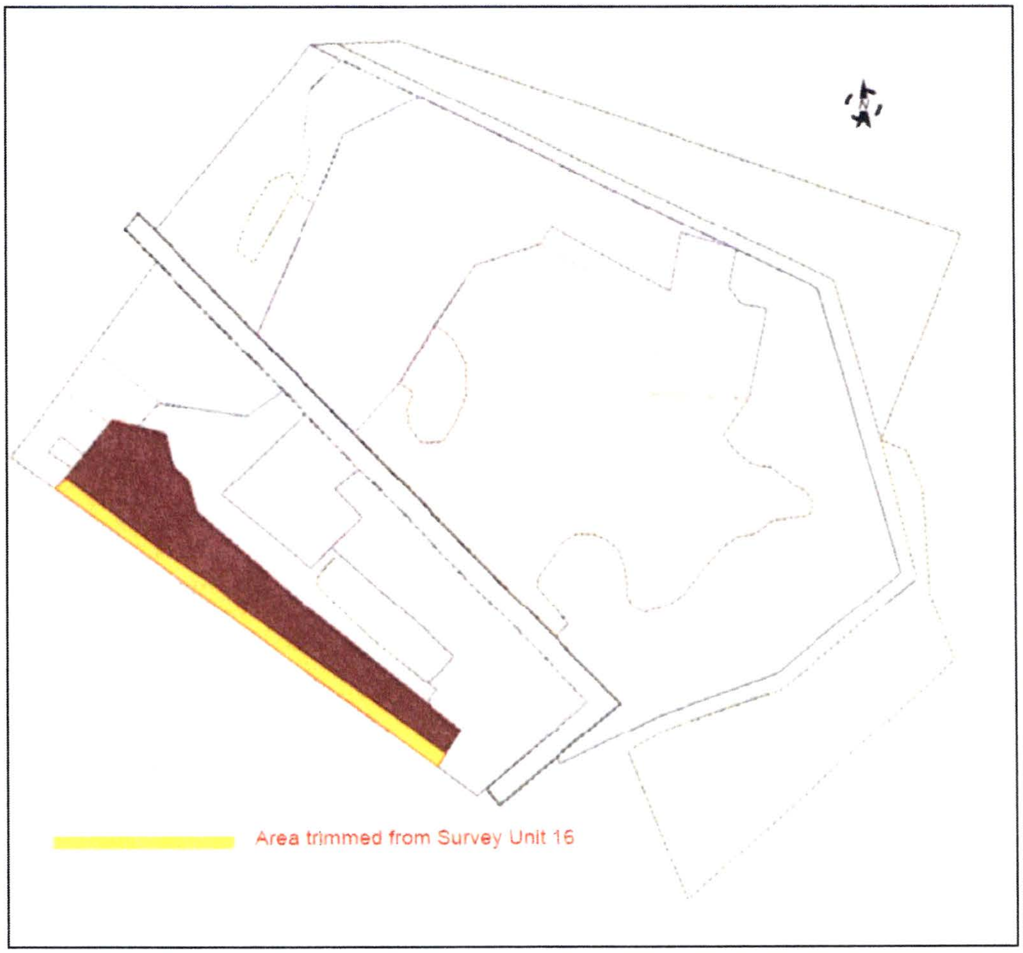

Figure 2-27 Area removed from Survey Unit 16

2.10.2 Sampling Density Determination

The final design of Survey Unit 16 was ultimately determined in 2006 using professional judgment relying on the consideration of four mathematical points; 6.1 m^2 determined by the statistical test calculation using pre-remediation data no longer considered representative of the radiological status, 23 m^2 determined by the "expected maximum concentration" calculation using pre-remediation data no longer considered representative of the radiological status, 50 m^2 determined for the majority of neighboring survey units which share similar historical properties (Survey Units 13, 14 [49 m^2], 17, and 18), and 100 m^2 as suggested by the MARSSIM (NRC 2000) to evaluate areas of elevated radioactivity for open land areas. Because surface scanning is not applicable for subsurface soil characterization and known elevated concentrations of residual radioactivity existed in these areas in the past, a conservative approach was taken. The reference system spacing area identified in MARSSIM (100 m^2) is reduced by a factor of more than four, resulting in a reference system spacing surface area of 23 m^2 (approximately every 4.8 m). Each sample, therefore, represented a volume no greater than the limiting critical volume, 23 m^3 (volume resulting from the nominal corehole spacing required to satisfy the "expected maximum concentration" calculation).

Sampling Survey Unit 16 at a 23 m^2 grid would produce a sufficient number of coreholes to accurately assess the radiological nature of the survey unit. In order to determine the placement of coreholes using VSP, a different statistical parameter was used. Instead of using built-in algorithms needed to satisfy the WRS test, the "Locating a Hotspot" function was utilized. This allows the user to manually set the size and shape of the hotspot to force the sampling density to accommodate. In other words, by setting the diameter of a circular hotspot to 4.8m, VSP placed a corehole every 23 m^2 as desired. Figure 2-28 presents relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes. The final corehole density sampled in Survey Unit 16 is shown in Table 2-12. A detailed report describing the sampling design, automatically generated by the VSP software, is provided in Appendix B.

Table 2-12 Corehole Density Summary Table

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
16	4,112	23	178

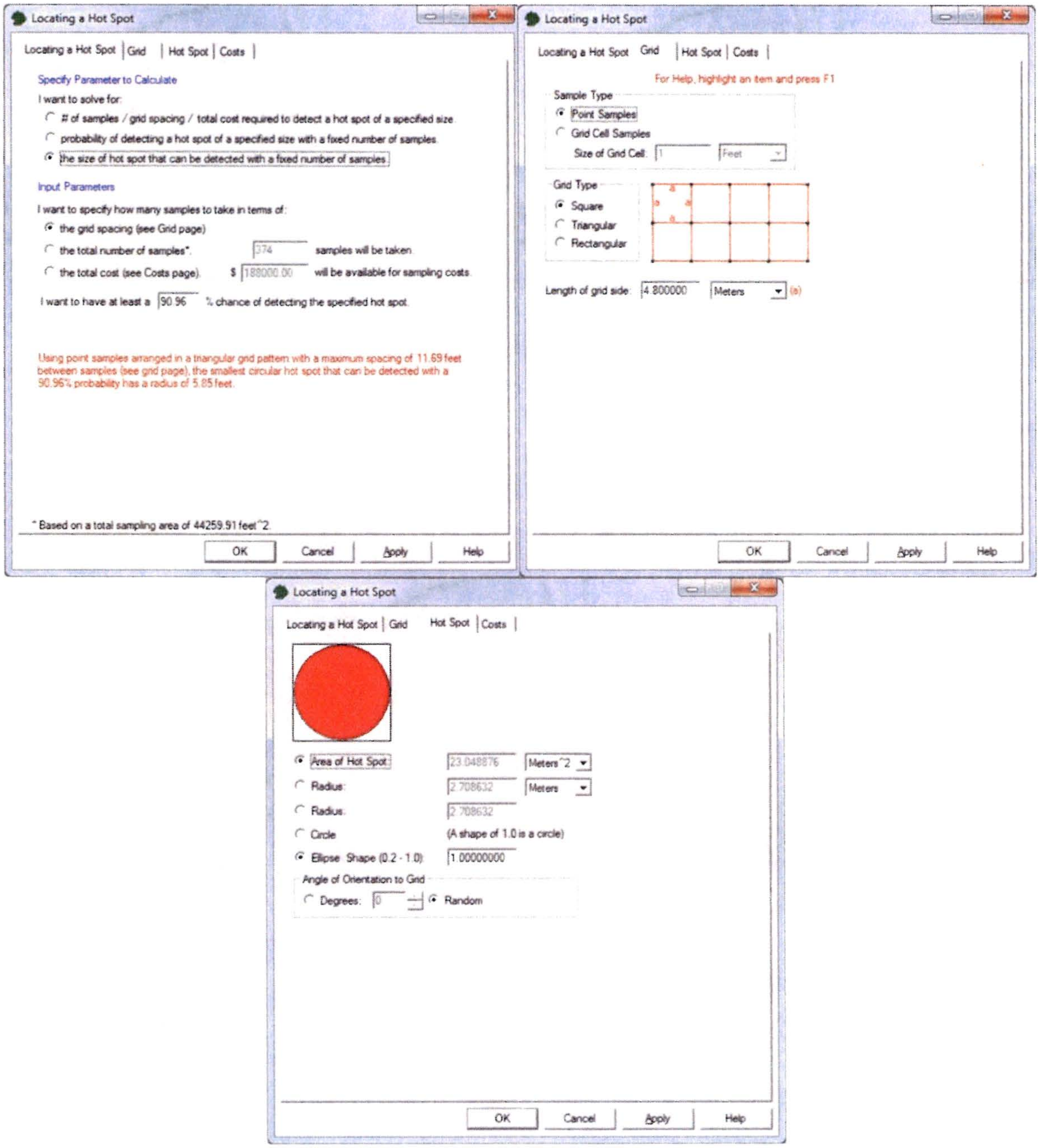

Figure 2-28 Screen Shots, VSP Sample Size Calculation Using "Locating a Hot Spot" Function, Survey Unit 16

Table 2-13 Summary of Sampling Design, Survey Unit 16

Survey Unit 16	
Primary Objective of Design	Compare a site mean or median to a reference area mean or median
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Wilcoxon Rank Sum Test - MARSSIM version
Calculated total number of samples for each site and reference area [a]	178
Number of samples on map [b]	178
Number of selected sample areas [c]	1
Specified sampling area [d]	4111.9 m^2
Size of grid / Area of grid cell [e]	4.8 m / 23.0 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

The resulting design placed 178 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 16. Amec Foster Wheeler assigned a unique number to each corehole, listed in Table 2-14 and presented in Figure 2-29.

Table 2-14 Planned Corehole Locations, Survey Unit 16

Sample ID	Easting (X)	Northing (Y)	Sample ID	Easting (X)	Northing (Y)
384	3022390.72	673544.05	430	3022233.23	673701.53
385	3022374.97	673559.8	431	3022248.98	673701.53
386	3022390.72	673559.8	432	3022154.49	673717.28
387	3022406.47	673559.8	433	3022170.24	673717.28
388	3022343.47	673575.54	434	3022185.99	673717.28
389	3022359.22	673575.54	435	3022201.73	673717.28
390	3022374.97	673575.54	436	3022217.48	673717.28
391	3022390.72	673575.54	437	3022233.23	673717.28
392	3022406.47	673575.54	438	3022138.74	673733.03
393	3022327.72	673591.29	439	3022154.49	673733.03
394	3022343.47	673591.29	440	3022170.24	673733.03
395	3022359.22	673591.29	441	3022185.99	673733.03
396	3022374.97	673591.29	442	3022201.73	673733.03
397	3022311.97	673607.04	443	3022217.48	673733.03
398	3022327.72	673607.04	444	3022107.24	673748.78
399	3022343.47	673607.04	445	3022122.99	673748.78
400	3022359.22	673607.04	446	3022138.74	673748.78
401	3022280.48	673622.79	447	3022154.49	673748.78
402	3022296.23	673622.79	448	3022170.24	673748.78
403	3022311.97	673622.79	449	3022185.99	673748.78
404	3022327.72	673622.79	450	3022091.49	673764.53
405	3022343.47	673622.79	451	3022107.24	673764.53
406	3022264.73	673638.54	452	3022122.99	673764.53
407	3022280.48	673638.54	453	3022138.74	673764.53
408	3022296.23	673638.54	454	3022154.49	673764.53
409	3022311.97	673638.54	455	3022170.24	673764.53
410	3022327.72	673638.54	456	3022075.75	673780.28
411	3022248.98	673654.29	457	3022091.49	673780.28
412	3022264.73	673654.29	458	3022107.24	673780.28
413	3022280.48	673654.29	459	3022122.99	673780.28
414	3022296.23	673654.29	460	3022138.74	673780.28
415	3022311.97	673654.29	461	3022154.49	673780.28
416	3022217.48	673670.04	462	3022044.25	673796.02
417	3022233.23	673670.04	463	3022060	673796.02
418	3022248.98	673670.04	464	3022075.75	673796.02
419	3022264.73	673670.04	465	3022091.49	673796.02
420	3022280.48	673670.04	466	3022107.24	673796.02
421	3022201.73	673685.78	467	3022122.99	673796.02
422	3022217.48	673685.78	468	3022138.74	673796.02
423	3022233.23	673685.78	469	3022028.5	673811.77
424	3022248.98	673685.78	470	3022044.25	673811.77
425	3022264.73	673685.78	471	3022060	673811.77
426	3022170.24	673701.53	472	3022075.75	673811.77
427	3022185.99	673701.53	473	3022091.49	673811.77
428	3022201.73	673701.53	474	3022107.24	673811.77
429	3022217.48	673701.53	475	3022122.99	673811.77

Table 2-14 Planned Corehole Locations, Survey Unit 16 (Continued)

Sample ID	Easting (X)	Northing (Y)	Sample ID	Easting (X)	Northing (Y)
476	3022012.75	673827.52	519	3021965.5	673906.26
477	3022028.5	673827.52	520	3021981.25	673906.26
478	3022044.25	673827.52	521	3021997	673906.26
479	3022060	673827.52	522	3022012.75	673906.26
480	3022075.75	673827.52	523	3022028.5	673906.26
481	3022091.49	673827.52	524	3022044.25	673906.26
482	3022107.24	673827.52	525	3021886.76	673922.01
483	3021981.25	673843.27	526	3021902.51	673922.01
484	3021997	673843.27	527	3021918.26	673922.01
485	3022012.75	673843.27	528	3021934.01	673922.01
486	3022028.5	673843.27	529	3021949.76	673922.01
487	3022044.25	673843.27	530	3021965.5	673922.01
488	3022060	673843.27	531	3021981.25	673922.01
489	3022075.75	673843.27	532	3021997	673922.01
490	3022091.49	673843.27	533	3022012.75	673922.01
491	3021965.5	673859.02	534	3022028.5	673922.01
492	3021981.25	673859.02	535	3021902.51	673937.76
493	3021997	673859.02	536	3021918.26	673937.76
494	3022012.75	673859.02	537	3021934.01	673937.76
495	3022028.5	673859.02	538	3021949.76	673937.76
496	3022044.25	673859.02	539	3021965.5	673937.76
497	3022060	673859.02	540	3021981.25	673937.76
498	3022075.75	673859.02	541	3021997	673937.76
499	3021949.76	673874.77	542	3022012.75	673937.76
500	3021965.5	673874.77	543	3021918.26	673953.51
501	3021981.25	673874.77	544	3021934.01	673953.51
502	3021997	673874.77	545	3021949.76	673953.51
503	3022012.75	673874.77	546	3021965.5	673953.51
504	3022028.5	673874.77	547	3021981.25	673953.51
505	3022044.25	673874.77	548	3021997	673953.51
506	3021918.26	673890.52	549	3022012.75	673953.51
507	3021934.01	673890.52	550	3021918.26	673969.26
508	3021949.76	673890.52	551	3021934.01	673969.26
509	3021965.5	673890.52	552	3021949.76	673969.26
510	3021981.25	673890.52	553	3021965.5	673969.26
511	3021997	673890.52	554	3021981.25	673969.26
512	3022012.75	673890.52	555	3021997	673969.26
513	3022028.5	673890.52	556	3022012.75	673969.26
514	3022044.25	673890.52	557	3021934.01	673985.01
515	3021902.51	673906.26	558	3021949.76	673985.01
516	3021918.26	673906.26	559	3021965.5	673985.01
517	3021934.01	673906.26	560	3021981.25	673985.01
518	3021949.76	673906.26	561	3021997	673985.01
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet					

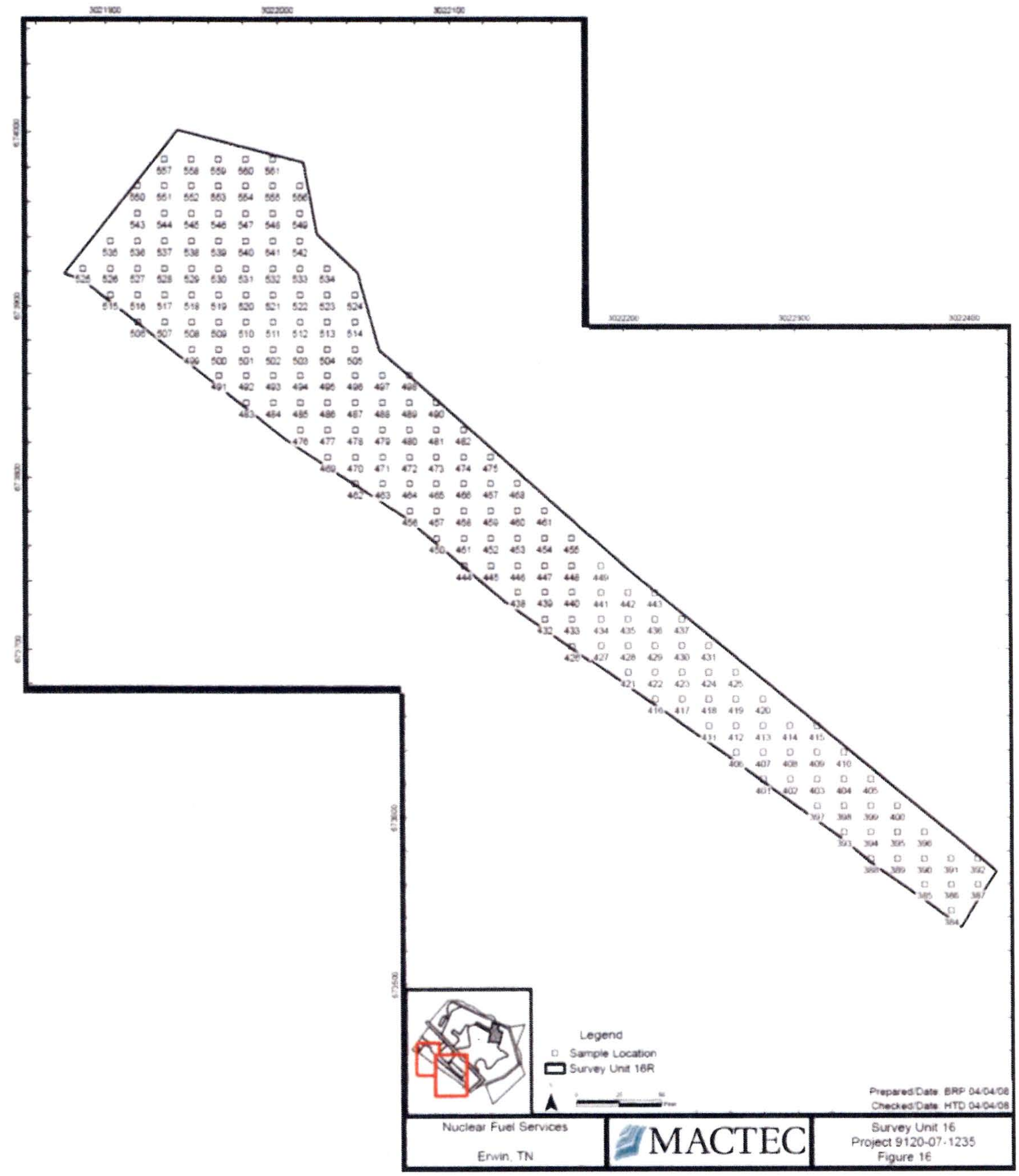

Figure 2-29 Survey Unit 16 Corehole Locations

2.11 SURVEY UNIT 17 DESIGN

2.11.1 Survey Unit Description

Survey Unit 17 (as shown in Figure 2-30) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 2,843 m^2.

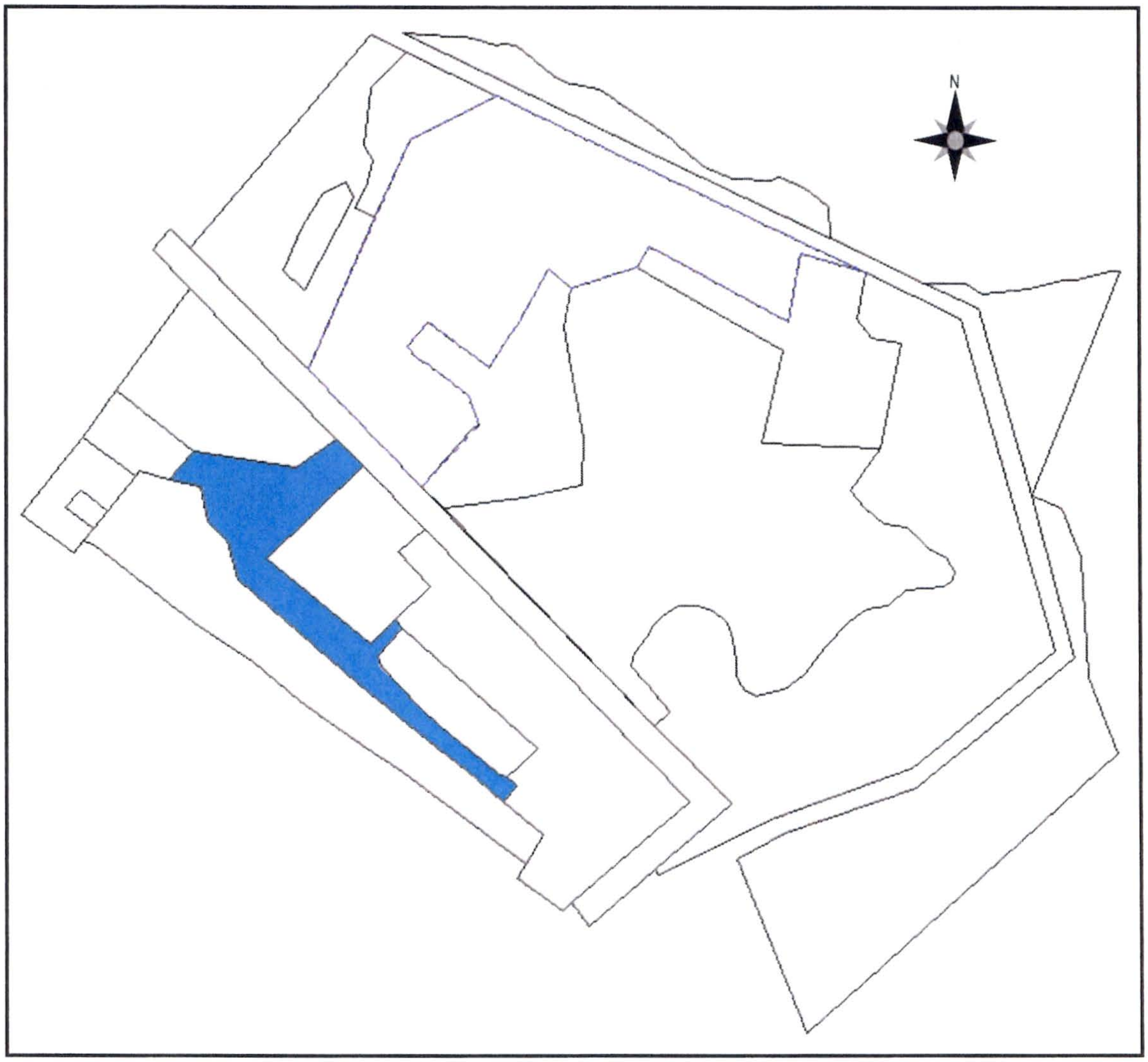

Figure 2-30 Survey Unit 17 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. Visualization of the historical data using iso-contour graphics generated in SADA indicates that elevated readings may still be present in the far northwestern corner of Survey Unit 17, and in the southwest area of the survey unit (Figure 2-6). It was necessary, therefore, to demarcate exact survey unit borders by "zooming in" on the historical dataset. Elevated data points causing an exaggerated area of influence were grouped together as a single data population, bound into a survey unit, and taken into account in the design of Survey Unit 17.

The long, western border of Survey Unit 17 is Survey Unit 16, which is the extent of previous remediation of a former settling pond. The long, eastern edge of the survey unit is bound in the northern portion by Survey Unit 18, a former operations area, and by Survey Unit 20, a remediated part of a former settling pond, in the southern portion. The northern boundary of Survey Unit 17 is Survey Units 12 and 13, which comprise the northwestern extent of the former ponds area. The northeastern corner of the survey unit is bound by Survey Unit 11, the former security zone, and the extreme southeastern corner is bound by Survey Unit 19.

2.11.2 Sampling Density Determination

The number of corehole locations for Survey Unit 17 was calculated using the method described in Section 2.6.2. Similar to Survey Unit 6, the number of coreholes for Survey Unit 17 was not constrained by the survey unit wide area statistical test. For Survey Unit 17, the highest 90th percentile and maximum concentrations observed were greater than the corresponding permissible surface soil DCGL. Therefore, the "reasonable maximum concentration" value and the "expected maximum concentration" value intersected the respective volume factor curves. This indicates that it was necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil. Both the "reasonable maximum concentration" and "expected maximum concentration" calculations returned a maximum corehole density of 1 m^2, resulting in a total of 2,843 coreholes.

Rather than place a corehole every 1 m^2 as dictated by the "reasonable maximum concentration" and "expected maximum value" calculations, an alternative sampling density was determined. As explained in Section 4.3 of the Characterization Plan (MACTEC 2007), a sampling density of one corehole location every 50 m^2 was selected to obtain current and accurate data for the survey unit. Guidance to determine the corehole density was found in MARSSIM (NRC 2000). MARSSIM recommends, in Section 5.3.3.2, Characterization Surveys, Land Area Surveys, that "A typical reference system spacing for open land areas is 10 meters (100 m^2)". This spacing is somewhat arbitrary and is chosen to facilitate determining survey unit locations and evaluating areas of elevated radioactivity." Because surface scanning is not applicable for subsurface soil characterization and known elevated concentrations of residual radioactivity exist in these areas, an alternative approach is taken here. The reference system spacing area identified in MARSSIM (100 m^2) is reduced by a factor of two, resulting in a reference system spacing surface area of 50 m^2 (approximately every 7 m).

Sampling Survey Unit 17 at a 50 m^2 grid would produce a sufficient number of coreholes to accurately assess the radiological nature of the survey unit. In order to determine the placement of coreholes using VSP, a different statistical parameter was used. Instead of using built-in algorithms needed to satisfy the WRS test, the "Locating a Hotspot" function was utilized. This allows the user to manually set the size and shape of the hotspot to force the sampling density to accommodate. In other words, by setting the diameter of a circular hotspot to 7 meters, VSP placed a corehole every 50 m^2 as desired. Figure 2-31 and Table 2-15 present relevant information used to determine the appropriate number and spacing of the coreholes.

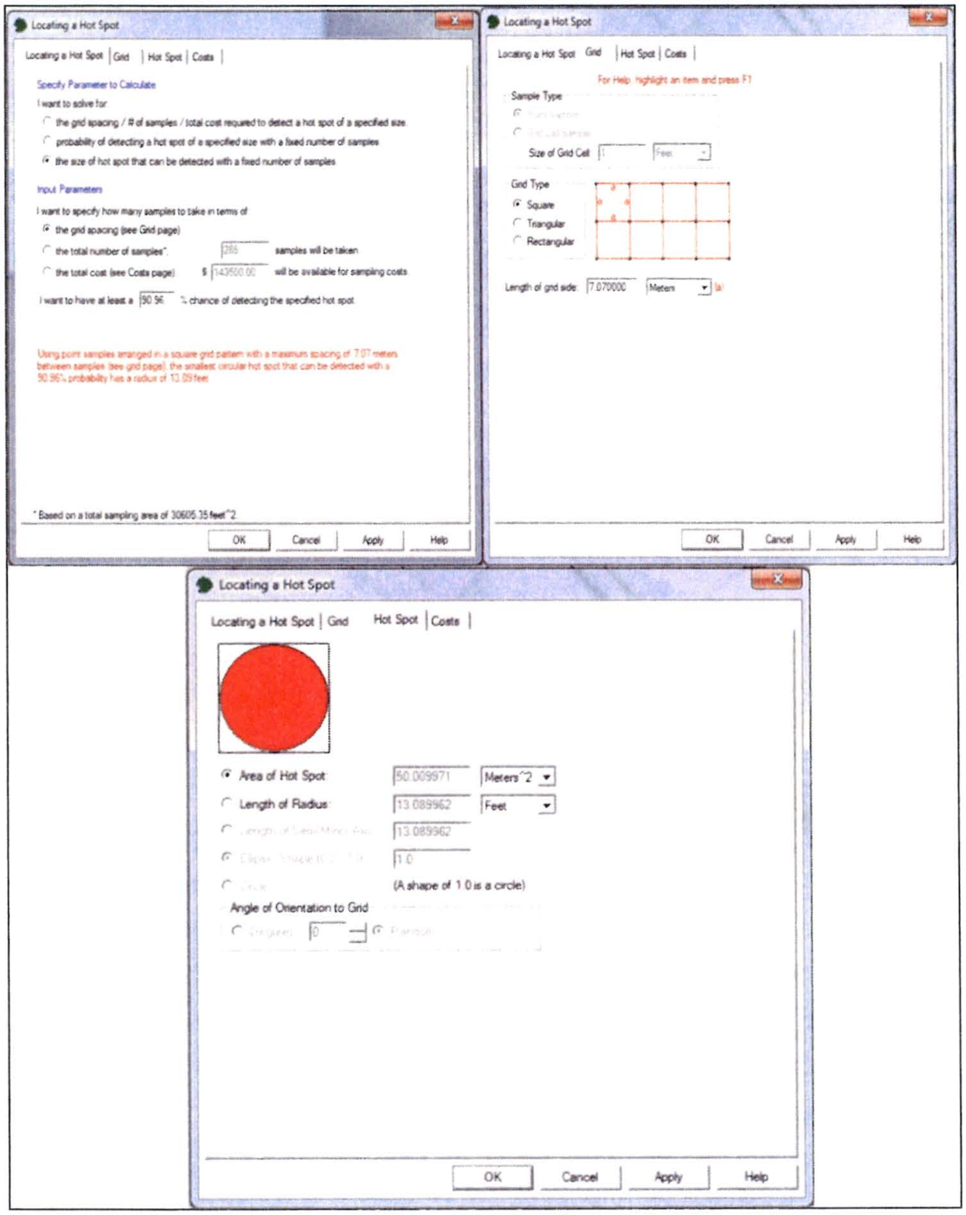

Figure 2-31 Screen Shot, VSP Sample Size Calculation, Survey Unit 17

Table 2-15 Summary of Sampling Design, Survey Unit 17

Survey Unit 17	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Singer and Wickman algorithm
Calculated total number of samples for each survey and reference area [a]	57
Number of samples on map [b]	57
Number of selected sample areas [c]	1
Specified sampling area [d]	2843 m^2
Size of grid / Area of grid [e]	7.07 m / 50.0 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

2.11.3 Confirmation of Selected Sampling Density

Survey Unit 17 underwent additional remediation in June and July of 2009. Field records indicate that the survey unit was excavated down ~0.5 to 2.0 m with volumetric sampling occurring throughout and at the conclusion of the excavation process. The post-remedial action sample results from the 2009 remedial actions were not included in the 2006 dataset. Furthermore, mapping the 2006 pre-remediation samples and plotting them against the post-remediation contour map demonstrates that the Survey Unit 17 soils represented by the 2006 dataset were excavated in 2009 and disposed of as part of NFS' approved soil remediation activities. Therefore, the 2009 post-remediation dataset is representative of the radiological conditions of the site at the time of FSS activities and is considered the relevant historical dataset for use in designing the FSS and demonstrating compliance and acceptability with the sampling density criteria for Survey Unit 17. The historical dataset of Survey Unit 17, Appendix A.6, is the analytical results of the 2009 post-remediation samples.

The selected corehole spacing (one corehole every 50 m^2) was reevaluated using the 2009 post-remediation dataset for Survey Unit 17. To reevaluate the Survey Unit 17 survey design, the 2009 post-remediation sample results were plotted in SADA to verify their locations within the survey units. Next, the dataset was inputted into the Subsurface Soil DCGL calculators as the historical dataset, replacing the 2006 dataset which was no longer considered representative of the radiological condition of Survey Unit 17. This test was performed to determine what the resultant corehole spacing would have been, if the post-remediation data had been available and used during the original survey design. This evaluation confirmed the suitability of the survey design for Survey Unit 17. It affirmed that the corehole spacing prescribed in the survey design (one corehole every 50 m^2) was far more dense than would reasonably be required to assess the radiation dose consequences of locally elevated pockets of residual radioactivity within the survey unit. Using the 2009 dataset, the Subsurface Soil DCGL calculators conclude that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *90th Percentile* is 999 m^2 (the default maximum size of the Subsurface Soil DCGL calculators) and that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *Observed Maximum* is 999 m^2.

The resulting design placed 57 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 17 (Table 2-16, Figure 2-32). Amec Foster Wheeler assigned a unique number to each corehole. Further detail regarding the actual number of coreholes sampled in Survey Unit 17 is provided in Appendix H.

Table 2-16 Planned Corehole Locations, Survey Unit 17

Sample ID	Easting (X)	Northing (Y)
612	3022372.013	673610.284
613	3022348.818	673633.480
614	3022372.013	673633.480
615	3022325.622	673656.675
616	3022302.427	673679.871
617	3022256.036	673703.066
618	3022279.232	673703.066
619	3022232.841	673726.262
620	3022256.036	673726.262
621	3022209.645	673749.457
622	3022232.841	673749.457
623	3022186.450	673772.653
624	3022209.645	673772.653
625	3022163.254	673795.848
626	3022186.450	673795.848
627	3022209.645	673795.848
628	3022232.841	673795.848
629	3022140.059	673819.044
630	3022163.254	673819.044
631	3022186.450	673819.044

Table 2-16 Planned Corehole Locations, Survey Unit 17, Continued

Sample ID	Easting (X)	Northing (Y)
632	3022116.863	673842.239
633	3022140.059	673842.239
634	3022070.472	673865.435
635	3022093.668	673865.435
636	3022116.863	673865.435
637	3022070.472	673888.630
638	3022093.668	673888.630
639	3022070.472	673911.825
640	3022093.668	673911.825
641	3022047.277	673935.021
642	3022070.472	673935.021
643	3022093.668	673935.021
644	3022116.863	673935.021
645	3022024.081	673958.216
646	3022047.277	673958.216
647	3022070.472	673958.216
648	3022093.668	673958.216
649	3022116.863	673958.216
650	3022140.059	673958.216
651	3022024.081	673981.412
652	3022047.277	673981.412
653	3022070.472	673981.412
654	3022093.668	673981.412
655	3022116.863	673981.412
656	3022140.059	673981.412
657	3022163.254	673981.412
658	3022000.886	674004.607
659	3022024.081	674004.607
660	3022047.277	674004.607
661	3022070.472	674004.607
662	3022093.668	674004.607
663	3022116.863	674004.607
664	3022140.059	674004.607
665	3022163.254	674004.607
666	3022186.450	674004.607
667	3022163.254	674027.803
668	3022186.382	674027.735

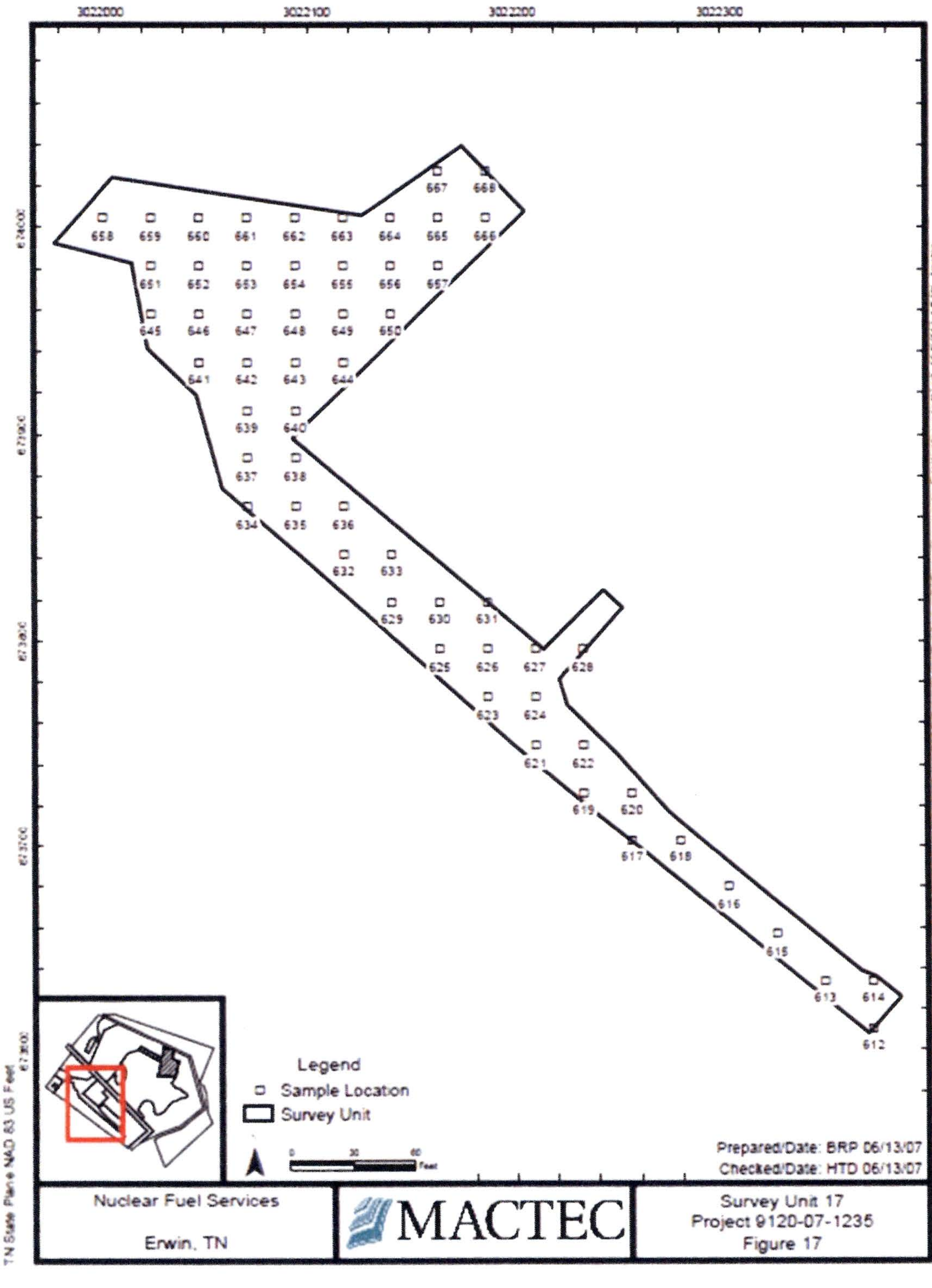

Figure 2-32 Survey Unit 17 Corehole Locations

2.12 SURVEY UNIT 18 DESIGN

2.12.1 Survey Unit Description

Survey Unit 18 (as shown in Figure 2-33) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 1,997 m^2.

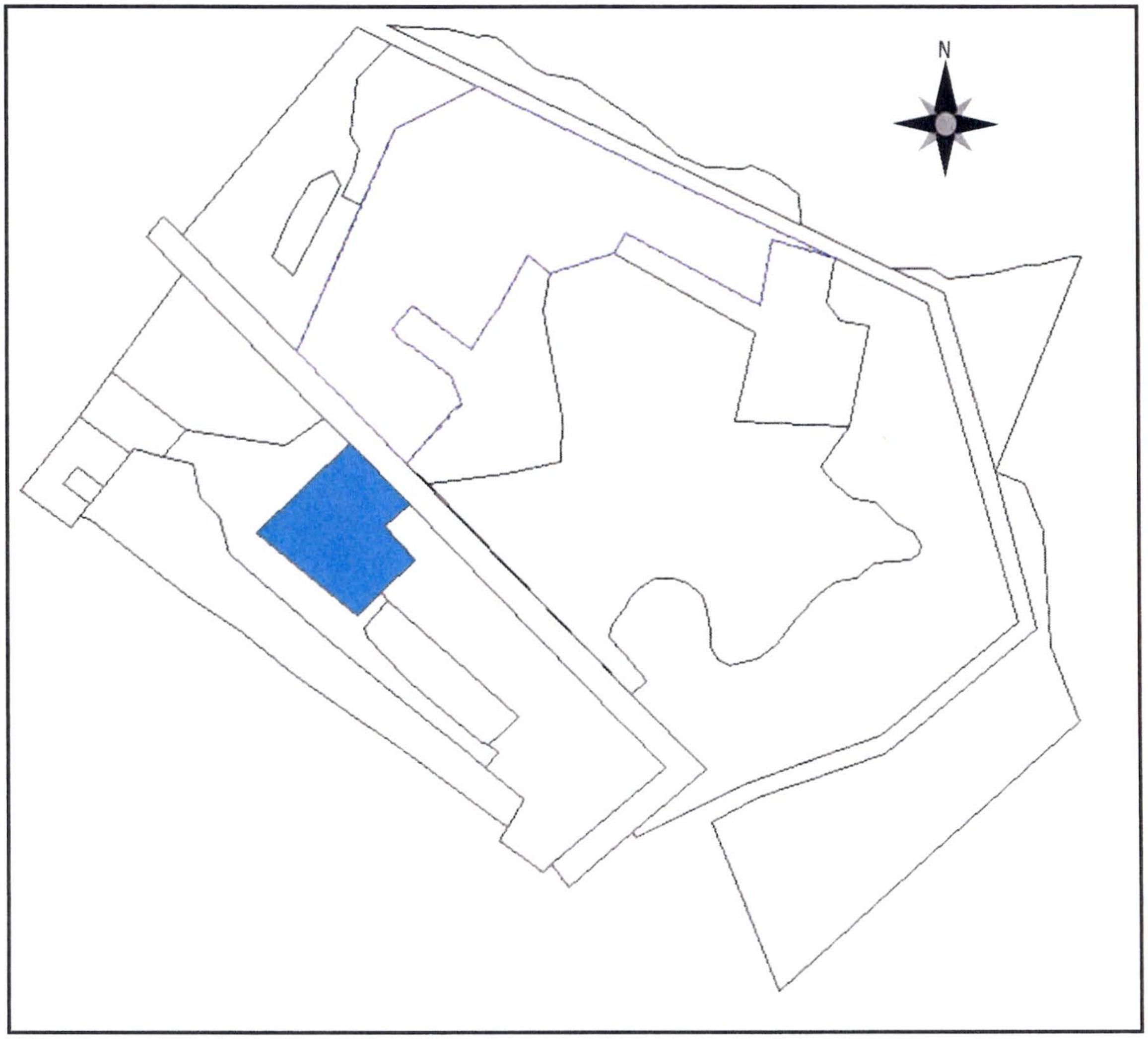

Figure 2-33 Survey Unit 18 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. Visualization of the historical data using iso-contour graphics generated in SADA indicates that elevated readings may still be present in portions of Survey Unit 18 (Figure 2-6). It was necessary, therefore, to demarcate exact survey unit borders by "zooming in" on the historical dataset. Elevated data points causing an exaggerated area of influence were grouped together as a single data population, bound into the survey unit, and taken into account in the design of Survey Unit 18.

Survey Unit 18 is bounded by Survey Unit 17 on the northwestern, southwestern, and part of the southeastern borders. The remainder of the southeastern border is bound by Survey Unit 19, an area in which remediation activities have been performed. The northwestern border is bound by Survey Unit 11, the former security area.

2.12.2 Sampling Density Determination

The number of corehole locations for Survey Unit 18 was calculated using the method described in Section 2.6.2. Similar to Survey Units 6 and 17, the number of coreholes for Survey Unit 18 was not constrained by the survey unit wide area statistical test. For Survey Unit 18, the highest 90th percentile and maximum concentrations observed were greater than the corresponding permissible surface soil DCGL. Therefore, the "reasonable maximum concentration" value and the "expected maximum concentration" value intersected the respective volume factor curves. This indicates that it was necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil. Both the "reasonable maximum concentration" and "expected maximum concentration" calculations returned a maximum corehole density of 1 m^2, resulting in a total of 2,843 coreholes.

Rather than place a corehole every 1 m^2 as dictated by the "reasonable maximum concentration" and "expected maximum value" calculations, an alternative sampling density was determined. As explained in Section 4.3 of the Characterization Plan (MACTEC 2007), a sampling density of one corehole location every 50 m^2 was selected to obtain current and accurate data for the survey unit. Guidance to determine the corehole density was found in MARSSIM (NRC 2000). MARSSIM recommends, in Section 5.3.3.2, Characterization Surveys, Land Area Surveys, that "A typical reference system spacing for open land areas is 10 meters (100 m^2)". This spacing is somewhat arbitrary and is chosen to facilitate determining survey unit locations and evaluating areas of elevated radioactivity." Because surface scanning is not applicable for subsurface soil characterization and known elevated concentrations of residual radioactivity exist in these areas, an alternative approach is taken here. The reference system spacing area identified in MARSSIM (100 m^2) is reduced by a factor of two, resulting in a reference system spacing surface area of 50 m^2 (approximately every 7 m).

Sampling Survey Unit 18 at a 50 m^2 grid would produce a sufficient number of coreholes to accurately assess the radiological nature of the survey unit. In order to determine the placement of coreholes using VSP, a different statistical parameter was used. Instead of using built-in algorithms needed to satisfy the WRS test, the "Locating a Hotspot" function was utilized. This allows the user to manually set the size and shape of the hotspot to force the sampling density to accommodate. In other words, by setting the diameter of a circular hotspot to 7 meters, VSP placed a corehole every 50 m2 as desired. Figure 2-34 and

Table 2-17 present relevant information used to determine the appropriate number and spacing of the coreholes.

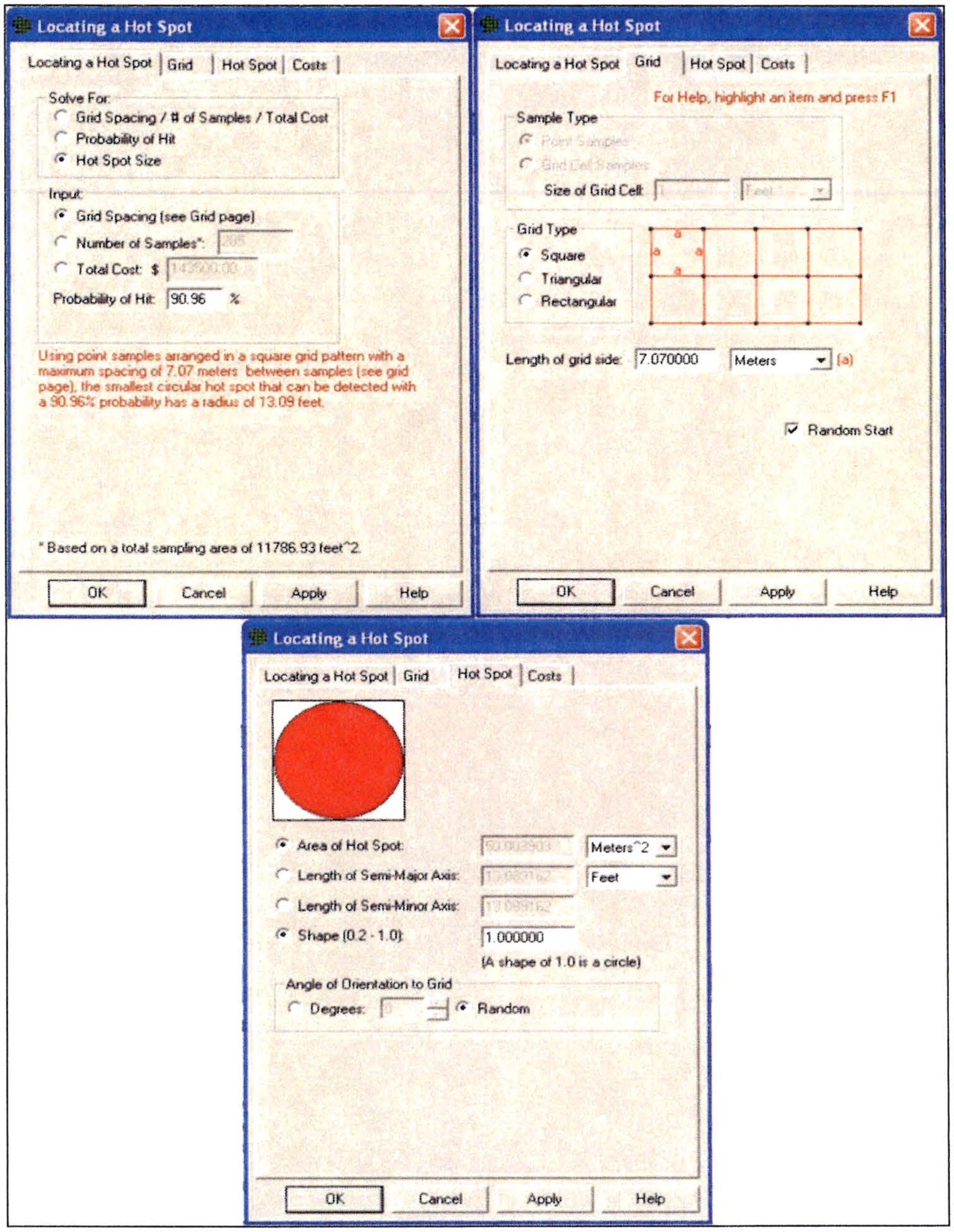

Figure 2-34 Screen Shots, VSP Sample Size Calculation Using "Locating a Hot Spot" Function, Survey Unit 18

Table 2-17 Summary of Sampling Design, Survey Unit 18

Survey Unit 18	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Working (Null) Hypothesis	The difference between the medians(means) is greater than or equal to the threshold
Formula for calculating number of sampling locations	Singer and Wickman algorithm
Calculated total number of samples for each survey and reference area [a]	41
Number of samples on map [b]	41
Number of selected sample areas [c]	1
Specified sampling area [d]	1997 m^2
Size of grid / Area of grid [e]	7.07 m / 50.0 m^2
Grid pattern	Square

[a] Based on the analyte with the highest minimum number of survey unit samples.
[b] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[c] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[d] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[e] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples.

2.12.3 Confirmation of Selected Sampling Density

Survey Unit 18 underwent additional remediation in June of 2009. Field records indicate that the survey unit was excavated down ~2.0 m with volumetric sampling occurring throughout and at the conclusion of the excavation process. The post-remedial action sample results from the 2009 remedial actions were not included in the 2006 dataset. Furthermore, mapping the 2006 pre-remediation samples and plotting them against the post-remediation contour map demonstrates that the Survey Unit 18 soils represented by the 2006 dataset were excavated in 2009 and disposed of as part of NFS' approved soil remediation activities. Therefore, the 2009 post-remediation dataset is representative of the radiological conditions of the site at the time of FSS activities and is considered the relevant historical dataset for use in designing the FSS and demonstrating compliance and acceptability with the sampling density criteria for Survey Unit 18. The historical dataset of Survey Unit 18, Appendix A.7, is the analytical results of the 2009 post-remediation samples.

The selected corehole spacing (one corehole every 50 m^2) was reevaluated using the 2009 post-remediation dataset for Survey Unit 18. To reevaluate the Survey Unit 18 survey design, the 2009 post-remediation sample results were plotted in SADA to verify their locations within the survey units. Next, the dataset was inputted into the Subsurface Soil DCGL calculators as the historical dataset, replacing the 2006 dataset which was no longer considered representative of the radiological condition of Survey Unit 18. This test was performed to determine what the resultant corehole spacing would have been, if the post-remediation data had been available and used during the original survey design. This evaluation confirmed the suitability of the survey design for Survey Unit 18. It affirmed that the corehole spacing prescribed in the survey design (one corehole every 50 m^2) was far more dense than would reasonably be required to assess the radiation dose consequences of locally elevated pockets of residual radioactivity within the survey unit. Using the 2009 dataset, the Subsurface Soil DCGL calculators conclude that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *90th Percentile* is 999 m^2 (the default maximum size of the Subsurface Soil DCGL calculators) and that the *Minimum Areal Sample Frequency required to Satisfy* $DCGL_{EMC}$ *Observed Maximum* is 999 m^2.

The resulting design placed 41 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 18 (Table 2-18, Figure 2-35). Amec Foster Wheeler assigned a unique number to each corehole. Further detail regarding the actual number of coreholes sampled in Survey Unit 18 is provided in Appendix H.

Table 2-18 Planned Corehole Locations, Survey Unit 18

Sample ID	Easting (X)	Northing (Y)
669	3022212.223	673805.054
670	3022189.027	673828.250
671	3022212.223	673828.250
672	3022235.418	673828.250
673	3022165.832	673851.445
674	3022189.027	673851.445
675	3022212.223	673851.445
676	3022235.418	673851.445
677	3022258.614	673851.445
678	3022142.636	673874.640
679	3022165.832	673874.640
680	3022189.027	673874.640
681	3022212.223	673874.640
682	3022235.418	673874.640
683	3022258.614	673874.640
684	3022096.245	673897.836
685	3022119.441	673897.836
686	3022142.636	673897.836
687	3022165.832	673897.836
688	3022189.027	673897.836
689	3022212.223	673897.836
690	3022235.418	673897.836
691	3022119.441	673921.031
692	3022142.636	673921.031
693	3022165.832	673921.031
694	3022189.027	673921.031
695	3022212.223	673921.031
696	3022235.418	673921.031
697	3022258.614	673921.031
698	3022142.636	673944.227
699	3022165.832	673944.227
700	3022189.027	673944.227
701	3022212.223	673944.227
702	3022235.418	673944.227
703	3022258.614	673944.227
704	3022165.832	673967.422
705	3022189.027	673967.422
706	3022212.223	673967.422
707	3022235.418	673967.422
708	3022189.027	673990.618
709	3022212.223	673990.618

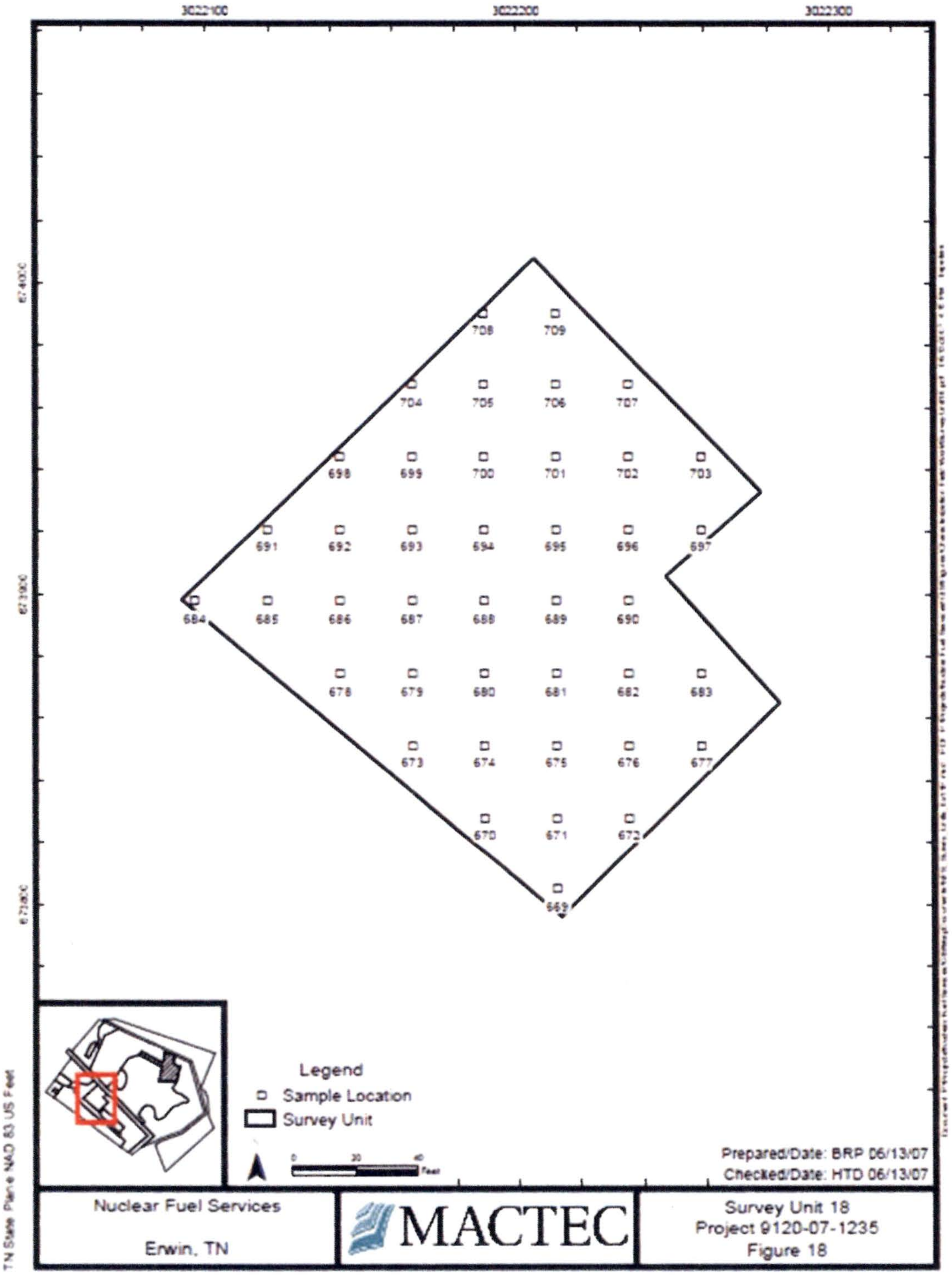

Figure 2-35 Survey Unit 18 Corehole Locations

2.13 SUMMARY FINAL DESIGN AND SAMPLE PLACEMENT, SU 4, 6, 7, 12, 16, 17, 18

Table 2-19 presents a summary of the survey units included in this report, including size of the survey unit, grid size, and the number of coreholes planned for each survey unit.

Table 2-19 Summary Final Design and Sample Placement Survey Units 4, 6, 7, 12, 16, 17, and 18

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
4	13,773	336	41
6	3,101	50	60
7	10,213	319	32
12	2,624	50	53
16	4,112	23	178
17	2,843	50	57
18	1,997	50	41

3.0 FIELD IMPLEMENTATION

Field personnel performing work at the site were required to attend and pass NFS' Radiation Worker and General Employee training at the NFS training center. Prior to implementation of characterization activities at the site, additional training was given to the sampling team by Amec Foster Wheeler and NFS personnel on the field sampling procedures to be used during subsurface characterization activities.

The fundamental steps in the field sample collection process are:

- mobilization;
- identify physical corehole locations and stake the individual locations in the survey unit;
- setup drill rig at corehole location and advance a soil core sampling device to the required depth;
- retrieve soil core, and log subsurface lithology;
- segment soil core into 1-meter vertical increments and sample each increment;
- import sample collection information into the Field Sample Tracking Program; and
- ship soil samples off-site for laboratory analysis.

These steps are described in more detail in the sections that follow:

3.1 MOBILIZATION

The mobilization of Amec Foster Wheeler personnel and equipment as well as subcontractor equipment and personnel, for Survey Unit 16, began on August 11, 2008. The "Mini-Sonic" drill rig and associated support equipment (including skid-steer and pressure washer) and drill-operating personnel were provided by subcontractor Boart Longyear. In depth, classroom training of sampling team personnel on field sampling procedures began on August 12, 2008. On-the-job (OJT) training began the following day (August 13, 2008). OJT continued through the majority of August 13, 2008 with drilling/soil-sampling activities beginning late August 13, 2008 at the North site.

The mobilization of Amec Foster Wheeler personnel and equipment as well as subcontractor personnel and equipment, for Survey Units 4, 6, 12, 17, and 18 began on November 16, 2010. The "Mini-Sonic" drill rig and associated support equipment (including skid-steer and pressure washer) and drill-operating personnel were provided by subcontractor Boart Longyear. On-the-job (OJT) training began the following morning, November 17, 2010, and drilling/soil-sampling activities beginning late that afternoon.

The mobilization of Amec Foster Wheeler personnel and equipment as well as subcontractor equipment and personnel, for Survey Unit 7, began on September 22, 2013. The "Mini-

Sonic" drill rig and associated support equipment (including skid-steer and pressure washer) and drill-operating personnel were provided by subcontractor Boart Longyear. In depth, classroom training of sampling team personnel on field sampling procedures began on September 23, 2013. On-the-job (OJT) training began the following day (September 24, 2013), with drilling/soil-sampling activities beginning later that same day.

3.2 FIELD IDENTIFICATION OF SAMPLE LOCATIONS

Using the corehole placement locations generated by the VSP software, Global Positioning System (GPS) coordinate files were created and uploaded to a handheld GPS instrument. The GPS instrument was then used to navigate to the corehole locations in the field.

3.2.1 Handheld Global Positioning System

The GPS unit utilized at the site during subsurface characterization was the Trimble GeoXH handheld device (Figure 3-1). The GeoXH is capable of delivering sub-foot GPS accuracy providing precise corehole location determination in the field.

Figure 3-1 Trimble GeoXH Handheld GPS Unit

The corehole locations were laid out and marked at the site using wooden steaks, surveyors marking paint, and orange ribbon as appropriate. Stakes were labeled with the corehole ID number as well as the survey unit number. A small amount of vegetation growing on the cover or in the immediate vicinity of the selected corehole locations needed to be removed.

This work was performed by NFS personnel. The surface of the survey units were cleared of any debris hindering drilling/sampling operations.

After the coreholes were located, an inspection of each corehole location was conducted to ensure that each marked sample location could be accessed and sampled safely. Locations that were inaccessible, or which presented a safety concern, were relocated within the survey unit boundary and in accordance with approved NFS sampling procedures (NFS 2007a), as described in Section 3.2.2.

3.2.2 Relocation of Coreholes

If an obstruction (e.g., proximity to an overhead or underground utility line) or a safety concern (e.g., steep bank of excavation) prohibited sampling at the planned location, Amec Foster Wheeler, in conjunction with NFS, designated an alternative sample location. The alternative location was chosen to be consistent with the characterization design objectives and without the intent to bias the outcome of analytical results. To achieve these objectives, a field protocol was included in the controlling procedure (NFS 2007a). The protocol requires that an alternate sample location for a corehole must fall within a radius equal to ½ the distance between planned sample nodes. For example, in the case of Survey Unit 4, the distance between planned sample nodes was 18.3 m. Therefore, the maximum distance a sample could be relocated was 9.15 m (½*18.3 m). This radius restriction ensured that the relocated corehole was representative of the same volume or "cube" of soil under consideration in the subsurface soil model governing the survey design. Alternative corehole locations were chosen to be within this designated radius and as close to the originally planned location as was feasible.

3.3 CORE SAMPLING WITH ROTARY-SONIC DRILL RIG

Rotary-Sonic drilling was selected as the primary method of subsurface soil sample collection due to the presence of large cobbles within the soil column to be sampled. Rotary-Sonic drilling provides the capability to drill through such cobbles such that essentially continuous subsurface core samples could be retrieved. To maximize access to coreholes across the entire North site, the track-mounted "Mini-Sonic" drill rig was selected due to its compact size and relative ease of maneuverability (Figure 3-2).

Figure 3-2 Track-mounted "Mini-Sonic" Drill Rig

3.3.1 Collecting Soil Cores

Prior to the commencement of drilling at the corehole location, the "Mini-Sonic" drill rig was positioned above the pre-staked location of the corehole. A safety exclusion zone was established around the drill rig to isolate the operational area from surrounding activities and to identify the area within which hardhats and hearing protection were required.

The "Mini-Sonic" drill rig utilizes a drilling technique which advances a core sample barrel down through the soil column using the combination of sonic vibrations, hydraulic pressure, and the rotation of the core barrel yielding a highly representative soil core. The core barrel is a 5 foot long 3 inch diameter hollow steel rod equipped with a specialized bit designed to drill through cobbles and rock. The barrel retains a core of the subsurface soil column drilled through. Core barrels were advanced and core samples were extracted in 5 foot depth intervals.

This series of photographs demonstrates a typical process of preparing, installing, and advancing a core barrel using the "Mini-Sonic" drill rig.

Figure 3-3 shows the preparation of the core rod by placing the rod onto the hydraulic "rod-handler". The drill head, to which the core barrel will be attached, is positioned directly above the corehole location.

Figure 3-3 Preparation of Core Barrel

The core barrel is lifted in place by the rod-handler and attached to the drill head before core barrel advancement (Figure 3-4).

Figure 3-4 Attachment of Core Barrel to Drill Head

Using sonic vibrations the core barrel is advanced through the subsurface material until the top of the core barrel is level with the ground surface (Figure 3-5).

Figure 3-5 Advancement of Core Barrel

After the 5 foot section of the sample core barrel was advanced to depth, the rod which contained the soil core was retrieved and removed from the ground. The core barrel was emptied into a clear plastic sleeve, preserving the geologic lithology of the subsurface from which the material was sampled from (Figure 3-6).

Figure 3-6 Extracting Soil Core from Core Barrel

Core drilling was terminated at each corehole location when it was determined that bedrock had been reached or when the boring depth reached 10 meters below existing surface grade.

Core drilling operations were conducted in Survey Unit 4 from June 16 through July 21, 2011, Survey Unit 6 from July 22 through August 10, 2011, Survey Unit 7 from September 23 through October 9, 2013, Survey Unit 12 from November 6 through November 14, 2007, and on June 14 and 15, 2011, Survey Unit 16 from August 14 through October 27, 2008, Survey Unit 17 from March 22 through April 6, 2011 and from June 6 through June 14, 2011, and Survey Unit 18 from November 17 through December 9, 2010. Further information regarding supplemental characterization core drilling operations is provided in Appendix H.

3.3.2 Corehole Abandonment and Drilling Area Demobilization

Sample coreholes were abandoned in accordance with Tennessee State regulations after soil sample collection was completed for that corehole. Non-shrinking bentonite grout was used to fill abandoned coreholes. The minimum volume of grout required to seal a corehole was calculated using the following formula:

$$V= (3.14)(r^2)(L)(7.48 \text{ gallons/ft}^3)$$

where:
V = corehole volume (gallons)
r = radius of the corehole (feet)
L = corehole depth

The grout mixture contained high-solids, bentonite grout with a minimum 20% solids and a weight of no less than 9.2 pounds per gallon. The actual amount of grout used during abandonment was compared to the calculated estimate to ensure that the proper volume was used. All abandoned coreholes were checked 24 to 48 hours after grout emplacement. At locations where the grout settled below ground level, additional grout was added to the corehole to bring it flush with ground level.

Contrary to most conventional drilling operations, the Rotary-Sonic drilling method required only minimal use of water and generated almost zero waste. Excess sample material (spoils) generated during the drilling/coring process that was not collected as part of the soil sample was containerized in approved waste containers and staged at a central staging area designated by NFS personnel for subsequent offsite disposal.

Upon completion of drilling activities at each corehole location, the drill site was thoroughly cleaned and returned to the original condition prior to drilling operations. After having been filled with bentonite grout, corehole locations were re-staked and marked. NFS' survey contractor followed the Amec Foster Wheeler sampling team in the field precisely surveying and recording the actual lateral position and elevation of each corehole (Table 3-1 thru Table 3-7).

Table 3-1 Surveyed Corehole Locations and Elevations, Survey Unit 4

Corehole ID#	Easting	Northing	Elevation (ft., msl)
50	3022543.70	673731.01	1640.6
51	3022492.66	673777.38	1641.5
52	3022663.70	373792.08	1641.1
53	3022727.63	673780.07	1637.6
54	3022442.03	673843.00	1631.2
55	3022490.02	673853.52	1632.9
56	3022543.95	673852.68	1635.1
57	3022605.70	673851.63	1640.7
58	3022665.66	673845.59	1638.3
59	3022725.09	673852.03	1636.2
60	3022787.90	673842.70	1638.7
61	3022362.01	673908.00	1642.7
62	3022423.93	673911.61	1631.2
63	3022487.06	673910.09	1631.0
64	3022552.12	673917.33	1642.0
65	3022592.82	673892.00	1641.6
66	3022667.13	673911.79	1635.0
67	3022727.53	673915.64	1636.7
68	3022785.71	673911.60	1638.5
69	3022845.33	673910.72	1639.5
70	3022417.55	673968.53	1632.4
71	3022484.64	673971.68	1642.1
72	3022538.65	673958.86	1637.2
73	3022609.17	673970.59	1634.6
74	3022664.45	673972.35	1635.4
75	3022724.98	673968.54	1636.7
76	3022756.98	673968.25	1638.7
77	3022483.86	674029.89	1635.3
78	3022544.37	674032.33	1634.3
79	3022603.22	674031.33	1633.8
80	3022665.85	674030.20	1637.2
81	3022485.36	674090.93	1634.7
82	3022544.20	674090.56	1635.2
83	3022603.70	674088.69	1635.4
84	3022666.70	674090.41	1636.9
85	3022482.82	674153.30	1634.8
86	3022544.89	674150.31	1634.7
87	3022603.91	674149.62	1635.0
88	3022666.14	674151.80	1636.7
89	3022484.41	674211.29	1635.1
90	3022543.88	674211.54	1634.7
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Table 3-2 Surveyed Corehole Locations and Elevations, Survey Unit 6

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
750	3022291.17	673970.74	1641.8
751	3022307.19	673966.67	1642.1
752	3022337.78	673968.76	1635.8
753	3022361.79	673968.74	1632.1
754	3022385.83	673966.44	1632.5
755	3022287.57	673986.04	1641.8
756	3022315.93	673991.48	1635.9
757	3022338.94	673992.68	1633.5
758	3022362.74	673991.68	1632.3
759	3022386.78	673994.98	1633.2
760	3022405.81	673995.7	1633.0
761	3022436.06	673999.07	1639.8
762	3022456.44	673993.11	1641.9
763	3022313.51	674015.34	1635.4
764	3022341.47	674015.21	1634.0
765	3022359.47	674015.76	1633.9
766	3022386.69	674014.33	1633.3
767	3022414.01	674021.33	1639.7
768	3022431.93	674016.58	1641.6
769	3022450.97	674011.68	1642.2
770	3022344.67	674041.62	1634.7
771	3022360.48	674036.52	1634.5
772	3022384.68	674039.86	1638.7
773	3022409.23	674038.34	1640.9
774	3022427.12	674033.54	1641.6
775	3022454.2	674038.66	1635.7
776	3022362.44	674063.33	1637.6
777	3022384.74	674063.48	1640.2
778	3022404.69	674061.29	1640.1
779	3022429.42	674063.55	1637.2
780	3022455.7	674064.73	1636.7
781	3022338.19	674086.34	1642.8
782	3022362.66	674086.05	1637.8
783	3022389.23	674086.63	1638.2
784	3022408	674087.12	1637.4
785	3022433.85	674088.46	1636.4
786	3022453.09	674085.82	1635.5
787	3022316.84	674109.84	1640.5
788	3022340.26	674111.84	1640.2

Table 3-2 Surveyed Corehole Locations and Elevations, Survey Unit 6 (Continued)

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
789	3022363.43	674110.1	1638.8
790	3022385.12	674109.21	1637.2
791	3022407.9	674110.37	1636.9
792	3022433.32	674109.51	1636.8
793	3022454.64	674109.01	1635.8
794	3022292.82	674136.14	1640.5
795	3022315.84	674134.73	1640.0
796	3022338.06	674132.93	1638.9
797	3022385.75	674134.43	1638.7
798	3022407.67	674134.28	1637.1
799	3022432.21	674132.62	1636.9
800	3022268.87	674156.38	1638.0
801	3022299.18	674154.66	1640.5
802	3022385.68	674154.28	1638.9
803	3022409.23	674156.37	1637.5
804	3022432.81	674156.54	1638.1
805	3022409.16	674177.51	1639.0
806	3022430.46	674177.73	1638.0
807	3022409.67	674203.24	1640.1
808	3022431.27	674202.93	1637.9
809	3022430.29	674227.57	1639.0
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Table 3-3 Surveyed Corehole Locations and Elevations, Survey Unit 7

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
7001	3022233.02	674042.12	1632.8
7002	3022303.8	674052.51	1633.2
7003	3022179.02	674103.79	1633.1
7004	3022231.66	674090.04	1634.7
7005	3022285.72	674093.67	1632.8
7006	3022168.36	674152.52	1633.5
7007	3022219.59	674147.05	1633.5
7008	3022345.1	674153.95	1634.9
7009	3022223.52	674215.34	1634.8
7010	3022295.91	674202.74	1632.8
7011	3022344.82	674213.89	1633.6
7012	3022404.95	674211.48	1634.4
7013	3022701.93	674217.56	1634.7
7014	3022226.36	674270.55	1635.4
7015	3022281.85	674272.5	1635.1
7016	3022352.52	674259.54	1630.7
7017	3022404.06	674271.45	1630.5
7018	3022461.67	674263.96	1632.9
7019	3022517.99	674274.66	1634.1
7020	3022579.94	674272.94	1634.2
7021	3022638.86	674270.07	1635.0
7022	3022696.49	674266.53	1634.9
7023	3022286.28	674329.86	1631.4
7024	3022349.47	674336.97	1632.1
7025	3022404.26	674329.76	1633.7
7026	3022463.23	674329.55	1634.5
7027	3022521.54	674329.65	1635.1
7028	3022580.16	674329.17	1635.3
7029	3022283.85	674386.55	1635.7
7030	3022343.56	674380.67	1631.8
7031	3022387.15	674382.16	1634.4
7032	3022460.75	674387.49	1634.6
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Table 3-4 Surveyed Corehole Locations and Elevations, Survey Unit 12

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
292	3022051.80	674015.75	1631.5
293	3022078.01	674018.96	1632.6
294	3022096.31	674017.65	1633.7
295	3022119.61	674018.14	1637.3
296	3022146.00	674015.46	1634.3
297	3022007.24	674044.16	1628.3
298	3022028.91	674037.57	1630.1
299	3022052.66	674041.84	1631.1
300	3022073.27	674040.95	1631.1
301	3022095.71	674041.98	1631.6
302	3022119.41	674036.64	1633.6
303	3022145.46	674035.66	1634.7
304	3022166.92	674036.19	1635.7
305	3021960.16	674061.85	1627.7
306	3021981.90	674062.04	1628.1
307	3022005.10	674063.35	1629.0
308	3022029.43	674062.49	1630.0
309	3022050.27	674064.03	1630.6
310	3022082.08	674061.21	1631.2
311	3022096.45	674063.81	1631.5
312	3022117.73	674066.48	1633.2
313	3022143.95	674060.91	1636.5
314	3021934.87	674083.87	1627.8
315	3021959.58	674084.44	1628.5
316	3021981.66	674086.52	1628.9
317	3022001.80	674084.84	1629.0
318	3022027.75	674087.56	1629.5
319	3022050.19	674087.18	1630.1
320	3022073.21	674087.39	1630.8
321	3022096.41	674087.34	1631.4
322	3022119.55	674087.60	1633.0
323	3021942.37	674112.53	1630.1
324	3021956.14	674111.01	1629.8
325	3021979.76	674109.80	1629.6
326	3022004.18	674110.63	1629.7
327	3022031.03	674108.62	1629.8
328	3022049.62	674111.00	1630.1
329	3022071.26	674109.27	1630.7
330	3022096.83	674110.31	1631.7
331	3021956.77	674133.30	1629.6

Table 3-4 Surveyed Corehole Locations and Elevations, Survey Unit 12 (Conitnued)

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
332	3021982.24	674132.87	1629.8
333	3022003.37	674133.88	1629.7
334	3022026.35	674133.94	1629.7
335	3022050.24	674133.88	1630.4
336	3022073.46	674133.72	1631.2
337	3021976.50	674151.23	1629.9
338	3022004.45	674156.62	1629.6
339	3022026.45	674156.75	1630.1
340	3022049.87	674156.92	1631.0
341	3021981.17	674174.91	1629.2
342	3022003.90	674179.88	1630.0
343	3022026.76	674180.31	1630.3
344	3022003.65	674203.46	1630.9
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Table 3-5 Surveyed Corehole Locations and Elevations, Survey Unit 16

ID#	Easting	Northing	Elevation (ft., msl)
384	3022404.83	673540.93	1631.1
385	3022378.03	673557.79	1631.0
386	3022393.64	673557.61	1631.0
387	3022407.95	673557.33	1631.2
388	3022352.91	673577.62	1629.7
389	3022361.21	673570.08	1629.6
390	3022375.34	673572.20	1630.4
391	3022392.34	673572.86	1630.8
392	3022406.85	673571.37	1631.2
393	3022331.84	673592.06	1629.4
394	3022344.69	673590.35	1629.7
395	3022360.60	673589.96	1629.9
396	3022376.47	673589.42	1629.9
397	3022314.92	673604.03	1629.9
398	3022329.72	673604.79	1629.8
399	3022347.07	673602.07	1629.7
400	3022358.63	673602.89	1629.7
401	3022285.93	673623.53	1629.4
402	3022298.44	673617.14	1629.4
403	3022316.20	673618.86	1630.0
404	3022331.69	673621.39	1629.9
405	3022341.05	673616.34	1629.8
406	3022271.62	673640.26	1629.6
407	3022283.53	673633.53	1629.6
408	3022298.07	673634.32	1629.8
409	3022314.69	673632.68	1630.1
410	3022329.77	673633.63	1630.2
411	3022251.26	673651.22	1629.7
412	3022267.01	673653.04	1629.6
413	3022281.80	673654.35	1629.9
414	3022298.03	673654.31	1630.2
415	3022307.92	673647.31	1630.5
416	3022225.23	673673.99	1628.0
417	3022234.33	673670.85	1628.8
418	3022249.71	673669.38	1629.2
419	3022265.26	673668.35	1629.9
420	3022282.06	673665.14	1630.1
421	3022207.99	673686.83	1627.0
422	3022218.41	673684.65	1628.2
423	3022235.88	673683.32	1628.7
424	3022250.14	673681.69	1628.9
425	3022258.28	673677.70	1629.4
426	3022179.29	673703.18	1627.5
427	3022194.04	673698.92	1627.3
428	3022203.42	673700.49	1627.5
430	3022233.31	673699.18	1628.2
431	3022244.85	673693.90	1628.6
432	3022164.85	673711.74	1626.9
433	3022174.52	673710.83	1627.8
434	3022189.04	673712.49	1627.0
435	3022203.40	673712.86	1627.3
436	3022218.41	673715.04	1628.0
437	3022229.75	673710.40	1627.9
438	3022147.87	673726.81	1626.7
439	3022158.97	673730.15	1626.5
440	3022173.47	673732.24	1627.7
441	3022188.85	673731.93	1628.1
442	3022204.53	673728.13	1628.1
443	3022210.55	673730.07	1628.7
444	3022114.97	673751.75	1626.3
445	3022128.49	673747.57	1626.4
446	3022140.14	673748.46	1626.1
447	3022155.32	673747.52	1626.7
448	3022173.74	673746.32	1627.3
449	3022188.27	673746.01	1628.5
450	3022096.20	673766.74	1626.7
451	3022106.90	673759.40	1626.5
452	3022122.88	673759.94	1626.1
453	3022139.31	673759.64	1627.0
454	3022161.46	673764.81	1628.6
455	3022171.89	673762.87	1628.7
456	3022078.00	673782.88	1626.7
457	3022091.99	673776.86	1626.6
458	3022108.14	673775.75	1626.7
459	3022123.33	673777.43	1627.6
460	3022139.57	673776.30	1628.5
461	3022153.81	673776.58	1629.2
462	3022053.89	673799.02	1626.6
463	3022063.17	673798.21	1627.0
464	3022076.49	673791.42	1626.7
465	3022091.21	673790.94	1626.7
466	3022107.36	673790.83	1627.2
467	3022124.12	673787.10	1628.4
468	3022137.51	673787.21	1629.2
469	3022036.69	673809.32	1626.5
470	3022046.13	673808.93	1626.9
471	3022062.57	673805.69	1626.5
472	3022076.46	673807.90	1626.5
473	3022092.79	673806.07	1627.3
474	3022106.96	673806.58	1628.3

Table 3-5 Surveyed Corehole Locations and Elevations, Survey Unit 16 (Continued)

ID#	Easting	Northing	Elevation (ft., msl)	ID#	Easting	Northing	Elevation (ft., msl)
429	3022218.13	673699.28	1627.4	475	3022121.22	673805.47	1628.9
476	3022015.36	673826.46	1628.2	519	3021968.84	673901.30	1627.8
477	3022032.54	673826.28	1627.4	520	3021983.35	673902.01	1627.9
478	3022045.37	673822.20	1627.1	521	3021998.77	673903.42	1627.9
479	3022062.44	673823.38	1627.0	522	3022014.36	673902.13	1628.7
480	3022078.80	673826.02	1627.1	523	3022025.95	673903.51	1628.6
481	3022095.81	673825.63	1628.7	524	3022043.30	673903.12	1629.1
482	3022104.60	673816.14	1628.6	526	3021905.17	673919.10	1630.9
483	3021988.43	673847.36	1628.7	527	3021920.04	673919.73	1630.2
484	3022001.08	673841.22	1628.1	528	3021936.07	673919.09	1628.0
485	3022015.46	673837.97	1628.4	529	3021948.74	673916.97	1627.9
486	3022029.60	673839.34	1628.7	530	3021968.60	673916.64	1627.7
487	3022044.75	673839.79	1628.2	531	3021983.13	673917.31	1627.9
488	3022058.53	673845.47	1628.4	532	3021999.37	673918.27	1628.0
489	3022078.27	673847.24	1629.3	533	3022013.86	673917.42	1628.2
490	3022084.01	673837.14	1628.0	534	3022028.95	673918.11	1628.8
491	3021972.96	673861.28	1628.7	535	3021905.22	673935.57	1630.3
492	3021983.95	673856.64	1628.0	536	3021920.28	673936.79	1629.1
493	3021998.38	673857.55	1628.0	537	3021935.73	673937.48	1628.8
494	3022011.82	673856.86	1628.4	538	3021953.33	673934.62	1628.0
495	3022026.92	673857.21	1628.4	539	3021967.98	673932.14	1627.9
496	3022044.99	673856.79	1629.1	540	3021981.13	673933.89	1627.9
497	3022063.80	673859.97	1629.2	541	3021996.29	673934.96	1627.6
498	3022069.71	673854.28	1629.3	542	3022012.74	673934.72	1628.1
499	3021952.87	673875.19	1628.4	543	3021920.28	673950.50	1629.5
500	3021965.49	673871.82	1628.2	544	3021936.99	673949.14	1627.8
501	3021983.20	673870.81	1627.8	545	3021951.60	673947.91	1627.7
502	3021999.86	673872.25	1628.1	546	3021968.72	673949.75	1627.4
503	3022015.81	673871.86	1628.0	547	3021982.01	673950.30	1627.8
504	3022030.39	673871.62	1628.7	548	3021995.42	67949.79	1627.8
505	3022046.13	673870.79	1629.7	549	3022012.72	673949.70	1628.5
506	3021927.82	673894.11	1627.8	550	3021920.93	673966.05	1628.0
507	3021936.86	673887.28	1627.7	551	3021936.56	673967.14	1627.3
508	3021953.88	673887.84	1628.0	552	3021951.80	673965.49	1626.9
509	3021968.14	673889.71	1628.1	553	3021966.46	673967.98	1625.8
510	3021982.74	673887.03	1628.2	554	3021983.01	673965.56	1628.6
511	3022001.15	673888.11	1628.1	555	3021999.29	673965.86	1628.4
512	3022016.67	673887.43	1628.9	556	3022010.61	673962.67	1629.0
513	3022032.06	673887.30	1628.9	557	3021936.08	673981.36	1628.1
514	3022041.17	673893.92	1628.7	558	3021952.00	673980.55	1627.1
515	3021910.49	673903.43	1628.4	559	3021967.53	673983.25	1629.0
516	3021921.82	673902.94	1628.1	560	3021981.86	673980.53	1628.7
517	3021936.24	673902.82	1627.9	561	3021998.33	673976.23	1628.6
518	3021953.09	673902.85	1627.9				

Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

Table 3-6 Surveyed Corehole Locations and Elevations, Survey Unit 17

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
612	3022375.25	673616.58	1634.90
613	3022355.02	673634.75	1635.47
614	3022368.52	673627.52	1635.18
615	3022331.41	673654.51	1635.00
616	3022304.11	673673.96	1635.31
617	3022262.19	673707.05	1634.48
618	3022277.87	673697.89	1635.37
619	3022238.03	673726.63	1633.54
620	3022255.47	673719.24	1634.50
621	3022214.60	673746.48	1632.84
622	3022233.29	673742.20	1634.35
623	3022190.27	673775.21	1632.65
624	3022208.48	673766.79	1632.41
625	3022164.52	673791.72	1632.55
626	3022184.54	673791.69	1632.62
627	3022214.08	673789.43	1632.88
628	3022228.08	673802.53	1633.44
629	3022142.56	673817.61	1633.33
630	3022165.46	673815.53	1632.67
631	3022188.75	673814.42	1633.01
632	3022117.33	673839.06	1632.99
633	3022139.73	673837.56	1632.66
634	3022080.64	673864.86	1632.90
635	3022095.30	673861.15	1632.54
636	3022121.08	673863.40	1632.47
637	3022079.11	673884.05	1632.54
638	3022096.79	673884.86	1631.72
639	3022074.04	673907.03	1632.35
640	3022095.58	673908.20	1631.02
641	3022049.58	673931.48	1632.91
642	3022065.46	673928.40	1632.66
643	3022096.75	673933.90	1629.60
644	3022120.32	673934.01	1631.60
645	3022032.30	673959.05	1633.21
646	3022053.97	673956.44	1631.80
647	3022070.32	673959.75	1631.11
648	3022097.03	673957.32	1631.25
649	3022120.17	673955.19	1631.72
650	3022141.17	673954.77	1631.90
651	3022023.00	673977.99	1632.74
652	3022049.92	673979.04	1632.57

Table 3-6 Surveyed Corehole Locations and Elevations, Survey Unit 17 (Continued)

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
653	3022073.61	673978.31	1633.19
654	3022095.23	673978.96	1632.66
655	3022118.75	673978.86	1631.65
656	3022143.24	673977.98	1632.88
657	3022166.87	673977.69	1634.44
658	3022004.72	674003.97	1629.65
659	3022024.40	674001.59	1631.62
660	3022049.42	674002.83	1631.29
661	3022071.24	674002.54	1632.36
662	3022092.26	674002.63	1633.03
663	3022118.24	674001.23	1633.03
664	3022140.60	674002.04	1633.85
665	3022166.08	674000.57	1635.03
666	3022190.17	674000.55	1635.28
667	3022163.28	674025.75	1635.45
668	3022183.92	674023.37	1635.05
A614	3022365.44	673631.50	1639.10
B614	3022372.43	673628.17	1639.60
C614	3022371.45	673622.44	1639.40
D614	3022365.36	673621.46	1639.20
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Further detail regarding the actual number of coreholes sampled in Survey Unit 17 is provided in Appendix H.

Table 3-7 Surveyed Corehole Locations and Elevations, Survey Unit 18

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
669	3022214.89	673802.49	1632.8
670	3022189.65	673824.81	1633.2
671	3022215.00	673823.29	1633.1
672	3022237.62	673824.29	1634.7
673	3022167.01	673848.45	1632.8
674	3022187.14	673847.98	1633.5
675	3022214.45	673847.77	1633.5
676	3022238.17	673846.74	1634.9
677	3022261.18	673848.28	1634.8
678	3022144.62	673871.34	1632.8
679	3022167.21	673872.53	1633.6
680	3022191.21	673871.95	1634.4
681	3022214.35	673871.31	1634.7
682	3022238.05	673870.93	1635.4
683	3022260.83	673871.96	1635.1
684	3022098.37	673892.22	1630.7
685	3022123.34	673894.60	1630.5
686	3022147.29	673896.61	1632.9
687	3022167.47	673894.98	1634.1
688	3022190.50	673893.90	1634.2
689	3022213.79	673893.91	1635.0
690	3022237.25	673894.91	1634.9
691	3022124.73	673920.34	1631.4
692	3022143.38	673917.03	1632.1
693	3022172.08	673916.04	1633.7
694	3022189.78	673917.12	1634.5
695	3022214.25	673916.95	1635.1
696	3022236.91	673917.93	1635.3
697	3022260.66	673917.90	1635.7
698	3022145.06	673940.03	1631.8
699	3022170.16	673939.68	1634.4
700	3022191.61	673940.63	1634.6
701	3022214.56	673941.06	1635.2
702	3022236.78	673938.57	1635.4
703	3022260.42	673941.25	1636.0
704	3022167.50	673964.91	1634.0

Table 3-7 Surveyed Corehole Locations and Elevations, Survey Unit 18 (Continued)

Corehole ID#	Easting (X)	Northing (Y)	Elevation (ft., msl)
705	3022190.62	673967.16	1634.6
706	3022214.48	673963.76	1635.3
707	3022237.19	673963.20	1635.7
708	3022190.44	673986.77	1634.9
709	3022213.43	673987.13	1636.0
E672	3022242.60	673832.43	1635.6
N672	3022229.44	673832.63	1635.3
S672	3022239.56	673821.22	1634.5
W672	3022229.79	673818.38	1633.7
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet			

Further detail regarding the actual number of coreholes sampled in Survey Unit 18 is provided in Appendix H.

3.4 SOIL SAMPLE COLLECTION

Upon removal of the soil core from the subsurface by Boart Longyear, the soil core (sample) was turned over to Amec Foster Wheeler personnel for the purpose of logging the geologic lithology of the subsurface soil environment. Amec Foster Wheeler erected a portable field sampling station (Figure 3-7) in proximity to the drilling location, where Amec Foster Wheeler personnel performed field sample collection procedures to log, segment, isolate, blend, containerize, and label samples.

Figure 3-7 Field Sample Isolation Station

3.4.1 Corehole Logging

The soil cores were transported to the field sampling station and placed on a table for examination. The Amec Foster Wheeler field geologist examined the soil core to classify the subsurface soil and to search for man-made debris (Figure 3-8). Soil classification and lithology was recorded by the geologist on Soil Boring Record sheets (Appendix D). The geologist determined the depth at which drilling would be terminated by examining the material in each sample core and evaluating whether or not bedrock (the vertical termination point) had been reached. Secondly, the geologist was responsible for subdividing the soil core into 1-meter vertical segments from which volumetric soil samples were collected and sampled. The division of the core into 1-meter increments corresponds to the vertical demarcation in the design of the sampling plan for Survey Units 4, 6, 7, 12, 16, 17, and 18.

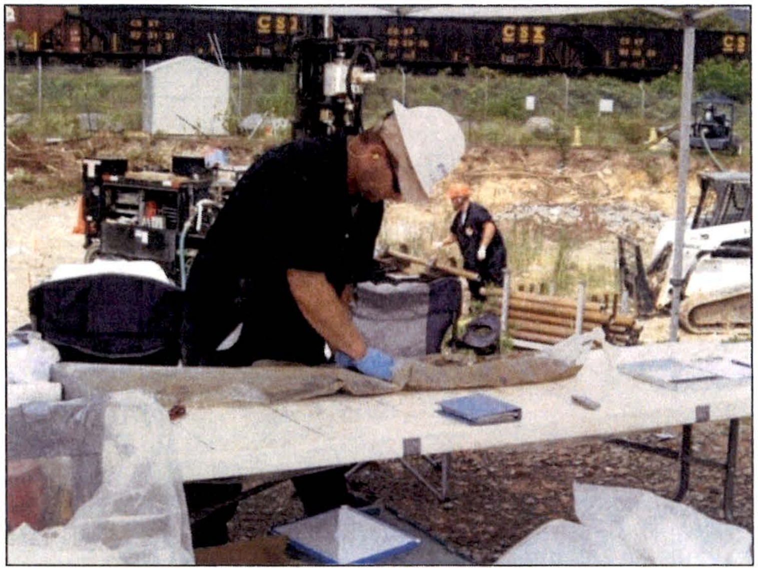

Figure 3-8 Geologist Examines Core and Logs Lithology

Following geologic lithology logging, Amec Foster Wheeler personnel performed field sample collection procedures to blend, isolate, containerize, and label samples.

3.4.2 Field Sample Collection

Amec Foster Wheeler personnel performed required processes on the soil samples, placed the soil samples in designated laboratory sample containers, identified and cataloged the containerized samples, and then stored the samples in the appropriate sample storage area (e.g. refrigerator, cabinet) until shipment to an off-site laboratory for further sample preparation (if necessary) and analysis. A series of processes and decisions in support of sample collection were required. These processes and decisions are described in the sections that follow.

3.4.2.1 Unique Sample Identification and Nomenclature

To maintain consistency and comparability of sample location identification throughout the course of the characterization, each soil sample was uniquely identified by Amec Foster Wheeler field personnel and labeled accordingly. Each vertical increment from every corehole was assigned a unique sample identification which indicated the corehole number and the sample depth increment (Figure 3-9). This sample identification is referred to as the "Field Sample ID." All samples collected from a particular corehole and depth increment are tagged with this "Field Sample ID."

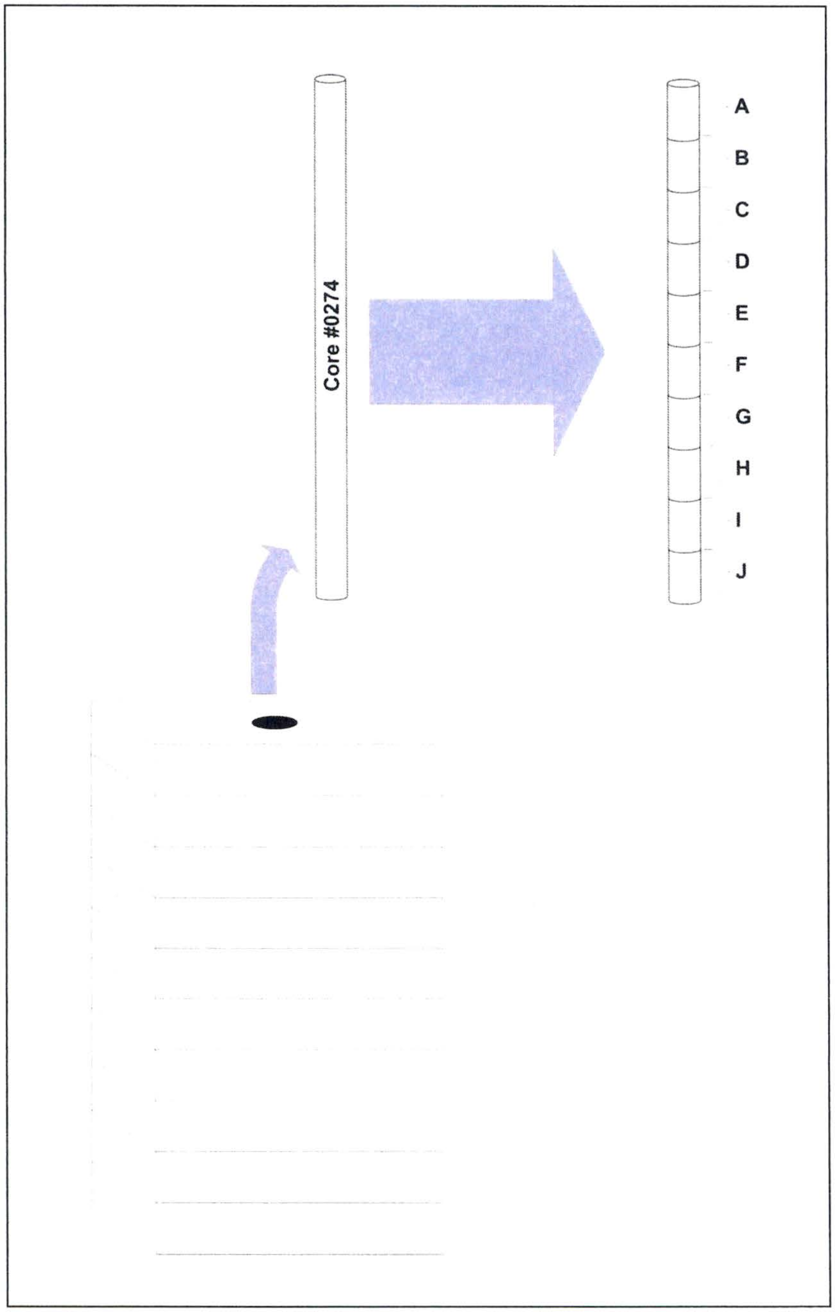

Figure 3-9 Field Sample Identification Numbering System

3.4.2.2 Sample Types

The analytical requirements for the subsurface soil characterization and FSS project call for every soil sample to be analyzed for Am-241, Th-232, and U-235 by gamma spectroscopy. In addition, a subset of samples was to be analyzed for each of the thirteen isotopes of concern identified in the site DP. For all isotopes other than Tc-99, a single 2-L poly jar was filled with field-blended sample material from each increment (Figure 3-10). Tc-99 samples were collected prior to field blending by placing sample material into a 50 mL centrifuge tube (Figure 3-11).

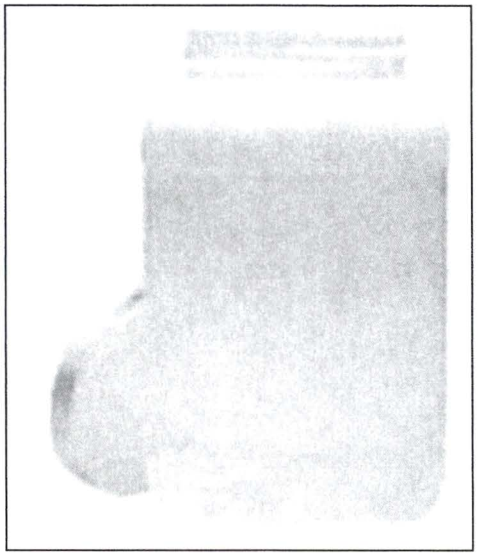

Figure 3-10 Container for Isotopes Other Than Tc-99

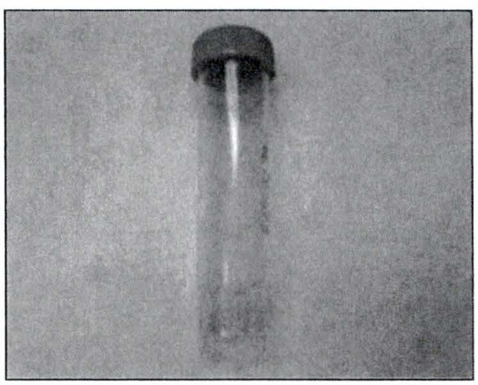

Figure 3-11 Container for Tc-99 Sample

To distinguish multiple sample containers filled with sample from a single corehole/increment from one another, a unique sample container ID was employed. The sample container ID is composed of the "Field Sample ID" and the Sample Type Identifier, as presented in Figure 3-12.

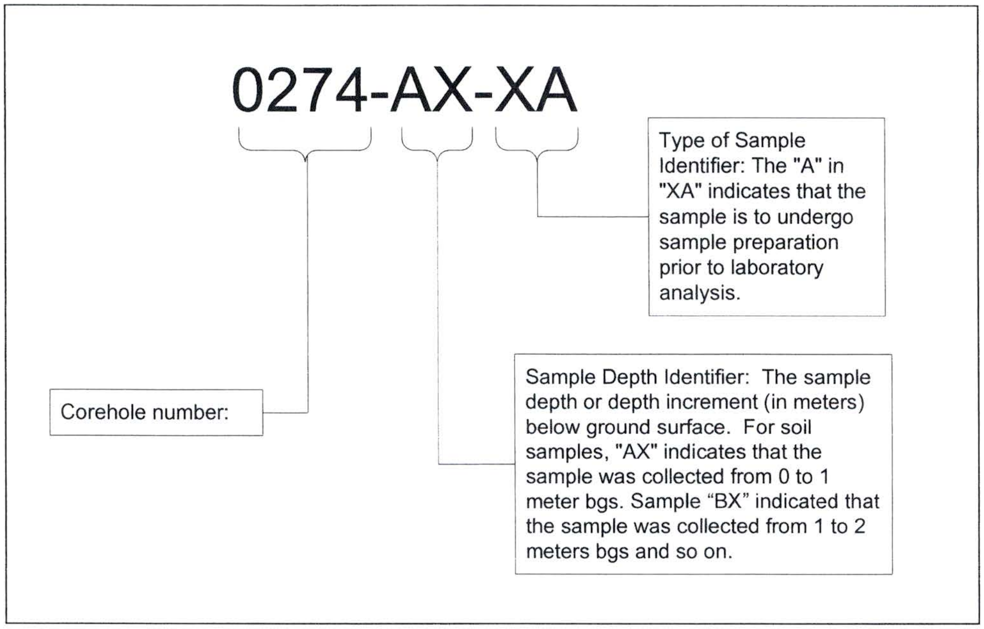

Figure 3-12 Sample Identification Format

In the example presented in Figure 3-12, the first four digits identify the unique corehole identification number (0274), the next two characters indicate the depth increment below-ground-surface (bgs) (meters) of the sample, and the last two characters are used to indicate what type of analysis the sample will undergo (e.g. gamma spectroscopy or alpha spectroscopy).

The depth increments were delineated at 1 meter intervals. The 0-1 meter bgs soil increment was labeled as increment "AX". The 1-2 meter bgs soil increment was labeled as "BX" and so on through increment "JX" (9-10 meters bgs) which was the predetermined maximum drilling depth if no bedrock was encountered prior to 10 meters deep. The Figure 3-12 example indicates the 0-1 meter bgs soil increment at location 0274 by the label "0274-AX".

Notice the label also contains an "XA" following the corehole ID and depth increment indicator. The "XA" is the type of sample identifier. Table 3-8 presents a summary of sample type identifiers applicable to radiological characterization of subsurface soils.

Table 3-8 Summary of Sample Containers, Database Identifiers

Sample Type	Container	Potential Laboratory Analysis	Laboratory
A	2L poly container	Sample Preparation (Dry and Grind)	Teledyne Brown
		Gamma Spectroscopy	NFS
		Gamma Spectroscopy	Paragon
		Gamma Spectroscopy	ORISE
		Alpha Spectroscopy (U/Pu/Am/Th)	Paragon
		Alpha Spectroscopy (U/Pu/Am/Th)	ORISE
E	50 mL plastic vials	LSC (Tc-99)	ORISE
F	50 mL plastic vials	LSC (Tc-99)	Paragon
Q	50 mL plastic vials	LSC (Tc-99)	Paragon Duplicate

Each bottle or container filled with sample was affixed with a label containing the following information:

- "Field Sample ID",
- project name,
- collection date and time,
- sampler,
- sample matrix (soil, liquid)
- preservation (if necessary),
- sample container size and material, and
- sample type (analytical measurement requested).

The Field Sample Tracking Program (Appendix C) was used to prepare pre-printed labels for each individual sample container, where applicable[2]. The system was enhanced for this project to incorporate the ability to print unique barcodes on the labels for each sample container (Figure 3-13).

2 Pre-printed sample labels generated by the Field Sample Tracking Program were used when it was known in advance that a particular sample would be collected. For example, it was known in advance that a 2-L soil sample would be collected from each increment of every core. Commercially available blank sample labels were used when a sample was added in the field. For example, in certain cases a decision was made in the field to add a "Full Suite" of radiological analyses to a particular increment (see Section 3.4.2.3). In this case, a pre-printed label for the Tc-99 sample container would not have been printed and the commercially available blank sample label was used. The same required information was included regardless of the label used.

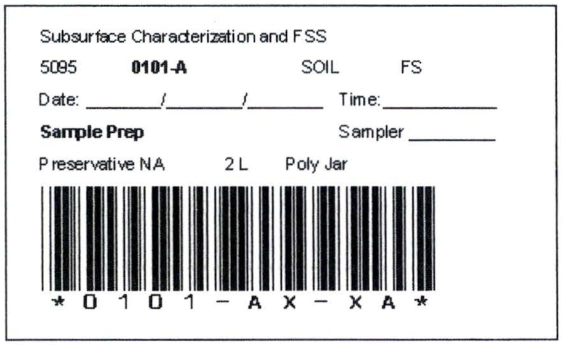

Figure 3-13 Preprinted Sample Container Label with Barcode

3.4.2.3 Full Suite Determination

As described earlier, samples from 10% of the total number of core segments were selected for full-suite radiological analysis. The selection process was designed to provide spatial representativeness in both the lateral and vertical dimensions. The first samples selected for full-suite analysis were those selected for regulatory confirmation sampling by the NRC.[3] Following those selections, the sampling team pre-selected samples for full-suite analysis from the "A" increment at suitable locations to ensure appropriate lateral spatial representation. The lateral spatial distribution of pre-selected full-suite samples for Survey Units 4, 6, 7, 12, 16, 17, and 18 is presented in Figure 3-14, Figure 3-16, Figure 3-18, Figure 3-20, Figure 3-22, Figure 3-25, and Figure 3-27, respectively.

Additional samples were selected for full-suite analysis "on-the-fly" from various depth intervals to complete the required subset of 10%, and provide for vertical spatial representation. The vertical spatial distributions of full-suite samples for Survey Units 4, 6, 7, 12, 16, 17, and 18 is presented in Figure 3-15, Figure 3-17, Figure 3-19, Figure 3-21, Figure 3-23, Figure 3-24, Figure 3-26, and Figure 3-28, respectively.

A total of 263 core segment samples from 41 coreholes were collected from Survey Unit 4. Twenty-seven of these samples were submitted to the offsite laboratory for full-suite analysis including two NRC regulatory confirmation samples (Figure 3-15).

A total of 289 core segment samples from 60 coreholes were collected from Survey Unit 6. Thirty-one of these samples were submitted to the offsite laboratory for full-suite analysis (Figure 3-17).

A total of 219 core segment samples from 32 coreholes were collected from Survey Unit 7. Twenty-two of these samples were submitted to the offsite laboratory for full-suite analysis (Figure 3-19).

3 The NRC selected samples from Survey Units 4, 12, 16, 17, and 18 for regulatory confirmation analysis.

A total of 204 core segment samples from 53 coreholes were collected from Survey Unit 12. Twenty-two of these samples were submitted to the offsite laboratory for full-suite analysis including one NRC regulatory confirmation samples (Figure 3-21).

A total of 634 core segment samples from 197 coreholes were collected from Survey Unit 16. Sixty-eight of these samples were submitted to the offsite laboratory for full-suite analysis including 6 NRC regulatory confirmation samples (Figure 3-23 and Figure 3-24).

A total of 313 core segment samples from 61 coreholes were collected from Survey Unit 17. Thirty-five of these samples were submitted to the offsite laboratory for full-suite analysis including six NRC regulatory confirmation samples (Figure 3-26).

A total of 300 core segment samples from 45 coreholes were collected from Survey Unit 18. Thirty-two of these samples were submitted to the offsite laboratory for full-suite analysis including two NRC regulatory confirmation samples (Figure 3-28).

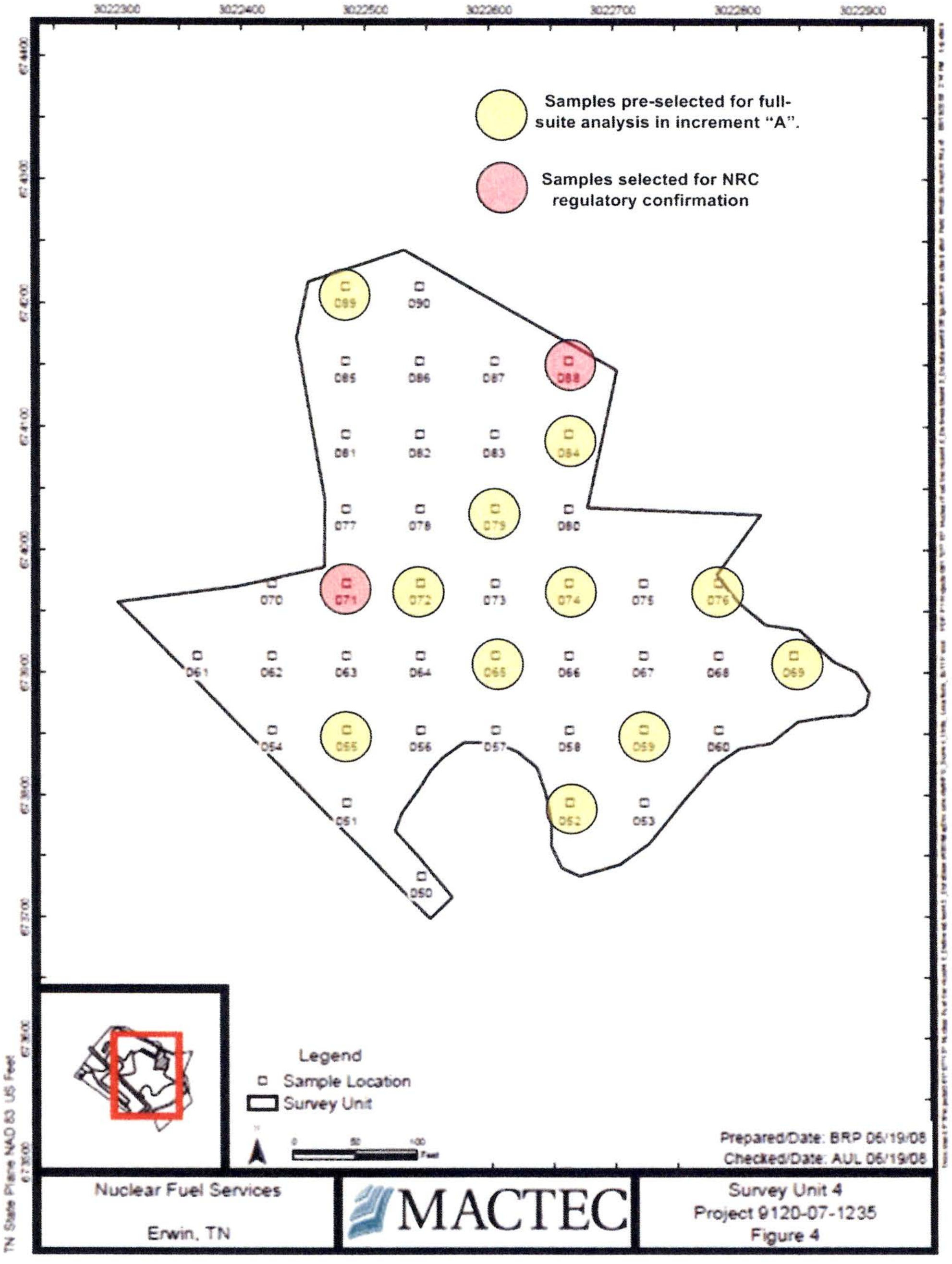

Figure 3-14 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 4

Corehole ID#

Model Layer	050	051	052	053	054	055	056	057	058	059	060	061	062	063	064	065	066	067	068	069
1	A	A										A								
2	B	B	A					A				B			A	A				
3	C	C	B	A				B	A		A	C			B	B			A	A
4	D	D	C	B		A	A	C	B	A	B	D			C	C	A	A	B	B
5	E	E	D	C	A	B	B	D	C	B	C	E	A	A	D	D	B	B	C	C
6	F	F	E	D	B	C	C	E	D	C	D	F	B	B	E	E	C	C	D	D
7	G	G	F	E	C	D	D	F	E	D	E	G	C	C	F	F	D	D	E	E
8		H	G	F	D	E	E	G	F	E	F	H	D	D	G	G	E	E	F	F
9		I	H	G	E	F		H	G	F	G	I		E		H	F	F	G	G
10			I	H	F	G		I		G	H					I			H	H
11				I	G						I					J			I	
12					H						J								J	
13					I															
14					J															
15																				

Model Layer	070	071	072	073	074	075	076	077	078	079	080	081	082	083	084	085	086	087	088	089	090
1																					
2		A																			
3		B					A														
4		C	A			A	B	A			A	A	A	A	A	A	A	A	A	A	A
5	A	D	B	A	A	B	C	B	A	A	B	B	B	B	B	B	B	B	B	B	B
6	B	E	C	B	B	C	D	C	B	B	C	C	C	C	C	C	C	C	C	C	C
7	C	F	D	C	C	D	E	D	C	C	D	D	D	D	D	D	D	D	D		D
8		G	E	D	D	E	F			D	E			E	E		E		E		
9			F	E	E	F	G			E	F			F							
10			G		F	G	H			F	G										
11			H		G																
12																					
13																					
14																					
15																					

Samples selected for gamma spec analysis
Samples selected for full-suite radiological analyses
Samples selected by the NRC for regulatory confirmation analyses

Figure 3-15 Spatial Distribution (Vertical) – Full-Suite Samples, SU 4

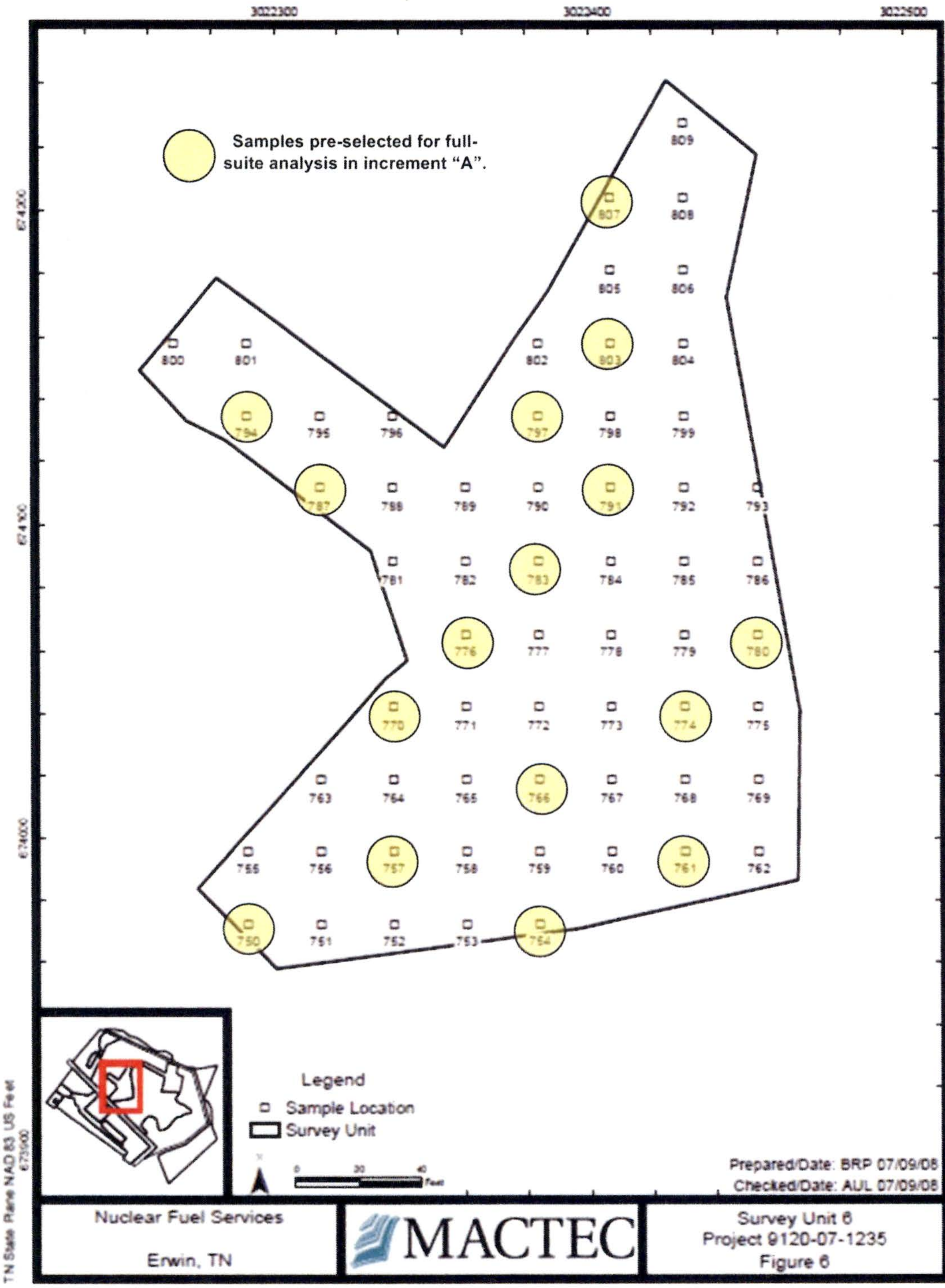

Figure 3-16 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 6

Corehole ID#

Model Layer	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764
1	**A**	A				A									
2	B	B				B							A		
3	C	C	A			C	**A**					**A**	B	A	
4	D	D	B	A	**A**	D	B	**A**	A	A	A	B	**C**	B	A
5	E	E	C	**B**	B	E	C	B	B	**B**	B	C	D	C	B
6	F	F	D	C	C	F	D	C	C	C		D	E	D	C
7	G	G	E	D	D	G	E	D				E		E	D
8		H		E			F	E	E					F	E
9		I							F					G	F
10		J													G
11															H
12															I
13															
14															
15															

Model Layer	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779
1															
2				A	A				A	A			A	A	
3			A	B	B			A	B	B		**A**	B	**B**	A
4	A	**A**	B	C	C	**A**	A	B	C	C	A	B	C	**C**	B
5	B	B	C	D	**D**	B	B	C	D	D	**B**	C	D	D	C
6	**C**	C	D	E	E	C	C	D	E	E	C	D	E	E	D
7		D				D		E				E			
8						E									
9															
10															
11															
12															
13															
14															
15															

Model Layer	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794
1		A													
2		B						**A**	A	A					**A**
3		**C**	A	**A**	A	A		B	B	B	A	**A**	A		B
4	**A**	D	B	B	B	**B**	A	C	C	C	B	B	**B**	A	C
5	B	E	C	C	C	C	B	D	D		C	C	C	**B**	D
6	C		D	D	D	D	C	E				D	D	C	E
7	D				E	E	D					E		D	
8					F										
9															
10															
11															
12															
13															
14															
15															

Model Layer	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809
1							A								
2	A	A	**A**			A	B	A			A		**A**	A	A
3	B	B	B	A	A	B	C	B	**A**	A	B	A	B	B	B
4	C	C	C	B	B	C	D	C	B	B	C	B	C	C	C
5	D	D	D	C	C	**D**	E	D	C	C	D	**C**	D	D	D
6		E	E	D	D	E	F	E	D		E	D	E	E	
7				E	E								F		
8													G		
9													H		
10															
11															
12															
13															
14															
15															

Samples selected for gamma spectroscopy analysis
Samples selected for full-suite radiological analyses

Figure 3-17 Spatial Distribution (Vertical) – Full-Suite Samples, SU 6

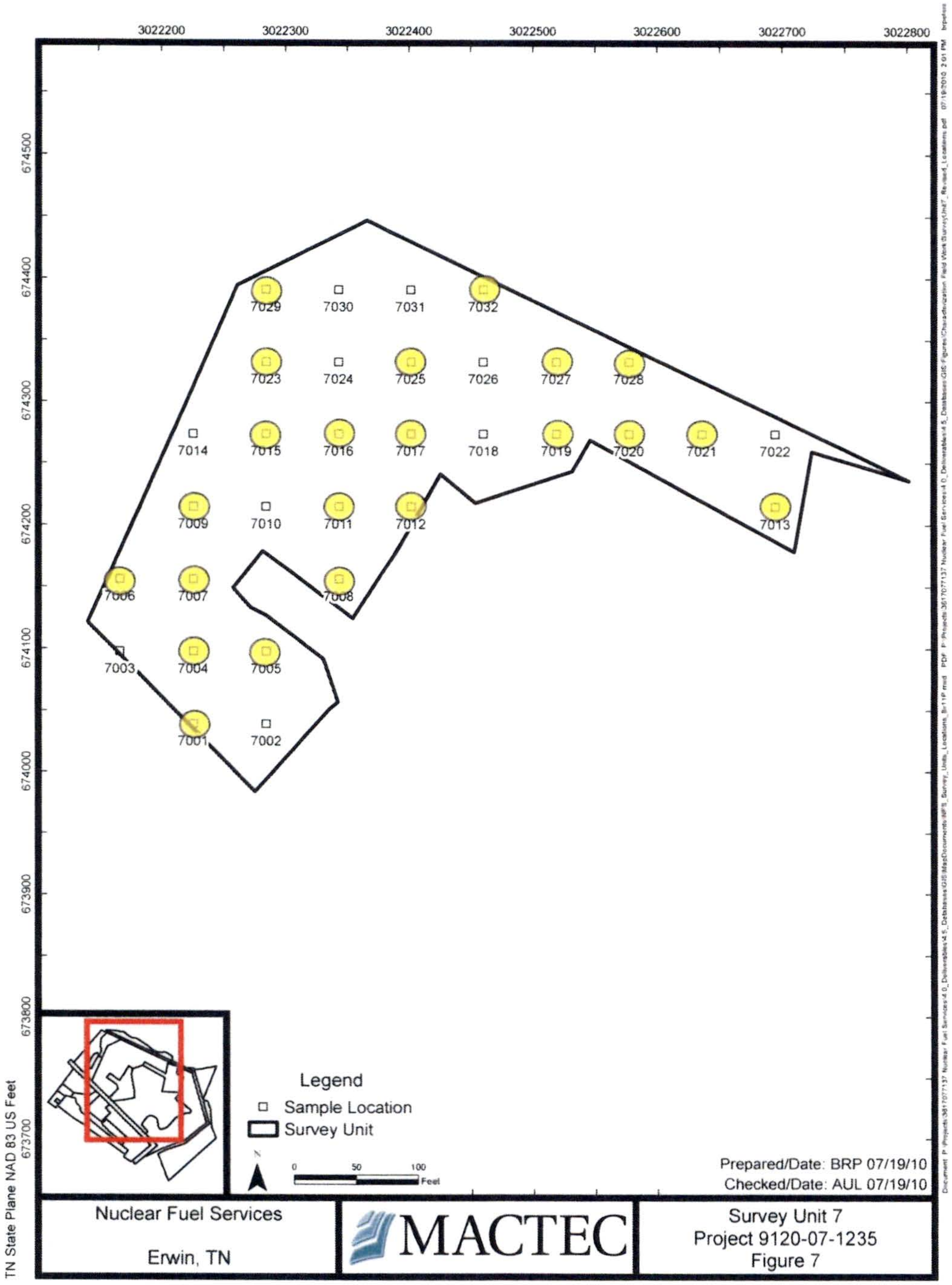

Figure 3-18 Spatial Distribution (Lateral) – Full-Suite Samples, SU 7

Model Layer	Corehole ID#																															
	7001	7002	7003	7004	7005	7006	7007	7008	7009	7010	7011	7012	7013	7014	7015	7016	7017	7018	7019	7020	7021	7022	7023	7024	7025	7026	7027	7028	7029	7030	7031	7032
1	A	A	B	A	A			A	A	A	A	A	A		A	A	A	A	A	A	A	A		A	A	A	A	A			A	A
2	B	B	C	B	B	A	A	B	B	B	B	B	B	A	B	B	B	B	B	B	B	B	A	B	B	B	B	B	A	A	B	B
3	C	C	D	C	C	B	B	C	C	C	C	C	C	B	C	C	C	C	C	C	C	C	B	C	C	C	C	C	B	B	C	C
4	D	D	E	D	D	C	C	D	D	D	D	D	D	C	D	D	D	D	D	D	D	D	C	D	D	D	D	D	C	C	D	D
5	E	E	F	E	E	D	D	E	E	E	E	E	E	D	E	E	E	E	E	E	E	E	D	E	E	E	E	E	D	D	E	E
6	F	F	G	F		E	E	F	F		F	F	F	E		F	F	F		F	F	F	E	F	F		F		E	E	F	F
7	G				G	F	F	G	G			G	G	F		G			G	G	G	G	F					G	F	F		
8	H				H	G	G	H	H			H	H						H													
9					I	H	H	I	I										I													
10		J				I	I												J													
11							J																									
12																																
13																																
14																																
15																																

Samples selected for gamma spec analysis
Samples selected for full-suite radiological analyses

Figure 3-19 Spatial Distribution (Vertical) – Full-Suite Samples, SU 7

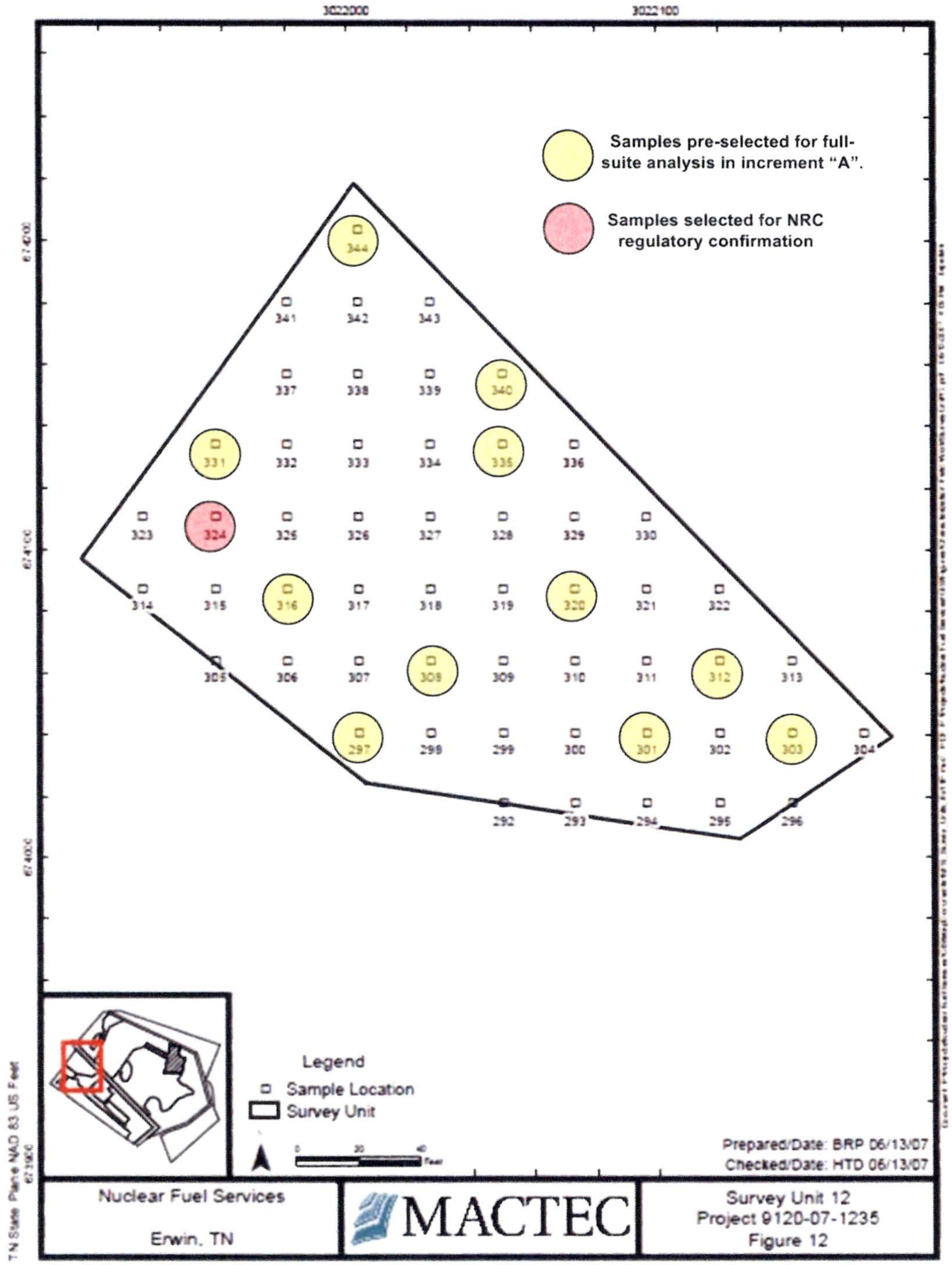

Figure 3-20 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 12

Model Layer	Corehole ID#																																																			
	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344
1																																																					
2																																																					
3				A								A	A								A	A									A	A							A						A	A		A	A	A	A	A	A
4	A	A	A	B	A		A	A	A	A	A	B	B	A	A	A	A	A	A	A	B	B	A	A	A	A	A	A	A	A	B	B	A	A	A	A	A	A	B	A	A	A	A	A	B	B	A	B	B	B	B	B	B
5	B	B	B	C	B	A	B	B	B	B	B	C	C	B	B	B	B	B	B	B	C	C	B	B	B	B	B	B	B	B	C	C	B	B	B	B	B	B	C	B	B	B	B	B	C	C	B	C	C	C	C	C	C
6		C	C	D	C	B	C	C	C	C		D	D	C	C	C	C	C	C	C	D	D	C	C	C	C	C	C	C	C	D	D	C	C	C	C	C	C	D	C	C	C	C	C	D	D	C	D	D	D	D	D	D
7					D	C			D							D		D			E			D				D	D			E	D		D		D	D		D	D	D	D	D			D						E
8					E	D																		E																	E						E						F
9					F																																																
10					G																																																
11					H																																																
12																																																					
13																																																					
14																																																					
15																																																					

Samples selected for gamma spec analysis
Samples selected for full-suite radiological analyses
Samples selected by the NRC for regulatory confirmation analyses

Figure 3-21 Spatial Distribution (Vertical) – Full-Suite Samples, SU 12

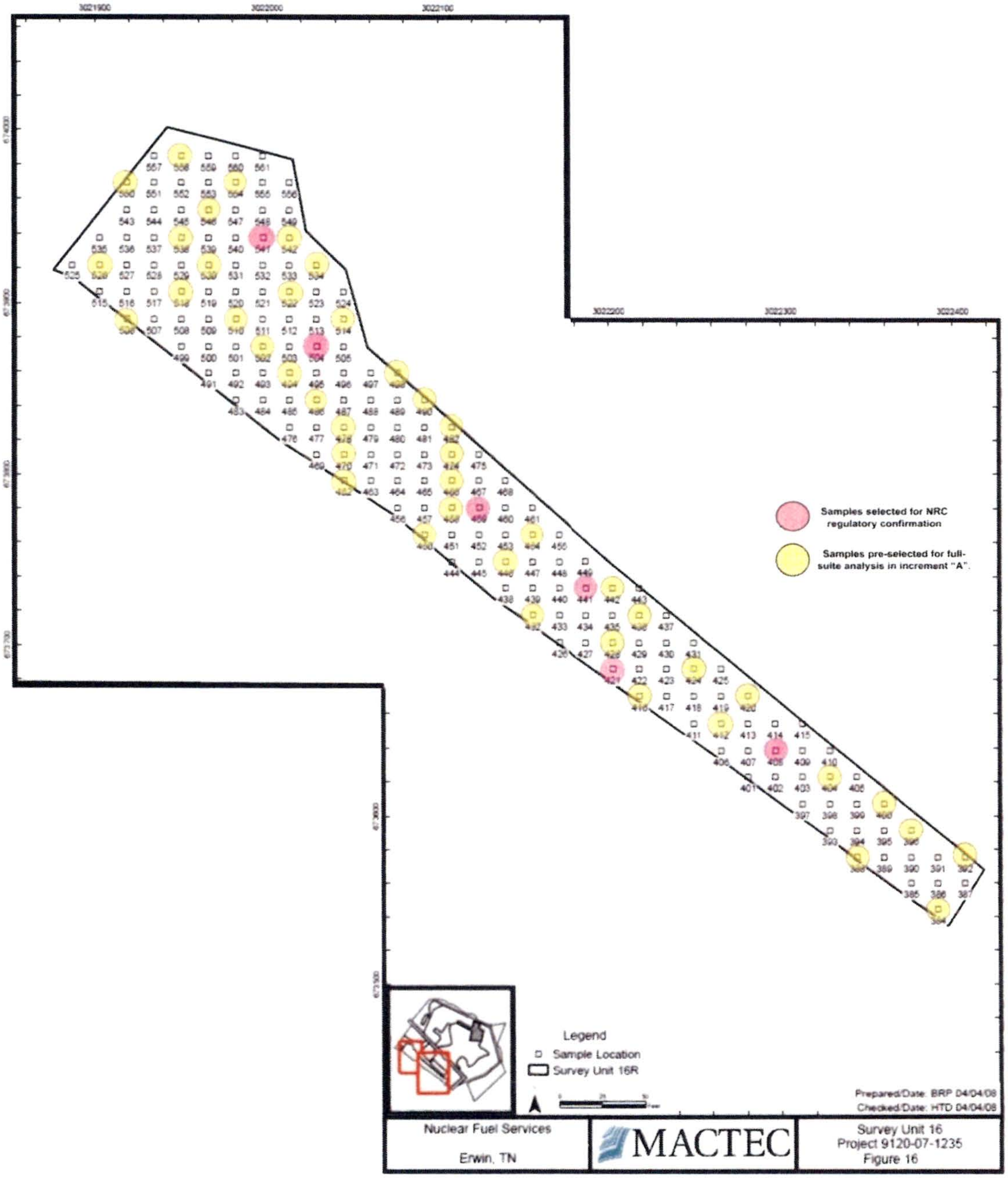

Figure 3-22 Spatial Distribution (Lateral) – Full-Suite Samples, SU 16

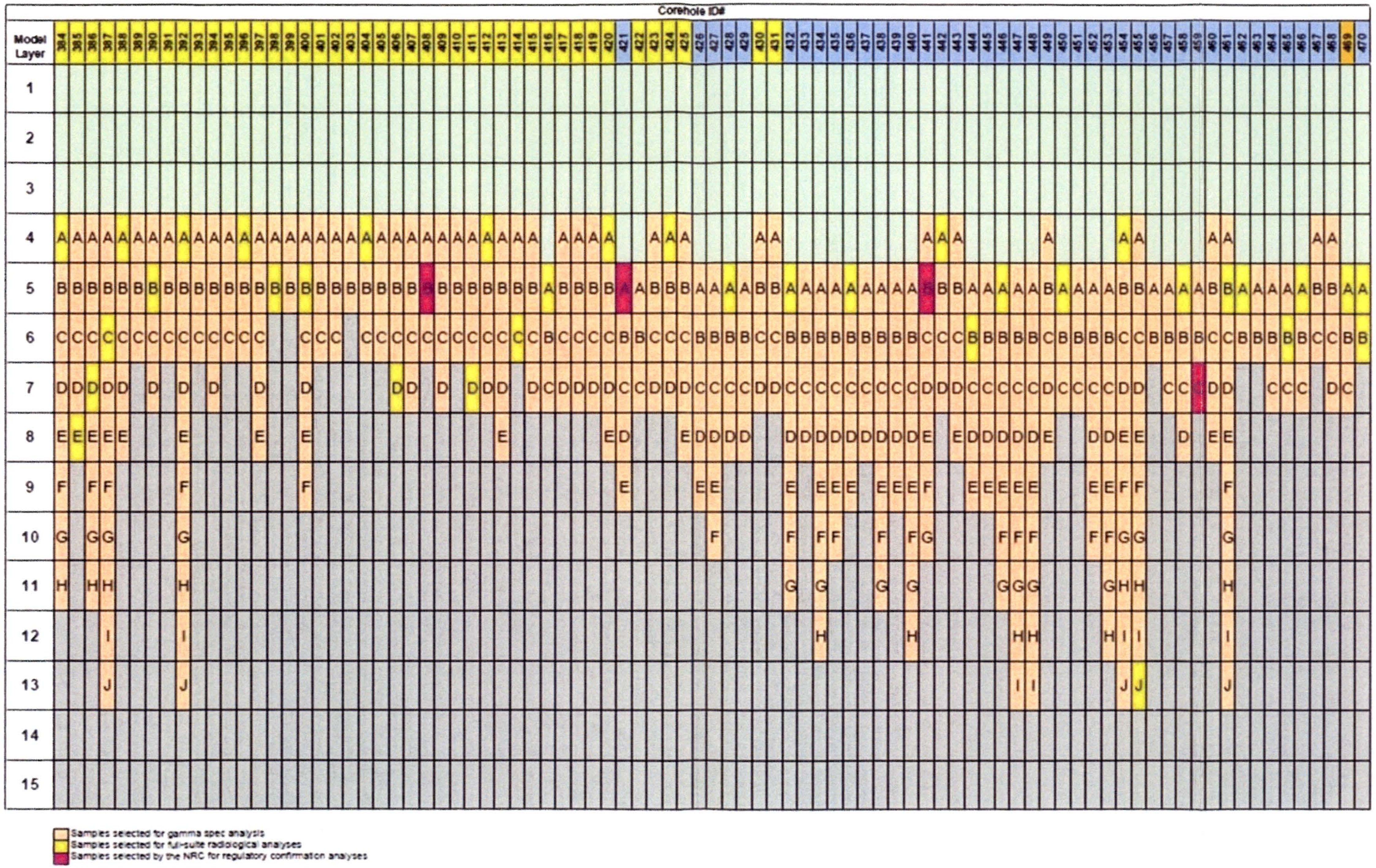

Figure 3-23 Spatial Distribution (Vertical) – Full-Suite Samples, SU 16-A (Coreholes 384-470)

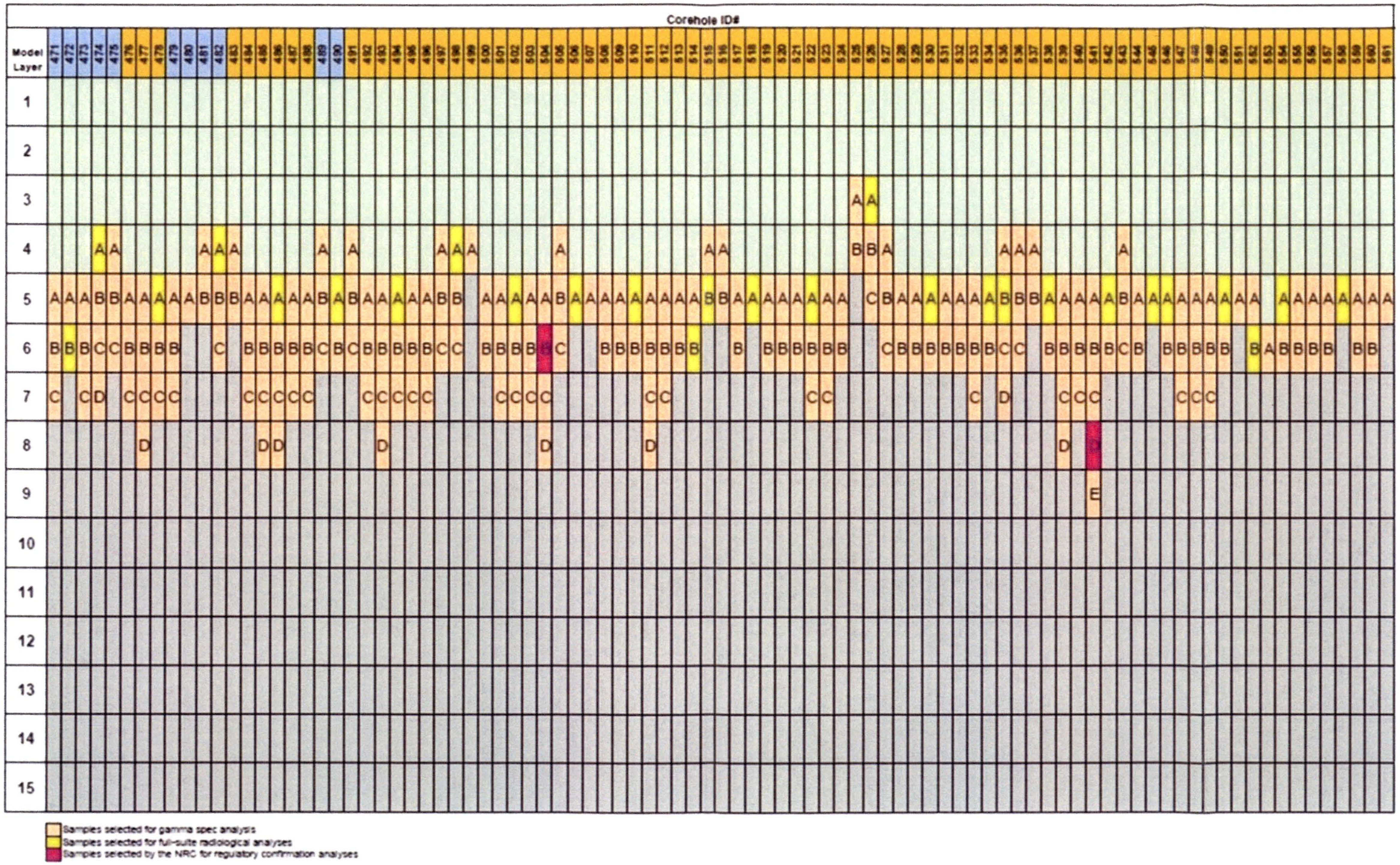

Figure 3-24 Spatial Distribution (Vertical) – Full-Suite Samples, SU 16-B (Coreholes 471-561)

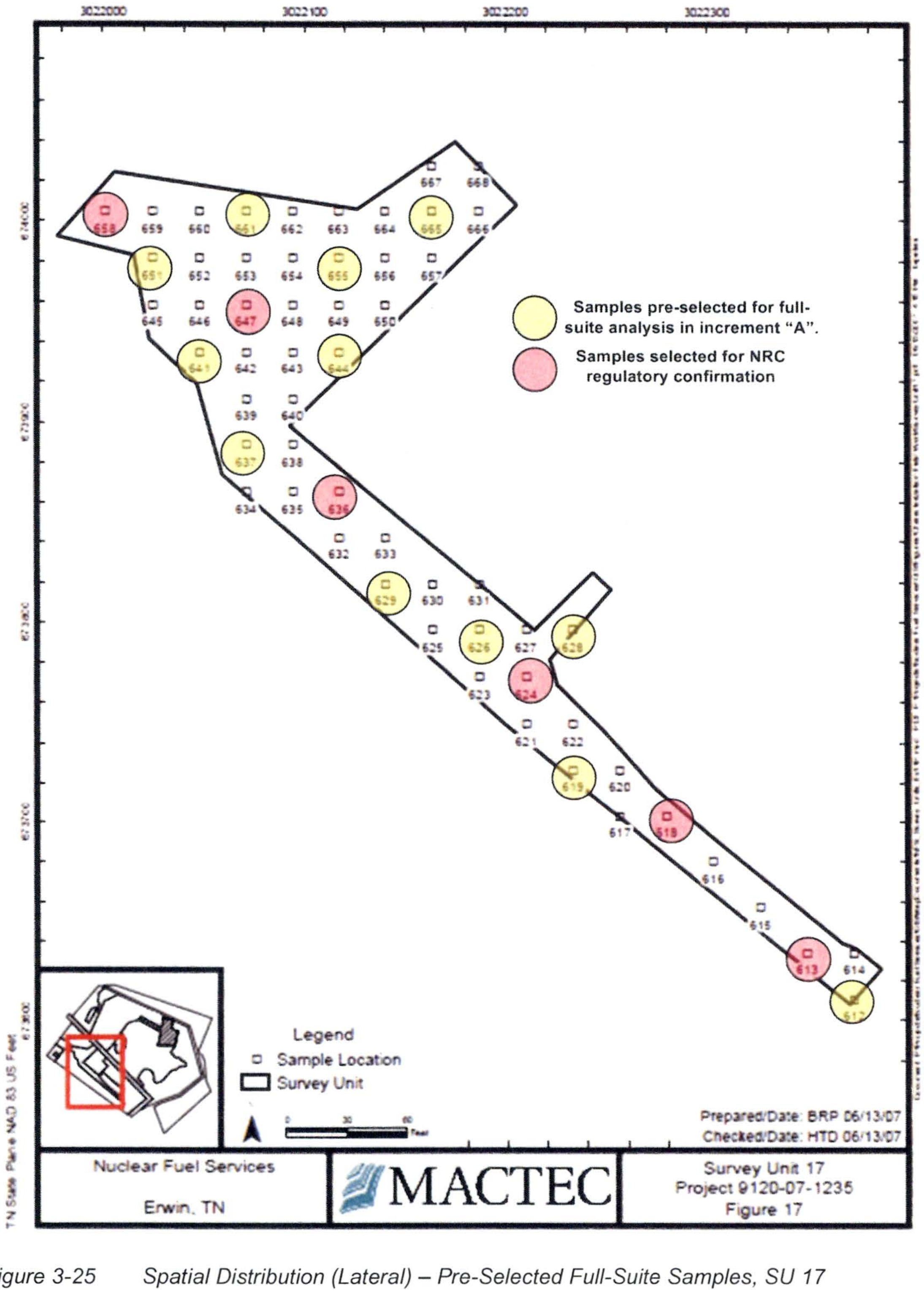

Figure 3-25 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 17

Corehole ID #

Model Layer	612	613	614[a]	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630
1			A																
2		A	B		A		A		A		A								
3	A	B	C	A	B	A	B	A	B	A	B	A	A	A	A	A	A	A	A
4	B	C	D	B	C	B	C	B	C	B	C	B	B	B	B	B	B	B	B
5	C	D	E	C	D	C	D	C	D	C	D	C	C	C	C	C	C	C	C
6	D	E	F	D	E	D	E	D	E	D	E	D	D	D	D	D	D	D	D
7	E	F	G	E	F	E	F	E		E		E	E	E	E	E	E	E	E
8	F		H	F	G	F				F		F	F	F	F	F	F		
9	G			G	H					G		G	G	G	G	G	G		
10	H									H		H	H	H	H	H	H		
11										I		I	I	I	I	I	I		
12										J		J	J	J	J	J	J		
13																			
14																			
15																			

Model Layer	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649
1																			
2																			
3	A	A	A	A	A	A													
4	B	B	B	B	B	B	A	A	A	A	A	A		A	A	A			A
5	C	C	C	C	C	C	B	B	B	B	B	B	A	B	B	B	A	A	B
6	D		D	D	D	D	C	C	C	C	C	C	B	C	C	C	B	B	C
7	E					E	D		D	D		D			D	D		C	D
8	F														E			D	
9	G																		
10	H																		
11	I																		
12	J																		
13																			
14																			
15																			

Model Layer	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668
1																			
2																			
3																A	A	A	A
4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B
5	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C
6	C	C	C	C	C	C	C	C		C	C	C	C	C	C		D		
7	D			D	D			D			D		D	D	D				
8	E				E			E						E					
9																			
10																			
11																			
12																			
13																			
14																			
15																			

Samples selected for gamma spec analysis

Samples selected for full-suite radiological analyses

Samples selected by the NRC for regulatory confirmation analyses

Figure 3-26 Spatial Distribution (Vertical) – Full-Suite Samples, SU 17

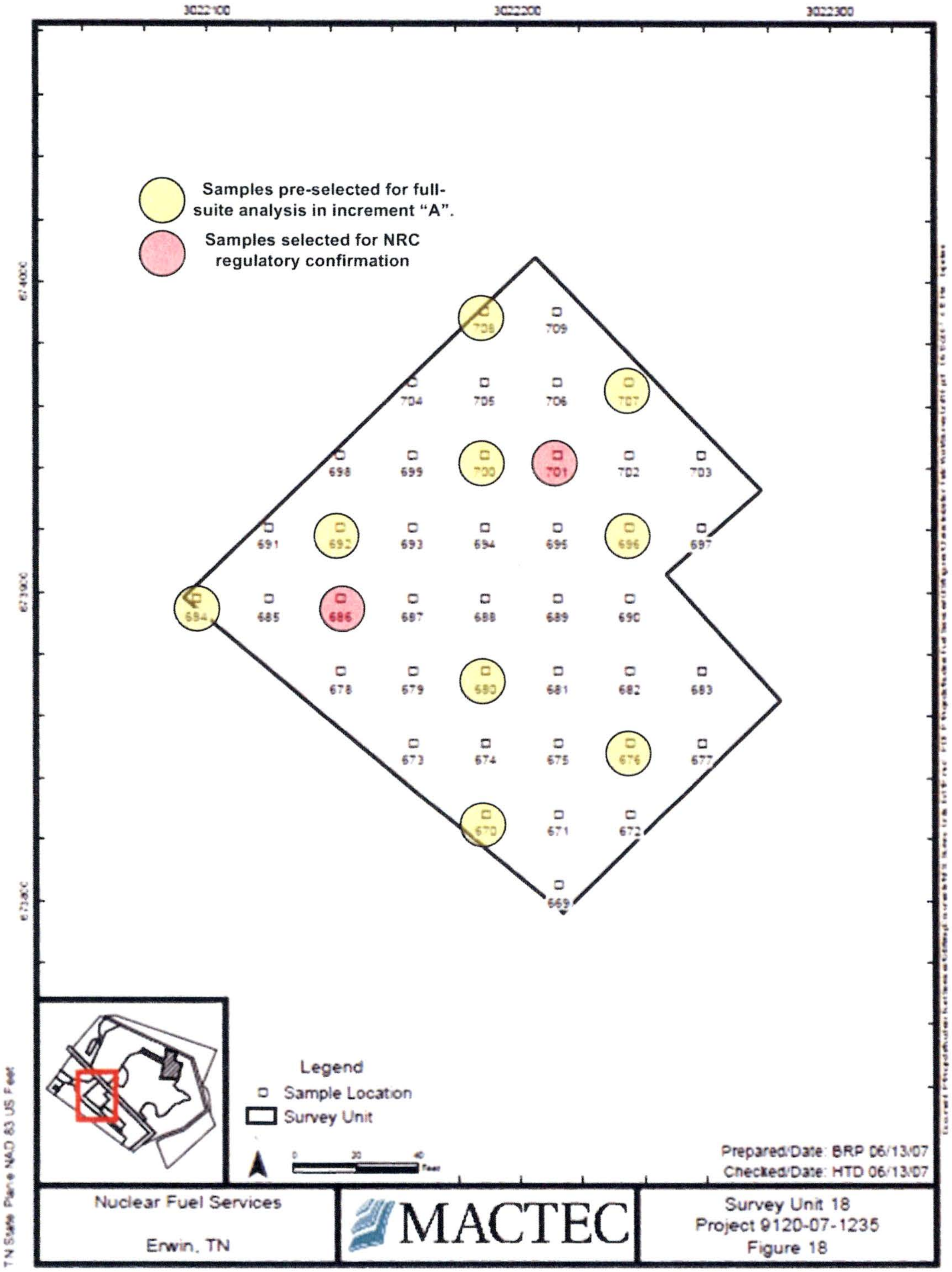

Figure 3-27 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 18

Model Layer	Corehole ID#																																								
	669	670	671	672[a]	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709
1																																									
2				A																																					
3	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A			A	A	A	A	A			A	A	A	A	A		A	A	A	A	A		A	A	A	A	A
4	B	B	B	C	B	B	B	B	B	B	B	B	B	B	B	A	A	B	B	B	B	B	A	A	B	B	B	B	B	A	B	B	B	B	B	A	B	B	B	B	B
5	C	C	C	D	C	C	C	C	C	C	C	C	C	C	C	B	B	C	C	C	C	C	B	B	C	C	C	C	C	B	C	C	C	C	C	B	C	C	C	C	C
6	D	D	D	E	D	D	D	D	D	D	D	D	D	D	D	C		D		D	D	D	C	C	D	D	D	D	D	C	D	D	D	D	D	C	D	D	D	D	D
7	E	E	E	F		E	E	E	E			E	E	E	E					E	E	E	D	D	E	E	E	E	E		E	E	E	E	E	D	E	E	E	E	E
8	F	F	F	G			F	F	F					F	F						F	F	E			F	F		F		F	F	F	F	F	E		F	F	F	F
9	G	G	G	H				G	G						G						G		F				G				G	G	G			F			G		G
10	H	H	H	I				H	H						H																	H				G					H
11	I	I	I	J				I	I						I																	I				H					I
12	J	J	J	K				J	J						J																	J				I					J
13																																									
14																																									
15																																									

Samples selected for gamma spec analysis
Samples selected for full-suite radiological analyses
Samples selected by the NRC for regulatory confirmation analyses

Figure 3-28 Spatial Distribution (Vertical) – Full-Suite Samples, SU 18

3.4.2.4 Field Sample Homogenization

The volume of soil produced by the 3-inch diameter core barrel used by the "Mini-Sonic" drill rig for a 1-meter sample interval was 4.56 liters (L). The largest volume that could be homogenized (dried and ground) and processed in the analytical laboratory was 2 L. Consequently the core volume was larger than the isolated sample volume. Field blending was necessary because it was imperative that the soil sample to be isolated and analyzed was representative of the entire volume of the 1-meter core segment. Field blending of individual core segments was a prerequisite step to obtaining soil samples (for other than Volatile Organic Compounds (VOC) and Tc-99).

After segmentation of soil sample into 1-meter core segments, the sample volume was placed into standard five-gallon plastic buckets with a polyethylene liner, in which the soil was field blended. The polyethylene liners were replaced between each sample to prevent cross-contamination. Each sample was blended by hand for a minimum of 30 seconds to thoroughly homogenize the soil.

3.4.2.5 Soil Sampling, Tc-99

For samples that were designated for full-suite analyses, Tc-99 samples were collected prior to homogenizing the sample. Collecting the sample prior to homogenization was done to avoid the potential for volatilization of contaminants. While Tc-99 is not classified as a volatile compound, it is, however, highly soluble and could be influenced if moisture in the sample were to escape the sample matrix.

Approximately 40mL of sample was placed into a 50mL centrifuge tube. The centrifuge tube was sealed with electrical tape, labeled, and affixed with a Custody Seal to provide assurance that the sample remained tamper free. After a Tc-99 sample was isolated, the Tc-99 container was placed in a cooler with ice to further prevent the escape of moisture. Sampling equipment was either discarded or decontaminated between each sample.

3.4.2.6 Soil Sampling, Isotopes Other Than Tc-99

All of the radiological analyses except for Tc-99 were performed on soil from a single, large sample container. Approximately 2 L of sample was placed into a poly jar (Figure 3-29). The poly jar was sealed with electrical tape, labeled, and affixed with a Custody Seal to provide assurance that the sample remained tamper free (Figure 3-30). No preservation methods were necessary for this sample container type. Sampling equipment was either discarded or decontaminated between each sample.

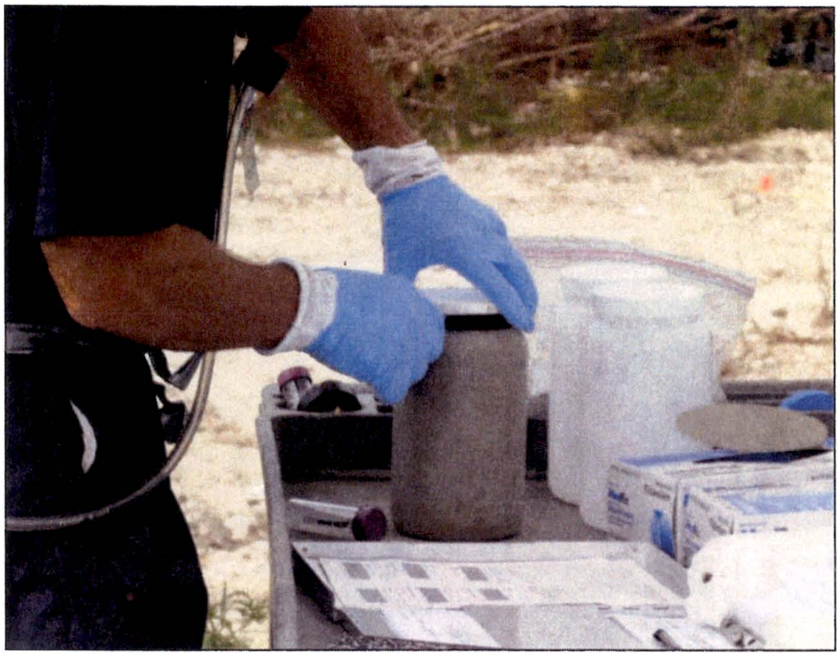

Figure 3-29 Collection of 2-L Soil Sample

Figure 3-30 2-L Poly Jar Filled with Sample Material and Sealed

3.4.2.7 Soil Sampling, for Non-Radiological Contaminates of Concern

NFS is a participant in the Facility Action Plan (FAP) process by the Division of Solid Waste Management of the Tennessee Department of Environment and Conservation in order to accelerate corrective action at RCRA SWMUs and Areas of Concern. During the characterization, ten percent of the sample locations were sampled for RCRA constituents. RCRA sample results will not be addressed in this FSS Report.

3.5 SAMPLE MANAGEMENT AND CONTROL

3.5.1 Field Sample Tracking Program

In order to minimize possible transcription errors and to efficiently catalogue samples, Amec Foster Wheeler developed and utilized a proprietary database called the Field Sample Tracking Program. Uniquely adapted to this characterization effort, Amec Foster Wheeler personnel used Microsoft Access software (Microsoft 2007) to create a database which enables users to print sample container labels, import sample collection dates and times, generate Chain of Custody (COC) records used during sample shipments, and to track the status of samples throughout the field sampling process. See Appendix C for a detailed description of the Field Sample Tracking Program database.

3.5.2 Field Logs

During the course of the Subsurface Soil characterization and FSS, relevant field data was recorded on various field logs. In addition to the corehole location and soil boring logs previously discussed, the field sample team documented information and data relevant to the sample collection process itself. Data regarding individual samples was recorded on Field Sample Data sheets. Field Sample Data sheets contained all the information necessary to uniquely identify, track, and ship samples collected in the field (Figure 3-31). The analytical methods, time and date of collection, samplers' name, survey unit, corehole number, core segment ID, and unique sample number for each sample were specified on the Field Sample Data sheet. The data sheet identified whether the sample was selected for SWMU, full suite radiological, and/or regulatory confirmation sampling. Survey Units 4, 6, 7, 12, 16, 17 and 18 Field Sample Data sheets are presented in Appendix E.

The NFS Sampling Supervisor maintained a narrative log documenting compliance with the NFS field sample collection procedures as well as the site conditions. No additional information relevant to sample identification, labeling, or data evaluation, other than that which was already documented on the Field Sample Data sheet, was logged by the Sampling Supervisor.

MACTEC

MACTEC Development Corp.
751 Horizon Ct. Suite 104
Grand Junction, CO 81506
Phone 970.243.2861
Fax 970.256.7356

FIELD SAMPLE DATA SHEET

Survey Unit ID#: 11	**Date Collected** (mm/dd/yy): 07/12/07 **Time Collected** (24 hour): 425
Core ID #: 0274	**Core Segment ID #:** B

Site: NFS North Site
1205 Banner Hill Road
Erwin, TN 37650

Client:	Nuclear Fuel Services
Project Name:	Subsurface Characterization and FSS
Project Mgr:	Jeffrey Lively
Project No:	9120071235

SWMU Sample: ☐	Full-Suite Radiological: ☐	
Regulatory Confirmation Sample: ☐	Gamma Only: ☐	Full-Suite: ☐

Unique Sample ID Number																					
Core #	Segment #	Sample #	NUMBER of CONTAINERS	Sample Preparation (Dry & Grind)	Gamma Spectroscopy (NFS)	Gamma Spectroscopy (Paragon)	Alpha Spectroscopy (Paragon): Am, Pu, U, Th	Tc-99 by Liquid Scint (Paragon)	Pu-241 by Liquid Scint (Paragon)	Gamma Spectroscopy (ORISE)	Alpha Spectroscopy (ORISE): Am, Pu, U, Th	Tc-99 by Liquid Scint (ORISE)	Pu-241 by Liquid Scint (ORISE)	PCBs, Aroclor 1254 (Paragon)	SW 846, 6010C (Paragon):Arsenic, Beryllium	SW 846, 8270C (Paragon): Semi-Volatile Organics	SW 846, 8260B (Paragon): VOCs by Terra Core	SW 846, 7196A (Paragon): Hexavalent Chromium	SW 846, 7471A (Paragon): Mercury		Sample Preservation (Check if YES)
0274	BX	XA	1	✓	✓																

Field Sampler: Art Samiljan [signature] (Print and Sign) **Date:** 07/12/07

NFS File Classification: DCM-23-05-02

Figure 3-31 Example Field Sample Data Sheet

3.5.3 Sample Custody

Sample custody was deemed an important aspect of this field sampling program since regulatory decisions would rely on the integrity of the analytical results generated. Sample custody was maintained in the field, in the shipping and receiving processes, and in the laboratories where samples were processed and analyzed. Sample custody for samples collected during the field sampling event was maintained by personnel collecting the samples. Each sampler was responsible for documenting the generation of each sample collected (Figure 3-31). Immediately after isolating the sample, the sample container was affixed with a tamper evident custody seal to provide evidence of sample integrity. Samples were maintained within the sight of the sampling team personnel until they were "checked in" to the field sample office (the MACTEC executive suite). Samples were thereafter secured in locked storage cabinets (and refrigerators, as applicable) awaiting shipment.

3.6 SAMPLE SHIPMENT

Due to the analytical requirements of the sampling program, samples were required to be sent to several different laboratories for processing and analyses (Figure 3-32). Samples requiring non-radiological analyses were shipped directly to Paragon Analytics (Paragon), now part of the ALS Laboratory Group in Fort Collins, Colorado for analysis. Samples slated for radiological analyses (with the exception of samples to be analyzed for Tc-99) were first shipped to Teledyne Brown Engineering's laboratory (Teledyne) in Knoxville, TN, where they were dried, ground to a homogenous matrix, and then split, as required, for subsequent analyses by other laboratories.

A split of each sample was shipped from Teledyne to Nuclear Fuel Services' laboratory in Erwin, TN. There, gamma spectroscopic analysis [NFS refers to this analysis as non-destructive analysis (NDA)], was performed on each sample providing analytical results for the three principal gamma emitting nuclides among the isotopes of concern.

Samples that were slated to be analyzed for each of the isotopes of concern ("full-suite" analysis) required alpha spectroscopy and liquid scintillation techniques in addition to gamma spectroscopy. For such samples (10% of the total number of soil samples), Teledyne prepared an additional spilt and provided this sample to Paragon for analysis. Tc-99 samples, which required no sample preparation, from soil core segments slated for full-suite analysis were shipped directly to Paragon for analysis.

Samples that were selected by the NRC for assay as part of their confirmatory survey process were identified and uniquely marked in the field. Samples slated for confirmatory analysis (with the exception of samples to be analyzed for Tc-99) were first shipped to Teledyne in Knoxville, TN, where they were dried, ground to a homogenous matrix. Teledyne prepared an additional split that was shipped to the NRC selected independent laboratory ORISE for subsequent analyses. Tc-99 samples selected for confirmatory analysis, which required no sample preparation, were shipped directly to ORISE for analysis.

3.6.1 Sample Shipment

Prior to sample shipment off site, all samples from Survey Units 4, 6, 7, 12, 16, 17, and 18 were classified as exempt from Department of Transportation hazardous material regulations. Samples not requiring preservation by temperature control were packaged into lined and padded cardboard boxes for shipment. Samples requiring preservation by temperature control were packaged into lined coolers and packed with ice for shipment. Amec Foster Wheeler generated COC records along with NFS generated transmittal letters were placed inside each sample shipping container (box or cooler). Custody seals were then placed on the boxes and coolers prior to shipment to the laboratory. Custody seals were used to indicate that the sample shipping containers were not opened during shipping, thus providing additional assurance that samples had not been compromised during shipment.

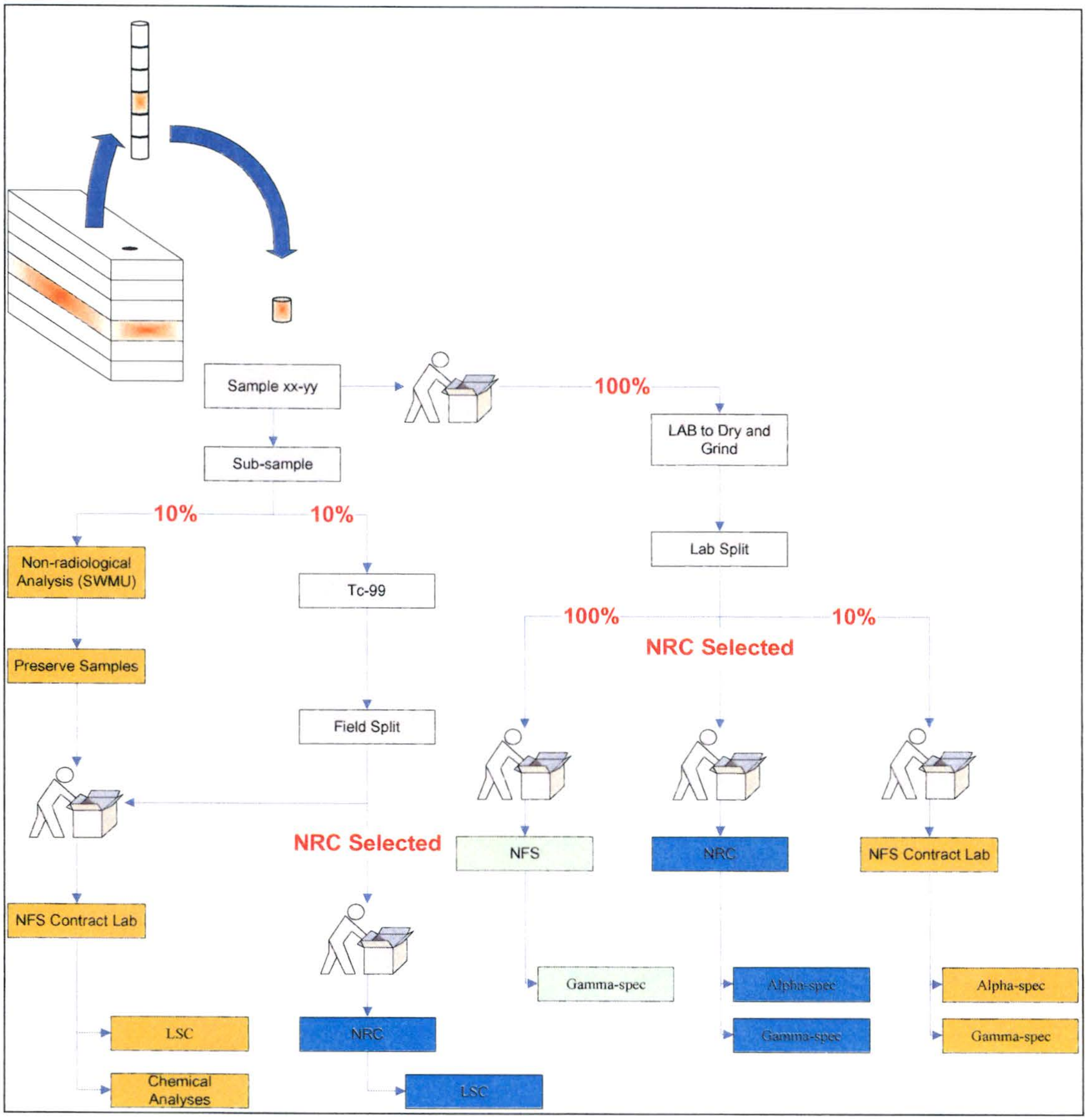

Figure 3-32 NFS Sample Flow Diagram

COC records were generated in the field using the Field Sample Tracking Program database prior to shipment and accompanied samples during shipment, sample preparation (if necessary), and during laboratory analysis (see Appendix C for COC example). The COC record documents:

- the requested analysis and applicable test method;
- the dates and times of sample collection;

- the names of the sampler;
- the date and time that the samples were delivered for shipping; and
- the names of those receiving the samples at the laboratory.

3.6.2 Laboratory Sample Homogenization

Subcontracted off-site laboratory Teledyne was responsible for sample preparation. Incoming shipments from NFS containing radiological samples were received, catalogued, and verified against the Amec Foster Wheeler generated COC (hard copy and electronic copy). Sample preparation consisted of first drying the appropriate aliquot of sample in an oven for several hours until the sample was completely dry. After allowing the sample to cool, the sample was placed in a clean labeled can containing steel balls. The can was placed onto a mill (Figure 3-33) and milled for at least an hour to grind and homogenize the sample. Following homogenization, the sample was sieved to remove remaining rocks and debris (greater than 0.25") and the sample was then split into separate sample containers for shipment to NFS, Paragon, and/or ORISE, as appropriate.

Figure 3-33 Example of Teledyne Jar Mill Machine with Sample Containers

4.0 SAMPLING RESULTS

The results of samples collected from Survey Units 4, 6, 7, 12, 16, 17, and 18 during the implementation of the Subsurface Soil Characterization and FSS project are presented in this section. A discussion of the demonstration of compliance with the applicable residual radioactivity DCGLs for Survey Units 4, 6, 7, 12, 16, 17, and 18 are presented in Section 5.0. Quality control data is presented separately in Section 6.0 of this report.

The subsurface soil sampling plans for Survey Units 4, 6, 7, 12, 16, 17, and 18 were designed to determine whether the residual radioactivity present in subsurface soils is present in concentrations below the permissible concentration corresponding to the approved array of subsurface soil DCGLs. The design of the sampling plans includes elements that enabled the statistical comparison of the sampling data collected from Survey Units 4, 6, 7, 12, 16, 17, and 18 with that previously collected in the RBA. The WRS test (sometimes referred to as the Mann-Whitney test) was used to determine whether there is a statistically significant difference between the mean residual radioactivity in subsurface soils from Survey Units 4, 6, 7, 12, 16, 17, 18 and the RBA.

4.1 REFERENCE BACKGROUND AREA

Because many of the radionuclides of concern at the North site are naturally present in background concentrations in soils, NFS elected to characterize their concentrations in an area unimpacted by radiological operations from the site (designated as the [RBA]). NFS selected a reference area which has similar physical, chemical, and geological characteristics as the North site and would, therefore, have representative background conditions. The methods and results from the reference area sampling project are presented in NFS' *Final Report for North site Reference Area and Final Status Survey of Survey Unit RBG-1* (NFS 2003).

The Subsurface Soil Characterization and FSS Project uses the analytical results from sampling of the soils in the RBA in assessing compliance with the subsurface soil DCGLs. The RBA data is also used to infer concentrations of naturally occurring radioactivity that might be present in non-impacted fill materials that might be imported to the site and in bedrock materials that underlie the impacted soil column in a survey unit. NFS measured the concentrations of the various isotopes of uranium and thorium in the RBA. Concentrations of the transuranic radionuclides and fission products among the contaminants of concern in the North site soils were conservatively assumed to be zero in the RBA. Data collected from the RBA will be used in the assessment of residual radioactivity in each of the survey units designated for the North site.

The RBA is approximately 2,045 m^2 (45 m x 45 m). Four hundred and three samples were collected from 85 coreholes in the RBA. The number of samples collected from each depth interval in the RBA is specified in Table 4-1. A single sample in the 12- to 16-foot interval and several samples in the 16- to 20-foot interval were not collected due to auger refusal in the corehole. See Appendix F for complete RBA analytical results.

Table 4-1 Number of RBA Samples Collected from Each Interval

Depth Interval	Approximate Depth (Feet)	Approximate Depth (Meters)	Number of Sample Locations
RA1	1.0 – 4.0	0.3 – 1.2	85
RA2	4.0 – 8.0	1.2 – 2.4	85
RA3	8.0 – 12.0	2.4 – 3.7	85
RA4	12.0 – 16.0	3.7 – 4.9	84
RA5	16.0 – 20.0	4.9 – 6.1	64

4.1.1 Subsurface Soil Sample Results, Reference Background Area

Soil samples from 1-meter vertical depth intervals were collected for the subsurface soil survey in Survey Units 4, 6, 7, 12, 16, 17, and 18 to a depth of 10 meters (or to the top of bedrock). Core samples in the RBA were collected from depths to 6.1 meters. Because the vertical segmentation of cores in the RBA was measured in feet, the RBA depth intervals do not precisely correspond to the survey unit depth intervals. This is not a significant issue since there was very little vertical variability in the concentrations of isotopes measured in the RBA. Still, care was exercised to select the appropriate reference area depth interval data subset to background correct survey unit data.

RBA data was catalogued and partitioned such that it fit to a matrix that corresponds with the designed depth intervals for each survey unit and which assigned the most appropriate and relevant background dataset to each vertical increment in the compliance model (Table 4-2). The matrix was constructed by selecting samples from the RBA interval that most closely coincides with the survey unit's depth(s) measuring from ground surface. When the survey unit's depth interval from the ground surface fell within two different depth intervals from the RBA, the RBA depth interval that falls most within the survey unit's depth interval was used for the data evaluation and interpretation. If a single RBA depth interval "best fit" more than one vertical increment for the survey unit, it was assigned to both of those increments. For example, concentration data from RBA depth interval RA3 (Table 4-1) was assigned to the Reference Area matrix for survey unit depth intervals 3 and 4 (Table 4-2). Also, concentration data from RBA depth interval RA5 (Table 4-1) was assigned to the Reference Area matrix for survey unit depth intervals 6 through 10 (Table 4-2). The reference area matrix was used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

Table 4-2 RBA Mean Concentrations Assignment Matrix

RBA Depth	Matrix Name	Depth Interval	Am-241	Pu-238	Pu-239/240	Pu-241	Pu-242	Tc-99	Th-230	Th-232	U-233/234	U-235	U-238
RA1	RA1	1	0.00	0.00	0.00	0.00	0.00	1.72	1.62	1.72	0.15	1.52	0.55
RA2	RA2	2	0.00	0.00	0.00	0.00	0.00	1.70	1.68	1.60	0.15	1.51	0.56
RA3	RA3	3	0.00	0.00	0.00	0.00	0.00	1.64	1.76	1.53	0.15	1.43	0.58
RA3	RA4	4	0.00	0.00	0.00	0.00	0.00	1.64	1.76	1.53	0.15	1.43	0.58
RA4	RA5	5	0.00	0.00	0.00	0.00	0.00	1.39	1.66	1.30	0.13	1.15	0.54
RA5	RA6	6	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA7	7	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA8	8	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA9	9	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA10	10	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA11	11	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA12	12	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA13	13	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA14	14	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56
RA5	RA15	15	0.00	0.00	0.00	0.00	0.00	1.33	1.76	1.24	0.14	1.13	0.56

4.2 CONFIGURING DATA FOR USE IN SSDCGL CALCULATORS

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Information in this section contains proprietary trade secret information which has been redacted in this version.

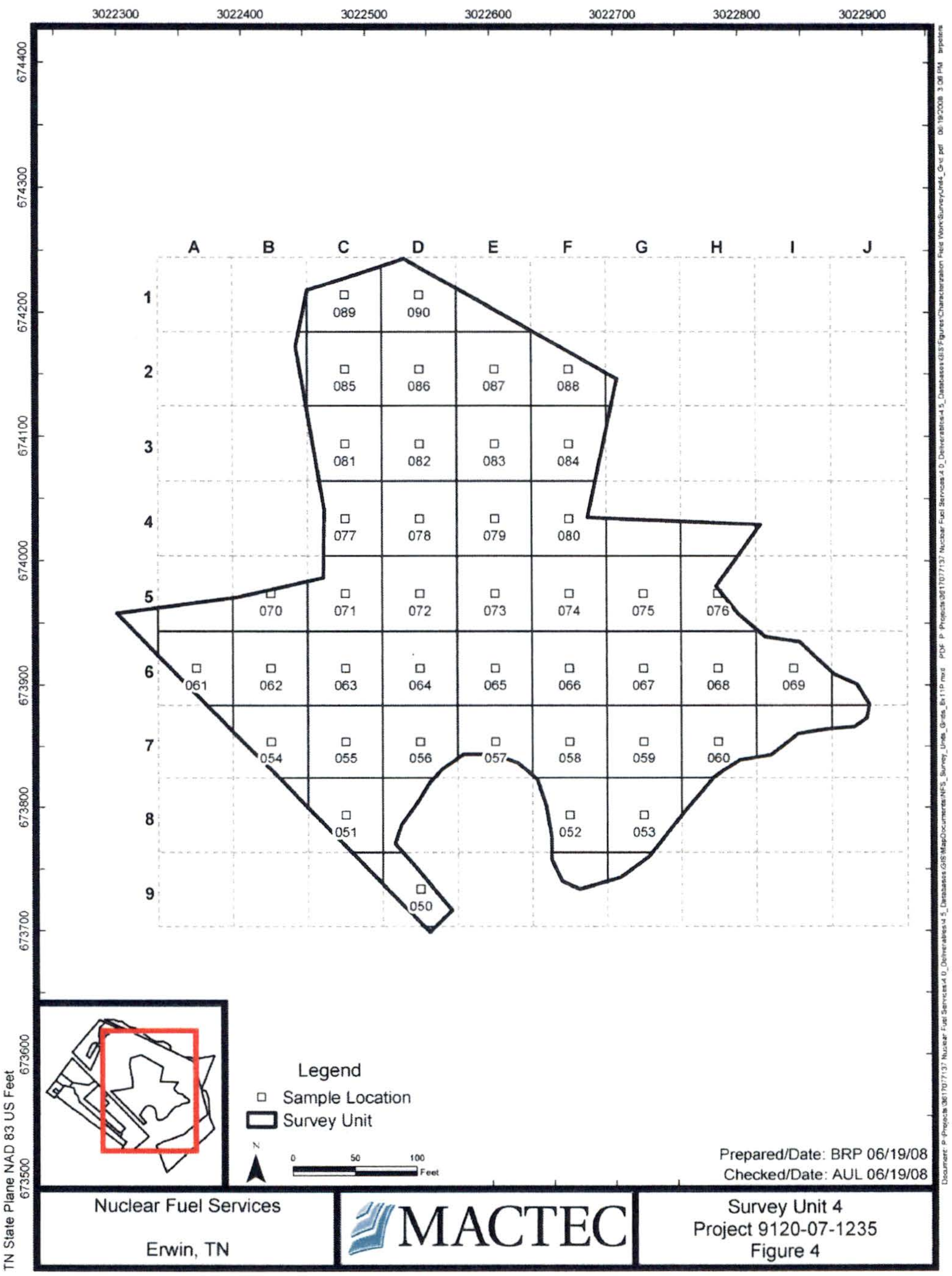

Figure 4-1 Lateral Alignment Matrix, Survey Unit 4

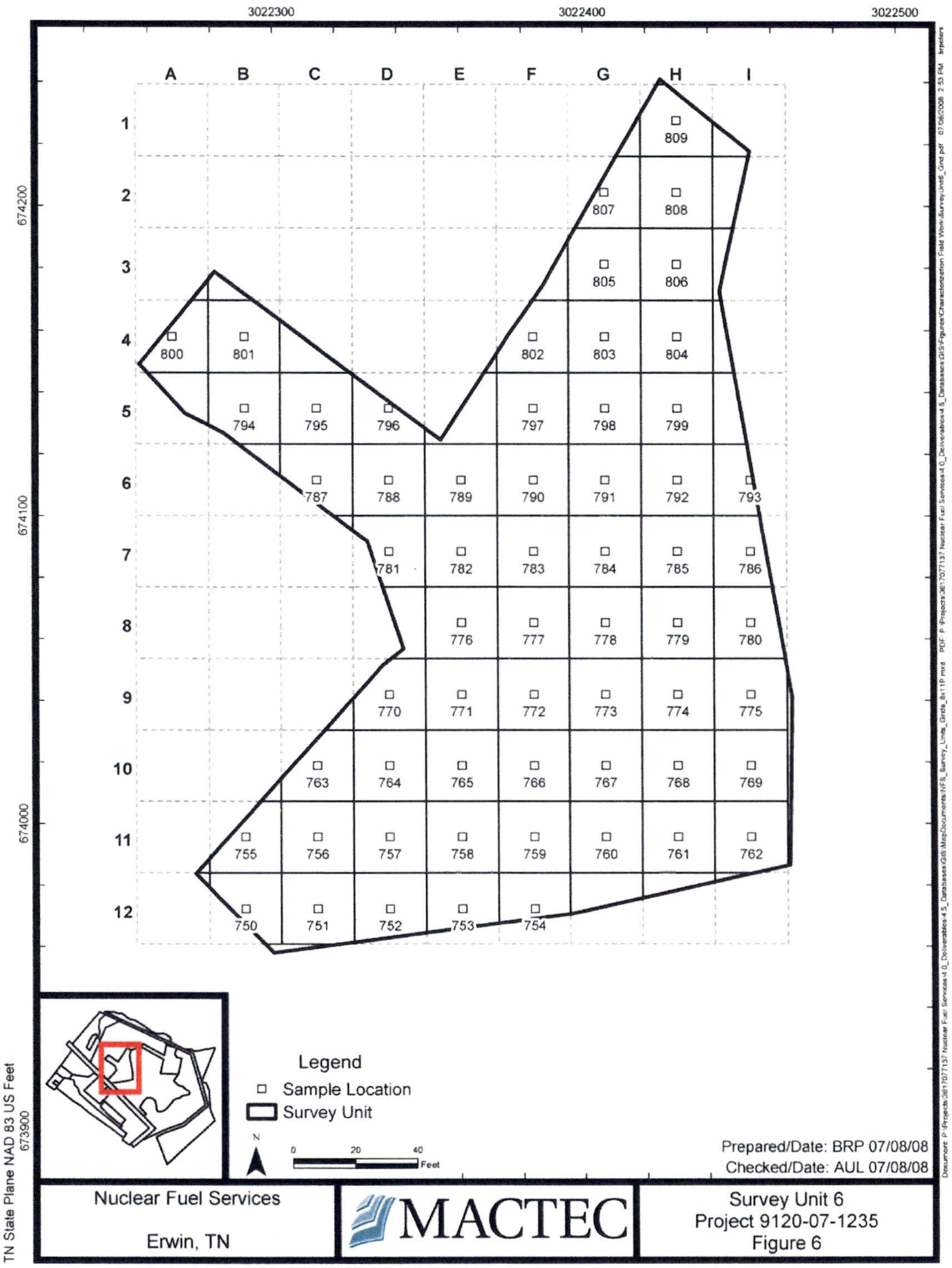

Figure 4-2 Lateral Alignment Matrix, Survey Unit 6

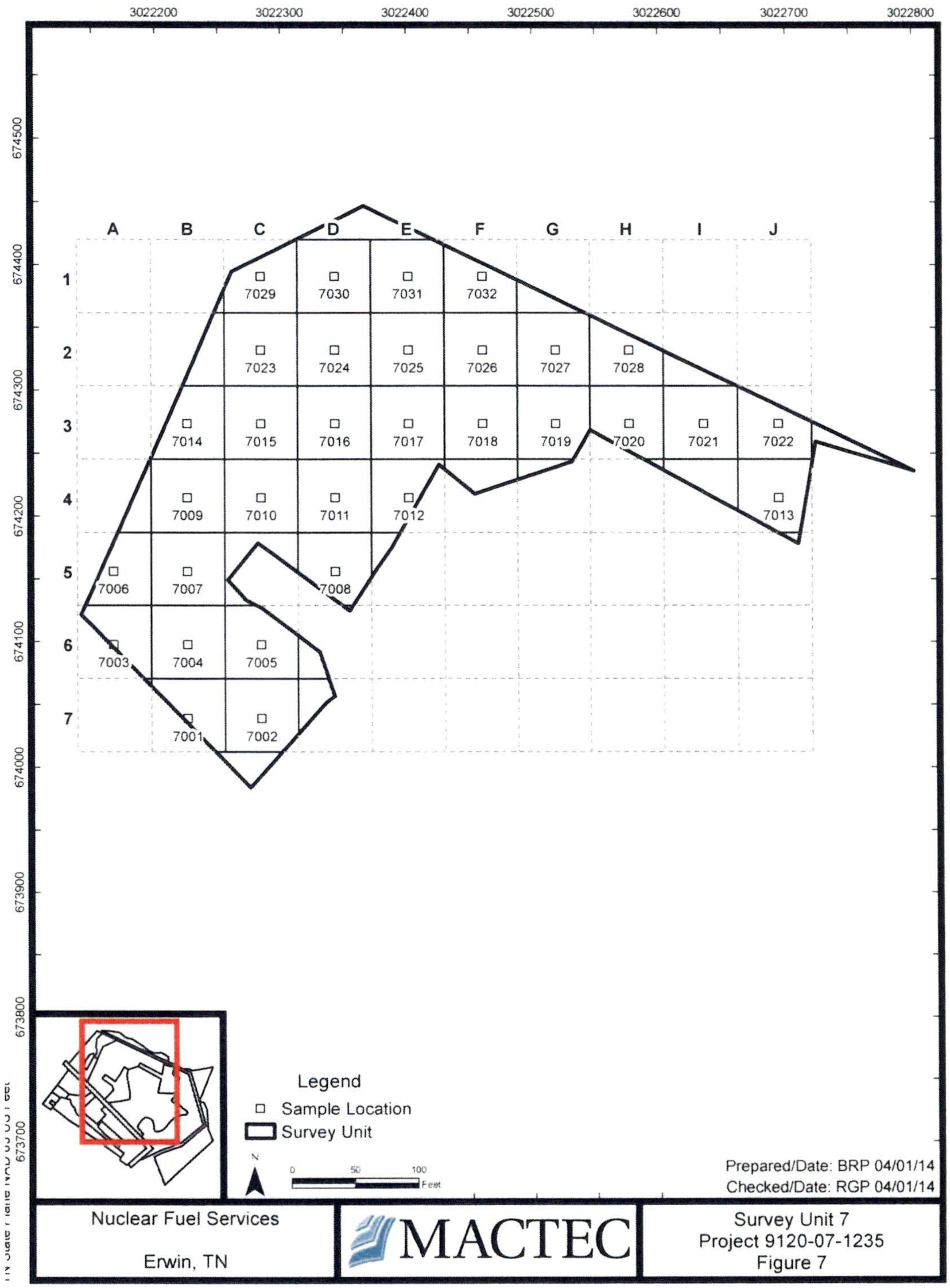

Figure 4-3 Lateral Alignment Matrix, Survey Unit 7

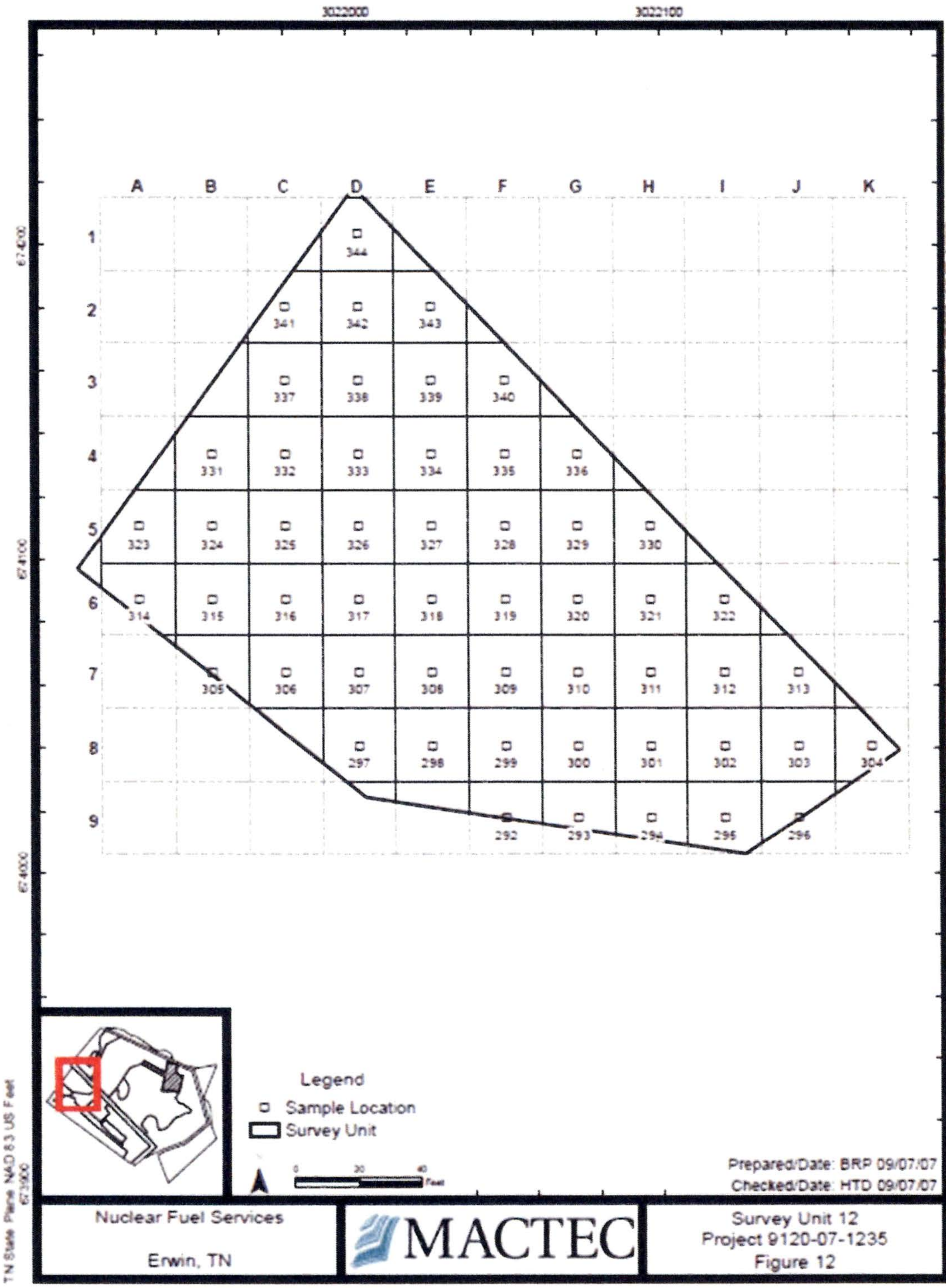

Figure 4-4 Lateral Alignment Matrix, Survey Unit 12

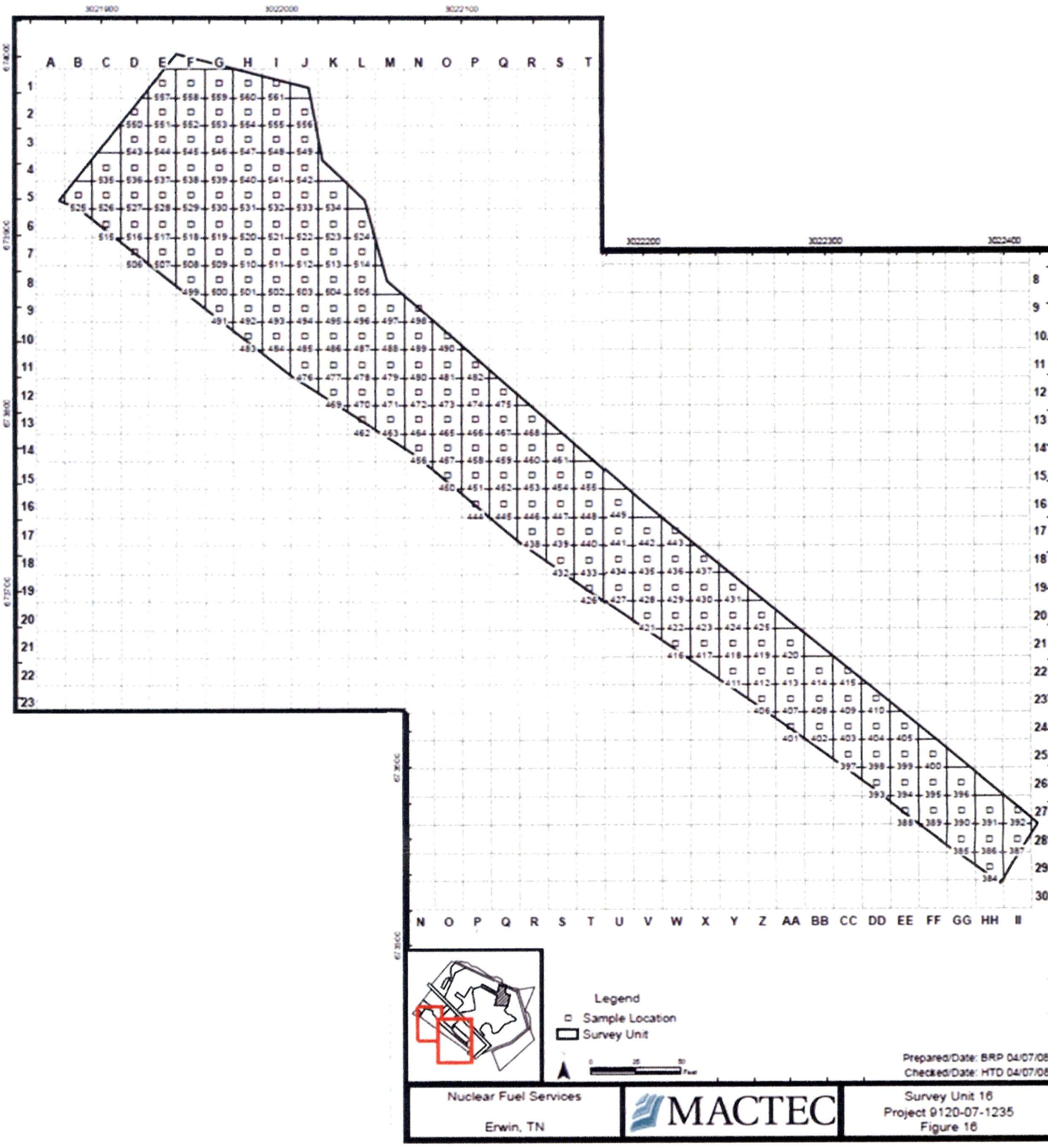

Figure 4-5 Lateral Alignment Matrix, Survey Unit 16

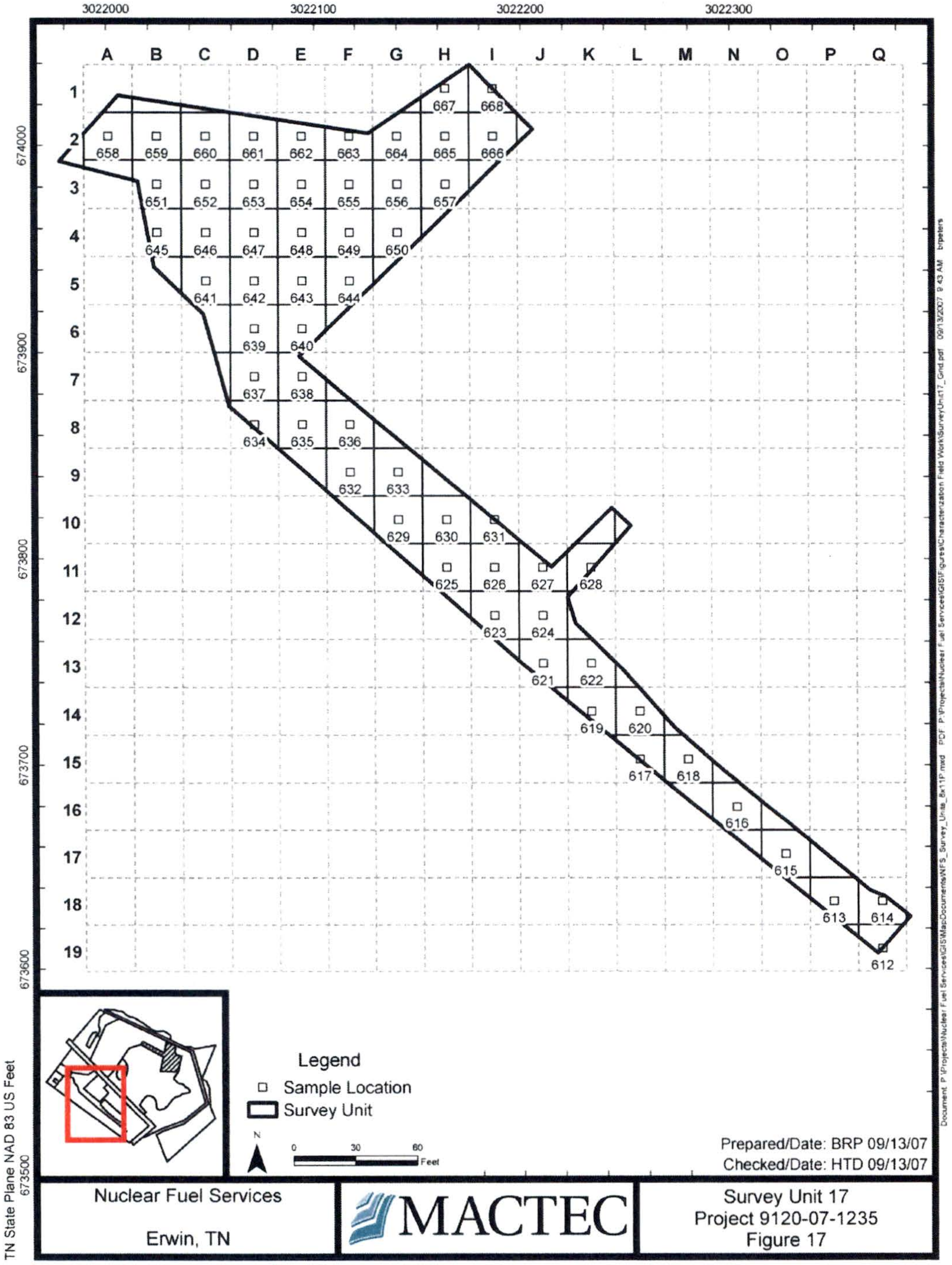

Figure 4-6 Lateral Alignment Matrix, Survey Unit 17

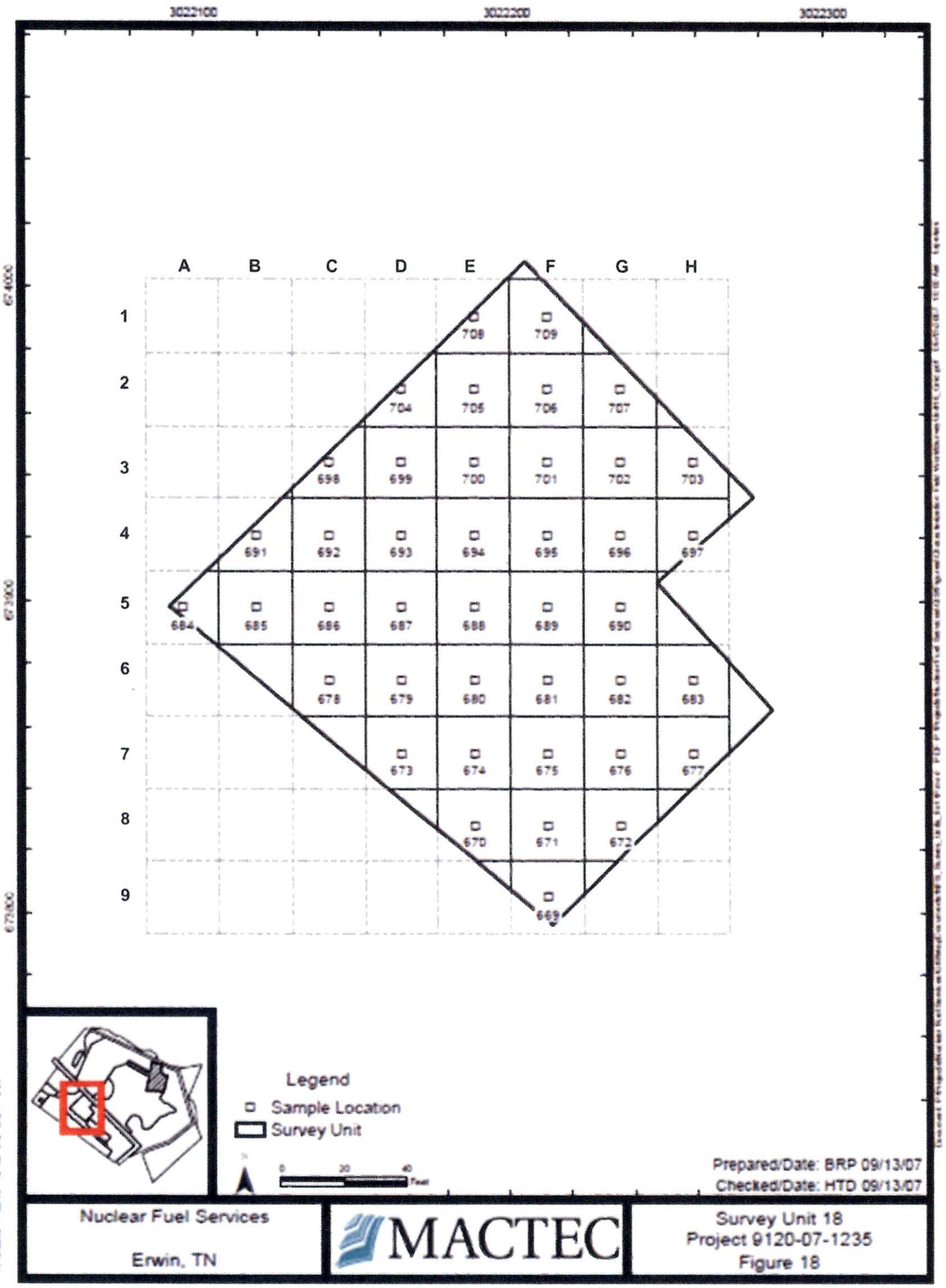

Figure 4-7 Lateral Alignment Matrix, Survey Unit 18

4.2.1 Dividing Survey Unit 16 for SSDCGL Calculators

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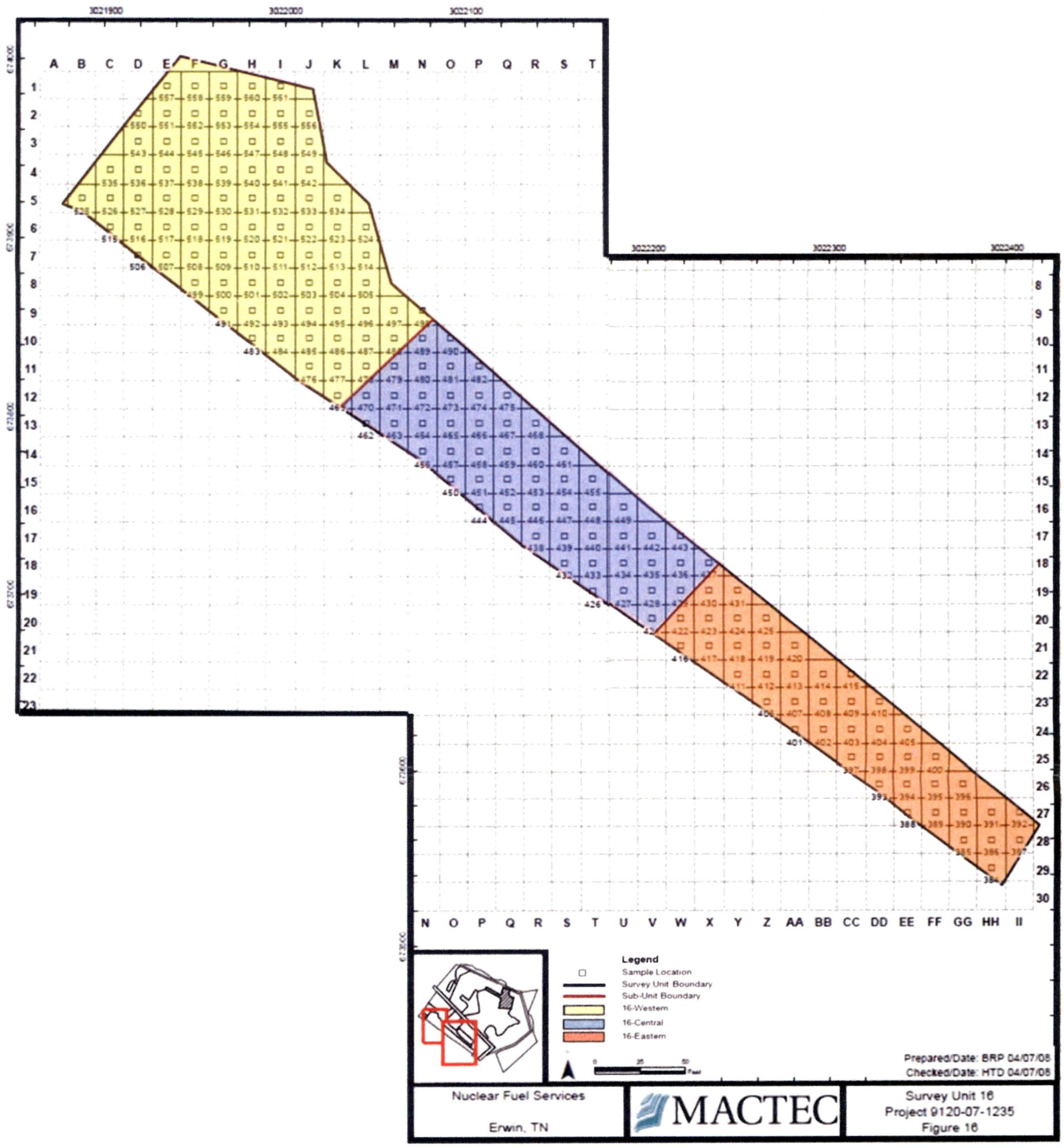

Figure 4-8 Survey Unit 16 Subdivided into Eastern, Central, and Western Sections

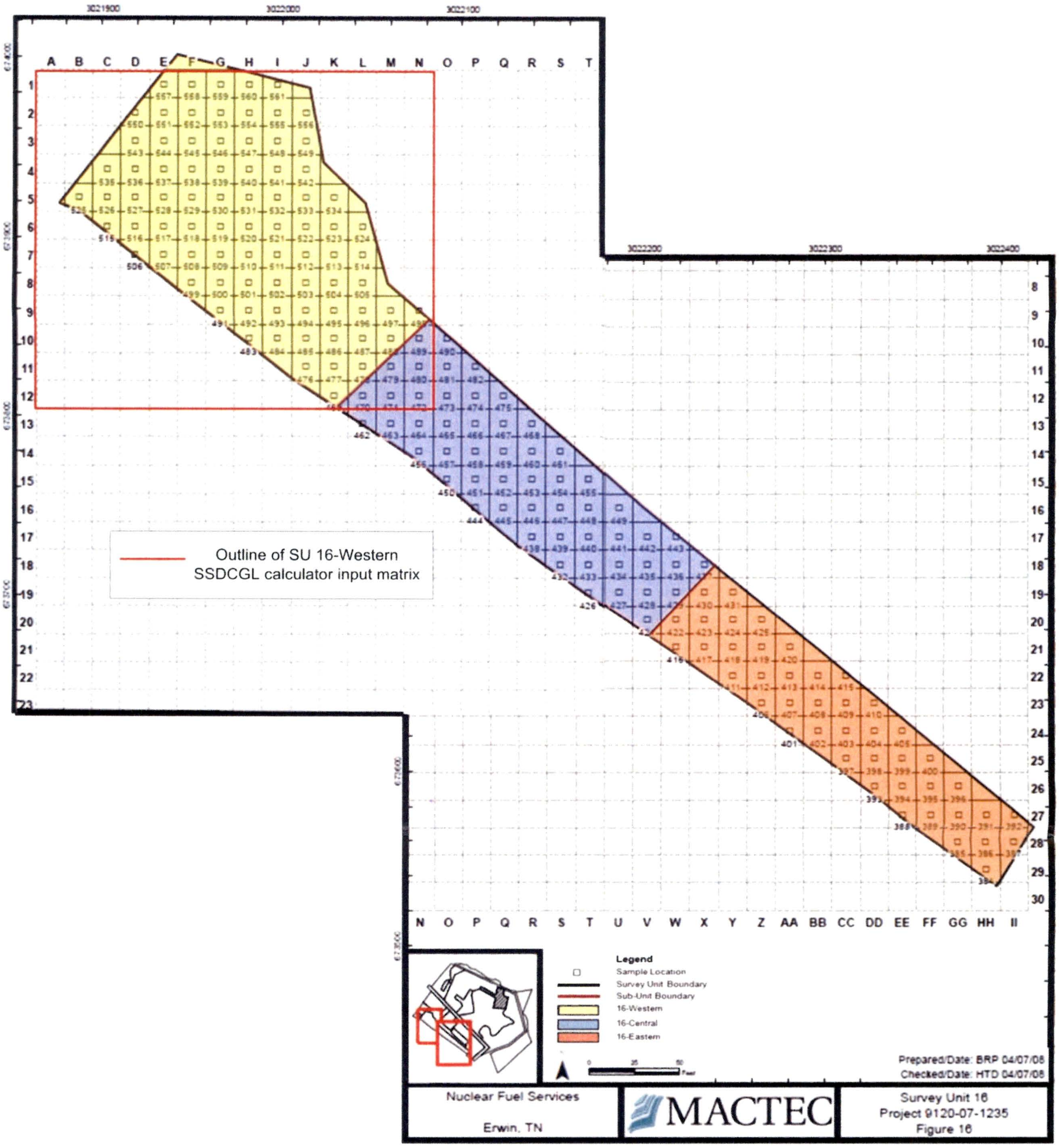

Figure 4-9 Lateral Alignment Matrix, Survey Unit 16-Western

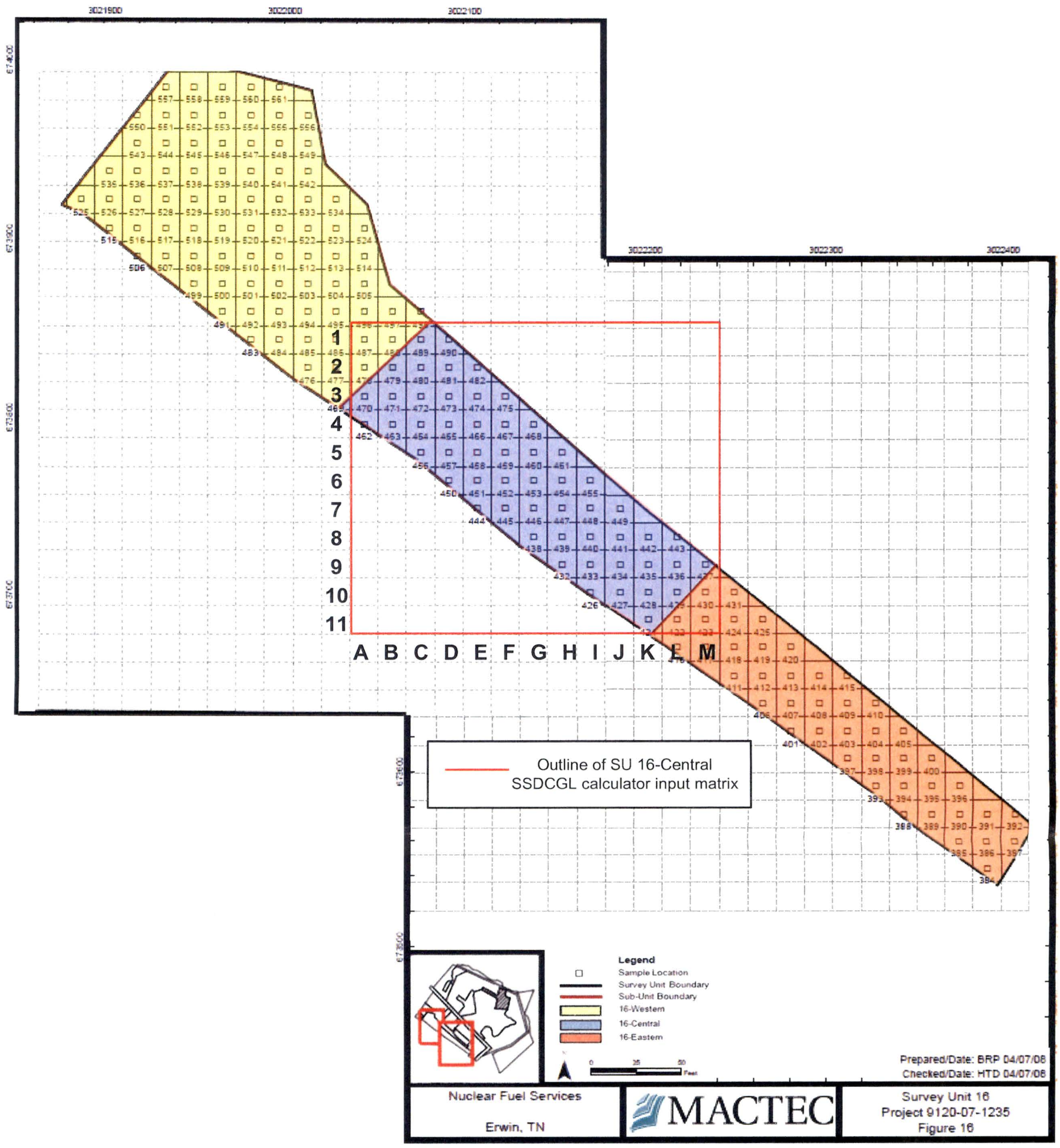

Figure 4-10 Lateral Alignment Matrix, Survey Unit 16-Central

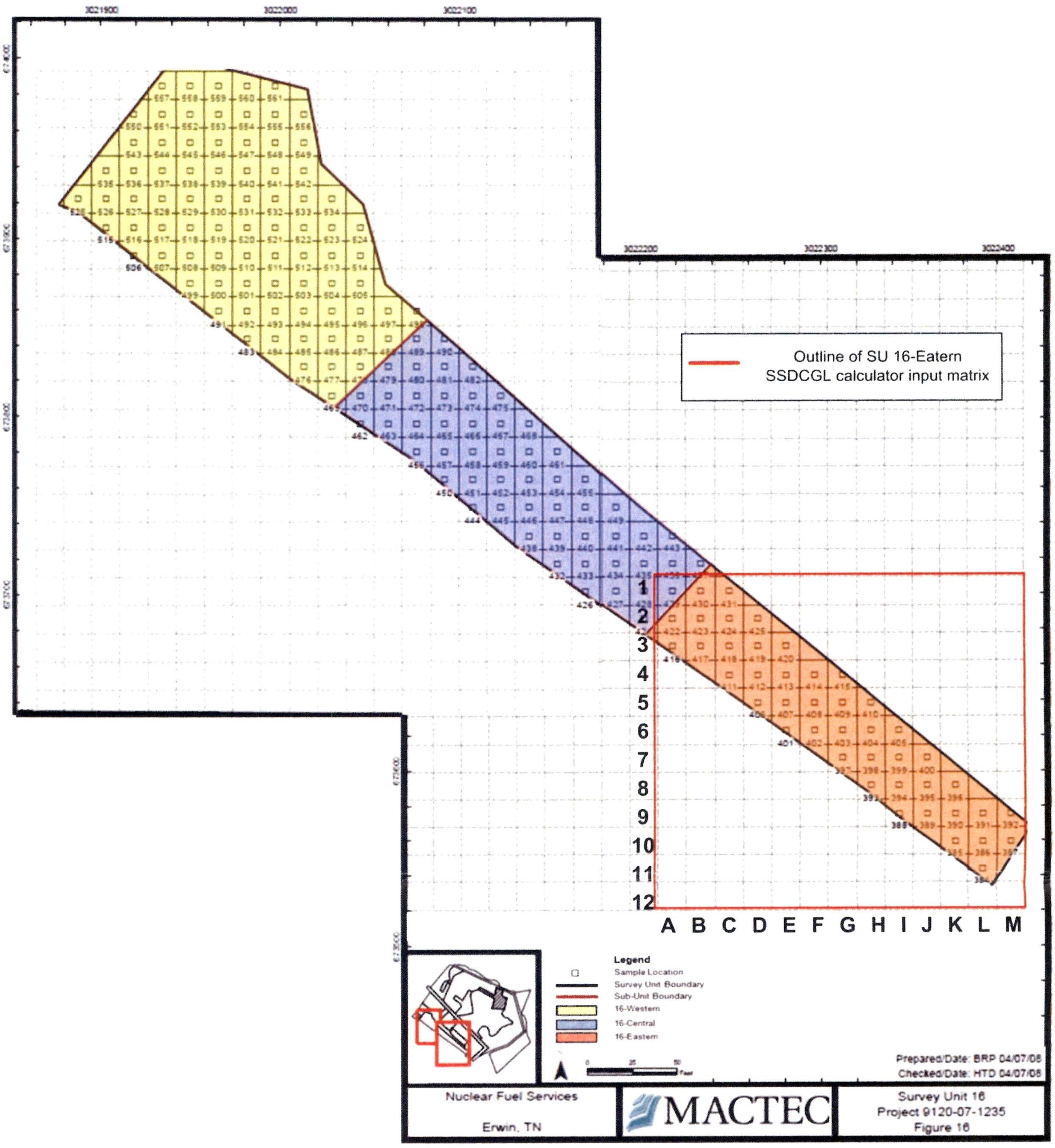

Figure 4-11 Lateral Alignment Matrix, Survey Unit 16-Eastern

4.2.2 Cross-Linking Field Sample IDs with the SSDCGL Calculator Sample Cell Matrix

Information in this section contains proprietary trade secret information which has been redacted in this version.

4.2.3 Vertical Adjustment of Corehole Position within the SSDCGL Calculator Sample Cell Matrix

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 4-3 Position of Coreholes as Determined by Professional Land Survey, SU 4

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting	Northing	At Top of Core	At Top of Bedrock [1]
50	3022543.70	673731.01	1640.6	1617.6
51	3022492.66	673777.38	1641.5	1614.5
52	3022663.70	373792.08	1641.1	1613.6
53	3022727.63	673780.07	1637.6	1609.6
54	3022442.03	673843.00	1631.2	1598.2
55	3022490.02	673853.52	1632.9	1612.4
56	3022543.95	673852.68	1635.1	1618.1
57	3022605.70	673851.63	1640.7	1611.7
58	3022665.66	673845.59	1638.3	1617.8
59	3022725.09	673852.03	1636.2	1615.2
60	3022787.90	673842.70	1638.7	1606.2
61	3022362.01	673908.00	1642.7	1613.7
62	3022423.93	673911.61	1631.2	1620.2
63	3022487.06	673910.09	1631.0	1616.0
64	3022552.12	673917.33	1642.0	1619.5
65	3022592.82	673892.00	1641.6	1609.1
66	3022667.13	673911.79	1635.0	1616.0
67	3022727.53	673915.64	1636.7	1618.2
68	3022785.71	673911.60	1638.5	1605.5
69	3022845.33	673910.72	1639.5	1615.5
70	3022417.55	673968.53	1632.4	1624.9
71	3022484.64	673971.68	1642.1	1619.6
72	3022538.65	673958.86	1637.2	1612.7
73	3022609.17	673970.59	1634.6	1621.1
74	3022664.45	673972.35	1635.4	1613.4
75	3022724.98	673968.54	1636.7	1615.7
76	3022756.98	673968.25	1638.7	1614.7
77	3022483.86	674029.89	1635.3	1622.8
78	3022544.37	674032.33	1634.3	1625.4
79	3022603.22	674031.33	1633.8	1616.3
80	3022665.85	674030.20	1637.2	1615.2
81	3022485.36	674090.93	1634.7	1624.2
82	3022544.20	674090.56	1635.2	1622.2
83	3022603.70	674088.69	1635.4	1617.9
84	3022666.70	674090.41	1636.9	1621.9
85	3022482.82	674153.30	1634.8	1624.3
86	3022544.89	674150.31	1634.7	1623.2
87	3022603.91	674149.62	1635.0	1622.0
88	3022666.14	674151.80	1636.7	1622.7
89	3022484.41	674211.29	1635.1	1625.6
90	3022543.88	674211.54	1634.7	1623.2

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

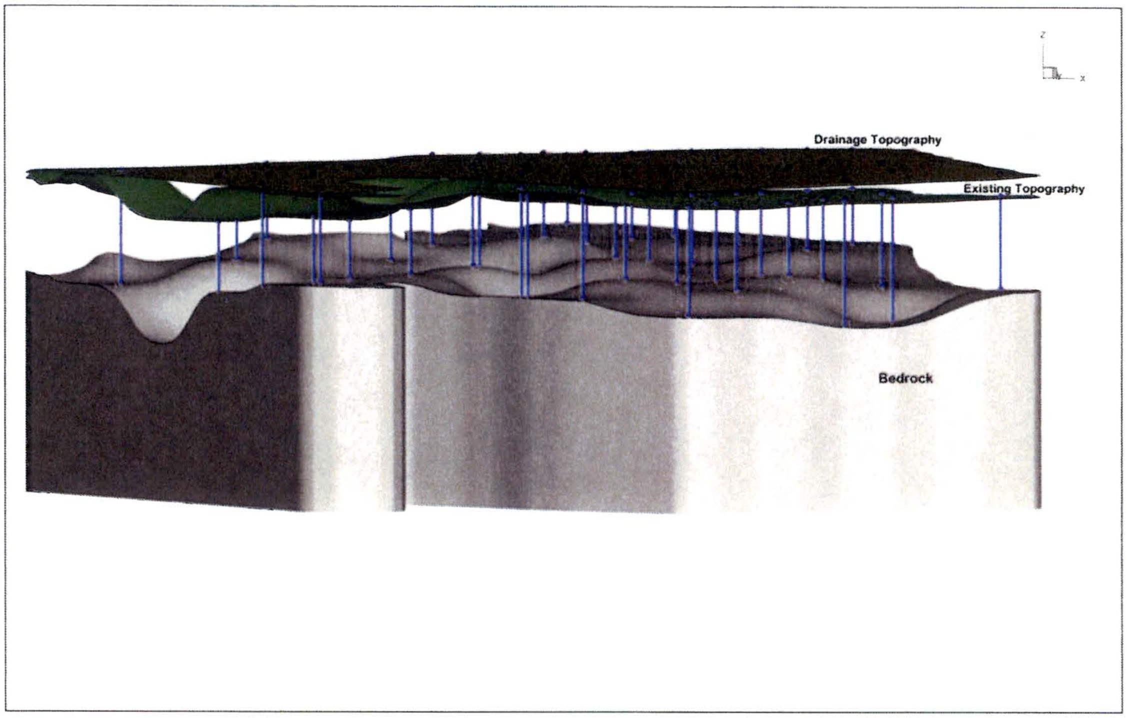

Figure 4-12 Surveyed Corehole Locations and Elevations, Shown with Drainage Plan and Bedrock Surfaces, Survey Unit 4

Table 4-4 Position of Coreholes as Determined by Professional Land Survey, SU 6

	Actual Location [2]		Elevation (ft. above msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
750	3022291.17	673970.74	1641.8	1620.8
751	3022307.19	673966.67	1642.1	1611.1
752	3022337.78	673968.76	1635.8	1622.3
753	3022361.79	673968.74	1632.1	1618.1
754	3022385.83	673966.44	1632.5	1620.0
755	3022287.57	673986.04	1641.8	1619.8
756	3022315.93	673991.48	1635.9	1616.4
757	3022338.94	673992.68	1633.5	1618.5
758	3022362.74	673991.68	1632.3	1612.8
759	3022386.78	673994.98	1633.2	1625.7
760	3022405.81	673995.70	1633.0	1626.5
761	3022436.06	673999.07	1639.8	1625.8
762	3022456.44	673993.11	1641.9	1626.4
763	3022313.51	674015.34	1635.4	1635.4
764	3022341.47	674015.21	1634.0	1607.0
765	3022359.47	674015.76	1633.9	1624.4
766	3022386.69	674014.33	1633.3	1622.3
767	3022414.01	674021.33	1639.7	1627.7
768	3022431.93	674016.58	1641.6	1625.6
769	3022450.97	674011.68	1642.2	1627.2
770	3022344.67	674041.62	1634.7	1619.7
771	3022360.48	674036.52	1634.5	1625.0
772	3022384.68	674039.86	1638.7	1622.2
773	3022409.23	674038.34	1640.9	1624.9
774	3022427.12	674033.54	1641.6	1625.6
775	3022454.20	674038.66	1635.7	1626.2
776	3022362.44	674063.33	1637.6	1623.6
777	3022384.74	674063.48	1640.2	1625.2
778	3022404.69	674061.29	1640.1	1625.1
779	3022429.42	674063.55	1637.2	1623.2
780	3022455.70	674064.73	1636.7	1625.7
781	3022338.19	674086.34	1642.8	1627.3
782	3022362.66	674086.05	1637.8	1625.8
783	3022389.23	674086.63	1638.2	1626.7
784	3022408.00	674087.12	1637.4	1619.4
785	3022433.85	674088.46	1636.4	1621.9
786	3022453.09	674085.82	1635.5	1624.5
787	3022316.84	674109.84	1640.5	1625.0
788	3022340.26	674111.84	1640.2	1630.0
789	3022363.43	674110.10	1638.8	1629.8
790	3022385.12	674109.21	1637.2	1629.2
791	3022407.90	674110.37	1636.9	1621.4
792	3022433.32	674109.51	1636.8	1625.8

Table 4-4 Position of Coreholes as Determined by Professional Land Survey, SU 6 (Continued)

	Actual Location [2]		Elevation (ft. above msl)	
Corehole ID#	**Easting (X)**	**Northing (Y)**	**At Top of Core**	**At Top of Bedrock [1]**
793	3022454.64	674109.01	1635.8	1625.3
794	3022292.82	674136.14	1640.5	1625.5
795	3022315.84	674134.73	1640.0	1629.0
796	3022338.06	674132.93	1638.9	1623.4
797	3022385.75	674134.43	1638.7	1623.7
798	3022407.67	674134.28	1637.1	1622.1
799	3022432.21	674132.62	1636.9	1623.4
800	3022268.87	674156.38	1638.0	1622.0
801	3022299.18	674154.66	1640.5	1611.5
802	3022385.68	674154.28	1638.9	1623.4
803	3022409.23	674156.37	1637.5	1627.0
804	3022432.81	674156.54	1638.1	1628.6
805	3022409.16	674177.51	1639.0	1623.0
806	3022430.46	674177.73	1638.0	1627.5
807	3022409.67	674203.24	1640.1	1616.1
808	3022431.27	674202.93	1637.9	1620.9
809	3022430.29	674227.57	1639.0	1626.5

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

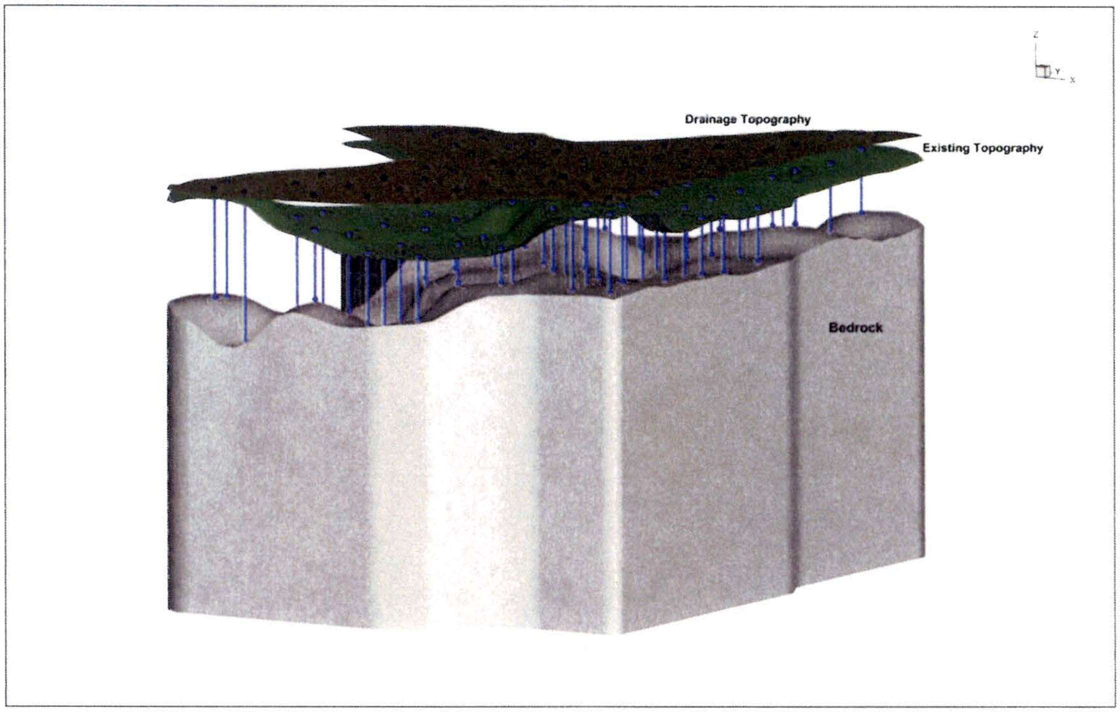

Figure 4-13 Surveyed Corehole Locations and Elevations, Shown with Drainage Plan and Bedrock Surfaces, Survey Unit 6

Table 4-5 Position of Coreholes as Determined by Professional Land Survey, SU 7

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
7001	3022233.02	674042.12	1632.8	1608.8
7002	3022303.80	674052.51	1633.2	1601.2
7003	3022179.02	674103.79	1633.1	1611.1
7004	3022231.66	674090.04	1634.7	1614.7
7005	3022285.72	674093.67	1632.8	1603.8
7006	3022168.36	674152.52	1633.5	1605.0
7007	3022219.59	674147.05	1633.5	1598.5
7008	3022345.10	674153.95	1634.9	1606.9
7009	3022223.52	674215.34	1634.8	1599.8
7010	3022295.91	674202.74	1632.8	1616.3
7011	3022344.82	674213.89	1633.6	1613.1
7012	3022404.95	674211.48	1634.4	1606.4
7013	3022701.93	674217.56	1634.7	1610.2
7014	3022226.36	674270.55	1635.4	1616.9
7015	3022281.85	674272.50	1635.1	1617.6
7016	3022352.52	674259.54	1630.7	1607.7
7017	3022404.06	674271.45	1630.5	1612.0
7018	3022461.67	674263.96	1632.9	1612.9
7019	3022517.99	674274.66	1634.1	1601.1
7020	3022579.94	674272.94	1634.2	1611.7
7021	3022638.86	674270.07	1635.0	1613.0
7022	3022696.49	674266.53	1634.9	1612.9
7023	3022286.28	674329.86	1631.4	1611.4
7024	3022349.47	674336.97	1632.1	1613.1
7025	3022404.26	674329.76	1633.7	1614.7
7026	3022463.23	674329.55	1634.5	1619.5
7027	3022521.54	674329.65	1635.1	1617.6
7028	3022580.16	674329.17	1635.3	1611.8
7029	3022283.85	674386.55	1635.7	1616.7
7030	3022343.56	674380.67	1631.8	1611.3
7031	3022387.15	674382.16	1634.4	1616.4
7032	3022460.75	674387.49	1634.6	1616.6

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

Figure 4-14 shows the position and depth of the coreholes in Survey Unit 7 at the time of sampling in reference to the final surface elevation as defined in the Drainage Plan. Figure 4-15 illustrates the interwoven nature of the two surfaces (surface at the time of sampling and final surface elevation).

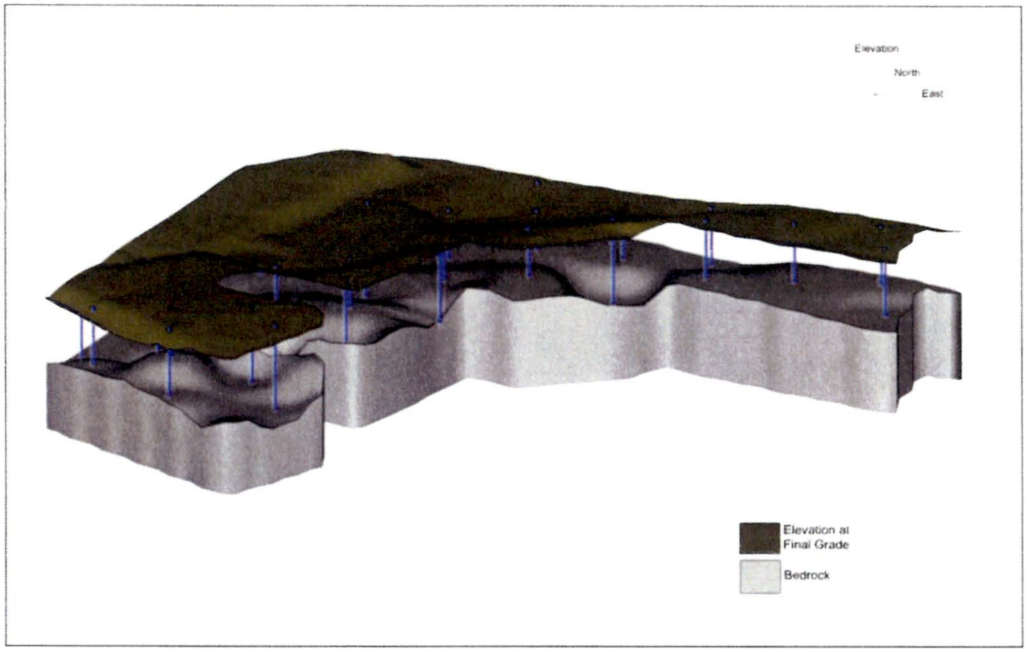

Figure 4-14 Three-Dimensional View, Vertical Alignment Matrix at Final Grade, Survey Unit 7

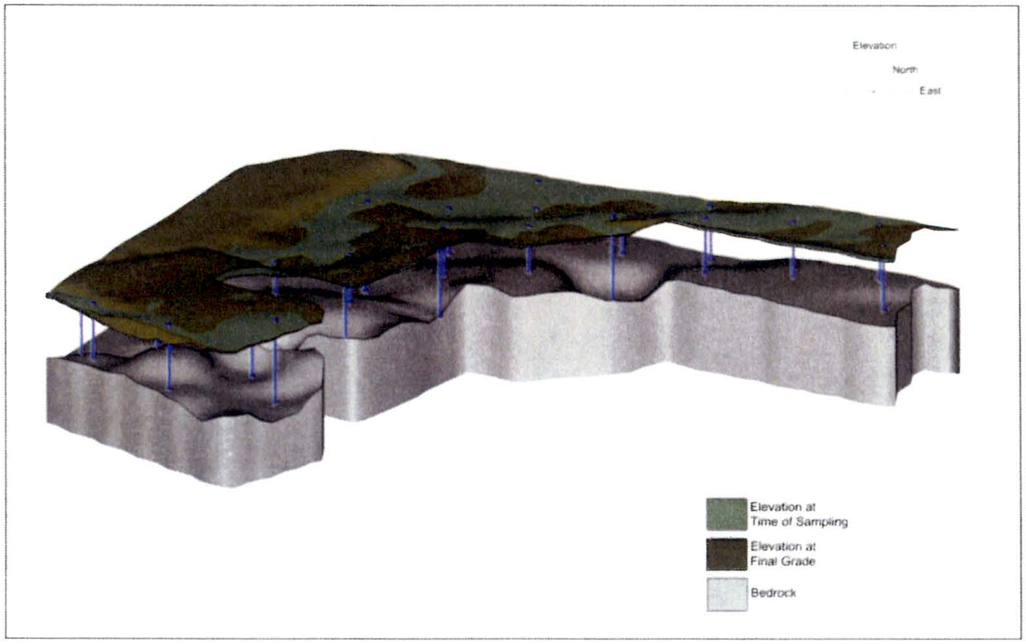

Figure 4-15 Three-Dimensional View, Vertical Alignment Matrix at Time of Sampling and Final Grade, Survey Unit 7

Table 4-6 Position of Coreholes as Determined by Professional Land Survey, SU 12

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
292	3022051.80	674015.75	1631.5	1631.5
293	3022078.01	674018.96	1632.6	1632.6
294	3022096.31	674017.65	1633.7	1633.7
295	3022119.61	674018.14	1637.3	1637.3
296	3022146.00	674015.46	1634.3	1634.3
297	3022007.24	674044.16	1628.3	1628.3
298	3022028.91	674037.57	1630.1	1630.1
299	3022052.66	674041.84	1631.1	1631.1
300	3022073.27	674040.95	1631.1	1631.1
301	3022095.71	674041.98	1631.6	1631.6
302	3022119.41	674036.64	1633.6	1633.6
303	3022145.46	674035.66	1634.7	1634.7
304	3022166.92	674036.19	1635.7	1635.7
305	3021960.16	674061.85	1627.7	1627.7
306	3021981.90	674062.04	1628.1	1628.1
307	3022005.10	674063.35	1629.0	1629.0
308	3022029.43	674062.49	1630.0	1630.0
309	3022050.27	674064.03	1630.6	1630.6
310	3022082.08	674061.21	1631.2	1631.2
311	3022096.45	674063.81	1631.5	1631.5
312	3022117.73	674066.48	1633.2	1633.2
313	3022143.95	674060.91	1636.5	1636.5
314	3021934.87	674083.87	1627.8	1627.8
315	3021959.58	674084.44	1628.5	1628.5
316	3021981.66	674086.52	1628.9	1628.9
317	3022001.80	674084.84	1629.0	1629.0
318	3022027.75	674087.56	1629.5	1629.5
319	3022050.19	674087.18	1630.1	1630.1
320	3022073.21	674087.39	1630.8	1630.8
321	3022096.41	674087.34	1631.4	1631.4
322	3022119.55	674087.60	1633.0	1633.0
323	3021942.37	674112.53	1630.1	1630.1
324	3021956.14	674111.01	1629.8	1629.8
325	3021979.76	674109.80	1629.6	1629.6
326	3022004.18	674110.63	1629.7	1629.7
327	3022031.03	674108.62	1629.8	1629.8
328	3022049.62	674111.00	1630.1	1630.1
329	3022071.26	674109.27	1630.7	1630.7
330	3022096.83	674110.31	1631.7	1631.7
331	3021956.77	674133.30	1629.6	1629.6
332	3021982.24	674132.87	1629.8	1629.8

Table 4-6 Position of Coreholes as Determined by Professional Land Survey, SU 12 (Continued)

Corehole ID#	Actual Location [2]		Elevation (ft., msl)	
	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
333	3022003.37	674133.88	1629.7	1629.7
334	3022026.35	674133.94	1629.7	1629.7
335	3022050.24	674133.88	1630.4	1630.4
336	3022073.46	674133.72	1631.2	1631.2
337	3021976.50	674151.23	1629.9	1629.9
338	3022004.45	674156.62	1629.6	1629.6
339	3022026.45	674156.75	1630.1	1630.1
340	3022049.87	674156.92	1631.0	1631.0
341	3021981.17	674174.91	1629.2	1629.2
342	3022003.90	674179.88	1630.0	1630.0
343	3022026.76	674180.31	1630.3	1630.3
344	3022003.65	674203.46	1630.9	1630.9

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

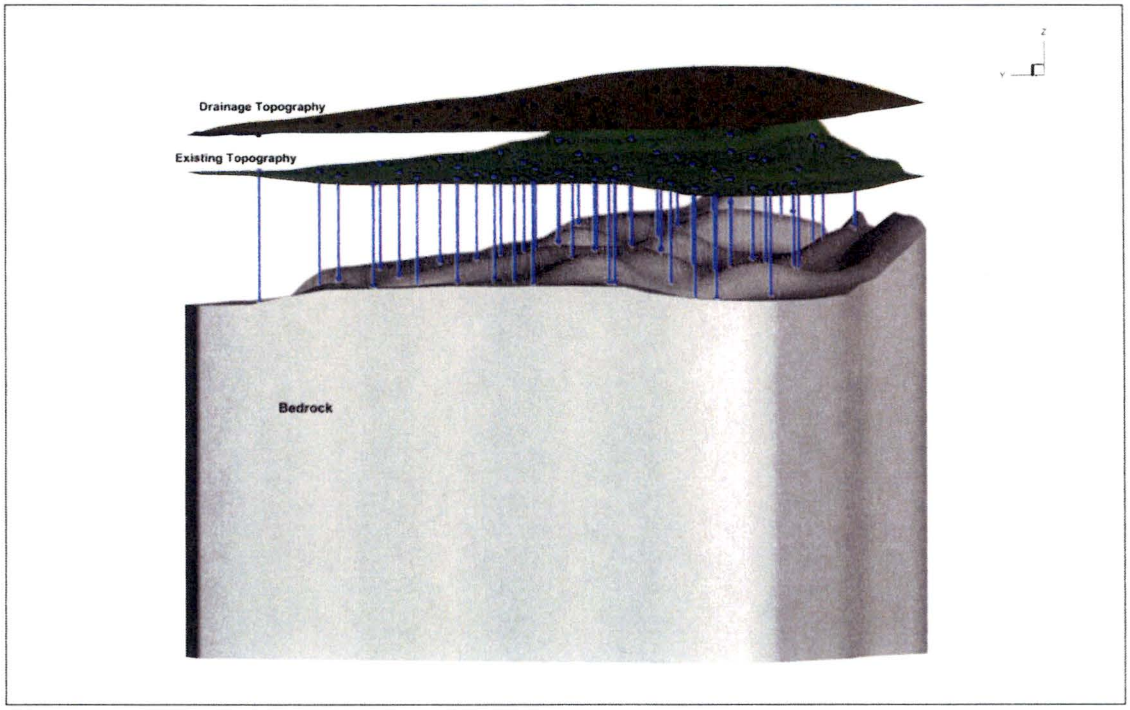

Figure 4-16 Surveyed Corehole Locations and Elevations, Shown with Drainage Plan and Bedrock Surfaces, Survey Unit 12

Table 4-7 Position of Coreholes as Determined by Professional Land Survey, SU 16-Western

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	**Easting (X)**	**Northing (Y)**	**At Top of Core**	**At Top of Bedrock [1]**
469	3022036.69	673809.32	1626.5	1621.5
476	3022015.36	673826.46	1628.2	1623.2
477	3022032.54	673826.28	1627.4	1617.4
478	3022045.37	673822.20	1627.1	1618.1
483	3021988.43	673847.36	1628.7	1622.7
484	3022001.08	673841.22	1628.1	1620.6
485	3022015.46	673837.97	1628.4	1618.4
486	3022029.60	673839.34	1628.7	1618.7
487	3022044.75	673839.79	1628.2	1621.7
488	3022058.53	673845.47	1628.4	1620.9
491	3021972.96	673861.28	1628.7	1621.7
492	3021983.95	673856.64	1628.0	1620.5
493	3021998.38	673857.55	1628.0	1618.0
494	3022011.82	673856.86	1628.4	1619.9
495	3022026.92	673857.21	1628.4	1619.4
496	3022044.99	673856.79	1629.1	1620.1
497	3022063.80	673859.97	1629.2	1623.2
498	3022069.71	673854.28	1629.3	1622.3
499	3021952.87	673875.19	1628.4	1625.4
500	3021965.49	673871.82	1628.2	1623.2
501	3021983.20	673870.81	1627.8	1620.3
502	3021999.86	673872.25	1628.1	1620.1
503	3022015.81	673871.86	1628.0	1621.0
504	3022030.39	673871.62	1628.7	1618.7
505	3022046.13	673870.79	1629.7	1621.2
506	3021927.82	673894.11	1627.8	1624.8
507	3021936.86	673887.28	1627.7	1625.2
508	3021953.88	673887.84	1628.0	1625.0
509	3021968.14	673889.71	1628.1	1623.1
510	3021982.74	673887.03	1628.2	1622.2
511	3022001.15	673888.11	1628.1	1615.1
512	3022016.67	673887.43	1628.9	1619.9
513	3022032.06	673887.30	1628.9	1622.9
514	3022041.17	673893.92	1628.7	1622.7
515	3021910.49	673903.43	1628.4	1626.9
516	3021921.82	673902.94	1628.1	1628.1
517	3021936.24	673902.82	1627.9	1622.4
518	3021953.09	673902.85	1627.9	1625.4
519	3021968.84	673901.30	1627.8	1618.8
520	3021983.35	673902.01	1627.9	1625.4
521	3021998.77	673903.42	1627.9	1614.4
522	3022014.36	673902.13	1628.7	1620.7
523	3022025.95	673903.51	1628.6	1620.1
524	3022043.30	673903.12	1629.1	1624.1
525	3021890.34	673917.13	1630.7	1625.7

Table 4-7 Position of Coreholes as Determined by Professional Land Survey, SU 16-Western (Continued)

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
526	3021905.17	673919.10	1630.9	1621.4
527	3021920.04	673919.73	1630.2	1625.2
528	3021936.07	673919.09	1628.0	1621.5
529	3021948.74	673916.97	1627.9	1623.4
530	3021968.60	673916.64	1627.7	1623.7
531	3021983.13	673917.31	1627.9	1623.9
532	3021999.37	673918.27	1628.0	1623.5
533	3022013.86	673917.42	1628.2	1621.2
534	3022028.95	673918.11	1628.8	1622.8
535	3021905.22	673935.57	1630.3	1620.8
536	3021920.28	673936.79	1629.1	1624.1
537	3021935.73	673937.48	1628.8	1627.3
538	3021953.33	673934.62	1628.0	1623.0
539	3021967.98	673932.14	1627.9	1616.9
540	3021981.13	673933.89	1627.9	1620.9
541	3021996.29	673934.96	1627.6	1608.1
542	3022012.74	673934.72	1628.1	1618.6
543	3021920.28	673950.50	1629.5	1625.0
544	3021936.99	673949.14	1627.8	1622.8
545	3021951.60	673947.91	1627.7	1624.7
546	3021968.72	673949.75	1627.4	1621.4
547	3021982.01	673950.30	1627.8	1618.8
548	3021995.42	673949.79	1627.8	1620.3
549	3022012.72	673949.70	1628.5	1620.5
550	3021920.93	673966.05	1628.0	1623.5
551	3021936.56	673967.14	1627.3	1625.3
552	3021951.80	673965.49	1626.9	1623.4
553	3021966.46	673967.98	1625.8	1622.8
554	3021983.01	673965.56	1628.6	1624.1
555	3021999.29	673965.86	1628.4	1622.4
556	3022010.61	673962.67	1629.0	1624.0
557	3021936.08	673981.36	1628.1	1625.1
558	3021952.00	673980.55	1627.1	1625.1
559	3021967.53	673983.25	1629.0	1623.5
560	3021981.86	673980.53	1628.7	1625.2
561	3021998.33	673976.23	1628.6	1625.6

1. Elevation at top of bedrock is calculated from soil boring logs and based on surveyed elevation at top of corehole.

2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

Table 4-8 Position of Coreholes as Determined by Professional Land Survey, SU 16-Central

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
421	3022207.99	673686.83	1627.0	1612.0
426	3022179.29	673703.18	1627.5	1613.0
427	3022194.04	673698.92	1627.3	1610.8
428	3022203.42	673700.49	1627.5	1616.5
429	3022218.13	673699.28	1627.4	1616.4
432	3022164.85	673711.74	1626.9	1607.9
433	3022174.52	673710.83	1627.8	1614.8
434	3022189.04	673712.49	1627.0	1603.0
435	3022203.40	673712.86	1627.3	1607.8
436	3022218.41	673715.04	1628.0	1609.5
437	3022229.75	673710.40	1627.9	1614.9
438	3022147.87	673726.81	1626.7	1602.7
439	3022158.97	673730.15	1626.5	1612.5
440	3022173.47	673732.24	1627.7	1602.7
441	3022188.85	673731.93	1628.1	1605.1
442	3022204.53	673728.13	1628.1	1615.1
443	3022210.55	673730.07	1628.7	1615.2
444	3022114.97	673751.75	1626.3	1611.3
445	3022128.49	673747.57	1626.4	1612.4
446	3022140.14	673748.46	1626.1	1605.1
447	3022155.32	673747.52	1626.7	1607.2
448	3022173.74	673746.32	1627.3	1607.8
449	3022188.27	673746.01	1628.5	1614.5
450	3022096.20	673766.74	1626.7	1619.2
451	3022106.90	673759.40	1626.5	1619.0
452	3022122.88	673759.94	1626.1	1607.6
453	3022139.31	673759.64	1627.0	1601.0
454	3022161.46	673764.81	1628.6	1600.6
455	3022171.89	673762.87	1628.7	1595.7
456	3022078.00	673782.88	1626.7	1621.7
457	3022091.99	673776.86	1626.6	1619.6
458	3022108.14	673775.75	1626.7	1613.7
459	3022123.33	673777.43	1627.6	1619.6
460	3022139.57	673776.30	1628.5	1614.5
461	3022153.81	673776.58	1629.2	1599.7
462	3022053.89	673799.02	1626.6	1621.1
463	3022063.17	673798.21	1627.0	1622.5
464	3022076.49	673791.42	1626.7	1619.7
465	3022091.21	673790.94	1626.7	1619.2
466	3022107.36	673790.83	1627.2	1618.7

Table 4-8 Position of Coreholes as Determined by Professional Land Survey, SU 16-Central (Continued)

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
467	3022124.12	673787.10	1628.4	1620.9
468	3022137.51	673787.21	1629.2	1616.7
470	3022046.13	673808.93	1626.9	1621.9
471	3022062.57	673805.69	1626.5	1619.0
472	3022076.46	673807.90	1626.5	1620.5
473	3022092.79	673806.07	1627.3	1618.8
474	3022106.96	673806.58	1628.3	1616.3
475	3022121.22	673805.47	1628.9	1619.9
479	3022062.44	673823.38	1627.0	1617.5
480	3022078.80	673826.02	1627.1	1622.1
481	3022095.81	673825.63	1628.7	1625.2
482	3022104.60	673816.14	1628.6	1619.6
489	3022078.27	673847.24	1629.3	1622.3
490	3022084.01	673837.14	1628.0	1624.5

1. *Elevation at top of bedrock is calculated from soil boring logs and based on surveyed elevation at top of corehole.*
2. *Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet*

Table 4-9 Position of Coreholes as Determined by Professional Land Survey, SU 16-Eastern

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
384	3022404.83	673540.93	1631.1	1607.1
385	3022378.03	673557.79	1631.0	1616.5
386	3022393.64	673557.61	1631.0	1606.5
387	3022407.95	673557.33	1631.2	1600.7
388	3022352.91	673577.62	1629.7	1613.7
389	3022361.21	673570.08	1629.6	1621.6
390	3022375.34	673572.20	1630.4	1618.4
391	3022392.34	673572.86	1630.8	1621.8
392	3022406.85	673571.37	1631.2	1599.7
393	3022331.84	673592.06	1629.4	1619.4
394	3022344.69	673590.35	1629.7	1617.7
395	3022360.60	673589.96	1629.9	1621.9
396	3022376.47	673589.42	1629.9	1622.4
397	3022314.92	673604.03	1629.9	1612.9
398	3022329.72	673604.79	1629.8	1624.3
399	3022347.07	673602.07	1629.7	1623.7
400	3022358.63	673602.89	1629.7	1611.7
401	3022285.93	673623.53	1629.4	1619.4
402	3022298.44	673617.14	1629.4	1622.4
403	3022316.20	673618.86	1630.0	1623.5
404	3022331.69	673621.39	1629.9	1619.9
405	3022341.05	673616.34	1629.8	1622.8
406	3022271.62	673640.26	1629.6	1617.6
407	3022283.53	673633.53	1629.6	1618.1
408	3022298.07	673634.32	1629.8	1622.3
409	3022314.69	673632.68	1630.1	1619.6
410	3022329.77	673633.63	1630.2	1621.7
411	3022251.26	673651.22	1629.7	1618.7
412	3022267.01	673653.04	1629.6	1617.1
413	3022281.80	673654.35	1629.9	1616.4
414	3022298.03	673654.31	1630.2	1620.7
415	3022307.92	673647.31	1630.5	1619.5
416	3022225.23	673673.99	1628.0	1619.5
417	3022234.33	673670.85	1628.8	1615.8
418	3022249.71	673669.38	1629.2	1616.2
419	3022265.26	673668.35	1629.9	1617.4
420	3022282.06	673665.14	1630.1	1616.1
422	3022218.41	673684.65	1628.2	1620.2
423	3022235.88	673683.32	1628.7	1617.7
424	3022250.14	673681.69	1628.9	1615.9
425	3022258.28	673677.70	1629.4	1610.4
430	3022233.31	673699.18	1628.2	1615.2
431	3022244.85	673693.90	1628.6	1616.6

1. Elevation at top of bedrock is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet.

Figure 4-17 illustrates the entirety of Survey Unit 16 in with no vertical scale exaggeration. Figure 4-18, Figure 4-19, and Figure 4-20 show the position and depth of the coreholes, as well as their relationship to the final surface elevation as defined in the Drainage Plan. Note the vertical scale has been exaggerated to three times the horizontal scale for illustration purposes in these three figures.

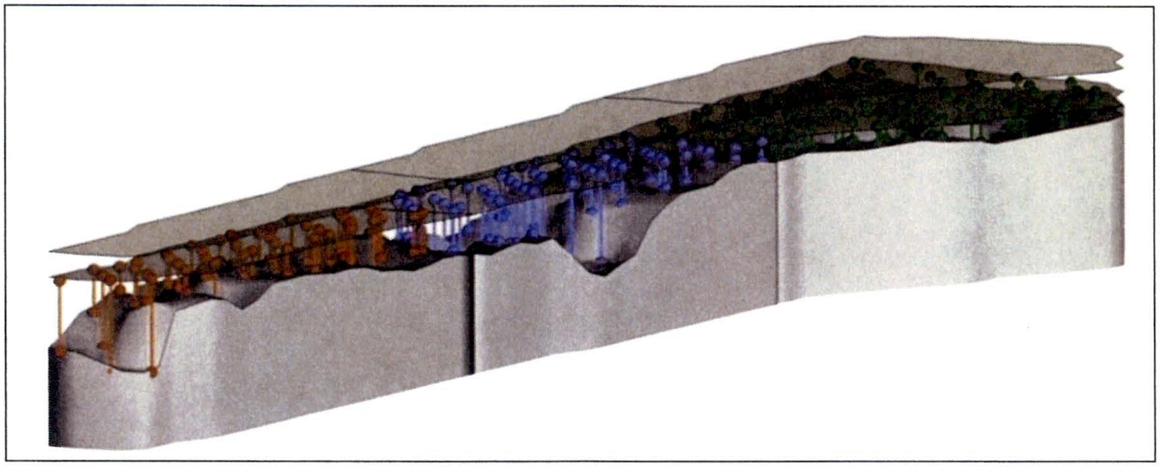

Figure 4-17 Three-Dimensional View, Vertical Alignment Matrix, Survey Unit 16

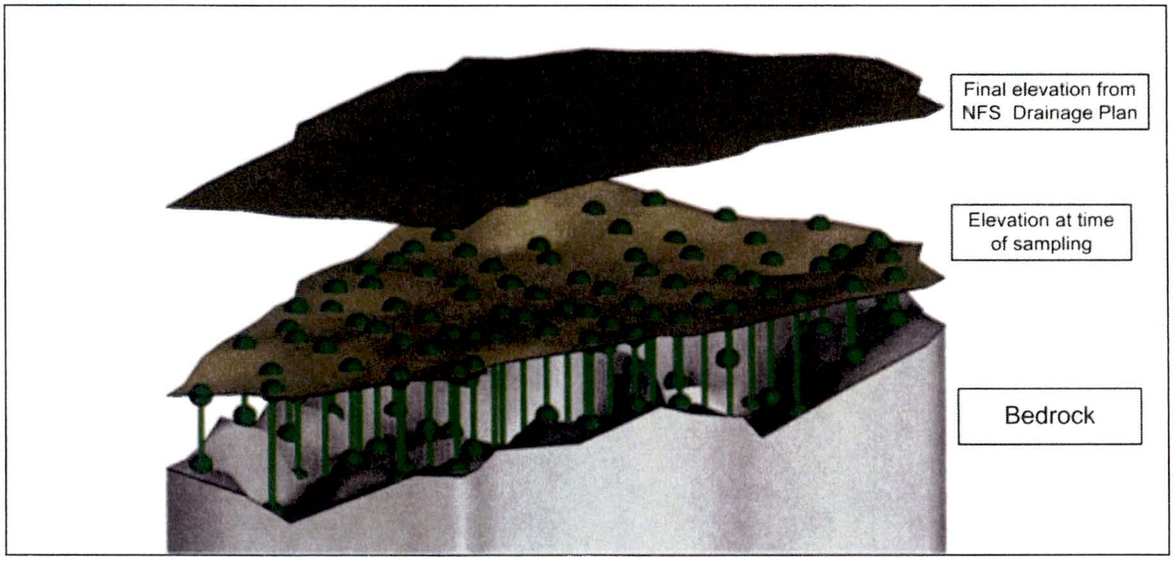

Figure 4-18 Three-Dimensional View, Vertical Alignment Matrix, Survey Unit 16-Western

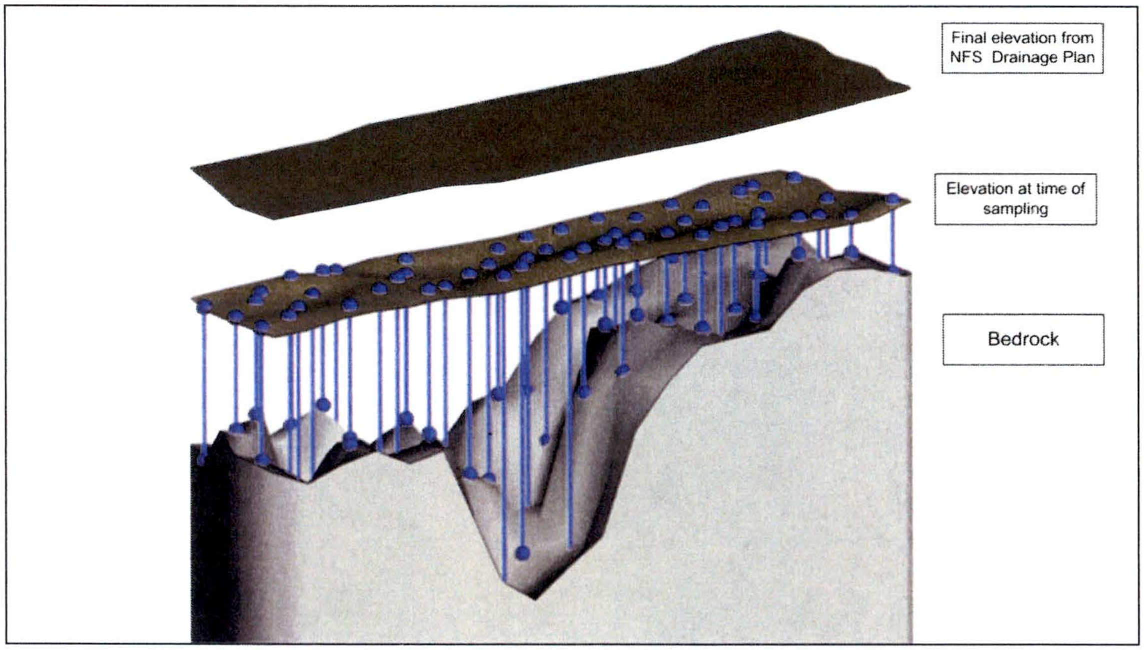

Figure 4-19 Three-Dimensional View, Vertical Alignment Matrix, Survey Unit 16-Central

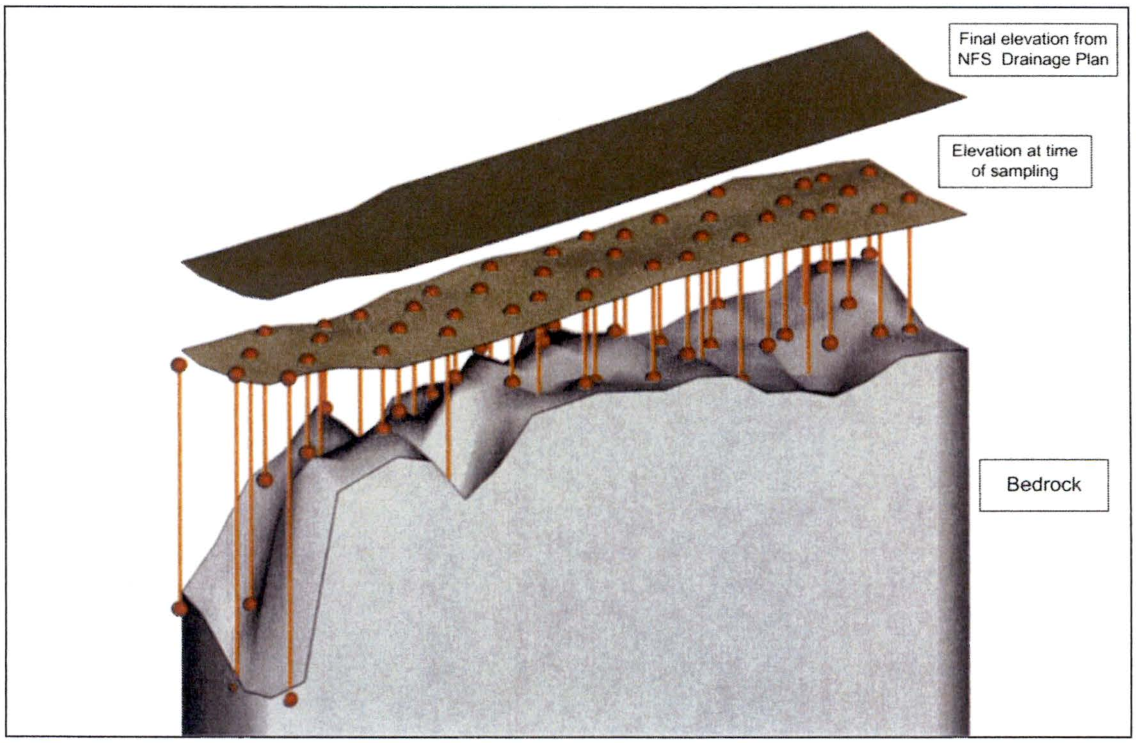

Figure 4-20 Three-Dimensional View, Vertical Alignment Matrix, Survey Unit 16-Eastern

Table 4-10 Position of Coreholes as Determined by Professional Land Survey, SU 17

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
612	3022375.25	673616.58	1634.90	1607.9
613	3022355.02	673634.75	1635.47	1617.5
614	3022368.52	673627.52	1635.18	1621.7
615	3022331.41	673654.51	1635.00	1614.0
616	3022304.11	673673.96	1635.31	1611.8
617	3022262.19	673707.05	1634.48	1617.0
618	3022277.87	673697.89	1635.37	1617.9
619	3022238.03	673726.63	1633.54	1617.5
620	3022255.47	673719.24	1634.50	1634.5
621	3022214.60	673746.48	1632.84	1632.8
622	3022233.29	673742.20	1634.35	1634.4
623	3022190.27	673775.21	1632.65	1622.7
624	3022208.48	673766.79	1632.41	1632.4
625	3022164.52	673791.72	1632.55	1599.6
626	3022184.54	673791.69	1632.62	1632.6
627	3022214.08	673789.43	1632.88	1632.9
628	3022228.08	673802.53	1633.44	1598.4
629	3022142.56	673817.61	1633.33	1620.3
630	3022165.46	673815.53	1632.67	1615.2
631	3022188.75	673814.42	1633.01	1600.0
632	3022117.33	673839.06	1632.99	1626.0
633	3022139.73	673837.56	1632.66	1621.7
634	3022080.64	673864.86	1632.90	1621.9
635	3022095.30	673861.15	1632.54	1621.0
636	3022121.08	673863.40	1632.47	1632.5
637	3022079.11	673884.05	1632.54	1621.5
638	3022096.79	673884.86	1631.72	1623.2
639	3022074.04	673907.03	1632.35	1621.4
640	3022095.58	673908.20	1631.02	1620.0
641	3022049.58	673931.48	1632.91	1625.4
642	3022065.46	673928.40	1632.66	1622.2
643	3022096.75	673933.90	1629.60	1625.1
644	3022120.32	673934.01	1631.60	1623.6
645	3022032.30	673959.05	1633.21	1619.7
646	3022053.97	673956.44	1631.80	1620.3
647	3022070.32	673959.75	1631.11	1631.1
648	3022097.03	673957.32	1631.25	1620.3
649	3022120.17	673955.19	1631.72	1620.7
650	3022141.17	673954.77	1631.90	1615.9
651	3022023.00	673977.99	1632.74	1625.2
652	3022049.92	673979.04	1632.57	1625.1

Table 4-10 Position of Coreholes as Determined by Professional Land Survey, SU 17 (Continued)

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	**Easting (X)**	**Northing (Y)**	**At Top of Core**	**At Top of Bedrock [1]**
653	3022073.61	673978.31	1633.19	1621.2
654	3022095.23	673978.96	1632.66	1619.2
655	3022118.75	673978.86	1631.65	1623.7
656	3022143.24	673977.98	1632.88	1623.9
657	3022166.87	673977.69	1634.44	1619.9
658	3022004.72	674003.97	1629.65	1629.7
659	3022024.40	674001.59	1631.62	1624.1
660	3022049.42	674002.83	1631.29	1620.3
661	3022071.24	674002.54	1632.36	1625.4
662	3022092.26	674002.63	1633.03	1623.0
663	3022118.24	674001.23	1633.03	1618.0
664	3022140.60	674002.04	1633.85	1623.9
665	3022166.08	674000.57	1635.03	1635.0
666	3022190.17	674000.55	1635.28	1623.8
667	3022163.28	674025.75	1635.45	1635.5
668	3022183.92	674023.37	1635.05	1635.1
A614	3022365.44	673631.50	1639.10	1614.1
B614	3022372.43	673628.17	1639.60	1623.6
C614	3022371.45	673622.44	1639.40	1623.4
D614	3022365.36	673621.46	1639.20	1615.2

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

Further detail regarding the actual number of coreholes sampled in Survey Unit 17 presented in Appendix H.

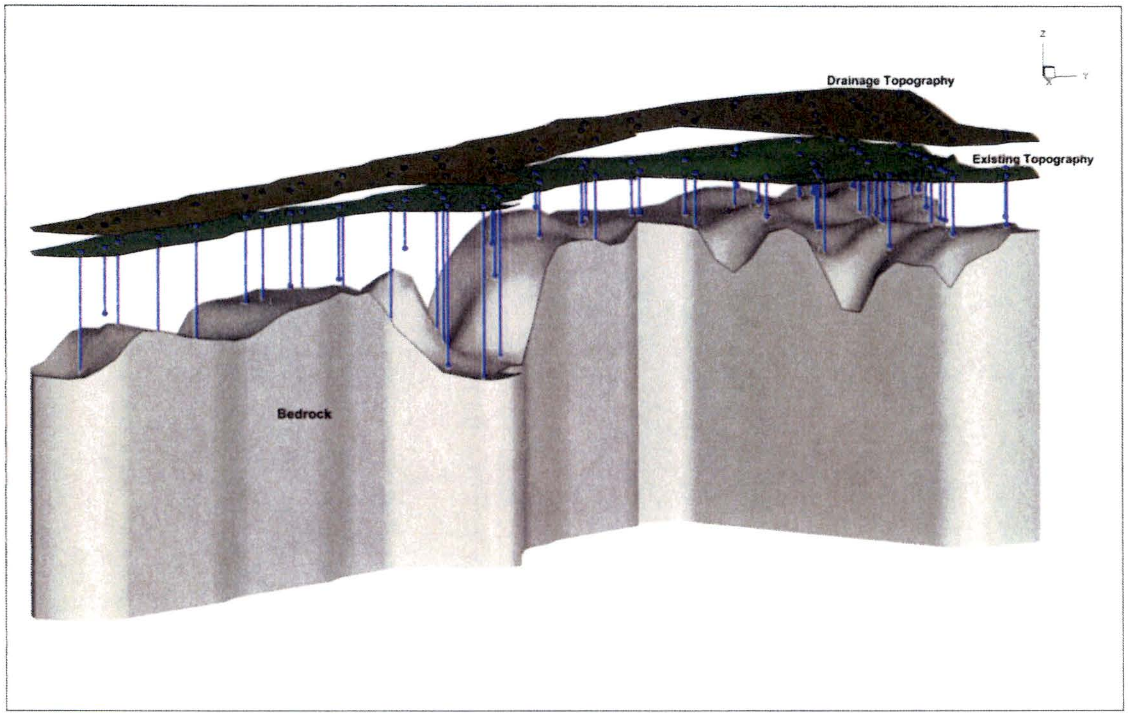

Figure 4-21 Surveyed Corehole Locations and Elevations, Shown with Drainage Plan and Bedrock Surfaces, Survey Unit 17

Table 4-11 Position of Coreholes as Determined by Professional Land Survey, SU 18

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
669	3022214.89	673802.49	1632.8	1597.8
670	3022189.65	673824.81	1633.2	1598.2
671	3022215.00	673823.29	1633.1	1598.1
672	3022237.62	673824.29	1634.7	1599.7
673	3022167.01	673848.45	1632.8	1620.8
674	3022187.14	673847.98	1633.5	1619.5
675	3022214.45	673847.77	1633.5	1615.5
676	3022238.17	673846.74	1634.9	1599.9
677	3022261.18	673848.28	1634.8	1599.8
678	3022144.62	673871.34	1632.8	1620.8
679	3022167.21	673872.53	1633.6	1623.1
680	3022191.21	673871.95	1634.4	1619.4
681	3022214.35	673871.31	1634.7	1621.2
682	3022238.05	673870.93	1635.4	1612.4
683	3022260.83	673871.96	1635.1	1602.1
684	3022098.37	673892.22	1630.7	1621.7
685	3022123.34	673894.60	1630.5	1625.5
686	3022147.29	673896.61	1632.9	1621.9
687	3022167.47	673894.98	1634.1	1625.6
688	3022190.50	673893.90	1634.2	1620.2
689	3022213.79	673893.91	1635.0	1613.0
690	3022237.25	673894.91	1634.9	1615.9
691	3022124.73	673920.34	1631.4	1612.4
692	3022143.38	673917.03	1632.1	1621.1
693	3022172.08	673916.04	1633.7	1619.7
694	3022189.78	673917.12	1634.5	1617.5
695	3022214.25	673916.95	1635.1	1613.1
696	3022236.91	673917.93	1635.3	1620.3
697	3022260.66	673917.90	1635.7	1616.7
698	3022145.06	673940.03	1631.8	1622.8
699	3022170.16	673939.68	1634.4	1612.4
700	3022191.61	673940.63	1634.6	1604.8
701	3022214.56	673941.06	1635.2	1612.2
702	3022236.78	673938.57	1635.4	1616.4
703	3022260.42	673941.25	1636.0	1619.0
704	3022167.50	673964.91	1634.0	1606.5
705	3022190.62	673967.16	1634.6	1618.6

Table 4-11 Position of Coreholes as Determined by Professional Land Survey, SU 18 (Continued)

	Actual Location [2]		Elevation (ft., msl)	
Corehole ID#	Easting (X)	Northing (Y)	At Top of Core	At Top of Bedrock [1]
706	3022214.48	673963.76	1635.3	1616.8
707	3022237.19	673963.20	1635.7	1612.7
708	3022190.44	673986.77	1634.9	1617.4
709	3022213.43	673987.13	1636.0	1602.0
E672	3022242.60	673832.43	1635.6	1635.6
N672	3022229.44	673832.63	1635.3	1635.3
S672	3022239.56	673821.22	1634.5	1634.5
W672	3022229.79	673818.38	1633.7	1633.7

1. Elevation at top of bedrock (residuum) is calculated from soil boring logs and based on surveyed elevation at top of corehole.
2. Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Conus), Units US Survey Feet

Further detail regarding the actual number of coreholes sampled in Survey Unit 18 presented in Appendix H.

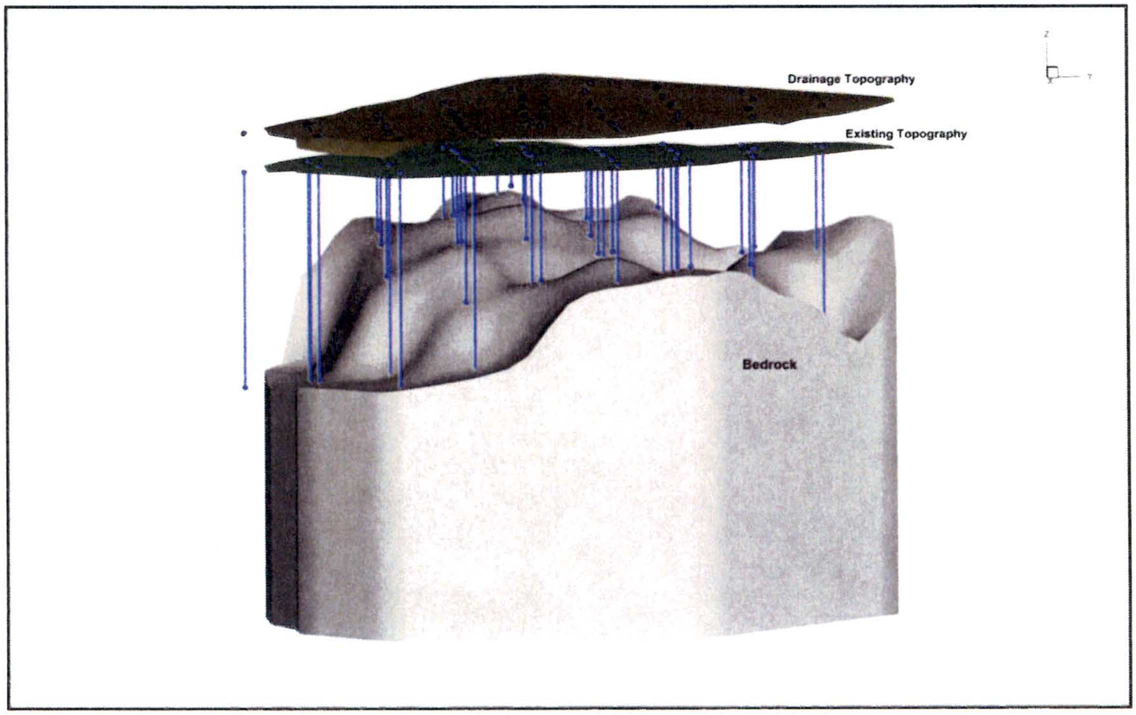

Figure 4-22 Surveyed Corehole Locations and Elevations, Shown with Drainage Plan and Bedrock Surfaces, Survey Unit 18

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Table 4-12 *Summary of Maximum Depth Layers Assigned, Survey Units 4, 6, 7, 12, 16, 17, and 18*

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Figure 4-23 Vertical Alignment Matrix, Survey Unit 4

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Figure 4-24 Vertical Alignment Matrix, Survey Unit 6

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Figure 4-25 Vertical Alignment Matrix, Survey Unit 7

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Figure 4-26 Vertical Alignment Matrix, Survey Unit 12

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Figure 4-27 Vertical Alignment Matrix, Survey Unit 16-Western

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Figure 4-28 Vertical Alignment Matrix, Survey Unit 16-Central

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Figure 4-29 Vertical Alignment Matrix, Survey Unit 16-Eastern

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Figure 4-30 Vertical Alignment Matrix, Survey Unit 17

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Figure 4-31 Vertical Alignment Matrix, Survey Unit 18

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Figure 4-32 Assignment of Background Concentrations to Sample Cell Voids, SU 4

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Figure 4-33 Assignment of Background Concentrations to Sample Cell Voids, SU 6

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Figure 4-34 Assignment of Background Concentrations to Sample Cell Voids, SU 7

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Figure 4-35 Assignment of Background Concentrations to Sample Cell Voids, SU 12

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Figure 4-36 Assignment of Background Concentrations to Sample Cell Voids, SU 16-Western

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Figure 4-37 Assignment of Background Concentrations to Sample Cell Voids, SU 16-Central

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Figure 4-38 Assignment of Background Concentrations to Sample Cell Voids, SU 16-Eastern

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Figure 4-39 Assignment of Background Concentrations to Sample Cell Voids, SU 17

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Figure 4-40 Assignment of Background Concentrations to Sample Cell Voids, SU 18

4.3 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 4

While the compliance metrics associated with the approved subsurface soil DCGL methodology require that the data be evaluated in a number of spatial configurations and sample combinations using the sums-of-fractions (wide area average, local area average of nearest neighbors, local area average of vertical columns, and individually), it is informative to consider the data on an isotope-specific basis. From this perspective one can identify the isotope(s) that most significantly contribute to residual radioactivity in the survey unit. Further, by comparing the isotope-specific summary statistics with the applicable surface soil DCGLs, the decision-makers are afforded the opportunity to assess the relative dose consequences of residual radioactivity present in the survey unit. While such views of the data are informative, they do not constitute compliance metrics in themselves. Compliance assessments are considered in Section 5.0. The following sections present the reviewed and validated data on an individual isotope basis and in units of pCi/g (dry weight).

4.3.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 263 soil samples collected from Survey Unit 4 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-41), Th-232 (Figure 4-42), and Am-241 (Figure 4-43) are presented in this subsection.[4] All isotopic data is in units of pCi/g.

[4] The entire datasets for samples from Survey Units 4, 6, 7, 12, 16, 17, and 18 are tabulated in Appendix G.

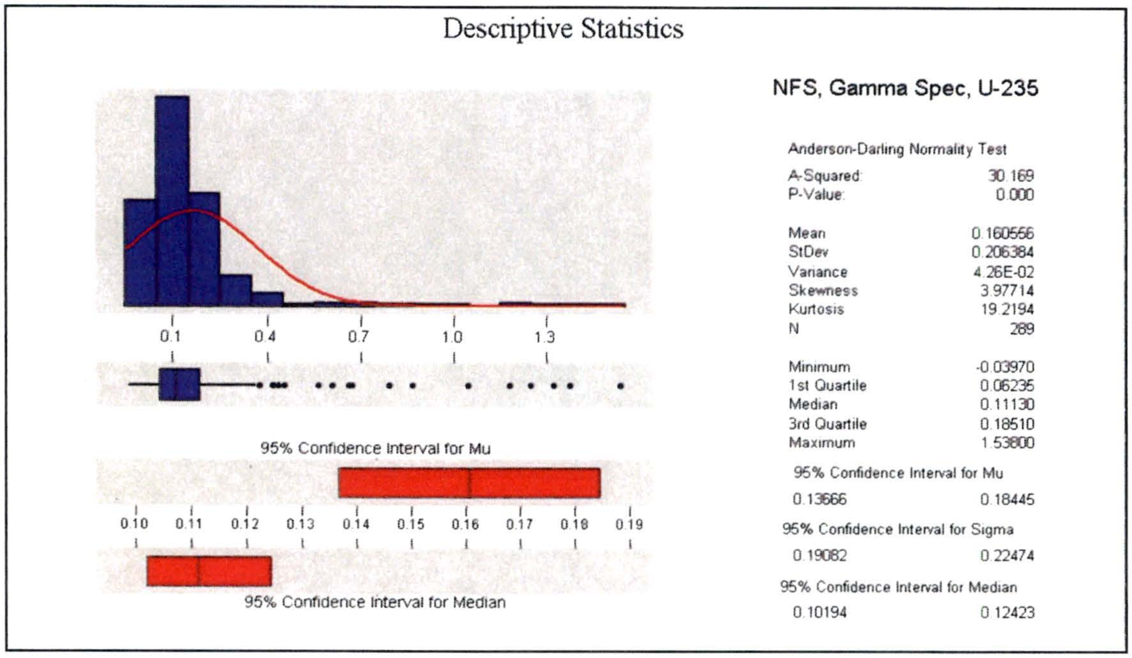

Figure 4-41 Summary Statistics: U-235, NFS, Gamma Spectroscopy,SU 4

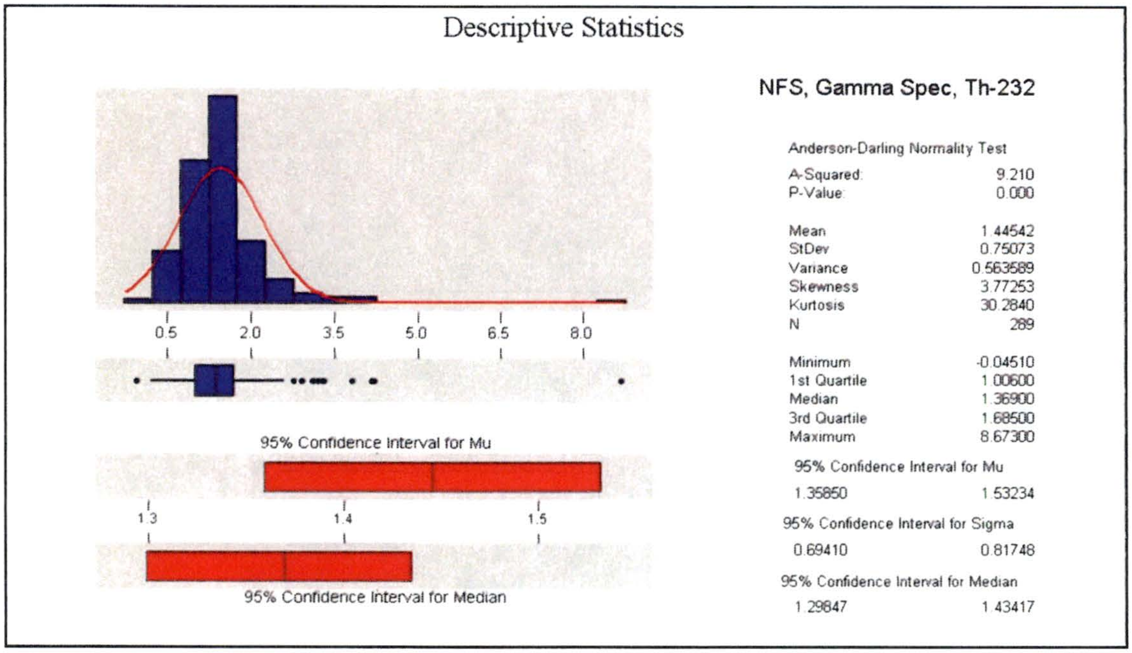

Figure 4-42 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 4

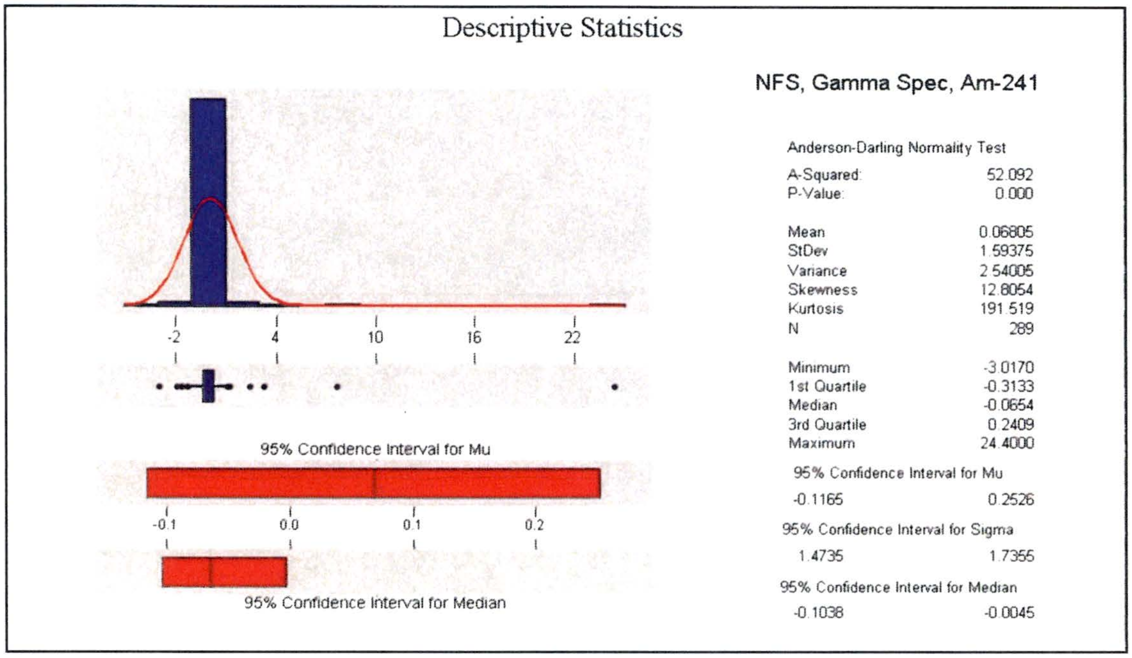

Figure 4-43 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 4

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 4 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.3.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 263 soil samples collected from Survey Unit 4, 27 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-44), Th-232 (Figure 4-45), and Am-241 (Figure 4-46) are presented in this subsection. All isotopic data is in units of pCi/g.

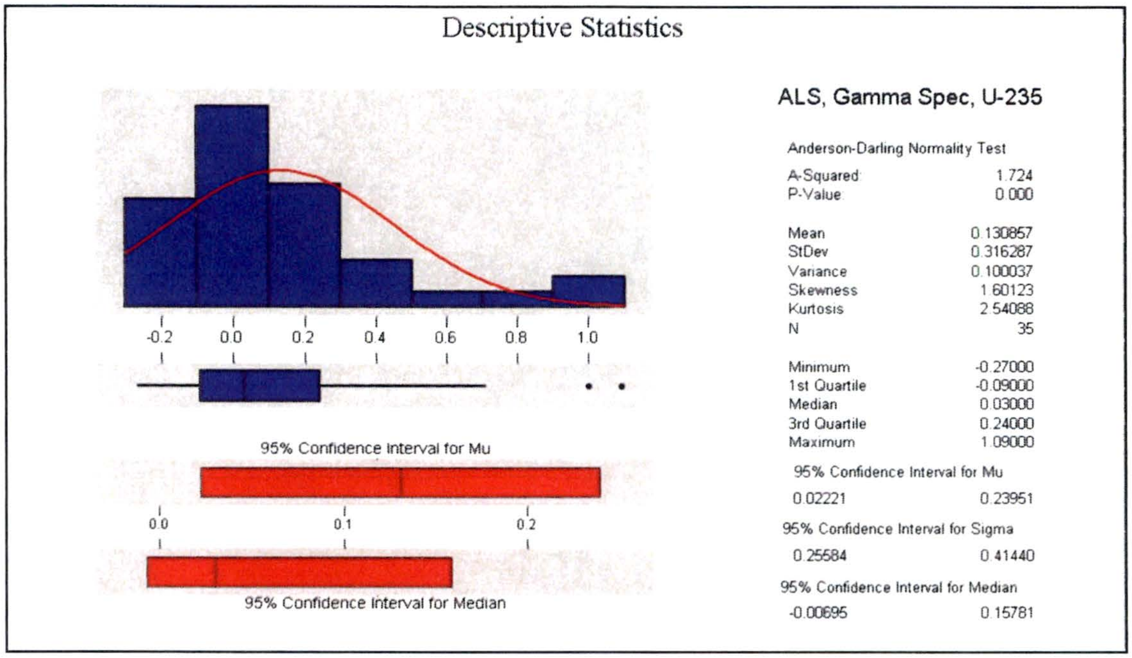

Figure 4-44 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 4

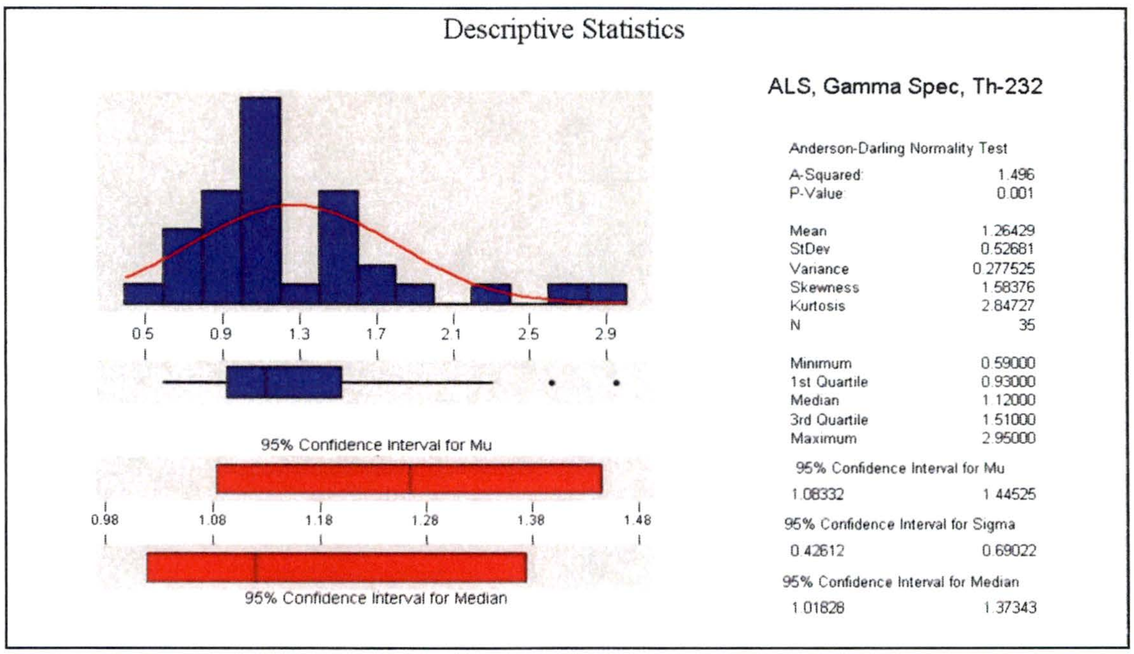

Figure 4-45 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 4

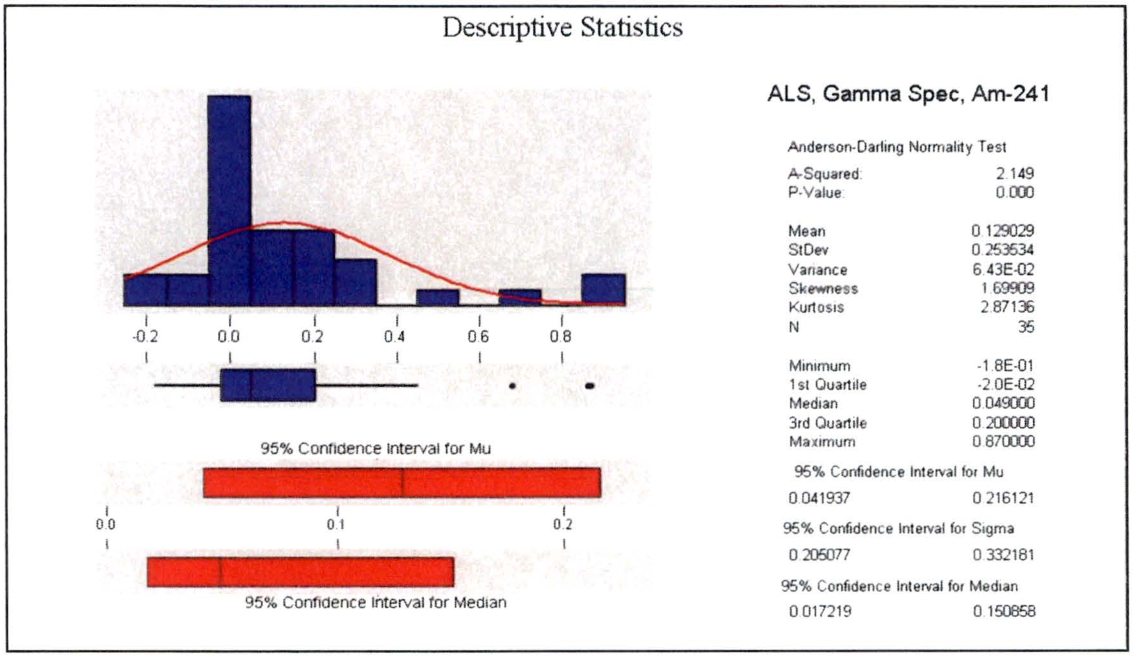

Figure 4-46 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 4

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 4 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.3.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 263 soil samples collected from Survey Unit 4, 27 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-47), Pu-238 (Figure 4-48), Pu-239/240 (Figure 4-49), Pu-241 (Figure 4-50), Pu-242 (Figure 4-51), Th-230 (Figure 4-52), Th-232 (Figure 4-53), U-233/234 (Figure 4-54), U-235 (Figure 4-55), U-238 (Figure 4-56), and Tc-99 (Figure 4-57) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

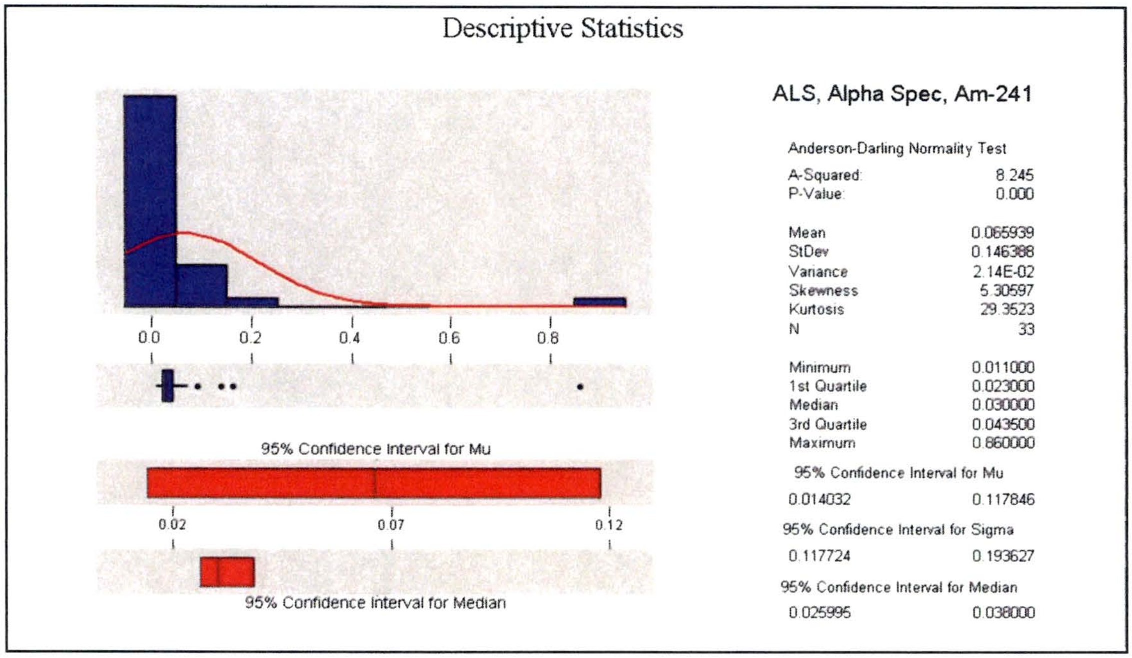

Figure 4-47 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 4

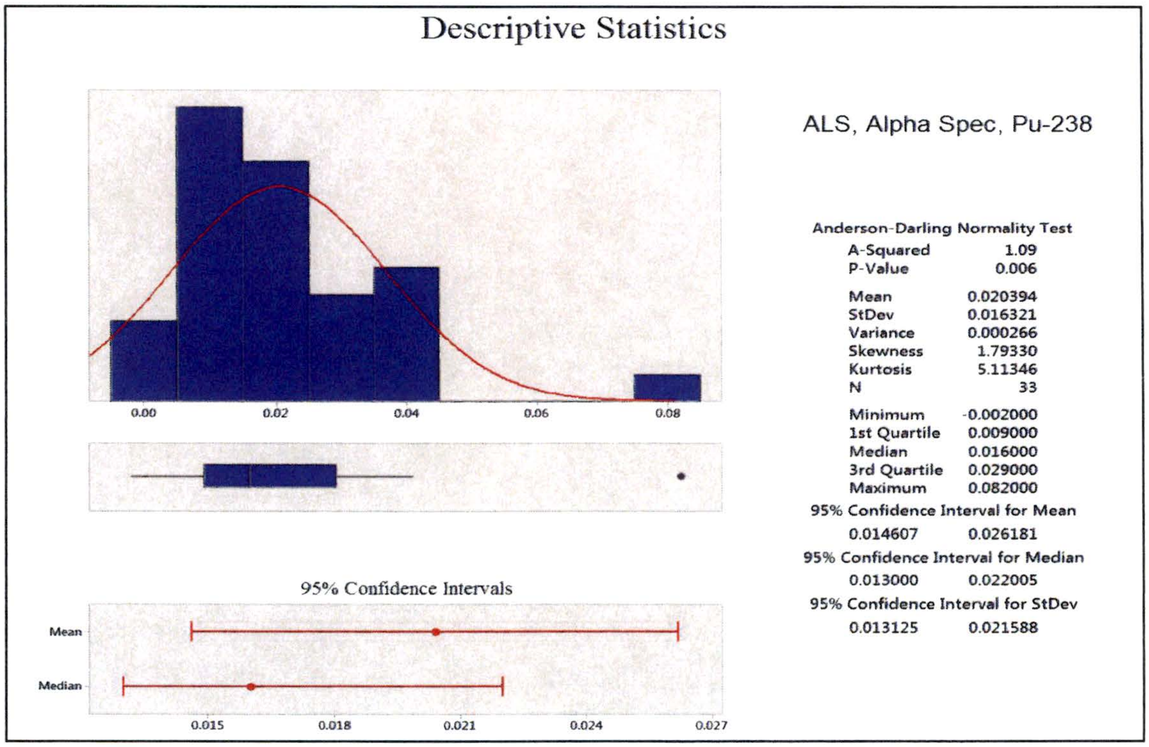

Figure 4-48 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 4

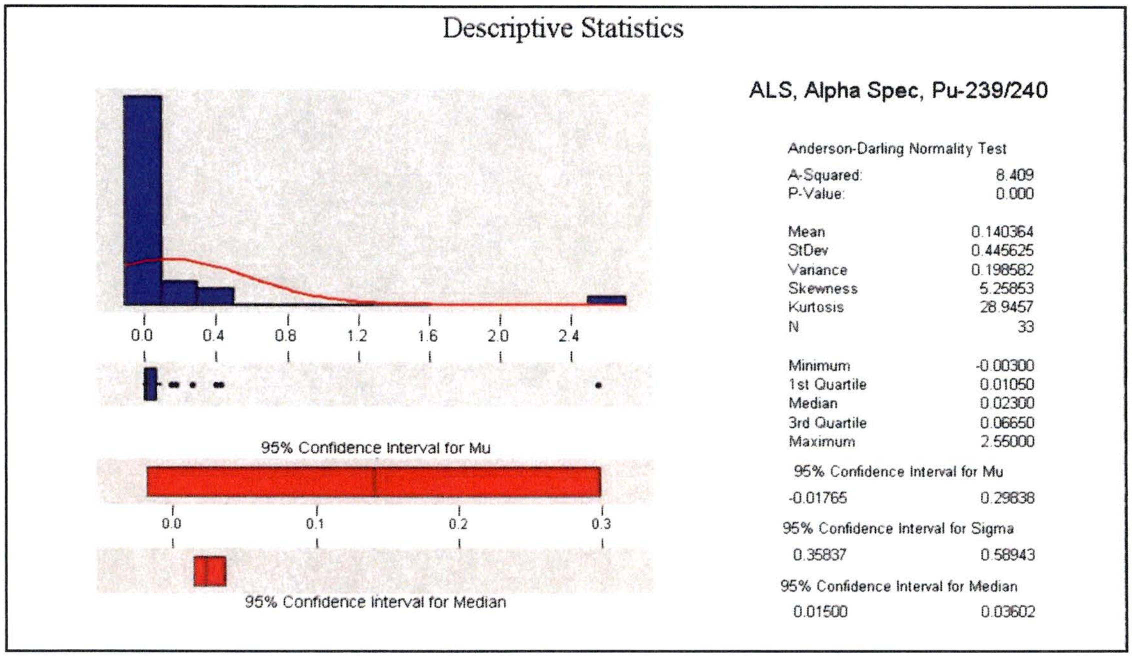

Figure 4-49 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 4

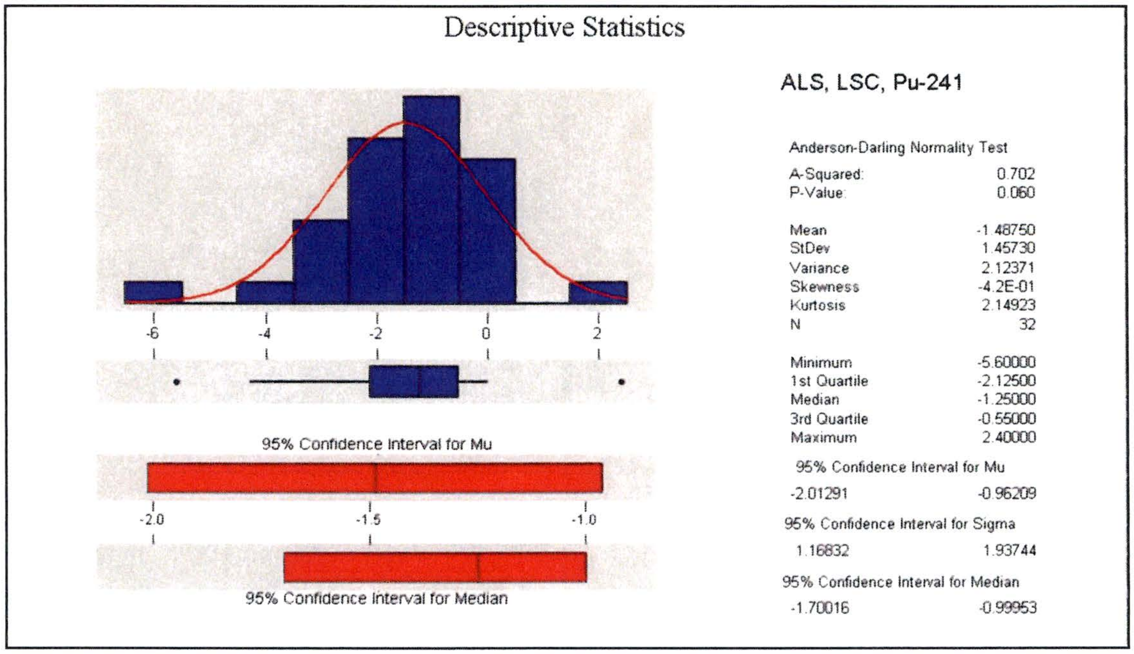

Figure 4-50 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 4

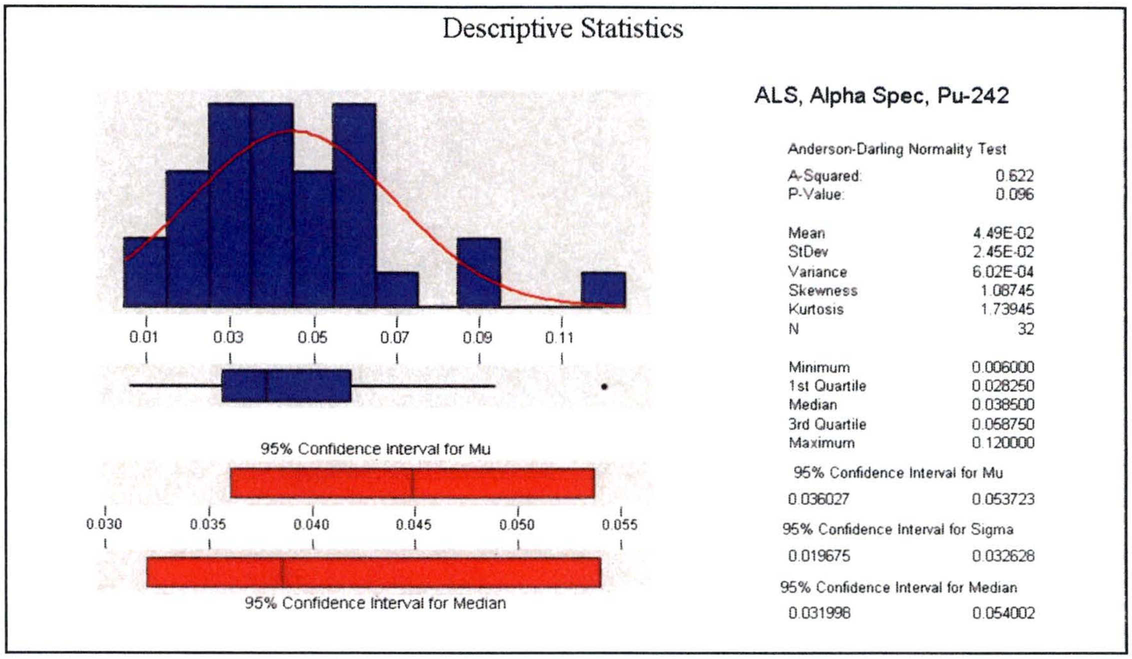

Figure 4-51 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 4

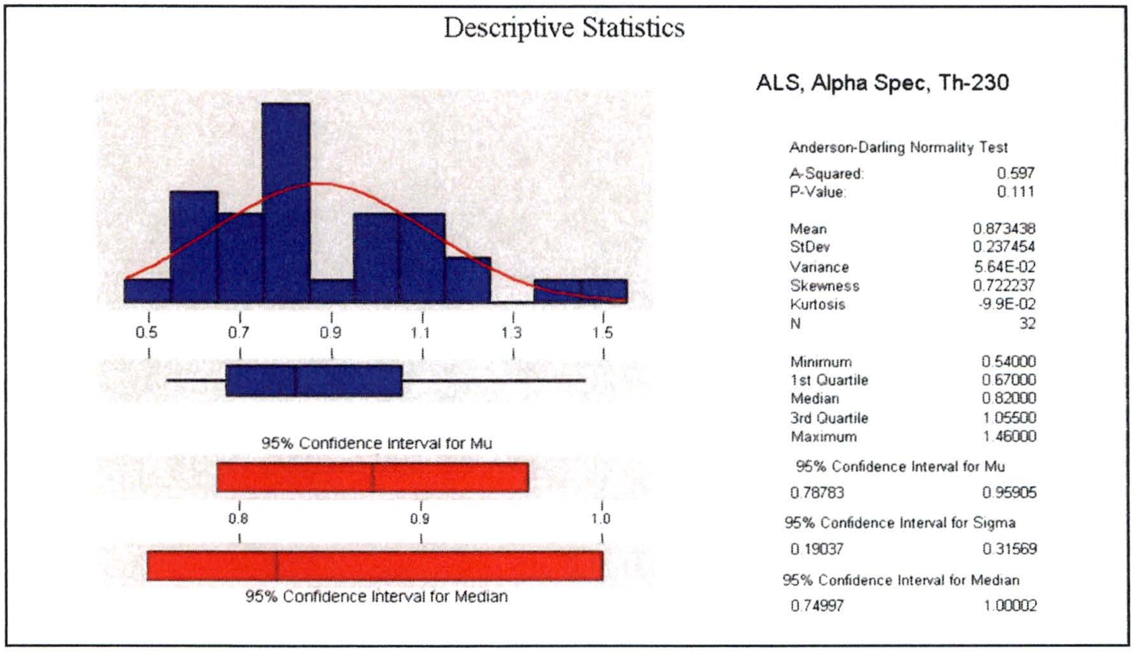

Figure 4-52 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 4

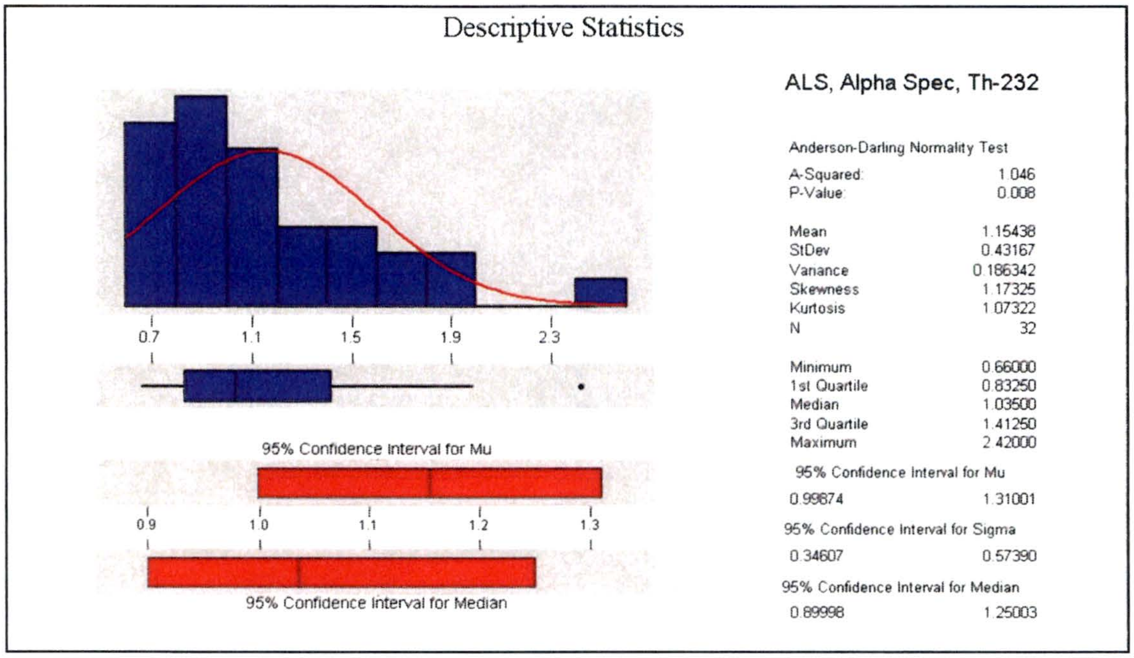

Figure 4-53 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 4

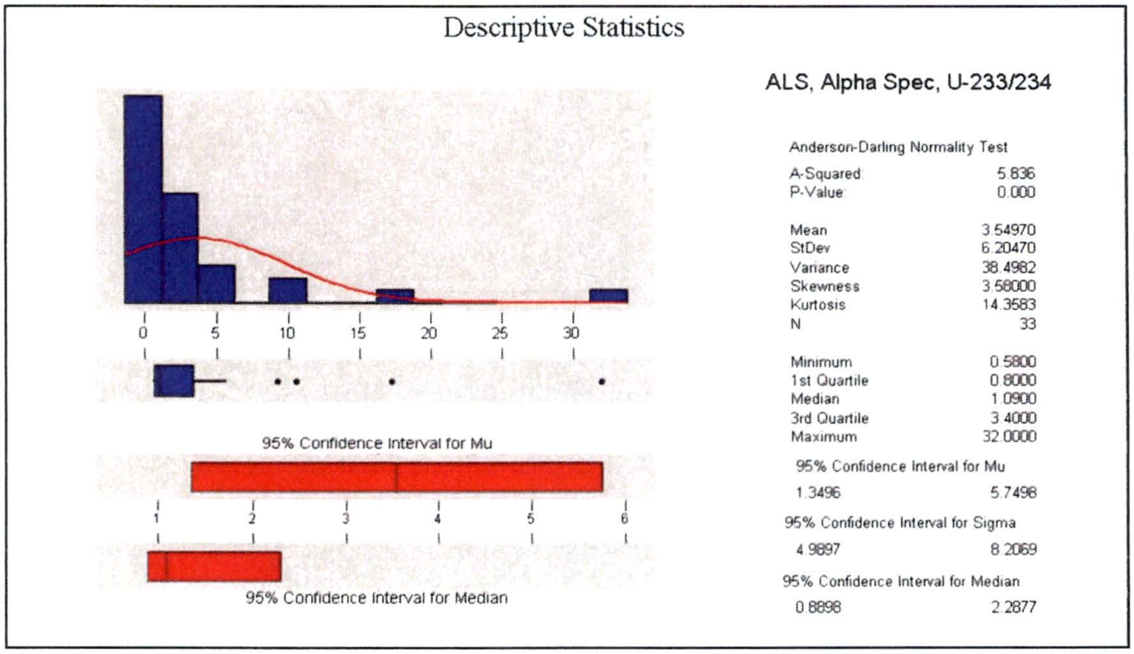

Figure 4-54 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 4

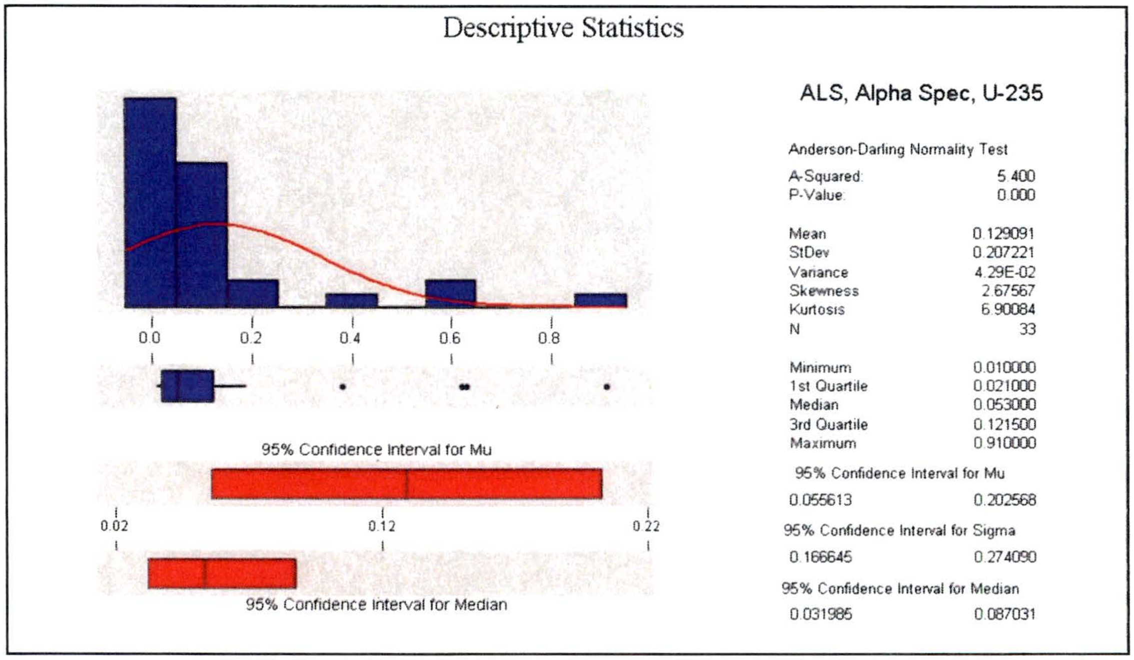

Figure 4-55 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 4

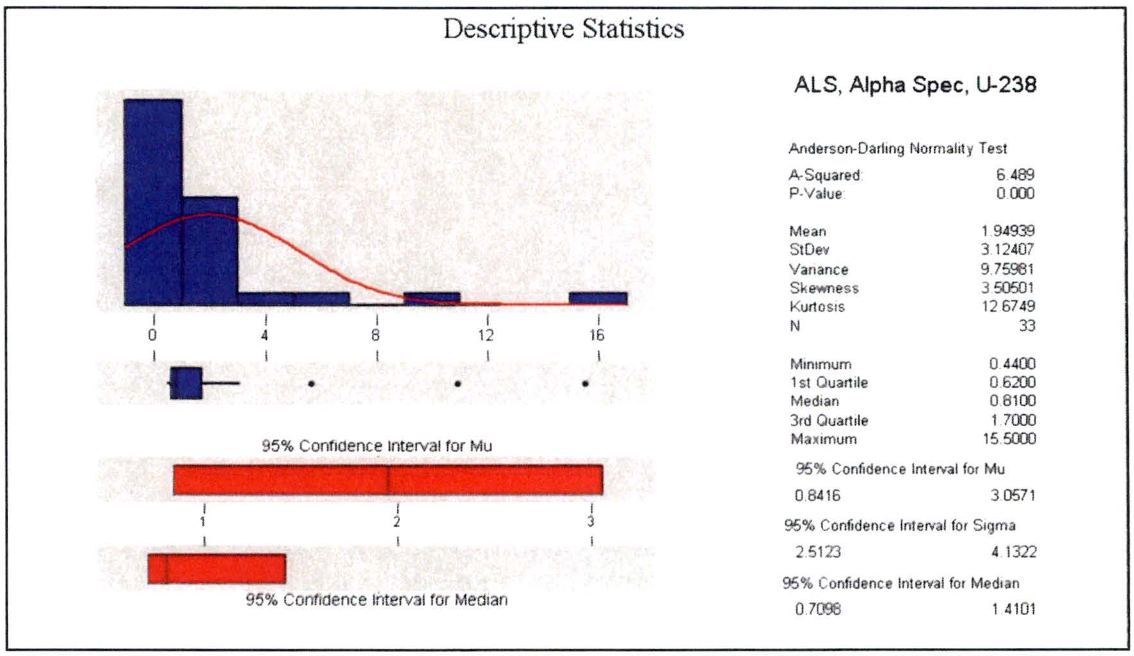

Figure 4-56 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 4

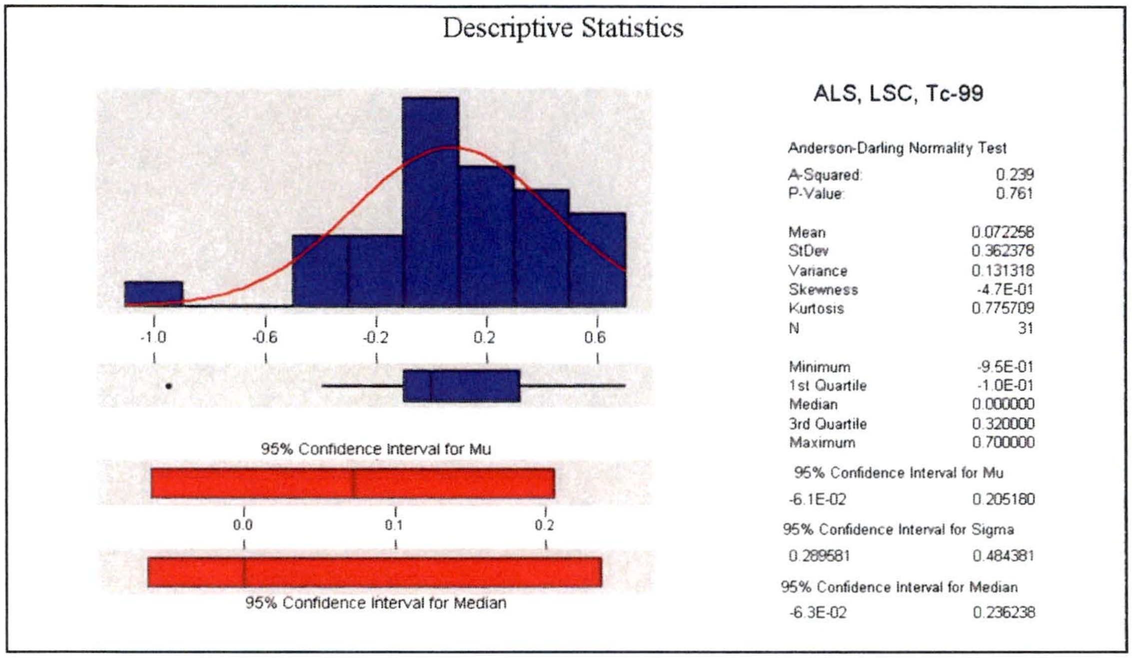

Figure 4-57 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 4

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 4 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.4 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 6

4.4.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 289 soil samples collected from Survey Unit 6 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-58), Th-232 (Figure 4-59), and Am-241 (Figure 4-60) are presented in this subsection. All isotopic data is in units of pCi/g.

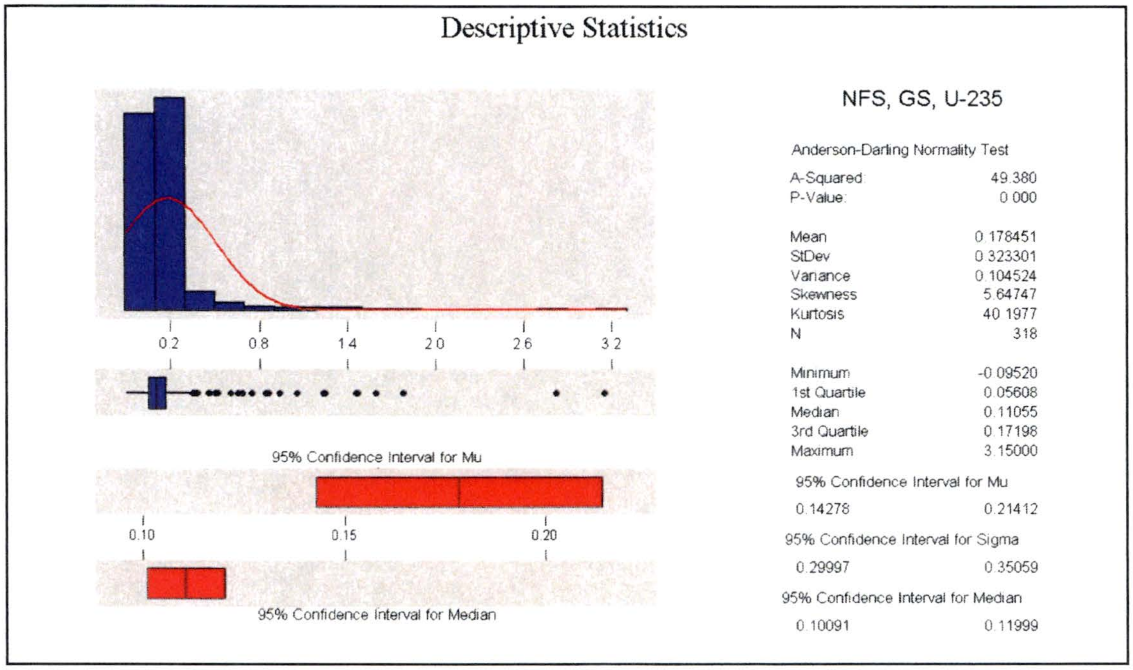

Figure 4-58 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 6

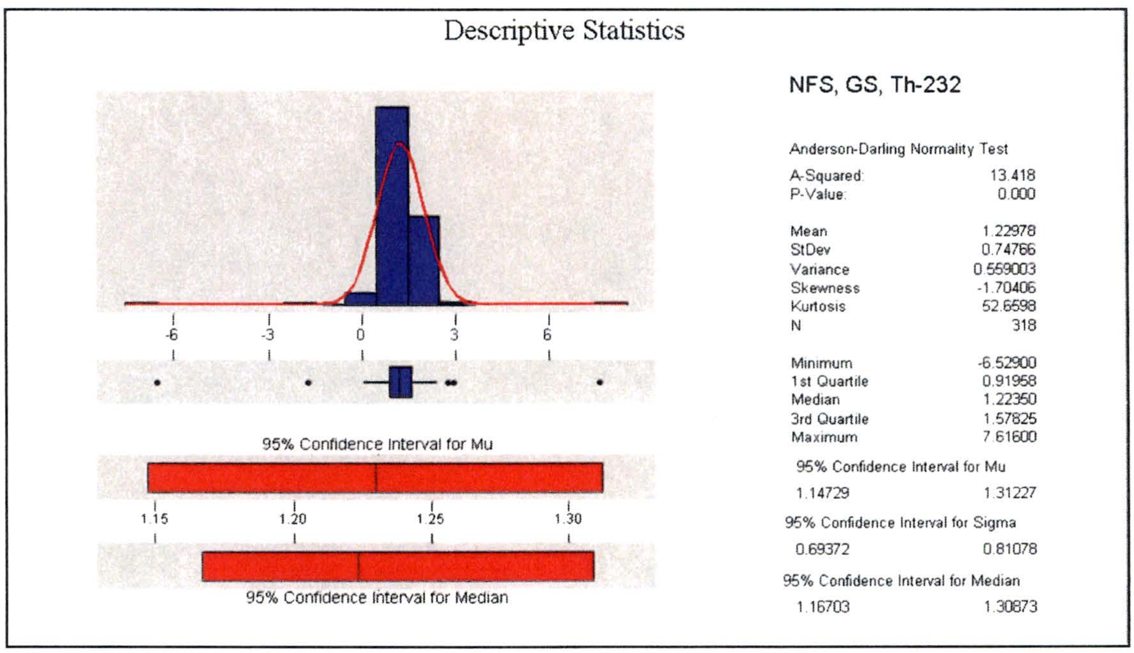

Figure 4-59 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 6

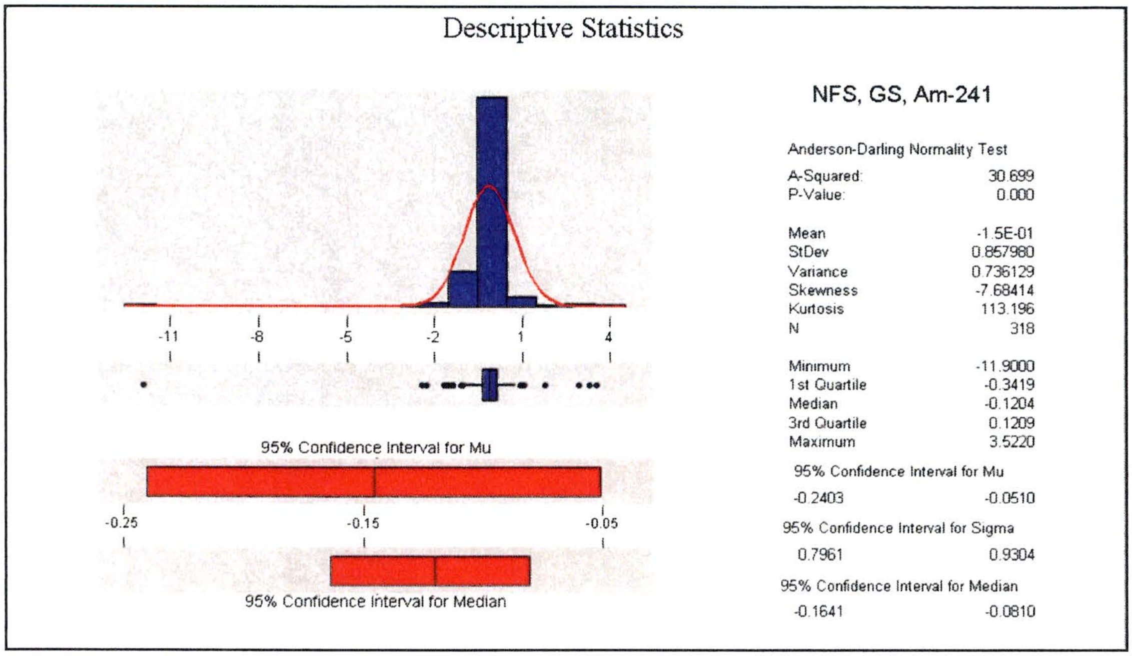

Figure 4-60 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 6

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 6 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.4.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 289 soil samples collected from Survey Unit 6, 31 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-61), Th-232 (Figure 4-62), and Am-241 (Figure 4-63) are presented in this subsection. All isotopic data is in units of pCi/g.

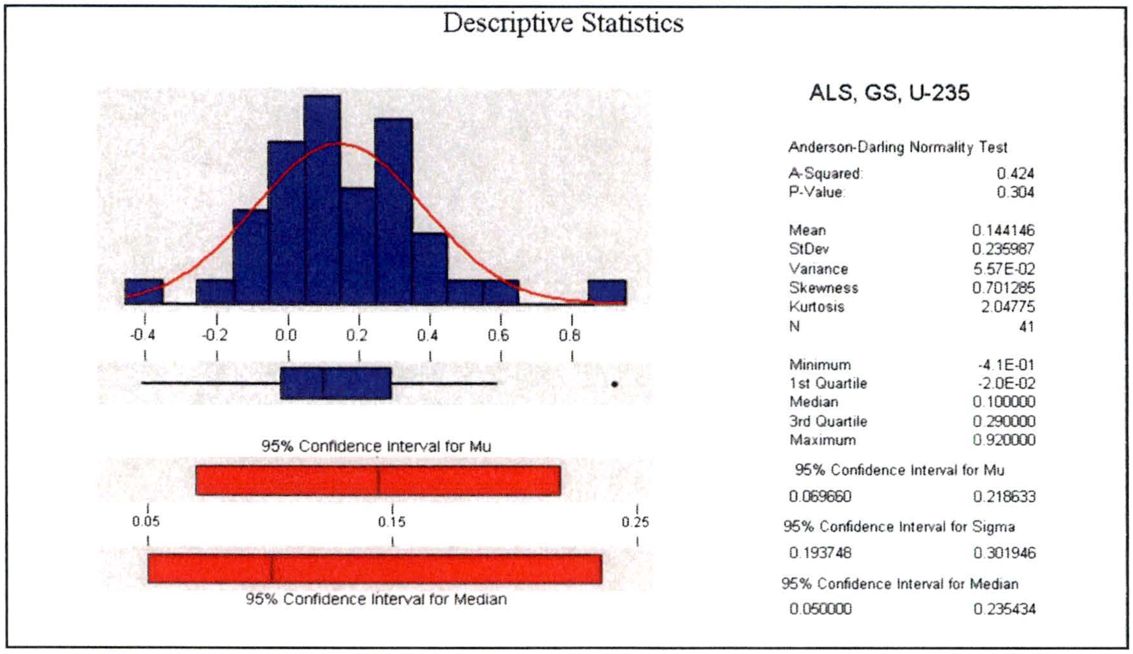

Figure 4-61 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 6

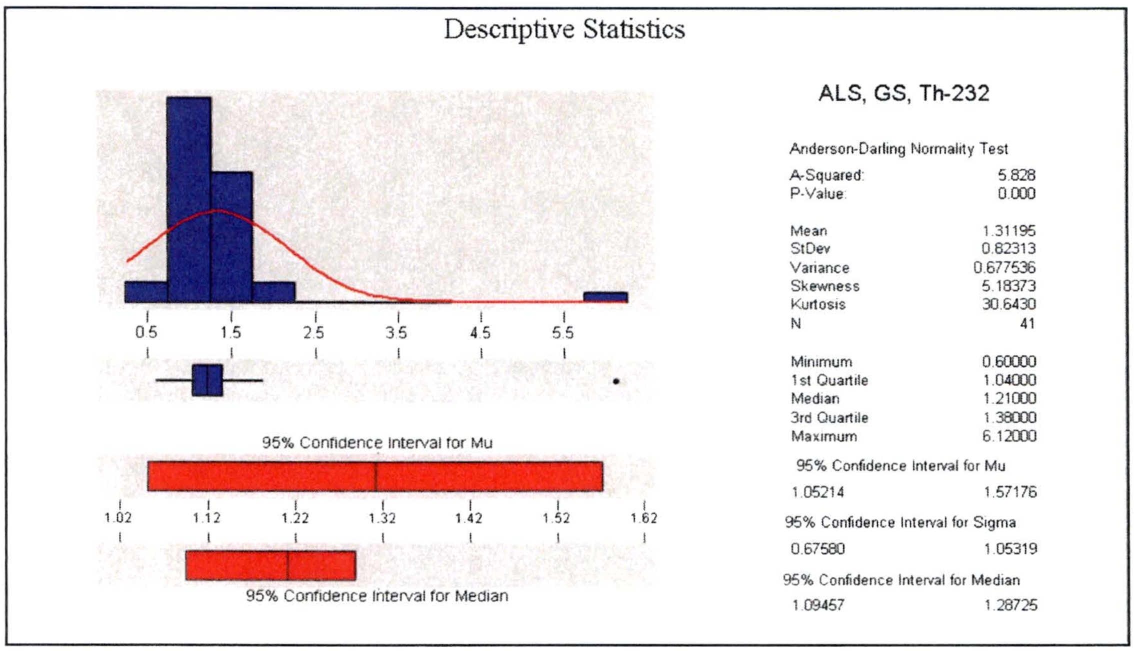

Figure 4-62 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 6

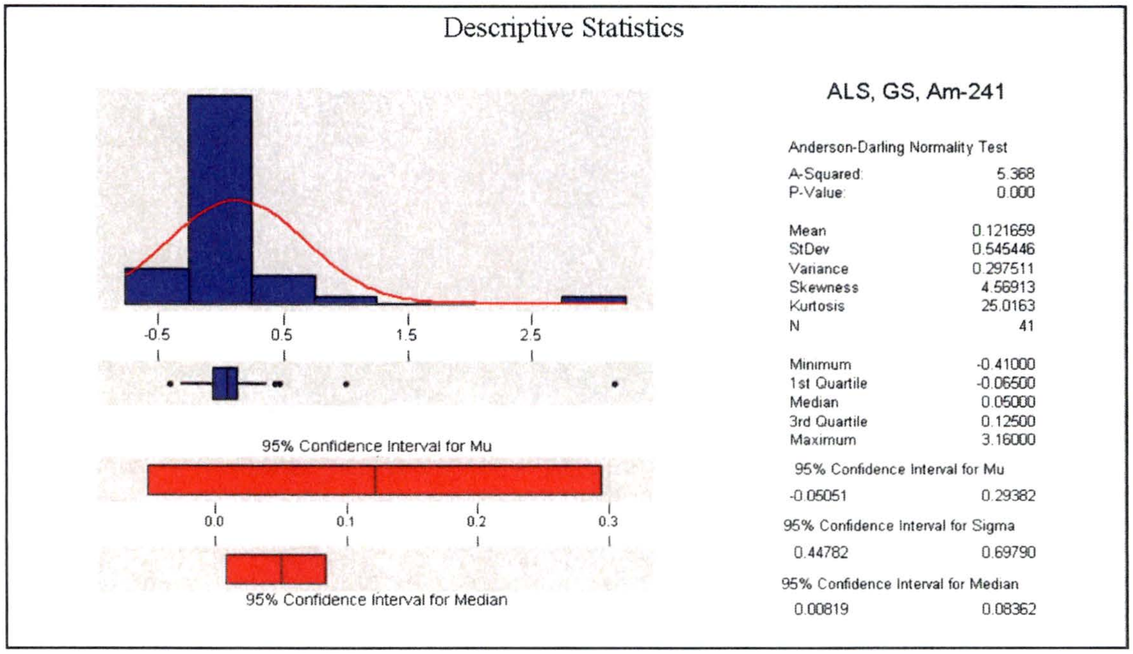

Figure 4-63 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 6

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 6 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.4.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 289 soil samples collected from Survey Unit 6, 31 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-64), Pu-238 (Figure 4-65), Pu-239/240 (Figure 4-66), Pu-241 (Figure 4-67), Pu-242 (Figure 4-68), Th-230 (Figure 4-69), Th-232 (Figure 4-70), U-233/234 (Figure 4-71), U-235 (Figure 4-72), U-238 (Figure 4-73) are presented in this subsection. Additional duplicate samples were collected for Tc-99 resulting in a total of 45 samples (Figure 4-74). Again, all isotopic data is in units of pCi/g.

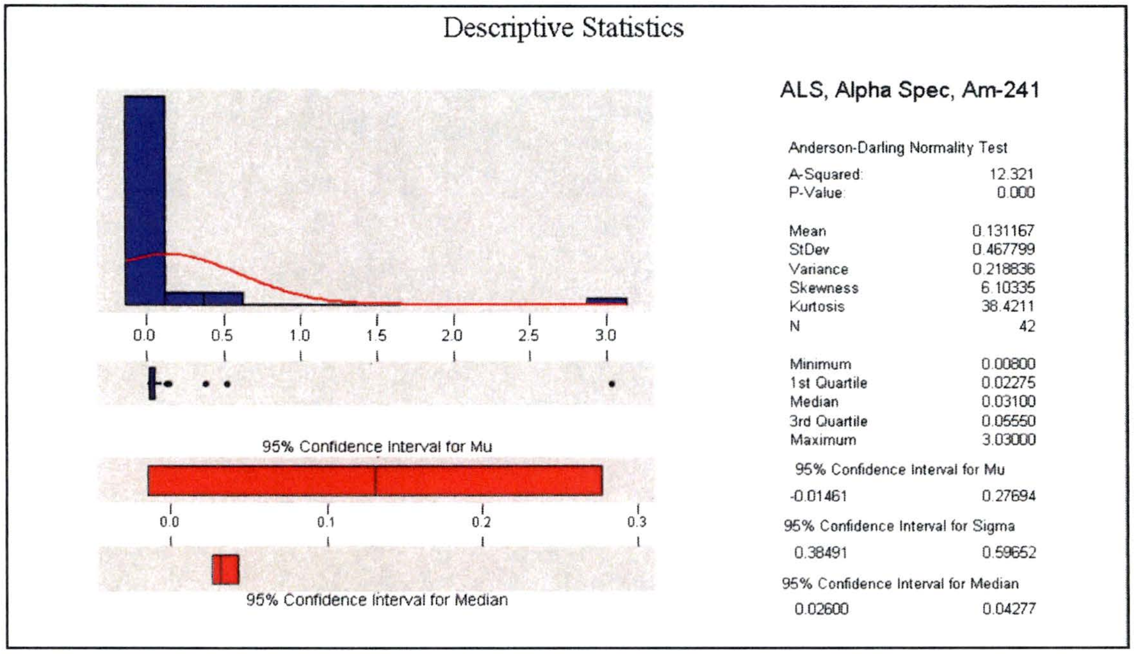

Figure 4-64 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 6

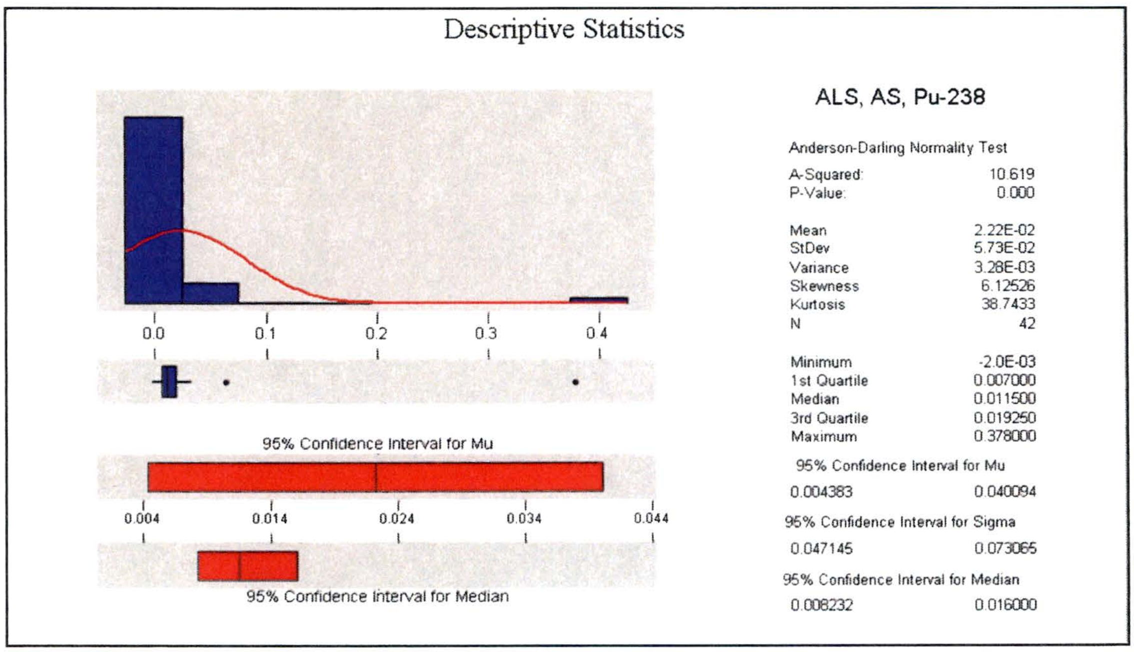

Figure 4-65 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 6

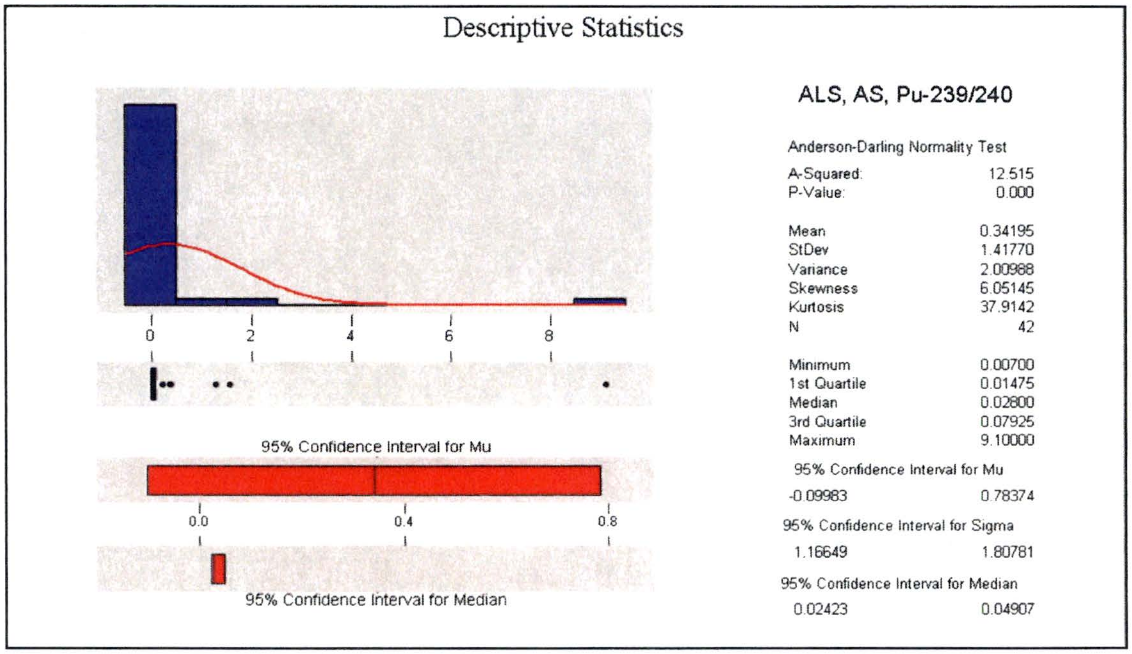

Figure 4-66 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 6

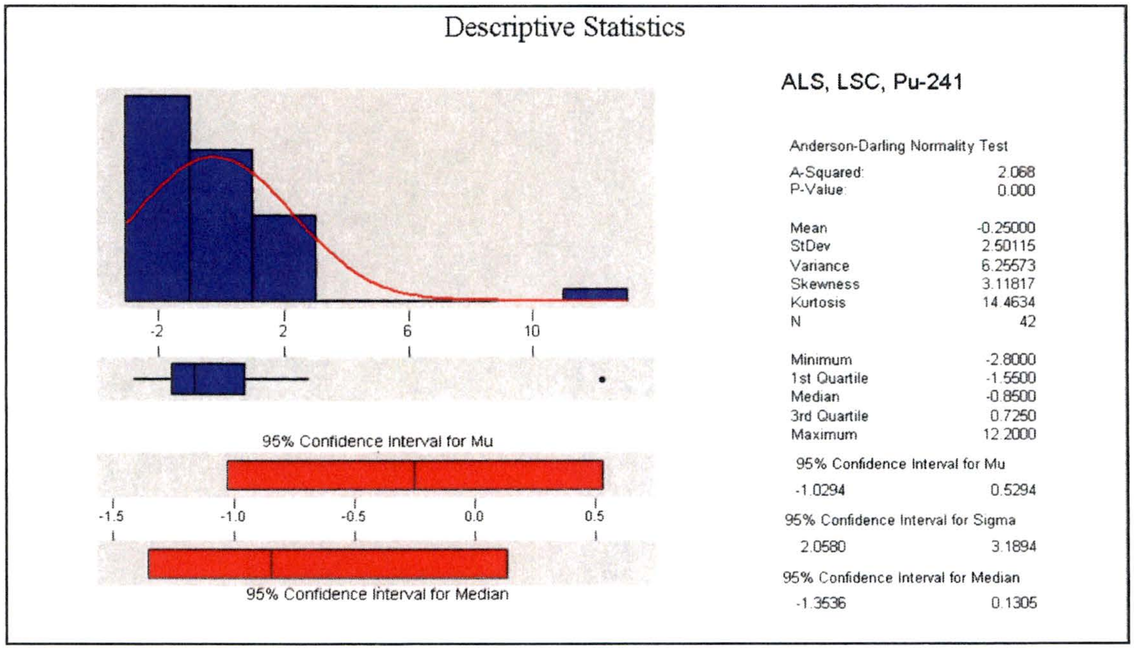

Figure 4-67 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 6

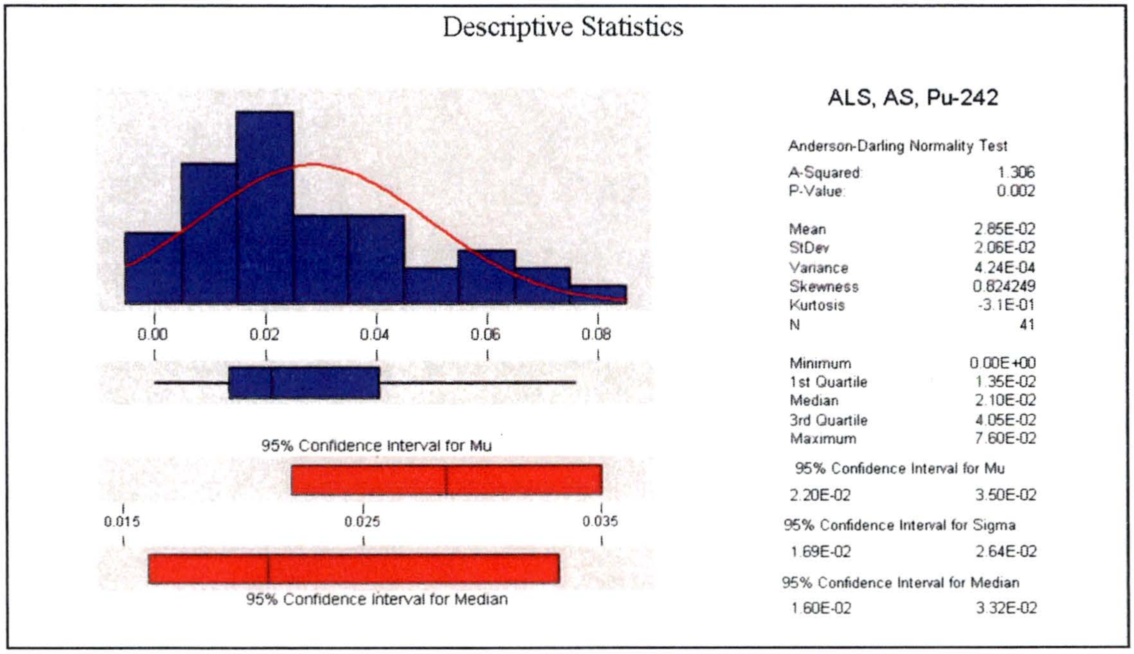

Figure 4-68 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 6

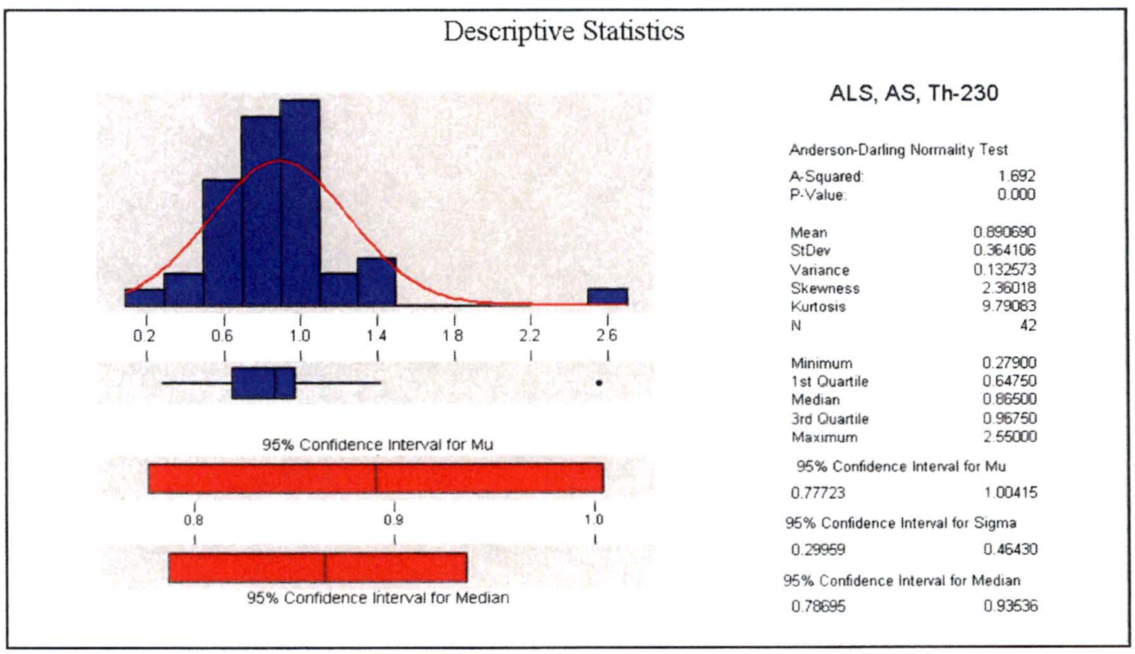

Figure 4-69 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 6

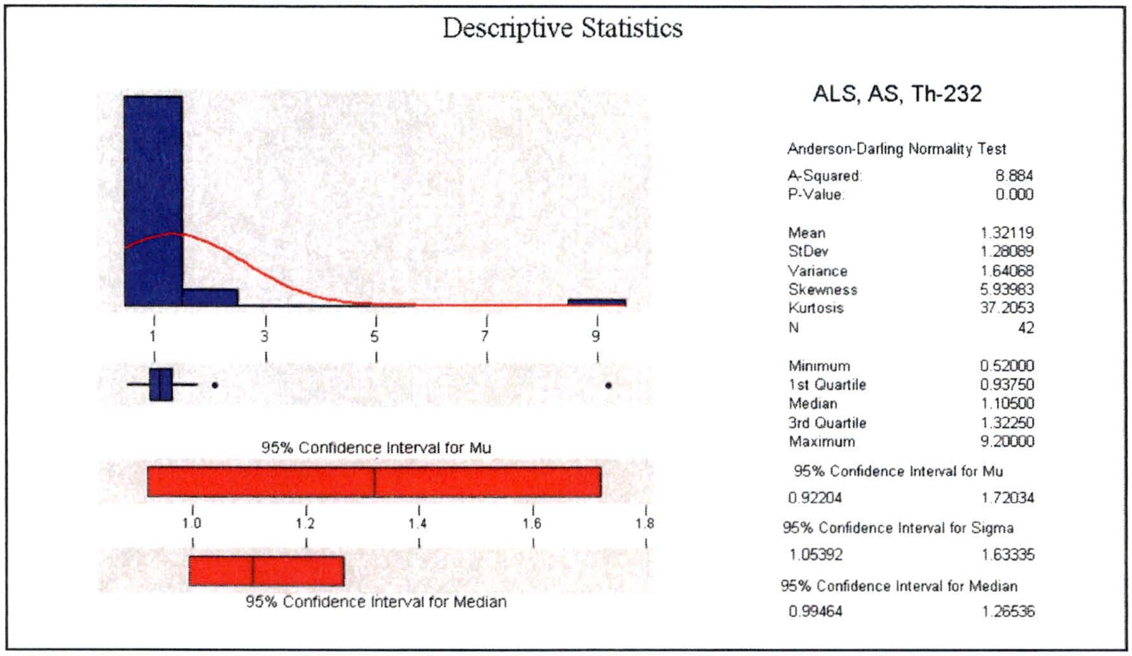

Figure 4-70 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 6

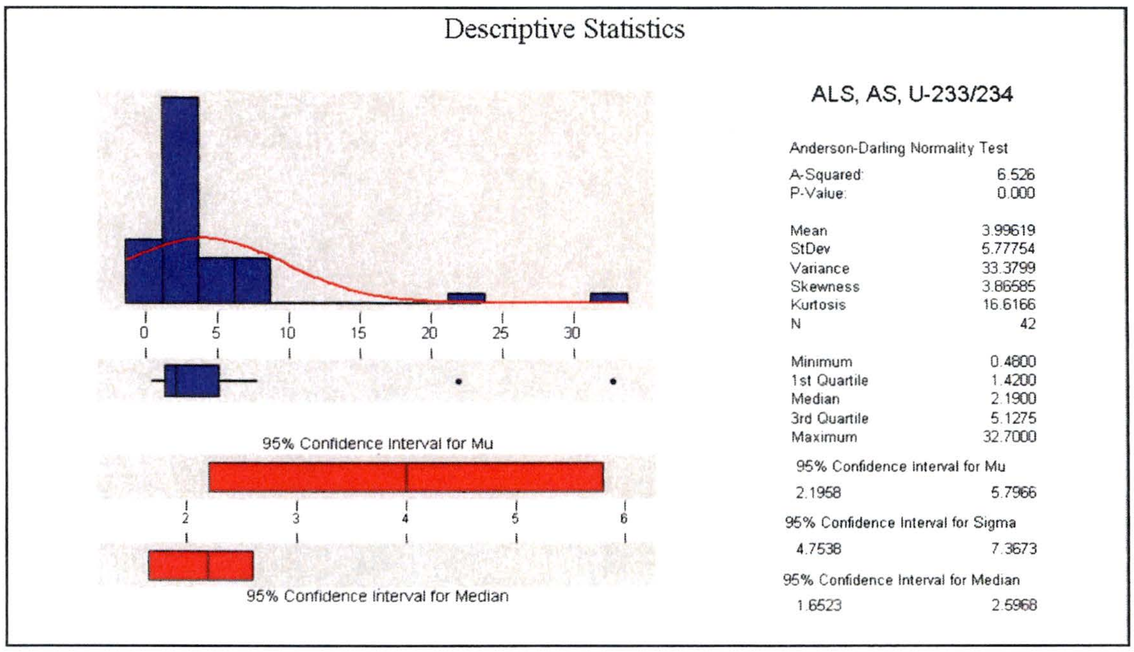

Figure 4-71 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 6

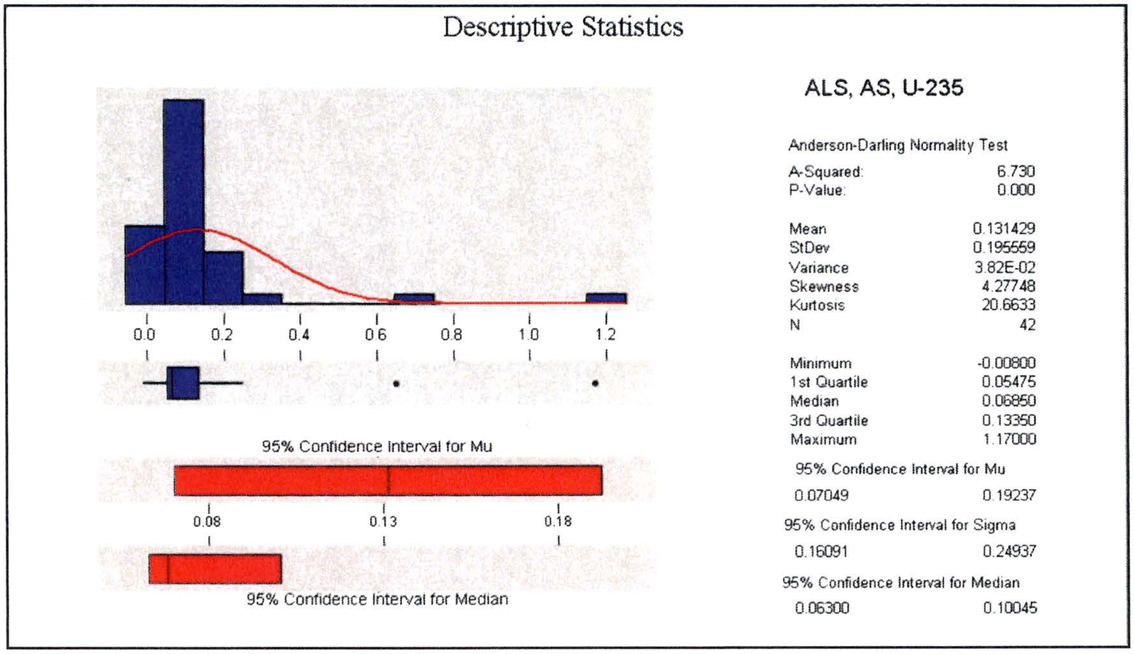

Figure 4-72 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 6

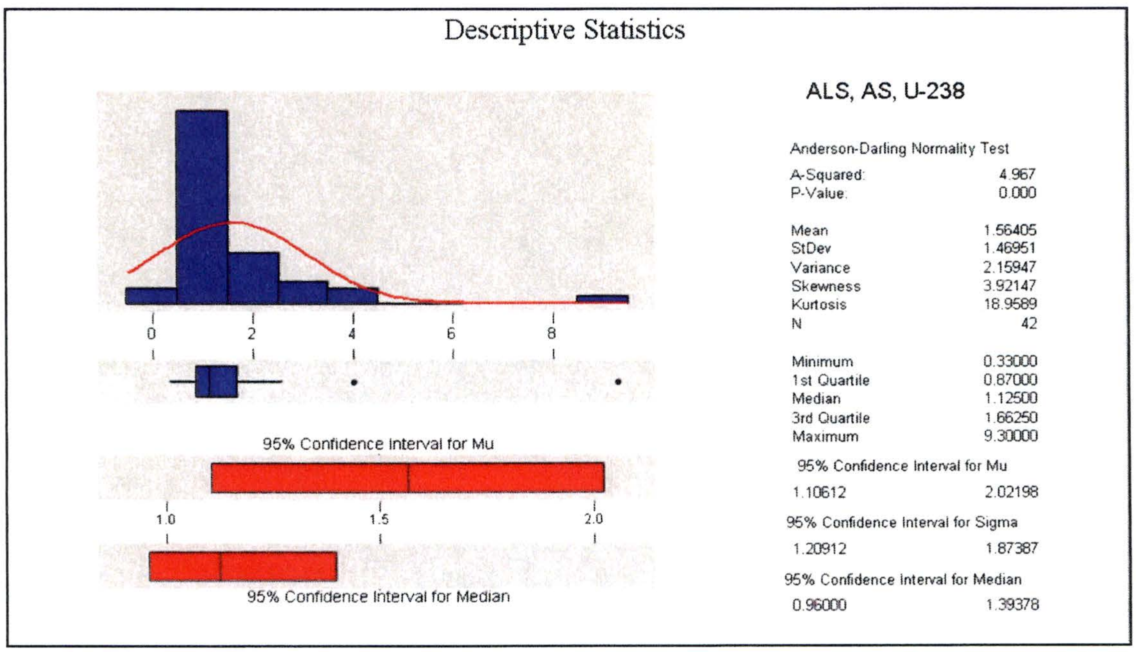

Figure 4-73 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 6

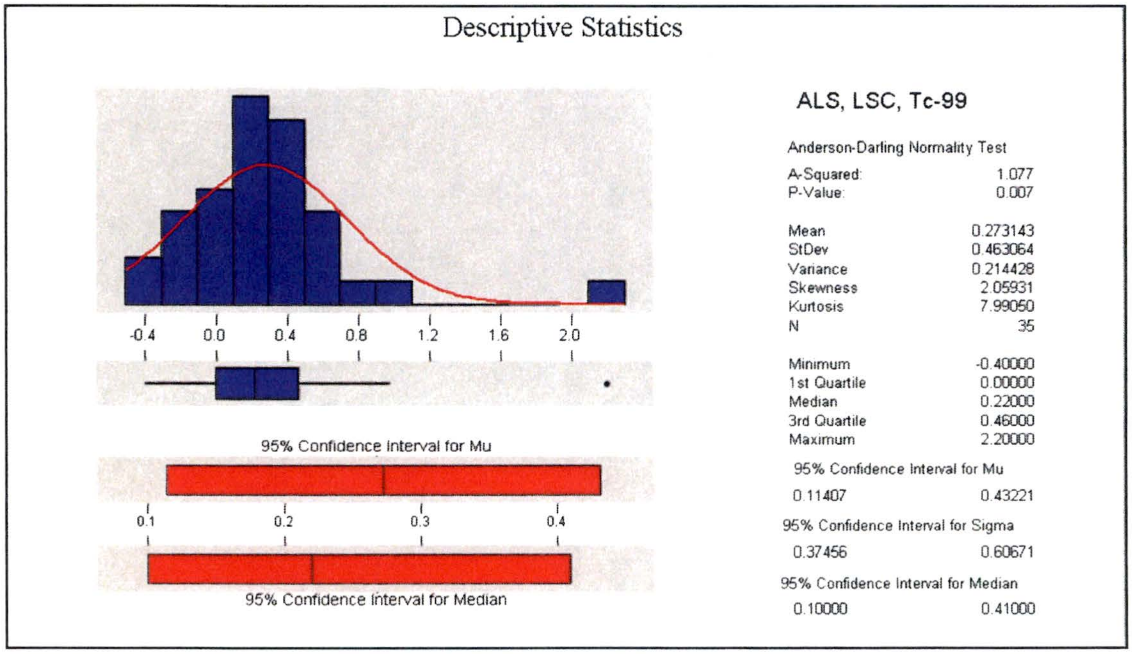

Figure 4-74 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 6

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 6 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.5 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 7

4.5.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 219 soil samples collected from Survey Unit 7 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-75), Th-232 (Figure 4-76), and Am-241 (Figure 4-77) are presented in this subsection. All isotopic data is in units of pCi/g.

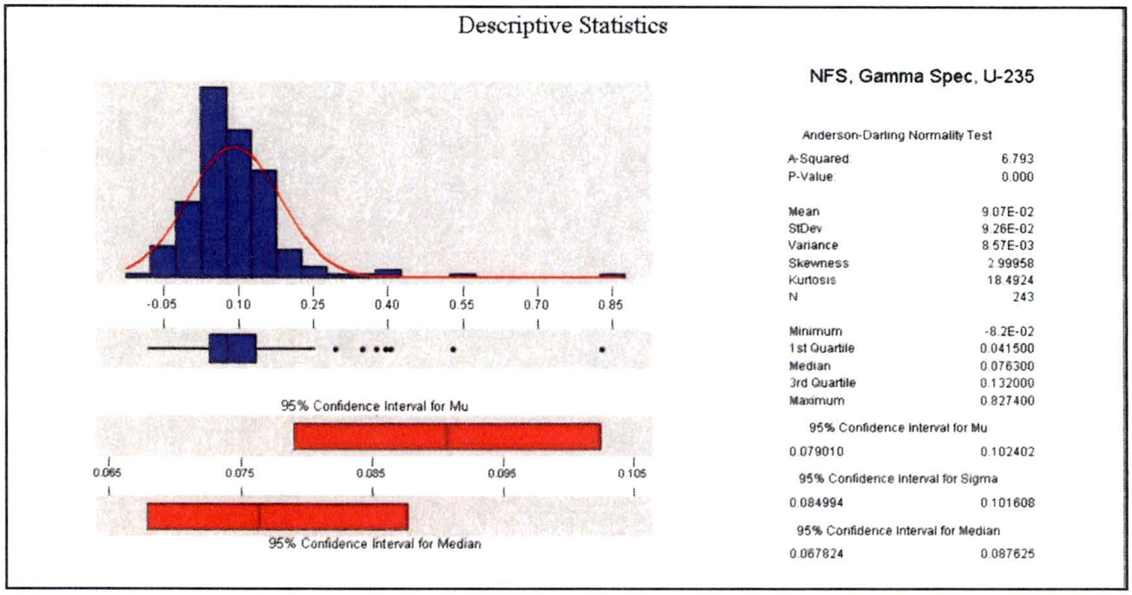

Figure 4-75 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 7

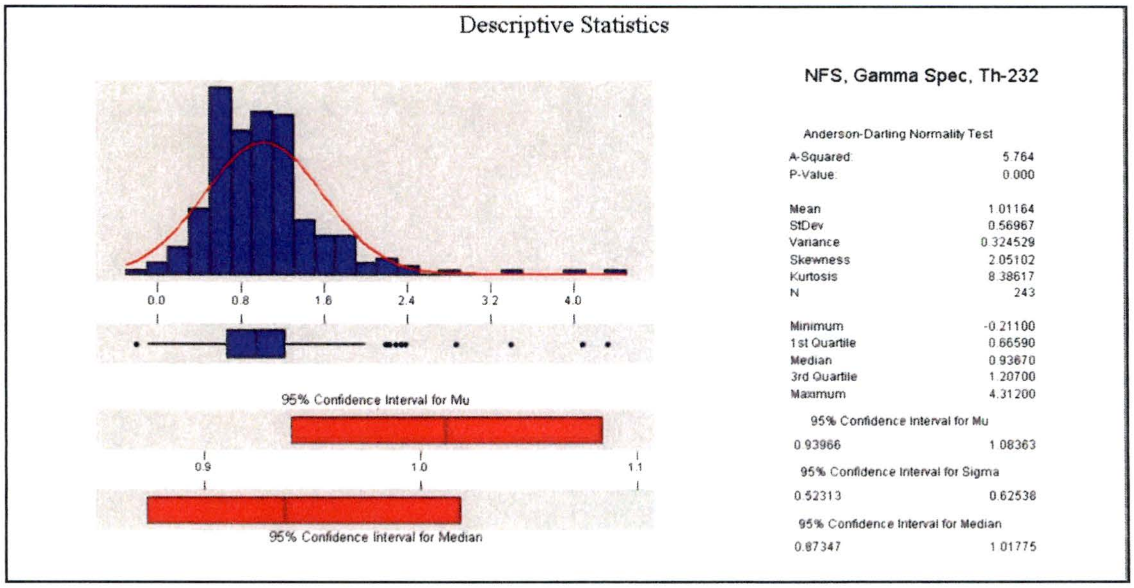

Figure 4-76 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 7

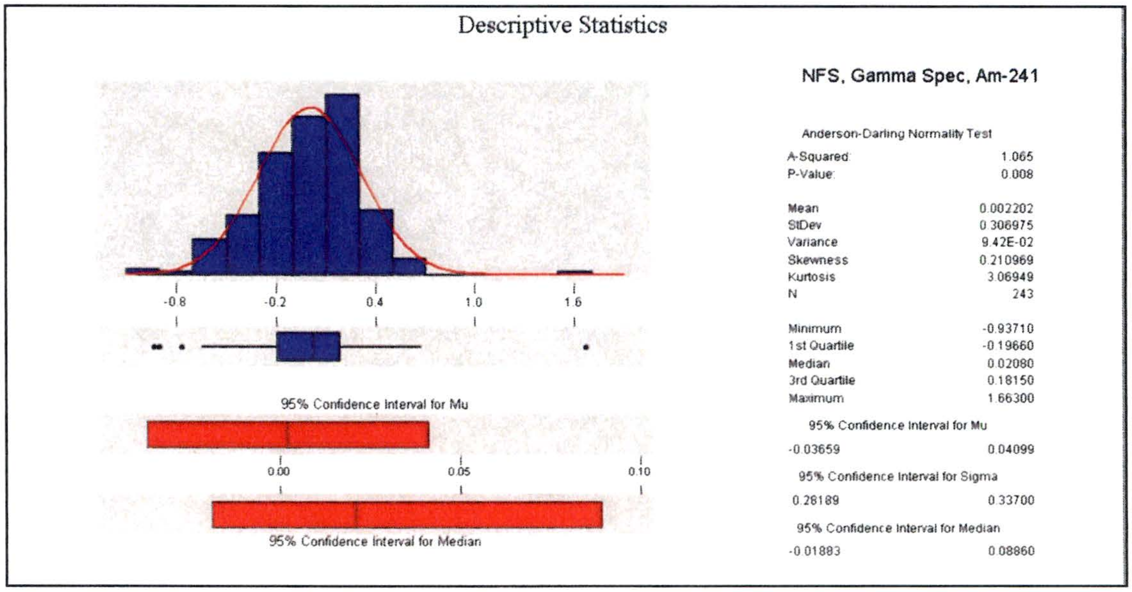

Figure 4-77 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 7

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 7 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.5.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 219 soil samples collected from Survey Unit 7, 22 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-78), Th-232 (Figure 4-79), and Am-241 (Figure 4-80) are presented in this subsection. All isotopic data is in units of pCi/g.

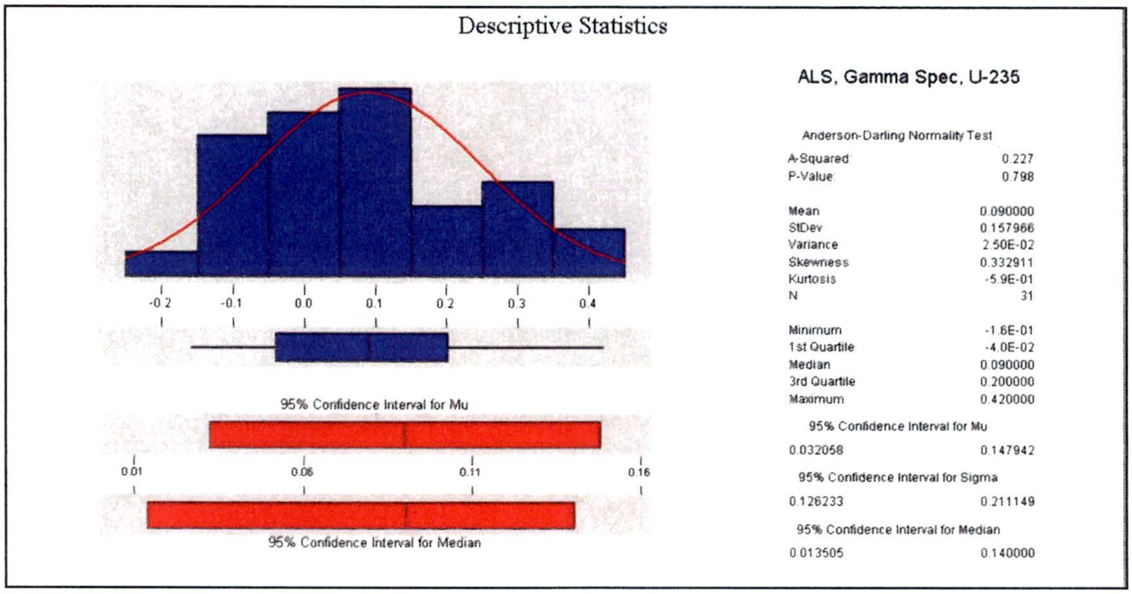

Figure 4-78 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 7

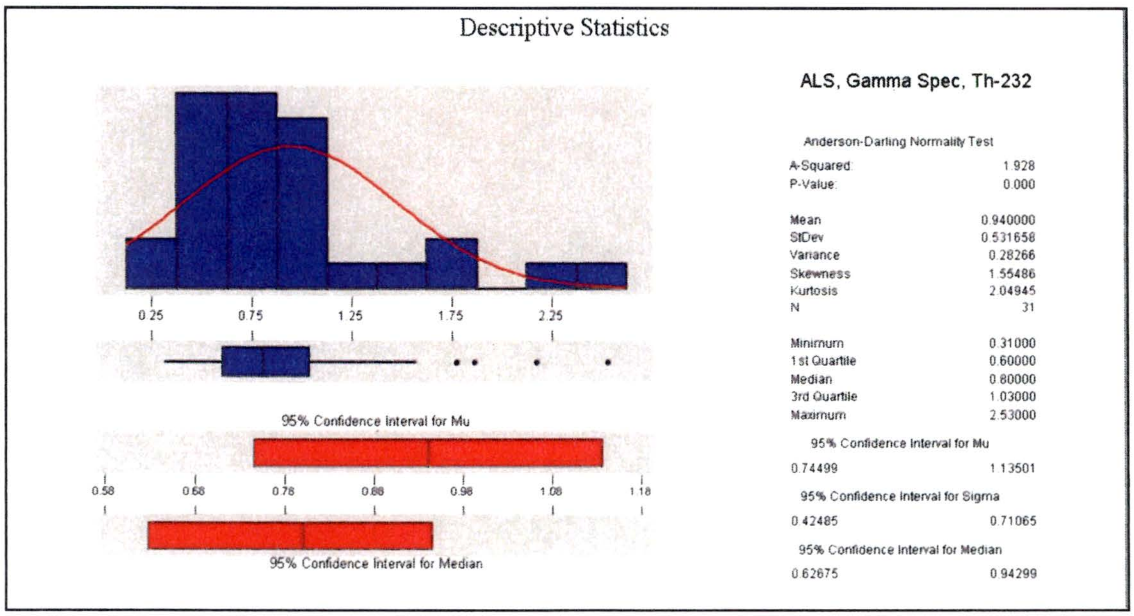

Figure 4-79 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 7

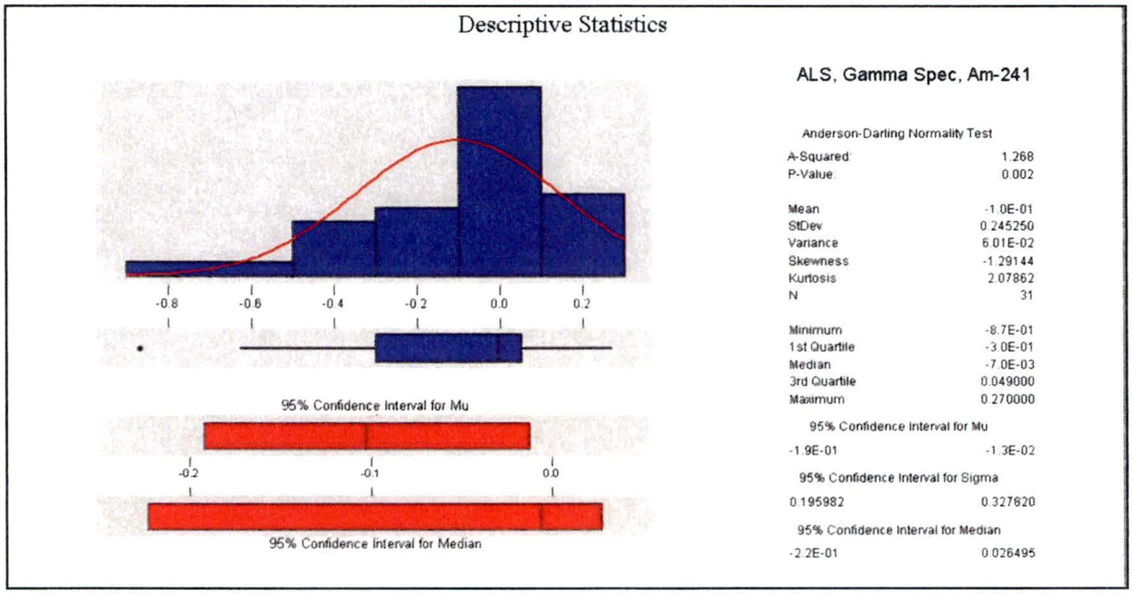

Figure 4-80 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 7

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 7 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.5.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 219 soil samples collected from Survey Unit 7, 22 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-81), Pu-238 (Figure 4-82), Pu-239/240 (Figure 4-83), Pu-241 (Figure 4-84), Pu-242 (Figure 4-85), Th-230 (Figure 4-86), Th-232 (Figure 4-87), U-233/234 (Figure 4-88), U-235 (Figure 4-89), U-238 (Figure 4-90), and Tc-99 (Figure 4-91) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

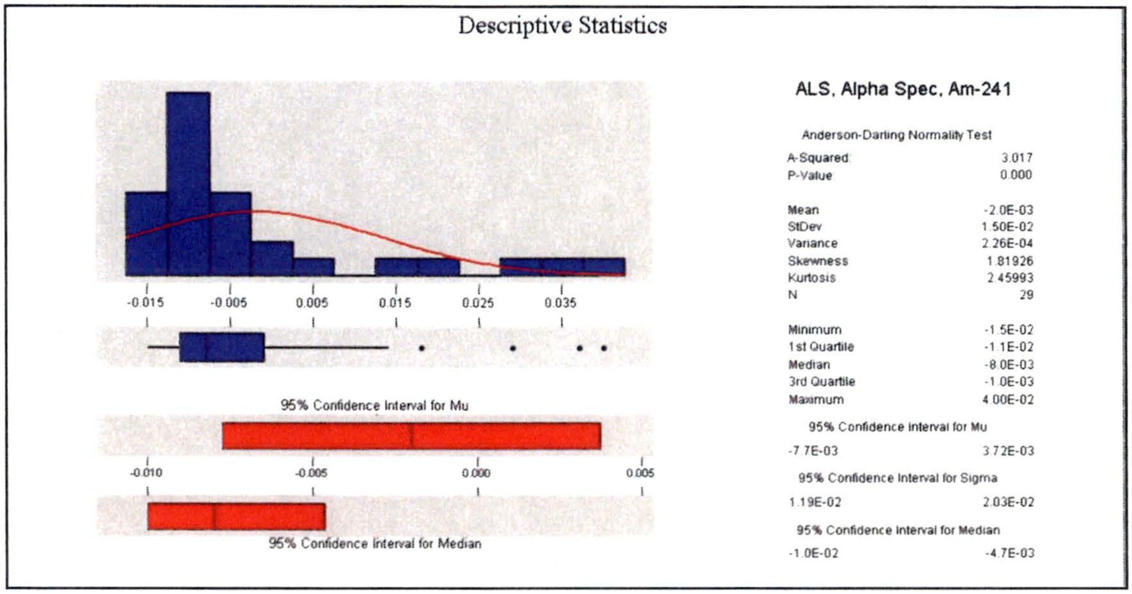

Figure 4-81 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 7

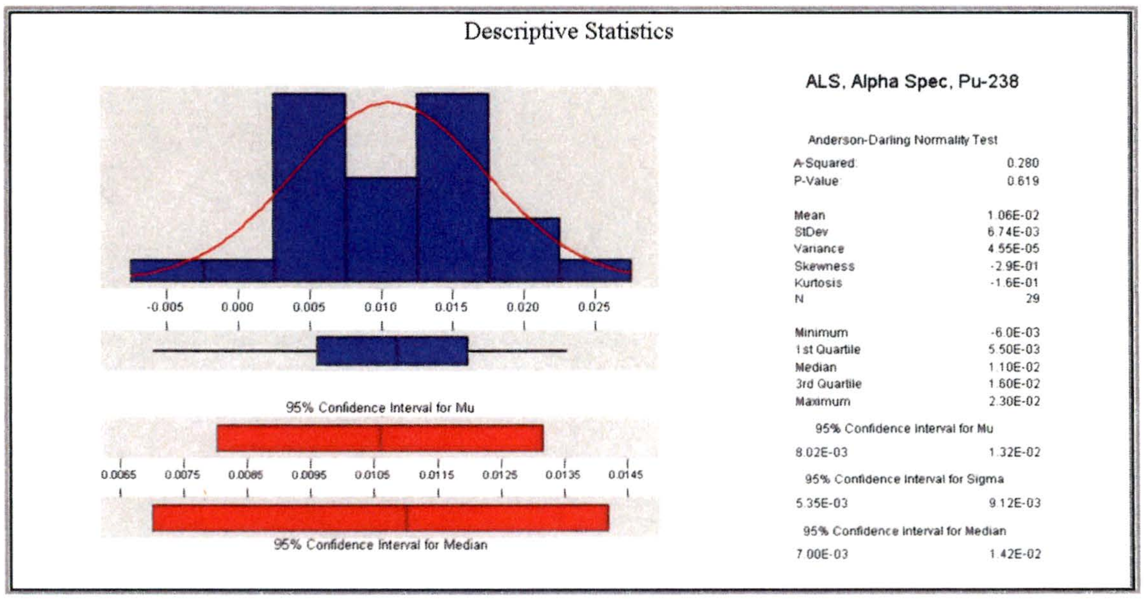

Figure 4-82 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 7

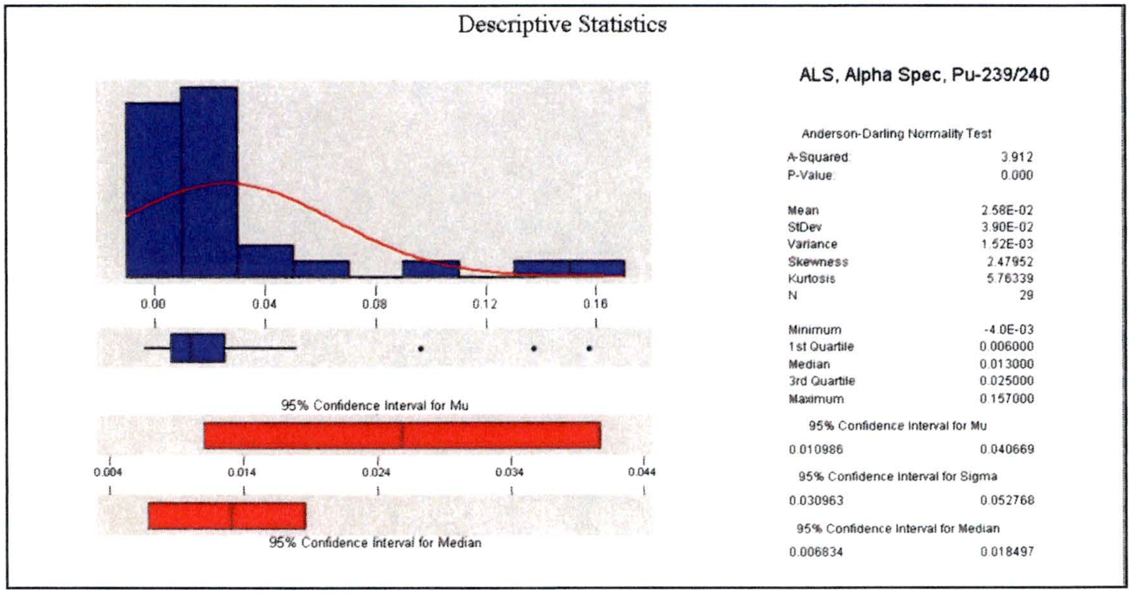

Figure 4-83 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 7

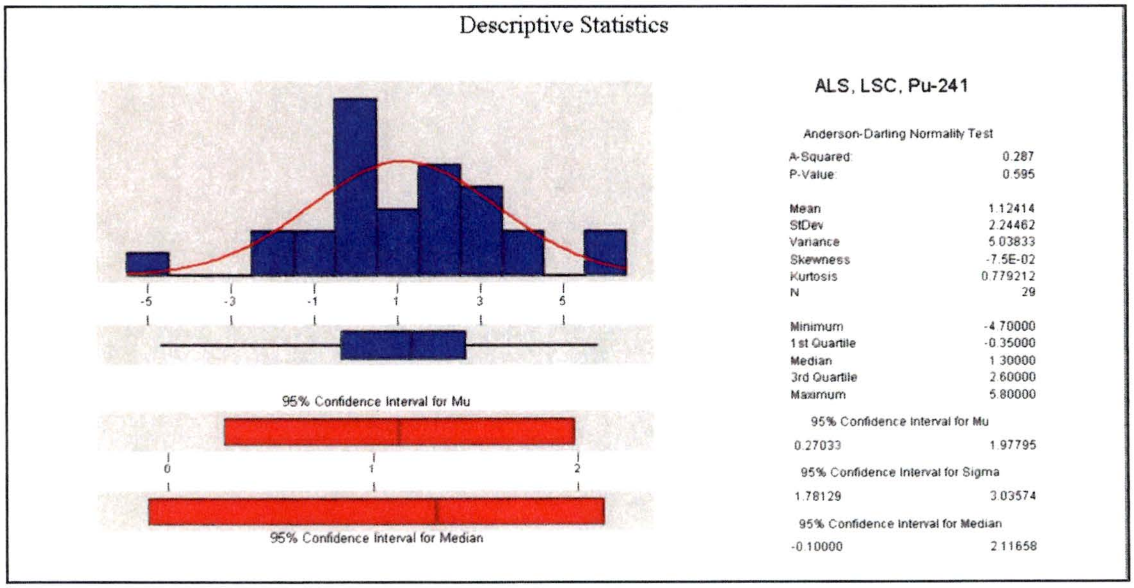

Figure 4-84 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 7

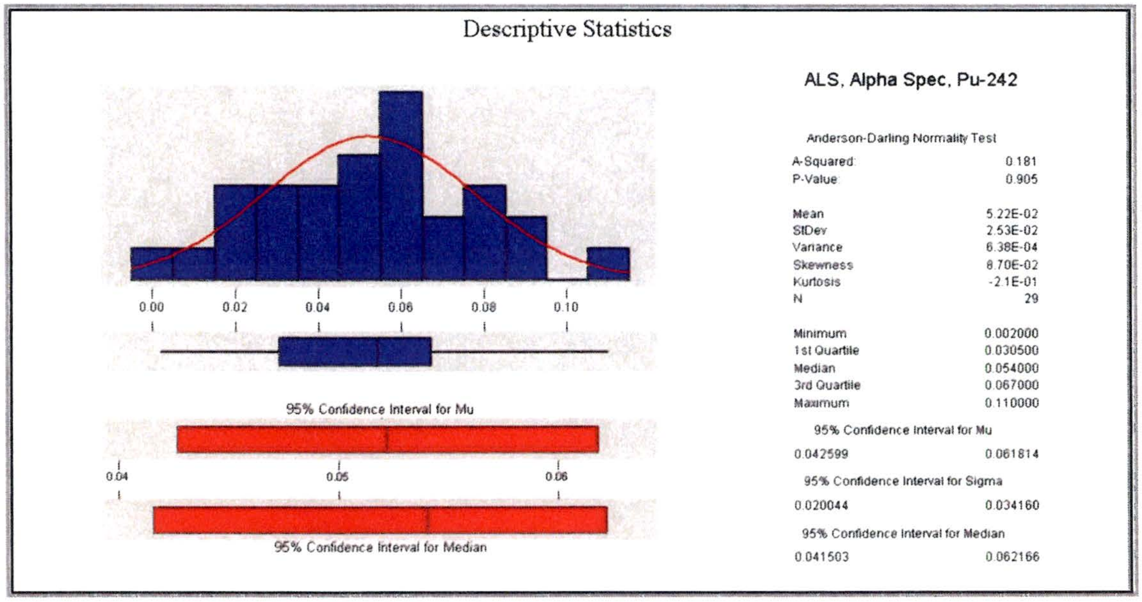

Figure 4-85 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 7

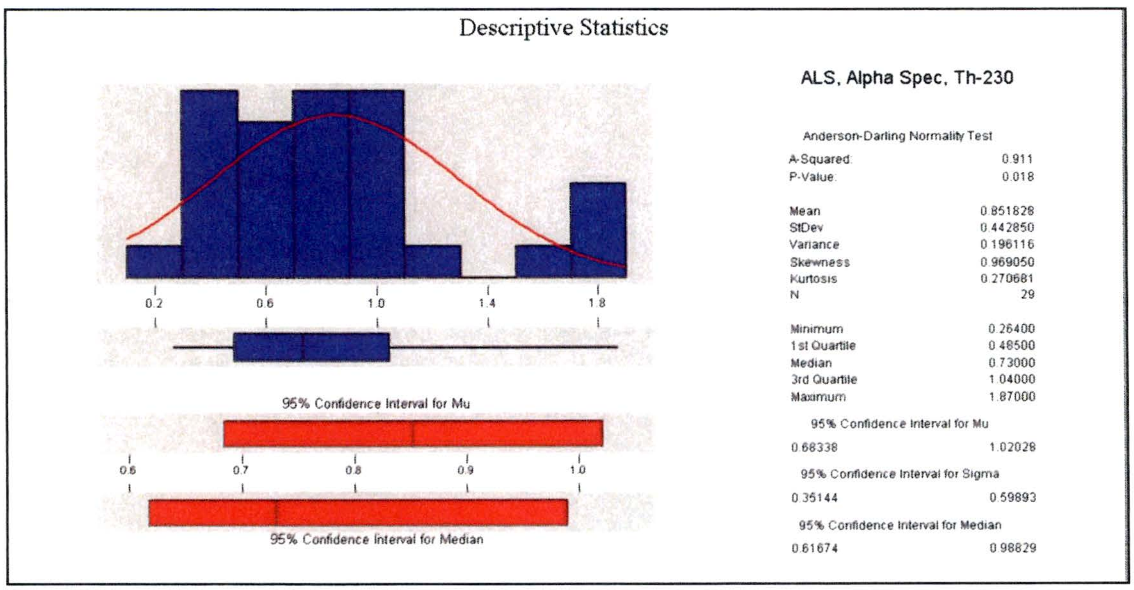

Figure 4-86 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 7

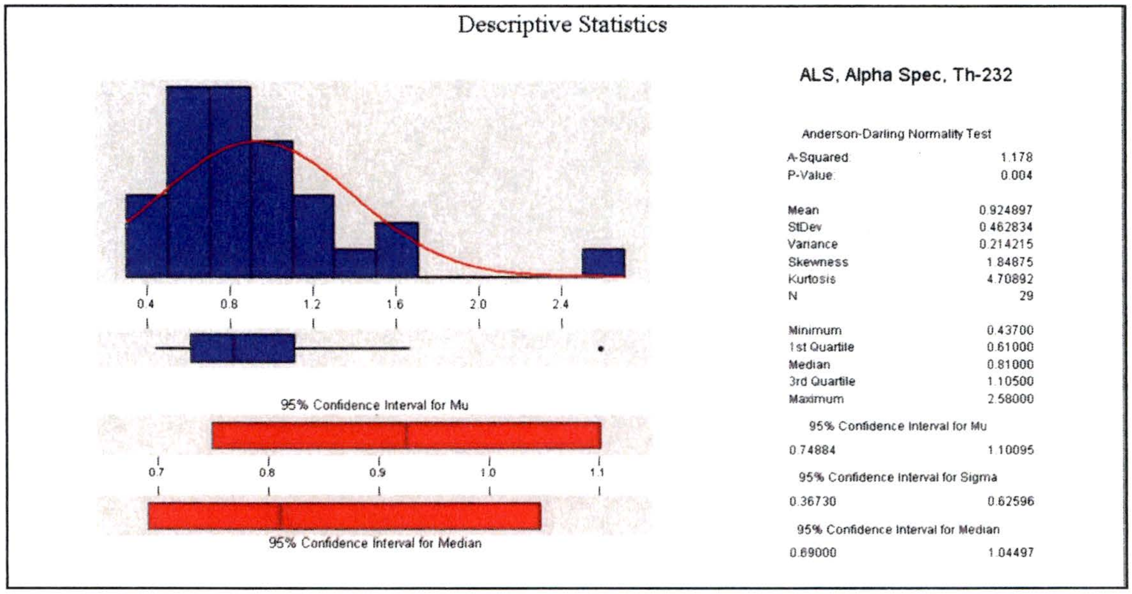

Figure 4-87 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 7

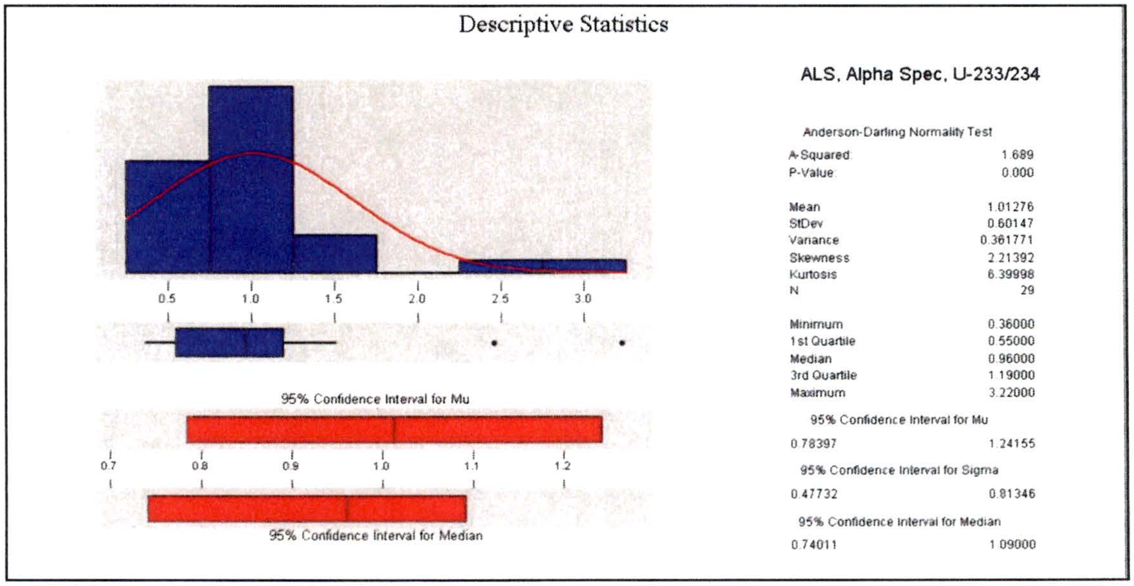

Figure 4-88 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 7

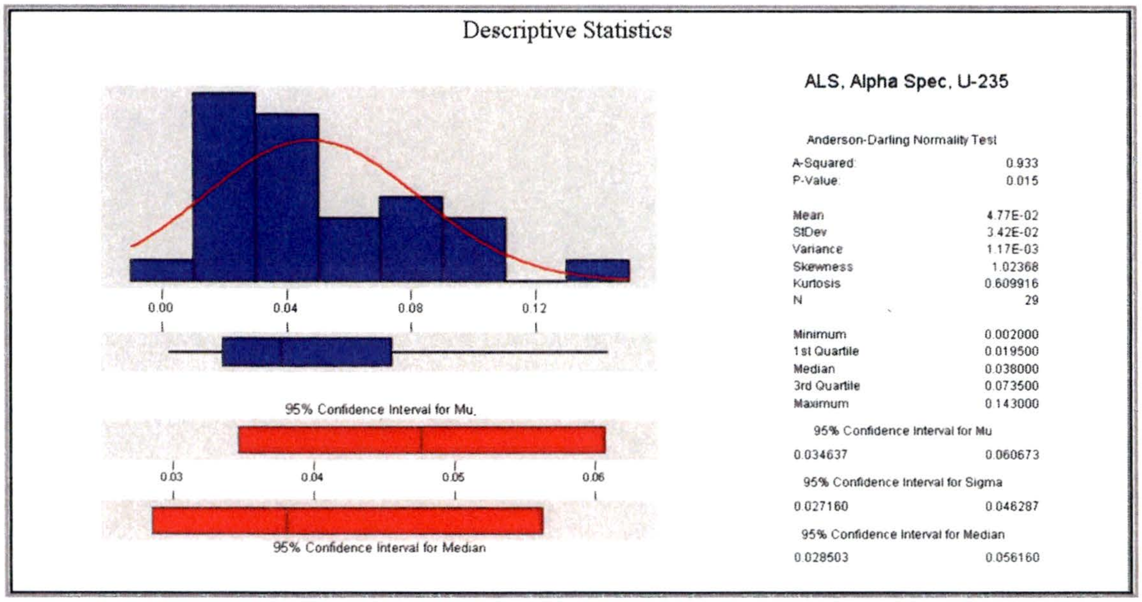

Figure 4-89 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 7

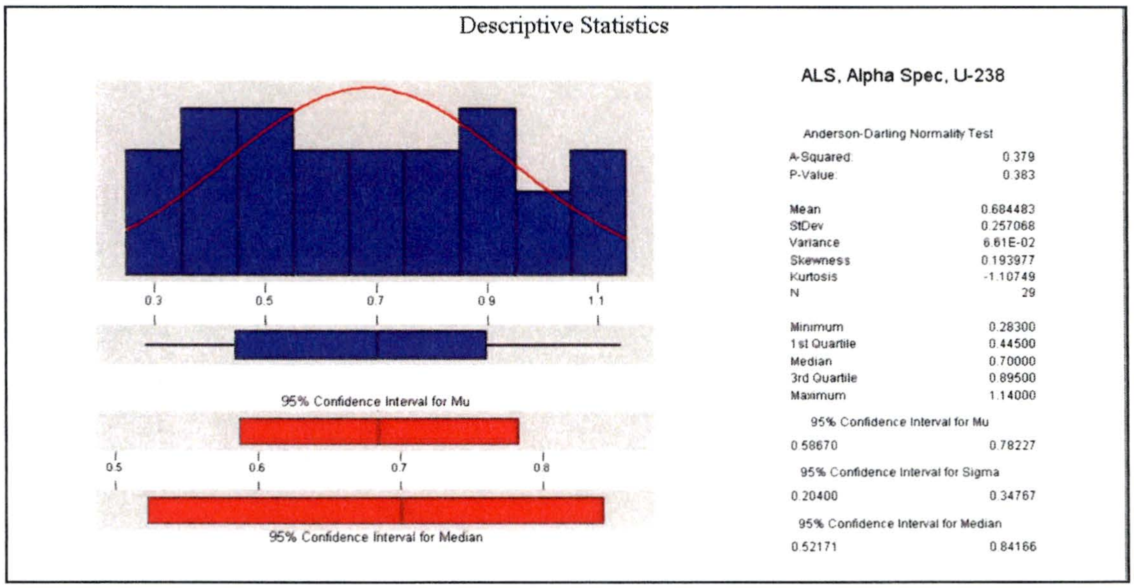

Figure 4-90 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 7

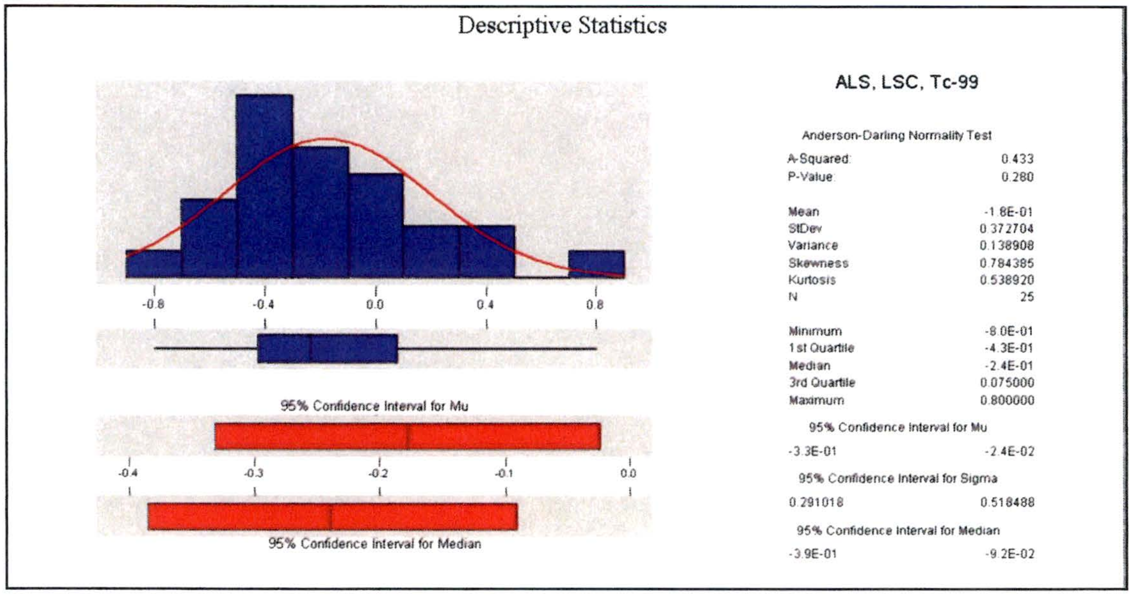

Figure 4-91 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 7

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 7 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.6 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 12

4.6.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 209 soil samples collected from Survey Unit 12 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-92), Th-232 (Figure 4-93), and Am-241 (Figure 4-94) are presented in this subsection. All isotopic data is in units of pCi/g.

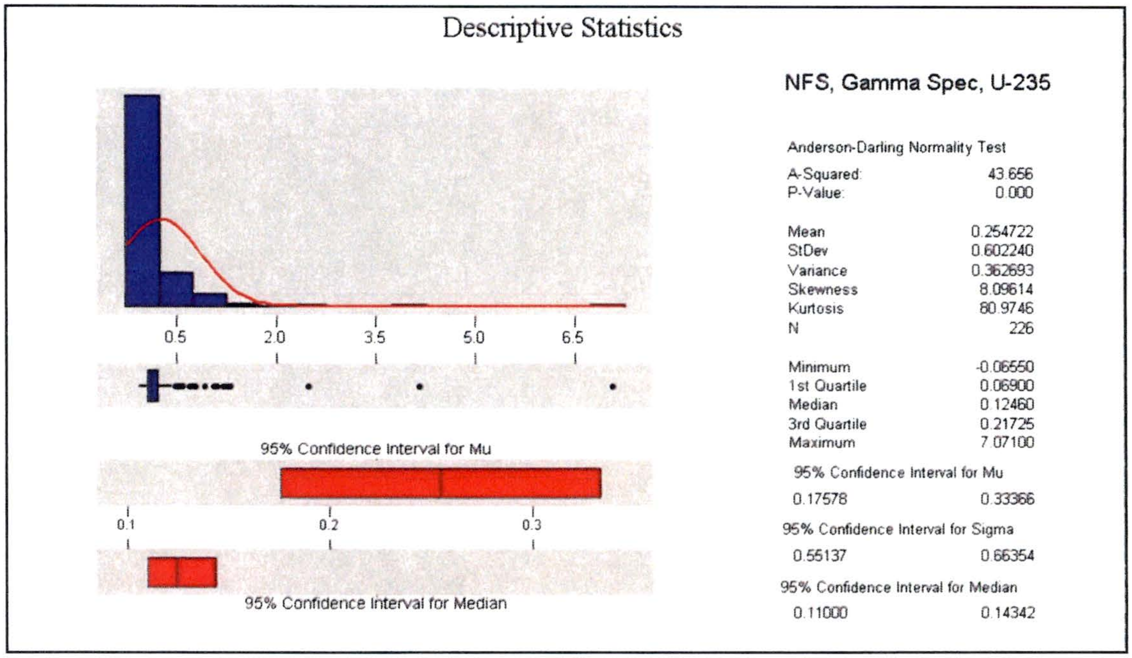

Figure 4-92 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 12

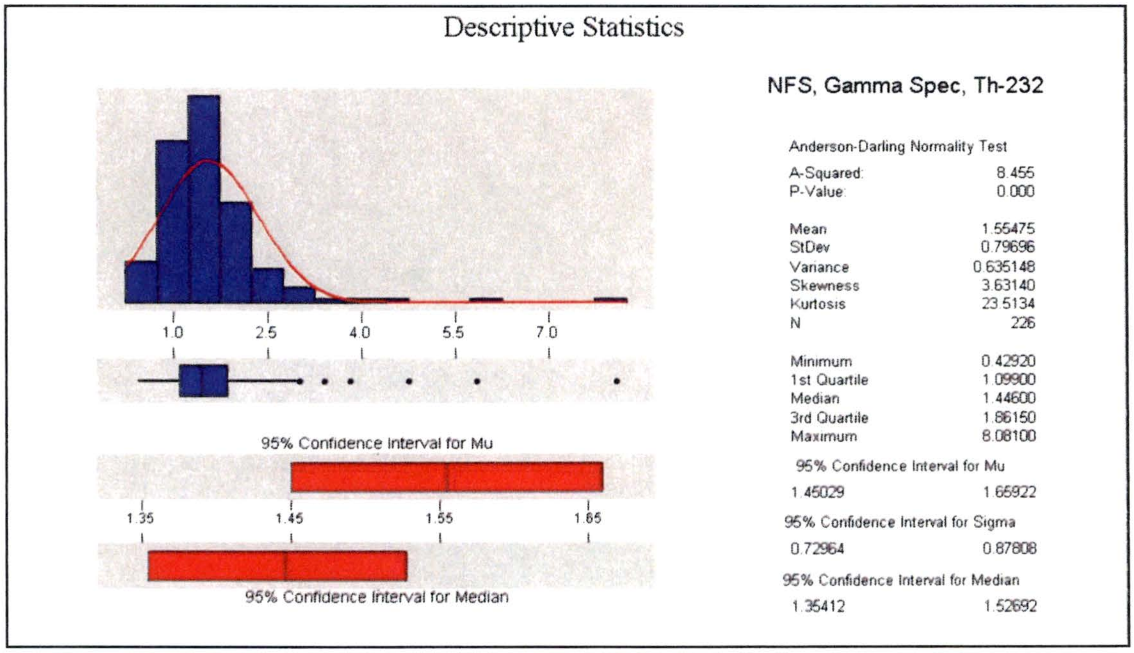

Figure 4-93 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 12

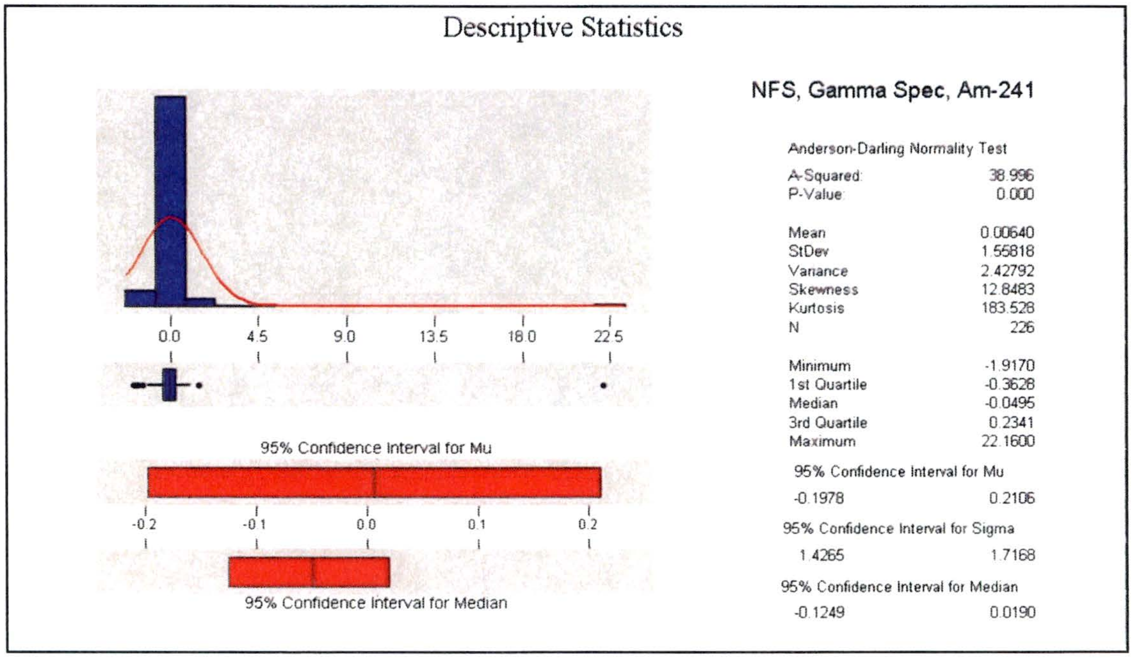

Figure 4-94 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 12

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 12 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.6.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 209 soil samples collected from Survey Unit 12, 21 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-95), Th-232 (Figure 4-96), and Am-241 (Figure 4-97) are presented in this subsection. All isotopic data is in units of pCi/g.

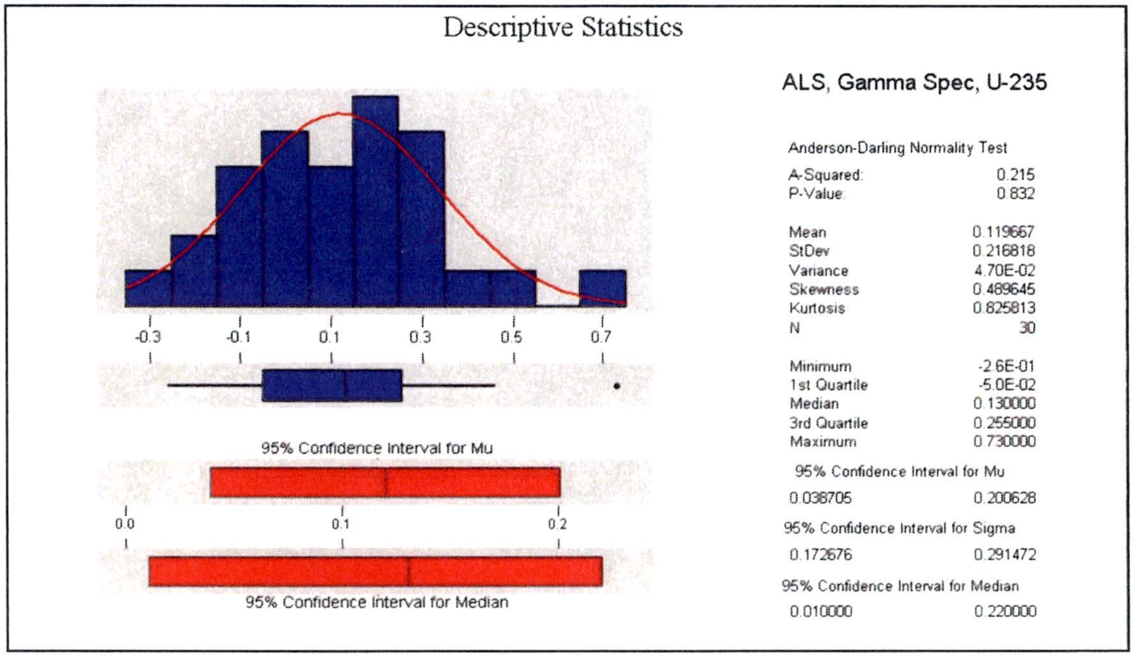

Figure 4-95 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 12

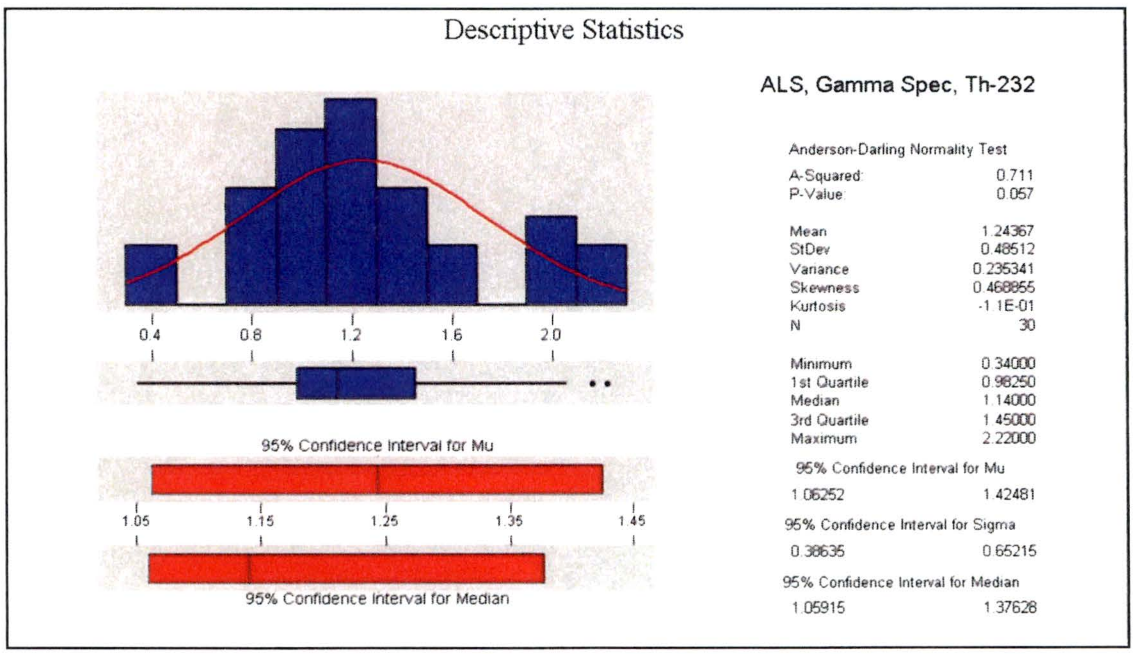

Figure 4-96 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 12

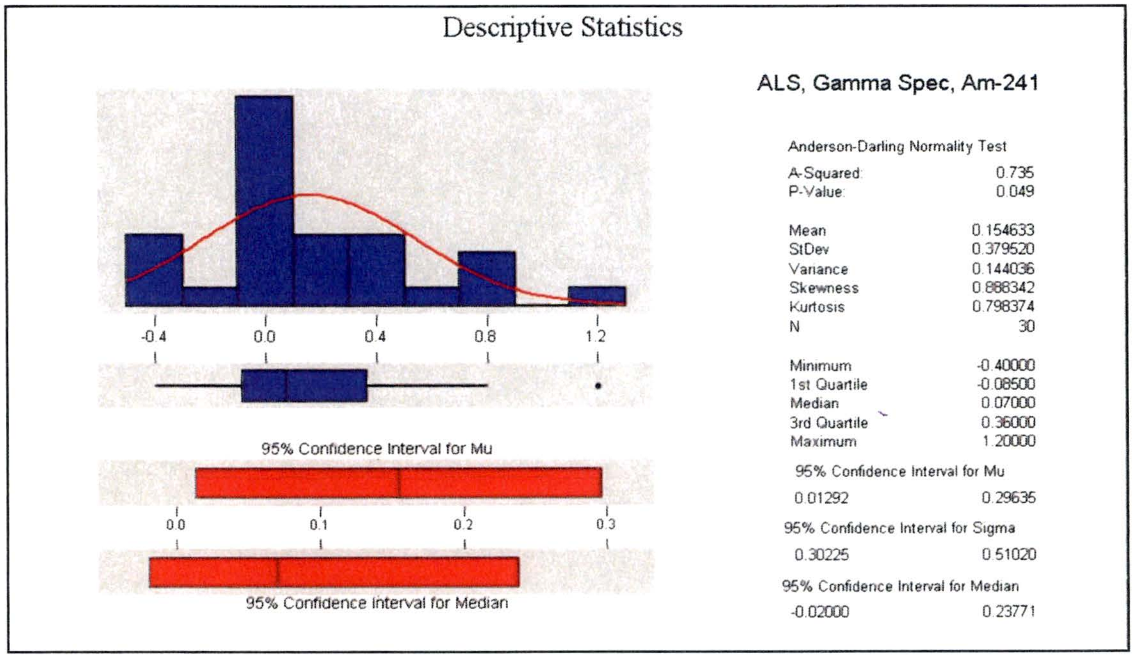

Figure 4-97 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 12

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 12 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.6.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 209 soil samples collected from Survey Unit 12, 21 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 Figure 4-98), Pu-238 (Figure 4-99), Pu-239/240 (Figure 4-100), Pu-241 (Figure 4-101), Pu-242 (Figure 4-102), Th-230 (Figure 4-103), Th-232 (Figure 4-104), U-233/234 (Figure 4-105), U-235 (Figure 4-106), U-238 (Figure 4-107), and Tc-99 (Figure 4-108) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

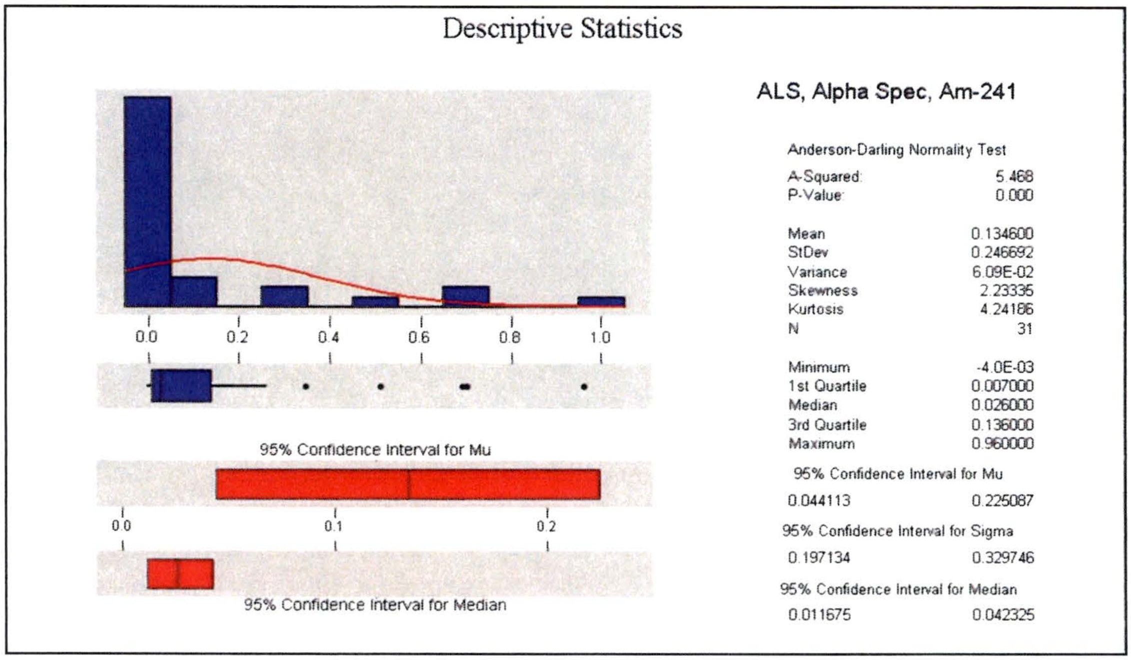

Figure 4-98 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 12

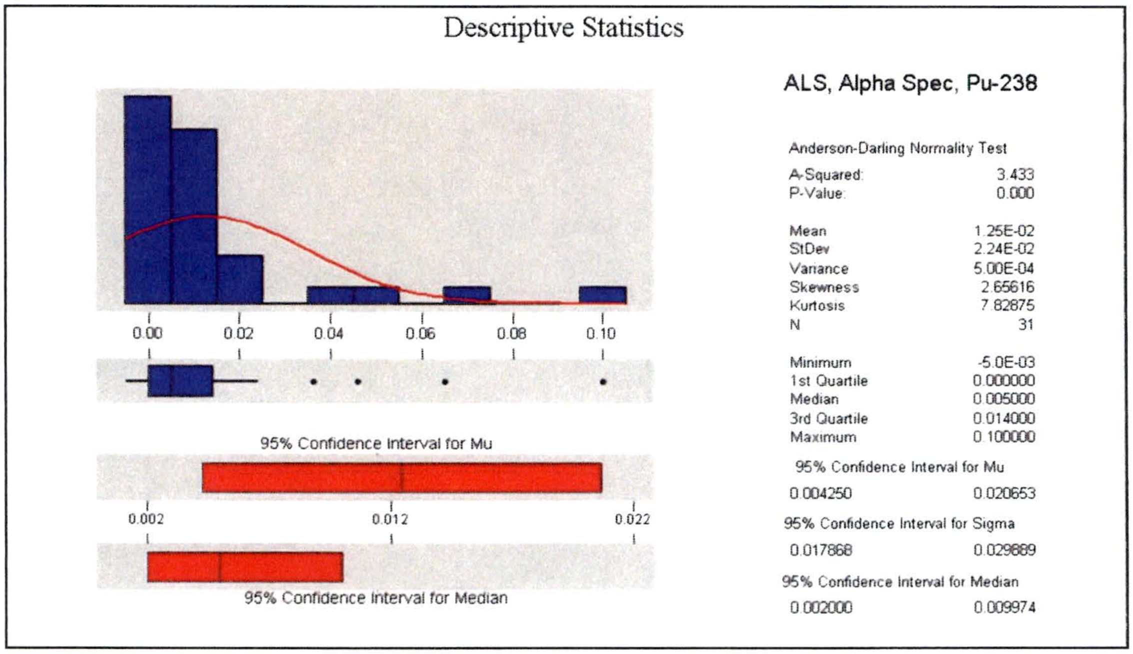

Figure 4-99 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 12

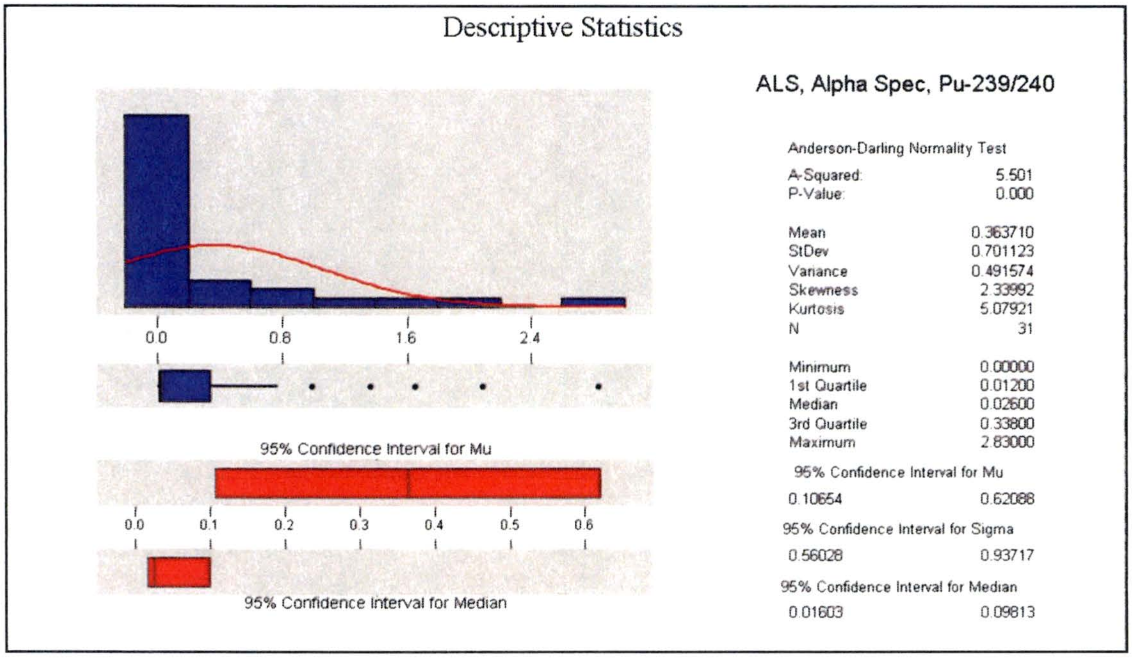

Figure 4-100 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 12

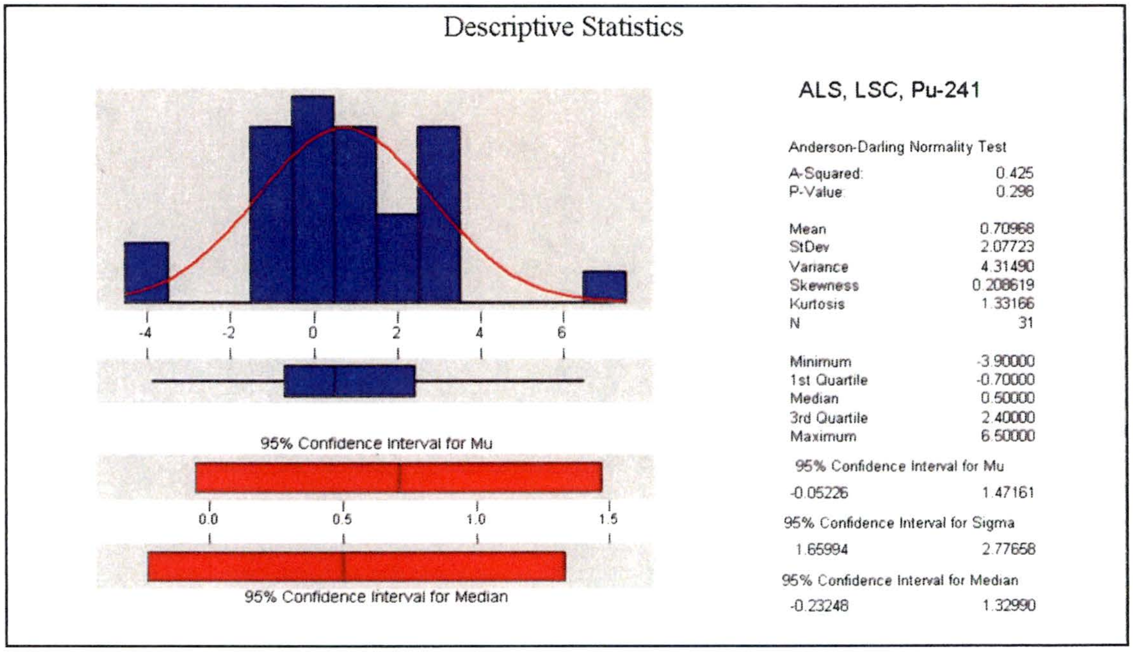

Figure 4-101 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 12

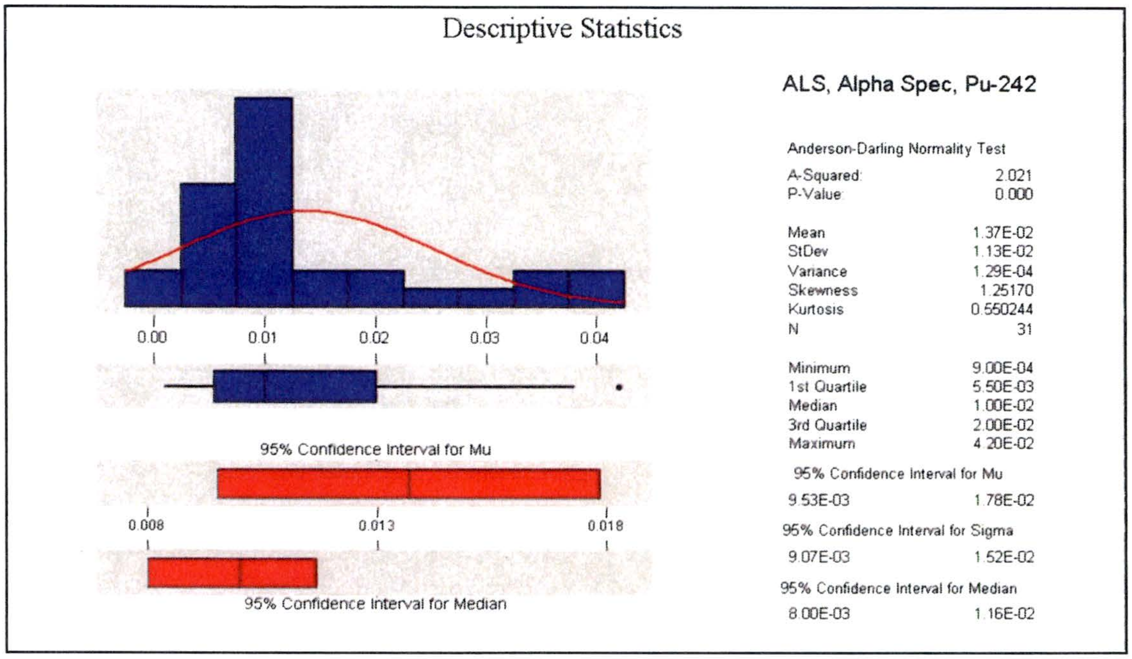

Figure 4-102 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 12

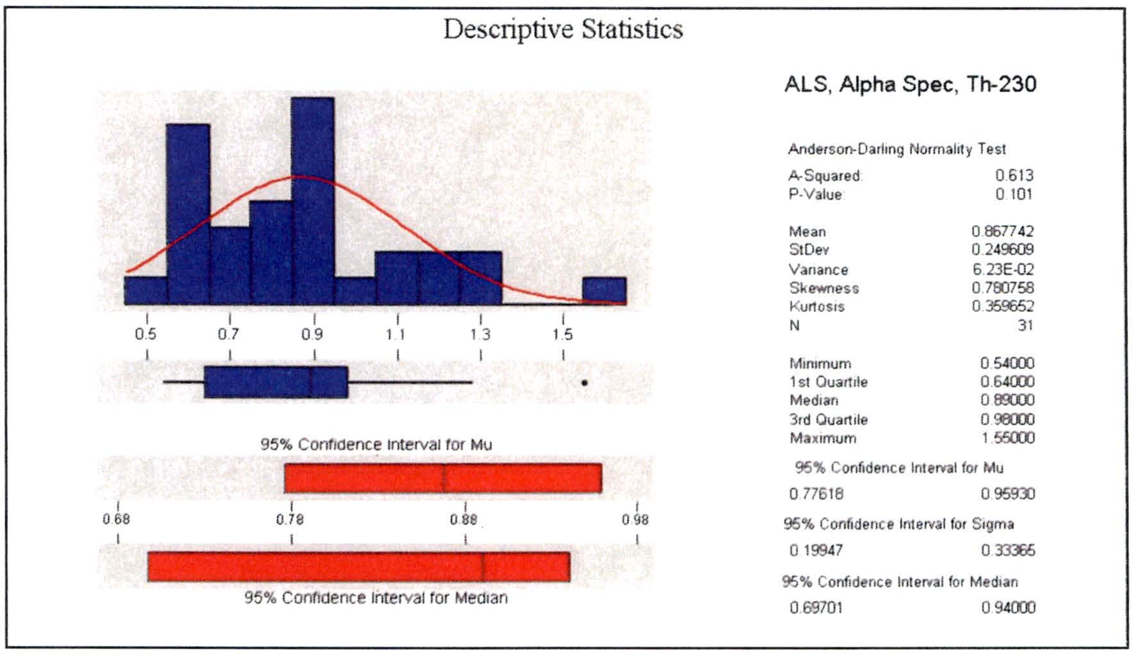

Figure 4-103 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 12

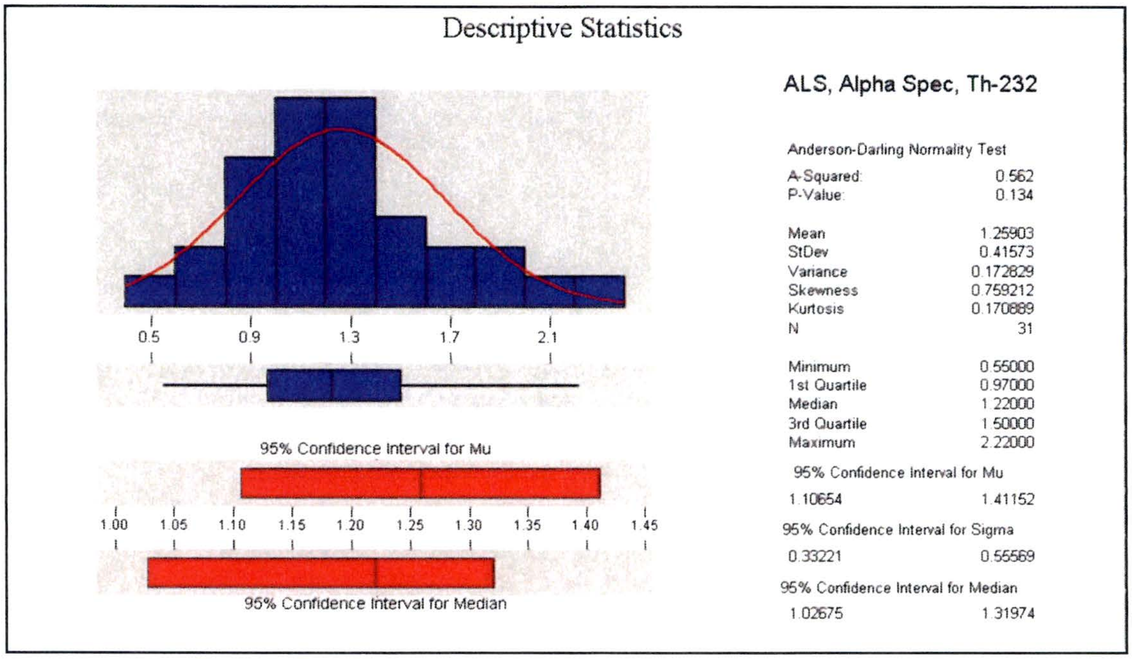

Figure 4-104 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 12

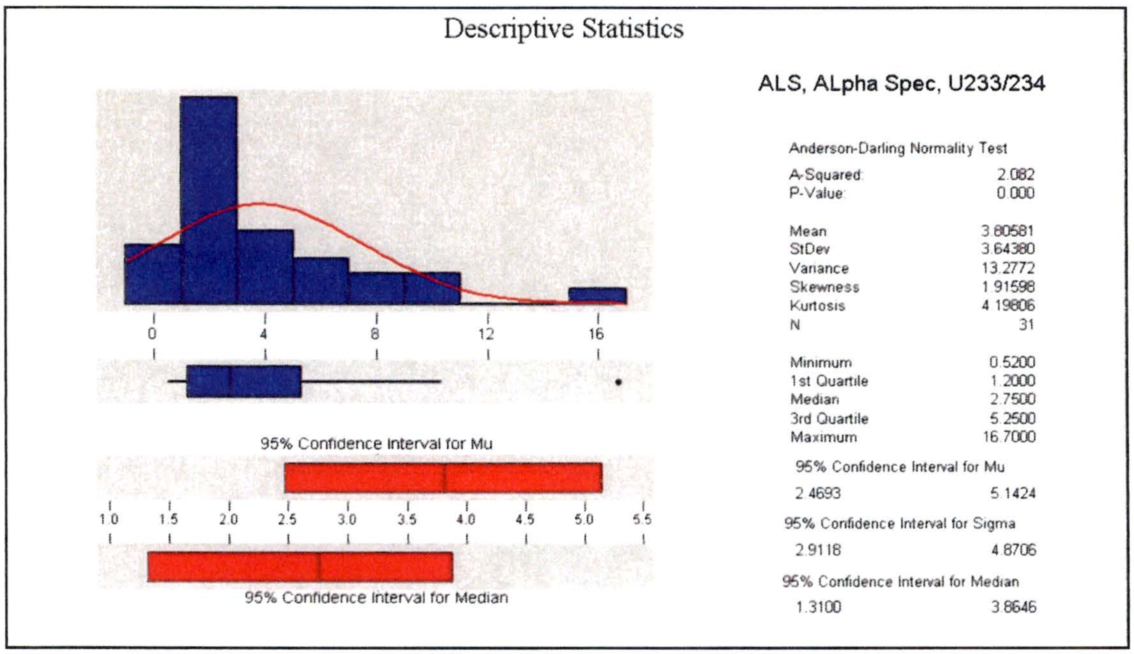

Figure 4-105 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 12

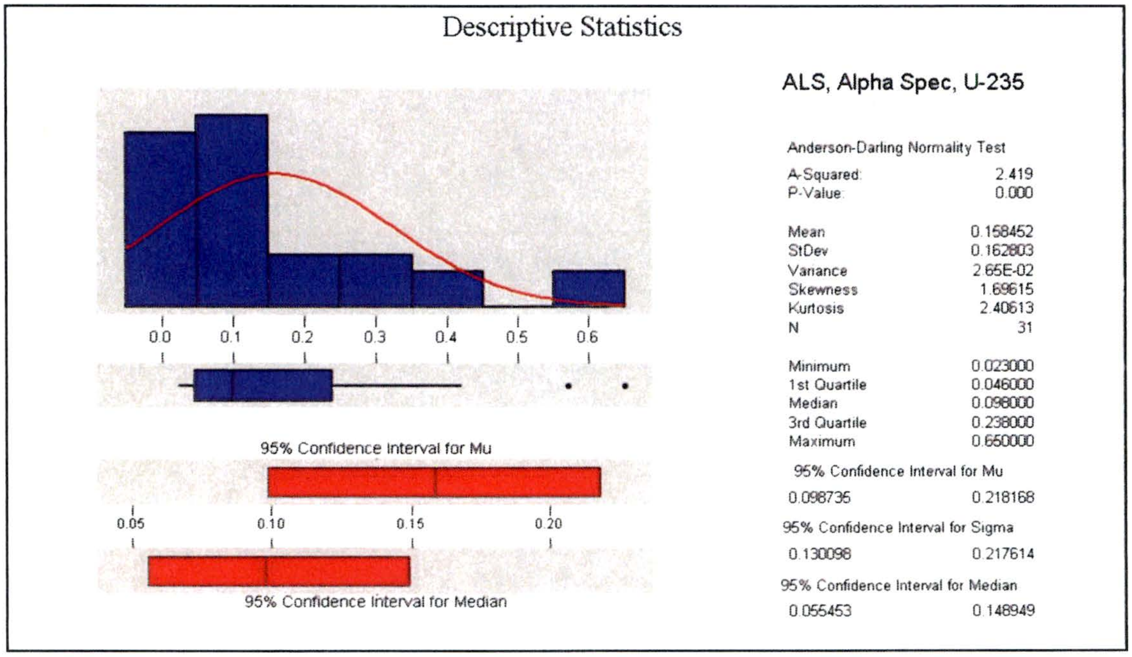

Figure 4-106 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 12

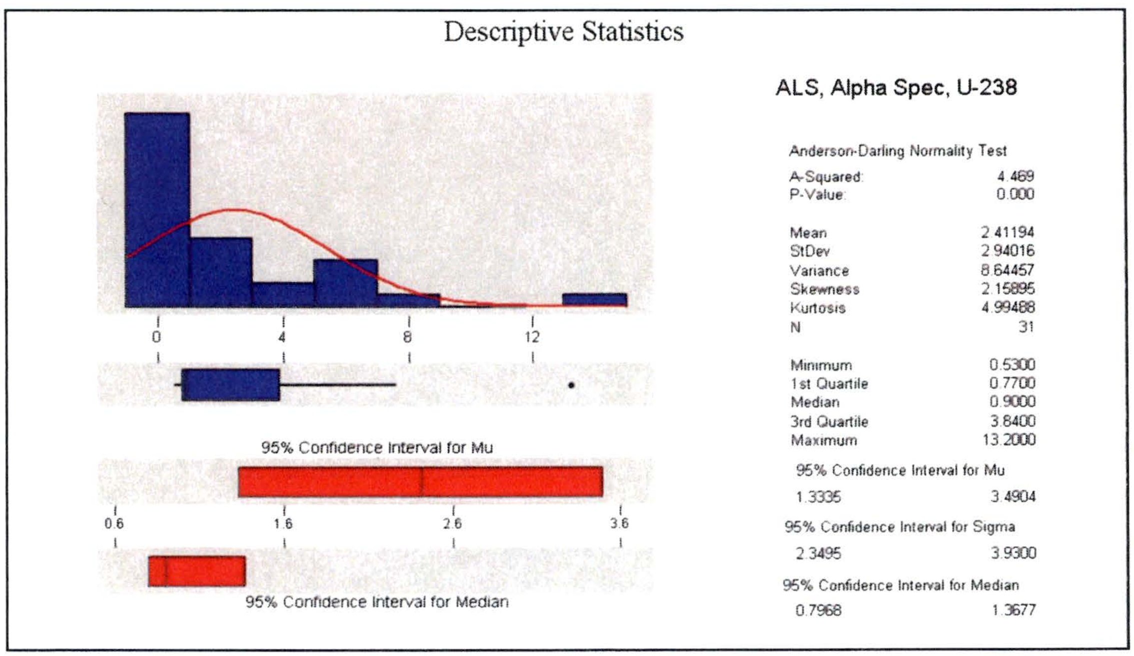

Figure 4-107 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 12

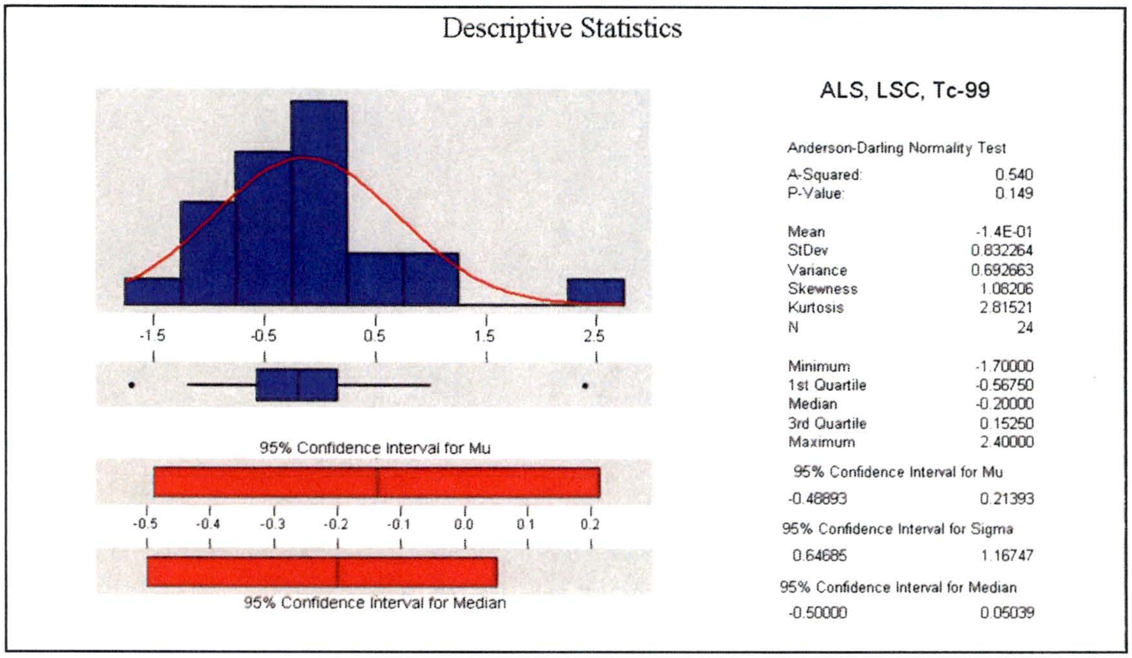

Figure 4-108 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 12

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 12 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.7 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 16-WESTERN

4.7.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 201 soil samples collected from Survey Unit 16-Western (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-109), Th-232 (Figure 4-110), and Am-241 (Figure 4-111) are presented in this subsection. All isotopic data is in units of pCi/g.

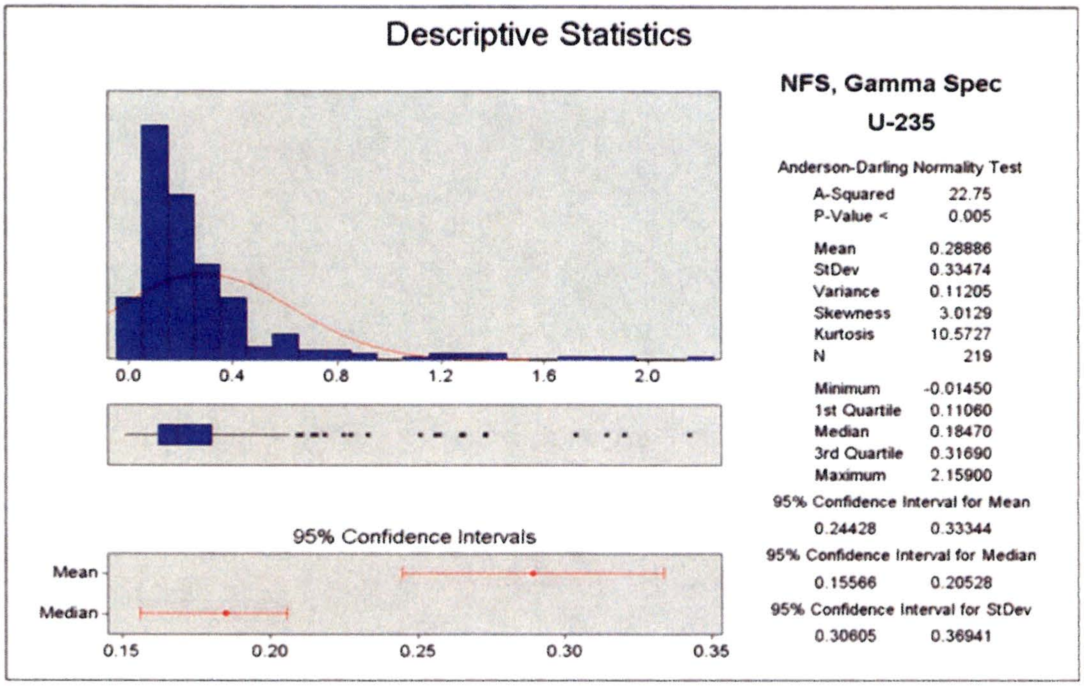

Figure 4-109 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 16-Western

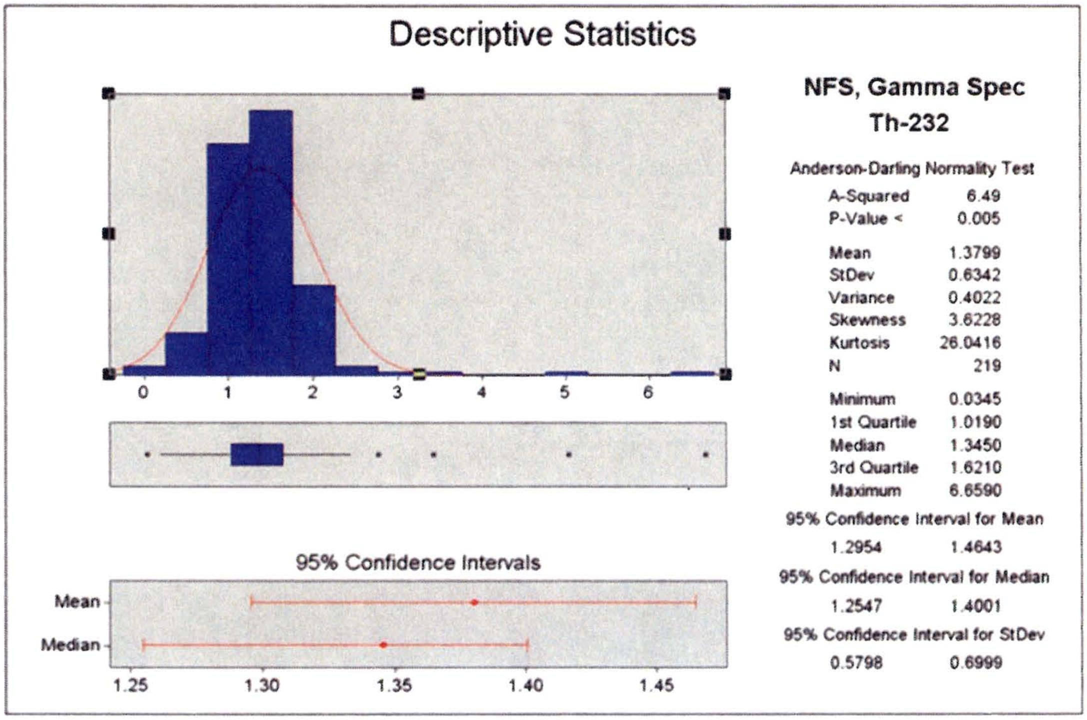

Figure 4-110 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 16-Western

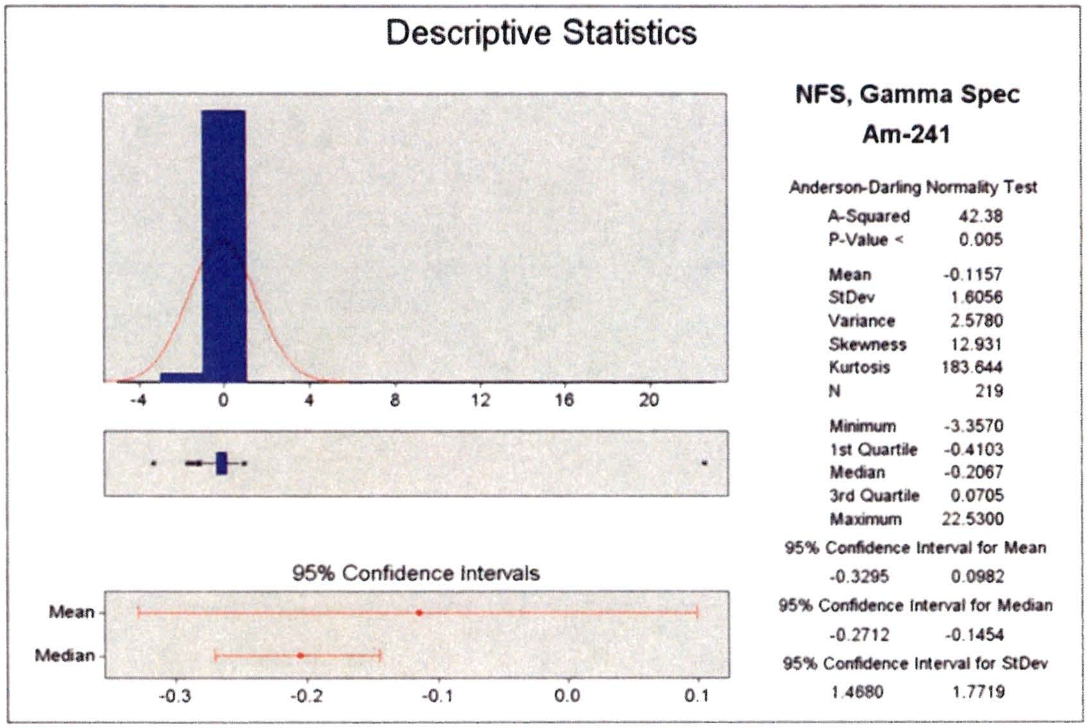

Figure 4-111 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 16-Western

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 16-Western is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.7.2 Paragon Gamma Spectroscopy Soil Sample Results

Of the 201 soil samples collected from Survey Unit 16-Western, 26 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the Paragon generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-112), Th-232 (Figure 4-113), and Am-241 (Figure 4-165) are presented in this subsection. All isotopic data is in units of pCi/g.

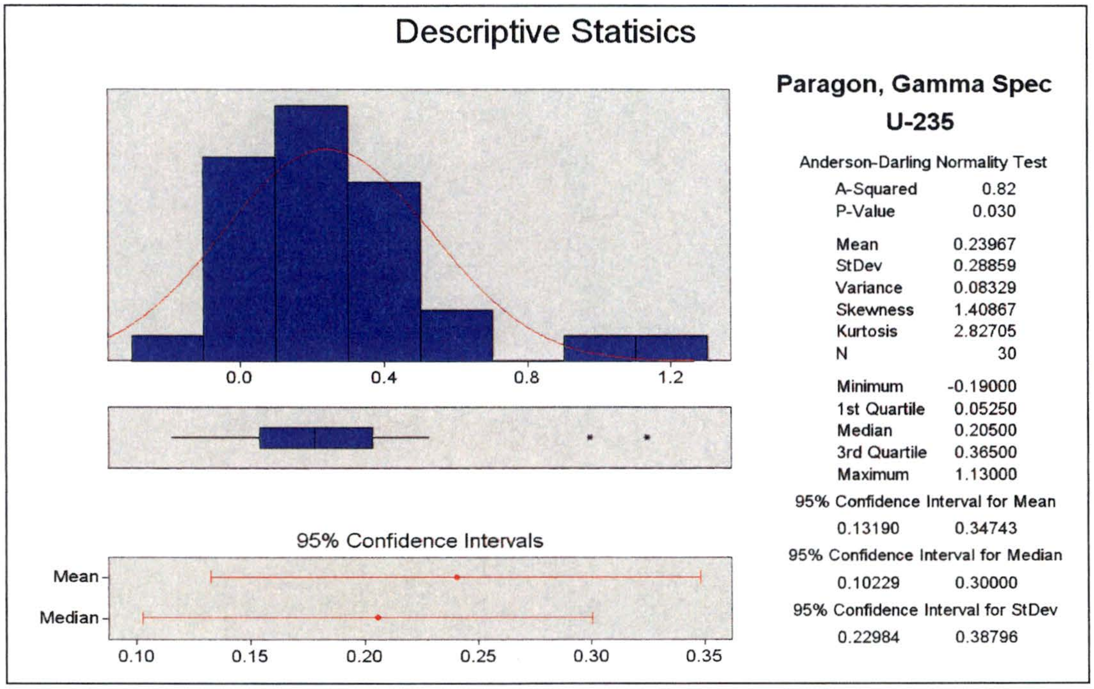

Figure 4-112 Summary Statistics: U-235, Paragon, Gamma Spectroscopy, SU 16-Western

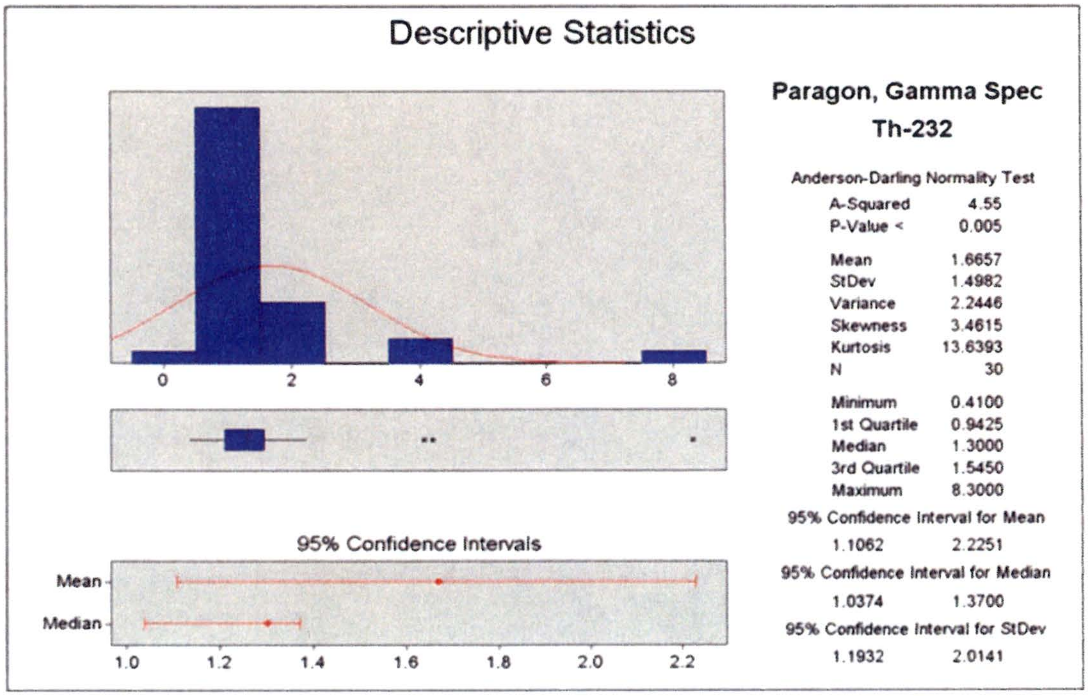

Figure 4-113 Summary Statistics: Th-232, Paragon, Gamma Spectroscopy, SU 16-Western

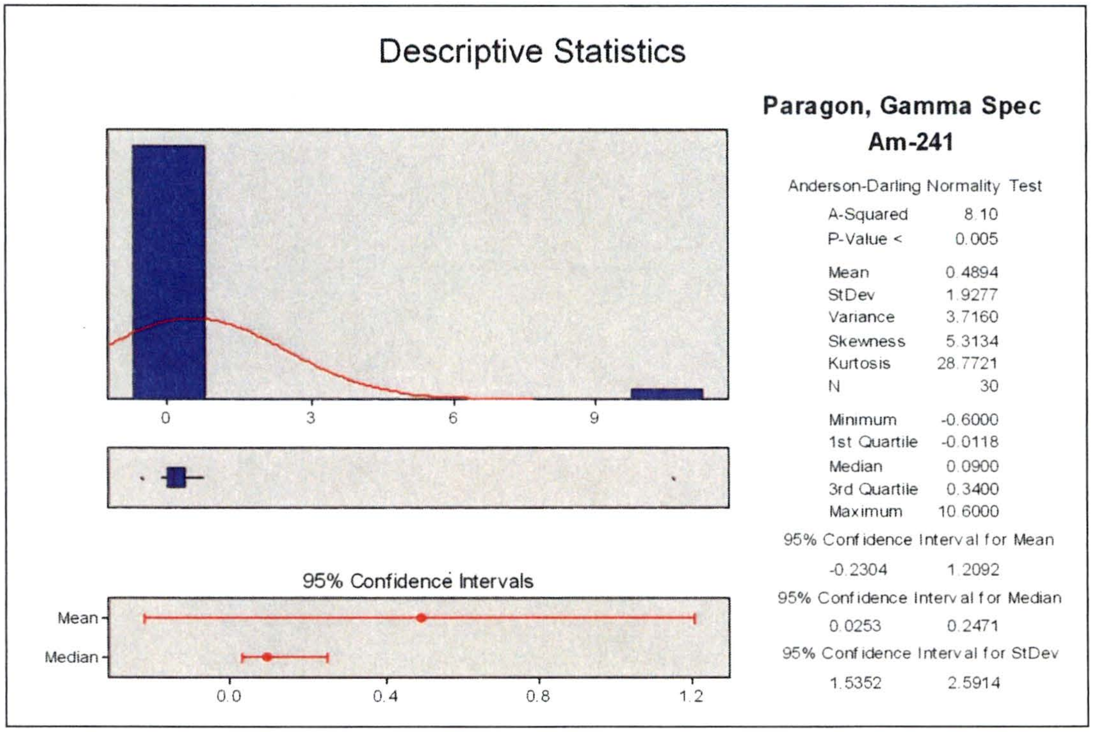

Figure 4-114 Summary Statistics: Am-241, Paragon, Gamma Spectroscopy, SU 16-Western

From the summary statistics for the gamma spectroscopy analyses performed by Paragon, it is again evident that the residual radioactivity in Survey Unit 16-Western is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by Paragon yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.7.3 Paragon Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 201 soil samples collected from Survey Unit 16-Western, 26 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the Paragon generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-115), Pu-238 (Figure 4-116), Pu-239/240 (Figure 4-117), Pu-241 (Figure 4-118), Pu-242 (Figure 4-119), Th-230 (Figure 4-171), Th-232 (Figure 4-120), U-233/234 (Figure 4-121), U-235 (Figure 4-122), U-238 (Figure 4-123), and Tc-99 (Figure 4-124) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

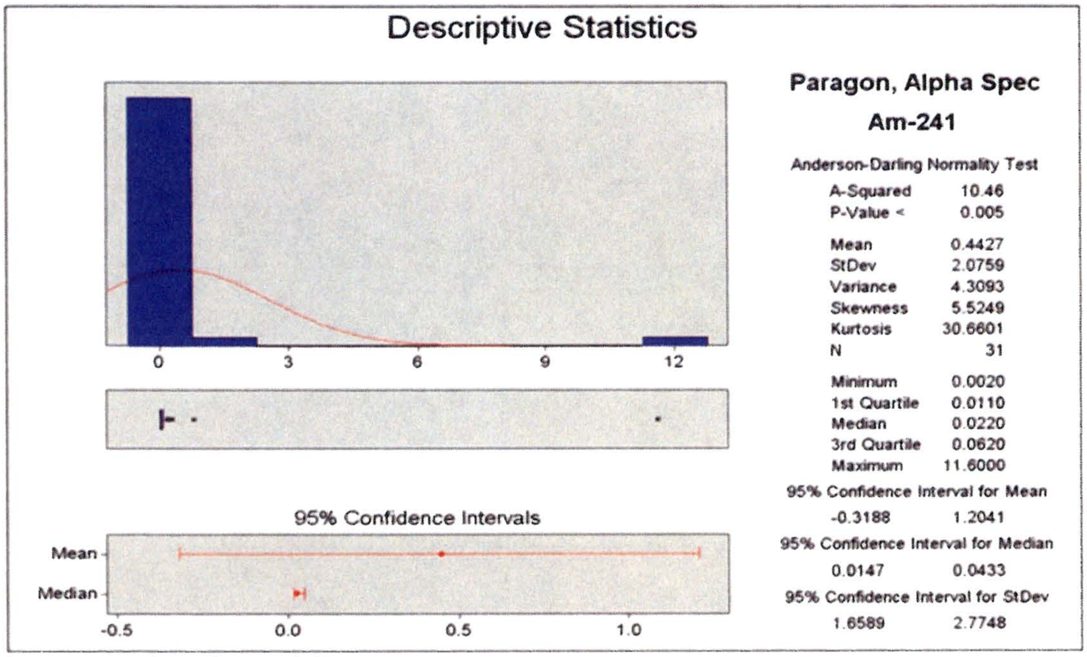

Figure 4-115 Summary Statistics: Am-241, Paragon, Alpha Spectroscopy, SU 16-Western

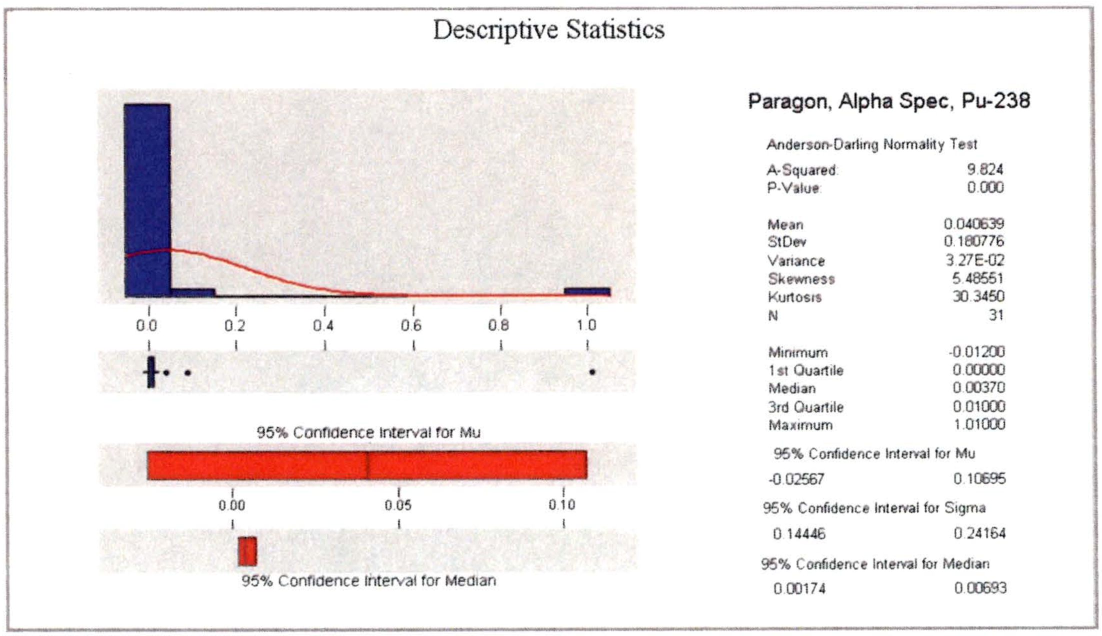

Figure 4-116 Summary Statistics: Pu-238, Paragon, Alpha Spectroscopy, SU 16-Western

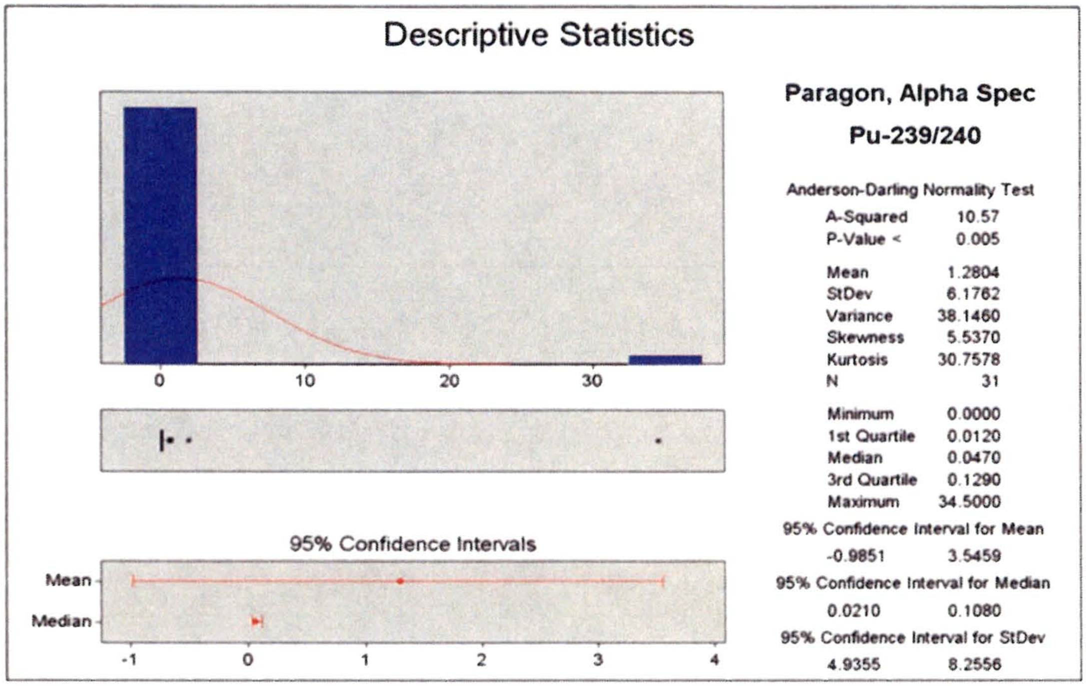

Figure 4-117 Summary Statistics: Pu-239/240, Paragon, Alpha Spectroscopy, SU 16-Western

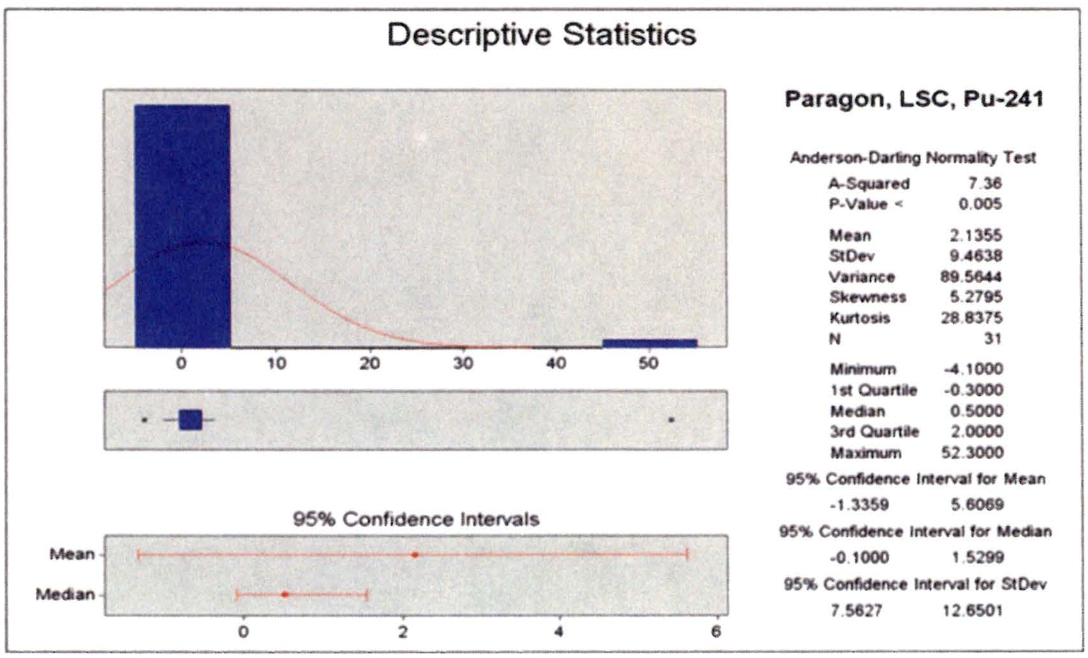

Figure 4-118 Summary Statistics: Pu-241, Paragon, Liquid Scintillation, SU 16-Western

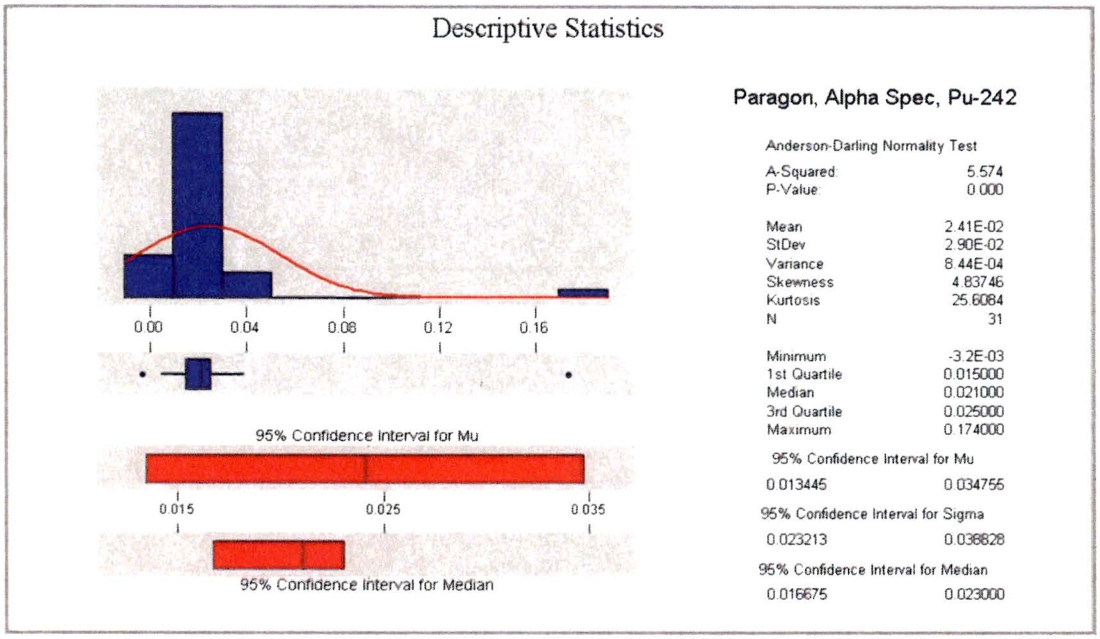

Figure 4-119 Summary Statistics: Pu-242, Paragon, Alpha Spectroscopy, SU 16-Western

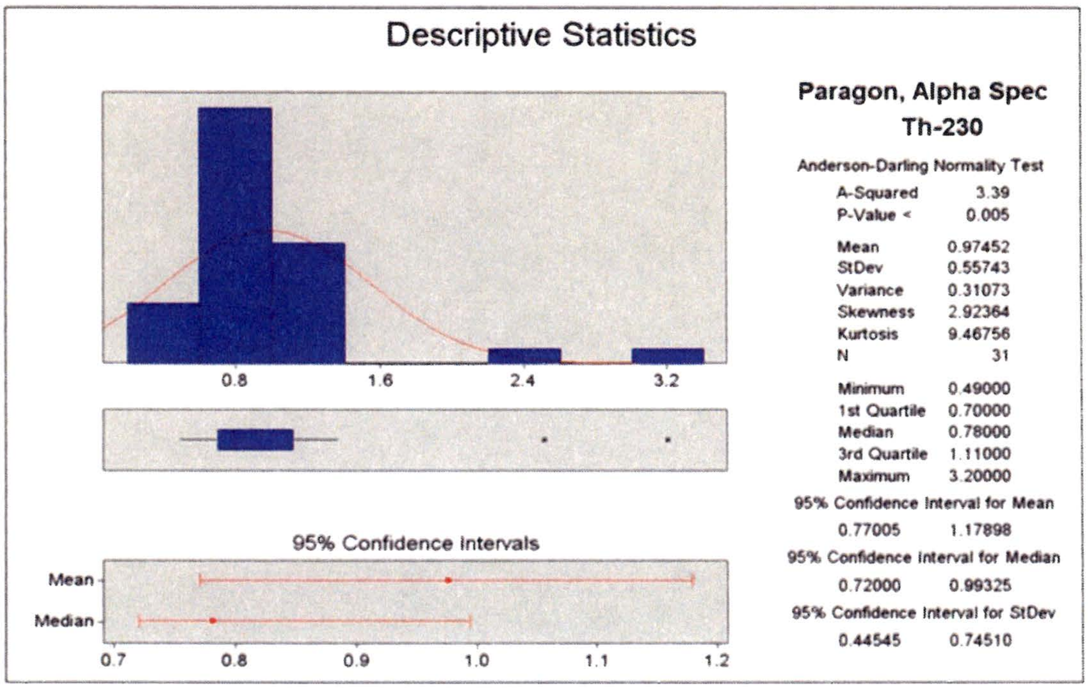

Figure 4-120 Summary Statistics: Th-230, Paragon, Alpha Spectroscopy, SU 16-Western

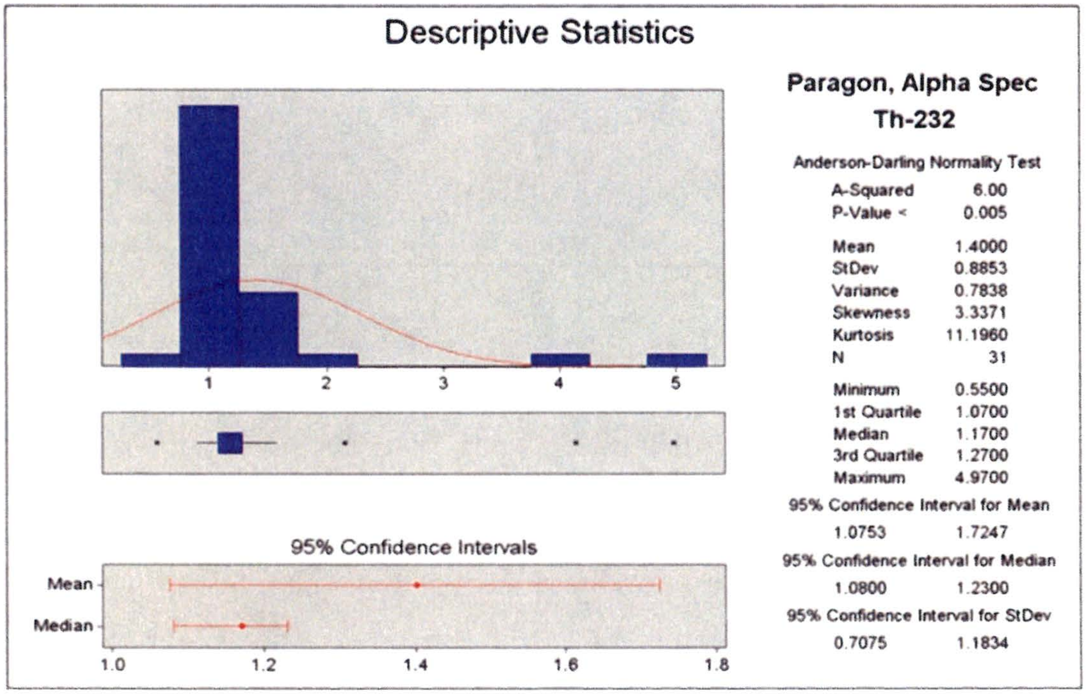

Figure 4-121 Summary Statistics: Th-232, Paragon, Alpha Spectroscopy, SU 16-Western

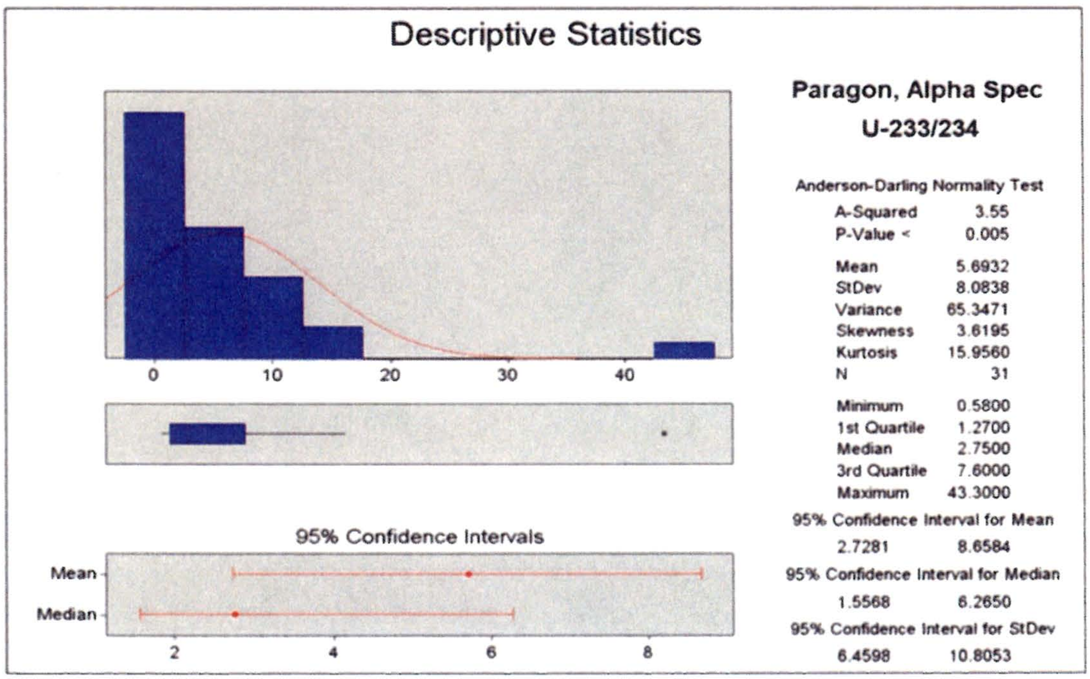

Figure 4-122 Summary Statistics: U-233/234, Paragon, Alpha Spectroscopy, SU 16-Western

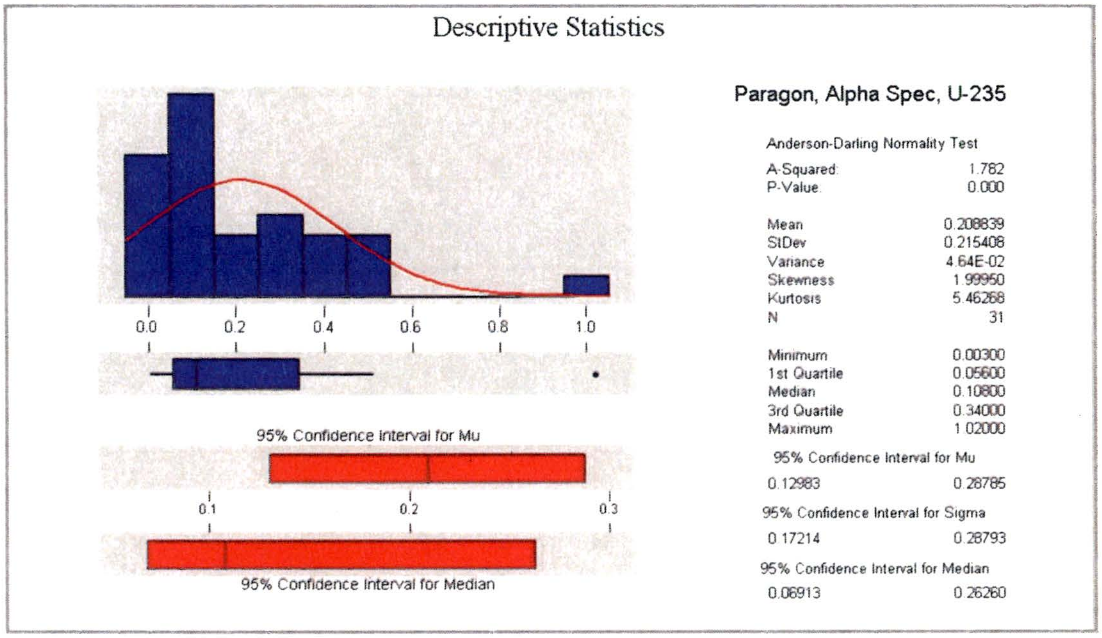

Figure 4-123 Summary Statistics: U-235, Paragon, Alpha Spectroscopy, SU 16-Western

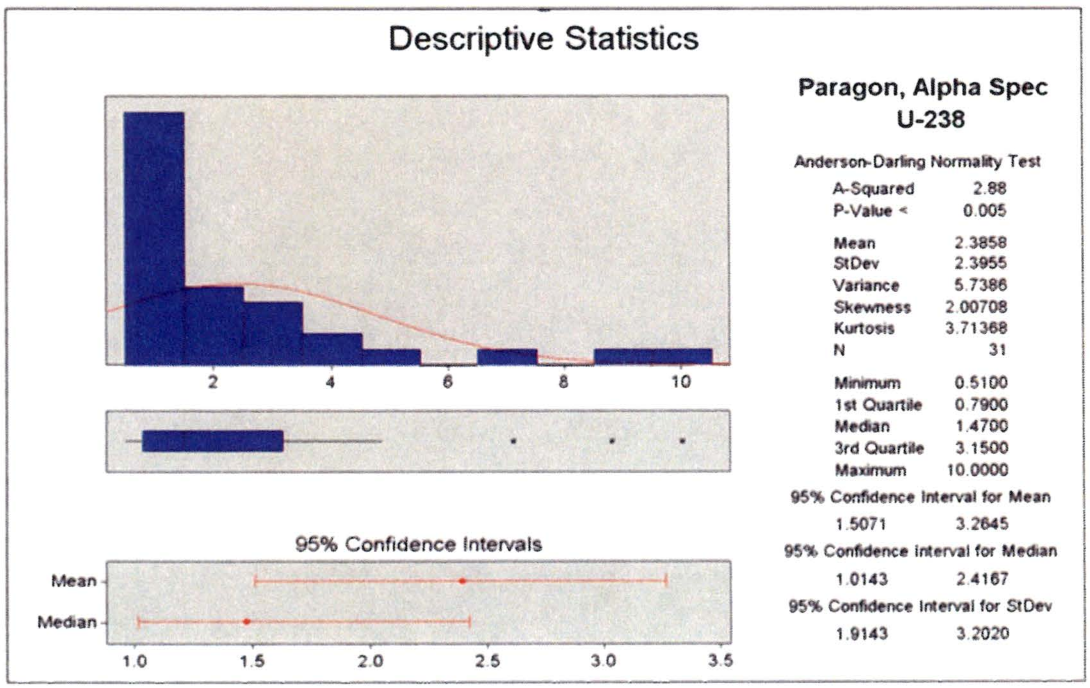

Figure 4-124 Summary Statistics: U-238, Paragon, Alpha Spectroscopy, SU 16-Western

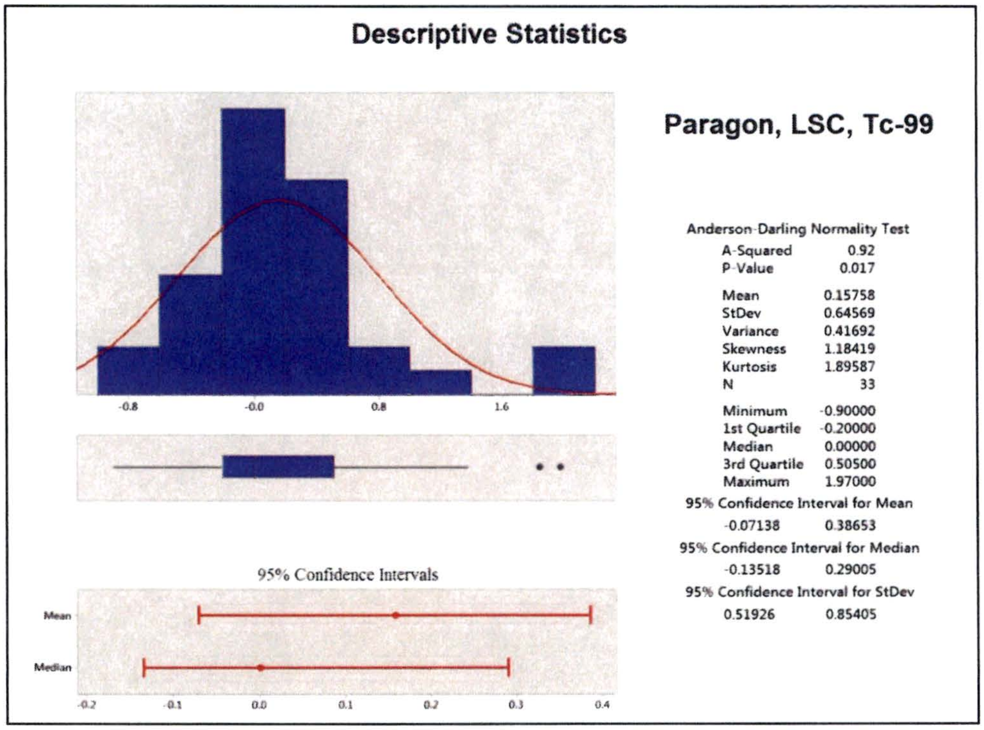

Figure 4-125 Summary Statistics: Tc-99, Paragon, Liquid Scintillation, SU 16-Western

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by Paragon, it is evident that the residual radioactivity in Survey Unit 16-Western associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.8 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 16-CENTRAL

4.8.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 252 soil samples collected from Survey Unit 16-Central (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-126), Th-232 (Figure 4-127), and Am-241 (Figure 4-128) are presented in this subsection. All isotopic data is in units of pCi/g.

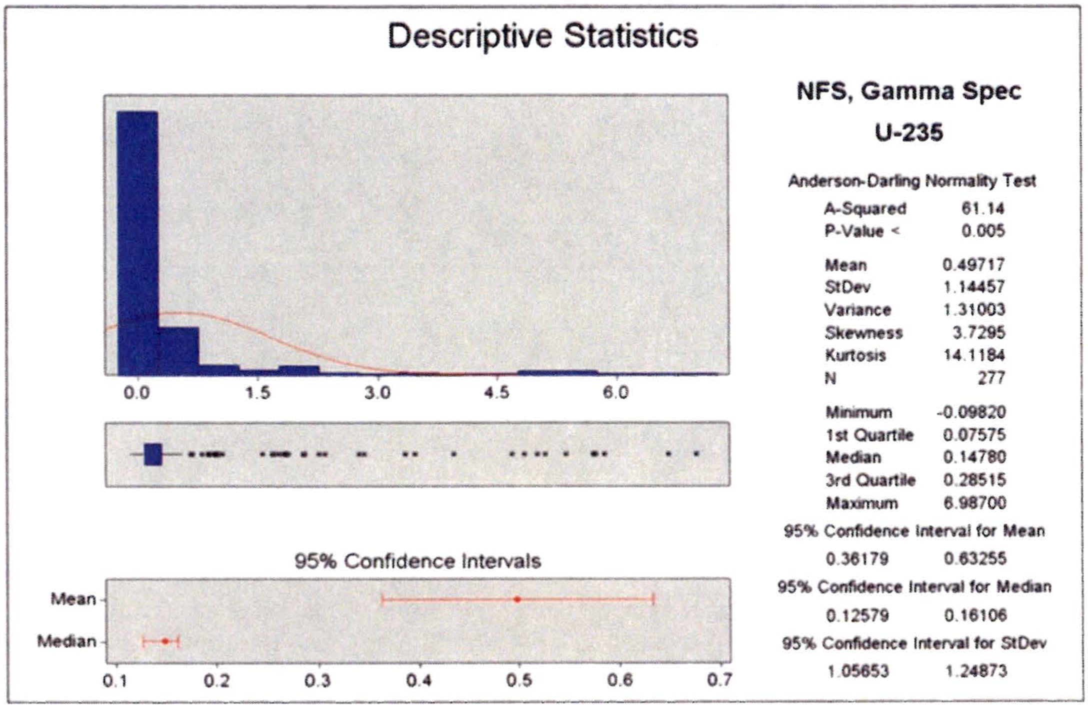

Figure 4-126 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 16-Central

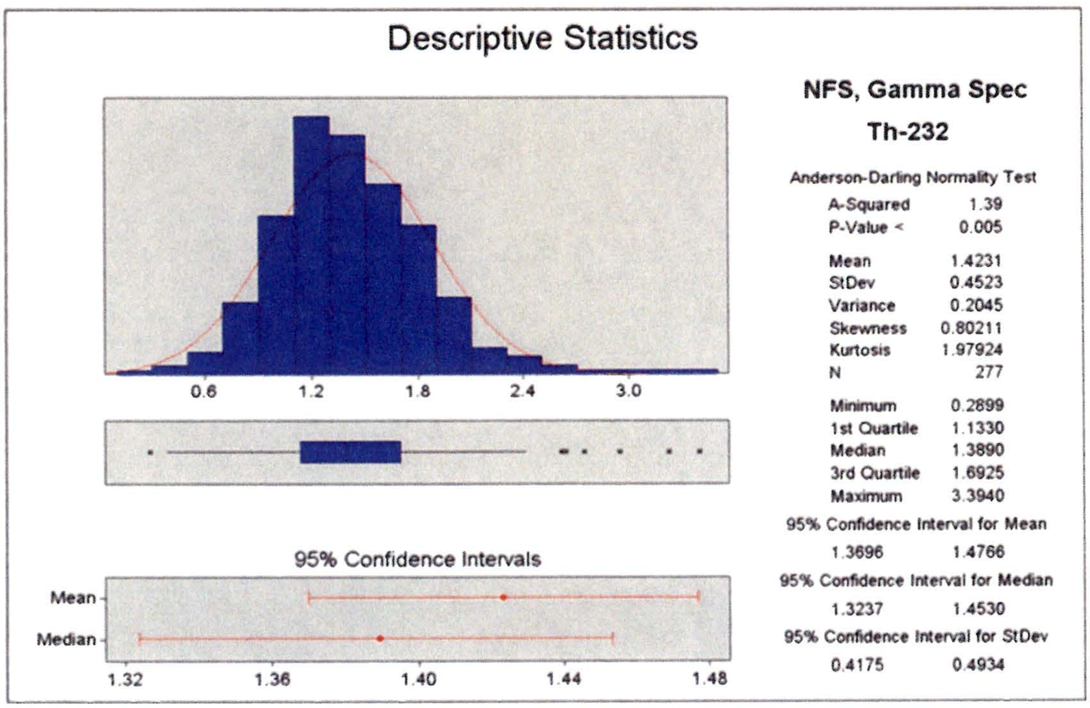

Figure 4-127 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 16-Central

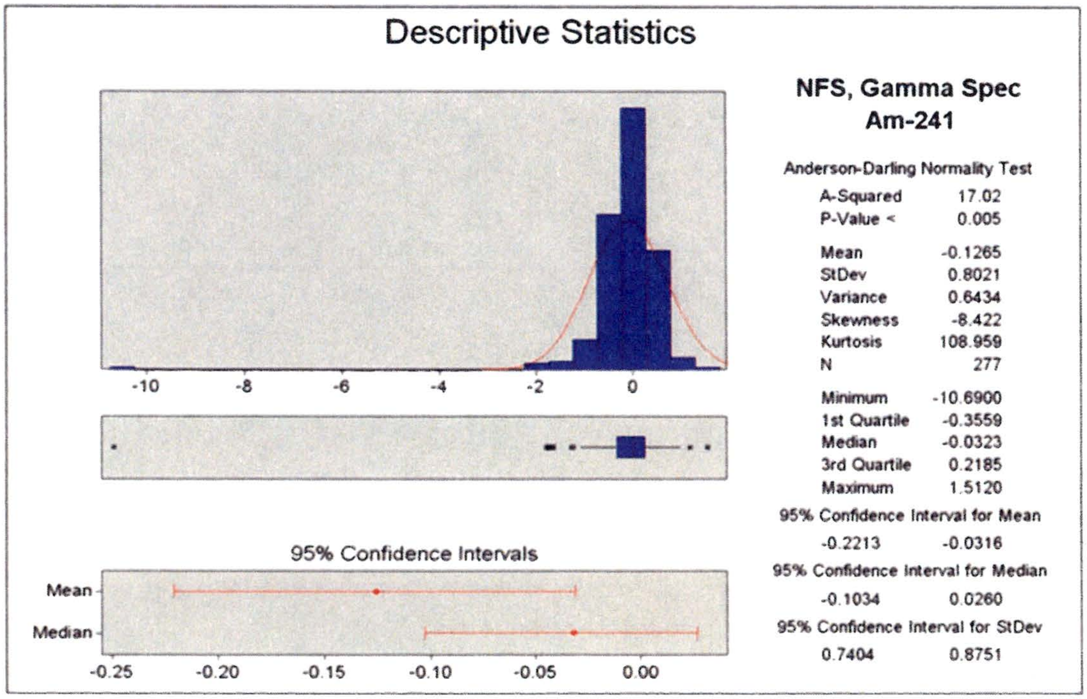

Figure 4-128 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 16-Central

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 16-Central is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.8.2 Paragon Gamma Spectroscopy Soil Sample Results

Of the 252 soil samples collected from Survey Unit 16-Central, 23 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the Paragon generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-129), Th-232 (Figure 4-130), and Am-241 (Figure 4-131) are presented in this subsection. All isotopic data is in units of pCi/g.

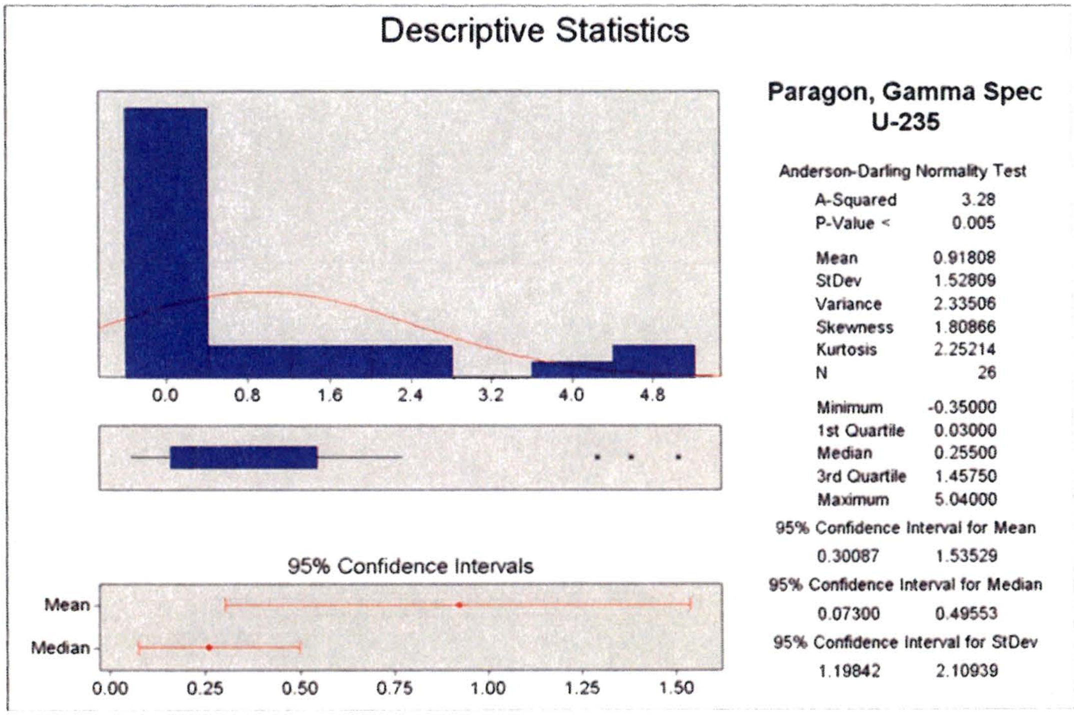

Figure 4-129 Summary Statistics: U-235, Paragon, Gamma Spectroscopy, SU 16-Central

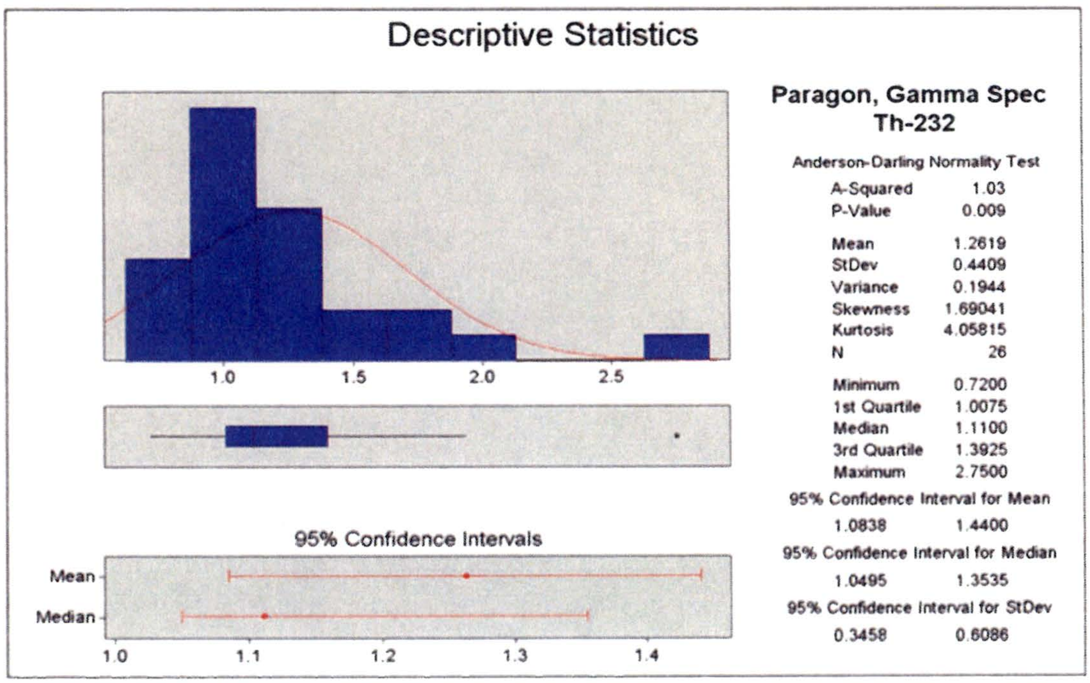

Figure 4-130 Summary Statistics: Th-232, Paragon, Gamma Spectroscopy, SU 16-Central

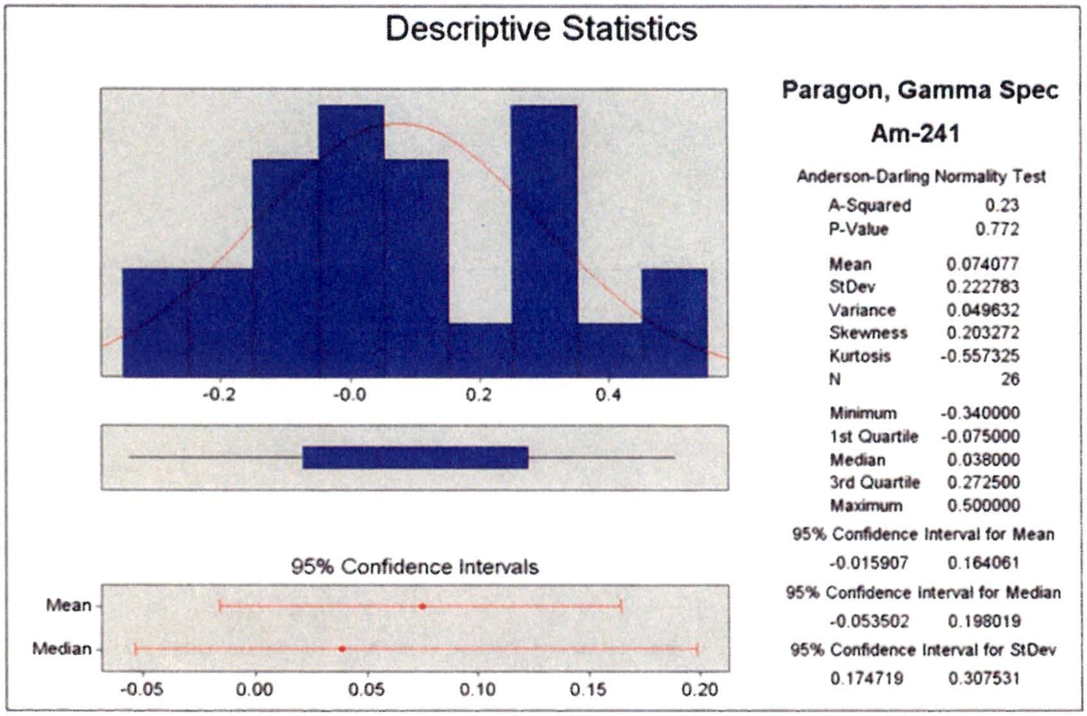

Figure 4-131 Summary Statistics: Am-241, Paragon, Gamma Spectroscopy, SU 16-Central

From the summary statistics for the gamma spectroscopy analyses performed by Paragon, it is again evident that the residual radioactivity in Survey Unit 16-Central is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by Paragon yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.8.3 Paragon Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 252 soil samples collected from Survey Unit 16-Central, 23 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the Paragon generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-132), Pu-238 (Figure 4-133), Pu-239/240 (Figure 4-134), Pu-241 (Figure 4-135), Pu-242 (Figure 4-136), Th-230 (Figure 4-137), Th-232 (Figure 4-138), U-233/234 (Figure 4-139), U-235 (Figure 4-140), U-238 (Figure 4-141), and Tc-99 (Figure 4-142) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

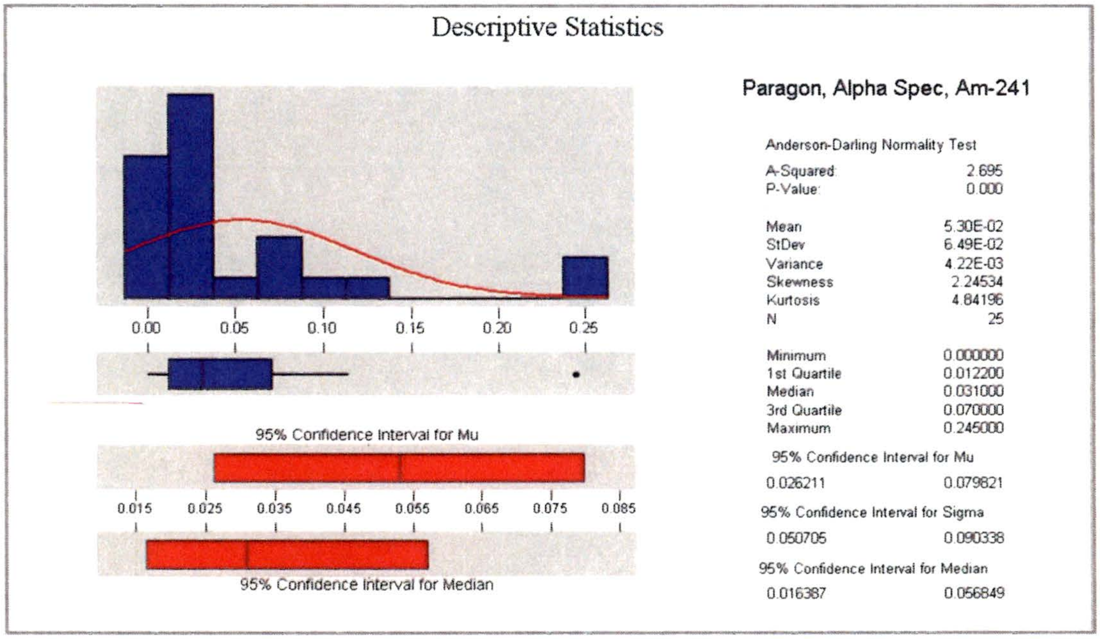

Figure 4-132 Summary Statistics: Am-241, Paragon, Alpha Spectroscopy, SU 16-Central

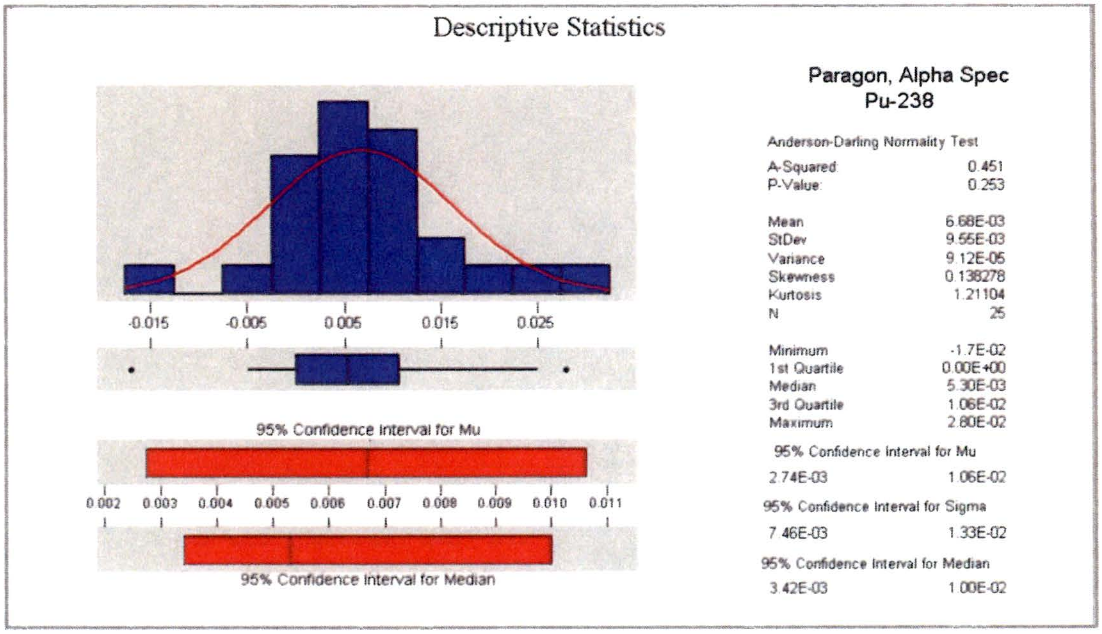

Figure 4-133 Summary Statistics: Pu-238, Paragon, Alpha Spectroscopy, SU 16-Central

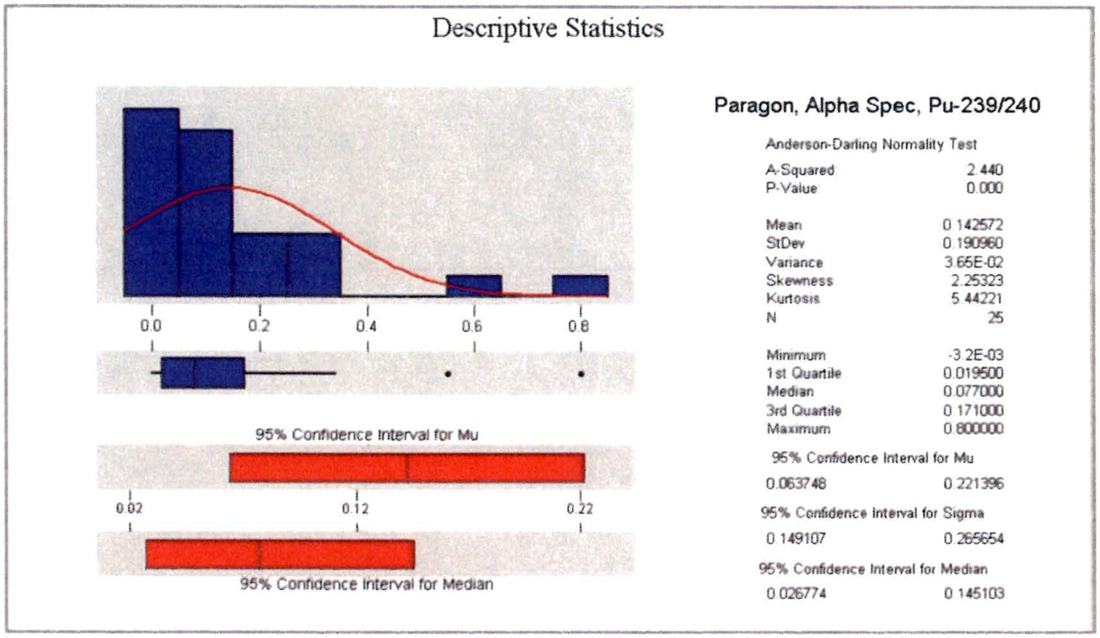

Figure 4-134 Summary Statistics: Pu-239/240, Paragon, Alpha Spectroscopy, SU 16-Central

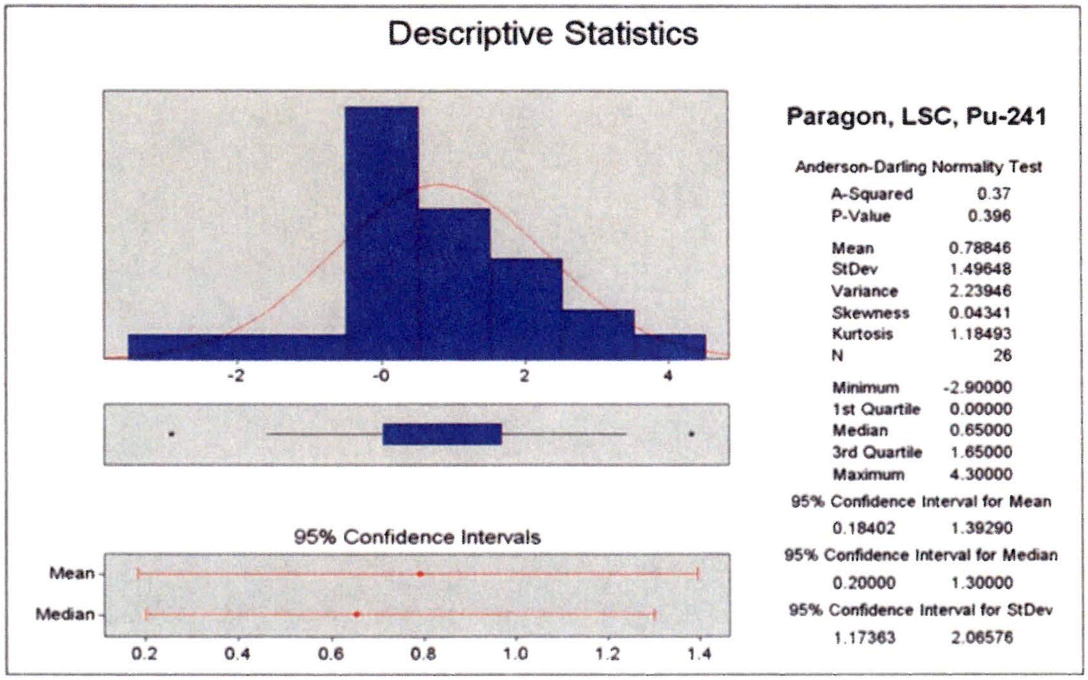

Figure 4-135 Summary Statistics: Pu-241, Paragon, Liquid Scintillation, SU 16-Central

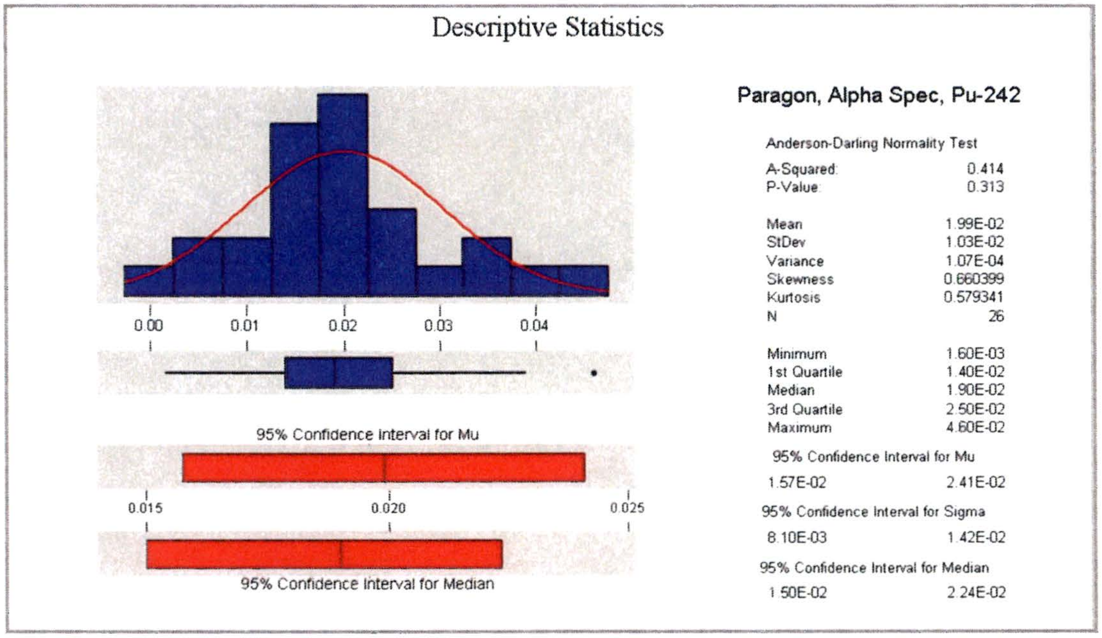

Figure 4-136 Summary Statistics: Pu-242, Paragon, Alpha Spectroscopy, SU 16-Central

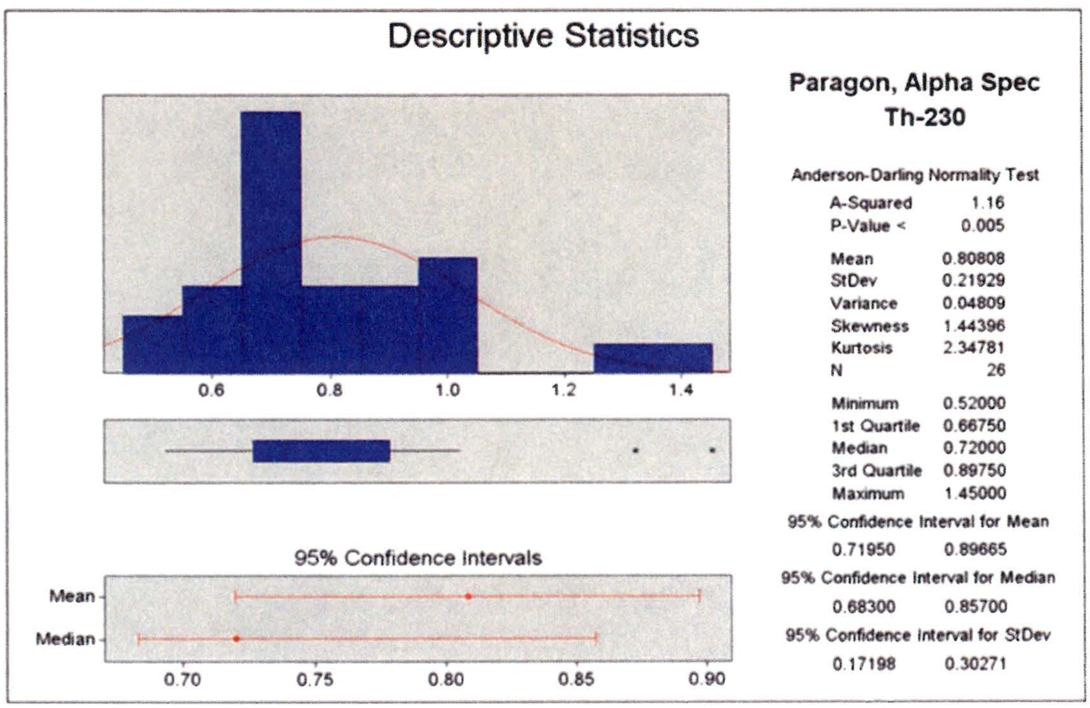

Figure 4-137 Summary Statistics: Th-230, Paragon, Alpha Spectroscopy, SU 16-Central

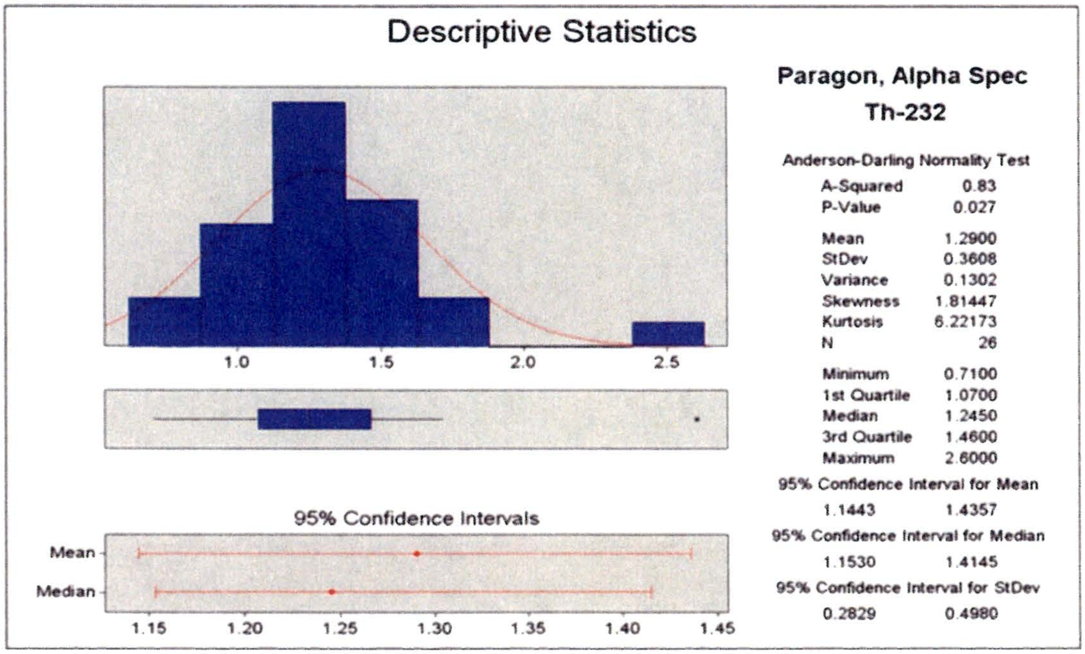

Figure 4-138 Summary Statistics: Th-232, Paragon, Alpha Spectroscopy, SU 16-Central

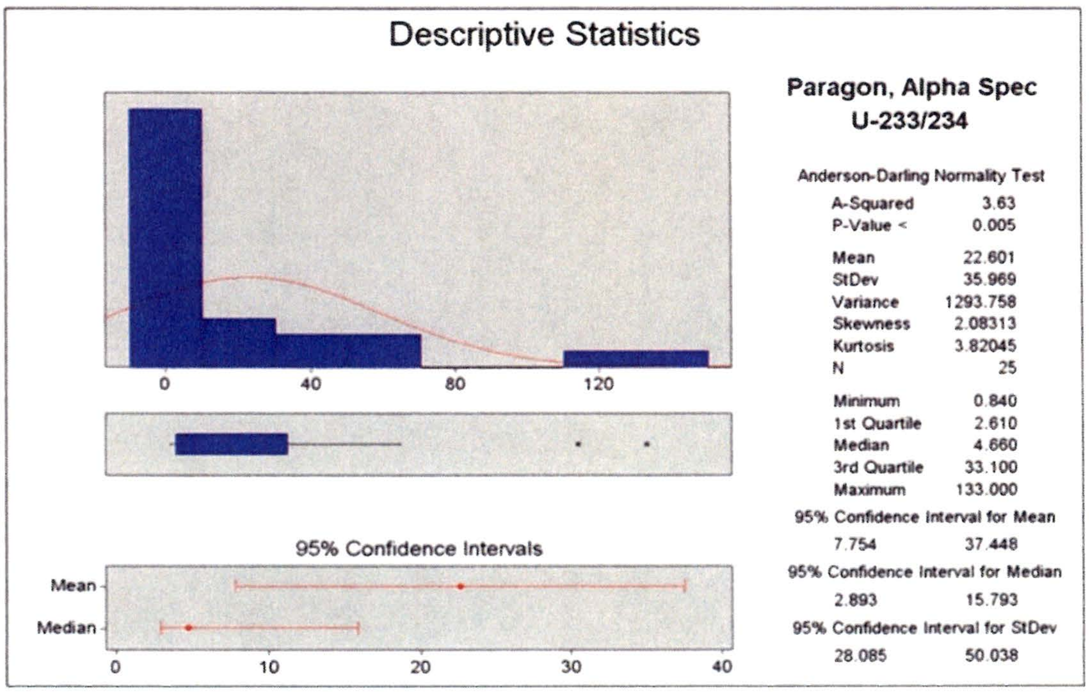

Figure 4-139 Summary Statistics: U-233/234, Paragon, Alpha Spectroscopy, SU 16-Central

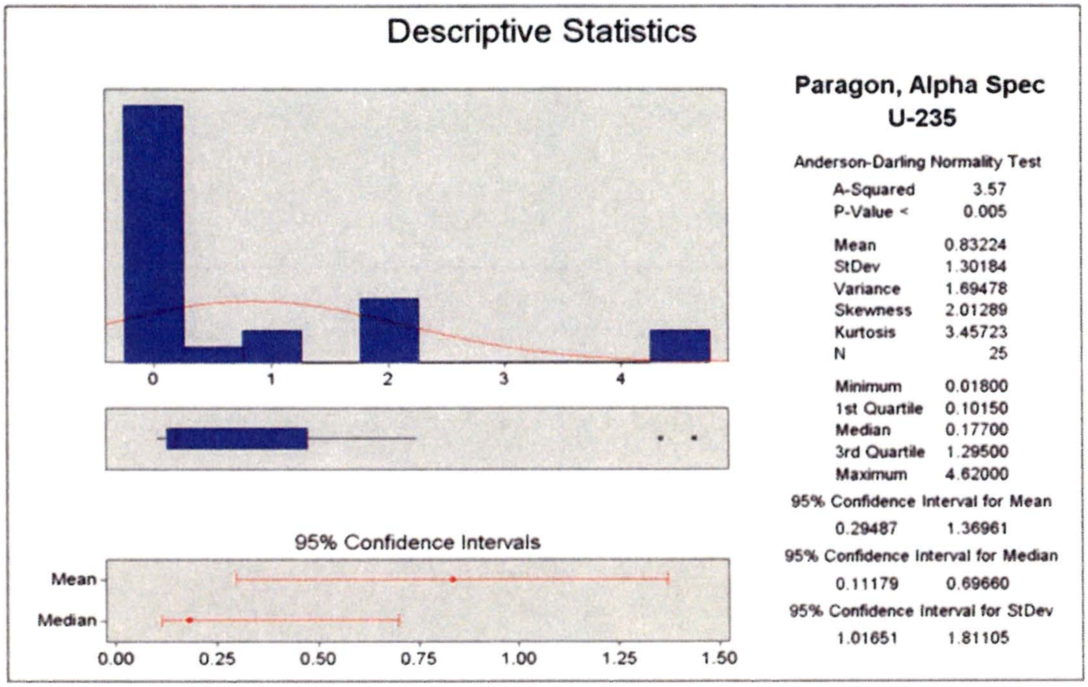

Figure 4-140 Summary Statistics: U-235, Paragon, Alpha Spectroscopy, SU 16-Central

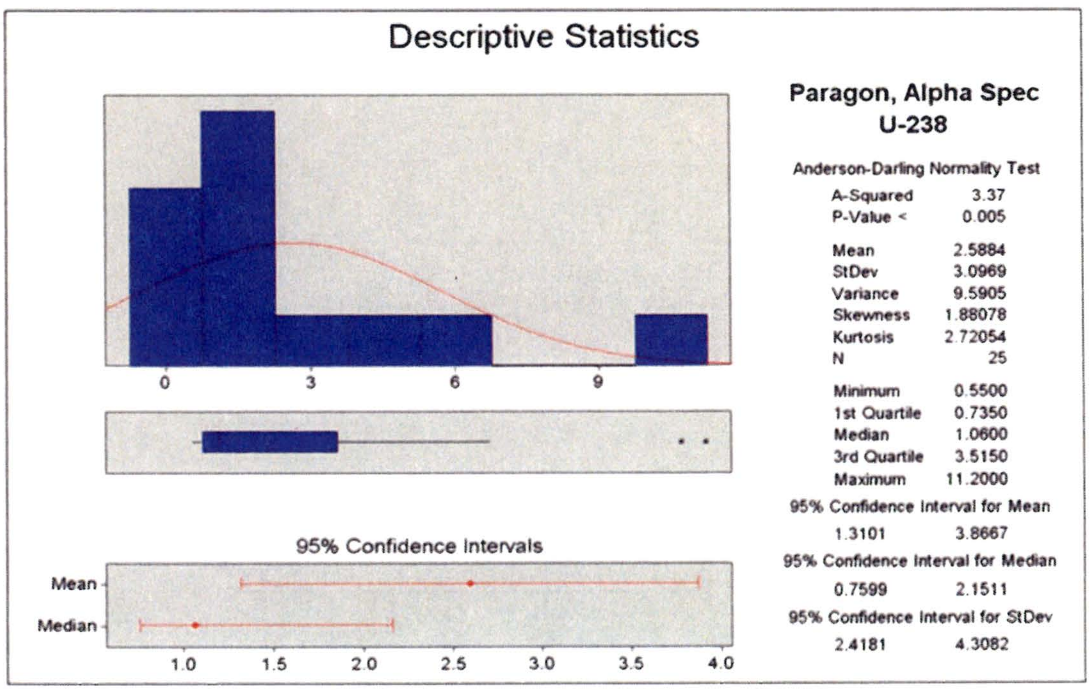

Figure 4-141 Summary Statistics: U-238, Paragon, Alpha Spectroscopy, SU 16-Central

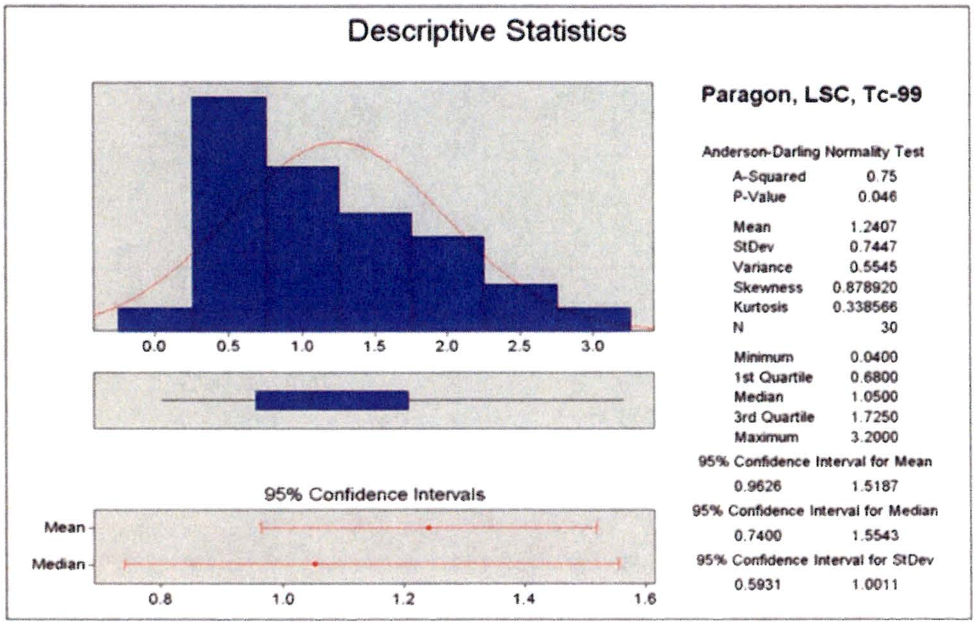

Figure 4-142 Summary Statistics: Tc-99, Paragon, Liquid Scintillation, SU 16-Central

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by Paragon, it is evident that the residual radioactivity in Survey Unit 16-Central associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.9 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 16-EASTERN

4.9.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 180 soil samples collected from Survey Unit 16-Eastern (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-143), Th-232 (Figure 4-144), and Am-241 (Figure 4-145) are presented in this subsection. All isotopic data is in units of pCi/g.

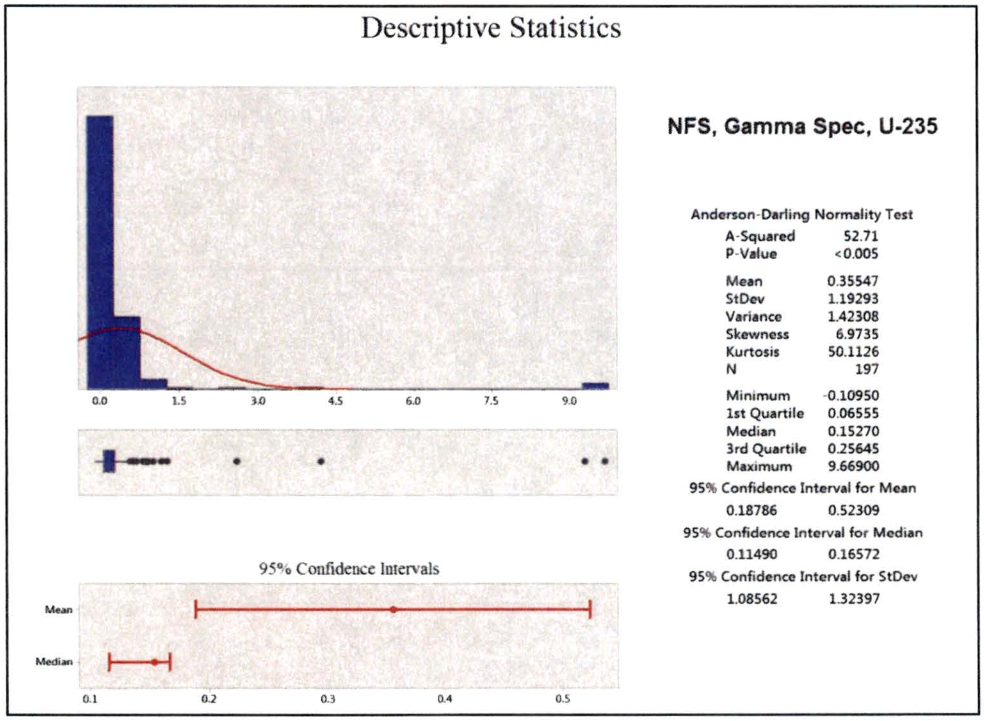

Figure 4-143 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 16-Eastern

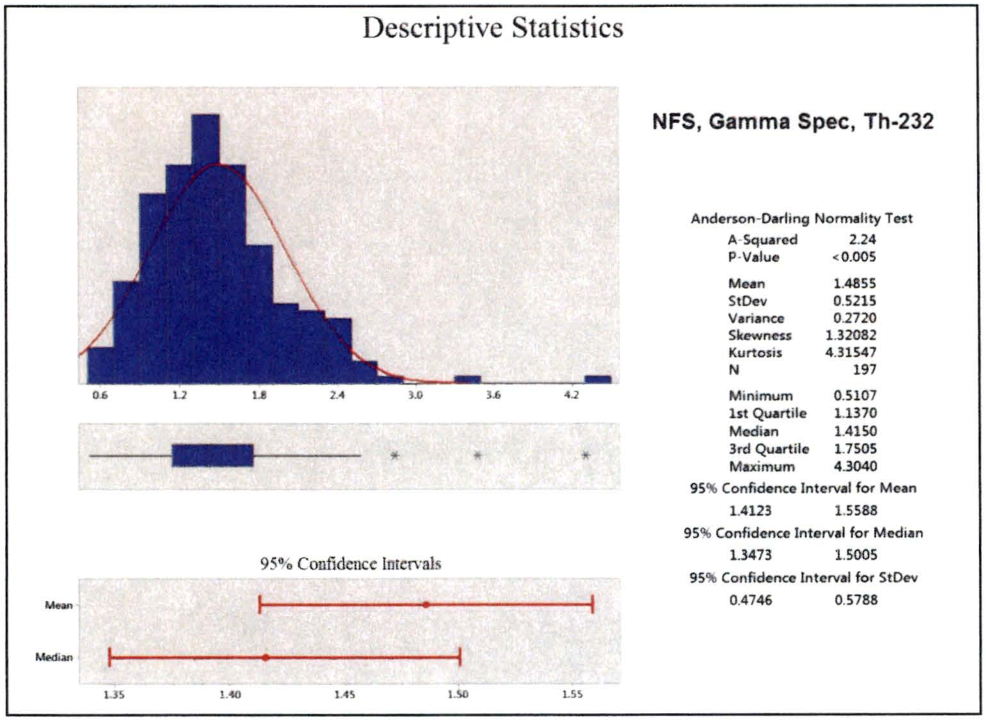

Figure 4-144 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 16-Eastern

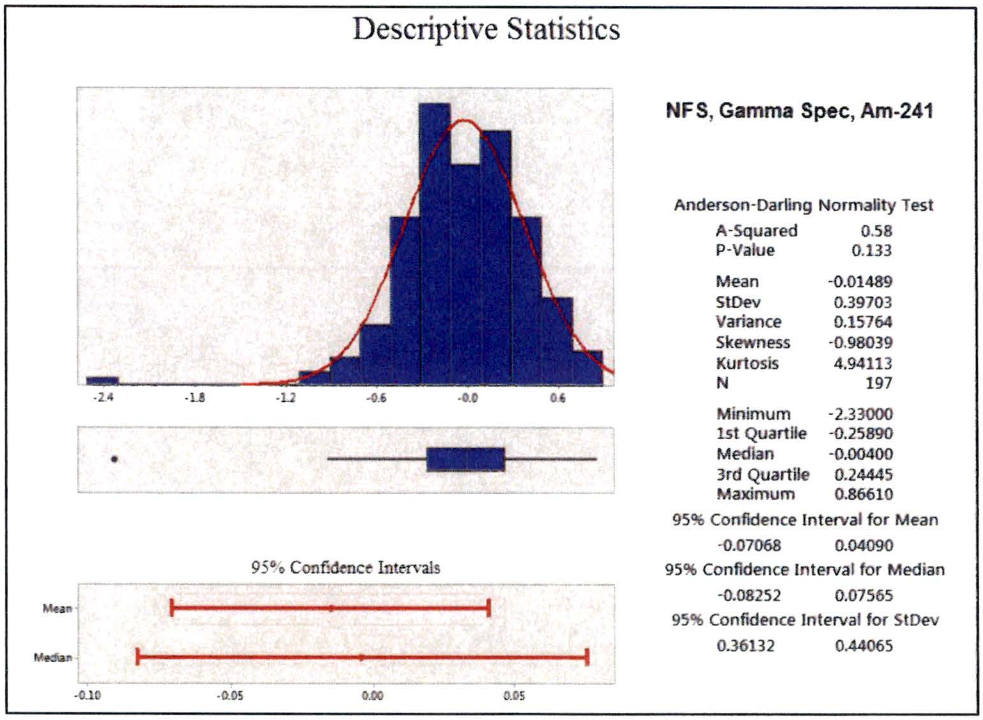

Figure 4-145 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 16-Eastern

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 16-Eastern is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.9.2 Paragon Gamma Spectroscopy Soil Sample Results

Of the 180 soil samples collected from Survey Unit 16-Eastern, 19 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the Paragon generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-146), Th-232 (Figure 4-147), and Am-241 (Figure 4-148) are presented in this subsection. All isotopic data is in units of pCi/g.

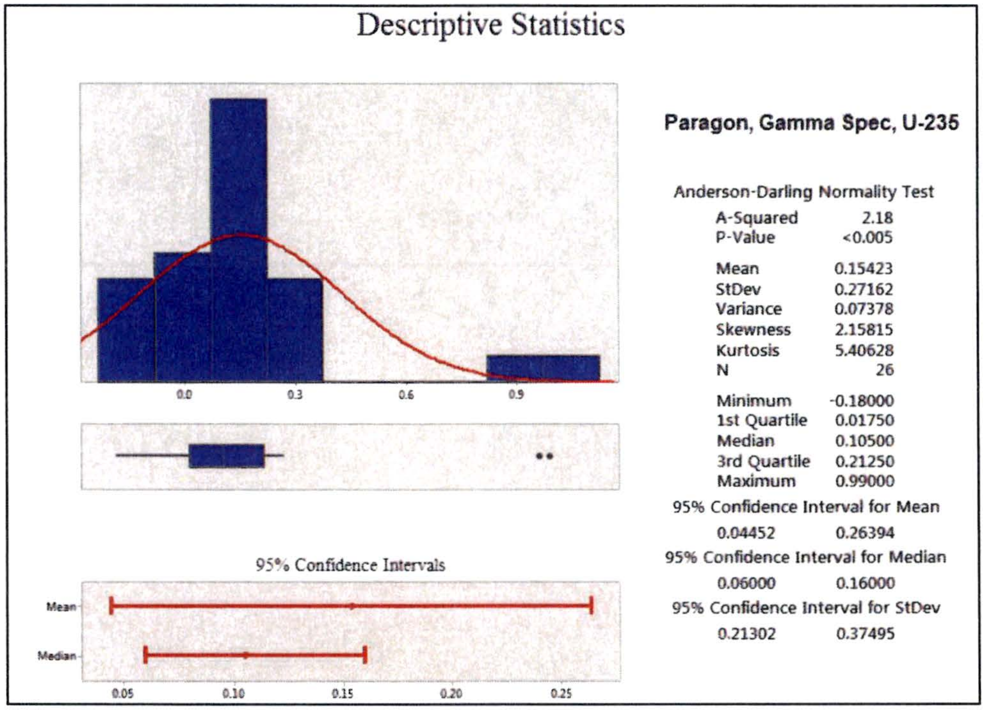

Figure 4-146 Summary Statistics: U-235, Paragon, Gamma Spectroscopy, SU 16-Eastern

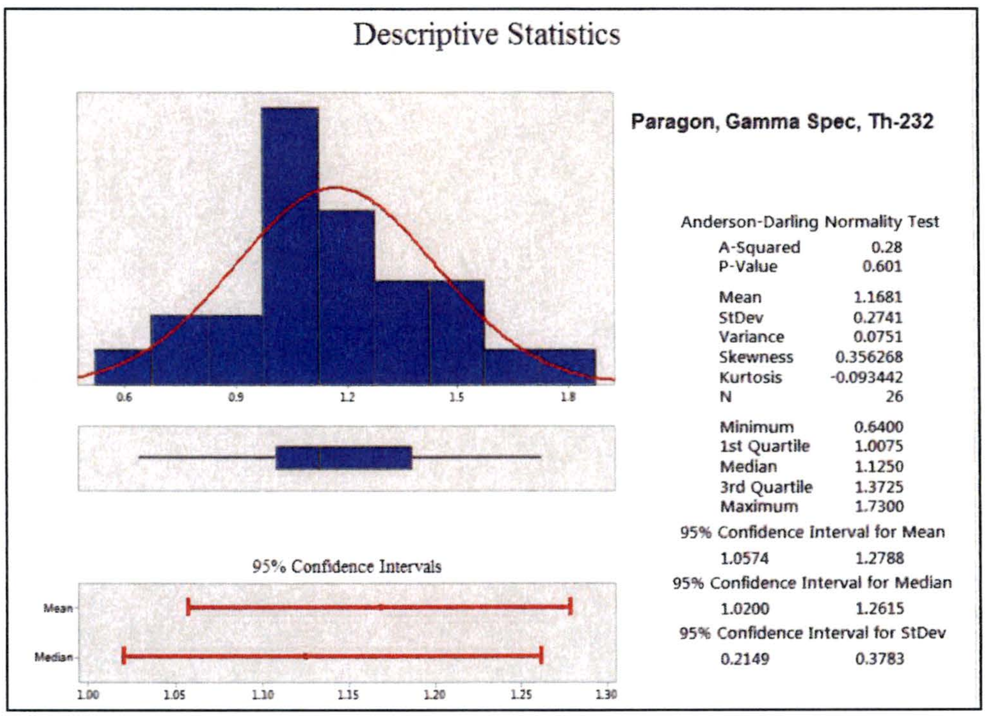

Figure 4-147 Summary Statistics: Th-232, Paragon, Gamma Spectroscopy, SU 16-Eastern

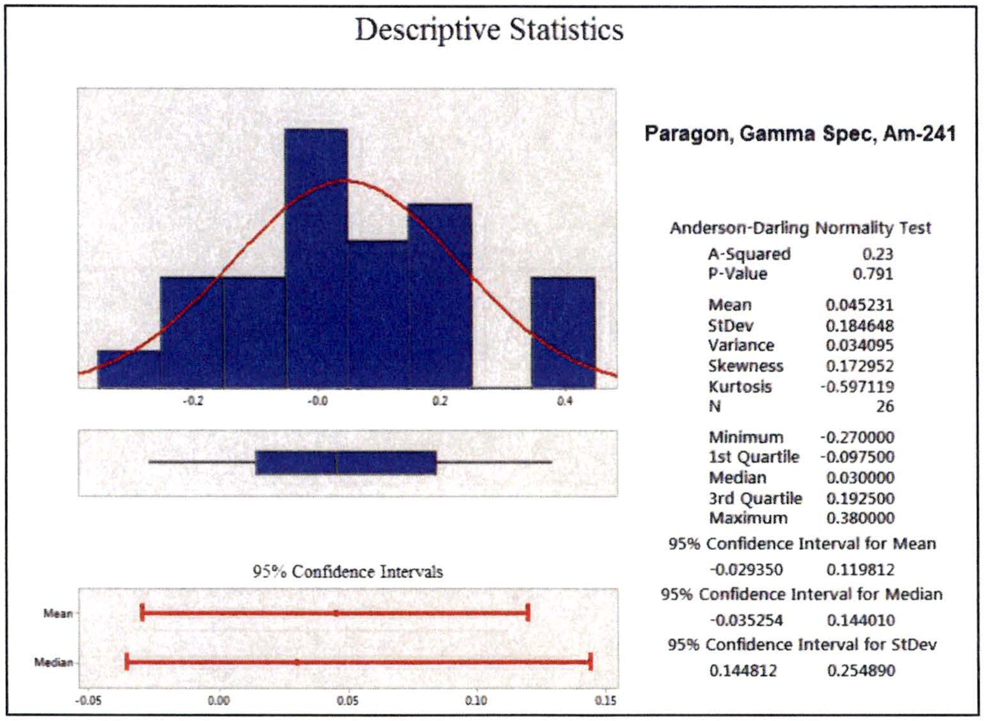

Figure 4-148 Summary Statistics: Am-241, Paragon, Gamma Spectroscopy, SU 16-Eastern

From the summary statistics for the gamma spectroscopy analyses performed by Paragon, it is again evident that the residual radioactivity in Survey Unit 16-Eastern is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by Paragon yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.9.3 Paragon Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 180 soil samples collected from Survey Unit 16-Eastern, 19 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by Paragon and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the Paragon generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-149), Pu-238 (Figure 4-150), Pu-239/240 (Figure 4-168), Pu-241 (Figure 4-152), Pu-242 (Figure 4-153), Th-230 (Figure 4-154), Th-232 (Figure 4-172), U-233/234 (Figure 4-156), U-235 (Figure 4-157), U-238 (Figure 4-158), and Tc-99 (Figure 4-159) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

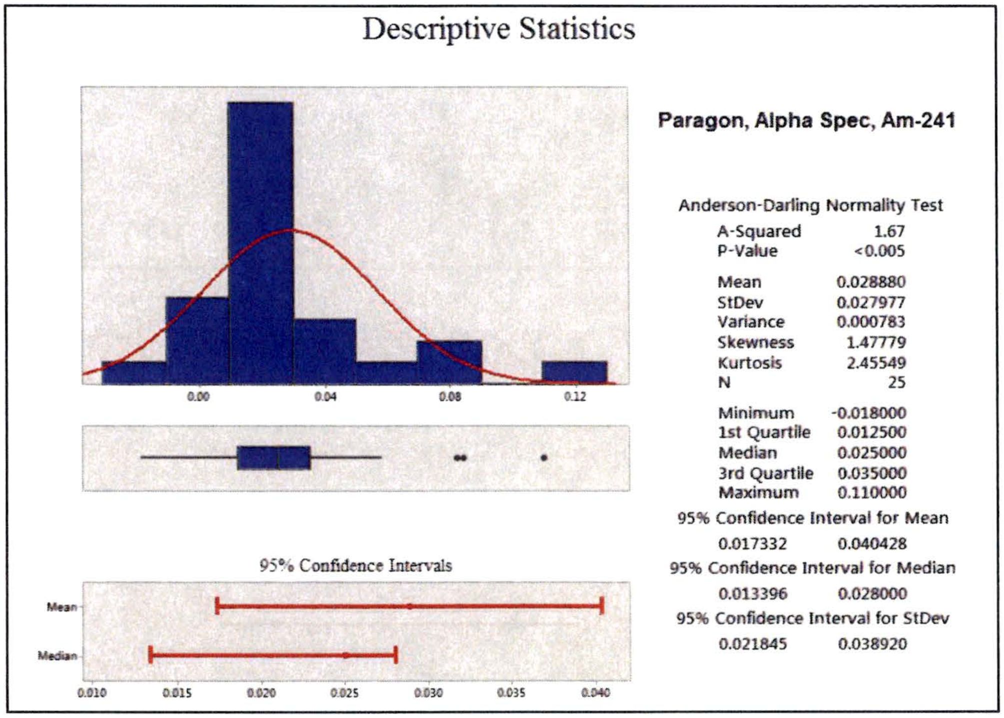

Figure 4-149 Summary Statistics: Am-241, Paragon, Alpha Spectroscopy, SU 16-Eastern

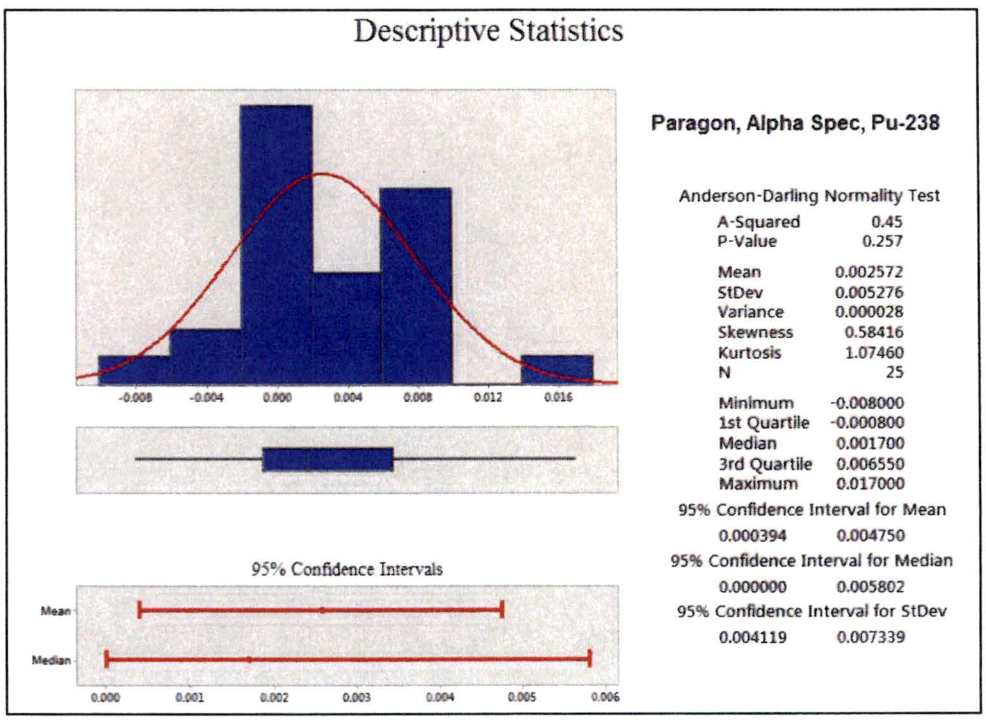

Figure 4-150 Summary Statistics: Pu-238, Paragon, Alpha Spectroscopy, SU 16-Eastern

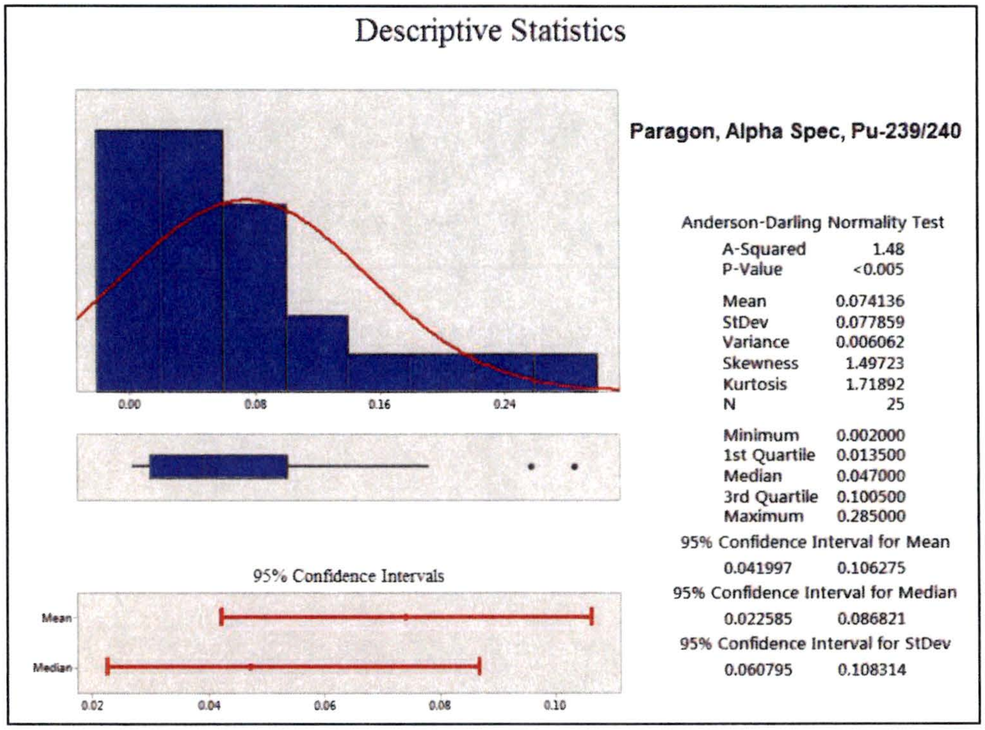

Figure 4-151 Summary Statistics: Pu-239/240, Paragon, Alpha Spectroscopy, SU 16-Eastern

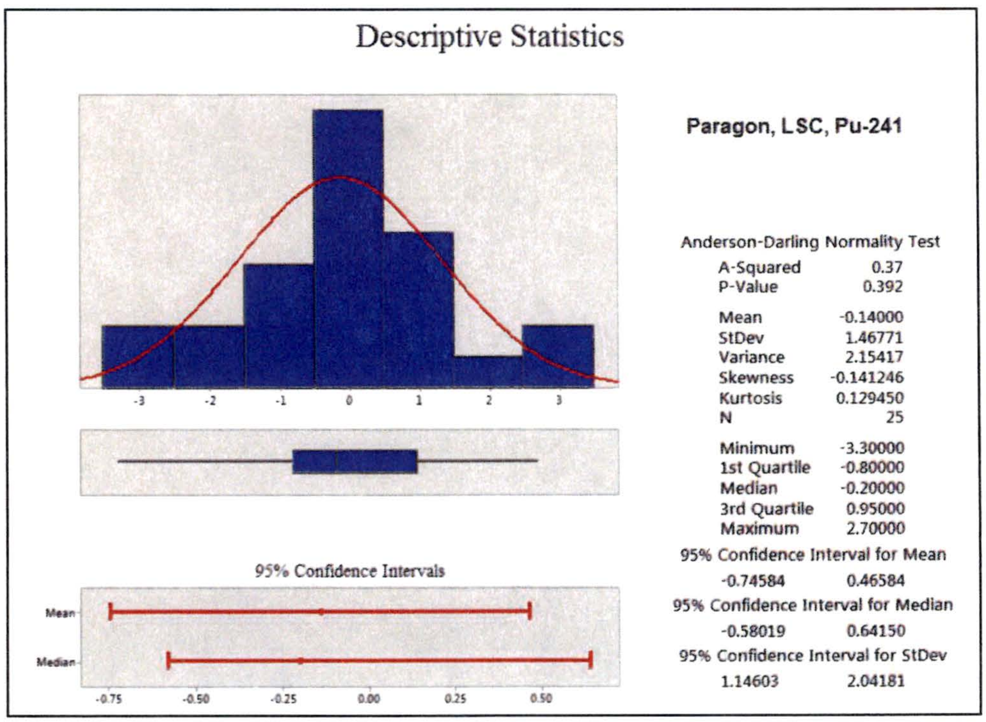

Figure 4-152 Summary Statistics: Pu-241, Paragon, Liquid Scintillation, SU 16-Eastern

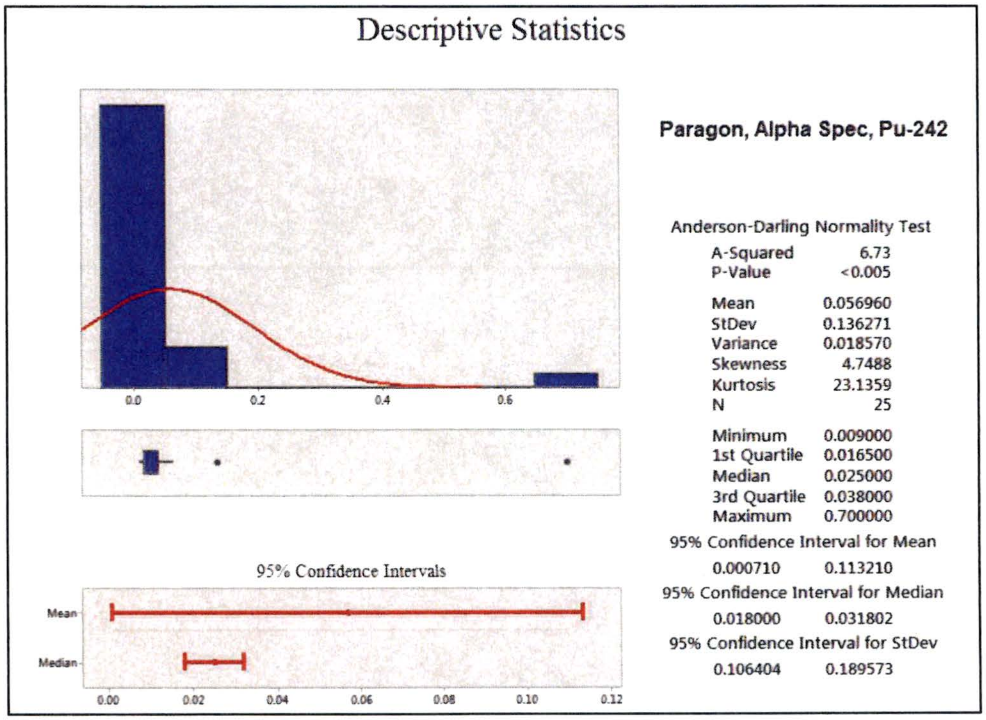

Figure 4-153 Summary Statistics: Pu-242, Paragon, Alpha Spectroscopy, SU 16-Eastern

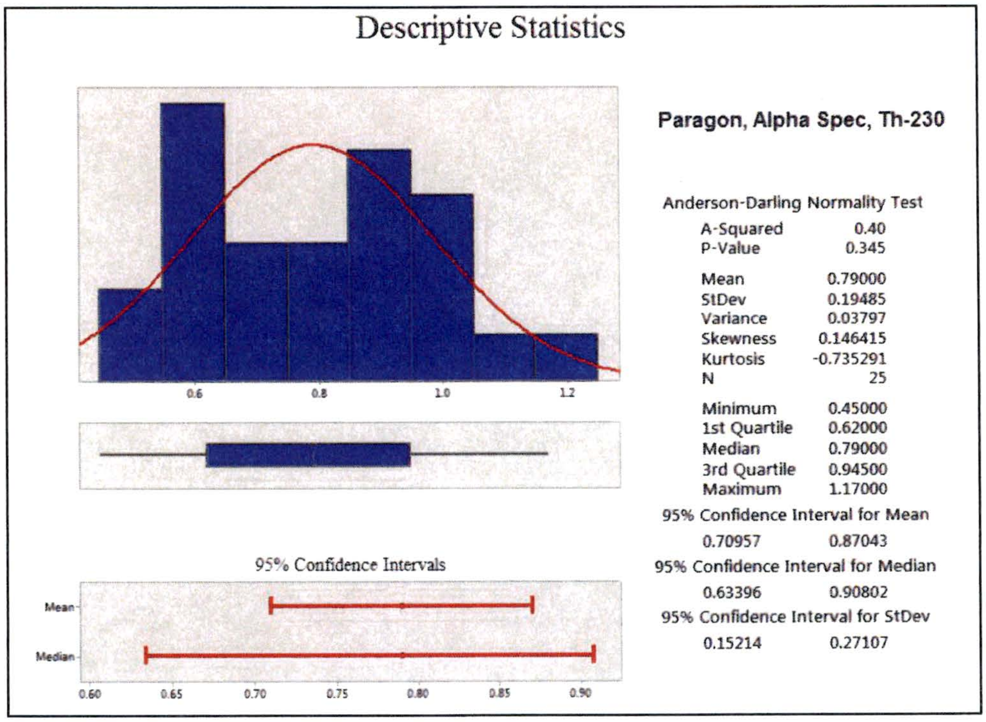

Figure 4-154 Summary Statistics: Th-230, Paragon, Alpha Spectroscopy, SU 16-Eastern

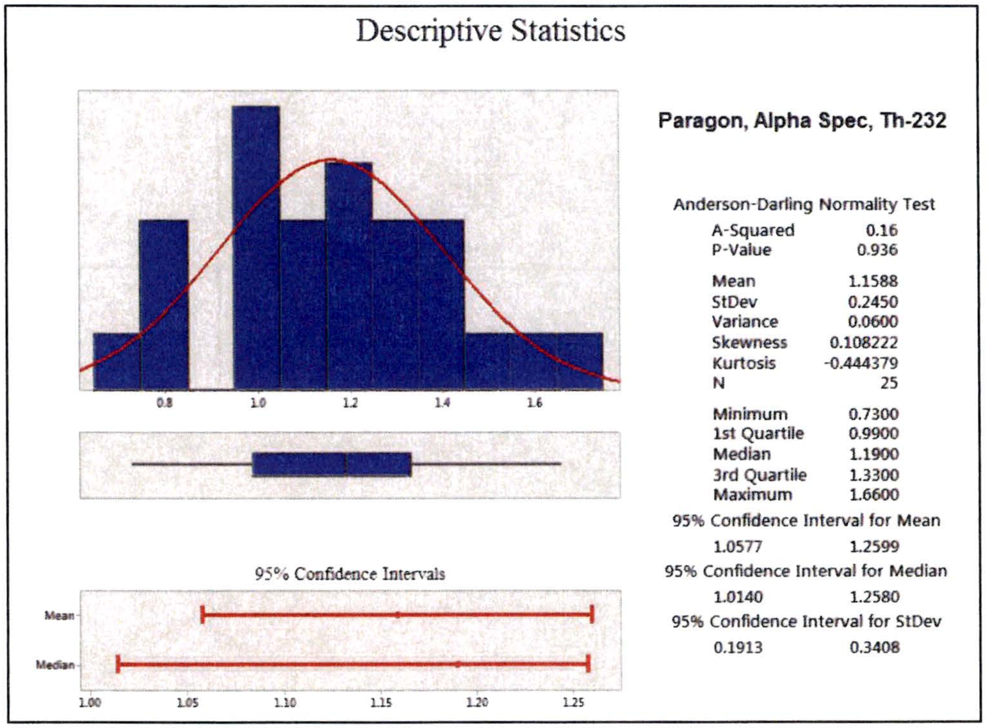

Figure 4-155 Summary Statistics: Th-232, Paragon, Alpha Spectroscopy, SU 16-Eastern

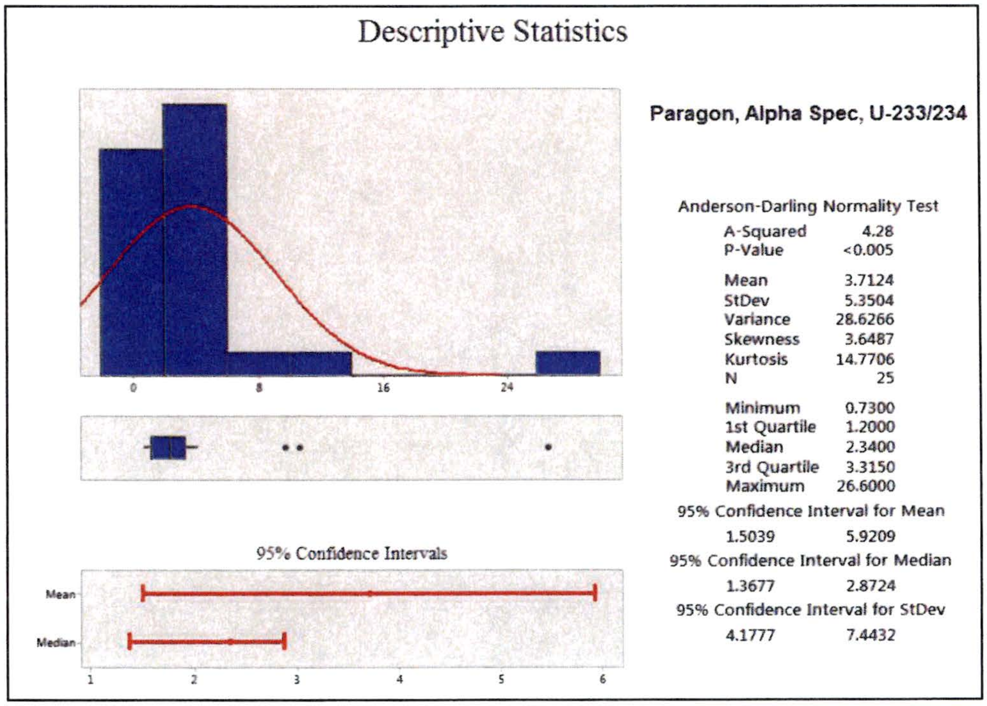

Figure 4-156 Summary Statistics: U-233/234, Paragon, Alpha Spectroscopy, SU 16-Eastern

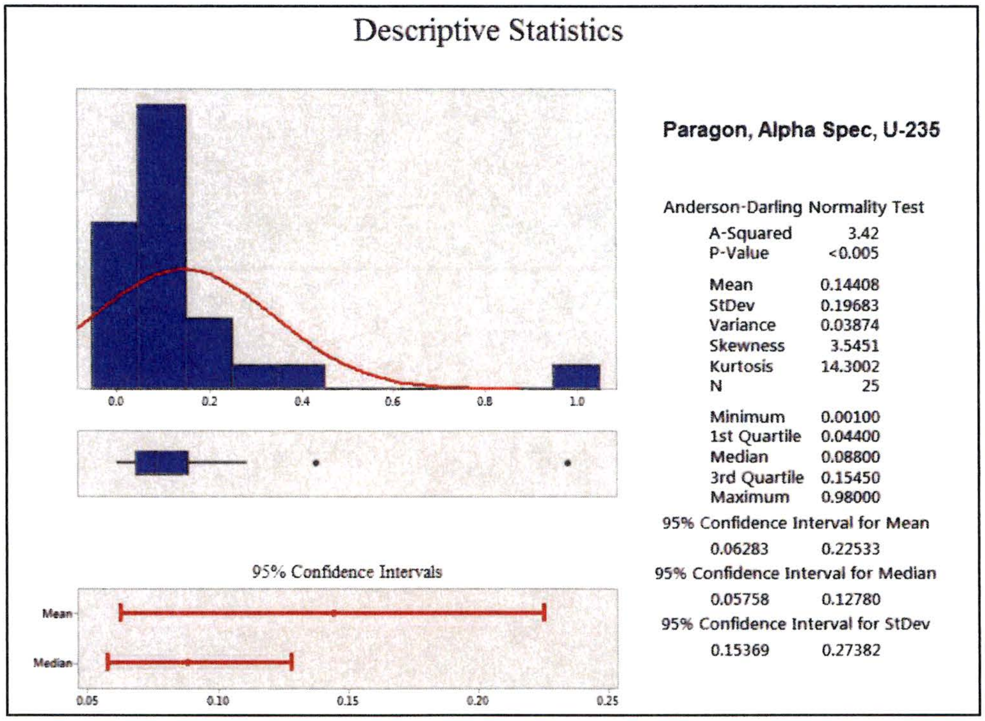

Figure 4-157 Summary Statistics: U-235, Paragon, Alpha Spectroscopy, SU 16-Eastern

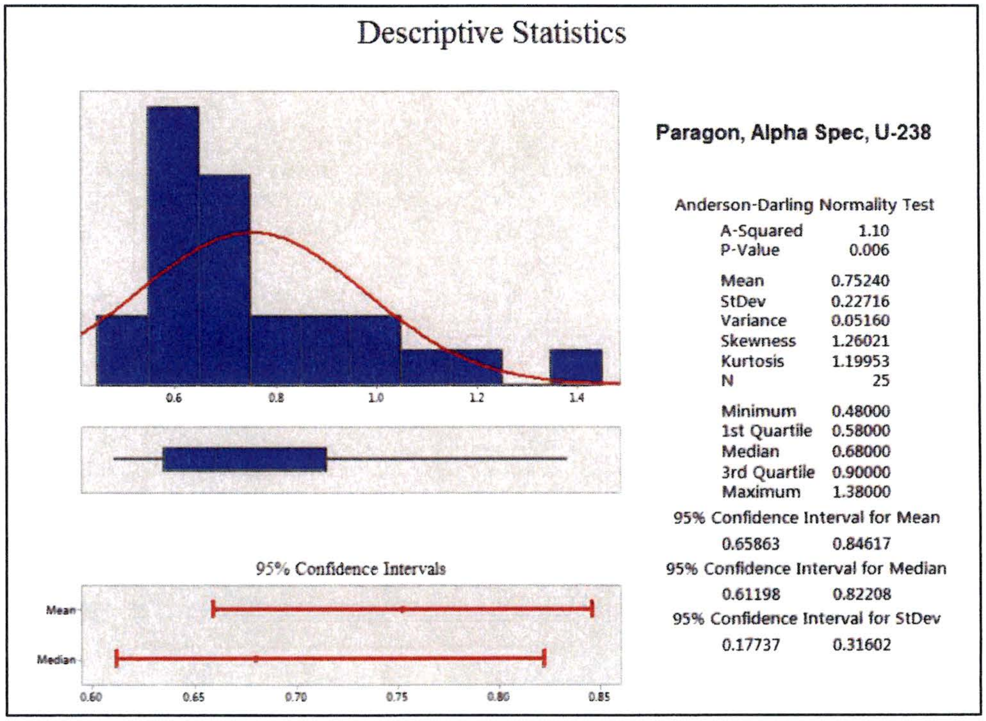

Figure 4-158 Summary Statistics: U-238, Paragon, Alpha Spectroscopy, SU 16-Eastern

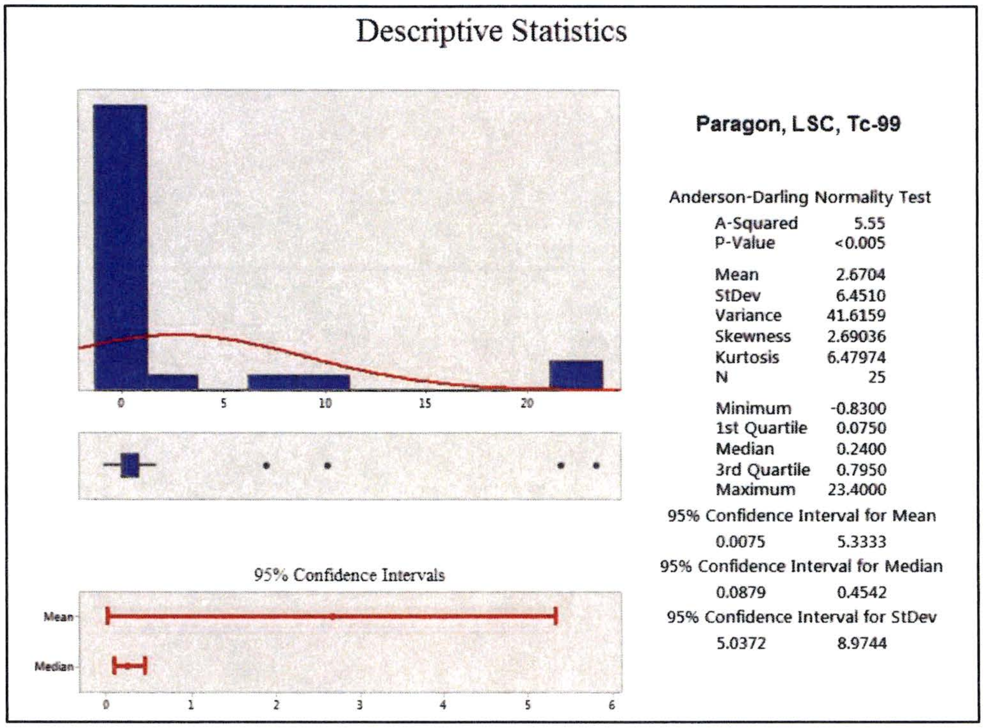

Figure 4-159 Summary Statistics: Tc-99, Paragon, Liquid Scintillation, SU 16-Eastern

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by Paragon, it is evident that the residual radioactivity in Survey Unit 16-Eastern associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.10 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 17

4.10.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 313 soil samples collected from Survey Unit 17 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-160), Th-232 (Figure 4-161), and Am-241 (Figure 4-162) are presented in this subsection. All isotopic data is in units of pCi/g.

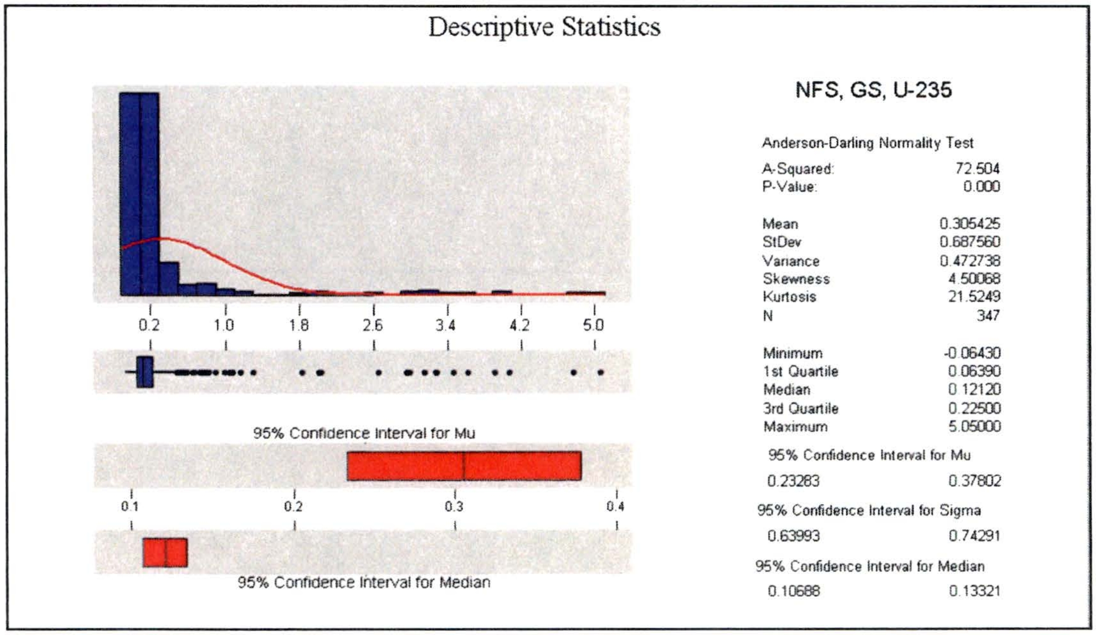

Figure 4-160 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 17

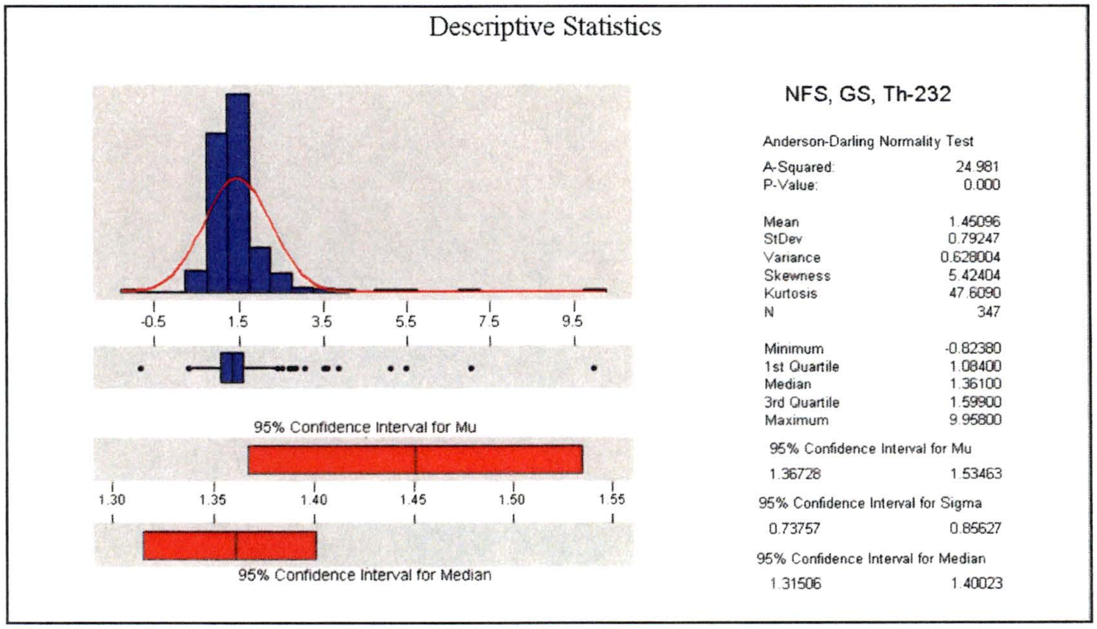

Figure 4-161 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 17

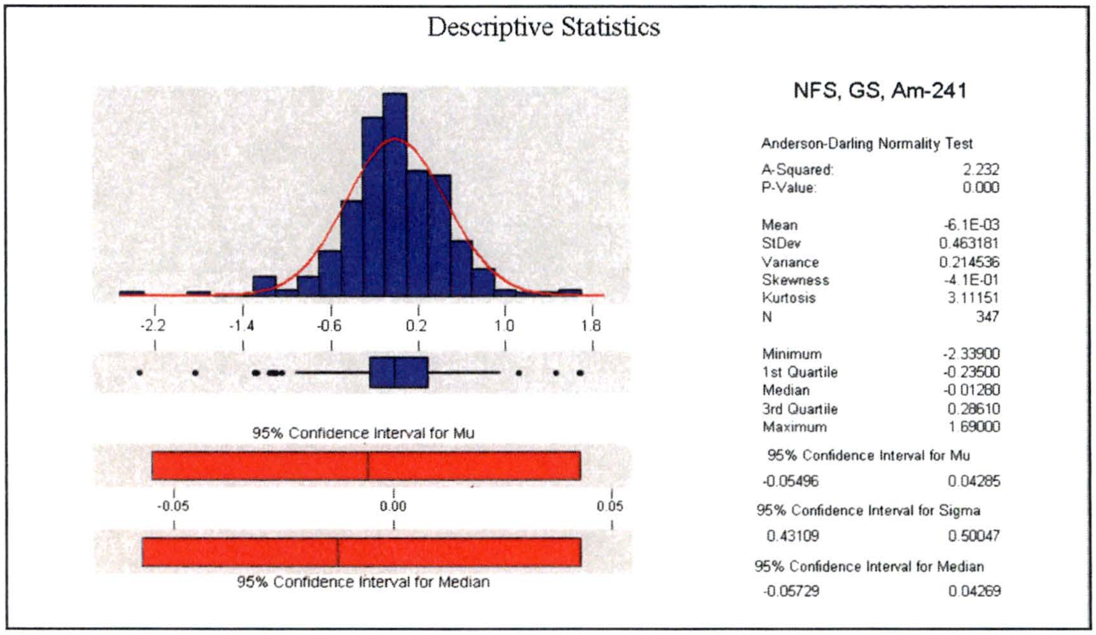

Figure 4-162 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 17

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 17 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.10.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 313 soil samples collected from Survey Unit 17, 35 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-163), Th-232 (Figure 4-164), and Am-241 (Figure 4-165) are presented in this subsection. All isotopic data is in units of pCi/g.

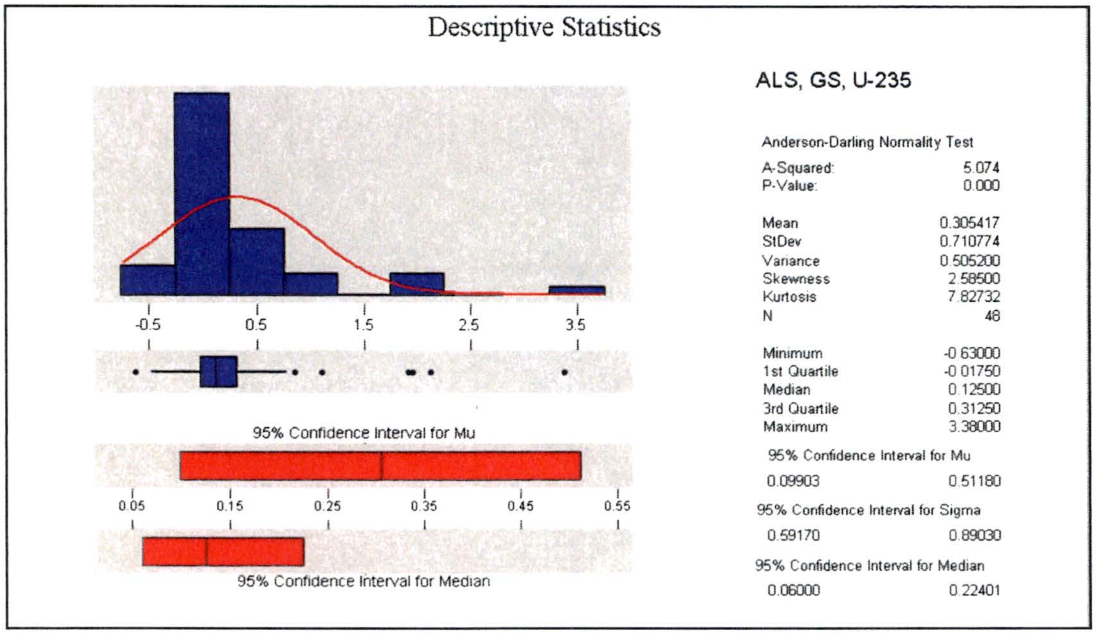

Figure 4-163 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 17

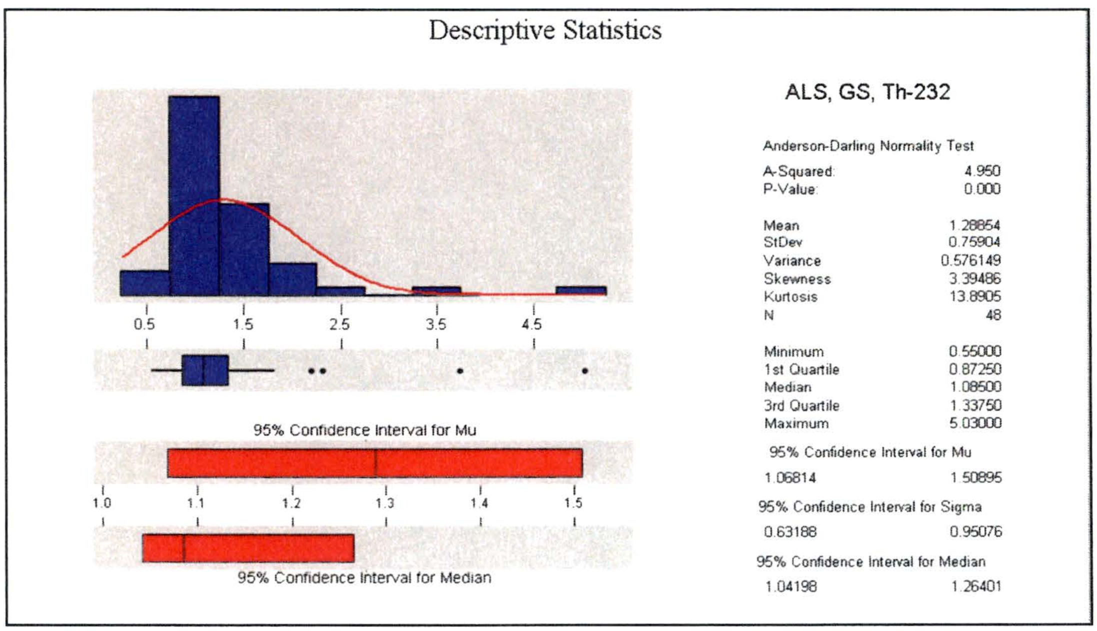

Figure 4-164 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 17

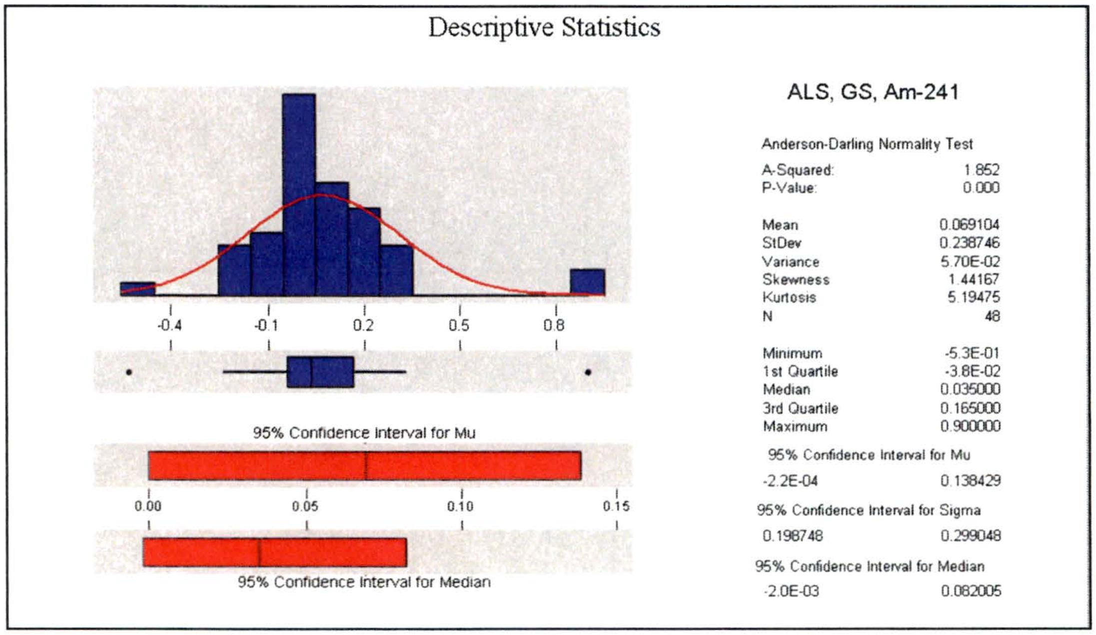

Figure 4-165 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 17

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 17 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.10.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 313 soil samples collected from Survey Unit 17, 35 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-166), Pu-238 (Figure 4-167), Pu-239/240 (Figure 4-168), Pu-241 (Figure 4-169), Pu-242 (Figure 4-170), Th-230 (Figure 4-171), Th-232 (Figure 4-172), U-233/234 (Figure 4-173), U-235 (Figure 4-174), U-238 (Figure 4-175), and Tc-99 (Figure 4-176) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

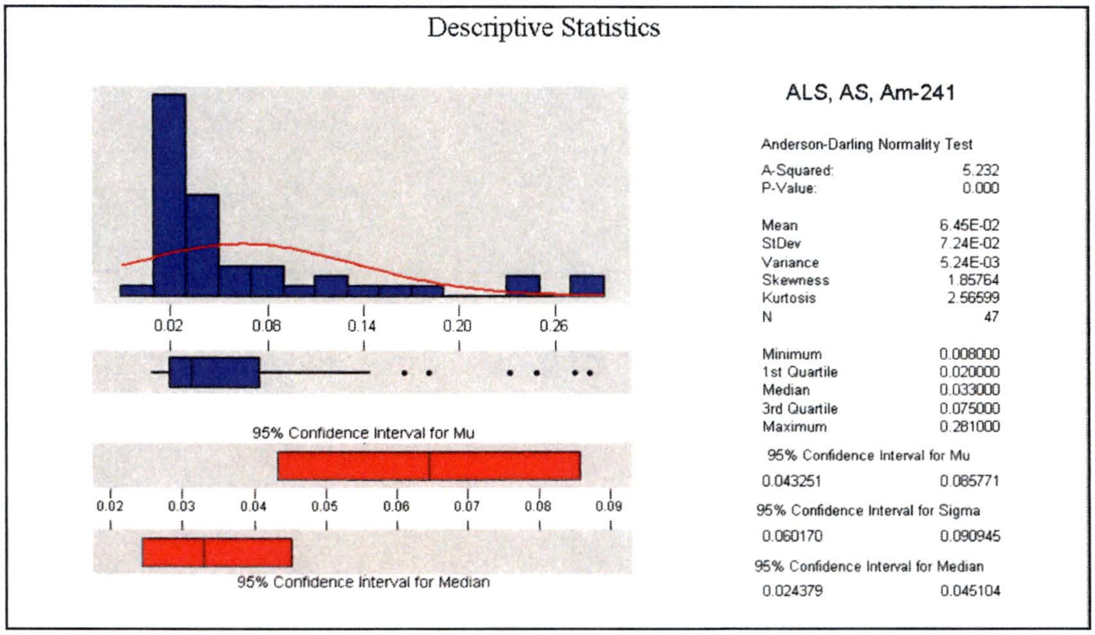

Figure 4-166 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 17

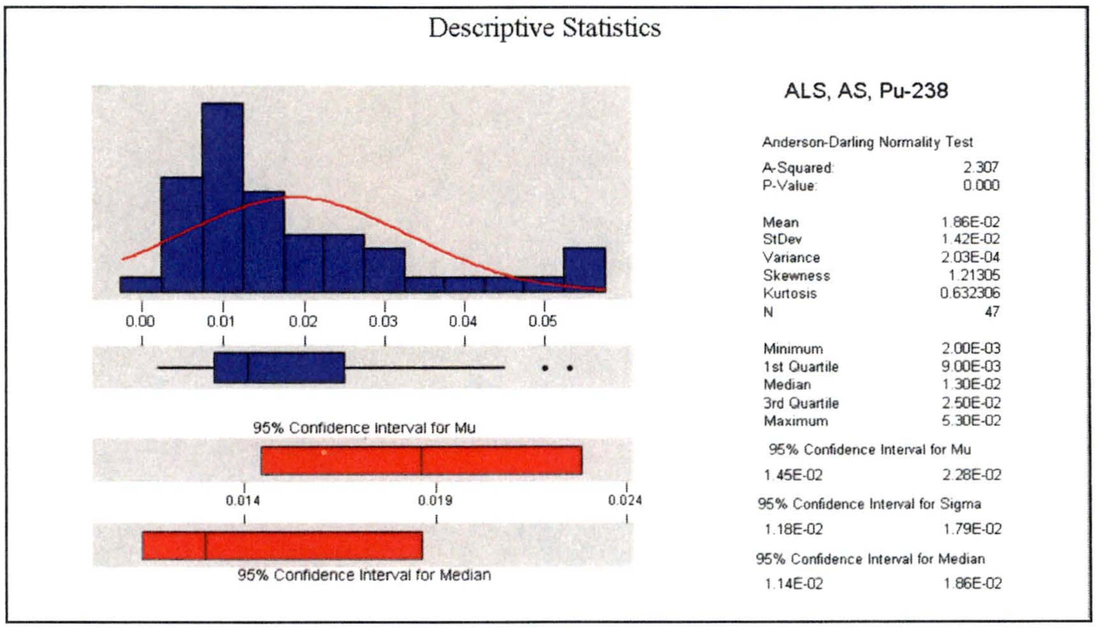

Figure 4-167 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 17

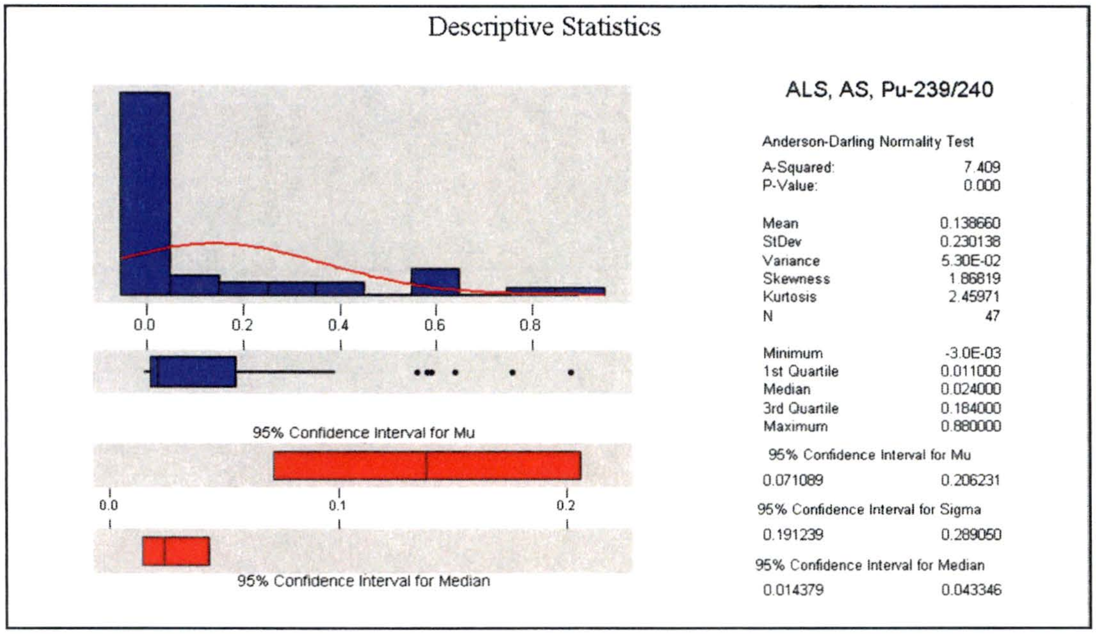

Figure 4-168 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 17

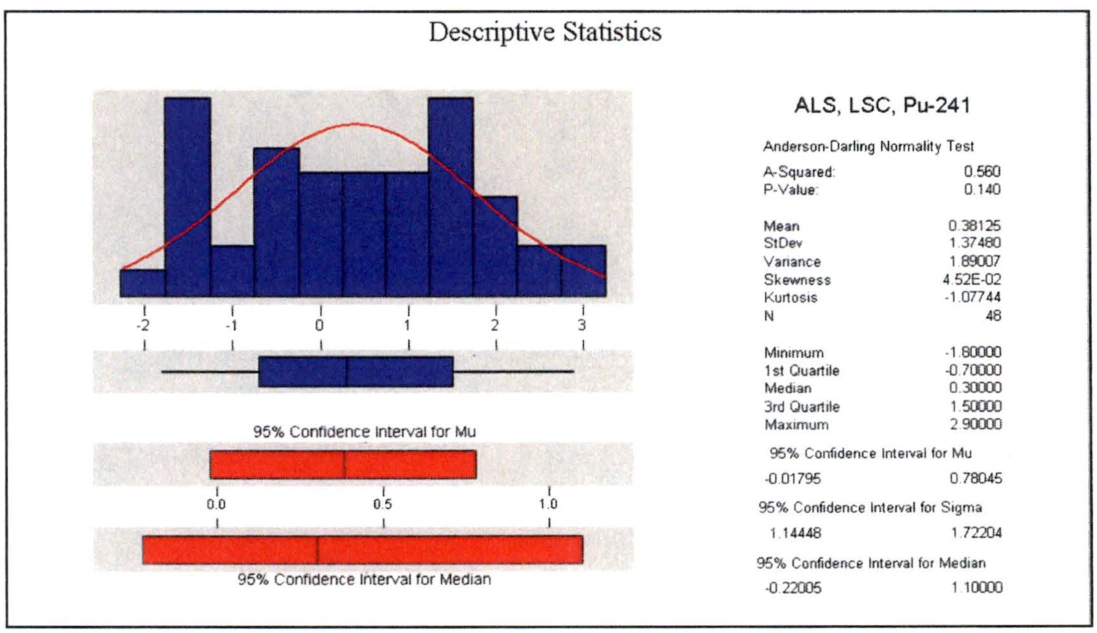

Figure 4-169 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 17

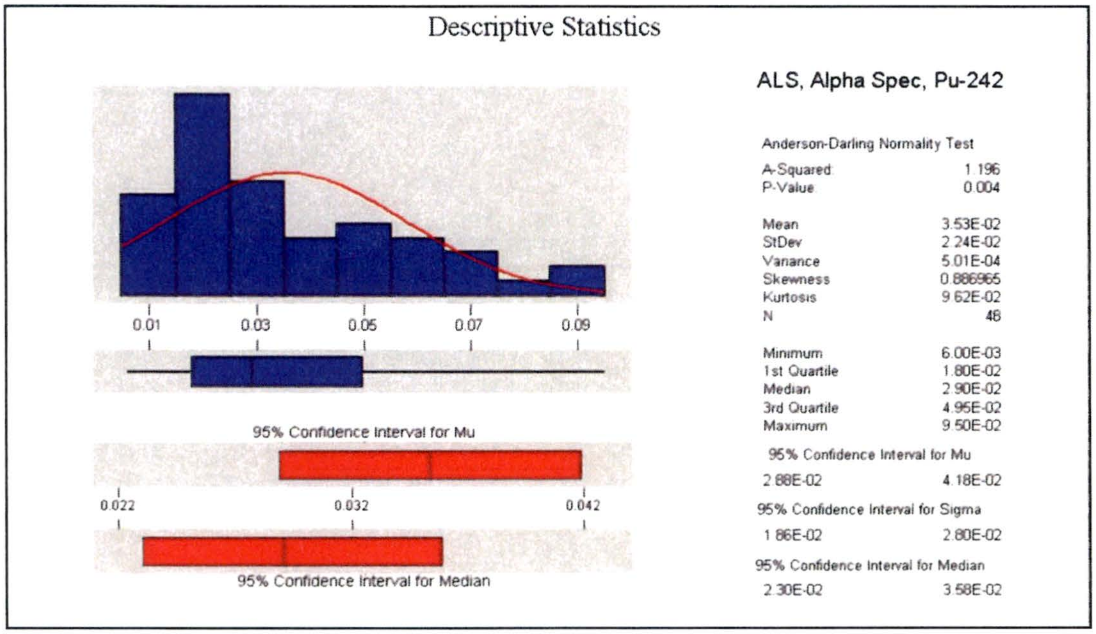

Figure 4-170 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 17

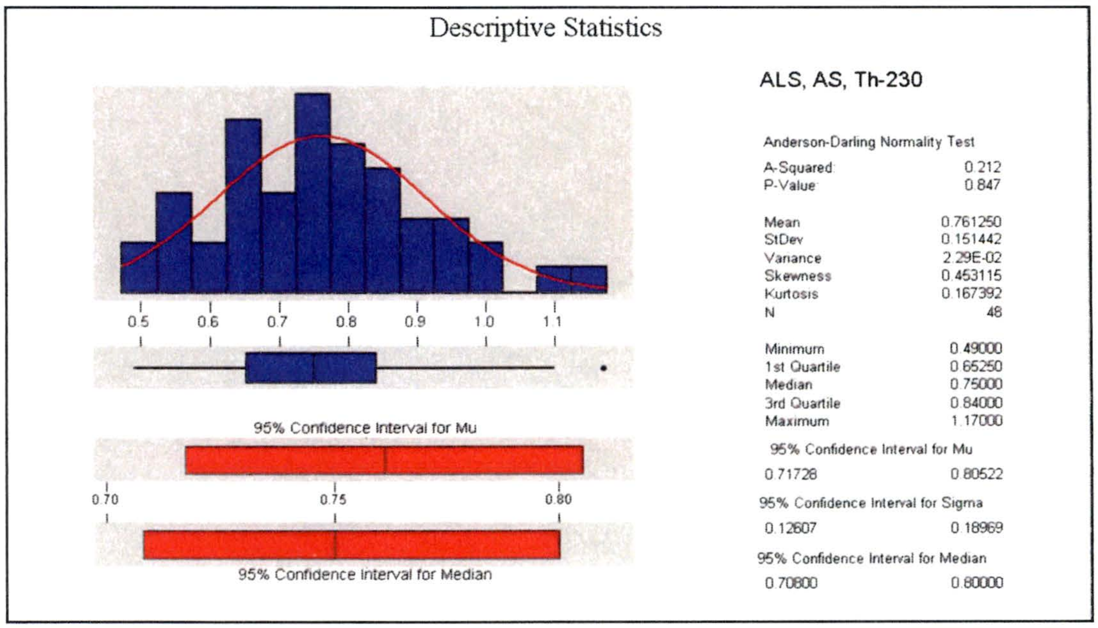

Figure 4-171 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 17

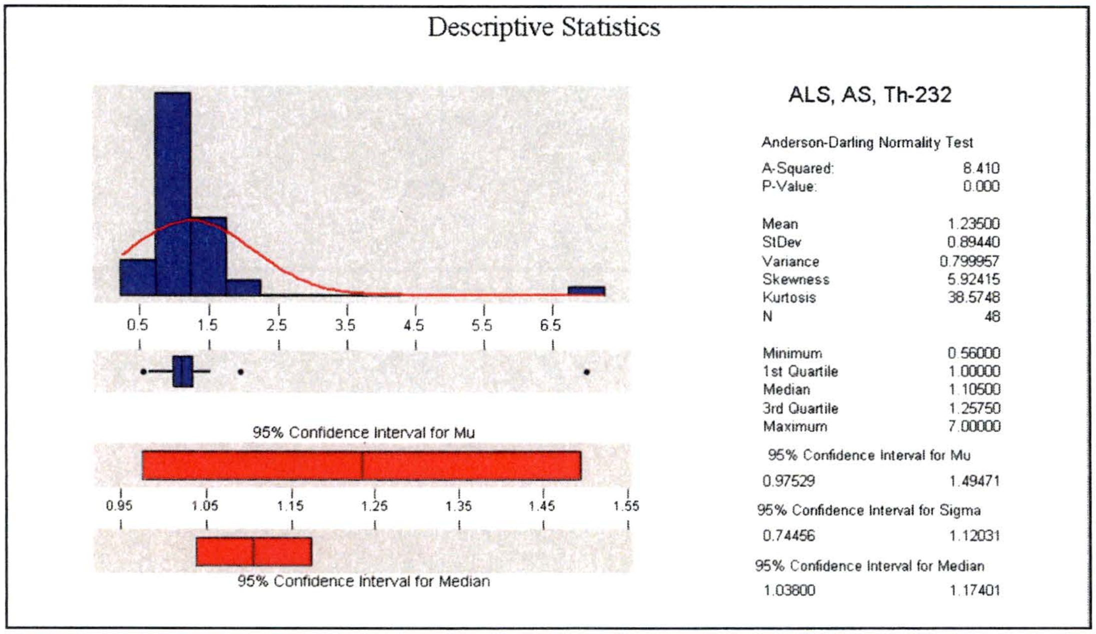

Figure 4-172 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 17

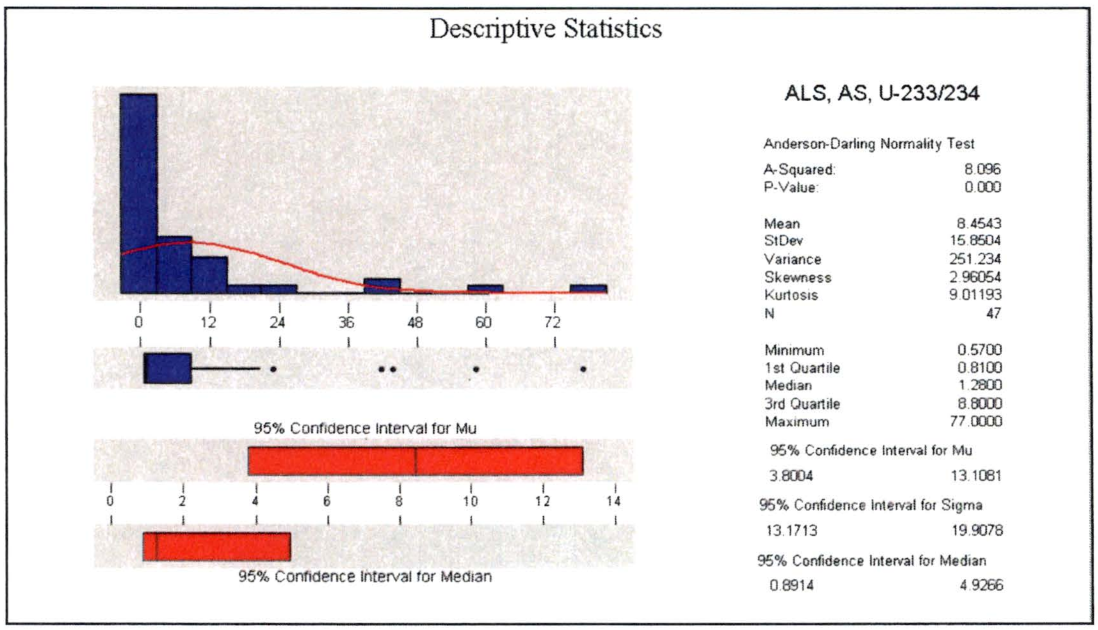

Figure 4-173 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 17

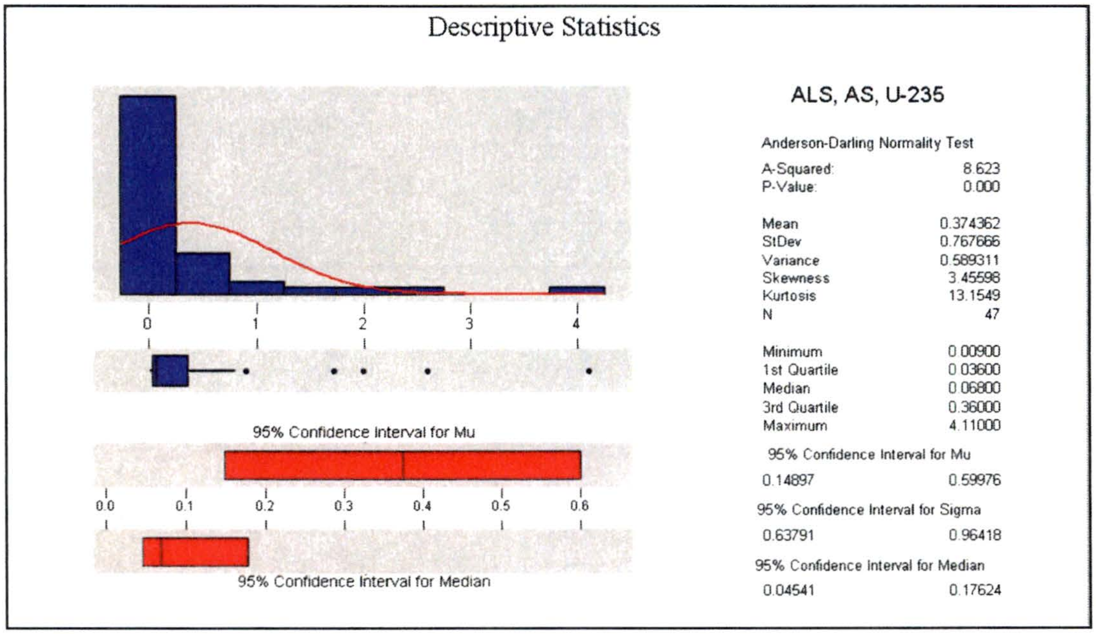

Figure 4-174 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 17

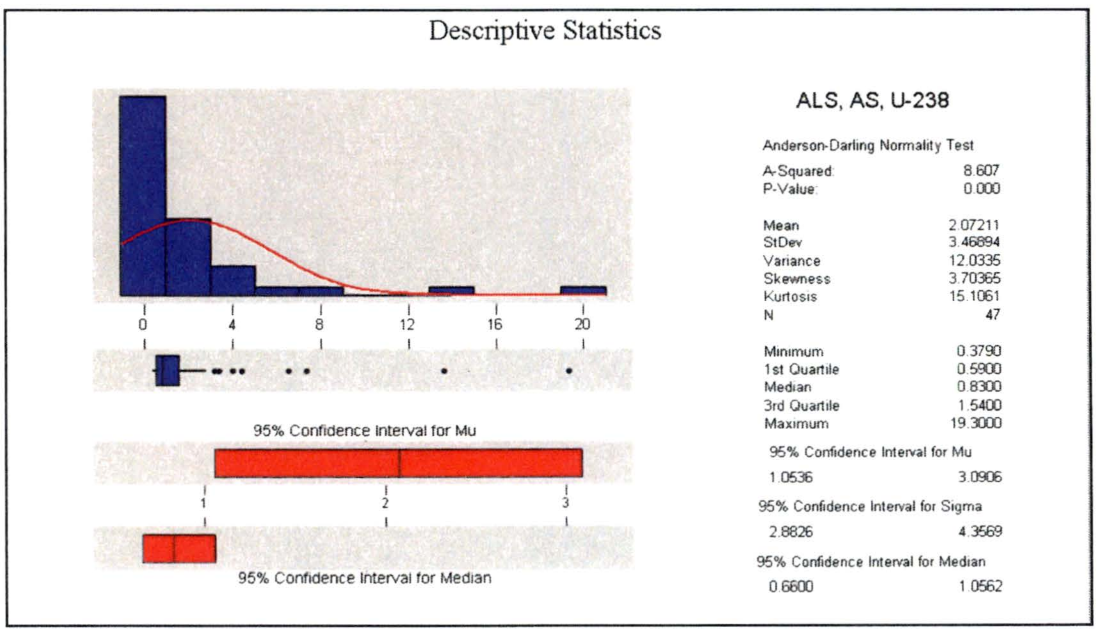

Figure 4-175 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 17

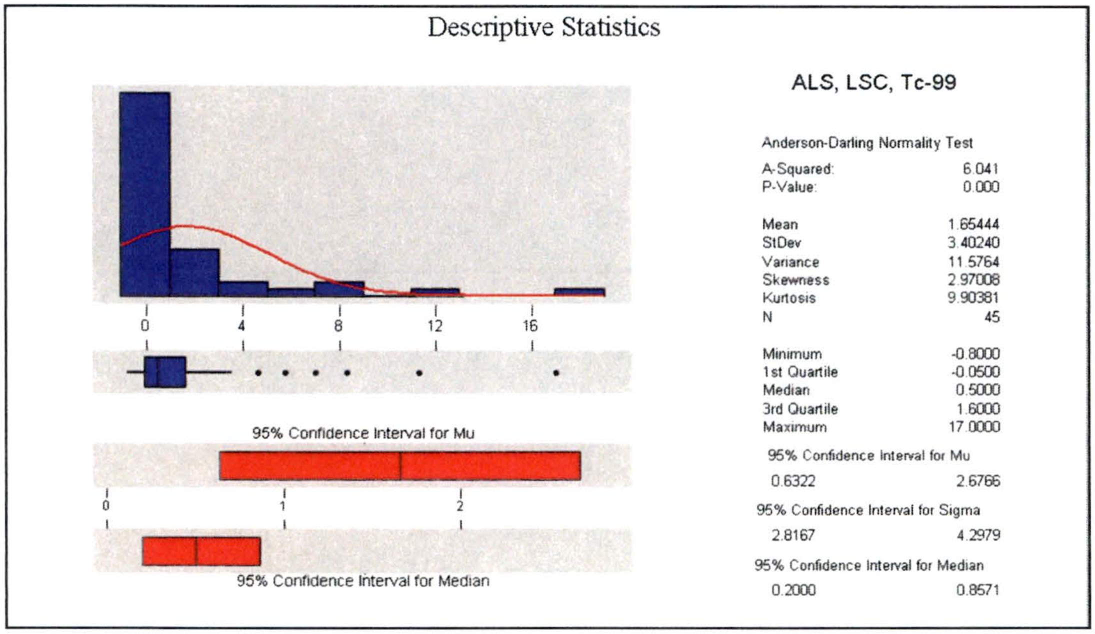

Figure 4-176 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 17

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 17 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.11 SUBSURFACE SOIL SAMPLE RESULTS, SURVEY UNIT 18

4.11.1 NFS Gamma Spectroscopy Soil Sample Results

Each of the 300 soil samples collected from Survey Unit 18 (plus duplicate samples) was analyzed by NFS for the three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the NFS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-177), Th-232 (Figure 4-178), and Am-241 (Figure 4-179) are presented in this subsection. All isotopic data is in units of pCi/g.

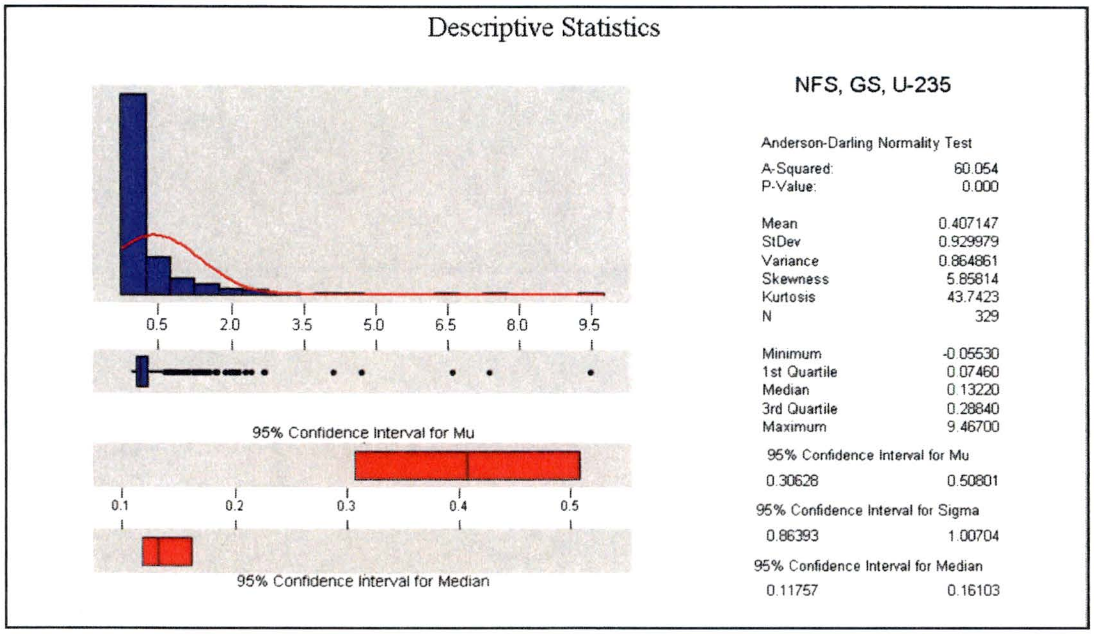

Figure 4-177 Summary Statistics: U-235, NFS, Gamma Spectroscopy, SU 18

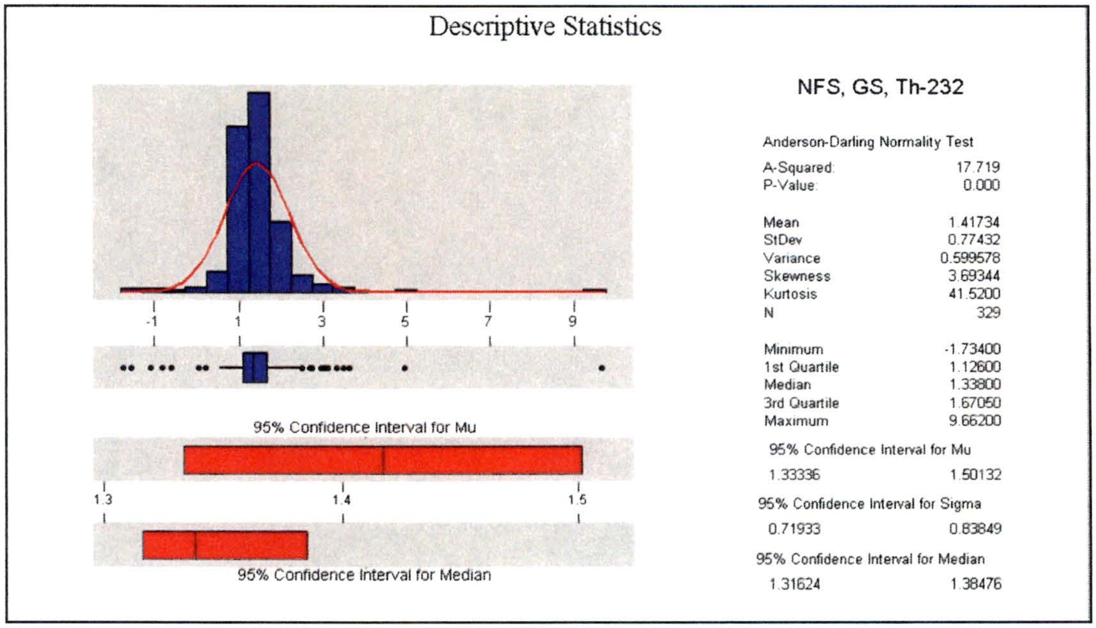

Figure 4-178 Summary Statistics: Th-232, NFS, Gamma Spectroscopy, SU 18

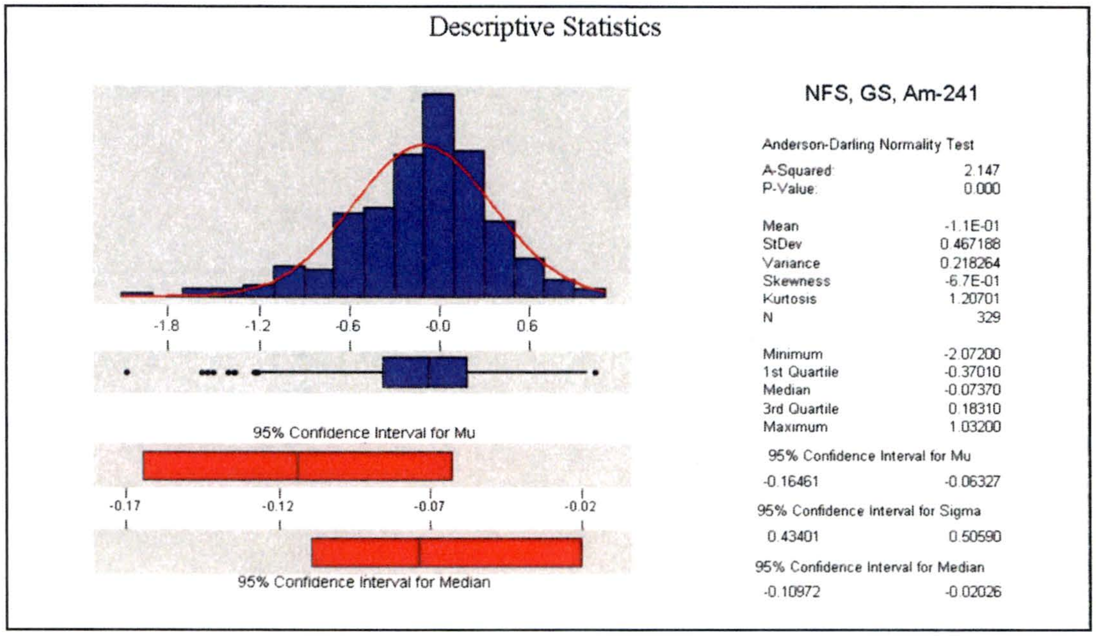

Figure 4-179 Summary Statistics: Am-241, NFS, Gamma Spectroscopy, SU 18

From the summary statistics for the surrogate radionuclide gamma spectroscopy analyses, it is evident that the residual radioactivity in Survey Unit 18 is comparable to concentrations expected to be naturally found in non-impacted soils. Various estimators of central tendency (i.e., mean, median) yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed.

4.11.2 ALS Gamma Spectroscopy Soil Sample Results

Of the 300 soil samples collected from Survey Unit 18, 32 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include gamma spectroscopy analysis of the same three gamma emitting surrogate isotopes, U-235, Th-232, and Am-241. A tabular and graphical summary of the ALS generated dataset representing gamma spectroscopy analyses for U-235 (Figure 4-180), Th-232 (Figure 4-181), and Am-241 (Figure 4-182) are presented in this subsection. All isotopic data is in units of pCi/g.

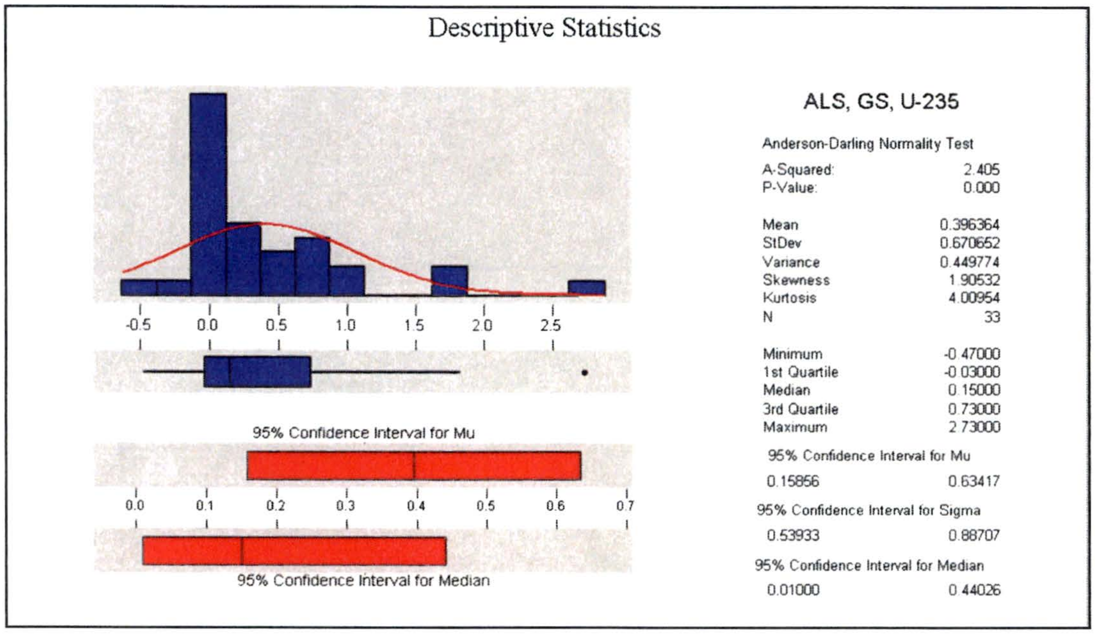

Figure 4-180 Summary Statistics: U-235, ALS, Gamma Spectroscopy, SU 18

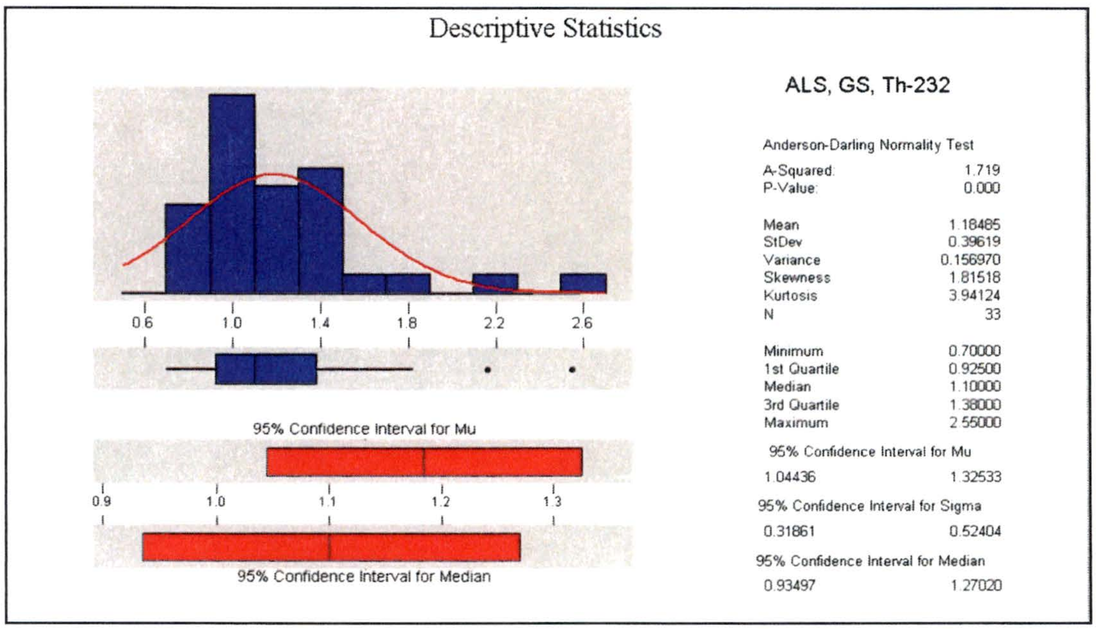

Figure 4-181 Summary Statistics: Th-232, ALS, Gamma Spectroscopy, SU 18

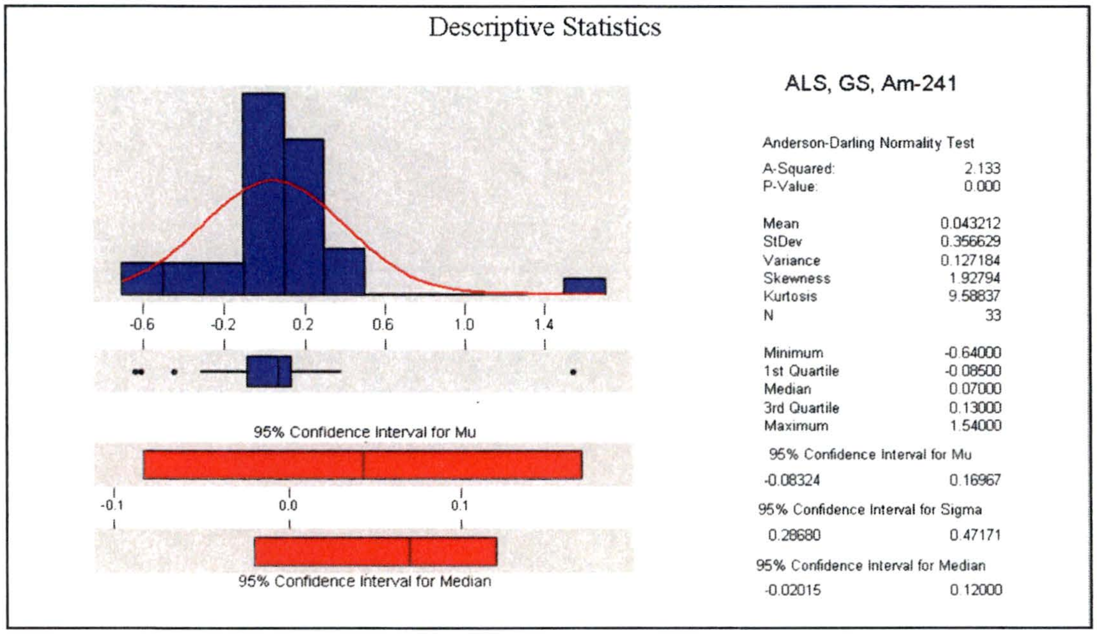

Figure 4-182 Summary Statistics: Am-241, ALS, Gamma Spectroscopy, SU 18

From the summary statistics for the gamma spectroscopy analyses performed by ALS, it is again evident that the residual radioactivity in Survey Unit 18 is comparable to concentrations expected to be naturally found in non-impacted soils. Again, too, the estimators of central tendency yielded nearly equivalent results, suggesting that the data sets are approximately normally distributed. Additionally, the results generated by NFS and those generated by ALS yielded essentially equivalent measures of the mean and median isotopic concentrations.

4.11.3 ALS Alpha Spectroscopy and Liquid Scintillation Counting Soil Sample Results

Of the 300 soil samples collected from Survey Unit 18, 32 (plus duplicate samples) were selected for full-suite radiological analysis. The full-suite analyses were performed by ALS and include alpha spectroscopy and liquid scintillation analyses of the isotopes that are inferred from the concentrations of surrogate isotopes. A tabular and graphical summary of the ALS generated dataset representing alpha spectroscopy and liquid scintillation analyses for Am-241 (Figure 4-183), Pu-238 (Figure 4-184), Pu-239/240 (Figure 4-185), Pu-241 (Figure 4-186), Pu-242 (Figure 4-187), Th-230 (Figure 4-188), Th-232 (Figure 4-189), U-233/234 (Figure 4-190), U-235 (Figure 4-191), U-238 (Figure 4-192), and Tc-99 (Figure 4-193) are presented in this subsection. Again, all isotopic data is in units of pCi/g.

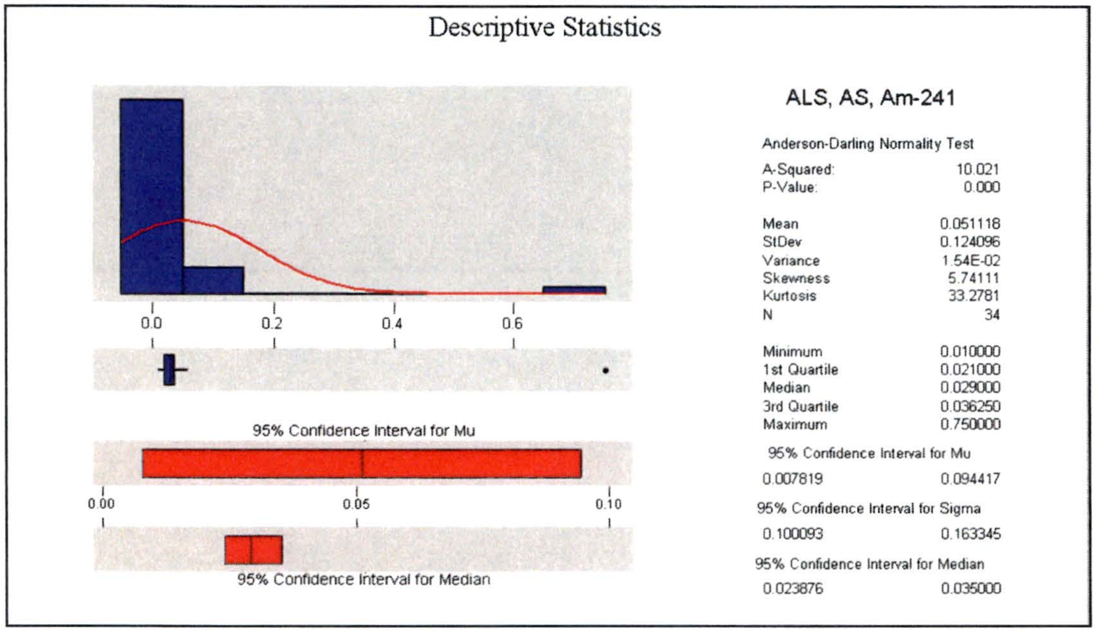

Figure 4-183 Summary Statistics: Am-241, ALS, Alpha Spectroscopy, SU 18

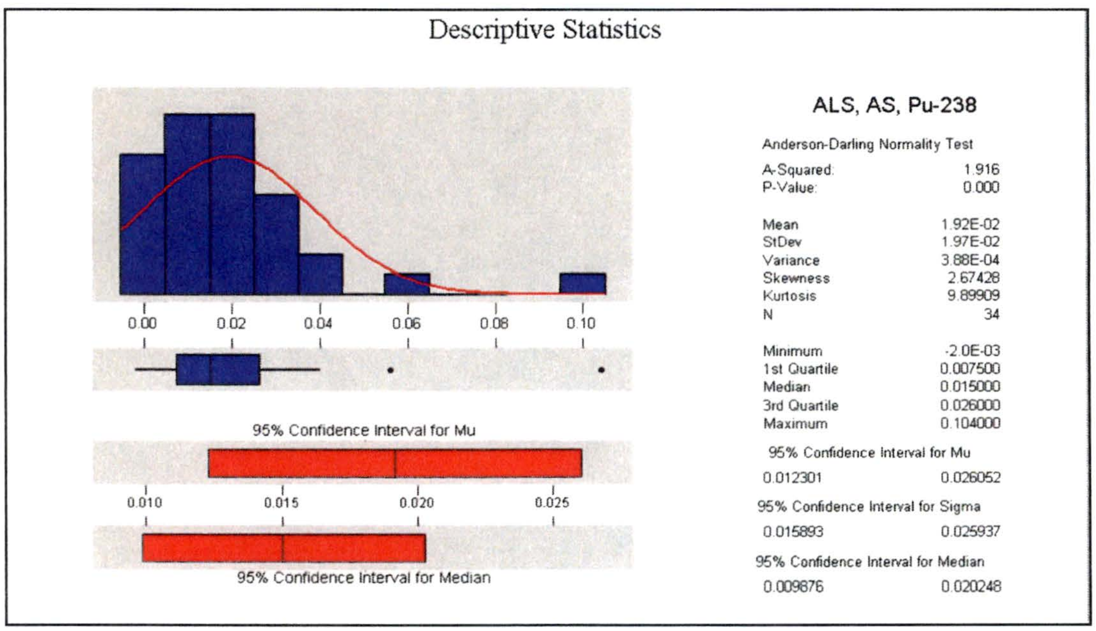

Figure 4-184 Summary Statistics: Pu-238, ALS, Alpha Spectroscopy, SU 18

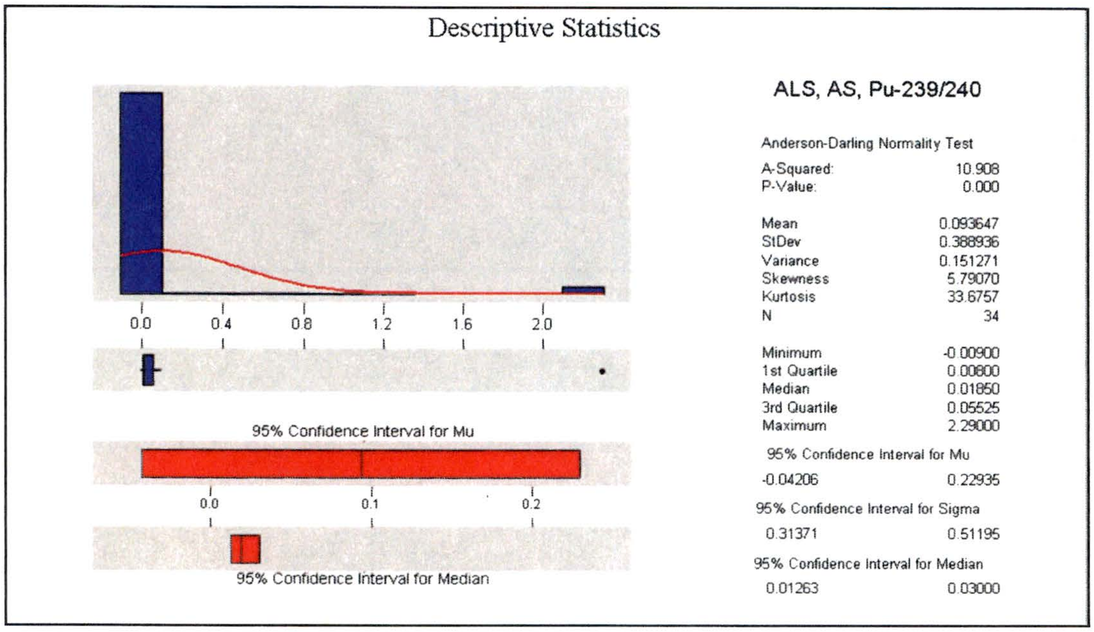

Figure 4-185 Summary Statistics: Pu-239/240, ALS, Alpha Spectroscopy, SU 18

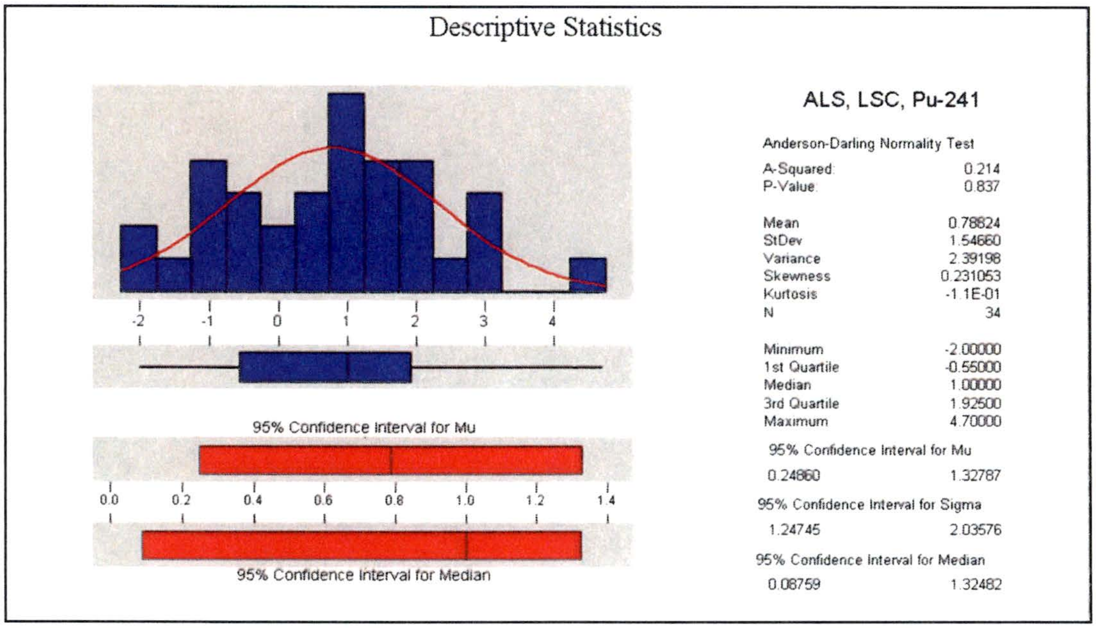

Figure 4-186 Summary Statistics: Pu-241, ALS, Liquid Scintillation, SU 18

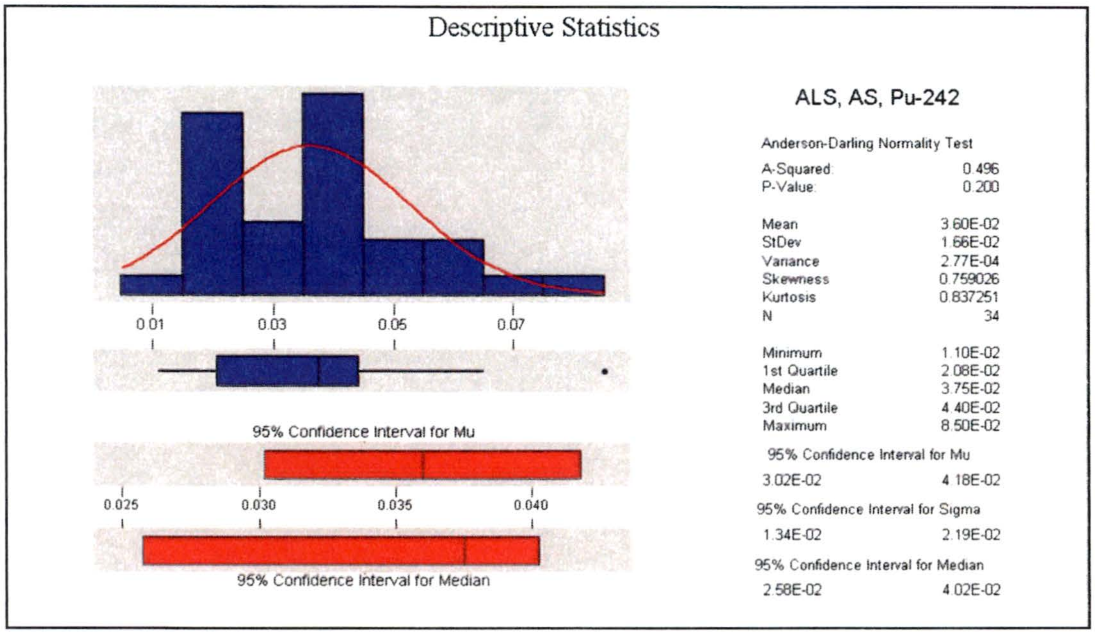

Figure 4-187 Summary Statistics: Pu-242, ALS, Alpha Spectroscopy, SU 18

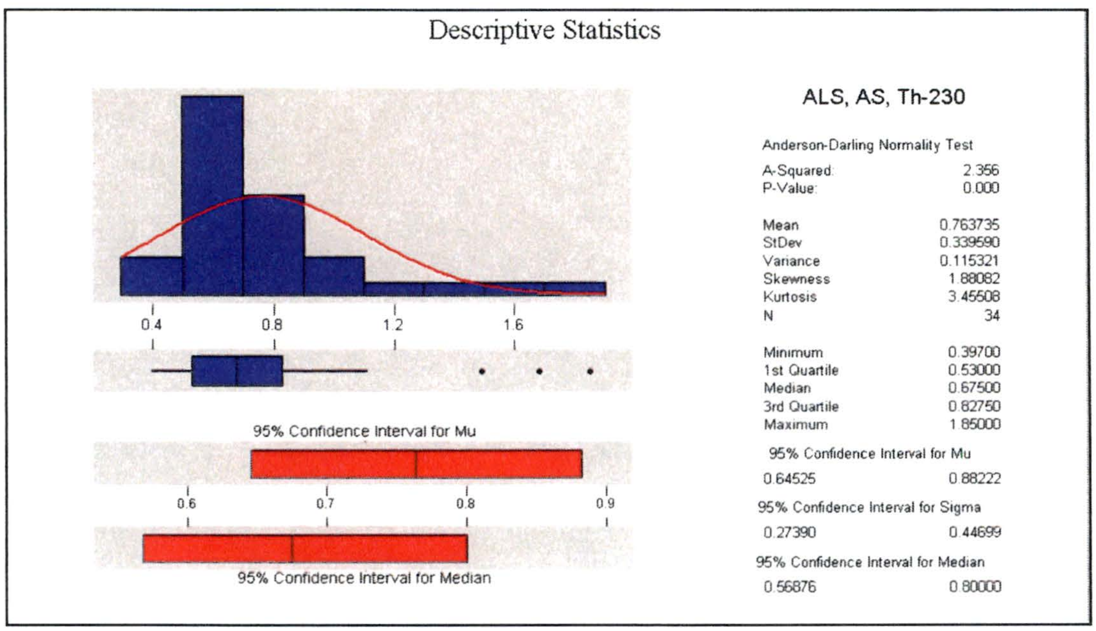

Figure 4-188 Summary Statistics: Th-230, ALS, Alpha Spectroscopy, SU 18

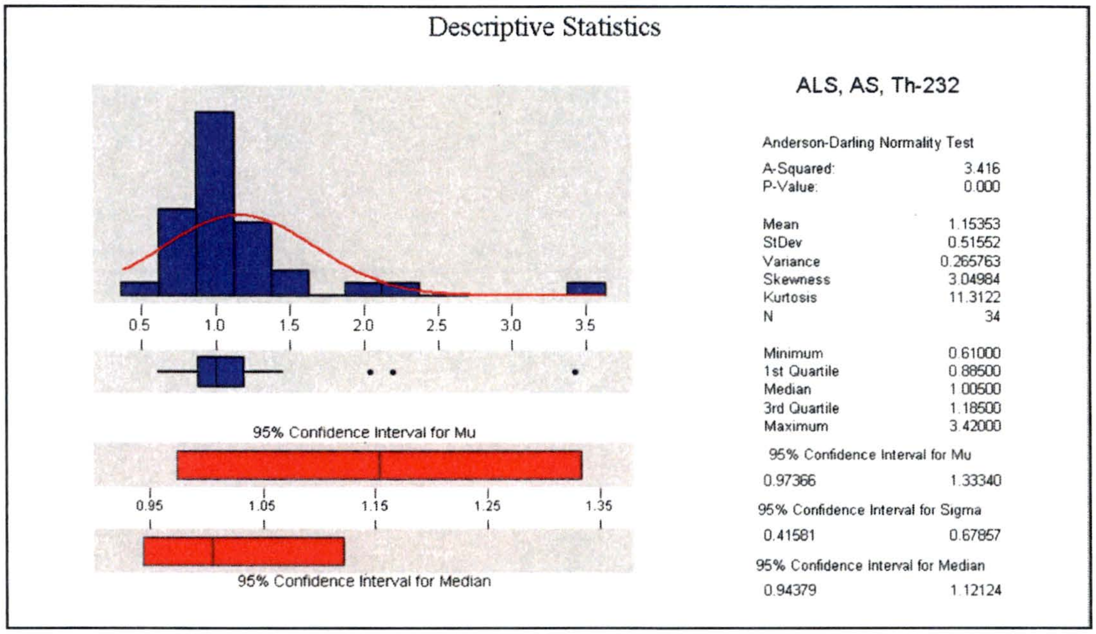

Figure 4-189 Summary Statistics: Th-232, ALS, Alpha Spectroscopy, SU 18

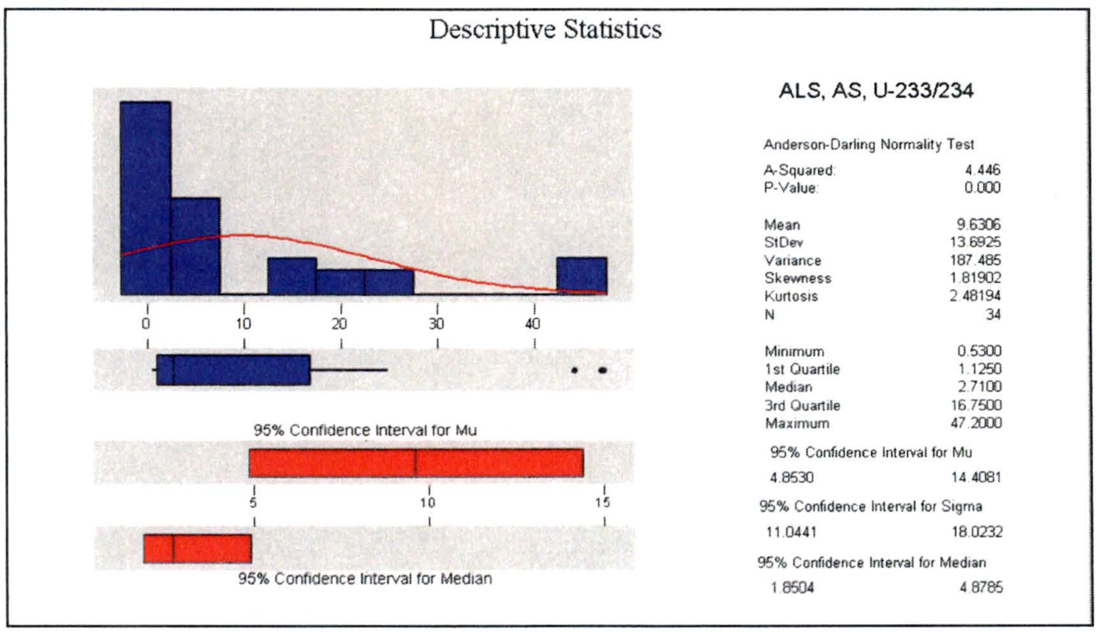

Figure 4-190 Summary Statistics: U-233/234, ALS, Alpha Spectroscopy, SU 18

Figure 4-191 Summary Statistics: U-235, ALS, Alpha Spectroscopy, SU 18

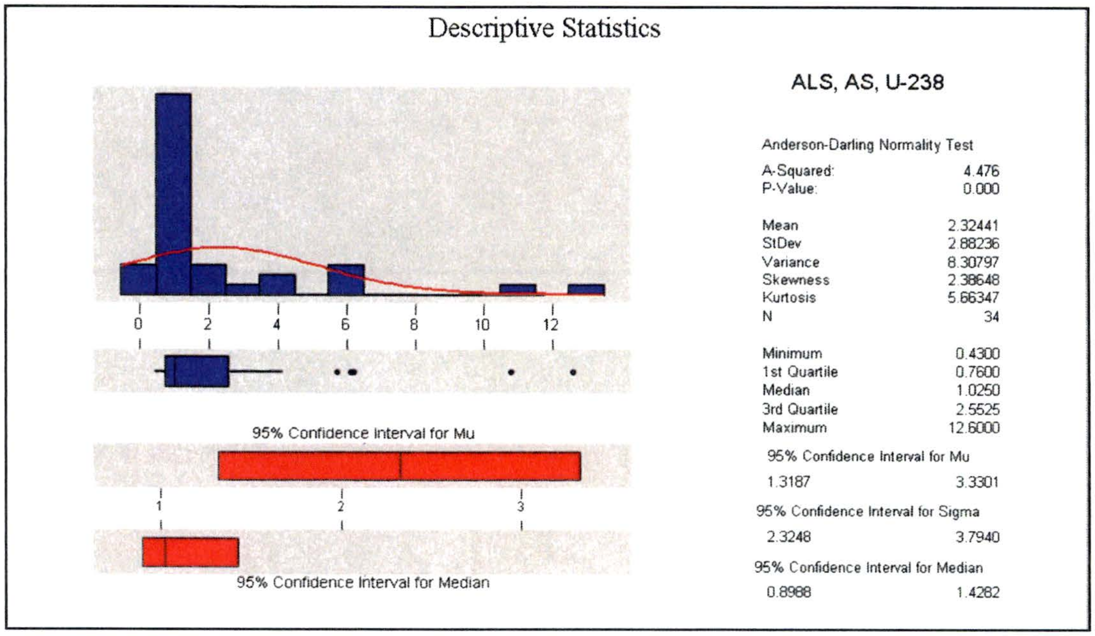

Figure 4-192 Summary Statistics: U-238, ALS, Alpha Spectroscopy, SU 18

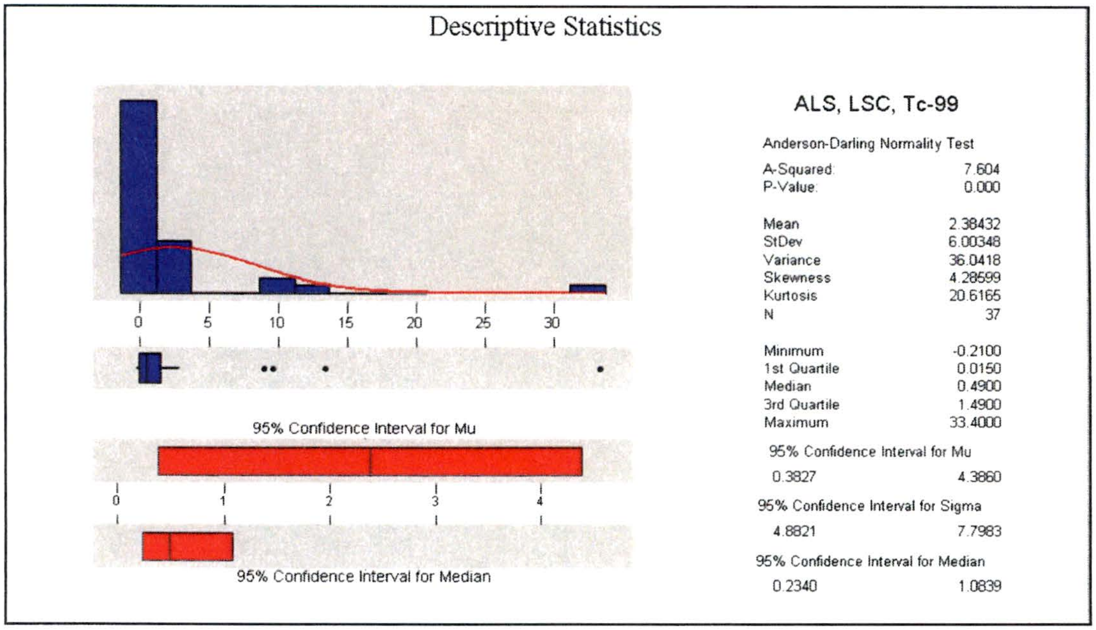

Figure 4-193 Summary Statistics: Tc-99, ALS, Liquid Scintillation, SU 18

From the summary statistics for the alpha spectroscopy and liquid scintillation analyses performed by ALS, it is evident that the residual radioactivity in Survey Unit 18 associated with the inferred isotopes is comparable to the concentrations expected to be naturally found in non-impacted soils. The datasets of anthropogenic isotopes have estimators of central tendency that are centered about zero with maximum values at or below the minimum detectable concentration (specified reporting limit). The datasets of isotopes that occur in nature have concentrations comparable to the concentrations expected to be found in non-impacted soils.

4.12 SURROGATE RATIOS

From the alpha spectroscopy and liquid scintillation analyses performed on samples selected for full-suite analysis, a mathematical assessment of the populations of the isotopes that were to be inferred from the three principal gamma emitting isotopes. As required in the site-specific DP, the surrogate to inferred isotope ratio was to be established by conservatively assigning the 95% upper confidence limit (UCL_{95}) of the observed mean ratio from the dataset derived from the specific survey unit. Calculating and assigning the UCL_{95} ratio is conservative in that the ratio used to infer the unmeasured isotopes is always selected with a conservative estimator of the mean relationship (UCL_{95}). Calculating and assigning the UCL_{95} ratio is self-regulating in that the UCL_{95} statistic is sensitive to and responsive to outliers (skewness) and small sample sizes.

Am-241, U-235, and Th-232 are the surrogate radionuclides for the North site.

- Am-241 is the surrogate for the Pu isotopes.
- Th-232 is the surrogate for Th-230.
- U-235 is the surrogate for U-233/U-234, U-238, and Tc-99.

To calculate the UCL_{95} of the observed mean ratio from the dataset, the sample specific ratios between each of surrogate and inferred isotopes is calculated. Next, the population of sample-specific ratios for each surrogate/inferred isotope pair was evaluated to calculate the UCL_{95} of the mean ratio.

For Survey Unit 4, 27 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-13 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 6, 31 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-14 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 7, 22 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-15 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 12, 24 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-16 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 16-Western, 26 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-17 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 16-Central, 22 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-18 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 16-Eastern, 18 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-19 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 17, 35 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-20 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

For Survey Unit 18, 32 samples were selected for full-suite analysis. The reported analytical results are compiled in Table 4-21 and used to populate the Amec Foster Wheeler-developed calculator tools used to evaluate compliance with the SSDCGL criteria.

Table 4-13 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 4

Correlation Data to Establish Surrogate Ratios																			
Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)												Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0050-C	0.031	0.5	0.015	0.009	-0.3	0.013	0.75	0.89	1.09	0.074	0.81	0.5	0.3	-9.7	0.4	0.8	6.8	14.7	10.9
0051-E	0.039	0.7	0.014	-0.003	-1.6	0.038	0.66	0.9	0.84	0.059	0.61	0.4	-0.1	-41.0	1.0	0.7	11.9	14.2	10.3
0052-A	0.021	0.7	0.018	0.03	-0.7	0.039	0.81	0.93	0.68	0.01	0.78	0.9	1.4	-33.3	1.9	0.9	70.0	68.0	78.0
0055-A	0.03	0.13	0.023	0.016	-1.2	0.043	1.04	1.99	4.83	0.125	1.78	0.8	0.5	-40.0	1.4	0.5	1.0	38.6	14.2
0057-D	0.025	0.57	0.001	0.039	-2.5	0.036	0.63	0.7	0.74	0.053	0.64	0.0	1.6	-100.0	1.4	0.9	10.8	14.0	12.1
0058-C	0.028	-0.2	0.029	0	-1.1	0.033	0.7	1.04	0.58	0.011	0.52	1.0	0.0	-39.3	1.2	0.7	-18.2	52.7	47.3
0059-A	0.163	0.41	0.041	0.43	-4.3	0.06	0.84	1.08	5.7	0.179	1.62	0.3	2.6	-26.4	0.4	0.8	2.3	31.8	9.1
0060-C	0.03	0.27	0.015	0.001	-1.9	0.053	0.77	0.96	1.02	0.057	0.75	0.5	0.0	-63.3	1.8	0.8	4.7	17.9	13.2
0061-A	0.032	-0.05	0.004	0.032	-3	0.054	0.88	0.99	1.42	0.016	0.92	0.1	1.0	-93.8	1.7	0.9	-3.1	88.8	57.5
0062-B	0.093	-0.2	0.041	0.27	-3.2	0.06	0.97	1.88	9.2	0.38	3.06	0.4	2.9	-34.4	0.6	0.5	-0.5	24.2	8.1
0063-B	0.038	-0.1	0.007	0.047	0	0.12	0.84	1.71	3.89	0.102	1.42	0.2	1.2	0.0	3.2	0.5	-1.0	38.1	13.9
0065-A	0.019	-0.01	-0.002	0.015	-2.9	0.02	1.07	1.25	1.52	0.01	1.46	-0.1	0.8	-152.6	1.1	0.9	-1.0	152.0	146.0
0067-D	0.045	0.2	0.035	0.151	-1.6	0.058	0.75	0.72	2.87	0.118	1.95	0.8	3.4	-35.6	1.3	1.0	1.7	24.3	16.5
0069-A	0.017	0.45	0.006	0.003	-0.7	0.029	0.79	1.03	0.92	0.041	0.67	0.4	0.2	-41.2	1.7	0.8	11.0	22.4	16.3
0071-C	0.061	-0.1	0.032	0.065	-1	0.006	1.37	1.55	10.5	0.62	15.5	0.5	1.1	-16.4	0.1	0.9	-0.2	16.9	25.0
0072-A	0.02	0.14	0.021	0.025	-1	0.067	1.06	1.36	1.76	0.047	1.31	1.1	1.3	-50.0	3.4	0.8	3.0	37.4	27.9
0073-C	0.063	-0.07	0.012	0.098	-0.1	0.032	0.73	1.12	1.26	0.029	1.02	0.2	1.6	-1.6	0.5	0.7	-2.4	43.4	35.2
0074-A	0.074	0.3	0.04	0.179	-0.5	0.02	1.09	1.43	3.17	0.126	2.39	0.5	2.4	-6.8	0.3	0.8	2.4	25.2	19.0
0076-A	0.023	0.42	0.029	0.022	-1.3	0.027	0.83	0.74	0.85	0.081	0.58	1.3	1.0	-56.5	1.2	1.1	5.2	10.5	7.2
0077-C	0.023	0.32	0.013	0.008	-1.8	0.031	0.77	0.82	1.01	0.02	0.75	0.6	0.3	-78.3	1.3	0.9	16.0	50.5	37.5
0079-A	0.042	0	0.025	0.068	-1.1	0.028	1.23	1.72	2.81	0.093	2.22	0.6	1.6	-26.2	0.7	0.7	0.0	30.2	23.9
0081-B	0.86	-0.3	0.082	2.55	-0.5	0.05	1.46	2.42	32	0.91	10.9	0.1	3.0	-0.6	0.1	0.6	-0.3	35.2	12.0
0082-C	0.015	0.16	0.011	0.028	-1.2	0.055	0.66	0.98	0.67	0.022	0.44	0.7	1.9	-80.0	3.7	0.7	7.3	30.5	20.0
0084-A	0.011	-0.4	0.013	0.015	2.4	0.035	0.57	0.68	0.68	0.048	0.47	1.2	1.4	218.2	3.2	0.8	-8.3	14.2	9.8
0087-B	0.038	0.22	0.007	0.033	-3.4	0.094	1	1.13	3.63	0.188	1.4	0.2	0.9	-89.5	2.5	0.9	1.2	19.3	7.4
0088-D	0.03	-0.4	0.006	0.009	-1.7	0.017	1.2	1.27	1.27	0.035	0.79	0.2	0.3	-56.7	0.6	0.9	-11.4	36.3	22.6
0089-A	0.139	-0.01	0.041	0.4	-0.4	0.087	1.1	1.52	17.2	0.63	5.6	0.3	2.9	-2.9	0.6	0.7	0.0	27.3	8.9
Mean	0.074	0.135	0.021	0.168	-1.356	0.045	0.910	1.215	4.152	0.151	2.236	0.499	1.308	-35.470	1.369	0.785	4.022	36.251	26.283
Std Dev	0.161	0.313	0.018	0.490	1.326	0.026	0.230	0.439	6.731	0.224	3.397	0.361	1.007	62.342	1.024	0.153	14.958	29.131	29.239
N	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
95% UCL	0.1	0.3	0.0	0.4	-0.9	0.1	1.0	1.4	6.7	0.2	3.5	0.6	1.7	-12.0	1.8	0.8	9.7	47.2	37.3
Max	0.9	0.7	0.1	2.6	2.4	0.1	1.5	2.4	32.0	0.9	15.5	1.3	3.4	218.2	3.7	1.1	70.0	152.0	146.0

Table 4-14 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 6

Correlation Data to Establish Surrogate Ratios																		
Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)											Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 :Am241	Pu242 :Am241	Th230 :Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0750-A	0.025	0.4	0.019	0.026	-1.7	0.023	0.83	0.72	1.74	0.103	0.89	0.8	1.0	-68.0	0.9	1.2	3.9	16.9	8.6
0753-C	0.03	0.22	0.022	0.012	-1.2	0.06	0.83	0.86	1.33	0.067	0.75	0.7	0.4	-40.0	2.0	1.0	3.3	19.9	11.2
0754-A	0.017	0.41	0.007	0.01	0.3	0.042	0.51	0.95	1.65	0.068	0.8	0.4	0.6	17.6	2.5	0.5	6.0	24.3	11.8
0756-A	0.019	0.41	0.012	0.014	1	0.002	0.53	0.71	2.34	0.061	1.45	0.6	0.7	52.6	0.1	0.7	6.7	38.4	23.8
0757-A	0.083	-0.1	0.008	0.214	-2.8	0.063	0.96	1.33	4.11	0.117	1.89	0.1	2.6	-33.7	0.8	0.7	-0.9	35.1	16.2
0759-B	0.026	0.05	0.001	0.039	0.6	0.053	0.62	1.02	2.2	0.088	1.01	0.0	1.5	23.1	2.0	0.6	0.6	25.0	11.5
0761-A	0.019	0.1	0.014	0.033	-2.5	0.019	1.4	1.3	6.6	0.167	4	0.7	1.7	-131.6	1.0	1.1	0.6	39.5	24.0
0762-C	0.057	0.1	0.003	0.012	0.5	0.031	1.41	2.08	1.66	0.044	1.6	0.1	0.2	8.8	0.5	0.7	2.3	37.7	36.4
0765-C	0.037	0.48	0.002	0.009	-0.8	0.076	0.43	0.66	0.56	-0.008	0.48	0.1	0.2	-21.6	2.1	0.7	-60.0	-70.0	-60.0
0766-A	0.146	0.5	0.016	0.346	1.9	0.034	0.81	1.22	7	0.25	2.59	0.1	2.4	13.0	0.2	0.7	2.0	28.0	10.4
0769-D	0.042	0.24	0.006	0.046	-1.2	0.016	0.92	1.27	4.97	0.138	2.56	0.1	1.1	-28.6	0.4	0.7	1.7	36.0	18.6
0770-A	0.104	0.1	0.014	0.373	-0.4	0.042	0.94	1.29	2.12	0.092	0.87	0.1	3.6	-3.8	0.4	0.7	1.1	23.0	9.5
0774-A	0.008	-0.4	0.011	0.025	-2.6	0.015	0.96	1.38	1.64	0.062	1.13	1.4	3.1	-325.0	1.9	0.7	-6.5	26.5	18.2
0775-B	0.017	0.28	0.012	0.015	-2.7	0.016	0.61	0.9	1.01	0.055	0.7	0.7	0.9	-158.8	0.9	0.7	5.1	18.4	12.7
0776-A	0.026	0.21	0.002	0.092	-1	0.021	0.78	1.11	2.39	0.063	0.96	0.1	3.5	-38.5	0.8	0.7	3.3	37.9	15.2
0778-B	0.023	0.46	0.007	0.018	0.8	0.021	1.08	1.57	1.3	0.069	1.05	0.3	0.8	34.8	0.9	0.7	6.7	18.8	15.2
0778-C	0.049	0.98	0.016	0.011	-1.4	0.01	0.81	1.25	0.85	0.031	0.65	0.3	0.2	-28.6	0.2	0.6	31.6	27.4	21.0
0780-A	0.027	-0.3	0.011	0.026	1.6	0.014	0.99	1.48	6.2	0.232	2.45	0.4	1.0	59.3	0.5	0.7	-1.3	26.7	10.6
0781-C	0.024	-0.21	0.012	0.009	0.2	0.033	0.64	1.1	0.83	0.047	0.61	0.5	0.4	8.3	1.4	0.6	-4.5	17.7	13.0
0783-A	3.03	2.2	0.378	9.1	12.2	0.066	2.55	9.2	32.7	1.17	9.3	0.1	3.0	4.0	0.0	0.3	1.9	27.9	7.9
0785-B	0.031	0.43	0.009	0.024	-1.4	0.037	0.62	0.93	6.1	0.181	2.07	0.3	0.8	-45.2	1.2	0.7	2.4	33.7	11.4
0787-A	0.52	0.05	0.063	1.56	2.4	0.011	0.75	0.78	6.8	0.189	1.34	0.1	3.0	4.6	0.0	1.0	0.3	36.0	7.1
0791-A	0.061	0.13	0.021	0.069	1.5	0	0.94	1.35	21.9	0.65	4.01	0.3	1.1	24.6	0.0	0.7	0.2	33.7	6.2
0792-B	0.037	0.4	0.005	0.03	-1.1	0.008	0.86	1.01	1.25	0.043	0.86	0.1	0.8	-29.7	0.2	0.9	9.3	29.1	20.0
0793-B	0.055	0.73	0.009	0.079	-1.4	0.026	0.65	0.95	5.6	0.132	1.65	0.2	1.4	-25.5	0.5	0.7	5.5	42.4	12.5
0794-A	0.129	0.6	0.02	0.346	2.4	0.01	1.25	1.06	2.26	0.062	1.41	0.2	2.7	18.6	0.1	1.2	9.7	36.5	22.7
0797-A	0.009	0	0.022	0.027	0.7	0.014	0.87	1.46	2.1	0.064	1.19	2.4	3.0	77.8	1.6	0.6	0.0	32.8	18.6
0800-D	0.042	-0.2	0.018	0.053	-0.1	0.012	0.279	0.52	0.48	0.02	0.33	0.4	1.3	-2.4	0.3	0.5	-10.0	24.0	16.5
0803-A	0.031	-0.37	0.009	0.034	-1.5	0.021	0.9	1.37	1.88	0.071	1.17	0.3	1.1	-48.4	0.7	0.7	-5.2	26.5	16.5
0806-C	0.015	0.62	0.006	0.027	-1.4	0.072	0.9	1.25	1.2	0.054	0.84	0.4	1.8	-93.3	4.8	0.7	11.5	22.2	15.6
0807-A	0.053	0.5	-0.002	0.011	-1.8	0.02	0.95	1.02	2.52	0.064	0.94	0.0	0.2	-34.0	0.4	0.9	7.8	39.4	14.7
Mean	0.15	0.29	0.02	0.41	-0.03	0.03	0.89	1.39	4.36	0.14	1.66	0.40	1.49	-26.11	0.94	0.73	1.13	26.17	12.82
Std Dev	0.54	0.48	0.07	1.64	2.72	0.02	0.40	1.48	6.60	0.22	1.68	0.48	1.08	75.16	1.00	0.19	13.37	19.31	14.86
N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
95% UCL	0.3	0.5	0.0	1.0	0.9	0.0	1.0	1.9	6.7	0.2	2.3	0.6	1.9	0.3	1.3	0.8	5.8	33.0	18.0
Max	3.0	2.2	0.4	9.1	12.2	0.1	2.6	9.2	32.7	1.2	9.3	2.4	3.6	77.8	4.8	1.2	31.6	42.4	36.4

Table 4-15 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 7

Correlation Data to Establish Surrogate Ratios																			
	Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)											Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
7001-A	-0.009	-0.45	0.019	0.017	2.1	0.022	1.62	1.28	1.16	0.084	1.11	-2.1	-1.9	-233.3	-2.4	1.3	-5.4	13.8	13.2
7004-C	0.04	-0.26	0.017	0.137	2.7	0.054	0.67	0.69	3.22	0.143	0.77	0.4	3.4	67.5	1.4	1.0	-1.8	22.5	5.4
7005-A	0.029	0.06	0.021	0.157	1.5	0.055	0.98	1.09	1.33	0.098	1.14	0.7	5.4	51.7	1.9	0.9	0.6	13.6	11.6
7006-I	-0.011	-0.1	0.004	0.017	0.3	0.032	0.73	0.67	0.54	0.014	0.59	-0.4	-1.5	-27.3	-2.9	1.1	-7.1	38.6	42.1
7007-E	0.018	-0.37	0.004	0.001	1	0.039	0.72	1.04	1.22	0.029	0.84	0.2	0.1	55.6	2.2	0.7	-12.8	42.1	29.0
7008-C	-0.006	-0.24	0.015	0.001	-0.5	0.05	0.391	0.445	0.37	0.014	0.283	-2.5	-0.2	83.3	-8.3	0.9	-17.1	26.4	20.2
7009-A	0.037	-0.24	0.006	0.096	5.8	0.021	0.63	0.69	0.76	0.038	0.48	0.2	2.6	156.8	0.6	0.9	-6.3	20.0	12.6
7011-C	-0.001	-0.09	0.017	0.011	2.5	0.002	0.51	0.55	0.54	0.01	0.43	-17.0	-11.0	-2500.0	-2.0	0.9	-9.0	54.0	43.0
7012-F	-0.011	0.8	0.013	0.015	-4.7	0.058	1.03	1.12	0.9	0.019	0.7	-1.2	-1.4	427.3	-5.3	0.9	42.1	47.4	36.8
7013-C	-0.008	-0.35	0.008	0.001	-0.6	0.029	1.05	1.21	0.84	0.083	0.85	-1.0	-0.1	75.0	-3.6	0.9	-4.2	10.1	10.2
7015-B	-0.01	-0.49	0.008	0.011	4	0.062	0.44	0.51	0.45	0.051	0.43	-0.8	-1.1	-400.0	-6.2	0.9	-9.6	8.8	8.4
7016-B	0.004	-0.39	0.007	0.006	-0.1	0.077	0.325	0.437	0.36	0.002	0.34	1.8	1.5	-25.0	19.3	0.7	-195.0	180.0	170.0
7017-A	-0.001	0.23	0.005	0.051	-0.7	0.053	0.55	0.75	1.51	0.062	0.43	-5.0	-51.0	700.0	-53.0	0.7	3.7	24.4	6.9
7019-I	-0.014	-0.8	0.014	0.003	-0.1	0.044	1.7	0.7	1.24	0.041	1.02	-1.0	-0.2	7.1	-3.1	2.4	-19.5	30.2	24.9
7020-D	-0.006	-0.58	0.014	-0.001	2.9	0.019	1.06	1.56	1.01	0.03	0.91	-2.3	0.2	-483.3	-3.2	0.7	-19.3	33.7	30.3
7021-A	-0.013	0.31	0.007	0.018	2.2	0.089	0.85	0.85	1.29	0.04	0.71	-0.5	-1.4	-169.2	-6.8	1.0	7.8	32.3	17.8
7023-D	-0.008	-0.6	0.015	0.007	1.4	0.08	0.65	0.9	0.64	0.014	0.53	-1.9	-0.9	-175.0	-10.0	0.7	-42.9	45.7	37.9
7025-A	-0.008	-0.13	0.018	0.04	-1.7	0.042	0.7	0.87	2.45	0.097	0.64	-2.3	-5.0	212.5	-5.3	0.8	-1.3	25.3	6.6
7027-E	-0.008	0.09	0.014	0.006	5.6	0.06	1.87	2.58	1.09	0.073	0.93	-1.8	-0.8	-700.0	-7.5	0.7	1.2	14.9	12.7
7028-D	-0.015	0.4	0	0.036	3	0.088	0.9	0.95	1.05	0.019	0.77	0.0	-2.4	-200.0	-5.9	0.9	21.1	55.3	40.5
7029-A	-0.01	-0.4	0.007	0.028	-0.2	0.08	0.43	0.52	0.49	0.026	0.46	-0.7	-2.8	20.0	-8.0	0.8	-15.4	18.8	17.7
7032-B	-0.014	0.28	0.01	-0.004	0	0.11	0.393	0.5	0.55	0.032	0.307	-0.7	0.3	0.0	-7.9	0.8	8.8	17.2	9.6
Mean	-0.001	-0.151	0.011	0.030	1.200	0.053	0.827	0.905	1.046	0.046	0.667	-1.720	-3.099	-138.927	-5.281	0.940	-12.799	35.227	27.618
Std Dev	0.017	0.385	0.006	0.044	2.400	0.027	0.431	0.479	0.683	0.036	0.260	3.691	11.152	602.760	12.256	0.360	43.856	35.196	34.234
N	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
95% UCL	0.0	0.0	0.0	0.0	2.2	0.1	1.0	1.1	1.3	0.1	0.8	-0.2	1.6	112.9	-0.2	1.1	5.5	49.9	41.9
Max	0.0	0.8	0.0	0.2	5.8	0.1	1.9	2.6	3.2	0.1	1.1	1.8	5.4	700.0	19.3	2.4	42.1	180.0	170.0

Table 4-16 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 12

Correlation Data to Establish Surrogate Ratios																			
Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)												Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0296-B	0.042	-0.040	0.002	0.018	3.100	0.030	0.93	1.240	3.630	0.09	0.93	0.0	0.4	73.8	0.7	0.8	-0.5	42.7	10.9
0297-A	0.510	-0.500	0.046	1.650	1.600	0.025	1.21	1.980	6.000	0.27	3.84	0.1	3.2	3.1	0.0	0.6	-1.9	22.5	14.4
0300-D	0.018	-0.264	0.005	0.013	2.800	0.001	1.05	1.140	1.160	0.05	0.79	0.3	0.7	155.6	0.1	0.9	-5.7	25.2	17.2
0301-A	0.142	0.500	0.024	0.387	0.200	0.006	0.94	1.310	4.290	0.14	1.28	0.2	2.7	1.4	0.0	0.7	3.6	31.3	9.3
0303-A	0.033	0.170	0.009	0.033	3.000	0.042	0.84	1.030	2.730	0.06	0.77	0.3	1.0	90.9	1.3	0.8	2.7	44.0	12.4
0308-A	0.700	-0.400	0.016	1.360	0.200	0.020	1.21	2.220	5.250	0.24	6.40	0.0	1.9	0.3	0.0	0.5	-1.7	22.1	26.9
0309-B	0.260	0.100	0.020	0.770	0.300	0.010	0.94	1.270	3.310	0.15	1.55	0.1	3.0	1.2	0.0	0.7	0.7	21.6	10.1
0312-A	0.011	-0.200	-0.002	0.026	-3.600	0.017	0.56	0.760	2.810	0.15	0.68	-0.2	2.4	-327.3	1.5	0.7	-1.4	19.1	4.6
0313-D	0.028	0.000	0.014	0.009	0.600	0.038	1.55	1.220	1.600	0.04	1.15	0.5	0.3	21.4	1.4	1.3	0.0	38.1	27.4
0314-C	0.043	-0.264	-0.002	0.078	0.000	0.013	0.54	0.970	10.200	0.40	6.10	0.0	1.8	0.0	0.3	0.6	-0.7	25.5	15.3
0315-E	0.004	-1.700	0.000	0.000	-0.300	0.003	0.58	0.550	0.650	0.03	0.53	0.0	0.0	-83.3	0.8	1.1	-65.4	25.0	20.4
0316-A	0.960	-0.760	0.100	2.830	6.500	0.004	0.98	1.640	16.700	0.65	13.20	0.1	2.9	6.8	0.0	0.6	-1.2	25.7	20.3
0316-B	0.346	-0.264	0.036	0.990	-3.900	0.036	0.89	1.290	8.000	0.32	7.60	0.1	2.9	-11.3	0.1	0.7	-0.8	25.0	23.8
0320-A	0.055	0.910	0.014	0.140	-1.500	0.005	0.90	1.290	2.010	0.05	0.79	0.3	2.5	-27.3	0.1	0.7	19.8	43.7	17.2
0321-C	0.037	1.000	0.005	0.256	-0.700	0.011	1.05	1.760	1.840	0.04	1.01	0.1	6.9	-18.9	0.3	0.6	23.3	42.8	23.5
0324-C	0.006	-0.200	0.005	0.014	-1.000	0.001	0.62	1.060	8.300	0.42	6.30	0.8	2.3	-166.7	0.2	0.6	-0.5	19.8	15.0
0328-D	0.005	-1.200	0.003	0.010	-0.800	0.008	0.64	0.800	0.520	0.03	0.64	0.6	2.0	-160.0	1.6	0.8	-36.4	15.8	19.4
0331-A	0.136	0.600	0.012	0.338	1.200	0.010	1.25	1.810	4.310	0.18	1.99	0.1	2.5	8.8	0.1	0.7	3.4	24.5	11.3
0332-E	0.010	-0.500	-0.005	0.010	-0.300	0.020	0.71	0.920	0.950	0.03	0.73	-0.5	1.0	-30.0	2.0	0.8	-20.0	38.0	29.2
0335-A	0.013	-0.830	0.002	0.024	-0.200	0.009	0.77	1.410	1.310	0.02	0.88	0.2	1.8	-15.4	0.7	0.5	-36.1	57.0	38.3
0338-E	0.012	-0.490	-0.005	0.017	0.900	0.005	0.61	1.100	1.310	0.10	0.81	-0.4	1.4	75.0	0.4	0.6	-5.0	13.4	8.3
0340-A	0.005	-1.010	0.005	0.012	3.000	0.010	0.90	1.500	0.990	0.10	0.89	1.0	2.4	600.0	2.0	0.6	-10.1	9.9	8.9
0342-B	-0.004	-0.400	0.002	0.009	2.200	0.008	0.81	1.110	1.200	0.06	0.72	-0.5	-2.3	-550.0	-2.0	0.7	-6.7	20.0	12.0
0344-A	0.007	-0.590	0.000	0.007	2.400	0.009	0.94	1.340	1.180	0.07	0.85	0.0	1.0	342.9	1.3	0.7	-8.8	17.6	12.7
Mean	0.141	-0.264	0.013	0.375	0.654	0.014	0.893	1.280	3.760	0.153	2.518	0.129	1.876	-0.374	0.536	0.720	-6.215	27.924	17.027
Std Dev	0.250	0.630	0.022	0.696	2.247	0.012	0.250	0.392	3.826	0.158	3.167	0.358	1.639	207.885	0.863	0.170	18.215	11.714	7.997
N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
95% UCL	0.2	0.0	0.0	0.7	1.6	0.0	1.0	1.4	5.3	0.2	3.8	0.3	2.5	82.8	0.9	0.8	1.1	32.6	20.2
Max	1.0	1.0	0.1	2.8	6.5	0.0	1.6	2.2	16.7	0.7	13.2	1.0	6.9	600.0	2.0	1.3	23.3	57.0	38.3

Table 4-17 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 16-Western

Correlation Data to Establish Surrogate Ratios

	Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)											Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0469-A	0.037	0.420	0.005	0.077	-1.800	0.018	0.590	1.130	12.900	0.460	1.640	0.1	2.1	-48.6	0.5	0.5	0.9	28.0	3.6
0478-A	0.199	1.840	0.039	0.640	0.600	0.023	0.780	1.230	9.200	0.370	1.760	0.2	3.2	3.0	0.1	0.6	5.0	24.9	4.8
0486-A	0.014	-0.100	0.002	0.021	-0.300	0.026	0.560	1.080	0.800	0.034	0.620	0.1	1.5	-21.4	1.9	0.5	-2.9	23.5	18.2
0494-A	0.018	-0.170	0.000	0.031	-1.500	0.039	0.770	1.200	1.420	0.058	0.640	0.0	1.7	-83.3	2.2	0.6	-2.9	24.5	11.0
0498-A	0.006	-0.200	0.005	0.000	0.400	0.015	0.720	1.180	1.140	0.038	0.510	0.9	0.0	70.2	2.6	0.6	-5.3	30.0	13.4
0502-A	0.293	0.000	0.024	0.700	1.800	0.025	1.360	2.150	7.600	0.268	2.820	0.1	2.4	6.1	0.1	0.6	0.0	28.4	10.5
0504-B	0.069	0.560	0.015	0.240	-0.800	0.015	1.170	1.500	9.200	0.510	4.150	0.2	3.5	-11.6	0.2	0.8	1.1	18.0	8.1
0506-A	0.077	-0.500	0.006	0.137	0.000	0.030	0.990	1.070	2.400	0.183	1.500	0.1	1.8	0.0	0.4	0.9	-2.7	13.1	8.2
0510-A	0.020	-0.060	-0.004	0.009	2.000	0.023	0.750	1.060	0.950	0.031	0.600	-0.2	0.4	100.0	1.2	0.7	-1.9	30.6	19.4
0514-B	0.008	0.000	-0.003	0.015	-0.100	0.022	1.000	1.170	11.900	0.480	7.100	-0.4	1.9	-12.7	2.8	0.9	0.0	24.8	14.8
0515-B	0.012	0.300	0.010	0.029	-0.100	0.021	1.320	1.220	1.560	0.108	1.680	0.8	2.4	-8.3	1.8	1.1	2.8	14.4	15.6
0518-A	0.027	-0.900	0.000	0.060	3.400	0.023	0.900	1.060	1.550	0.116	1.470	0.0	2.2	125.9	0.9	0.8	-7.8	13.4	12.7
0522-A	0.062	-0.430	0.008	0.110	0.400	0.022	0.730	1.110	6.200	0.290	3.360	0.1	1.8	6.5	0.4	0.7	-1.5	21.4	11.6
0526-A	0.780	-0.200	0.089	1.900	2.800	0.017	2.510	4.130	43.300	1.020	10.000	0.1	2.4	3.6	0.0	0.6	-0.2	42.5	9.8
0530-A	0.043	0.560	0.012	0.107	2.200	0.017	1.150	1.160	2.400	0.049	1.240	0.3	2.5	51.2	0.4	1.0	11.4	49.0	25.3
0534-A	0.022	0.580	0.002	0.040	0.500	0.012	0.650	0.970	1.600	0.059	0.790	0.1	1.8	22.7	0.5	0.7	9.8	27.1	13.4
0535-B	0.004	0.280	0.002	0.012	2.100	0.008	0.730	1.230	7.300	0.260	4.840	0.5	3.2	567.6	2.2	0.6	1.1	28.1	18.6
0538-A	0.002	0.160	0.000	0.005	-2.000	0.015	1.010	1.070	1.270	0.103	1.230	0.0	2.5	-1000.0	7.5	0.9	1.6	12.3	11.9
0541-D	0.008	-0.600	-0.002	0.003	1.200	0.005	0.900	1.080	1.140	0.104	1.050	-0.3	0.4	150.0	0.6	0.8	-5.8	11.0	10.1
0542-A	0.015	-0.560	0.002	0.008	-0.300	0.025	0.590	0.890	0.930	0.035	0.690	0.1	0.5	-20.0	1.7	0.7	-16.0	26.6	19.7
0545-A	0.172	0.600	0.023	0.530	3.100	0.019	1.160	1.570	6.400	0.212	2.680	0.1	3.1	18.0	0.1	0.7	2.8	30.2	12.6
0546-A	0.044	0.450	0.007	0.070	1.100	0.023	0.710	1.060	2.890	0.094	0.840	0.2	1.6	25.0	0.5	0.7	4.8	30.7	8.9
0550-A	0.011	0.200	0.000	0.035	1.800	0.009	0.820	1.430	3.780	0.192	2.290	0.0	3.2	163.6	0.8	0.6	1.0	19.7	11.9
0552-B	0.010	0.100	0.004	0.004	-4.100	0.022	0.490	0.550	0.580	0.003	0.640	0.4	0.4	-410.0	2.2	0.9	33.3	193.3	213.3
0554-A	0.021	-0.100	0.002	0.047	1.400	-0.003	0.860	1.270	7.800	0.340	3.580	0.1	2.2	66.7	-0.2	0.7	-0.3	22.9	10.5
0558-A	11.600	0.600	1.010	34.500	52.300	0.174	3.200	4.970	16.000	0.440	8.800	0.1	3.0	4.5	0.0	0.6	1.4	36.4	20.0
Mean	0.522	0.109	0.048	1.513	2.542	0.025	1.016	1.444	6.239	0.225	2.558	0.143	1.992	-8.900	1.203	0.727	1.142	31.723	20.695
Std Dev	2.265	0.545	0.197	6.740	10.293	0.032	0.596	0.962	8.713	0.226	2.558	0.275	0.985	251.985	1.566	0.150	8.448	34.156	39.602
N	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
95% UCL	1.4	0.3	0.1	4.1	6.5	0.0	1.2	1.8	9.6	0.3	3.5	0.2	2.4	88.0	1.8	0.8	4.4	44.9	35.9
Max	11.6	1.8	1.0	34.5	52.3	0.2	3.2	5.0	43.3	1.0	10.0	0.9	3.5	567.6	7.5	1.1	33.3	193.3	213.3

Table 4-18 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 16-Central

Correlation Data to Establish Surrogate Ratios																			
Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)										Surrogate Ratios									
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0421-A	0.062	0.900	0.015	0.173	0.400	0.025	0.980	2.600	6.600	0.193	1.110	0.2	2.8	6.5	0.4	0.4	4.7	34.2	5.8
0428-A	0.069	0.740	0.013	0.169	0.400	0.030	0.840	1.300	4.660	0.177	0.740	0.2	2.4	5.8	0.4	0.6	4.2	26.3	4.2
0432-A	0.022	1.000	0.004	0.072	0.000	0.025	0.740	1.460	2.720	0.080	0.940	0.2	3.3	0.0	1.1	0.5	12.5	34.0	11.8
0436-A	0.010	1.100	0.010	0.063	1.300	0.039	0.800	1.390	3.660	0.103	0.750	1.0	6.3	130.0	3.9	0.6	10.7	35.5	7.3
0441-B	0.028	0.800	0.009	0.087	1.600	0.014	0.850	1.640	3.960	0.131	1.060	0.3	3.1	57.1	0.5	0.5	6.1	30.2	8.1
0442-A	0.029	1.800	0.004	0.038	-1.600	0.014	0.660	1.480	1.540	0.018	0.620	0.1	1.3	-55.2	0.5	0.4	100.0	85.6	34.4
0444-B	0.100	2.000	0.010	0.304	1.200	0.019	0.700	1.460	6.800	0.200	1.250	0.1	3.0	12.0	0.2	0.5	10.0	34.0	6.3
0446-A	0.071	1.200	0.010	0.308	3.400	0.020	0.700	1.190	4.270	0.144	0.930	0.1	4.3	47.9	0.3	0.6	8.3	29.7	6.5
0450-A	0.004	0.740	-0.002	0.013	0.200	0.022	0.530	0.910	2.500	0.117	0.800	-0.5	3.3	50.0	5.5	0.6	6.3	21.4	6.8
0454-A	0.011	0.040	0.005	0.019	1.300	0.009	0.670	1.170	1.550	0.074	0.730	0.5	1.7	116.1	0.8	0.6	0.5	20.9	9.9
0458-A	0.033	0.500	0.003	0.077	-0.300	0.015	0.520	0.810	2.780	0.111	0.730	0.1	2.3	-9.1	0.5	0.6	4.5	25.0	6.6
0459-C	0.009	0.440	0.000	0.010	2.900	0.015	0.690	1.080	1.020	0.048	0.690	0.0	1.1	329.5	1.7	0.6	9.2	21.3	14.4
0461-B	0.015	1.000	0.000	0.006	-0.700	0.016	0.670	1.040	0.840	0.020	0.550	0.0	0.4	-46.7	1.1	0.6	50.0	42.0	27.5
0462-A	0.079	2.400	0.009	0.156	0.900	0.011	1.000	1.260	133.000	4.620	10.700	0.1	2.0	11.4	0.1	0.8	0.5	28.8	2.3
0465-B	0.244	2.200	0.021	0.550	1.200	0.034	0.990	1.530	48.700	1.800	4.720	0.1	2.3	4.9	0.1	0.6	1.2	27.1	2.6
0466-A	0.114	3.200	0.025	0.340	-0.500	0.006	0.700	1.230	10.100	0.440	1.520	0.2	3.0	-4.4	0.1	0.6	7.3	23.0	3.5
0470-A	0.035	1.600	0.011	0.091	0.000	0.002	0.870	1.160	64.600	2.170	6.700	0.3	2.6	0.0	0.0	0.8	0.7	29.8	3.1
0470-B	0.057	0.600	-0.017	0.000	1.900	0.033	1.450	1.330	4.790	0.215	1.670	-0.3	0.0	33.4	0.6	1.1	2.8	22.3	7.8
0472-B	0.022	1.400	0.005	0.066	0.400	0.023	1.320	1.140	114.000	4.330	11.200	0.2	3.0	18.2	1.0	1.2	0.3	26.3	2.6
0474-A	0.245	2.700	0.028	0.800	4.300	0.046	1.020	1.710	17.200	0.760	2.380	0.1	3.3	17.6	0.2	0.6	3.6	22.6	3.1
0482-A	0.036	1.300	-0.002	0.020	-2.900	0.019	0.640	0.710	20.200	0.790	2.270	-0.1	0.6	-80.6	0.5	0.9	1.6	25.6	2.9
0490-A	0.012	2.000	-0.005	-0.003	1.800	0.019	0.640	1.010	46.000	1.820	4.650	-0.4	-0.3	145.2	1.5	0.6	1.1	25.3	2.6
Mean	0.059	1.348	0.007	0.153	0.782	0.021	0.817	1.300	22.795	0.835	2.578	0.124	2.353	35.894	0.960	0.653	11.189	30.489	8.171
Std Dev	0.067	0.805	0.010	0.202	1.601	0.011	0.234	0.387	37.116	1.339	3.148	0.302	1.493	85.552	1.318	0.190	22.346	13.462	8.110
N	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
95% UCL	0.1	1.7	0.0	0.2	1.5	0.0	0.9	1.5	38.3	1.4	3.9	0.3	3.0	71.6	1.5	0.7	20.5	36.1	11.6
Max	0.2	3.2	0.0	0.8	4.3	0.0	1.5	2.6	133.0	4.6	11.2	1.0	6.3	329.5	5.5	1.2	100.0	85.6	34.4

Table 4-19 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 16-Eastern

Correlation Data to Establish Surrogate Ratios

Sample ID	Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)											Surrogate Ratios							
	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0384-A	0.11	0.47	0.0068	0.285	-0.5	0.026	0.95	1.52	10.6	0.43	0.99	0.1	2.6	-4.5	0.2	0.6	1.1	24.7	2.3
0385-E	0.035	0.2	0.004	0.047	-1.8	0.032	1.14	1.2	2.69	0.116	1.21	0.1	1.3	-51.4	0.9	1.0	1.7	23.2	10.4
0386-D	0.013	-0.44	-0.0016	0.042	1	0.041	0.65	1.23	1.61	0.034	0.56	-0.1	3.2	76.9	3.2	0.5	-12.9	47.4	16.5
0387-C	0.015	0.08	0.0063	0.075	-2.3	0.025	0.7	1.14	2.72	0.14	0.62	0.4	5.0	-153.3	1.7	0.6	0.6	19.4	4.4
0388-A	0.084	1	0.005	0.192	-0.6	0.018	0.94	1.56	26.6	0.98	1.38	0.1	2.3	-7.1	0.2	0.6	1.0	27.1	1.4
0390-B	0.023	-0.28	0	0.029	2.7	0.064	0.62	0.81	2.13	0.081	0.55	0.0	1.3	117.4	2.8	0.8	-3.5	26.3	6.8
0392-A	0.018	-0.83	0	0.045	-3.3	0.031	0.79	1.25	2.16	0.086	0.67	0.0	2.5	-183.3	1.7	0.6	-9.7	25.1	7.8
0396-A	0.035	0.59	0.009	0.105	-0.4	0.017	0.71	1.1	2.34	0.128	0.56	0.3	3.0	-11.4	0.5	0.6	4.6	18.3	4.4
0400-B	0.025	0.16	0	0.061	-0.1	0.016	0.91	1.37	3.05	0.127	0.69	0.0	2.4	-4.0	0.6	0.7	1.3	24.0	5.4
0404-A	0.058	0.19	0.006	0.166	0.9	0.022	0.77	1.35	4.15	0.121	0.83	0.1	2.9	15.5	0.4	0.6	1.6	34.3	6.9
0408-B	0.027	0.39	-0.008	0.096	1.4	0.133	0.79	1.01	3.85	0.194	0.7	-0.3	3.6	51.9	4.9	0.8	2.0	19.8	3.6
0411-D	0.009	0.08	0	0.006	0.8	0.025	1.17	1.26	1.34	0.088	0.98	0.0	0.7	88.9	2.8	0.9	0.9	15.2	11.1
DH-0412-A	0.012	23.4	0.007	0.021	-0.3	0.018	0.61	0.95	0.91	0.055	0.6	0.6	1.8	-25.0	1.5	0.6	425.5	16.5	10.9
0414-C	-0.018	10.1	-0.002	0.002	-1	0.01	0.99	1.03	1.1	0.07	0.68	0.1	-0.1	55.6	-0.6	1.0	144.3	15.7	9.7
0416-A	0.027	0.39	0.009	0.055	0	0.027	0.99	1.66	2.91	0.169	0.79	0.3	2.0	0.0	1.0	0.6	2.3	17.2	4.7
0420-A	0.028	1.71	0.002	0.126	-0.2	0.015	0.89	1.4	3.58	0.17	0.9	0.1	4.5	-7.1	0.5	0.6	10.1	21.1	5.3
0424-A	0.015	-0.28	0	0.029	-0.3	0.016	0.63	0.97	1.48	0.043	0.66	0.0	1.9	-20.0	1.1	0.6	-6.5	34.4	15.3
Mean	0.030	2.172	0.003	0.081	-0.235	0.032	0.838	1.224	4.307	0.178	0.786	0.100	2.403	-3.602	1.379	0.694	33.195	24.106	7.469
Std Dev	0.030	5.996	0.005	0.075	1.418	0.029	0.177	0.234	6.150	0.225	0.238	0.206	1.283	76.834	1.364	0.135	107.108	8.306	4.308
N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
95% UCL	0.0	5.0	0.0	0.1	0.4	0.0	0.9	1.3	7.2	0.3	0.9	0.2	3.0	32.9	2.0	0.8	84.1	28.1	9.5
Max	0.1	23.4	0.0	0.3	2.7	0.1	1.2	1.7	26.6	1.0	1.4	0.6	5.0	117.4	4.9	1.0	425.5	47.4	16.5

Table 4-20 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 17

Correlation Data to Establish Surrogate Ratios																			
	Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)											Surrogate Ratios							
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0612-A	0.181	1.7	0.038	0.56	-0.3	0.058	0.75	1.25	9.1	0.37	1.09	0.2	3.1	-1.7	0.3	0.6	4.6	24.6	2.9
0613-B	0.017	-0.3	0.01	0.024	-1.6	0.015	0.88	1.37	0.99	0.021	0.78	0.6	1.4	-94.1	0.9	0.6	-14.3	47.1	37.1
0614-D	0.094	0.3	0.023	0.32	0	0.031	0.65	1.24	10.6	0.39	0.94	0.2	3.4	0.0	0.3	0.5	0.8	27.2	2.4
0615-E	0.065	5.7	0.014	0.006	-0.5	0.07	0.63	0.68	0.94	0.021	0.58	0.2	0.1	-7.7	1.1	0.9	271.4	44.8	27.6
0617-C	0.035	11.3	0.009	0.055	-1.7	0.027	0.94	1.23	58.2	2.59	13.6	0.3	1.6	-48.6	0.8	0.8	4.4	22.5	5.3
0618-B	0.033	0.39	0.045	0.046	-0.8	0.033	0.7	1.01	41.8	1.72	6.5	1.4	1.4	-24.2	1.0	0.7	0.2	24.3	3.8
0619-A	0.072	-0.52	0.032	0.184	0	0.028	0.91	1.4	5.37	0.237	1.54	0.4	2.6	0.0	0.4	0.7	-2.2	22.7	6.5
0622-C	0.02	4.6	0.023	0.026	1.5	0.044	0.59	0.86	0.77	0.034	0.379	1.2	1.3	75.0	2.2	0.7	135.3	22.6	11.1
0624-A	0.126	7	0.053	0.379	-0.7	0.016	0.87	1.36	8.8	0.32	1.4	0.4	3.0	-5.6	0.1	0.6	21.9	27.5	4.4
0625-C	0.052	-0.06	0.012	0.012	0.9	0.028	0.51	1.13	0.64	0.04	0.47	0.2	0.2	17.3	0.5	0.5	-1.5	16.0	11.8
0626-A	0.281	2.8	0.035	0.64	1.9	0.064	1.17	1.94	20.7	0.89	3.13	0.1	2.3	6.8	0.2	0.6	3.1	23.3	3.5
0628-A	0.031	8.3	0.022	0.015	1.7	0.055	0.76	1.45	77	4.11	19.3	0.7	0.5	54.8	1.8	0.5	2.0	18.7	4.7
0628-H	0.012	17	0.006	0.015	-0.2	0.023	0.75	1.04	11.9	0.69	2.78	0.5	1.3	-16.7	1.9	0.7	24.6	17.2	4.0
0629-A	0.02	-0.04	0.008	0.004	2.5	0.048	0.68	1.36	0.88	0.009	0.65	0.4	0.2	125.0	2.4	0.5	-4.4	97.8	72.2
0631-B	0.011	2.17	0.016	0.003	0	0.095	0.72	1.04	0.81	0.013	0.48	1.5	0.3	0.0	8.6	0.7	166.9	62.3	36.9
0636-C	0.023	0.82	0.013	0.012	0.3	0.013	0.56	1.07	0.57	0.035	0.66	0.6	0.5	13.0	0.6	0.5	23.4	16.3	18.9
0637-A	0.051	-0.78	0.004	0.053	0.8	0.035	1.02	7	12.6	0.53	4.37	0.1	1.0	15.7	0.7	0.1	-1.5	23.8	8.2
0639-D	0.165	0.2	0.053	0.39	2.6	0.034	0.73	0.78	5.21	0.173	1.24	0.3	2.4	15.8	0.2	0.9	1.2	30.1	7.2
0641-A	0.085	0.9	0.025	0.185	-1.5	0.054	0.79	1.11	12.7	0.4	4	0.3	2.2	-17.6	0.6	0.7	2.3	31.8	10.0
0644-A	0.047	0.38	0.012	0.046	-0.3	0.048	0.67	1.13	1.28	0.068	0.56	0.3	1.0	-6.4	1.0	0.6	5.6	18.8	8.2
0647-B	0.029	1	0.016	0.034	0.3	0.017	0.82	1.02	1.25	0.036	0.86	0.6	1.2	10.3	0.6	0.8	27.8	34.7	23.9
0648-D	0.115	0.2	0.012	0.273	0.3	0.05	0.99	1.26	4.79	0.196	2.62	0.1	2.4	2.6	0.4	0.8	1.0	24.4	13.4
0651-A	0.018	0.75	0.002	-0.003	-1.6	0.068	0.67	1.1	0.81	0.056	0.56	0.1	-0.2	-88.9	3.8	0.6	13.4	14.5	10.0
0652-C	0.008	0.6	0.01	0	1.9	0.008	0.76	0.56	0.81	0.036	0.66	1.3	0.0	237.5	1.0	1.4	16.7	22.5	18.3
0655-A	0.248	1.4	0.053	0.59	1.4	0.039	0.91	1.52	6.9	0.36	2.77	0.2	2.4	5.6	0.2	0.6	3.9	19.2	7.7
0658-B	0.016	0.9	0.015	-0.001	-1.6	0.016	0.8	1.08	0.76	0.042	0.82	0.9	-0.1	-100.0	1.0	0.7	21.4	18.1	19.5
0661-A	0.02	0.64	0.021	0.019	0.8	0.034	0.56	0.86	0.84	0.056	0.66	1.1	1.0	40.0	1.7	0.7	11.4	15.0	11.8
0662-C	0.028	0.4	0.019	0.021	2.2	0.08	0.74	1	1.04	0.036	0.61	0.7	0.8	78.6	2.9	0.7	11.1	28.9	16.9
0664-B	0.04	0.04	0.008	0.011	1.7	0.088	0.54	1.01	0.77	0.016	0.58	0.2	0.3	42.5	2.2	0.5	2.5	48.1	36.3
0665-A	0.037	1.5	0.006	0.029	-0.7	0.015	0.84	1.25	2.71	0.1	0.83	0.2	0.8	-18.9	0.4	0.7	15.0	27.1	8.3
0666-D	0.016	-0.18	0.014	0.012	1.1	0.021	0.79	1.06	0.79	0.053	0.93	0.9	0.8	68.8	1.3	0.7	-3.4	14.9	17.5
0667-B	0.023	-0.4	0.01	0.025	1.5	0.006	0.84	1.17	1.87	0.082	1.07	0.4	1.1	65.2	0.3	0.7	-4.9	22.8	13.0
A614-D	0.075	-0.4	0.007	0.14	1.5	0.011	0.84	1.19	4.44	0.22	0.84	0.1	1.9	20.0	0.1	0.7	-1.8	20.2	3.8
C614-C	0.012	0.59	0.011	0.006	0.4	0.024	0.49	1.03	0.85	0.037	0.51	0.9	0.5	33.3	2.0	0.5	15.9	23.0	13.8
D614-D	0.028	0.7	0.013	0.014	-1.3	0.01	0.8	1.3	1.35	0.027	0.61	0.5	0.5	-46.4	0.4	0.6	25.9	50.0	22.6
Mean	0.061	1.989	0.019	0.118	0.357	0.037	0.762	1.310	8.881	0.400	2.268	0.511	1.222	12.888	1.254	0.665	22.851	28.648	14.963
Std Dev	0.067	3.745	0.014	0.184	1.277	0.024	0.151	1.021	16.837	0.829	3.853	0.389	0.984	61.601	1.556	0.186	56.014	16.459	13.919
N	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
95% UCL	0.1	3.2	0.0	0.2	0.8	0.0	0.8	1.6	14.5	0.7	3.5	0.6	1.5	33.3	1.8	0.7	41.4	34.1	19.6
Max	0.3	17.0	0.1	0.6	2.6	0.1	1.2	7.0	77.0	4.1	19.3	1.5	3.4	237.5	8.6	1.4	271.4	97.8	72.2

Table 4-21 Full-Suite Data & Surrogate Ratio Calculation Datasheet, SU 18

Correlation Data to Establish Surrogate Ratios																			
	Alpha Spectroscopy and Liquid Scintillation Results (pCi/g)										Surrogate Ratios								
Sample ID	Am-241	Tc-99	Pu-238	Pu-239/240	Pu-241	Pu-242	Th-230	Th-232	U-233/234	U-235	U-238	Pu238: Am241	Pu239/240 : Am241	Pu241 : Am241	Pu242 : Am241	Th230 : Th232	Tc99: U235	U233/U234 : U235	U238 :U235
0669-B	0.033	9.6	-0.002	0.03	-1.8	0.026	0.53	1.01	16.4	0.82	5.7	-0.1	0.9	-54.5	0.8	0.5	11.7	20.0	7.0
0669-D	0.02	9	0.015	0.003	-0.5	0.04	0.46	1.04	4.64	0.249	1.98	0.8	0.2	-25.0	2.0	0.4	36.1	18.6	8.0
0670-A	0.053	0.77	0.028	0.082	1.7	0.04	1.16	1.6	9.4	0.44	1.91	0.5	1.5	32.1	0.8	0.7	1.8	21.4	4.3
0672-C	0.01	0.2	0.003	0.008	-0.9	0.021	0.5	1	1.98	0.094	0.93	0.3	0.8	-90.0	2.1	0.5	2.1	21.1	9.9
0673-B	0.036	0.01	0.004	0.028	4.7	0.056	0.53	0.82	1.26	0.024	0.46	0.1	0.8	130.6	1.6	0.6	0.4	52.5	19.2
0674-D	0.057	33.4	0.029	0.096	1.6	0.033	1.68	2.04	16.6	0.8	2.28	0.5	1.7	28.1	0.6	0.8	41.8	20.8	2.9
0676-A	0.026	1.17	0.015	0.008	1.9	0.056	1.14	1.34	49	2.31	13.8	0.6	0.3	73.1	2.2	0.9	0.5	21.2	6.0
0677-D	0.05	2.8	0.003	0.017	-0.5	0.043	0.72	1.26	47	2.37	12.6	0.1	0.3	-10.0	0.9	0.6	1.2	19.8	5.3
0680-A	0.029	0.23	0.023	0.043	0.8	0.049	0.8	0.89	2.78	0.1	0.82	0.8	1.5	27.6	1.7	0.9	2.3	27.8	8.2
0683-D	0.052	-0.02	0.006	-0.002	1.1	0.016	0.67	1.1	1.91	0.103	0.73	0.1	0.0	21.2	0.3	0.6	-0.2	18.5	7.1
0684-A	0.024	-0.1	0.009	0.075	0.4	0.039	0.59	0.98	2.14	0.08	0.79	0.4	3.1	16.7	1.6	0.6	-1.3	26.8	9.9
0686-C	0.094	0.29	0.022	0.211	0.9	0.028	0.91	1.5	6.5	0.27	1.41	0.2	2.2	9.6	0.3	0.6	1.1	24.1	5.2
0687-B	0.03	0.67	0.017	0.005	1.2	0.039	0.96	1.08	0.96	0.06	1.03	0.6	0.2	40.0	1.3	0.9	11.2	16.0	17.2
0688-C	0.011	0	0.01	0.006	1.1	0.061	0.7	1.45	0.78	0.031	0.47	0.9	0.5	100.0	5.5	0.5	0.0	25.2	15.2
0689-B	0.075	2.2	0.017	0.072	0.6	0.05	0.84	1.05	4.42	0.192	1.11	0.2	1.0	8.0	0.7	0.8	11.5	23.0	5.8
0691-B	0.036	1.5	-0.001	0.01	0.4	0.018	0.52	0.89	0.75	0.05	0.51	0.0	0.3	11.1	0.5	0.6	30.0	15.0	10.2
0692-A	0.75	0.3	0.104	2.29	1.3	0.042	1.85	3.42	20.8	0.83	4.15	0.1	3.1	1.7	0.1	0.5	0.4	25.1	5.0
0695-B	0.035	0.94	0.008	0.055	2	0.039	0.51	0.8	24	0.94	3.54	0.2	1.6	57.1	1.1	0.6	1.0	25.5	3.8
0696-A	0.047	0.76	0.02	0.056	-0.8	0.031	0.53	0.76	47.2	1.61	3.28	0.4	1.2	-17.0	0.7	0.7	0.5	29.3	2.0
0697-F	0.021	-0.07	0.004	0.017	-0.7	0.023	1.11	1.16	0.98	0.043	0.91	0.2	0.8	-33.3	1.1	1.0	-1.6	22.8	21.2
0699-C	0.041	0.27	0.015	0.03	1	0.024	0.82	1.13	4.84	0.203	1.17	0.4	0.7	24.4	0.6	0.7	1.3	23.8	5.8
0700-A	0.026	13.4	0.012	0.057	1	0.02	1.49	2.19	17.2	0.63	2.31	0.5	2.2	38.5	0.8	0.7	21.3	27.3	3.7
0701-B	0.011	-0.12	0.012	0.005	-1.3	0.066	0.73	0.98	3.5	0.143	0.83	1.1	0.5	-118.2	6.0	0.7	-0.8	24.5	5.8
0703-D	0.024	0.1	0.025	0.018	1.9	0.031	0.397	0.61	1.14	0.044	0.98	1.0	0.8	79.2	1.3	0.7	2.3	25.9	22.3
0704-I	0.014	0.8	0.031	0.008	2.8	0.036	1.09	1.12	1.08	0.069	1.31	2.2	0.6	200.0	2.6	1.0	11.6	15.7	19.0
0707-A	0.035	-0.21	0.008	0.061	2.1	0.047	0.68	0.87	2.44	0.093	0.72	0.2	1.7	60.0	1.3	0.8	-2.3	26.2	7.7
0708-A	0.032	-0.2	0.056	0.019	1.3	0.085	0.85	1.4	5.15	0.17	1.02	1.8	0.6	40.6	2.7	0.6	-1.2	30.3	6.0
0708-C	0.021	-0.03	0.022	0.019	2.1	0.048	0.57	0.98	0.53	0.033	0.43	1.0	0.9	100.0	2.3	0.6	-0.9	16.1	13.0
E672-C	0.056	0.49	0.04	0.065	-1.6	0.04	0.96	1.34	24.8	1.02	6.2	0.7	1.2	-28.6	0.7	0.7	0.5	24.3	6.1
S672-E	0.024	1.48	0.033	0.003	0	0.056	0.58	0.95	18.3	0.96	6.1	1.4	0.1	0.0	2.3	0.6	1.5	19.1	6.4
W672-B	0.023	1.1	0.017	0.013	-0.8	0.042	0.69	1.16	3.44	0.226	1.35	0.7	0.6	-34.8	1.8	0.6	4.9	15.2	6.0
N672-A	0.011	2.3	0.011	0.074	-0.9	0.016	0.81	0.8	44.2	1.99	10.8	1.0	6.7	-81.8	1.5	1.0	1.2	22.2	5.4
Mean	0.056	2.595	0.019	0.109	0.691	0.039	0.824	1.210	12.066	0.531	2.863	0.593	1.201	18.942	1.546	0.690	5.927	23.281	8.756
Std Dev	0.128	6.430	0.020	0.400	1.425	0.016	0.350	0.529	15.251	0.679	3.533	0.517	1.285	64.467	1.315	0.149	11.172	6.770	5.550
N	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
95% UCL	0.1	4.8	0.0	0.2	1.2	0.0	0.9	1.4	17.4	0.8	4.1	0.8	1.6	41.3	2.0	0.7	9.8	25.6	10.7
Max	0.8	33.4	0.1	2.3	4.7	0.1	1.9	3.4	49.0	2.4	13.8	2.2	6.7	200.0	6.0	1.0	41.8	52.5	22.3

5.0 ANALYSIS OF SAMPLE RESULTS FOR COMPLIANCE

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Figure 5-1 SSDCGL Data Evaluation and Compliance Test Flow Diagram

5.1 CALCULATING INDIVIDUAL SAMPLE SUM OF FRACTIONS

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Equation 5 Calculating the Sample Net Concentration

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Equation 6 Calculating the Sample Net Sum-of-Fractions

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Figure 5-2 Histogram of Individual SOF_{NET} Values, SU 4

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Figure 5-3 Histogram of Individual SOF_{NET} Values, SU 6

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-4 Histogram of Individual SOF_{NET} Values, SU 7

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Figure 5-5 Histogram of Individual SOF_{NET} Values, SU 12

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Figure 5-6 Histogram of Individual SOF_{NET} Values, SU 16-Western

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Figure 5-7 Histogram of Individual SOF_{NET} Values, SU 16-Central

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-8 Histogram of Individual SOF_{NET} Values, SU 16-Eastern

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-9 Histogram of Individual SOF_{NET} Values, SU 17

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-10 Histogram of Individual SOF_{NET} Values, SU 18

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5.2 $DCGL_{WAA}$ ARITHMETIC MEAN COMPLIANCE TEST

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Equation 7 Calculating the Wide-Area Arithmetic Mean Activity for Each Depth Increment

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Equation 8 Calculating the Volume-Weighted, Wide-Area Arithmetic Mean Activity

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Table 5-1 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 4

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Table 5-2 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 6

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Table 5-3 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 7

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Table 5-4 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 12

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Table 5-5 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 16-Western

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Table 5-6 $DCGL_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 16-Central

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Table 5-7 DCGL$_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 16-Eastern

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Table 5-8 DCGL$_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 17

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Table 5-9 DCGL$_{WAA}$ Arithmetic Mean Compliance Test Summary, Survey Unit 18

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5.3 DCGL$_{WAA}$ STATISTICAL COMPLIANCE TEST

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Figure 5-11 Histogram, Reference Background Area SOFs

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Figure 5-12 Histogram, Survey Unit 4 SOFs

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Figure 5-13 Boxplot, Survey Unit 4 and RBA Sample Populations

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Figure 5-14 Comparison of Survey Unit 4 and RBA Sample Populations

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Figure 5-15 Histogram, Survey Unit 6 SOFs

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Figure 5-16 Boxplot, Survey Unit 6 and RBA Sample Populations

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Figure 5-17 Comparison of Survey Unit 6 and RBA Sample Populations

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Figure 5-18 Histogram, Survey Unit 7 SOFs

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Figure 5-19 Boxplot, Survey Unit 7 and RBA Sample Populations

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Figure 5-20 Comparison of Survey Unit 7 and RBA Sample Populations

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Figure 5-21 Histogram, Survey Unit 12 SOFs

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Figure 5-22 Boxplot, Survey Unit 12 and RBA Sample Populations

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Figure 5-23 Comparison of Survey Unit 12 and RBA Sample Populations

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Figure 5-24 Histogram, Survey Unit 16-Western SOFs

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Figure 5-25 Boxplot, Survey Unit 16-Western and RBA Sample Populations

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Figure 5-26 Comparison of Survey Unit 16-Western and RBA Sample Populations

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Figure 5-27 Histogram, Survey Unit 16-Central SOFs

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Figure 5-28 Boxplot, Survey Unit 16-Central and RBA Sample Populations

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Figure 5-29 Comparison of Survey Unit 16-Central and RBA Sample Populations

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Figure 5-30 Histogram, Survey Unit 16-Eastern SOFs

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Figure 5-31 Boxplot, Survey Unit 16-Eastern and RBA Sample Populations

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Figure 5-32 Comparison of Survey Unit 16-Eastern and RBA Sample Populations

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Figure 5-33 Histogram, Survey Unit 17 SOFs

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Figure 5-34 Boxplot, Survey Unit 17 and RBA Sample Populations

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Figure 5-35 Comparison of Survey Unit 17 and RBA Sample Populations

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Figure 5-36 Histogram, Survey Unit 18 SOFs

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Figure 5-37 Boxplot, Survey Unit 18 and RBA Sample Populations

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Figure 5-38 Comparison of Survey Unit 18 and RBA Sample Populations

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Equation 9 Calculating the Sample Gross SOF

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Equation 10 Calculating the Volume-Weighted Columnar Gross SOF

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Table 5-10 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 4

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Table 5-11 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 6

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Table 5-12 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 7

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Table 5-13 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 12

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Table 5-14 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 16-Western

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Table 5-15 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 16-Central

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Table 5-16 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 16-Eastern

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Table 5-17 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 17

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Table 5-18 DCGL$_{WAA}$ WRS Compliance Test Summary, Survey Unit 18

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5.4 DCGL$_{LAA}$ NEAREST NEIGHBOR COMPLIANCE TESTS

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Table 5-19 Depth Progression of Local Area Average Concept

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5.4.1 $DCGL_{LAA\text{-}S}$ Nearest Neighbor, Single Layer Compliance Test

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Figure 5-39 Possible Combinations of "Nearest Neighbors" Occurring for Each Sample

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Equation 11 Calculating the Nearest Neighbor Mean Isotopic Activity

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Equation 12 Calculating the SOF for the Nearest Neighbor Mean Activity

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Figure 5-40 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 4

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Figure 5-41 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 6

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Figure 5-42 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 7

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Figure 5-43 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 12

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Figure 5-44 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 16-Western

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Figure 5-45 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 16-Central

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Figure 5-46 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 16-Eastern

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Figure 5-47 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 17

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Figure 5-48 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Single Layer, SU 18

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Table 5-20 DCGL$_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 4

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Table 5-21 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 6

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Table 5-22 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 7

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Table 5-23 DCGL$_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 12

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Table 5-24 DCGL$_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 16-Western

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Table 5-25 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 16-Central

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 5-26 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 16-Eastern

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 5-27 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 17

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 5-28 $DCGL_{LAA}$ Nearest Neighbor, Single Layer Compliance Test Summary, Survey Unit 18

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5.4.2 DCGL$_{LAA-M}$ Nearest Neighbor Multiple Layer Compliance Test

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Figure 5-49 Local Area Averaging Projected to Multiple Depth Layers

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Equation 13 Calculating the Nearest Neighbor Mean Isotopic Activity

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Information in this section contains proprietary trade secret information which has been redacted in this version.

Equation 14 Calculating the Volume-Weighted Nearest Neighbor Mean Isotopic Activity

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Information in this section contains proprietary trade secret information which has been redacted in this version.

Equation 15 Calculating the Volume-Weighted Nearest Neighbor SOF

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Figure 5-50 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 4

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Figure 5-51 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 4

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Figure 5-52 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 6

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-53 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 6

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-54 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 7

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Figure 5-55 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 7

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Figure 5-56 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 12

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Figure 5-57 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 12

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Figure 5-58 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 16-Western

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-59 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 16-Western

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-60 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 16-Central

Information in this section contains proprietary trade secret information which has been redacted in this version.

Figure 5-61 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 16-Central

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Figure 5-62 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 16-Eastern

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Figure 5-63 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 16-Eastern

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Figure 5-64 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 17

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Figure 5-65 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 17

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Figure 5-66 Histogram of $DCGL_{LAA}$ Nearest Neighbor SOF_{NET} Values, SU 18

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Figure 5-67 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Multi-Layer, SU 18

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5.5 DCGL$_{LAA}$ COLUMNAR COMPLIANCE TEST

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Figure 5-68 Progressively Deeper Vertical Averaging in a Single Column

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Equation 16 Calculating the Columnar Weighted-Average Isotopic Activity

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Equation 17 Calculating the Columnar Weighted-Average SOF

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Figure 5-69 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 4

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Figure 5-70 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 4

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Figure 5-71 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 6

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Figure 5-72 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 6

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Figure 5-73 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 7

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Figure 5-74 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 7

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Figure 5-75 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 12

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Figure 5-76 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 12

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Figure 5-77 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 16-Western

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Figure 5-78 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 16-Western

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Figure 5-79 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 16-Central

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Figure 5-80 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 16-Central

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Figure 5-81 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 16-Eastern

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Figure 5-82 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 16-Eastern

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Figure 5-83 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 17

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Figure 5-84 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 17

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Figure 5-85 Histogram of $DCGL_{LAA}$ Columnar SOF_{NET} Values, SU 18

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Figure 5-86 Descriptive Statistics, SOFs, Nearest Neighbor Local Area Average, Columnar, SU 18

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5.6 DCGL$_{EMC}$ INDIVIDUAL SUBSURFACE COMPLIANCE TEST

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Equation 18 Calculating the Single Sample EMC Comparison SOF

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Figure 5-87 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 4

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Figure 5-88 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 4

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Figure 5-89 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 6

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Figure 5-90 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 6

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Figure 5-91 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 7

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Figure 5-92 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 7

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Figure 5-93 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 12

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Figure 5-94 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 12

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Figure 5-95 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 16-Western

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Figure 5-96 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 16-Western

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Figure 5-97 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 16-Central

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Figure 5-98 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 16-Central

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Figure 5-99 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 16-Eastern

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Figure 5-100 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 16-Eastern

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Figure 5-101 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 17

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Figure 5-102 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 17

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Figure 5-103 Histogram of $DCGL_{EMC}$ SOF_{NET} Values, SU 18

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Figure 5-104 Descriptive Statistics, $DCGL_{EMC}$ SOFs, Individual Sample Cells, SU 18

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Table 5-29 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 4

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Table 5-30 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 6

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Table 5-31 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 7

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Table 5-32 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 12

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Table 5-33 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 16-Western

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Table 5-34 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 16-Central

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Table 5-35 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 16-Eastern

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Table 5-36 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 17

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Table 5-37 Single Sample $DCGL_{EMC}$, Compliance Test Summary, Survey Unit 18

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5.7 SURROGATE RATIO COMPARISON

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5.7.1 Surrogate Ratio Comparison, Survey Unit 4

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Figure 5-105 Comparison of Surrogate Ratios Determined from SU 4 Historical Dataset vs. Ratios Determined from SU 4 FSS Dataset

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Table 5-38 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, SU 4

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Table 5-39 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 4

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Table 5-40 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 4

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Table 5-41 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 4

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5.7.2 Surrogate Ratio Comparison, Survey Unit 6

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Figure 5-106 Comparison of Surrogate Ratios Determined from SU 6 Historical Dataset vs. Ratios Determined from SU 6 FSS Dataset

Table 5-42 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, SU 6

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Table 5-43 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 6

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Table 5-44 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 6

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Table 5-45 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 6

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5.7.3 Surrogate Ratio Comparison, Survey Unit 7

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Figure 5-107 Comparison of Surrogate Ratios Determined from SU 16 Historical Dataset vs. Ratios Determined from SU 7 FSS Dataset

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Table 5-46 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, Survey Unit 7

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Table 5-47 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, Survey Unit 7

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Table 5-48 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 7

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Table 5-49 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 7

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5.7.4 Surrogate Ratio Comparison, Survey Unit 12

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Figure 5-108 Comparison of Surrogate Ratios Determined from SU 12 Historical Dataset vs. Ratios Determined from SU 12 FSS Dataset

Table 5-50 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, SU 12

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Table 5-51 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 12

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Table 5-52 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 12

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Table 5-53 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 12

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5.7.5 Surrogate Ratio Comparison, Survey Unit 16-Western

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Figure 5-109 Comparison of Surrogate Ratios Determined from SU 16 Historical Dataset vs. Ratios Determined from SU 16-Western FSS Dataset

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Table 5-54 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, Survey Unit 16

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Table 5-55 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, Survey Unit 16

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Table 5-56 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 16-Western

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Table 5-57 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 16-Western

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5.7.6 Surrogate Ratio Comparison, Survey Unit 16-Central

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Figure 5-110 Comparison of Surrogate Ratios Determined from SU 16 Historical Dataset vs. Ratios Determined from SU 16-Central FSS Dataset

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Table 5-58 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 16-Central

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Table 5-59 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 16-Central

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5.7.7 Surrogate Ratio Comparison, Survey Unit 16-Eastern

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Figure 5-111 Comparison of Surrogate Ratios Determined from SU 16 Historical Dataset vs. Ratios Determined from SU 16-Eastern FSS Dataset

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Table 5-60 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 16-Eastern

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Table 5-61 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from FSS Dataset, SU 16-Eastern

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5.7.8 Surrogate Ratio Comparison, Survey Unit 17

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Figure 5-112 Comparison of Surrogate Ratios Determined from SU 17 Historical Dataset vs. Ratios Determined from SU 17 FSS Dataset

Table 5-62 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, SU 17

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Table 5-63 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 17

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Table 5-64 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 17

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Table 5-65 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 17

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5.7.9 Surrogate Ratio Comparison, Survey Unit 18

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Figure 5-113 Comparison of Surrogate Ratios Determined from SU 18 Historical Dataset vs. Ratios Determined from SU 18 FSS Dataset

Table 5-66 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from Historical Dataset, SU 18

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Table 5-67 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 18

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Table 5-68 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using 90th Percentile Values from FSS Dataset, SU 18

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Table 5-69 Maximum Areal Frequency Required to Satisfy $DCGL_{EMC}$ test Using Maximum Values from Historical Dataset, SU 18

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5.8 POTENTIAL DOSE IMPACT OF HARD-TO-DETECT ISOTOPES

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Table 5-70 Insignificant Contibutors to Dose

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5.8.1 Potential Dose Impact of Hard-To-Detect Isotopes at the North Site

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Table 5-71 Potential Dose Impact of Hard-To-Detect Isotopes, North Site

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5.8.2 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 4

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Table 5-72 Potential Dose Impact of Hard-To-Detect Isotopes, SU 4

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5.8.3 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 6

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Table 5-73 Potential Dose Impact of Hard-To-Detect Isotopes, SU 6

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5.8.4 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 7

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Table 5-74 Potential Dose Impact of Hard-To-Detect Isotopes, SU 7

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5.8.5 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 12

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Table 5-75 Potential Dose Impact of Hard-To-Detect Isotopes, SU 12

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5.8.6 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 16

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Table 5-76 Potential Dose Impact of Hard-To-Detect Isotopes, SU 16

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5.8.7 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 17

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Table 5-77 Potential Dose Impact of Hard-To-Detect Isotopes, SU 17

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5.8.8 Potential Dose Impact of Hard-To-Detect Isotopes, Survey Unit 18

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Table 5-78 Potential Dose Impact of Hard-To-Detect Isotopes, SU 18

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5.9 ASSESSMENT OF THE ADEQUACY OF THE SAMPLE DESIGN FOR SURVEY UNITS 4, 6, 7, 12, 16-WESTERN, 16-CENTRAL, 16-EASTERN, 17, AND 18

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5.10 OVERALL ASSESSMENT OF SURVEY UNIT COMPLIANCE WITH THE SUBSURFACE SOIL DCGLS

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Table 5-79 Compliance Assessment Summary, Survey Unit 4

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Table 5-80 Compliance Assessment Summary, Survey Unit 6

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Table 5-81 Compliance Assessment Summary, Survey Unit 7

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Table 5-82 Compliance Assessment Summary, Survey Unit 12

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Table 5-83 Compliance Assessment Summary, Survey Unit 16-Western

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Table 5-84 Compliance Assessment Summary, Survey Unit 16-Central

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Table 5-85 Compliance Assessment Summary, Survey Unit 16-Eastern

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Table 5-86 Compliance Assessment Summary, Survey Unit 17

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Table 5-87 Compliance Assessment Summary, Survey Unit 18

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5.11 THE POTENTIAL DOSE IMPACT OF SURVEY UNITS 4, 6, 7, 12, 16-WESTERN, 16-CENTRAL, 16-EASTERN, 17, AND 18

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 5-88 Projected Annual Dose, Survey Unit 4

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Table 5-89 Projected Annual Dose, Survey Unit 6

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5.12 ASSESSMENT OF POTENTIAL FOR INTACT ORIGINAL SURFACE SOILS

Appendix B of the DP (Subsurface Soil Final Status Survey) was designed for impacted subsurface soils deeper than 15 cm. Surface soils that remain intact and at the surface following remediation and FSS activities may require further investigation as part of this FSS, in accordance with Section 5 of the DP (Surface Final Status Survey). An assessment was performed comparing the elevation differential of the surface grade at time of sampling to the surface of the final grade, as determined by the approved and executed Drainage Plan. This assessment concluded that there is virtually no potential for intact original surface soils in Survey Units 4, 12, 16, 17, and 18. It further concluded, however, that there is a potential for intact original surface soils in Survey Units 6 and 7. Therefore, a surface soil FSS in Survey Units 6 and 7 will be performed to supplement the subsurface FSS presented in this report.

Appendix I of this FSS Report provides further details of the assessment of potential for intact original surface soils in Survey Units 4, 6, 7, 12, 16, 17, and 18. The results of the surface FSS in Survey Units 6 and 7 will be subsequently presented as an addendum to this FSS Report.

Table 5-90 Projected Annual Dose, Survey Unit 7

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Table 5-91 Projected Annual Dose, Survey Unit 12

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Table 5-92 Projected Annual Dose, Survey Unit 16-Western

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Table 5-93 Projected Annual Dose, Survey Unit 16-Central

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Table 5-94 Projected Annual Dose, Survey Unit 16-Eastern

Information in this section contains proprietary trade secret information which has been redacted in this version.

Table 5-95 Projected Annual Dose, Survey Unit 17

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Table 5-96 Projected Annual Dose, Survey Unit 18

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6.0 QUALITY CONTROL & DATA QUALITY ANALYSIS

An important aspect of any survey or sampling process is the effort made to assure the quality of data collected. Thus, it was critical to assure the quality of the data through quality checks and controls, calibrations, and training. The purpose of this data quality assessment (DQA) is to evaluate the data collected from the field in light of its intended use in decision-making. Decision-makers should obtain an understanding from this section of the verity of the data used to assess the residual radioactivity in the survey unit.

Quality checks and controls were designed into the final radiological status survey to ensure adequate data quality. Quality control measurements were designed to provide a means of assessing the quality of the resulting datasets from individual survey units. The survey design specified that quality control samples be collected over the duration of the field sampling event. Analytical data generated from the analysis of soil samples collected was subjected to a rigorous data validation process designed to qualify the data provided and validate its appropriateness for the intended use. The DQA used guidance from MARSSIM (NRC 2000), *Guidance for Data Useability in Risk Assessment* (EPA 1992), and professional judgment. This section of the report discusses the quality control data collected to assure that quality objectives in the design of the survey were achieved. It then assesses the overall data quality against the published or industry accepted data quality indicators.

6.1 SUBSURFACE SOIL SAMPLES

Three measures of the analytical data quality are available for the surface soil sampling performed—laboratory QC samples (spikes), laboratory duplicates, and field duplicates (splits).

6.1.1 Laboratory Control Samples

Laboratory control samples (LCS) are incorporated by the contract laboratory (Paragon) as a quality assessment technique. LCS samples are samples that are processed, prepared, and assayed exactly as the field sample except that a known amount radioactivity has been added to the LCS. Analytical measurement of the radioactivity in the LCS should produce results consistent with the known amount of radioactivity in the LCS.

For gamma spectroscopy analysis, the LCS consists of a solid matrix sample of the same size and geometry as that of the soils being assayed. The LCS is "introduced" by the laboratory into each batch of samples being assayed by the gamma spec method. LCS samples were measured with a frequency of one in every 20 soil samples. The data validation process reviewed the accuracy of the laboratory reported results for LCS' analyzed by gamma spectroscopy and found that the results were consistently within the acceptable tolerance for accuracy. This provides good assurance that the methods and measures used by the laboratory to assess radioactivity in soil samples from the survey unit also yielded accurate results.

For radiochemical techniques, the LCS consists of a solid matrix sample aliquot of the same volume as that of the soils being assayed to which a sample is spiked with a known concentration of radioactivity and then measured using the analytical process used to assay the field samples. The quality measure for an LCS prepared in this manner is usually reported as "percent recovery." The LCS is "introduced" by the laboratory into each batch of samples being assayed by the gamma spec method. LCS samples were measured with a frequency of one in every 20 soil samples. The data validation process reviewed the accuracy of the laboratory reported results for LCS' analyzed by radiochemical techniques and found that the results were consistently within the acceptable tolerance for accuracy. This provides good assurance that the sample preparation, extraction, and measurement processes used by the laboratory to assess radioactivity in soil samples from the survey unit also yielded accurate results.

6.1.2 Laboratory Duplicate Samples

Laboratory duplicate samples are prepared by the analytical laboratory after samples are received from the field. Duplicate samples are essentially split samples processed by the laboratory to assess the reproducibility of the analytical processes employed. Duplicates for gamma spectroscopy analyses are not separate samples as is the case with radiochemical techniques. Rather, the laboratory replicates the measurement process on a selected soil sample from the batch in order to measure the reproducibility of the analytical process. A laboratory duplicate sample was prepared for each type of analysis and for each batch of 20 samples submitted. Reproducibility, as a measure of laboratory data quality, was judged by calculating the duplicate error ratio in accordance with NFS approved procedure (NFS 2007b). Each of the laboratory duplicate samples was within the expected tolerance for the analysis, indicating that the sample preparation, extraction, and measurement processes were in control and accurate.

6.1.3 Field Duplicate Samples

Field duplicate samples were also employed in the sample design to assess the precision of the analytical processes used to produce measured results. A subset of 10% of the field samples submitted for analysis were identified as field duplicates. Field duplicate samples for Tc-99 analysis were prepared in the field by the sampling team and were supplied to the analytical laboratory as field duplicate samples. However, because sample homogeneity is critical to the quality objective of field duplicate samples and because homogeneity of radioactivity in a soil sample is virtually impossible to achieve in the field, duplicate samples from analyses other than Tc-99 were prepared after the field sample was dried and ground to a homogenous matrix. The sample preparation laboratory (Teledyne) randomly selected samples to be "split" to form a duplicate sample. Teledyne prepared duplicates were supplied to NFS and to Paragon for assay as if they were typical field samples. In fact, the duplicate samples created by Teledyne and supplied to the analytical laboratories were identical in all respects to field samples.

For Survey Unit 4, a total of 26 field duplicate samples (10% of 263) were prepared and supplied to the NFS analytical laboratory. Three field duplicate samples (10% of 27 full-suite samples) were prepared and supplied to ALS.

For Survey Unit 6, a total of 29 field duplicate samples (10% of 289) were prepared and supplied to the NFS analytical laboratory. Five field duplicate samples (16% of 31 full-suite samples) were prepared and supplied to ALS.

For Survey Unit 7, a total of 24 field duplicate samples (10% of 219) were prepared and supplied to the NFS analytical laboratory. Five field duplicate sample (10% of 22 full-suite samples) were prepared and supplied to ALS.

For Survey Unit 12, a total 23 field duplicate samples (11% of 204) were prepared and supplied to the NFS analytical laboratory. Three field duplicate samples (13% of 22 full-suite samples) were prepared and supplied to ALS.

For Survey Unit 16, a total of 60 field duplicate samples (10% of 634) were prepared and supplied to the NFS analytical laboratory. Fourteen field duplicate sample (10% of 80 full-suite samples) were prepared and supplied to Paragon.

For Survey Unit 17, a total of 32 field duplicate samples (10% of 313) were prepared and supplied to the NFS analytical laboratory. Nine field duplicate samples (25% of 35 full-suite samples) were prepared and supplied to ALS.

For Survey Unit 18, a total of 29 field duplicate samples (10% of 300) were prepared and supplied to the NFS analytical laboratory. Four field duplicate samples (12% of 32 full-suite samples) were prepared and supplied to ALS.

Field duplicate sample results were evaluated in comparison with their associated paired (initial) sample to provide an indication of degree of precision afforded in the analytical process. The assessment of field duplicate analyses was performed in accordance with NFS Standard Operating Procedure (SOP) NFS-DC-008, *Data Validation Procedure*. This data validation procedure is an SOP applicable to decommissioning and operations support activities performed in support of licensed decommissioning activities at the NFS Site in Erwin, TN.

Field duplicates are evaluated using the Duplicate Error Ratio (DER) method outlined in SOP NFS-DC-008 to determine the precision of laboratory analyses when comparing the results and uncertainties of two discrete analyses from the same sample. The DER calculation utilized to assess precision among duplicate samples is as follows:

Duplicate Error Ratio (DER):

$$DER = \frac{|S - D|}{\sqrt{(2\sigma_S)^2 + (2\sigma_D)^2}}$$

Where,

S = Original Sample Value
D = Duplicate Value
σ_s = Original Sample Uncertainty
σ_D = Duplicate Sample Uncertainty

The uncertainties used in the DER calculations were total propagated uncertainties as reported by the laboratory. The established DER control limit value for assessing duplicate sample precision is ≤ 2.0. The vast majority of field duplicate samples in Survey Units 4, 6, 7, 12, 16-Western, 16-Central, 16-Eastern, 17, and 18 resulted in a DER ≤ 2.0. The percent of duplicate field samples in each suevy unit that met the established control limit value are summarized in Table 6-1. The degree of precision observed is remarkably good considering that the majority of the analytes were shown to have concentrations near the analytical detection limit and at a small fraction of the permissible surface soil DCGLs, providing additional evidence that the sample preparation, extraction, and measurement processes were in control and produced acceptably precise measures of the analytes.

Table 6-1 Summary of Duplicate Error Ratios

Survey Unit	DER ≤ 2.0 (%)
4	100%
6	100%
7	99%
12	99%
16-Western	94%
16-Central	96%
16-Eastern	96%
17	100%
18	99%

6.2 DETECTION LIMIT ADEQUACY

The results of the field duplicate sample analyses were evaluated in comparison to the results obtained from the initial sample from which the field duplicate was split.

Each of the measurement methods used to assess the residual radioactivity in the survey units of the site have measurement sensitivities that limit the ability of the measurement to detect and quantify radioactivity. A key concern and design element was to assure that sufficiently low detection sensitivities were achieved. The target minimum detection sensitivity (minimum detection limits) planned in the sample design was ≈50% of the applicable DCGL. The minimum detection sensitivities specified by contract to the analytical laboratories (contract required detection level, CRDL) are presented in Table 6-2 in pCi/g.

Table 6-2 Radio-Analytical Methods and Reporting Limit

Radioisotope	Analysis Method	Surface Soil DCGL	CRDL (pCi/g)	CRDL as % of DCGL
Am-241	Gamma Spectroscopy	130	0.5	0.4%
Th-232	Gamma Spectroscopy	3.7	0.9	24.3%
U-235	Gamma Spectroscopy	74	2.0	2.7%
U-233/234	Alpha Spectroscopy	642	1.0	0.2%
U-235	Alpha Spectroscopy	74	1.0	1.4%
U-238	Alpha Spectroscopy	306	1.0	0.3%
Pu-238	Alpha Spectroscopy	155	1.0	0.6%
Pu-239/240	Alpha Spectroscopy	140	1.0	0.7%
Pu-242	Alpha Spectroscopy	148	1.0	0.7%
Pu-241	Liquid Scintillation	4365	5.0	0.1%
Am-241	Alpha Spectroscopy	130	1.0	0.8%
Th-230	Alpha Spectroscopy	17	1.0	5.9%
Th-232	Alpha Spectroscopy	3.7	1.0	27.0%
Tc-99	Liquid Scintillation	414	10	2.4%

Given that the most limiting of the applicable DCGLs (the surface soil DCGLs) are appreciably larger than the CRDLs specified, the analytical detection limits specified are more than adequate to assess the data regarding compliance with the DCGLs. The analytical laboratories (both NFS and Paragon) met or exceeded the data quality targets for measurement sensitivity specified for the analyses (Table 6-2). The detection limits reported by the laboratories for each of the samples analyzed was less than or equal to the CRDL specified, demonstrating the detection sensitivities achieved were adequate to identify and quantify radioactivity at a fraction of the applicable limit or DCGL. As evidenced by comparing the decision limits as represented by the DCGL with the MDA associated with the measurement method employed in assessing the residual in the survey units of the site, each detection limit obtained was more than adequate to detect, observe, and make risk management decisions with confidence.

6.3 SAMPLE SIZE AND STATISTICAL POWER

A key element in the evaluation of the sampling and survey data is the variation within the data set. As the data variability increases, the ability of the risk manager to confidently make decisions about the true state of residual radioactivity in the survey unit in relation to the applicable DCGL and null hypothesis decreases. When variability is small (or excessively large) relative to the difference between the mean and the DCGL, the risk managers can be confident in the decisions made using the data set provided. When evaluating data variability, it is important to know, first, that the dataset is composed of a sufficiently large sample population (number of measurements).

Sample sizes were specified by design to provide a high level of assurance that the statistical power necessary to arrive at the appropriate decision regarding the condition of residual radioactivity in each survey unit would be achieved. The sample size was designed (allowing for a 20% contingency) considering that a false positive error rate (alpha error) of no greater than 5% and a false negative error rate (beta error) of no greater than 10% could be tolerated when measurement data sets were compared to the $DCGL_W$. The specified sample size (number of coreholes) for Survey Units 4, 6, 7, 12, 16, 17, and 18 and the actual number of coreholes collected are presented in Table 6-3.

Table 6-3 Specified and Collected Sample Size by Survey Unit

Survey Unit	Specified Sample Size	Coreholes Collected
4	41	41
6	60	60
7	32	32
12	53	53
16	178	178
17	57	61
18	41	45

Each of the coreholes planned for Survey Units 4, 6, 7, 12, 16, 17, and 18 were collected, plus an additional 4 coreholes in Survey Units 17 and 18. The retrospective "power" of the WRS Test to reject the null hypothesis with the actual sample size collected was significant. The WRS test rejects the null-hypothesis that residual radioactivity in Survey Units 4, 6, 7, 12, 16, 17, and 18 is either equal to or greater than the $DCGL_{WAA}$ with more than 95% confidence. The reported *a posteriori* power of the test to reject the null hypothesis with 95% confidence is 1.0 (essentially 100%). This derives from the fact that the critical sample size, given the measured population variability in the reference area and the survey unit, was much smaller than the sample size actually collected.

Because the power of the WRS Test is observed to be sufficiently high (much larger than 0.95), more rigorous statistical tests of the data sets are not warranted. Thus, risk managers can be assured that the data collected is sufficiently robust to decide that the residual radioactivity concentration in Survey Units 4, 6, 7, 12, 16, 17, and 18 is below the $DCGL_W$.

6.4 MEASUREMENT UNCERTAINTY AND DATA QUALITY INDICATORS

Measurement uncertainty stems from two sources: field sampling variation and laboratory measurement variation. Of the two sources, field-sampling variation is generally accepted as the greatest contributor to overall uncertainty because of the inherent logistics of sample collection. In order to control this potential source of error, the field-sampling methods used in the subsurface soil characterization and FSS employed proven standard techniques and were strictly governed by approved procedures used in the field sampling process.

An important activity in determining the usability of the data obtained from sampling of the survey unit is assessing the effectiveness of the sampling and survey program relative to the design objectives (NRC 2000, EPA 1992, EPA 1993b). Data Quality Indicators (DQIs) were identified as guidelines for the DQA process to provide quantitative and qualitative measures of overall data quality and usability. Table 6-4 presents the target DQIs and summarizes the post-sampling data quality assessment.

Inspection of Table 6-4 indicates that the DQIs were achieved, and the data are regarded as having sufficient quality to be useable for the intended purpose of confidently demonstrating that the residual radioactivity in subsurface soils in Survey Units 4, 6, 7, 12, 16, 17, and 18 are below the benchmark subsurface soil DCGLs and can be released from radiological controls without restriction.

6.5 SSDCGL CALCULATOR QUALITY VERIFICATION

The SSDCGL Calculators consists of a suite of 4 computer-assisted calculation aids using Microsoft Excel office software to perform a system of iterative computations required to support Amec Foster Wheeler's SSDCGL method. The quality and accuracy of the 4 computer-assisted calculation aids were independently verified by both Amec Foster Wheeler and NFS.

Amec Foster Wheeler has verified the accuracy and validity of the SSDCGL Calculators used in support of the NFS Subsurface Soil Characterization and Final Status Survey Project. The SSDCGL Calculators are designed to perform the requisite sequences of calculations necessary to develop Subsurface Soil DCGLs and to assess compliance with their associated compliance metrics. The SSDCGL Calculators were verified to implement the requisite compliance calculations specific to NFS' North Site Decommissioning Plan, Appendix B (NFS 2006). A verification dataset was generated and input into the SSDCGL Calculators and then compared to results that were generated by hand calculations. The result of Amec Foster Wheeler's verification process concluded that the SSDCGL Calculators accurately perform the series of calculations required and are judged to be valid for their intended use (MACTEC 2008).

NFS also reviewed the Amec Foster Wheeler Subsurface Soil Characterization calculation spreadsheets used in the preparation of the data for this report. The NFS review included a cell-by-cell verification of all data and calculation formulas and a comparison of the functionality of the worksheets to the intended functionality documented in this report. The result of the NFS review was that the calculation spreadsheets accurately performed their intended function and provided accurate and correct output for this data set.

6.6 OVERALL QUALITY ASSURANCE AND QUALITY CONTROL

Based on the forgoing analysis and observed practices in the field, it is apparent that overall project QA/QC goals were obtained. There are no significant data problems or gaps, nor any procedural inadequacies that might compromise the findings of this survey report. The data collected in the final status survey is regarded as high quality data for its intended use.

Table 6-4 Target Data Quality Indicators and Findings

DQI	Quality Objective	Significance	Action/Remark	Finding
Completeness	90% completeness	Less than complete data set could decrease confidence in supporting information.	All specified coreholes in Survey Units 4, 6, 7, 12, 16, 17, and 18 were collected, plus an additional four coreholes in Survey Units 17 and 18 (Table 6-3).	DQI accepted.
Comparability	Comparability between analytical methods (~±10%) • Common or equivalent sampling procedure used. • Professional judgment and field observations.	Affects ability to combine data sets produced using different sampling and/or analytical methods.	All analytical data of a given type / method was generated by a single laboratory using common methods and instruments. Consistent methods, both sampling and analytical, were used throughout the sampling process. Sampling and analytical methods were governed by written SOPs. No critical deviation from these procedures was encountered. No distinctly different data sets were compiled or combined in the evaluation. Thus, there is no concern for data comparability	DQI accepted.
Representativeness	A simple, computer generated, random sample allocation approach was followed to ensure unbiased sample location selection and spatial distribution of the sampling locations.	Non-representativeness increases or decreases Type I error depending on the bias and results in the need to collect additional samples to improve representativeness.	Sample allocation used in the field was identified using the computer software program *Visual Sample Plan.* The sample was designed to produce a random start, systematic square grid sample allocation distributed within the survey unit. A small number of the sample locations selected had to be relocated for personnel safety or location accessibility reasons. The sample relocation method used maintained the spatial and unbiased objectives of the sample allocation system. The sample locations selected meet the intent of the survey design and are considered representative of conditions in the survey unit. There are no analytical or measurement effects (e.g., holding times or compositing effects) affecting representativeness.	DQI accepted.
Precision	Field and laboratory processes will be governed by procedures. Replicate measurements are used to gauge reproducibility as an indicator of precision. The number of replicate measurements should meet or exceed the planned frequency of at least one in each survey unit and 5% of the planned number of measurements overall. The difference between initial and duplicate (replicate) measurements is within the acceptable tolerance as determined by the duplicate error ratio calculation in the NFS data validation procedure (DC-108).	Lack of precision affects the accuracy or confidence in the accuracy of the reported results.	All sampling and analytical measurement processes were controlled by approved written procedures. The specified minimum number of duplicate (replicate) measurements (10%) was achieved. The precision of the analytical methods was verified by the fact that more than 90 % of the combined duplicate (replicate) measurements Survey Units 4, 6, 7, 12, 16, 17, and 18 made were within the tolerance limits specified.	DQI accepted.
Accuracy	Field processes will be governed by procedures. Instruments will be calibrated with NIST traceable standards.	Accuracy is affected by bias and precision. A lack of accuracy can affect Type I and Type II errors depending on the bias.	All specified procedures were implemented. Duplicate and replicate measurements returned expected results. Instruments were calibrated to industry standard specifications and yielded responses to NIST certified calibration sources within ±10% of the known amount of radioactivity. LSC samples were consistently within the acceptable tolerance limits for the various analyses. As shown above, precision was acceptable.	DQI accepted.

7.0 SUMMARY AND CONCLUSIONS

NFS submits this FSS Report for the areas located in the NFS North site known as Survey Units 4, 6, 7, 12, 16, 17, and 18. This FSS was conducted in accordance with methods specified in the North site DP (NFS 2006). On the basis of the analysis presented in Sections 4.0 through 6.0 of this report, NFS has demonstrated that Survey Units 4, 6, 7, 12, 16, 17, and 18 have met each of the subsurface soil DCGLs.

The survey data were compared to the DCGLs both statistically and with non-statistical comparisons using the approved subsurface soil DCGLs. The radiological survey data demonstrate that the site meets the permissible concentrations (DCGLs) derived and specified in the DP. Concentrations of residual radioactivity were found to be essentially indistinguishable from background. Statistical evaluation of the data indicates that the residual radioactivity DCGLs were met with greater than 95% confidence.

QC samples were taken during the survey process. Review and analysis of the QC measures indicates that the data collected meet the data quality objectives and are acceptable for their intended use.

Thus, based upon the evidence provided by the FSS Report of Survey Units 4, 6, 7, 12, 16, 17, and 18, NFS concludes that all of the conditions and requirements for unrestricted radiological release of this portion of the NFS North site have been met. NFS concludes that Survey Units 4, 6, 7, 12, 16, 17, and 18 are in compliance with the NFS site DP, and meet the radiological release criteria for unrestricted use in accordance with 10 CFR 20 Subpart E.

8.0 ACRONYMS

ALS .... ALS Environmental
Am....................... americium
AMEC .... AMEC Environment & Infrastructure, Inc.

bgs .... below ground surface
Boart.................... Boart Longyear

CFR .... Code of Federal Regulations
COC .... Chain of Custody
cm^2 .... square centimeter
CRDL .... Contract Required Detection Limit
CT........................ Central Tendency
CV .... Coefficient of Variation

DCGL.................. derived concentration guideline level
$DCGL_W$ .... derived concentration guideline level for the average (or median) concentration in the survey unit
$DCGL_{EMC}$ .... elevated measurement comparison concentration guideline level
$DCGL_{LAA}$ .... local area average concentration guideline level
D&D .... Decontamination and Decommissioning
DP........................ Decommissioning Plan
dpm...................... disintegration per minute
DQA .... Data Quality Assessment
DQI...................... Data Quality Indicator
DQA .... data quality assessment
DQO .... Data Quality Objective

EPA .... U.S. Environmental Protection Agency

FAP .... Facility Action Plan
FSS .... Final Status Survey
ft. .... foot

GPS .... Global Positioning System

H_a .... alternative hypothesis
H_0 .... null hypothesis
HSA..................... Historical Site Assessment
HSWA .... Hazardous and Solid Waste Amendments

keV .... kilo-electron volts

L .... liter
LAA .... local area average
LBGR.................. Lower Bound of the Gray Region
L_C .... critical level
LCS .... laboratory control samples
L_D .... detection level
LCL_{95} .... 95% lower confidence limit

m.......................... meter
m^2 .... square meter
MACTEC .... MACTEC Development Corporation
MARSSIM .... Multi Agency Radiation Survey and Site Investigation Manual
MDA .... Minimum Detectable Activity
MDC.................... Minimum Detectable Concentration
mL .... milliliter
mrem .... millirem
msl .... mean sea level

N.......................... number of measurements (or data points)
NDA .... non-destructive analysis
NIST .... National Institute for Standards and Technology
NFS .... Nuclear Fuel Services
NRC .... U.S. Nuclear Regulatory Commission
NUREG .... Nuclear Regulatory Guide
OJT .... on-the-job training
ORISE .... Oak Ridge Institute for Science and Education

PA........................ protected area
Paragon................ Paragon Analytics, Inc.
p-value................. probability
pCi/g.................... picocuries per gram
Pu .... plutonium

QA....................... Quality Assurance
QC .... Quality Control

R^2......................... coefficient of determination
RBA .... reference background area
RBG .... radiological burial grounds
RCRA.................. Resource Conservation and Recovery Act
RESRAD .... RESidual RADioactivity (computer modeling code)

SADA.................. Spatial Analysis and Decision Assistance (computer program)

SOF .... sum of fraction
SOF_{NET} .... net sum of fraction
SOP .... standard operating procedure
SSDCGL .... subsurface soil derived concentration guideline level
SWMU .... Solid Waste Management Unit

Tc......................... technetium
Teledyne.............. Teledyne Brown Engineering
Th .... thorium

U.......................... uranium
UCL_{95}.................. 95% upper confidence limit
USEPA................ United States Environmental Protection Agency

VSP .... Visual Sample Plan (computer program)
VOC .... volatile organic compound

WRS .... Wilcoxon Rank Sum (statistical test)

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