FINAL STATUS SURVEY REPORT

SUBSURFACE SOIL CHARACTERIZATION AND FSS PROJECT

NUCLEAR FUEL SERVICES NORTH SITE
Erwin, Tennessee

SURVEY UNITS 2, 8, 9, 19, 20

PREPARED FOR:

NUCLEAR FUEL SERVICES, INC.

PREPARED BY:

MACTEC DEVELOPMENT CORPORATION
MACTEC PROJECT NO. 9120071235

REVISION 0
NOVEMBER 2009

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

MACTEC

FINAL STATUS SURVEY REPORT

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SURVEY UNITS 2, 8, 9, 19, 20

NUCLEAR FUEL SERVICES NORTH SITE

Erwin, Tennessee

US NRC SNM License Number 124
Docket Number 70-143

Prepared for:

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Contract No. POO7O3070423
Project No. 9120071235

Revision 0
November 2009

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E.0 EXECUTIVE SUMMARY

Nuclear Fuel Services (NFS) contracted MACTEC Development Corporation (MACTEC) 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 2, 8, 9, 19, and 20 is 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 MACTEC 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 2, 8, 9, 19, and 20. 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 2, 8, 9, 19, and 20 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 2, 8, and 9 are associated with the former radiological burial grounds, and Survey Units 19 and 20 are associated with the settling ponds.

Based on historical use of the land area comprised by Survey Units 2, 8, 9, 19, and 20 and an evaluation of the available relevant historical data from within and immediately surrounding the survey unit, Survey Units 2, 8, 9, 19, and 20 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 North site decommissioning project is based on the proprietary Subsurface Soil derived concentration guideline level (DCGL) methodology developed by MACTEC 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 2003). 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 2, 8, 9, 19, and 20 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 MACTEC to perform the post remediation characterization of residual radioactivity in soils at the NFS North 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.

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 2, 8, 9, 19, and 20 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 2, 8, 9, 19, and 20, 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 2, 8, 9, 19, and 20, 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 are three distinct areas: the north half is the Former Radiological Burial Ground, the southern half is the Ponds Areas, and separating the Burial Ground from the Ponds Areas is the Security Zone (Figure 1-2). Topography across the site fluctuates somewhat with elevations ranging from 1,628-1,675 feet above mean sea level (msl). Various physical features exist across the site including several ponds, two marsh areas, and a wooded region.

The site is situated on an alluvial plain and is geologically characterized by shallow depths to bedrock and a relatively shallow groundwater table throughout the year due to the influence of nearby springs, creeks, and the Nolichucky River. Due to the physical and chemical nature of the radioactive materials handled at the site, however, residual radioactivity in soil has little impact on groundwater at the site. Additionally, the NRC and the Tennessee Department of Environment and Conservation have agreed that radiological contamination present in the groundwater underlying the North site does not pose the risk of a radiological dose the public exceeding the NRC criteria (NRC, 1999, TDEC, 2001).

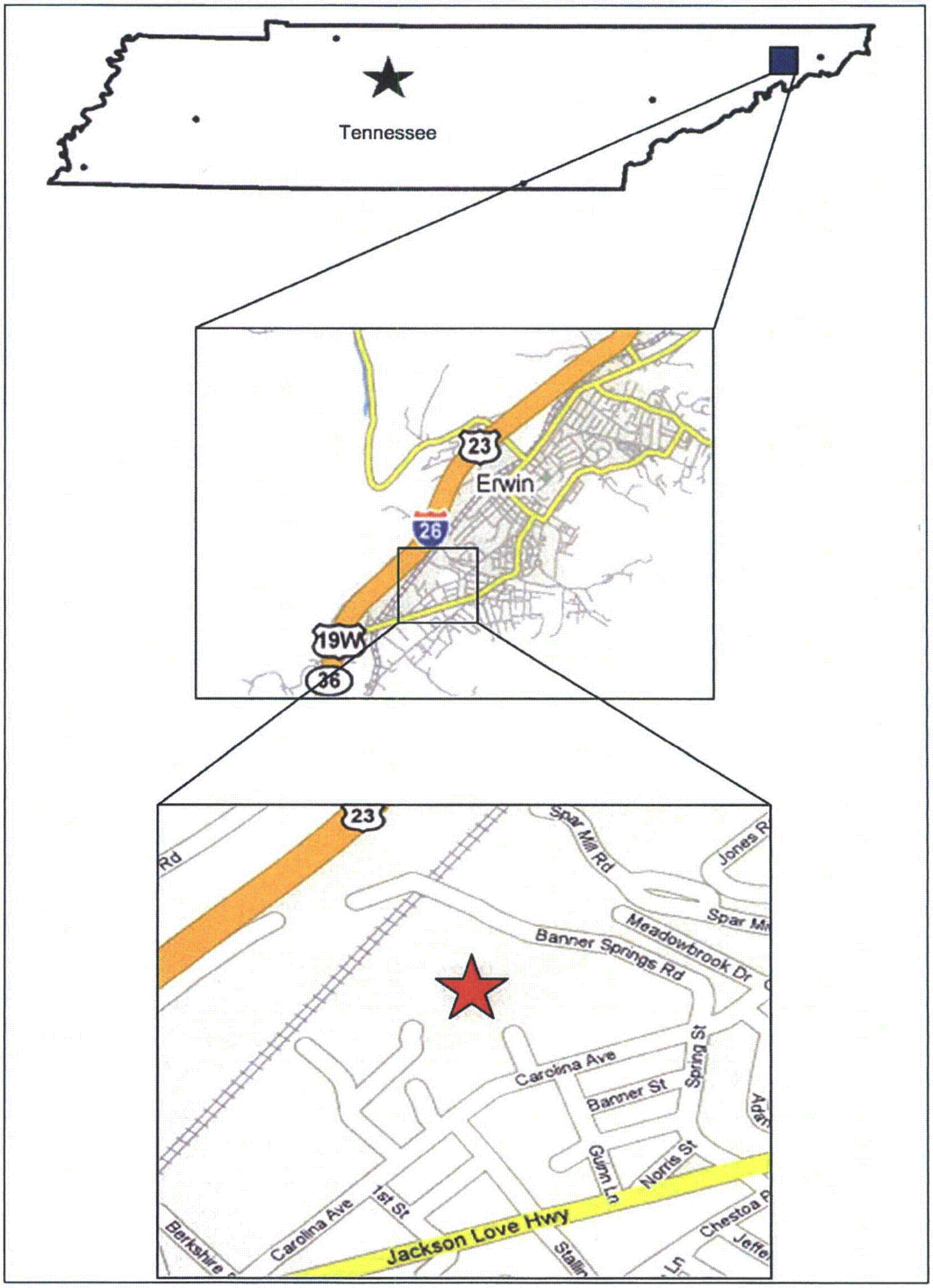

Figure 1-1 Site Location

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 assess 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.

NFS provided MACTEC with 23,429 historical analytical sample values obtained during previous characterization and remediation activities across the site. Of these 23,429 samples, MACTEC utilized 19,107 samples during the design of the subsurface soil characterization and FSS sampling plan. Analytical samples not used were removed from the dataset because they were located within the top 3 feet of previously excavated areas and thus predate the post-remediation radiological conditions in those areas. The vast majority of expunged data was labeled as “pre” versus “post” indicating the samples were taken previous to excavation/remediation. The expunged data was deemed irrelevant to current radiological conditions of the North site. Historic radiological data from the North site was imported into the computer software call Spatial Analysis and Decision Assistance (SADA) and plotted using site topographical maps (SADA 2005). Radiological data was spatially viewed using the SADA program to help delineate survey unit boundaries.

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 2, 8, 9, 19, and 20 and the basis for the future request to terminate the NRC issued radioactive materials license held by NFS.

1.8 DATA ANALYSIS FRAMEWORK

NFS and the NRC agreed early in the decontamination and dismantlement 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—release of the NFS site from radiological control through license termination. 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 terminate NFS's radioactive materials license.

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

MACTEC submits this FSS Report for Survey Units 2, 8, 9, 19, and 20 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 2, 8, 9, 19, and 20 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 were 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 thirteen isotopes in every sample. The *analytical design* calls for a surrogate isotope technique in which each of the three gamma-emitting isotopes for every sample is measured and each of the thirteen 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 1-2.

Each volumetric soil sample collected as part of the Subsurface Soil Characterization and FSS Project will be assayed with gamma spectroscopic analysis by NFS' onsite 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, Paragon Analytics, Inc., has a written laboratory quality program and approved analytical procedures. Standard laboratory quality measurements, including blanks, laboratory control samples, and replicate measurements were required.

Additionally, the NFS QA Department has performed audits of Paragon Analytics and approved this laboroatory 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 was 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 Units 19 and 20 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, MACTEC 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

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.

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.

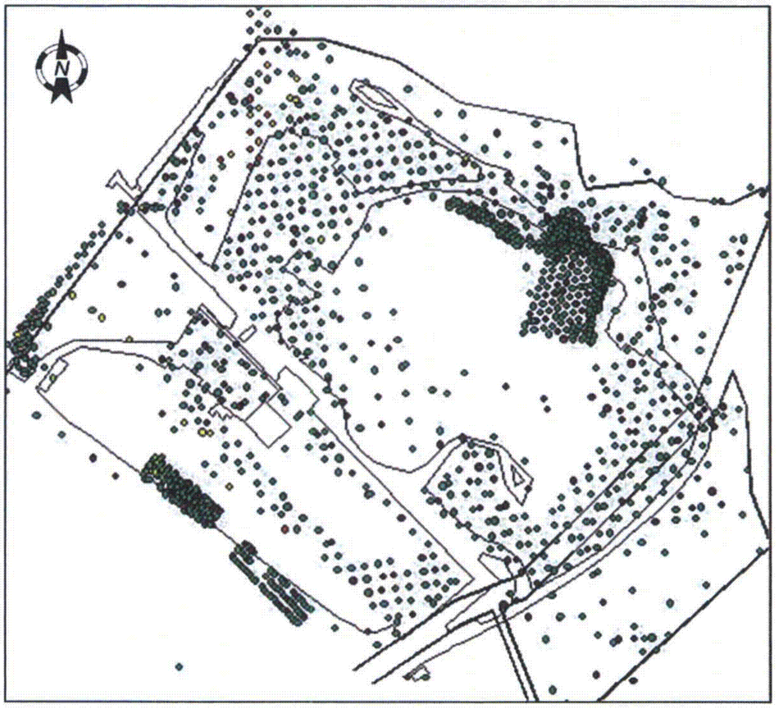

Figure 2-1 SADA Screenshot Showing the Placement of Historical Data

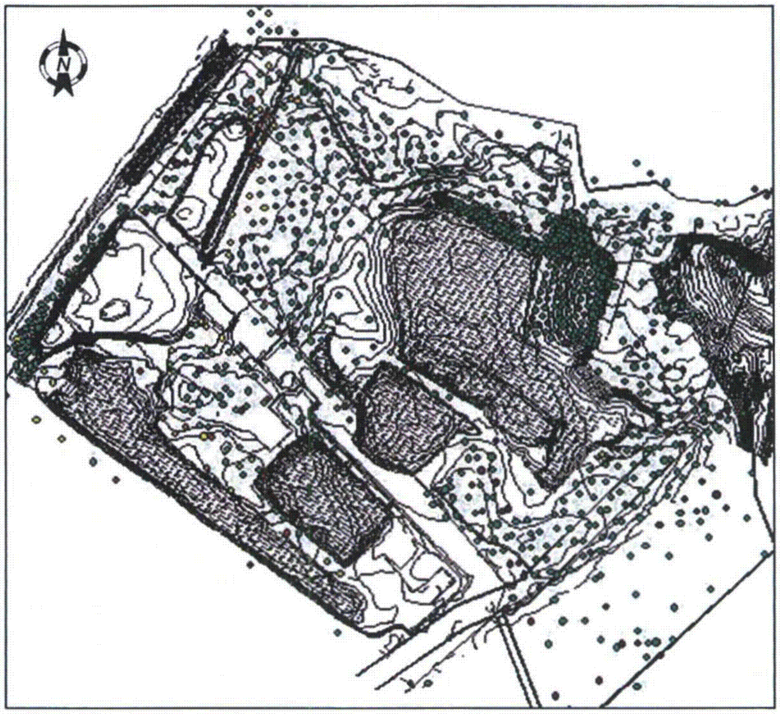

Figure 2-2 Surface Feature Drawing Superimposed on SADA Data

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.

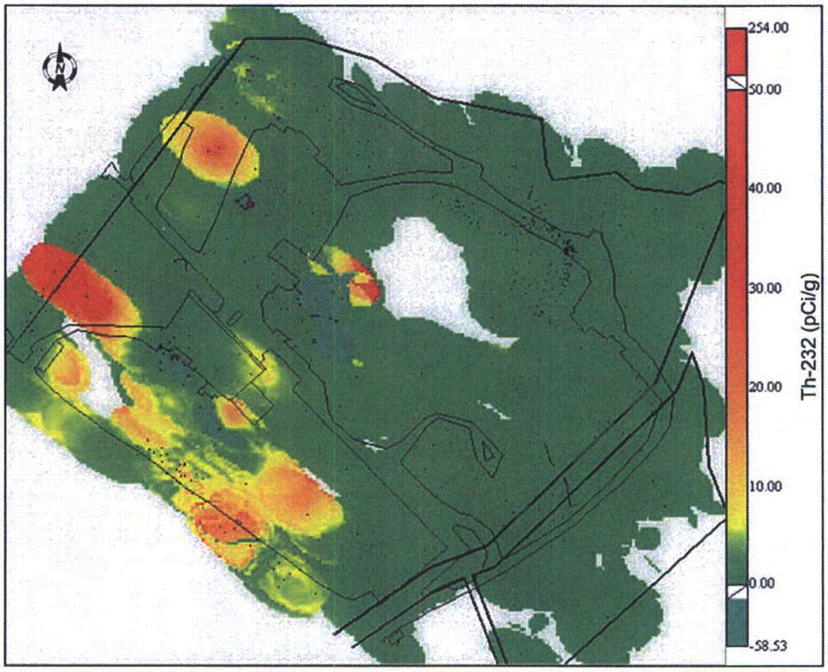

Figure 2-3 Iso-Concentration Contours Based on Historical Data

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, as 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.

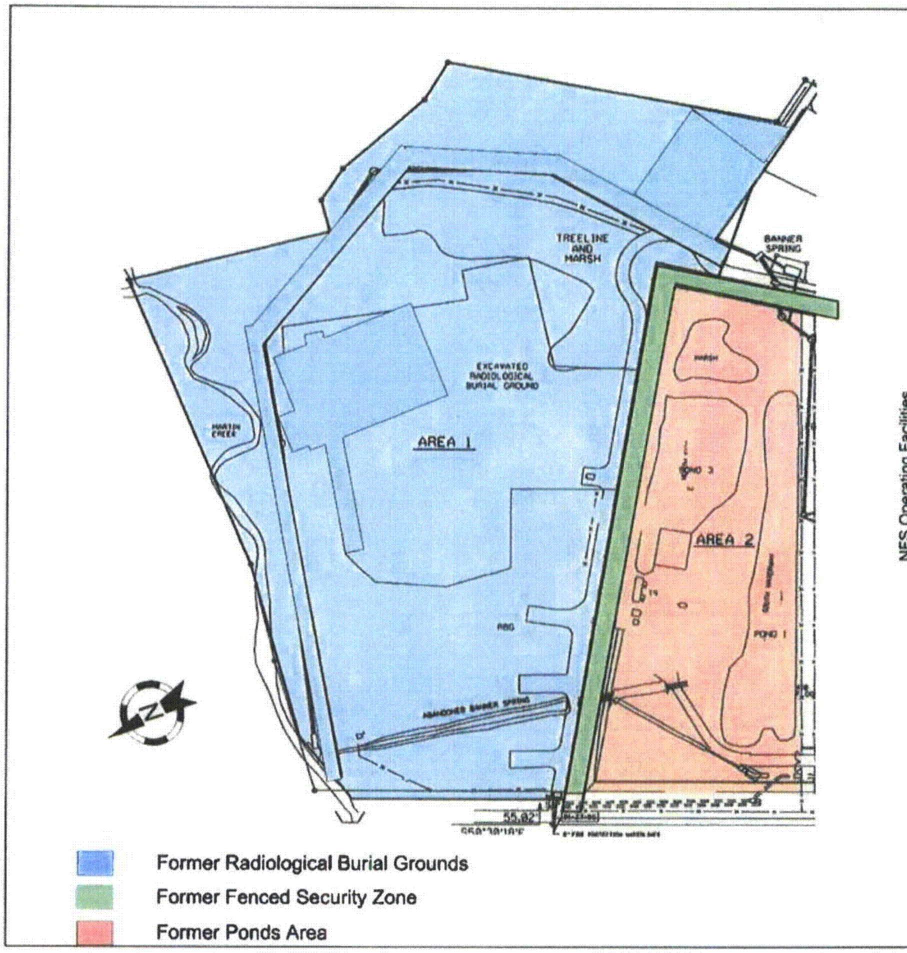

Figure 2-5 First Order Demarcation of Survey Units

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 MACTEC 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).

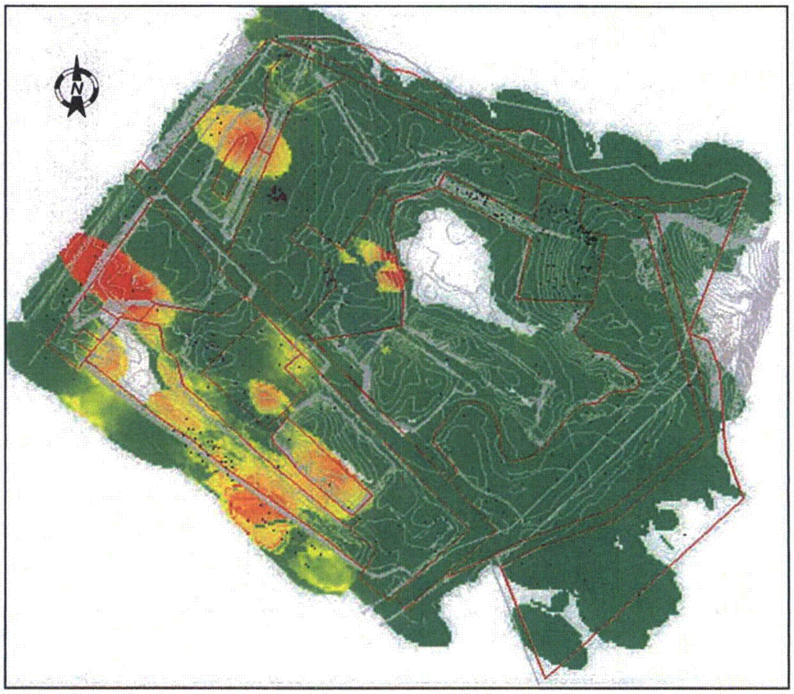

Figure 2-6 Survey Unit Demarcation - Iso-Concentration View

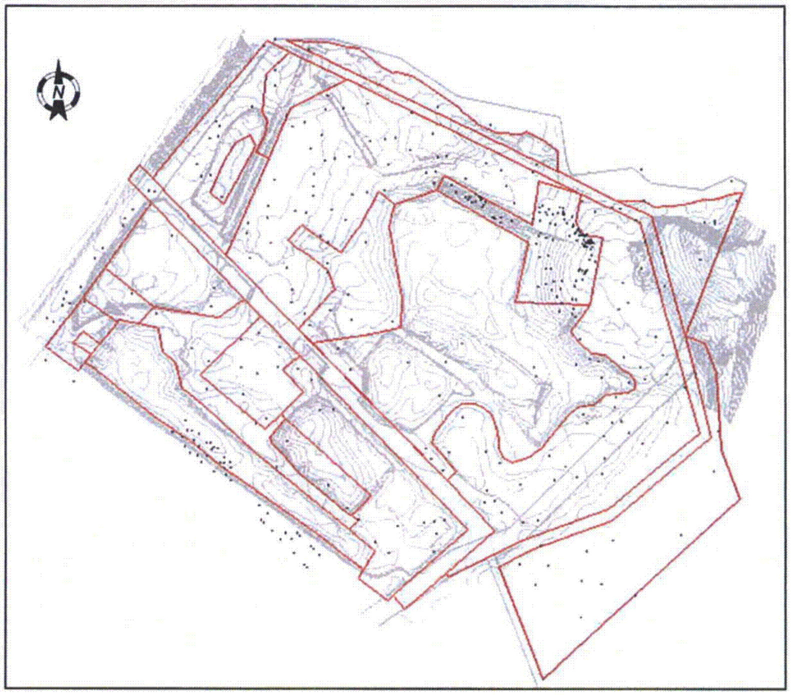

Figure 2-7 Survey Unit Demarcation – Physical Barriers (Features) View

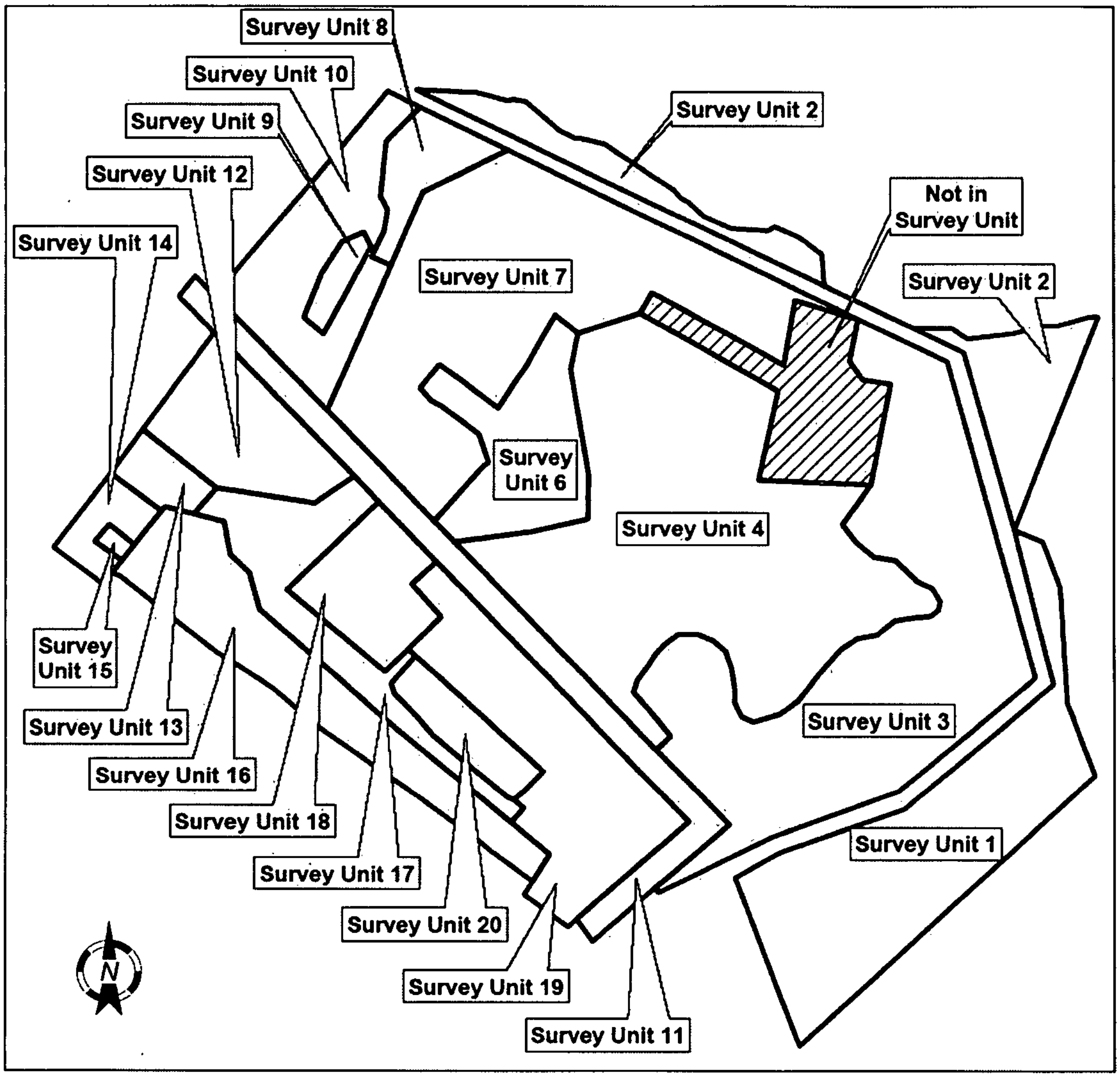

Figure 2-8 Survey Unit Enumeration

2.3.1 Survey Unit Classification

Survey unit classification, as described in MARSSIM, is not directly applicable to the subsurface soil DCGL method employed at the NFS North site. However, some benefit in understanding the site and its survey units is afforded by categorizing the survey units into classifications that express their relationship to the subsurface soil DCGLs. Survey units were categorized into one of three classifications (Figure 2-9) based on the prior occurrence of remedial activities within the survey unit and the radiological data (pre- and post-remediation) from within and surrounding the survey unit. Survey units were classified as follows:

- remedial activities and post-remedial sampling had been performed and data supports the conclusion that additional remedial activities are not likely to be necessary,
- remedial activities have not been performed, yet historic sampling results support the conclusion that remedial activities are not likely to be necessary,
- remedial activities have not been performed and historical sampling results support the conclusion that remedial activities may be necessary. In these areas robust characterization data is required.

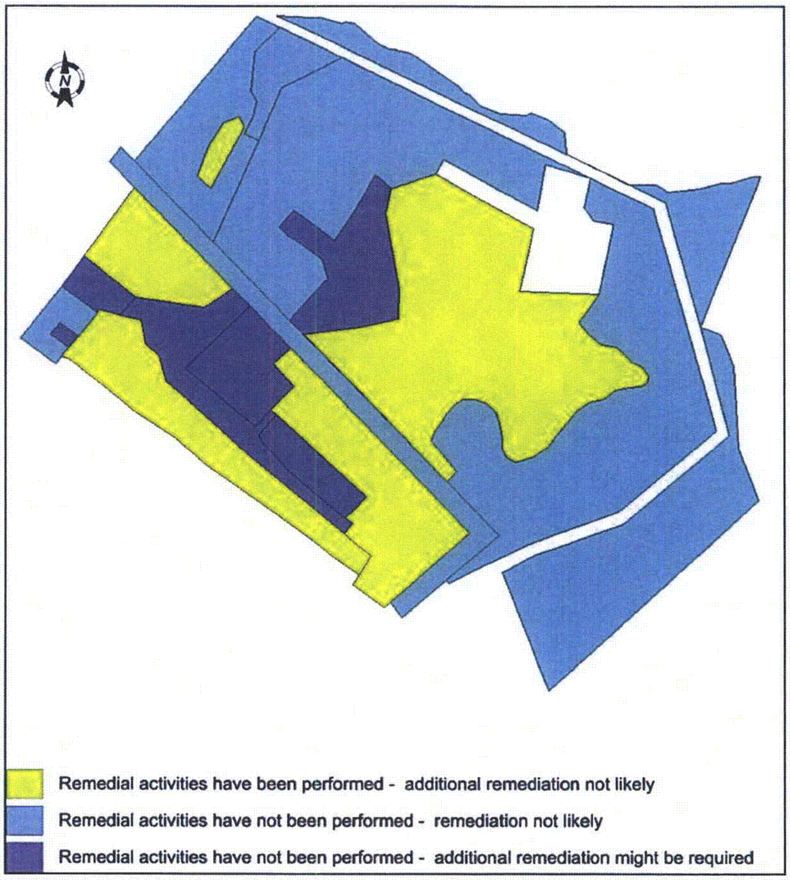

Figure 2-9 Survey Unit Classification Map

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 MACTEC 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, MACTEC utilized 19,107 sample results, from across the entire site, during the design of the Characterization Plan.

To assess the historical data in the context of its implication on the design of the sampling plan for individual survey units, MACTEC 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, 90th 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 foregoing 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 2, 8, 9, 19, and 20.

2.6 SURVEY UNIT 2 DESIGN

2.6.1 Survey Unit 2 Description

Survey Unit 2 (as shown in Figure 2-10) comprises a portion of the former RBG area of the site. The survey unit encompasses an area of 3,588 m^2.

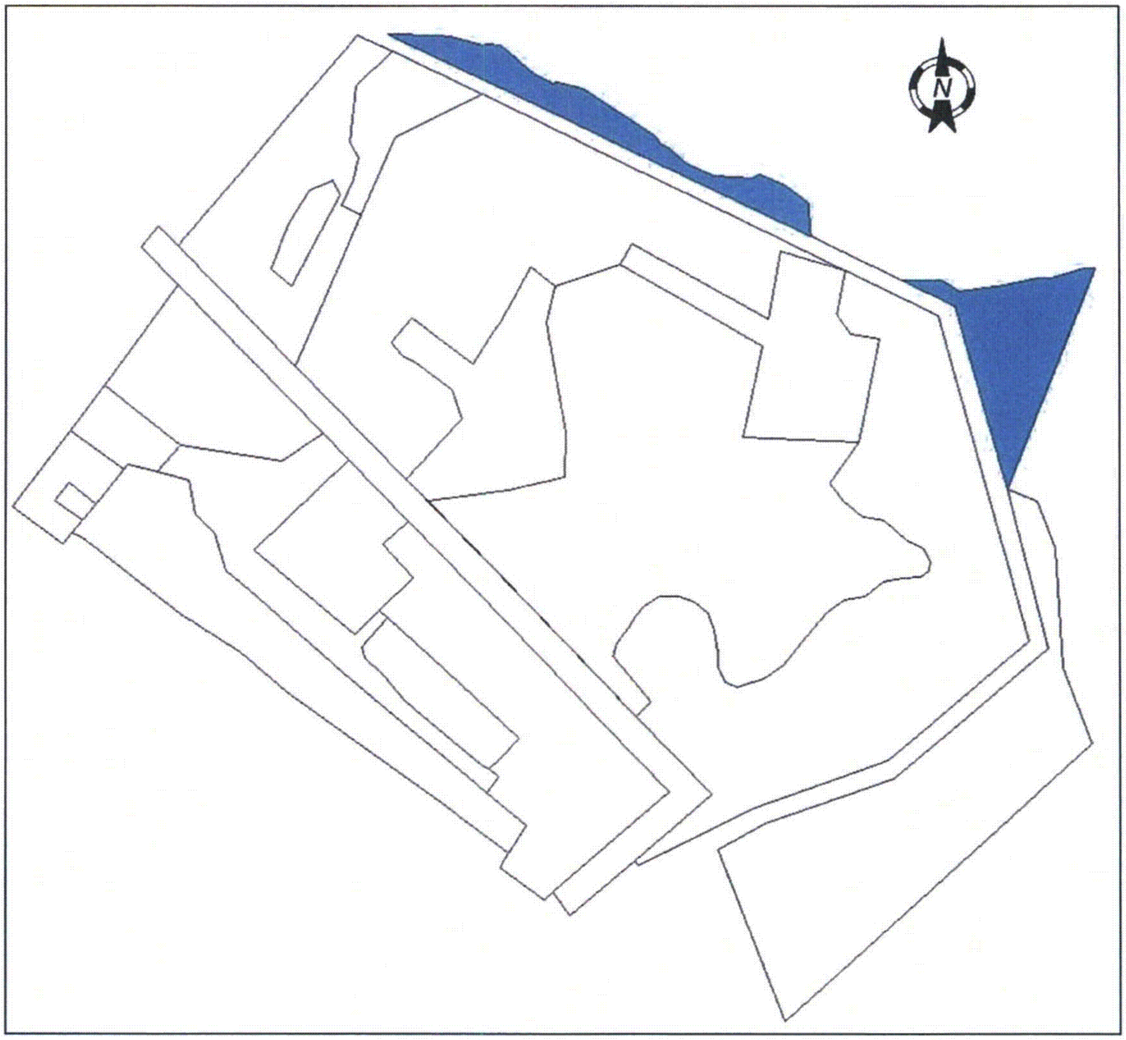

Figure 2-10 Survey Unit 2 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. This survey unit is identified as an area where remedial activities have not been performed and historic sampling results support the conclusion that remedial activities are not likely to be necessary (blue-shaded survey unit in Figure 2-9). The majority of the north border of Survey Unit 2 is bound by the banks of Martin Creek. Approximately half of the survey unit (the north half) lies north of a security fencing system that demarcates the extent of secured NFS property. The south half of the survey unit lies south of the security fencing system placing it within NFS secured property. The east portion of Survey Unit 2 lies south of this fence and east of the eastern security fence thus falling within NFS secured property. As stated in Section 1.4.3, there is no indication that radioactive contamination extends off the site to the north and east.

2.6.2 Sampling Density Determination

The number of corehole locations for Survey Unit 2 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 2 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 2 was extracted from the SADA database and loaded into the SSDCGL-RME Calculator for Survey Unit 2. In turn, the SSDCGL-RME Calculator returns the survey-unit-specific values of central tendency, standard deviation, 90th 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 2 can be found in the Survey Unit 2 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 ($DCGL_W$). MACTEC 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 2 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 30; 15 in both the survey unit and the RBA (Figure 2-11).

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

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 2.

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:

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

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:

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

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:

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

Equation 4 Standard Deviation Expressed as SOF

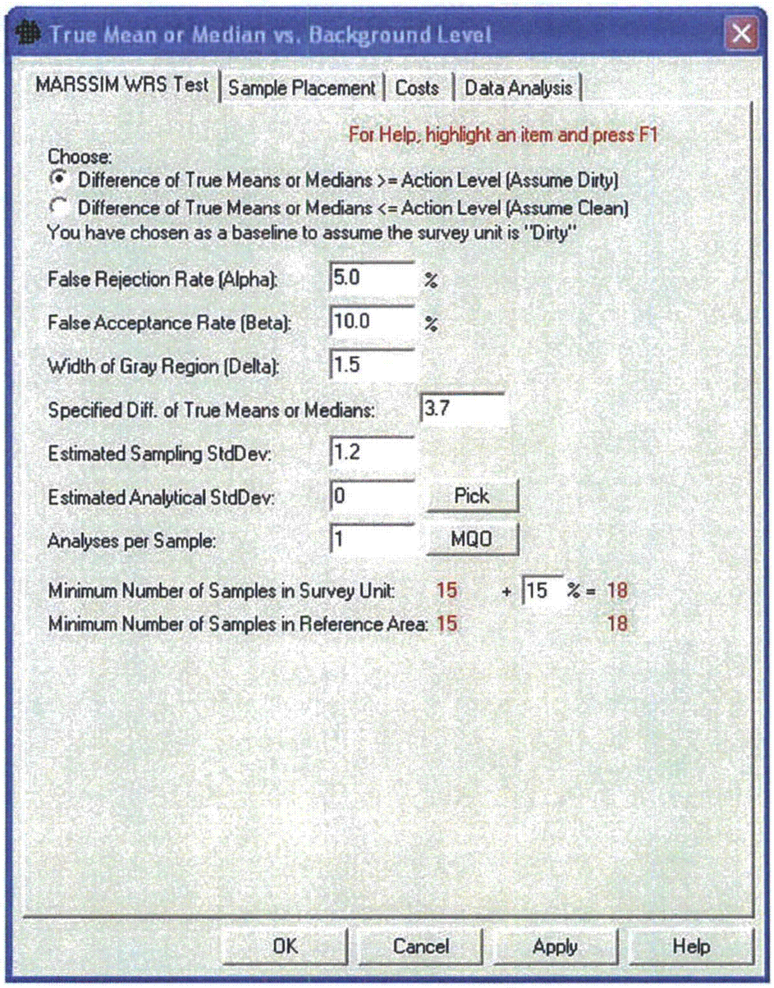

Figure 2-11 Screen Shot, VSP Sample Size Calculation, Survey Unit 2

Once the minimum number of coreholes (18) 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 18 coreholes over the area of Survey Unit 2 (3,588 m^2) is one corehole every 199 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 2 is 14.1 m by 14.1 m (199 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 199 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 90^{th} 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 2 at the time of the survey for Th-232 in layer 1 is distributed as shown in Figure 2-12. Note that the 90^{th} percentile is calculated to be 2.10 pCi/g. The maximum observed concentration is 8.9 pCi/g.

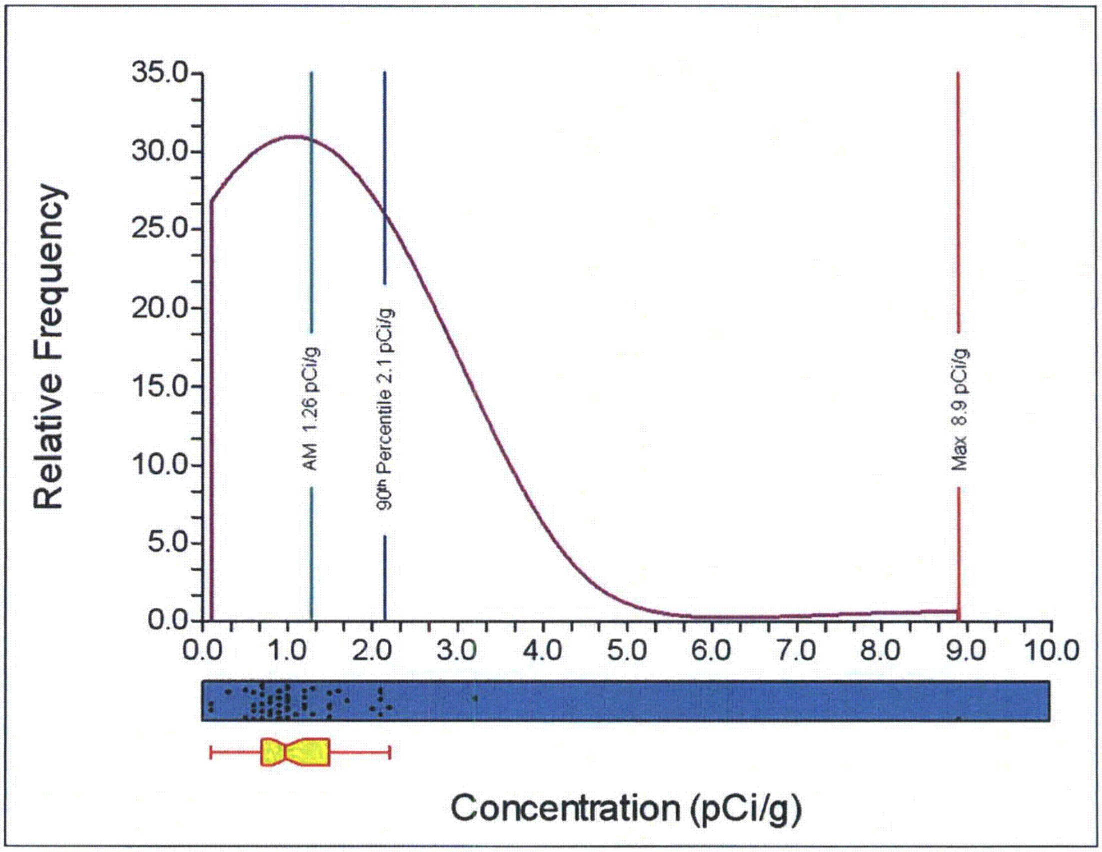

Figure 2-12 Sample Pre-Existing Data Distribution, Th-232, Layer #1, Survey Unit 2

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 2, 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 2, 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 199 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 2 is shown in Table 2-2.

Table 2-2 Corehole Density Summary Table

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
2	3,588	199	18

2.6.3 Final Design and Sample Placement

Having determined the appropriate number and spacing of the coreholes for Survey Unit 2, 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 18 coreholes were distributed over the survey unit using a systematic square grid with a random start location (Figure 2-13). 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.

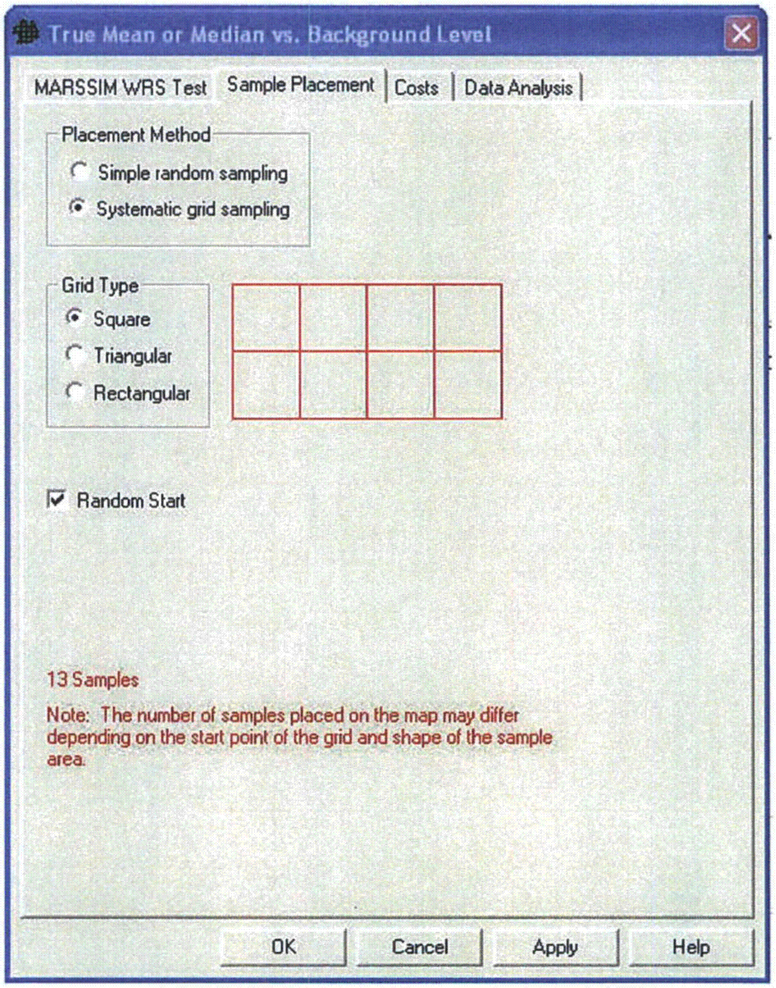

Figure 2-13 Sample Placement Architecture, Survey Unit 2

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

Survey Unit 2	
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]	13
Number of samples on map [b]	18
Number of selected sample areas [c]	1
Specified sampling area [d]	3,588 m^2
Size of grid / Area of grid cell [e]	14.1 m / 199 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 18 coreholes with assigned Tennessee state plane coordinates within the boundaries of Survey Unit 2 (Table 2-4, Figure 2-14). MACTEC assigned a unique four digit number to each corehole.

Table 2-4 Planned Corehole Locations, Survey Unit 2

Sample ID	Easting (X)	Northing (Y)
016	3023003.8764	674056.0947
017	3022977.2739	674128.4424
018	3023026.7490	674105.5698
019	3022307.4959	674498.1340
020	3022356.9709	674475.2613
021	3022406.4460	674452.3887
022	3022455.9210	674429.5161
023	3022505.3961	674406.6435
024	3022554.8711	674383.7709
025	3022604.3462	674360.8983
026	3022653.8212	674338.0257
027	3022703.2963	674315.1531
028	3022752.7713	674292.2805
029	3022901.1964	674223.6626
030	3022950.6715	674200.7900
031	3023000.1465	674177.9174
032	3023049.6216	674155.0448
033	3023072.4942	674204.5198

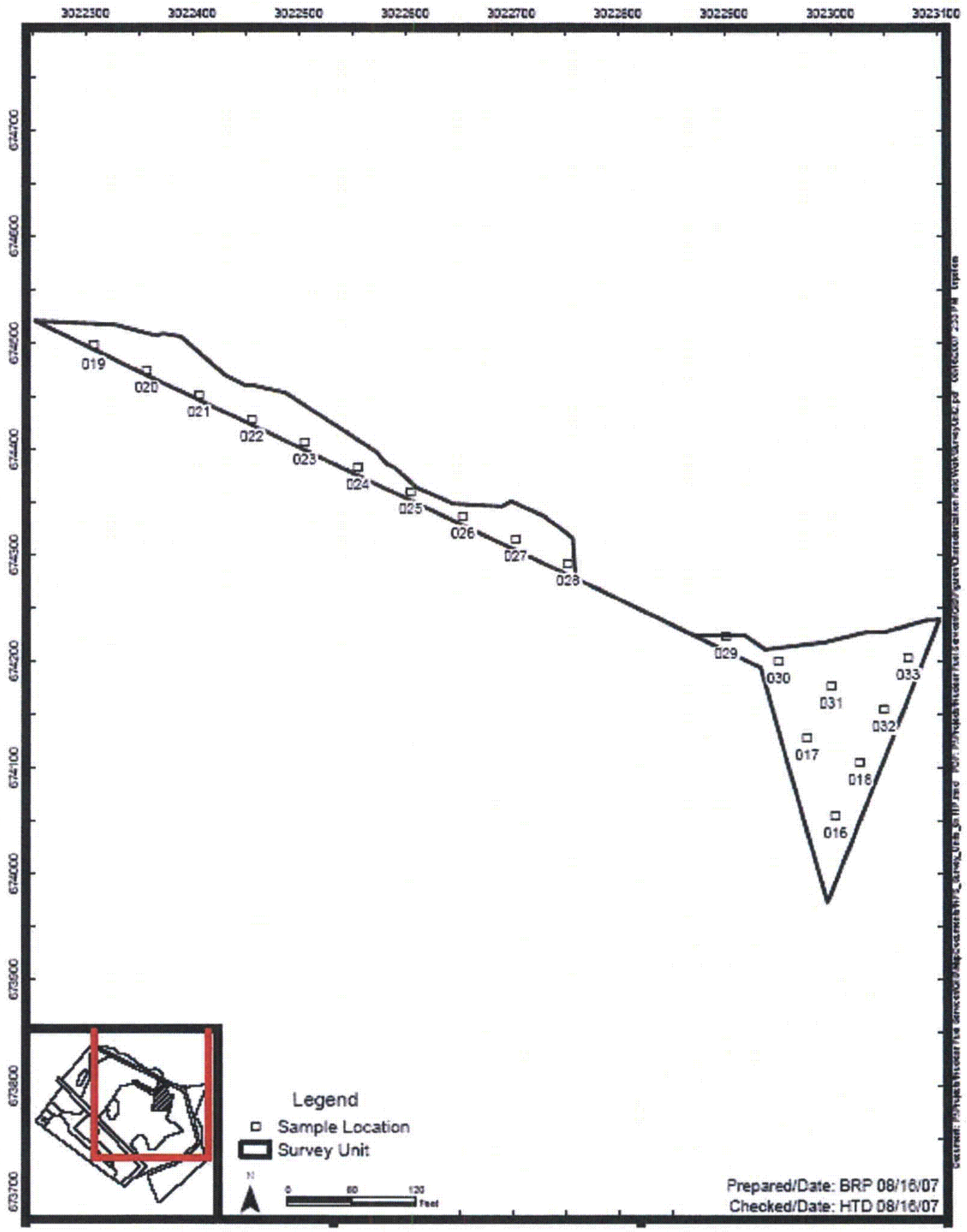

Figure 2-14 Survey Unit 2 Corehole Locations

Further detail regarding the actual number of coreholes sampled in Survey Unit 2 is presented in Appendix H.

2.7 SURVEY UNIT 8 DESIGN

Survey Unit 8 (as shown in Figure 2-15) comprises a portion of the former RBG area of the site. Survey Unit 8 encompasses an area of 1,151 m^2.

Figure 2-15 Survey Unit 8 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. This survey unit is identified as an area where remedial activities have not been performed and historic sampling results support the conclusion that remedial activities are not likely to be necessary (blue-shaded survey unit in Figure 2-9). Much of Survey Unit 8 encompasses a portion of the area where the Banner Springs Branch traversed before it was redirected around the North site. Consequently the elevation of Survey Unit 8 is lower than much of the surrounding area to the east (Survey Unit 7) and west (Survey Unit 10). The north border of Survey Unit 8 is bound by the relocated Banner Springs Branch, which was previously released.

Using the same final design criteria as outlined in Sections 2.6.2 and 2.6.3 used during the design of Survey Unit 2, the appropriate number and spacing of the coreholes was determined for Survey Unit 8. Figure 2-16 through Figure 2-18 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes.

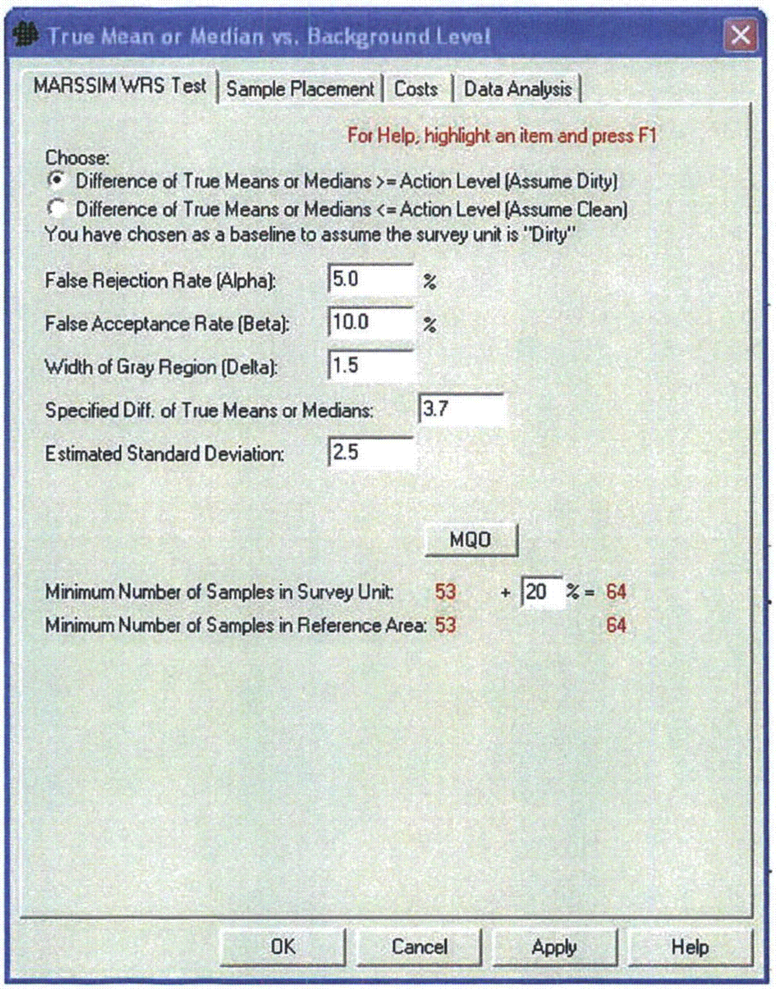

Figure 2-16 Screen Shot, VSP Sample Size Calculation, Survey Unit 8

Due to the lack of historical data in Layer #1 (0-1 meter depth) in Survey Unit 8, Figure 2-17 presents historical data from Layer #2 (1-2 meter depth).

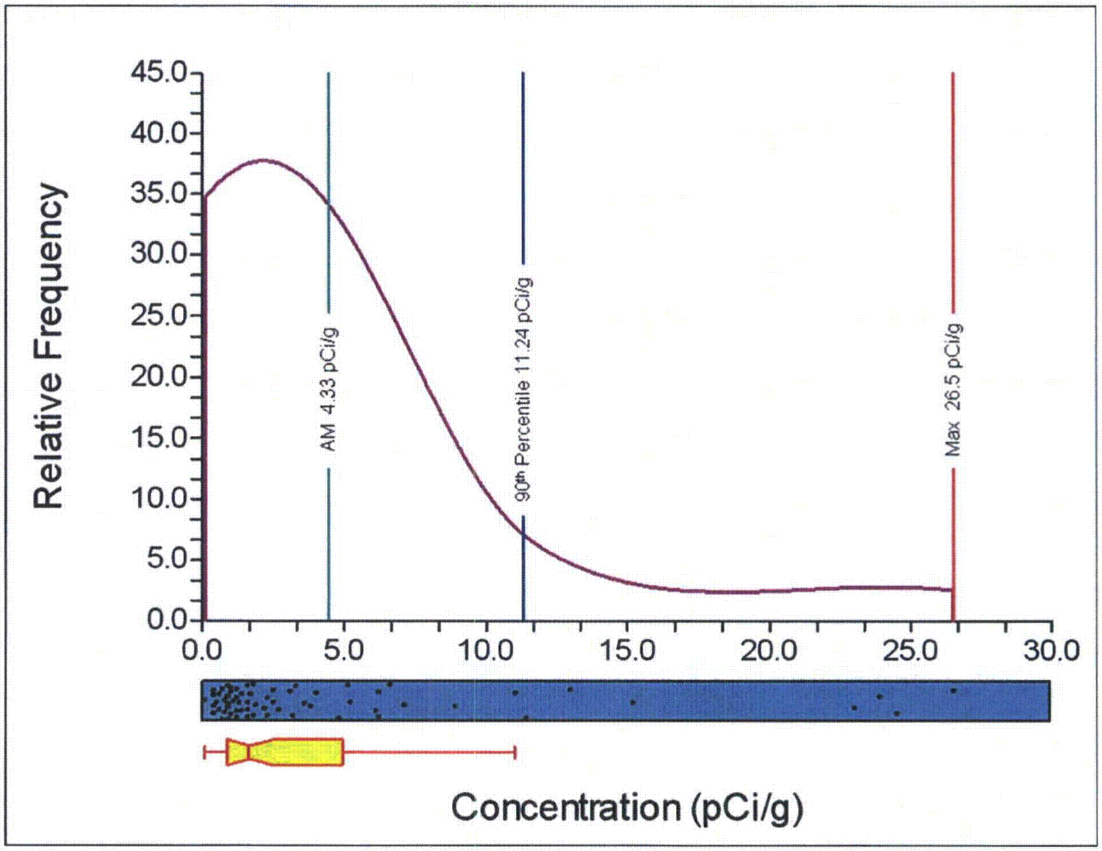

Figure 2-17 Sample Pre-Existing Data Distribution, Th-232, Layer #2, Survey Unit 8

Contrary to Survey Unit 2, the highest 90th percentile concentration observed in Survey Unit 8 was greater than the corresponding permissible surface soil DCGL. Therefore the "reasonable maximum concentration" value intersects the volume factor curve. This indicates that it was necessary to adjust the corehole density to compensate for the potential presence of localize anomalies. The "reasonable maximum concentration" calculation returned a maximum corehole density of 18.0 m^2 resulting in a total of 64 coreholes.

Table 2-5 Summary of Sampling Design, Survey Unit 8

Survey Unit 8	
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]	64
Number of samples on map [b]	64
Number of selected sample areas [c]	1
Specified sampling area [d]	1151 m^2
Size of grid / Area of grid [e]	4.24 m / 17.98 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.

Table 2-6 Planned Corehole Locations, Survey Unit 8

Sample ID	Easting (X)	Northing (Y)
145	3022200.0623	674316.8039
146	3022214.0162	674316.8039
147	3022214.0162	674330.7578
148	3022227.9701	674330.7578
149	3022214.0162	674344.7117
150	3022227.9701	674344.7117
151	3022227.9701	674358.6656
152	3022241.9240	674358.6656
153	3022227.9701	674372.6195
154	3022241.9240	674372.6195
155	3022214.0162	674386.5734
156	3022227.9701	674386.5734
157	3022241.9240	674386.5734
158	3022255.8779	674386.5734
159	3022214.0162	674400.5273
160	3022227.9701	674400.5273
161	3022241.9240	674400.5273

162	3022255.8779	674400.5273
163	3022269.8318	674400.5273
164	3022214.0162	674414.4812
165	3022227.9701	674414.4812
166	3022241.9240	674414.4812
167	3022255.8779	674414.4812
168	3022269.8318	674414.4812
169	3022283.7857	674414.4812
170	3022297.7396	674414.4812
171	3022214.0162	674428.4351
172	3022227.9701	674428.4351
173	3022241.9240	674428.4351
174	3022255.8779	674428.4351
175	3022269.8318	674428.4351
176	3022283.7857	674428.4351
177	3022297.7396	674428.4351
178	3022311.6935	674428.4351
179	3022325.6474	674428.4351
180	3022214.0162	674442.3890
181	3022227.9701	674442.3890
182	3022241.9240	674442.3890
183	3022255.8779	674442.3890
184	3022269.8318	674442.3890
185	3022283.7857	674442.3890
186	3022297.7396	674442.3890
187	3022311.6935	674442.3890
188	3022325.6474	674442.3890
189	3022339.6013	674442.3890
190	3022353.5552	674442.3890
191	3022227.9701	674456.3429
192	3022241.9240	674456.3429
193	3022255.8779	674456.3429
194	3022269.8318	674456.3429
195	3022283.7857	674456.3429
196	3022297.7396	674456.3429
197	3022311.6935	674456.3429
198	3022325.6474	674456.3429
199	3022339.6013	674456.3429
200	3022241.9240	674470.2968
201	3022255.8779	674470.2968
202	3022269.8318	674470.2968
203	3022283.7857	674470.2968
204	3022297.7396	674470.2968
205	3022311.6935	674470.2968
206	3022255.8779	674484.2507
207	3022269.8318	674484.2507
208	3022283.7857	674484.2507

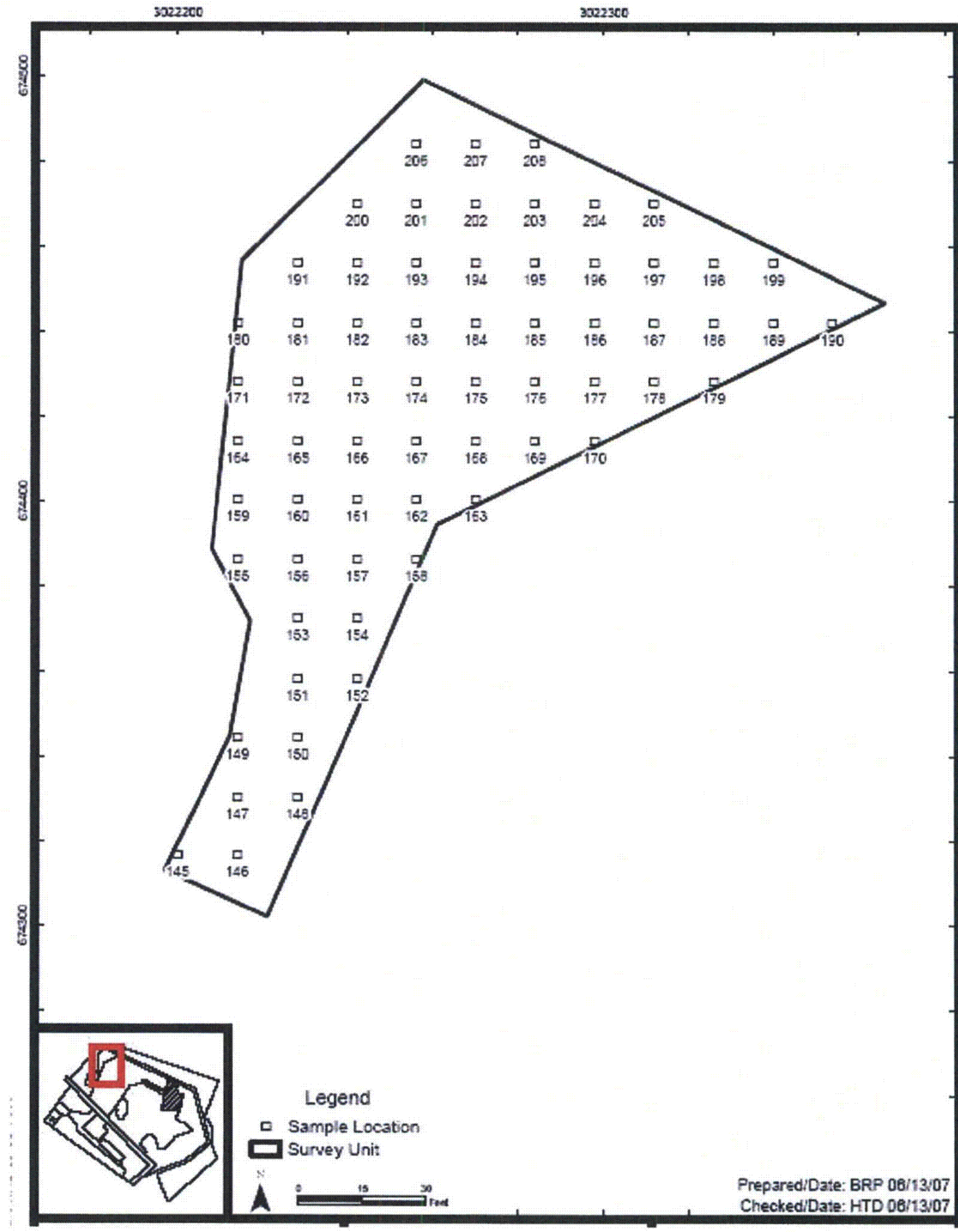

Figure 2-18 Survey Unit 8 Corehole Locations

2.8 SURVEY UNIT 9 DESIGN

Survey Unit 9 (as shown in Figure 2-19) comprises a portion of the former RBG area of the site. The survey unit encompasses an area of 404 m^2.

Figure 2-19 Survey Unit 9 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. This survey unit is identified as an area where remedial activities have been performed and historical sampling results support the conclusion that additional remedial activities are not likely to be necessary (yellow-shaded survey unit in Figure 2-9). Survey Unit 9 has a distinct oval-shape, and is entirely surrounded by Survey Unit 10. Visualization of the historical data using iso-contour graphics generated in SADA indicates that elevated readings may still be present in Survey Unit 9, and the area immediately surrounding the survey unit (Figure 2-7). 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 9. The historical data in the area surrounding Survey Unit 9 (Survey Unit 10) indicates elevated readings are confined to the area encompassed in Survey Unit 9. The shape of Survey Unit 9 reflects the extent of previous remedial excavation activities that occurred to remove known radiological contamination.

Using the same final design criteria as outlined in Sections 2.6.2 and 2.6.3 used during the design of Survey Unit 2, the appropriate number and spacing of the coreholes was determined for Survey Unit 9. Figure 2-20 through Figure 2-22 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes.

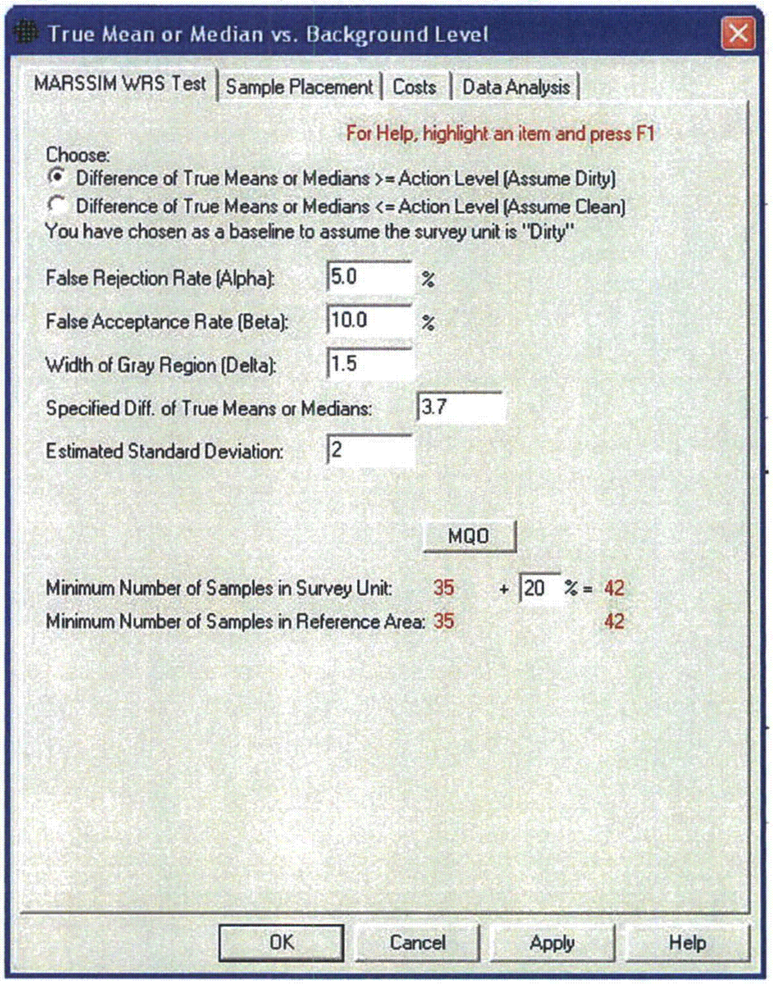

Figure 2-20 Screen Shot, VSP Sample Size Calculation, Survey Unit 9

Because previous remediation excavation activities occurred in Survey Unit 9, there is a lack of historical data in Layers #1-3 (0-3 meter depth), Figure 2-17 presents historical data from Layer #4 (3-4 meter depth).

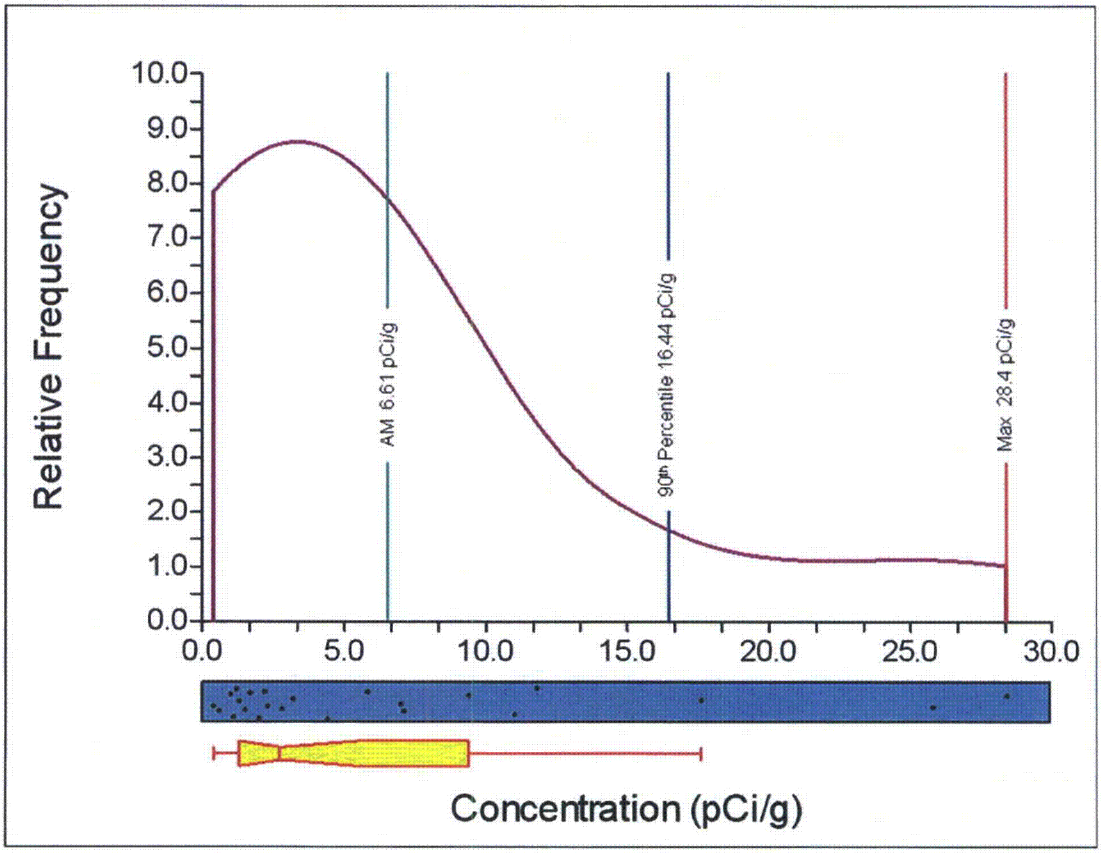

Figure 2-21 Sample Pre-Existing Data Distribution, Th-232, Layer #4, Survey Unit 9

Similar to Survey Unit 8, the maximum corehole density of Survey Unit 9 was constrained by the "reasonable maximum concentration" calculation. The highest 90th percentile concentration observed in Survey Unit 9 was greater than the corresponding permissible surface soil DCGL. Therefore the "reasonable maximum concentration" value intersects the volume factor curve. This indicates it was necessary to adjust the corehole density to compensate for the potential presence of localize anomalies in the subsurface soil. The "reasonable maximum concentration" calculation returned a maximum corehole density of 10.0 m^2 resulting in a total of 42 coreholes.

Table 2-7 Summary of Sampling Design, Survey Unit 9

Survey Unit 9	
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]	42
Number of samples on map [b]	42
Number of selected sample areas [c]	1
Specified sampling area [d]	404 m^2
Size of grid / Area of grid [e]	3.10 m / 9.6 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.

Table 2-8 Planned Corehole Locations, Survey Unit 9

Sample ID	Easting (X)	Northing (Y)
209	3022137.4871	674223.4430
210	3022127.3499	674233.5802
211	3022137.4871	674233.5802
212	3022117.2128	674243.7173
213	3022127.3499	674243.7173
214	3022137.4871	674243.7173
215	3022147.6243	674243.7173
216	3022127.3499	674253.8545
217	3022137.4871	674253.8545
218	3022147.6243	674253.8545
219	3022127.3499	674263.9916
220	3022137.4871	674263.9916
221	3022147.6243	674263.9916
222	3022157.7614	674263.9916
223	3022137.4871	674274.1288
224	3022147.6243	674274.1288
225	3022157.7614	674274.1288
226	3022167.8986	674274.1288
227	3022137.4871	674284.2659
228	3022147.6243	674284.2659
229	3022157.7614	674284.2659
230	3022167.8986	674284.2659
231	3022137.4871	674294.4031
232	3022147.6243	674294.4031
233	3022157.7614	674294.4031
234	3022167.8986	674294.4031
235	3022178.0357	674294.4031
236	3022147.6243	674304.5402
237	3022157.7614	674304.5402
238	3022167.8986	674304.5402
239	3022178.0357	674304.5402
240	3022157.7614	674314.6774
241	3022167.8986	674314.6774
242	3022178.0357	674314.6774
243	3022188.1729	674314.6774
244	3022157.7614	674324.8146
245	3022167.8986	674324.8146
246	3022178.0357	674324.8146
247	3022188.1729	674324.8146
248	3022167.8986	674334.9517
249	3022178.0357	674334.9517
250	3022188.1729	674334.9517

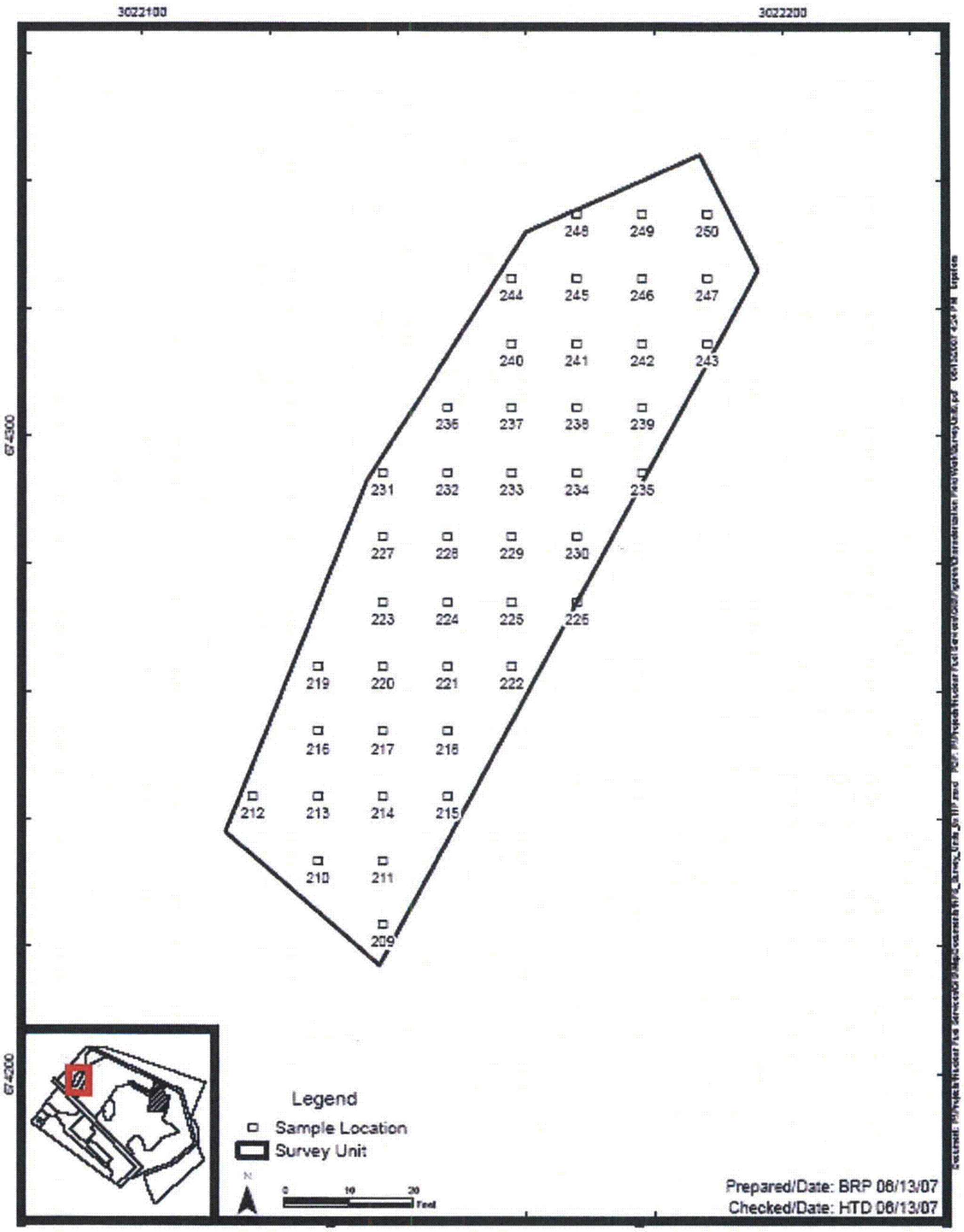

Figure 2-22 Survey Unit 9 Corehole Locations

2.9 SURVEY UNIT 19 DESIGN

Survey Unit 19 (as shown in Figure 2-23) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 5,040 m^2.

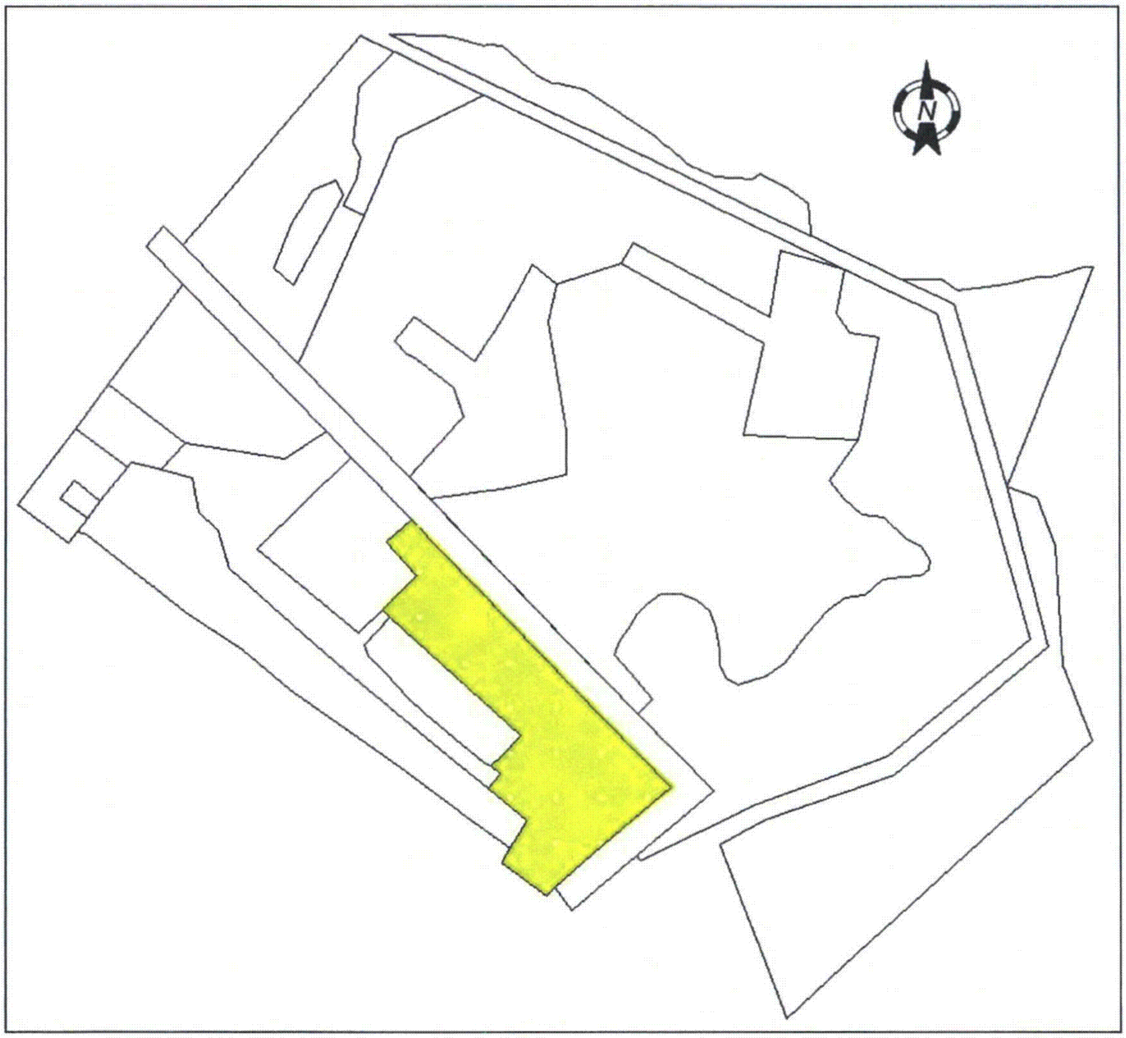

Figure 2-23 Survey Unit 19 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. This survey unit is identified as an area where remedial activities have been performed and historical sampling results support the conclusion that additional remedial activities are not likely to be necessary (yellow-shaded survey unit in Figure 2-9). Visualization of the historical data using iso-contour graphics generated in SADA indicates that elevated readings may still be present in the far northwest corner of Survey Unit 19, and in a small area to the west/northwest of the survey unit (Figure 2-7). 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 19.

The east and north borders of Survey Unit 19 are bound by a double-wide, high-security fencing system demarcating the area known as the former security zone (Survey Unit 11). Human activities occurred in areas to the south (former ponds area) of the former security zone resulting in eventual remediation of the majority of the ponds area, including the west half of Survey Unit 19 that is now an open excavation pit. The extent of previous remediation (denoted by steep excavation banks) comprises the west, north, and a portion of the south boundaries of Survey Unit 19. The east half of Survey Unit 19 encompasses a small protected wetlands area. The protected wetlands area was not remediated and historical data indicates no elevated radioactivity exists in this location.

Using the same final design criteria as outlined in Sections 2.6.2 and 2.6.3 used during the design of Survey Unit 2, the appropriate number and spacing of the coreholes was determined for Survey Unit 19. Figure 2-24 through Figure 2-26 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes.

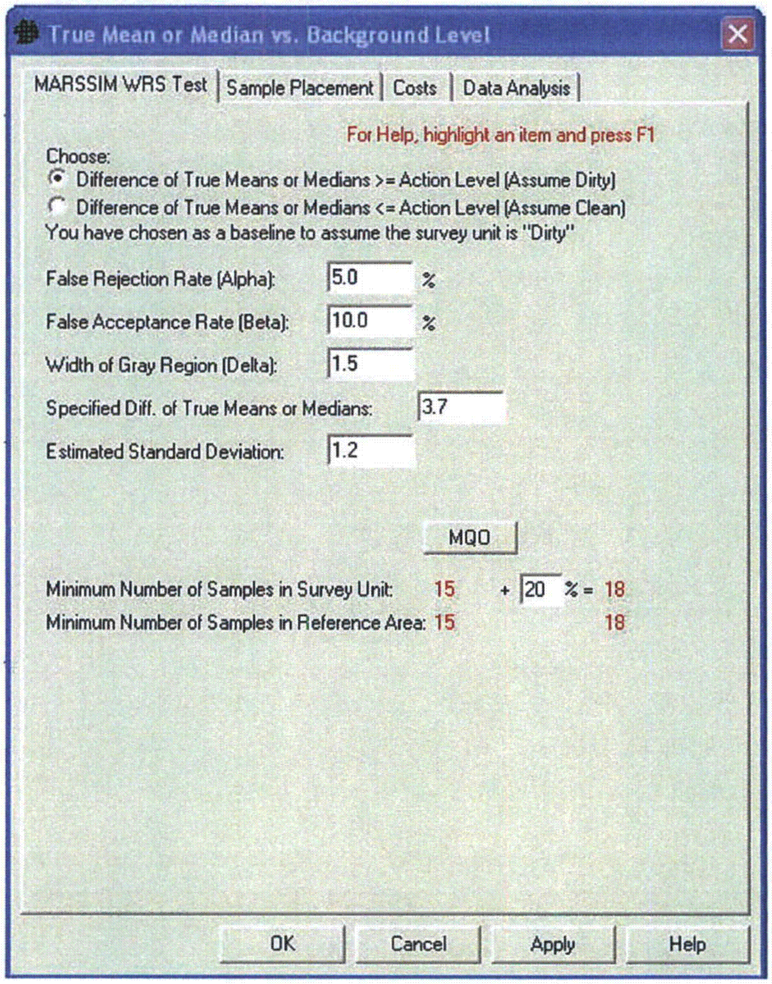

Figure 2-24 Screen Shot, VSP Sample Size Calculation, Survey Unit 19

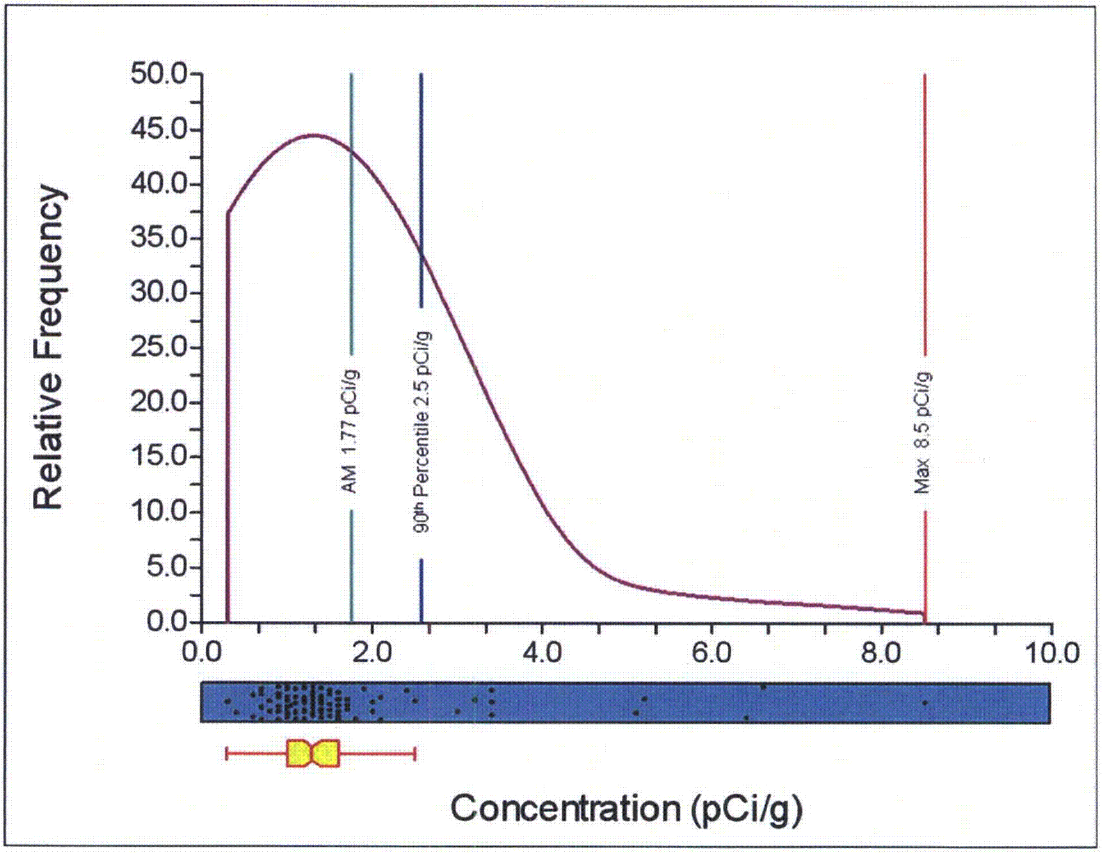

Figure 2-25 Sample Pre-Existing Data Distribution, Th-232, Layer #1, Survey Unit 19

Table 2-9 Summary of Sampling Design, Survey Unit 19

Survey Unit 19	
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]	18
Number of samples on map [b]	18
Number of selected sample areas [c]	1
Specified sampling area [d]	5040 m^2
Size of grid / Area of grid [e]	16.67 m / 278 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.

Table 2-10 Planned Corehole Locations, Survey Unit 19

Sample ID	Easting (X)	Northing (Y)
710	3022451.9039	673540.6232
711	3022506.8132	673540.6232
712	3022396.9946	673595.5325
713	3022451.9039	673595.5325
714	3022506.8132	673595.5325
715	3022561.7225	673595.5325
716	3022396.9946	673650.4418
717	3022451.9039	673650.4418
718	3022506.8132	673650.4418
719	3022396.9946	673705.3511
720	3022451.9039	673705.3511
721	3022342.0853	673760.2604
722	3022396.9946	673760.2604
723	3022287.1760	673815.1697
724	3022342.0853	673815.1697
725	3022287.1760	673870.0790
726	3022342.0853	673870.0790
727	3022287.1760	673924.9883

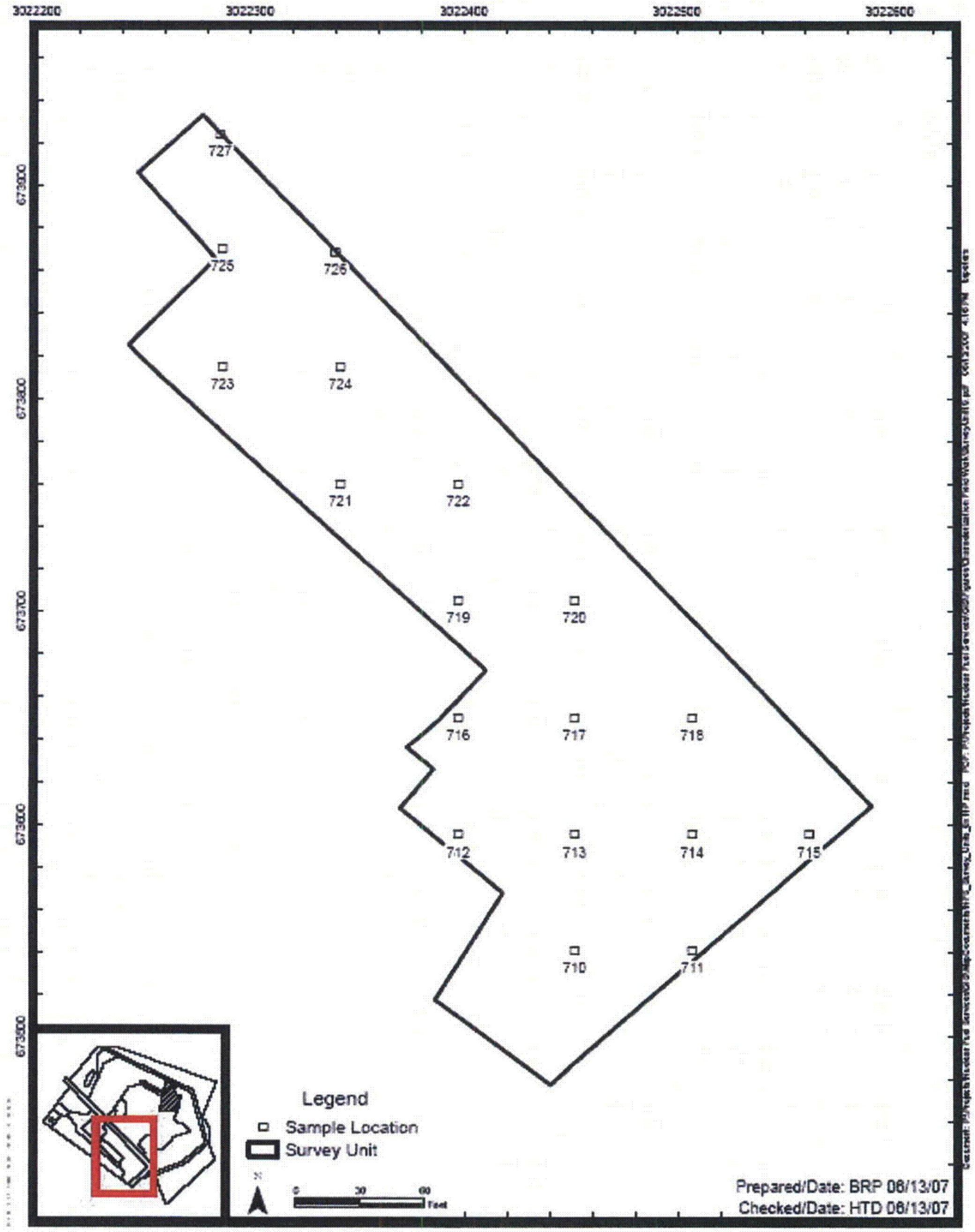

Figure 2-26 Survey Unit 19 Corehole Locations

2.10 SURVEY UNIT 20 DESIGN

Survey Unit 20 (as shown in Figure 2-27) comprises a portion of the former ponds area of the site. The survey unit encompasses an area of 1,097 m^2.

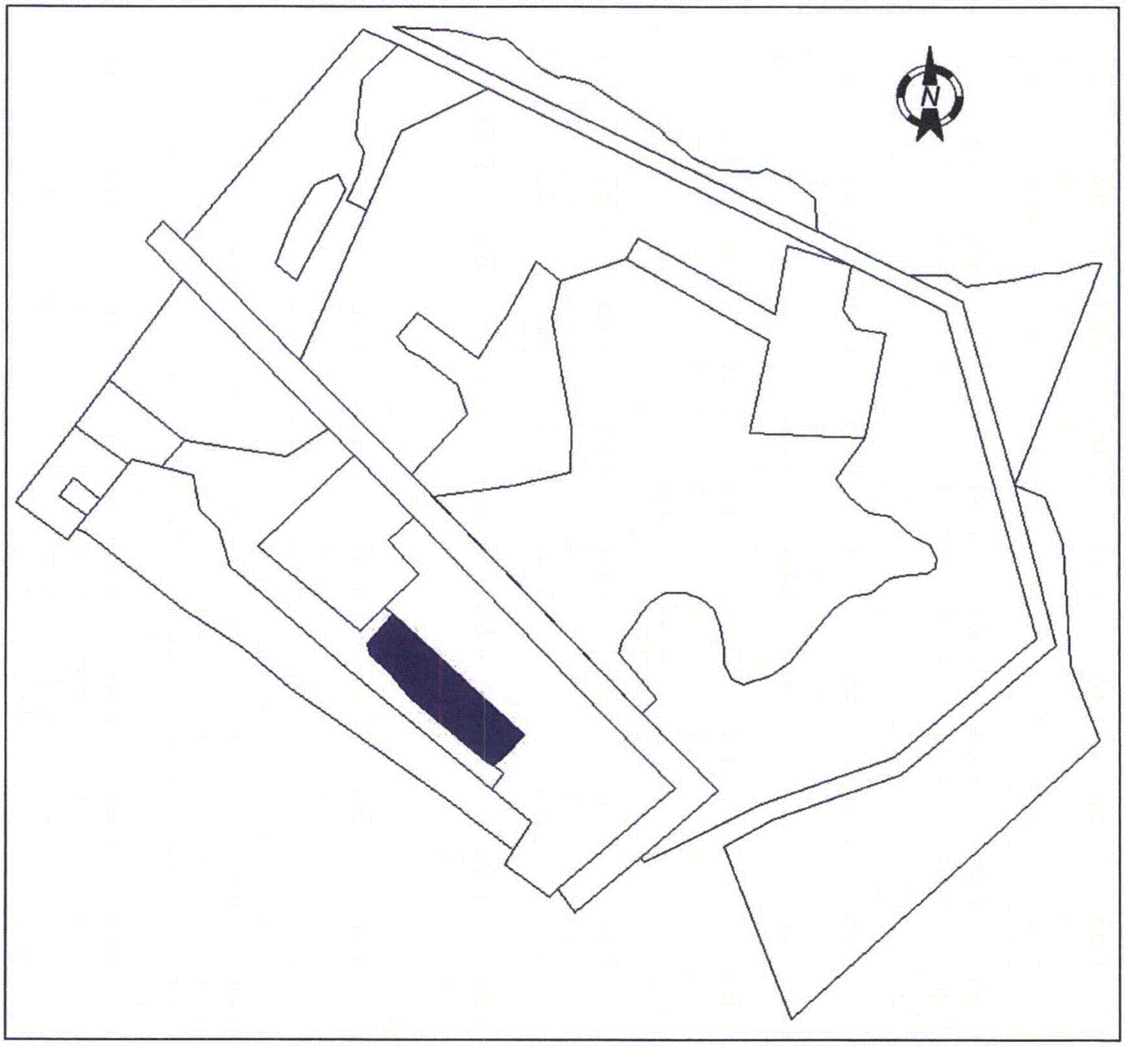

Figure 2-27 Survey Unit 20 Location Map

Demarcation of the survey unit was performed using the criteria described in Section 2.3. This survey unit is identified as an area where remedial activities have not been performed and historical sampling results support the conclusion that additional remedial activities may be necessary (purple-shaded survey unit in Figure 2-9). 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 20. 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 20.

The area encompassed by Survey Unit 20 was a former pond. All of Survey Unit 20 has been previously remediated, resulting in steep excavation banks demarcating the west, south, and east borders of Survey Unit 20 (Figure 2-7). Survey Unit 19 lies directly north and east of Survey Unit 20.

Similar to Survey Units 8 and 9, the number of coreholes for Survey Unit 20 was not constrained by the survey unit wide area statistical test. For Survey Unit 20, the highest 90^{th} percentile concentration observed was greater than the corresponding permissible surface soil DCGL. Therefore, the "reasonable maximum concentration" value intersects the volume factor curve. This indicates that it was necessary to adjust the corehole density to compensate for the potential presence of localized anomalies in the subsurface soil. The "reasonable maximum concentration" calculation returned a maximum corehole density of 5.0 m^2 resulting in a total of 220 coreholes.

Rather than place a corehole every 5m^2 as dictated by the "reasonable maximum concentration" calculation, a conservative and robust sampling density was determined. As explained in Section 4.3 of the Characterization Plan, a conservative and robust 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 conservative 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. 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, a conservative 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 20 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 7m, VSP placed a corehole every 50 m^2 as desired. Figure 2-28 through Figure

2-30 present relevant information used to determine the appropriate number and spacing of the coreholes, followed by planned locations of coreholes.

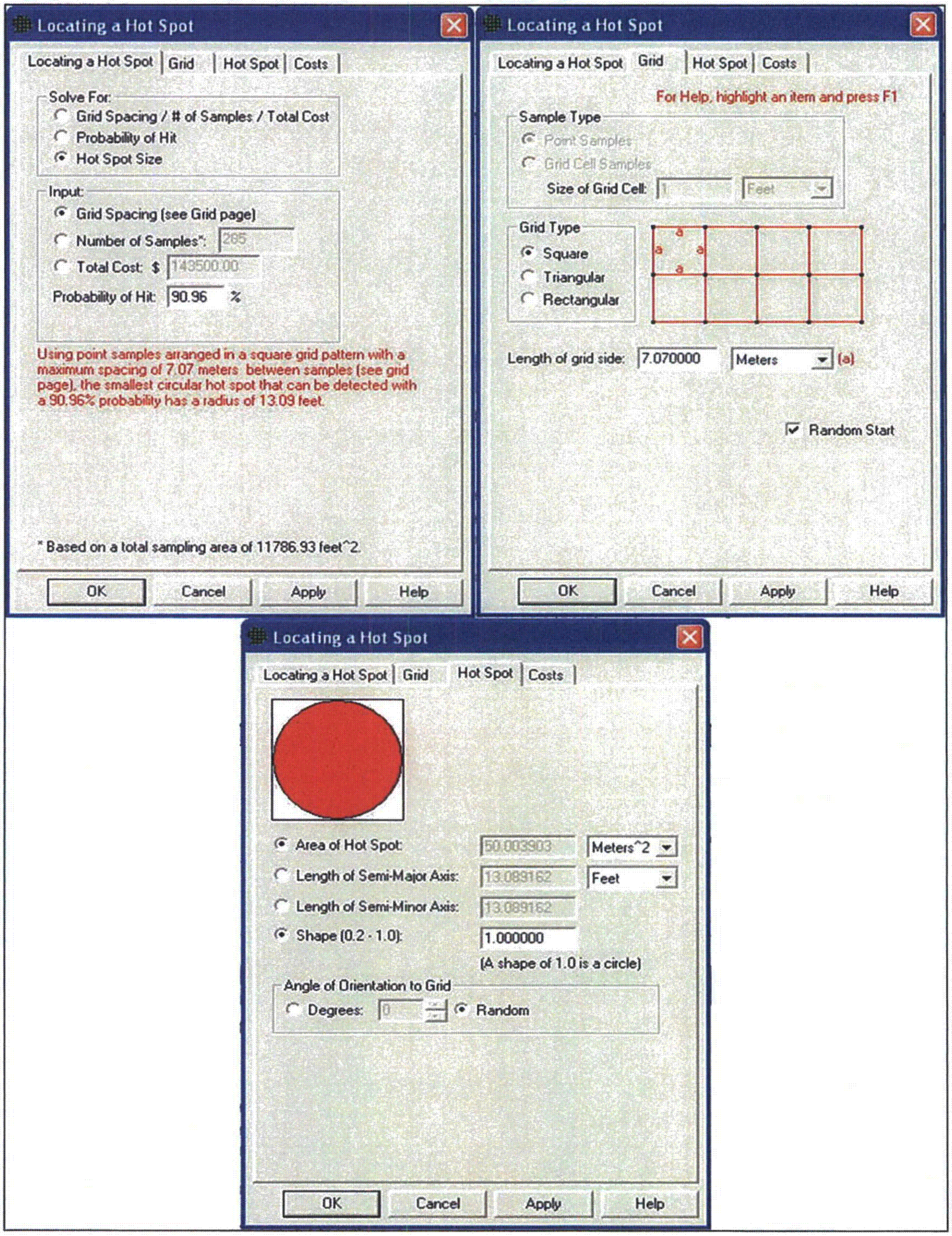

Figure 2-28 Screen Shots, VSP Sample Size Calculation Using "Locating a Hot Spot" Function, Survey Unit 20

Because previous remediation excavation activities occurred in Survey Unit 20, there is a complete lack of historical data in Layer #1 with minimum data in the remaining layers. Figure 2-17 presents a compilation of historical Th-232 data from Layers #2-5 (1-5 meter depth).

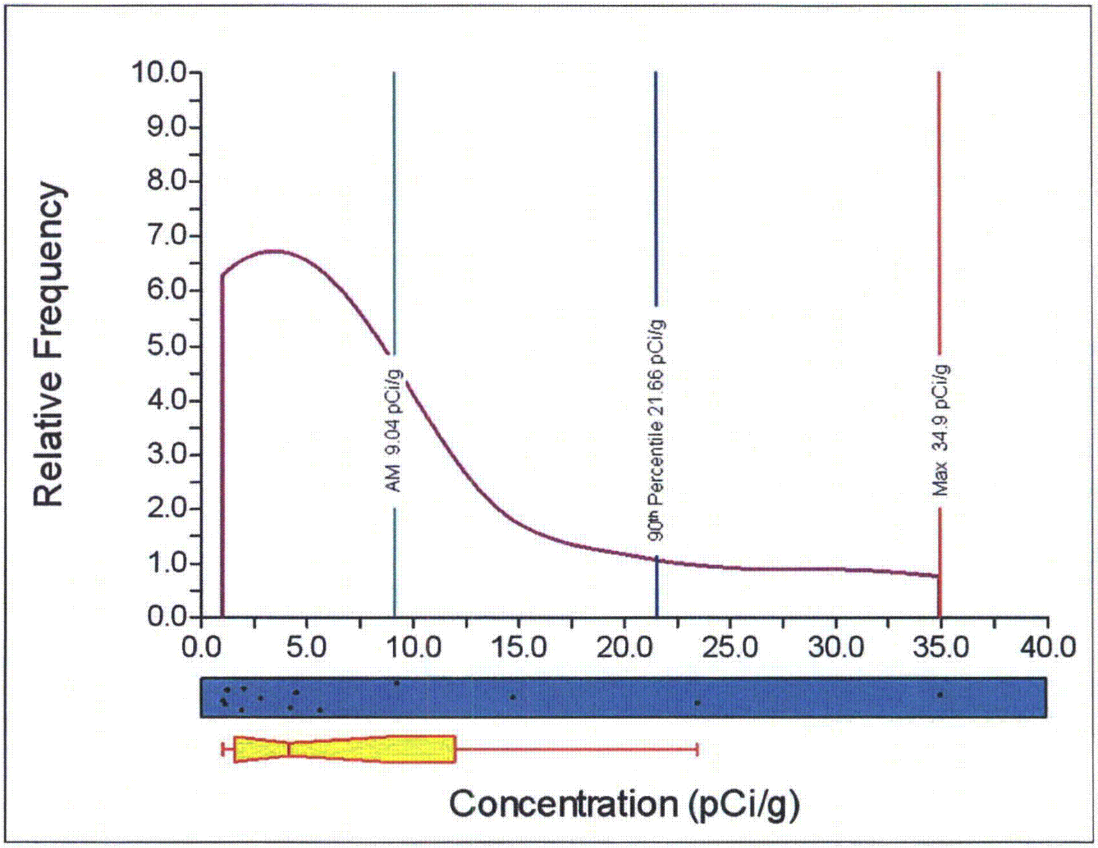

Figure 2-29 Sample Pre-Existing Data Distribution, Th-232, Layers #2-5, Survey Unit 20

Table 2-11 Summary of Sampling Design, Survey Unit 20

Survey Unit 20	
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]	22
Number of samples on map [b]	22
Number of selected sample areas [c]	1
Specified sampling area [d]	1097 m^2
Size of grid / Area of grid [e]	7.07 m / 49.77 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.

Table 2-12 Planned Corehole Locations, Survey Unit 20

Sample ID	Easting (X)	Northing (Y)
728	3022362.7291	673657.5192
729	3022385.9245	673657.5192
730	3022339.5336	673680.7147
731	3022362.7291	673680.7147
732	3022385.9245	673680.7147
733	3022293.1427	673703.9102
734	3022316.3381	673703.9102
735	3022339.5336	673703.9102
736	3022362.7291	673703.9102
737	3022269.9472	673727.1056
738	3022293.1427	673727.1056
739	3022316.3381	673727.1056
740	3022339.5336	673727.1056
741	3022246.7517	673750.3011
742	3022269.9472	673750.3011
743	3022293.1427	673750.3011
744	3022316.3381	673750.3011
745	3022246.7517	673773.4966
746	3022269.9472	673773.4966
747	3022293.1427	673773.4966
748	3022246.7517	673796.6920
749	3022269.9472	673796.6920

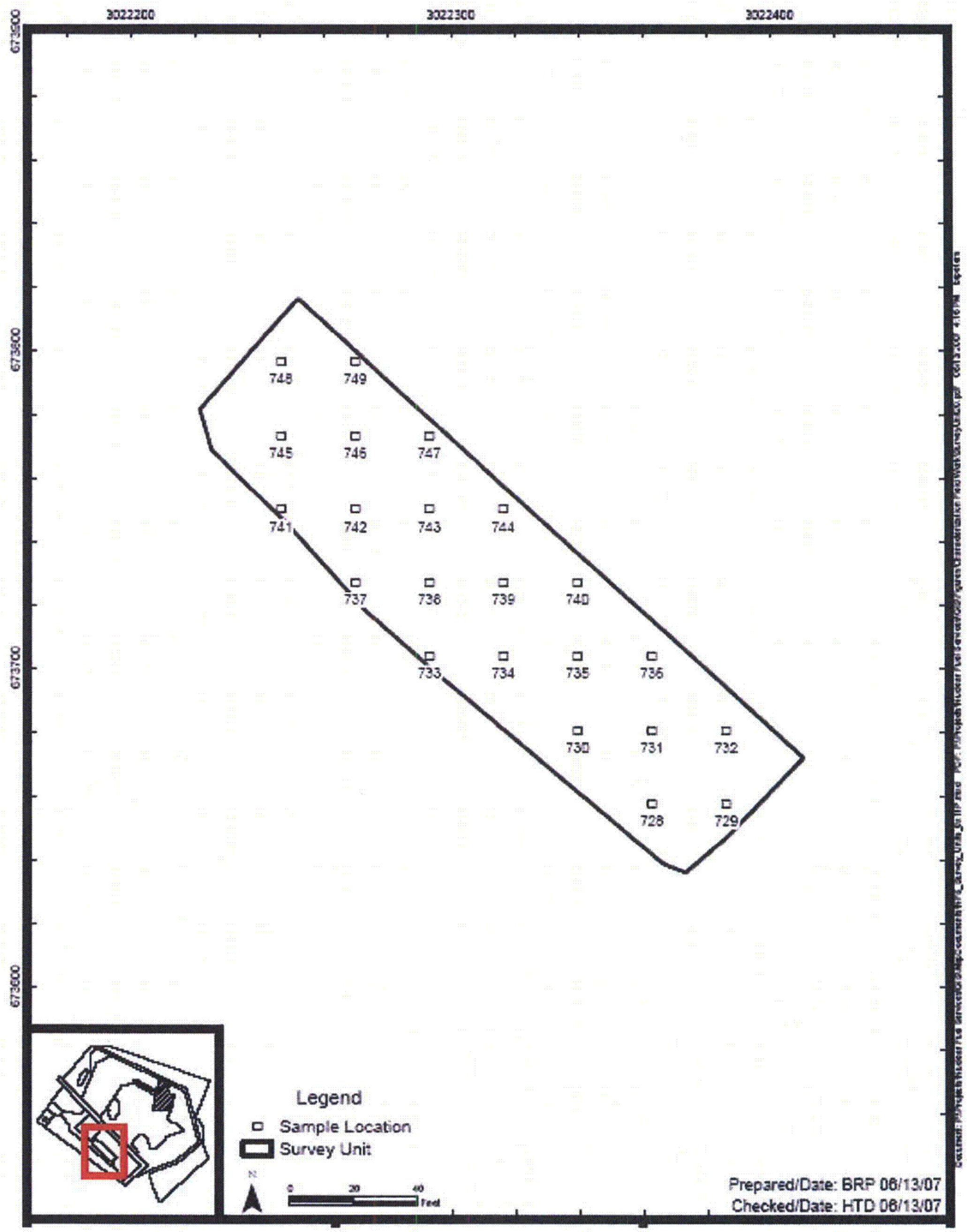

Figure 2-30 Survey Unit 20 Corehole Locations

2.11 SUMMARY FINAL DESIGN AND SAMPLE PLACEMENT, SU 2, 8, 9, 19, 20

Table 2-13 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 2-13 Summary Final Design and Sample Placement, Survey Units 2, 8, 9, 19, and 20

Survey Unit	Area (m^2)	Grid Size (m^2)	# Coreholes
2	3,588	199	18
8	1,151	18	64
9	404	10	41
19	5,040	278	18
20	1,097	50	22

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 MACTEC 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 MACTEC personnel and equipment as well as subcontractor equipment and personnel, began on June 18, 2007. 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 July 9, 2007. On-the-job (OJT) training began the following day (July 10, 2007). OJT continued through the majority of July 11, 2007 with drilling/soil-sampling activities beginning late July 11, 2007 at the North site.

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, MACTEC, 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-DC-103 (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 2, the distance between planned sample nodes was 14.1 m. Therefore, the maximum distance a sample could be relocated was 7.05 m (½*14.1 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 2 from October 2 through October 8, 2007 and October 23 through October 24, 2008, Survey Unit 8 from September 6 through September 25, 2007, Survey Unit 9 from August 21 through September 6, 2007, Survey Unit 19 from October 16 through October 29, 2007, and Survey Unit 20 from October 24 through November 5, 2007.

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 MACTEC sampling team in the field precisely surveying and recording the actual lateral position and elevation of each corehole (Table 3-1 through Table 3-5).

Table 3-1 Surveyed Corehole Locations and Elevations, Survey Unit 2

Core ID	Elevation (ft. msl)	Easting	Northing
16	1661.2	3023003.23	674056.69
17	1662.3	3022975.79	674119.5
18	1666.3	3023025.5	674107.29
19	1635.4	3022365.61	674490.43
20	1635.2	3022382.11	674483.1
21	1634.7	3022415.52	674468.11
22	1636.2	3022464.7	674441.48
23	1637	3022511.01	674416.51
24	1638.5	3022557.05	674388.33
25	1640.8	3022601.87	674358.25
26	1642.7	3022648.93	674331.26
27	1641.7	3022703.68	674316.58
28	1645.7	3022745.53	674279.2
29	1649.8	3022899.97	674212.24
30	1651.7	3022950.21	674193.96
31	1654.4	3022998.14	674188.57
32	1665.3	3023048.73	674146.51
33	1653.9	3023071.36	674204.01
1019	1634.7	3022316.35	674483.03
1020	1635.9	3022371.46	674485.62
1021	1636	3022394.66	674471.71
2020	1633.8	3022379.85	674500.76
2021	1632.6	3022399.79	674491.73
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 2 is provided in Appendix H.

Table 3-2 Surveyed Corehole Locations and Elevations, Survey Unit 8

Core ID	Elevation (ft. msl)	Easting	Northing
145	1631.9	3022200.02	674318.12
146	1632	3022210.65	674315.45
147	1631.8	3022213.43	674325.6
148	1636.3	3022234.51	674323.56
149	1631.8	3022216.84	674341.23
150	1635	3022229.03	674337.57
151	1632.6	3022226.8	674356.99
152	1634.4	3022243.78	674355.48
153	1633.4	3022229.38	674372.1
154	1633.9	3022242.76	674369.98
155	1634.7	3022217.28	674380.9
156	1635	3022227.56	674382.69
157	1632.9	3022245.33	674388.7
158	1632.9	3022254.32	674396.31
159	1635.8	3022215.26	674391.64
160	1634	3022230.29	674402.61
161	1632.5	3022242.51	674398.39
162	1631.9	3022256.08	674409.84
163	1635.4	3022275.38	674396.13
164	1634.1	3022213.69	674418.2
165	1634	3022226.09	674410.6
166	1631.9	3022244.36	674408.9
167	1631.2	3022255.73	674424.24
168	1632.1	3022261.13	674413.98
169	1634.5	3022284.69	674413.47
170	1634.9	3022298.21	674411.47
171	1633.6	3022217.15	674426.11
172	1633.3	3022223.2	674431.29
173	1631.8	3022242.92	674423.58
174	1631.2	3022253.33	674432.93
175	1631.6	3022268.71	674425.38
176	1633.9	3022289.1	674423.14
177	1633.9	3022301.63	674429
178	1635.1	3022315.02	674425.99
179	1635.8	3022327.22	674425.13
180	1633	3022218.37	674441.63
181	1633	3022231.01	674440.59
182	1633.1	3022240.53	674443.78
183	1631.1	3022258.34	674437.33
184	1631.3	3022272.33	674435.69
185	1632.9	3022286.52	674440.15
186	1633.9	3022302.38	674440.57
187	1635.1	3022315.01	674440.87
188	1635.7	3022329.05	674440.33
189	1635.5	3022342.34	674440.6
190	1636	3022355.93	674441.83
191	1633	3022227.98	674453.25
192	1633	3022241.52	674453.69
193	1632.8	3022259.72	674458.13
194	1632.8	3022272.4	674457.32
195	1633.5	3022285.06	674455.35
196	1633.9	3022300.19	674455.35
197	1635	3022314.74	674454.67
198	1635.5	3022330.83	674454.82
199	1635.9	3022340.5	674452.78
200	1633.1	3022243.78	674467.72
201	1633.2	3022257.86	674468.63
202	1633.4	3022271.91	674468.02
203	1633.6	3022285.78	674469.17
204	1634.3	3022300.34	674469.67
205	1635	3022314.24	674467.9
206	1633.2	3022255.35	674479.75
207	1633.6	3022272.01	674482
208	1633.9	3022287.94	674476.57

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 9

Core ID	Elevation (ft. msl)	Easting	Northing
209	1632.2	3022141.99	674222.81
210	1631.7	3022129.14	674233.27
211	1632.1	3022140.03	674232.23
212	1631.6	3022116.47	674244.31
213	1631.9	3022129.84	674243.32
214	1632.1	3022139.94	674242.81
215	1631.8	3022148.65	674242.45
216	1632	3022130	674251.83
217	1632	3022139.93	674242.49
218	1631.6	3022150.9	674252.86
219	1632	3022130.06	674263.37
220	1631.8	3022140.41	674262.96
221	1631.7	3022151.02	674261.74
222	1631.7	3022159.51	674262.25
223	1631.8	3022140.87	674271.78
224	1631.8	3022150.92	674269.72
225	1631.9	3022158.29	674273.69
226	1632.1	3022174.49	674270.58
227	1632.4	3022139.74	674283.06
228	1632.3	3022150.97	674281.89
229	1632	3022160.82	674283.7
230	1631.8	3022165.96	674283.89
231	1632.6	3022139.87	674291.62
232	1632.4	3022148.8	674291.93
233	1632.3	3022156.4	674293.08
234	1632.1	3022169.45	674294.83
235	1632	3022182.9	674292.27
236	1632.2	3022150.34	674302.53
237	1632.2	3022157.84	674304.72
238	1632.2	3022170.17	674303.99
239	1631.9	3022176.42	674304.65
240	1632.4	3022161.55	674312.59
241	1632.5	3022171.85	674311.35
242	1632.2	3022180.98	674313.7
243	1632.1	3022189.37	674313.43
244	1632.5	3022159.72	674321.42
245	1632.5	3022170.12	674321.2
246	1632	3022180.83	674321.4
247	1631.8	3022190.46	674321.9
248	1632.3	3022170.36	674332.83
249	1632.2	3022180.33	674329.01
250	1632	3022190.08	674328.46

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 19

Core ID	Elevation (ft. msl)	Easting	Northing
710	1635.1	3022455.68	673567.47
711	1634.8	3022487.92	673555.62
712	1633.9	3022398.84	673592.51
713	1635.4	3022451.59	673595.88
714	1634.8	3022498.19	673587.81
715	1637.4	3022567.04	673617.21
716	1635.1	3022404.04	673632.39
717	1635.1	3022438.97	673634.37
718	1638.2	3022522.56	673663.88
719	1630.9	3022405.02	673711.69
720	1637.2	3022468.4	673719.85
721	1629	3022348.69	673761.81
722	1632.3	3022397.09	673759.19
723	1627.7	3022298.23	673810.58
724	1630.5	3022348.91	673810.96
725	1635.1	3022287.47	673870.45
726	1636.8	3022328.24	673859.07
727	1635.7	3022285.58	673924.63
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 20

Core ID	Elevation (ft. msl)	Easting	Northing
728	1630.5	3022360.46	673656.48
729	1629.2	3022383.05	673658.57
730	1630.1	3022339.95	673677.65
731	1628.9	3022369.58	673671.73
732	1628.6	3022386.67	673676.55
733	1629.3	3022298.58	673704.43
734	1629.2	3022316.84	673699.2
735	1628.1	3022340.98	673700.74
736	1627.7	3022363.41	673701.21
737	1629.3	3022274.43	673730.23
738	1628.1	3022298.95	673720.77
739	1627.3	3022317.53	673723.74
740	1628.3	3022340.49	673724.23
741	1629.5	3022264.15	673746.12
742	1629.1	3022273.05	673745.74
743	1627.8	3022296.47	673744.47
744	1627	3022317.43	673746.93
745	1628.6	3022247.76	673770.89
746	1628.6	3022275.12	673766.49
747	1627.4	3022293.53	673769.63
748	1627.9	3022248.08	673789.34
749	1627.2	3022269.69	673791.79
Coordinate System: US State Plane 1983, Zone Tennessee 4100, Datum NAD 1983 (Con			

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 MACTEC personnel for the purpose of logging the geologic lithology of the subsurface soil environment. MACTEC erected a portable field sampling station (Figure 3-7) in proximity to the drilling location, where MACTEC 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 MACTEC 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 2, 8, 9, 19, and 20.

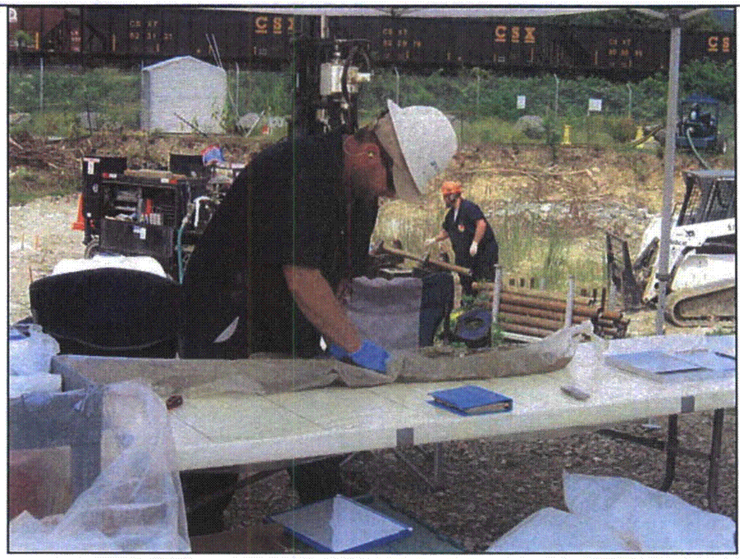

Figure 3-8 Geologist Examines Core and Logs Lithology

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

3.4.2 Field Sample Collection

MACTEC 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 decision 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 MACTEC 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."

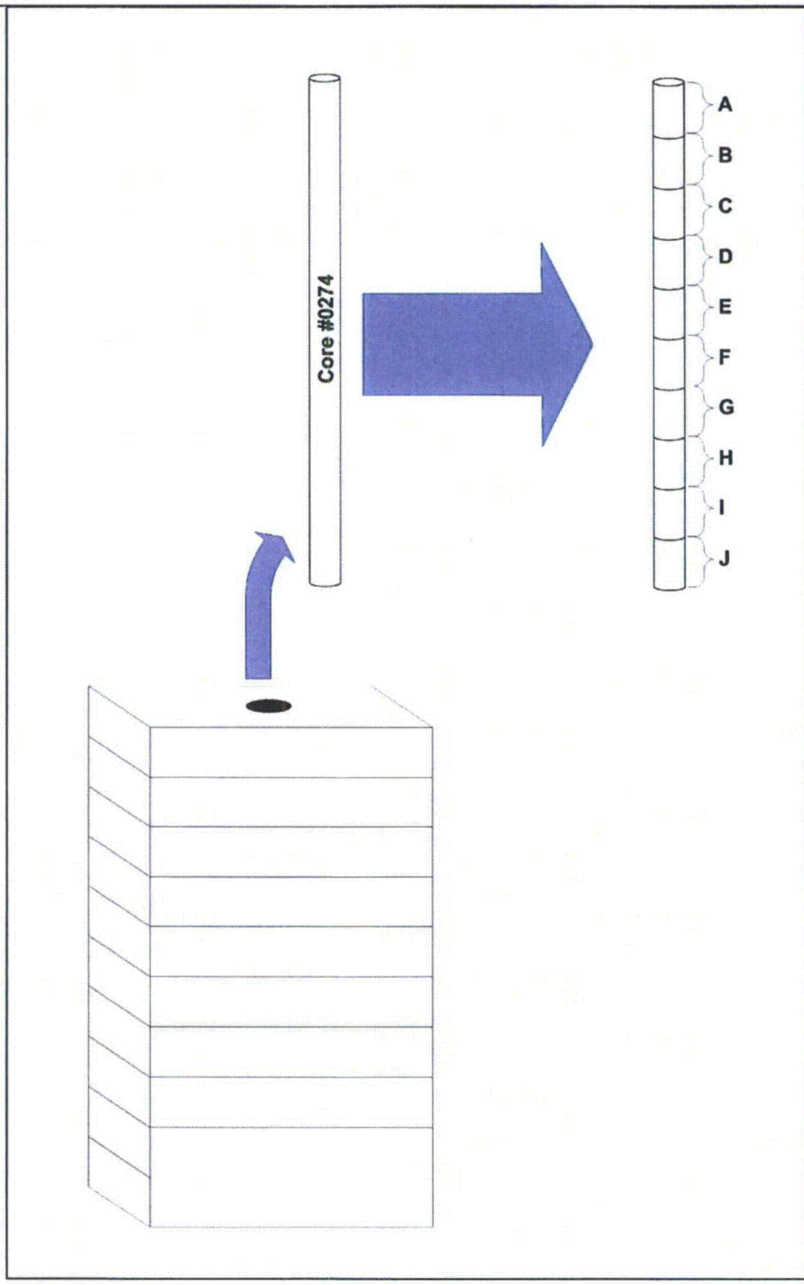

Figure 3-9 Field Sample Identification Numbering System

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).

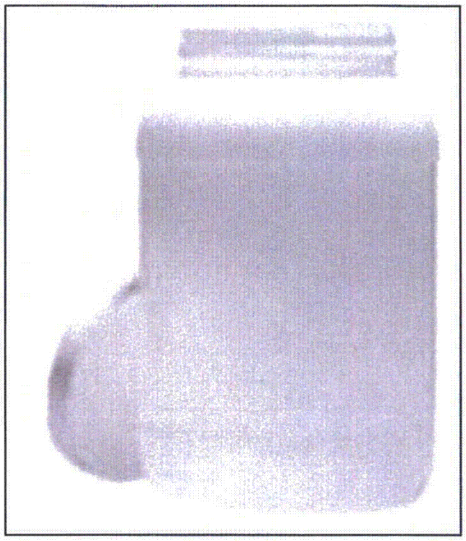

Figure 3-10 Container for Isotopes Other Than Tc-99

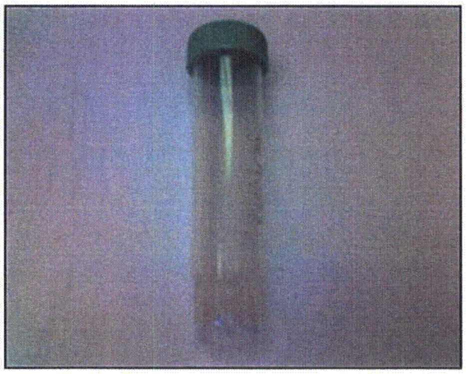

Figure 3-11 Container for Tc-99 Sample

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.

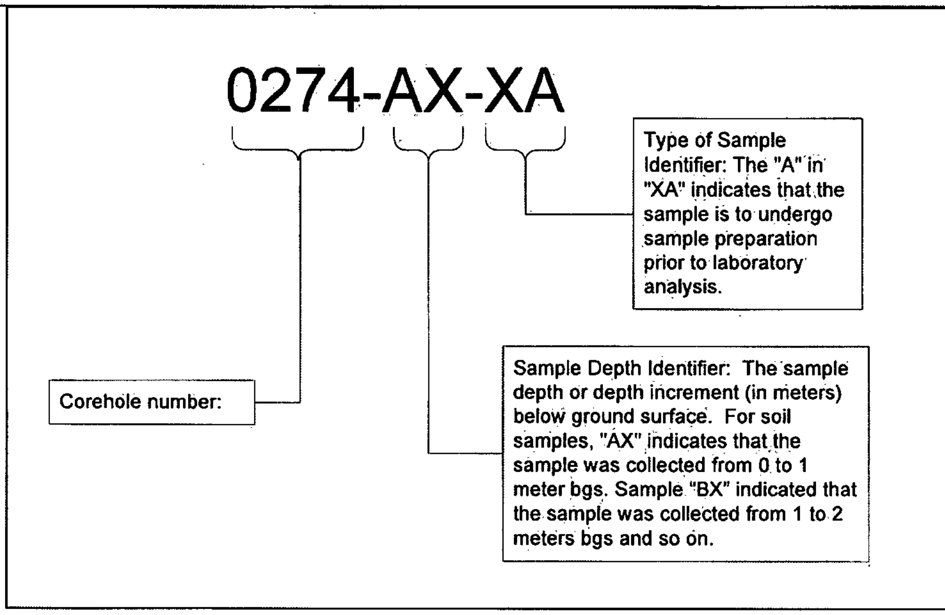

Figure 3-12 Sample Identification Format

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 3-6 presents a summary of sample type identifiers applicable to radiological characterization of subsurface soils.

Table 3-6 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.

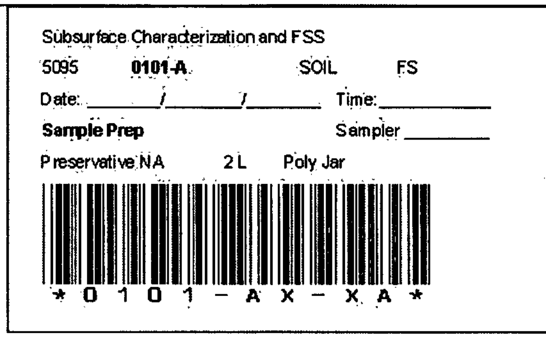

Figure 3-13 Preprinted Sample Container Label with Barcode

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.[3] In Survey Units 2, 8, and 9, the sampling team pre-selected samples for full-suite analysis from the "A" increment in every fourth corehole. The lateral spatial distribution of full-suite samples for Survey Units 2, 8, and 9 is presented in Figure 3-14, Figure 3-16, and Figure 3-18. Additional samples were selected "on-the-fly" for full-suite analysis to complete the required subset of 10%.

The selection of full-suite samples for Survey Units 19 and 20 was dictated by the selection of samples that the NRC chose for regulatory confirmation sampling. Spatial distribution figures displaying pre-selected samples for full-suite analysis from the "A" increment were not created. Using the NRC selection of samples as the pre-determined full-suite locations, additional samples were selected "on-the-fly" for full-suite analysis to complete the required subset of 10%. See Figure 3-20 and Figure 3-21 for distribution of samples selected for full-suite analysis.

A total of 166 core segment samples from 23 coreholes were collected from Survey Unit 2. Eighteen of these samples were submitted to the offsite laboratory for full-suite analysis (Figure 3-15). A total of 357 core segment samples from 64 coreholes were collected from Survey Unit 8. Thirty of these samples were submitted to the offsite laboratory for full-suite analysis (Figure 3-17). A total of 209 core segment samples from 42 coreholes were collected from Survey Unit 9. Twenty-one of these samples were submitted to the offsite laboratory for full-suite analysis (Figure 3-19). A total of 147 core segment samples from 18 coreholes were collected from Survey Unit 19. Fifteen of these samples were submitted to the offsite laboratory for full-suite analysis including three NRC regulatory confirmation samples (Figure 3-20). A total of 130 core segment samples from 22 coreholes were collected from Survey Unit 20. Twelve of these samples were submitted to the offsite laboratory for full-suite analysis including four NRC regulatory confirmation samples (Figure 3-21).

[3] The NRC selected samples from Survey Units 19 and 20 for regulatory confirmation analysis.

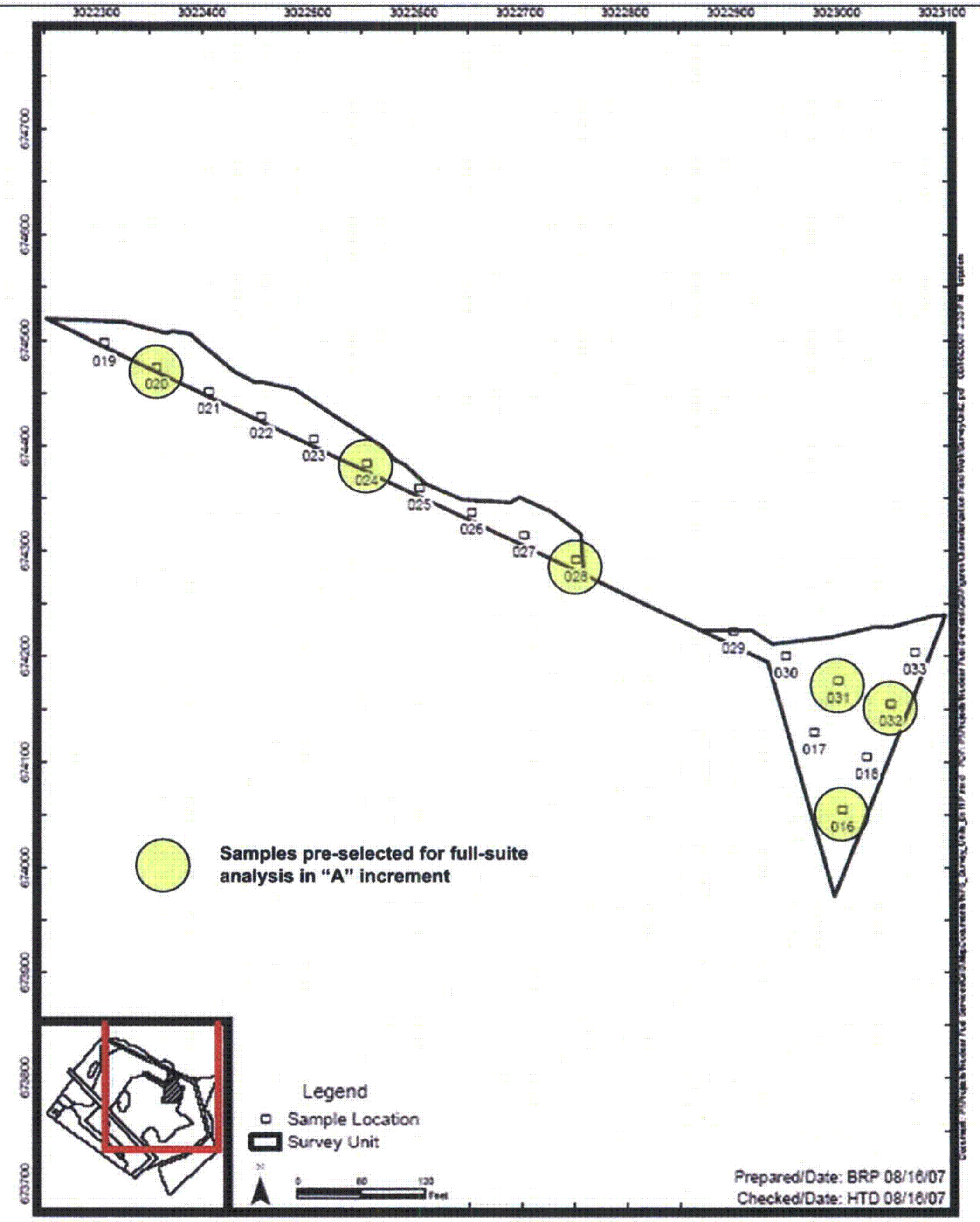

Figure 3-14 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 2

Model Layer	Corehole ID# 16	17	18	1019	20	21	22	23	24	25	26	27	28	29	30	31	32	2020	2021	33
1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
4	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
5	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
6	F	F	F	F					F	F	F	F	F	F	F	F	F			F
7	G	G	G						G		G		G	G	G	G	G			G
8	H	H	H										H	H	H	H	H			H
9	I	I	I											I	I	I	I			
10	J	J	J											J	J	J	J			

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 2

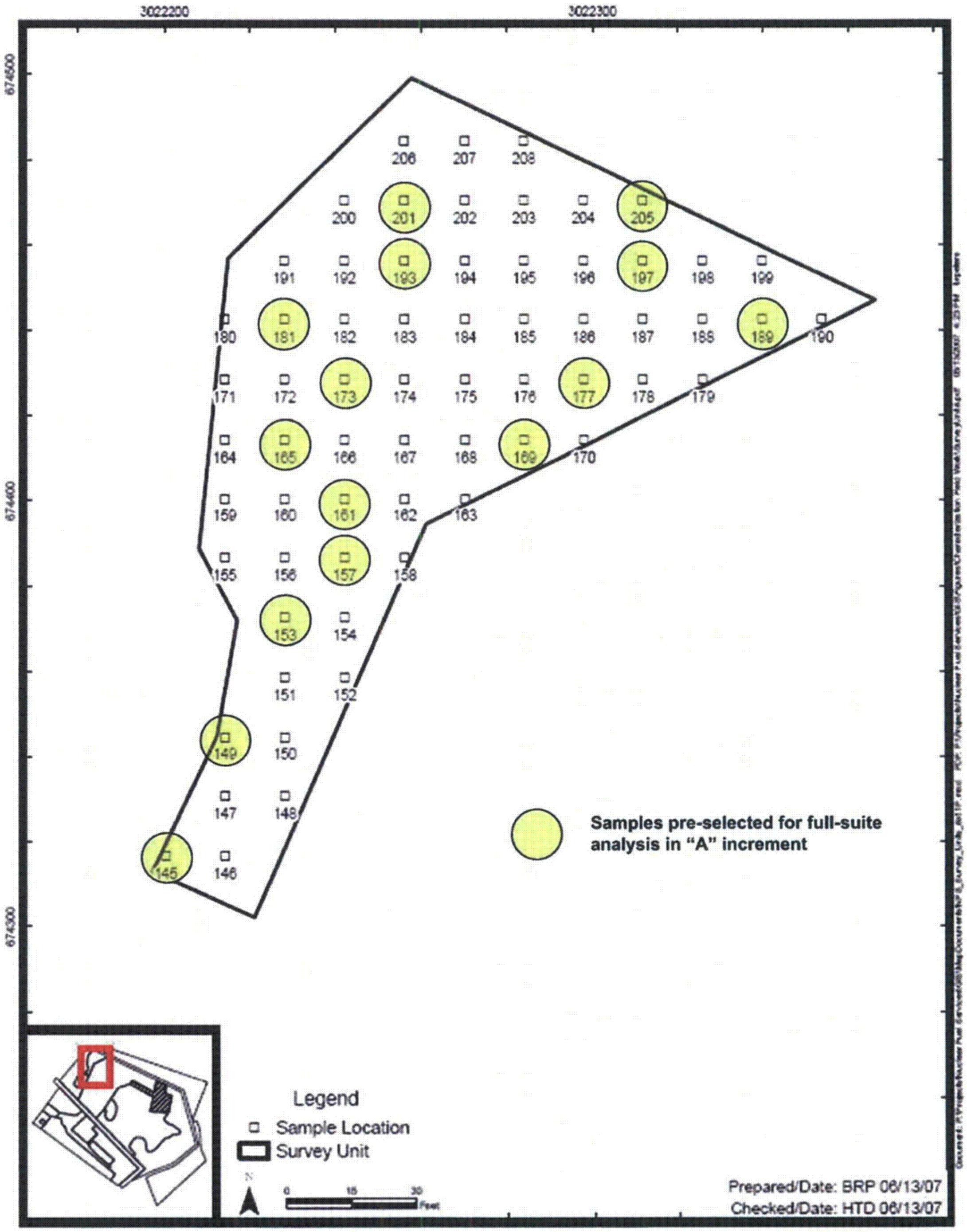

Figure 3-16 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 8

Corehole ID#

Model Layer	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208
1																																													A	A						A	A	A	A			A	A	A	A	A	A	A
2				A		A		A			A	A			A				A	A																							A	A	B	B				A	A	B	B	B	B	A	A	B	B	B	B	B	B	B
3	A	A	A	B	A	B	A	B	A	A	B	B	A	A	B	A	A	A	B	B	A	A		A	A	A	A	A	A			A	A	A	A	A	A	A			A	A	B	B	C	C	A	A	A	B	B	C	C	C	C	B	B	C	C	C	C	C	C	C
4	B	B	B	C	B	C	B	C	B	B	C	C	B	B	C	B	B	B	C	C	B	B	A	B	B	B	B	B	B	A	A	B	B	B	B	B	B	B	A	A	B	B	C	C	D	D	B	B	B	C	C	D	D	D	D	C	C	D	D	D	D	D	D	D
5	C	C	C	D	C	D	C	D	C	C	D	D	C	C	D	C	C	C	D	D	C	C	B	C	C	C	C	C	C	B	B	C	C	C	C	C	C	C	B	B	C	C	D	D	E	E	C	C	C	D	D	E	E	E	E	D	D	E	E	E	E	E	E	E
6	D	D	D	E	D	E	D	E	D	D	E	E	D	D	E	D	D	D	E	E	D	D	C	D	D	D	D	D	D	C	C	D	D	D	D	D	D	D	C	C	D	D	E	E	F	F	D	D	D	E	E	F	F	F	F	E	E		F	F	F	F	F	F
7	E	E	E	F	E	F	E		E	E	F	F	E	E	F	E	E		F	F	E	E	D	E	E	E	E	E	E	D	D	E	E	E	E	E	E	E	D	D	E	E	F	F			E	E	E		F						F							
8	F	F														F					F		E		F	F	F	F		E	E	F		F	F			F	E	E		F					F	F																
9																																																																
10																																																																

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

Figure 3-17 Spatial Distribution (Vertical) – Full-Suite Samples, SU 8

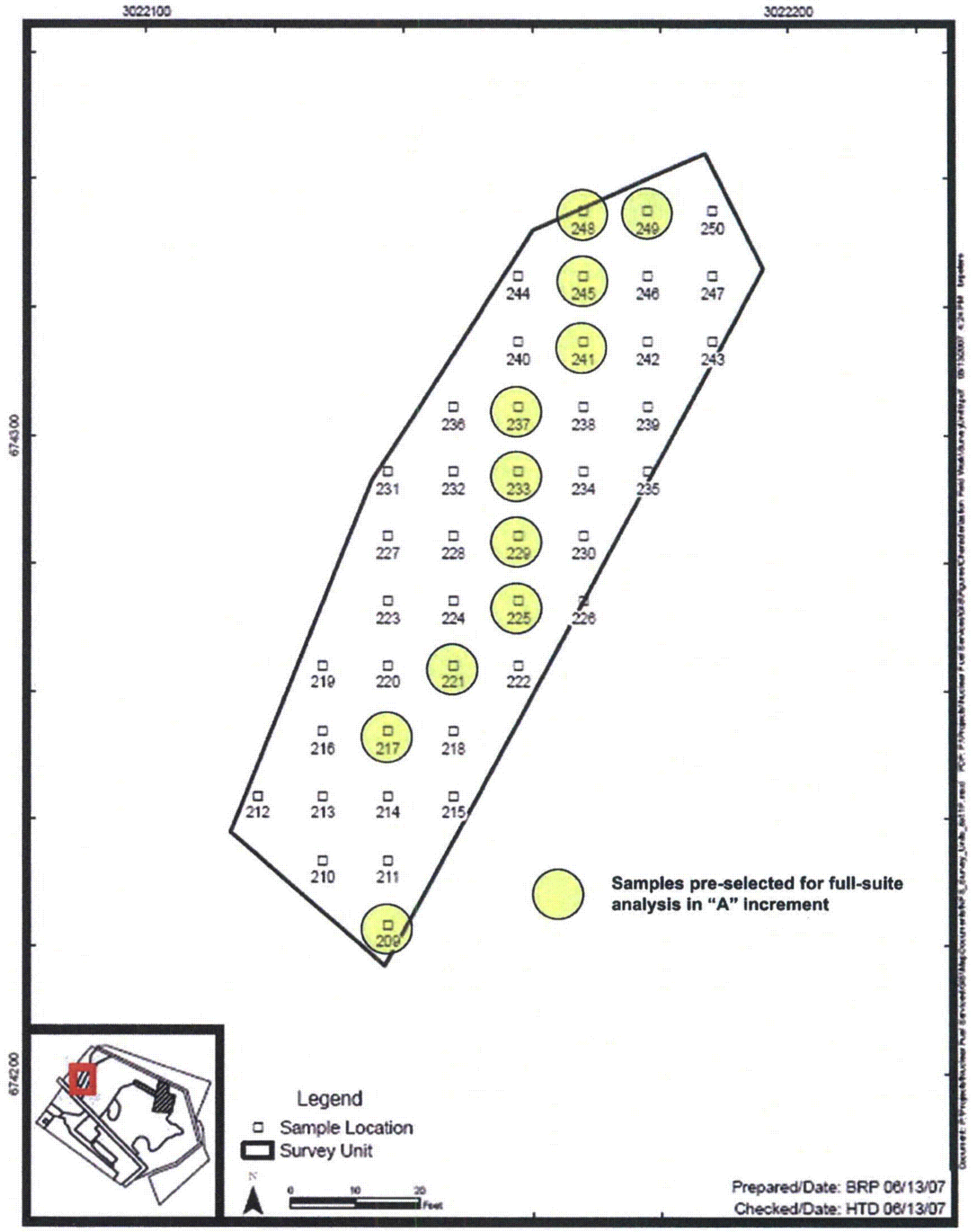

Figure 3-18 Spatial Distribution (Lateral) – Pre-Selected Full-Suite Samples, SU 9

	Corehole ID#																																								
Model Layer	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250
1																																										
2																																										
3	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	A	A	A	A	A	A
4	B	A	B	A	B	B	B	B	B	A	B	B	A	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
5	C	B	C	B	C	C	C	C	C	B	C	C	B	B	C	C	C	C	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
6	D	C	D	C	D	D	D	D	D	C	D	D	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
7	E	D	E	D	E			E	E	D	E	E	D	D		E	E	E	E	E	E	E	E	E	E	E		E	E	E	E	E	E	E	E		E		E	E	E	E
8		E	F							E				E				F										F						F	F				F			
9		F								F																																
10																																										

0

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

Figure 3-19 Spatial Distribution (Vertical) – Full-Suite Samples, SU 9

	Corehole ID#																	
Model Layer	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727
1	A	A	A	A	A		A											
2	B	B	B	B	B	A	B	A	A		A						A	
3	C	C	C	C	C	B	C	B	B		B					A	B	A
4	D	D	D	D	D	C	D	C	C	A	C	A	A		A	B	C	B
5	E	E	E	E	E	D	E	D	D	B	D	B	B	A	B	C	D	C
6		F	F	F	F	E	F	E	E	C		C	C	B	C	D	E	D
7		G		G	G	F	G	F	F	D		D	D	C	D	E	F	E
8		H		H		G	H	G	G	E		E	E	D	E	F	G	F
9				I		H	I	H	H	F		F	F	E	F	G	H	
10				J		I	J			G		G	G	F	G	H	I	
11						J				H		H	H	G	H		J	
12										I		I	I	H				
13										J		J	J	I				
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 3-20 Spatial Distribution (Vertical) – Full-Suite Samples, SU 19

Model Layer	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749
	Corehole ID#																					
1		A			A				A													A
2					B				B													B
3	A		A		C				C													C
4	B		B	A		A	A	A	D	A	A		A	A	A		A	A	A	A		D
5	C		C	B		B	B	B	E	B	B	A	B	B	B	A	B	B	B	B	A	E
6				C		C	C	C	F	C	C	B	C	C	C	B	C	C	C	C	B	F
7						D	D	D	G	D	D	C	D	D	D	C	D	D	D	D	C	G
8							E	E		E	E	D	E	E	E	D	E	E	E	E	D	H
9							F	F		F		E	F		F	E	F	F		F	E	I
10							G						G		G	F	G	G		G	F	J
11																G	H	H		H	G	
12																	I				H	
13																	J				I	
14																					J	
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 20

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 2L. 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 containers in which the soil was field blended. MACTEC utilized an ingenious apparatus, called a "Tumble Drum", which was custom-made for this task. The soil was placed in 5-gallon plastic pails with open-head screw on lids. The sample material was sealed in the pails, which, in turn, were secured in the "Tumble Drum" apparatus.[4] Field personnel rotated the drum for a minimum of 30 seconds to thoroughly blend the soil (Figure 3-22).

Figure 3-22 Field Blending Using Tumble Drum

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

[4] The field sampling procedure allowed for field blending by alternative methods such as mixing the soil in a stainless steel bowl. This alternative method was occasionally used when the soil composition favored its use (e.g. soil composition was super-saturated).

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 3-23). 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 3-24). No preservation methods were necessary for this sample container type. Sampling equipment was either discarded or decontaminated between each sample.

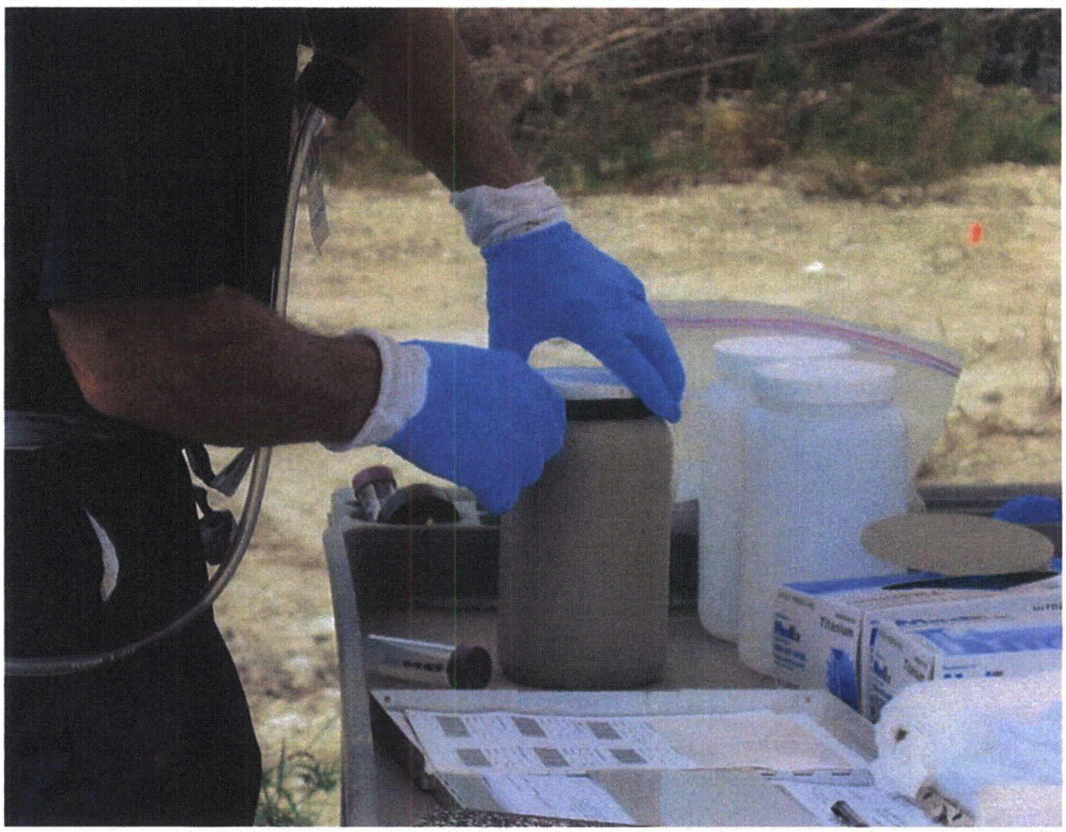

Figure 3-23 Collection of 2-L Soil Sample

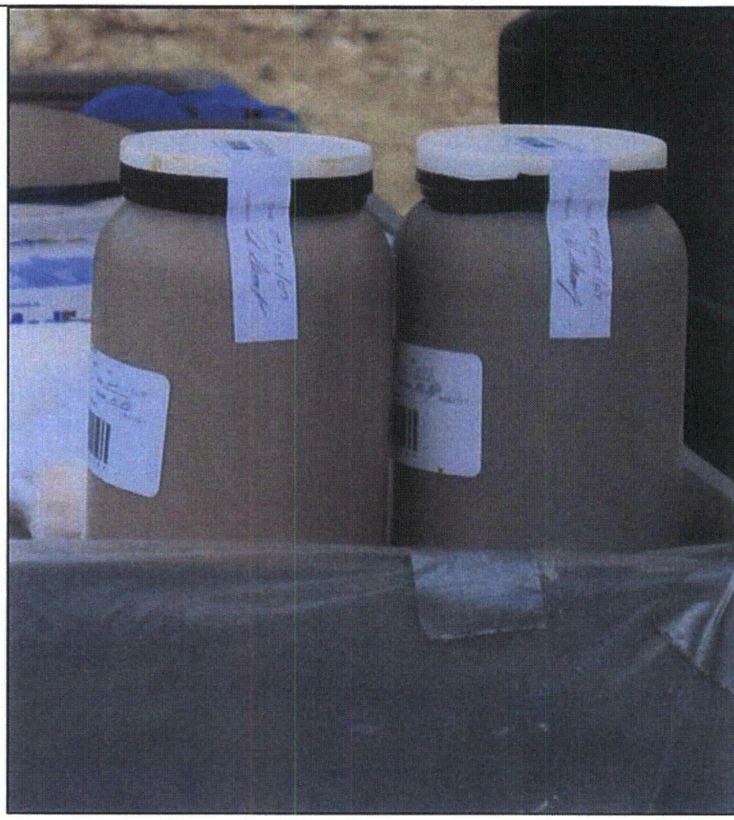

Figure 3-24 2-L Poly Jar Filled with Sample Material and Sealed

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, MACTEC developed and utilized a proprietary database called the Field Sample Tracking Program. Uniquely adapted to this characterization effort, MACTEC personnel used Microsoft Access software (Microsoft, 2003) 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 3-25). 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 2, 8, 9, 19, and 20 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 that 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): 1125
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 Samilkan [signature] (Print and Sign) **Date:** 07/12/07

NFS File Classification: DCM-23-05-02

Figure 3-25 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 3-25). 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 3-26). Samples requiring non-radiological analyses were shipped directly to Paragon Analytics (Paragon) in Fort Collins, CO 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 2, 8, 9, 19, and 20 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. MACTEC 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.

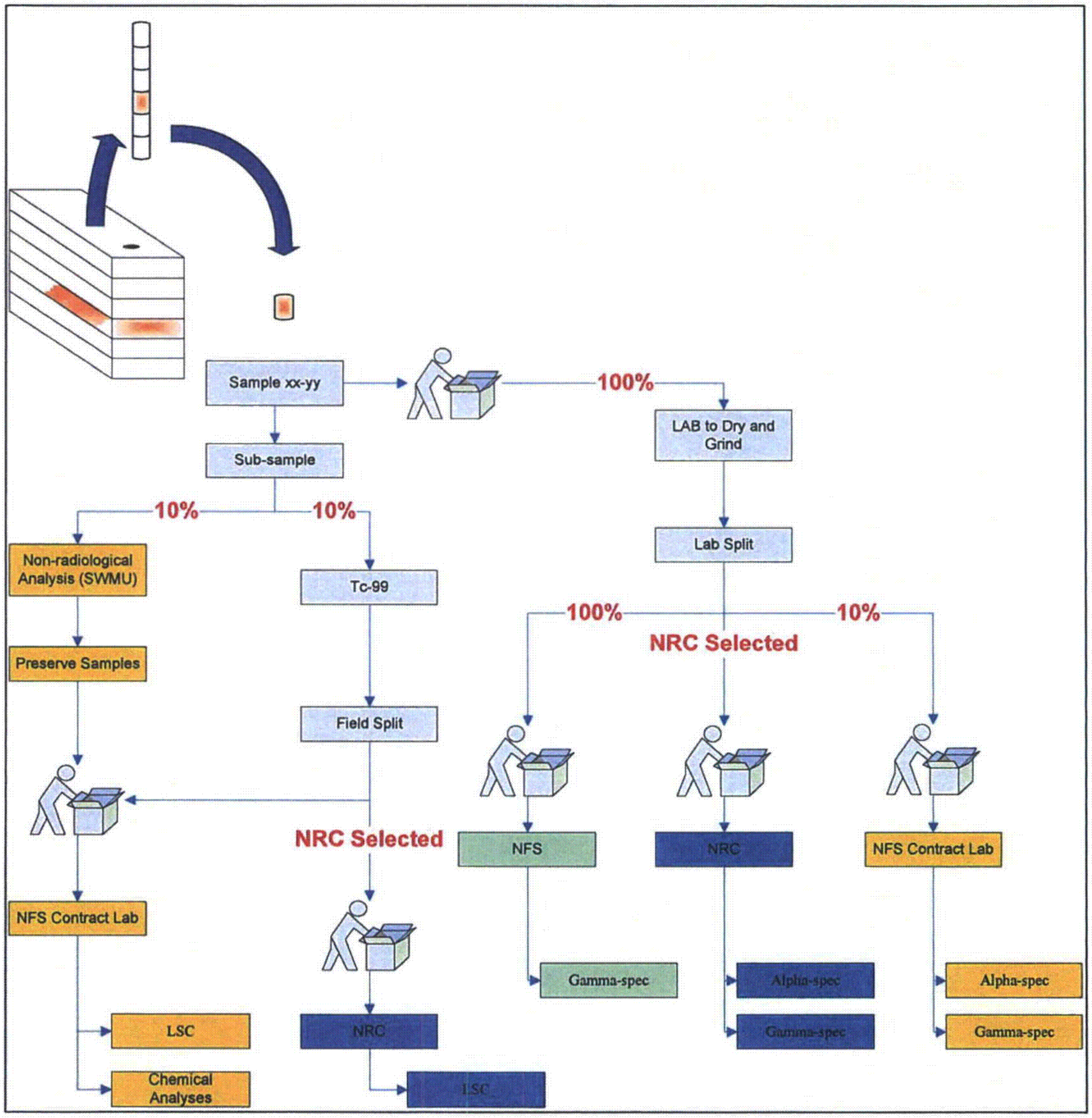

Figure 3-26 NFS Sample Flow Diagram

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 first received, catalogued, and verified against the MACTEC 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 3-27) 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.

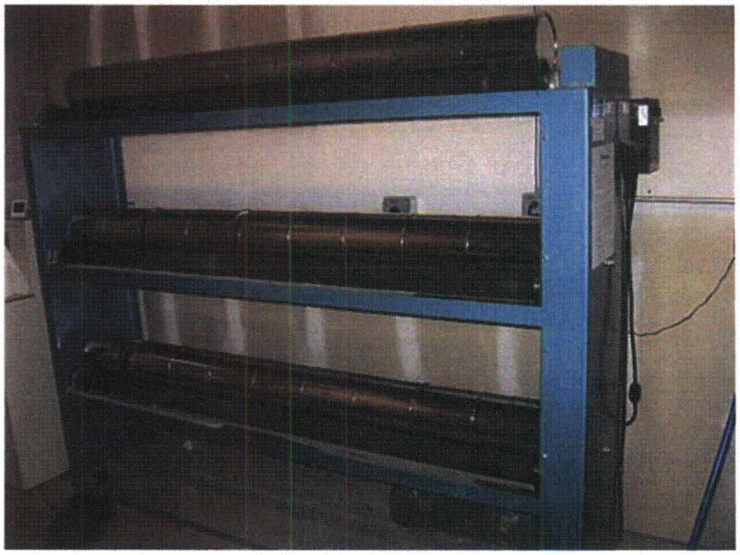

Figure 3-27 Example of Teledyne Jar Mill Machine with Sample Containers