BROOKHAVEN NATIONAL LABORATORY

FINAL

REMEDIAL ACTION FIELD SAMPLING PLAN AREA OF CONCERN 10 BUILDING 811 WASTE CONCENTRATION FACILITY

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1.0 OVERVIEW

The purpose of this Field Sampling Plan (FSP) is to guide the collection and analysis of samples supporting the remediation of radiologically contaminated soil at the Brookhaven National Laboratory (BNL), Upton, Suffolk County, New York. The remedial activities consist of the excavation and disposal of radiologically contaminated soils to meet prescribed cleanup goals and the removal, demolition, segmentation, and disposal of six underground storage tanks from Area of Concern (AOC) 10 Building 811 Waste Concentration Facility, as defined in the *Operable Unit (OU) I Record of Decision (ROD)*. The scope of remedial work and the historical background of the Building 811 Waste Concentration Facility are outlined in detail in the *Remedial Action Work Plan AOC 10 Building 811 Waste Concentration Facility* (BNL, 2001).

Sampling activities will be performed under the direct supervision of BNL's Environmental Restoration Division (ERD) and in full compliance with the OU I ROD, and the United States Environmental Protection Agency (EPA) requirements. Sampling activities will fulfill the obligations of the United States Department of Energy (DOE) for the BNL site, as established in the Interagency Agreement (IAG) between the DOE, EPA and the New York State Department of Environmental Conservation (NYSDEC).

1.1 OBJECTIVES

The primary objectives of the sampling activities for the AOC 10 remedial action are outlined below:

- To confirm the removal of radiologically contaminated soil within the AOC 10 excavated areas.
- To confirm the removal of soil contamination remaining following the removal of six Underground Storage Tanks (USTs).
- Provide supplemental data to guide remediation activities.

1.2 HEALTH AND SAFETY PLAN

The Health and Safety Plan (HASP) will be provided by the contractor and approved by BNL prior to the commencement of any field activities.

1.3 SAMPLING ORGANIZATION AND RESPONSIBILITY

The organization of the sampling activities for the AOC 10 remedial action is designed to provide a clear line of functional and program responsibility, and authority supported by a management control structure. An organizational chart is provided in Figure 1 of the Remedial Action Work Plan. The control structure involves BNL's ERD, Plant Engineering (PE), and Field Engineer, whose overall responsibilities include, but are not limited to the following:

- Establishing clearly defined lines of communication and coordination;

- Quality Assurance and Quality Control;
- Health and safety compliance in accordance with the HASP;
- Sampling and analysis coordination; and
- Oversight of sampling activities.

1.3.1 ENVIRONMENTAL RESTORATION DIVISION

The ERD is BNL's responsible project management group for this remedial action. The Project Manager from ERD will be responsible for compliance with the IAG, including documentation of conformance with the OU I ROD and completion of the closeout report.

1.3.2 FIELD ENGINEER

The Field Engineer will be an authorized representative of BNL and provide full-time supervision for all remedial field activities. The Field Engineer will have the authority to review and approve Subcontractor work.

The Field Engineer will initiate engineering change notices and non-conformance reports to submit to BNL. In addition, the Field Engineer will coordinate progress photos, maintain logbooks and be responsible for submitting daily and monthly reports. The Field Engineer will maintain these documents in a project file.

1.3.3 HEATH AND SAFETY OFFICER

The contractor Health and Safety Officer (HSO) will be assigned by the contractor to the site on a full-time basis for the duration of the project. The HSO will be responsible for the following: implementing and enforcing the HASP during field activities; maintaining all health and safety documentation onsite; upgrading/downgrading the level of personnel protection based on site conditions; performing site-specific training to all field personnel; ensuring that all personnel have reviewed the HASP; and communicating with the BNL Field Engineer to resolve any questions or issues which may arise during field activities.

The HSO will be selected by the contractor based on experience, management ability, and authority. The HSO will have experience in hazardous and radioactive waste remediation, and Health and Safety Plan implementation.

1.3.4 ANALYTICAL LABORATORIES

BNL will be responsible for obtaining the services of one or more analytical laboratories to fulfill the analytical and quality assurance requirements of this contract. Each laboratory will be audited by BNL or its authorized representative to verify that laboratory procedures are in accordance with appropriate standards prior to granting approval of the laboratory for use as a Subcontractor.

2.0 SITE BACKGROUND

At the Waste Concentration Facility, Building 811, liquid radioactive waste received from the Brookhaven Graphite Research Reactor, the Hot Laboratory Complex-Building 801, and the High Flux Beam Reactor, was temporarily stored and eventually distilled to remove particulates, and suspended and dissolved solids. The D-waste tanks (Tanks D-1, D-2 and D-3) were three 100,000 gallon aboveground storage tanks that were part of the original Waste Concentration Facility configuration. BNL defines D waste as liquid waste with a gross beta concentration greater than 90 picoCuries/milliliter (pCi/ml). The tanks were used to store the received waste at the Waste Concentration Facility from 1949 to 1987, when they were taken out of service.

Three documented incidents of leaks from the D-tanks have occurred. In 1982, a leak was discovered around a nipple in a valve at the bottom of Tank D-1. Tank D-1 was subsequently removed from service and emptied: however, some leakage continued from remaining sludge in the bottom of the tank. In 1985, a pin-hole leak was discovered in the side plate on the northwest side of Tank D-3. The wall plate was tested for soundness and a small patch was welded on for repair. The third leak occurred in 1987, when Tank D-3 was found to be leaking from the bottom seam between the tank bottom plate and a side wall plate. There are no documented incidences of leakage from Tank D-2.

All three tanks were dismantled and removed in 1995 as a removal action under the DOE/U.S. Environmental Protection Agency / New York State Department of Environmental Conservation Interagency Agreement. The contaminated concrete pads were given an additional temporary cover in 1998 to prevent the collection of rainwater that could become contaminated through leaching. As part of the D-tanks project, an engineering evaluation / cost analysis report (EE/CA), extensive sampling, and analysis of surface and subsurface soils were conducted around and under the foundation pad of the tanks. These data revealed levels of cesium-137 and strontium-90 higher than screening levels identified in the remedial investigation.

In addition to the three D-tanks, six 8,000-gallon stainless steel underground storage tanks (USTs) are located 50 feet north of Building 811. The six USTs (AOC 10C) were used to store class A and B radioactive wastes.

2.1 REGULATORY FRAMEWORK

On December 21, 1989, the BNL site was included on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List (NPL). In May 1992, the Department of Energy (DOE) entered into an Interagency Agreement (IAG) with the United States Environmental Protection Agency (EPA) and the New York State Department of Environmental Conservation (NYSDEC) under CERCLA, Section 120. The IAG established the framework and schedule for characterizing, assessing and remediating the site in accordance with the requirements of CERCLA, and the Resource Conservation and Recovery Act (RCRA). BNL originally grouped the AOCs into seven Operable Units (OU), which have subsequently been combined into six OUs.

The nature and extent of the radiologically-contaminated soil in AOC 10 have been addressed in the *Final Operable Unit II/VII Remedial Investigation Report* (IT Corporation, February 1999) and the supplemental soil sampling conducted by BNL in 1999 (BNL, 1999). An evaluation and recommendation of remedial alternatives for this soil was presented in the *Final Feasibility Study Report Operable Unit I and Radiologically-Contaminated Soils* (CDM Federal, March 1999). The remedial design for the AOC 10 remedial action activities was provided in the *Remedial Design and Specifications for Remedial Action Operable Unit I Contaminated Soil and Debris* (URS, October 2000). The *Record of Decision* (DOE, August 1999) selected excavation and offsite disposal as the remedial alternative for the radiologically-contaminated soil and underground storage tanks in AOC 10.

2.2 SITE CLEANUP CRITERIA

The cleanup goals established for radionuclides are based on two criteria recommended in EPA guidance,

- A total annual dose limit of 15 mrem in a year from all radionuclide contaminants through all exposure pathways, and
- A total annual dose limit of 4 mrem in a year from beta radiation and photon emitting radionuclides through the drinking water exposure pathway.

The NYSDEC guidance for radionuclides of 10 mrem/yr above background has been adopted as an As Low As Reasonably Achievable (ALARA) goal.

Post remediation sampling and dose assessments will be performed to ensure that the dose limit criteria are met for all radionuclides that are present. Sample analysis will include gross alpha, gross beta, tritium, strontium-89/90, isotopic thorium, isotopic plutonium, and gamma emitters by gamma spectroscopy. Cleanup levels for specific radionuclides corresponding to the dose criteria were calculated using the DOE Residual Radioactive Material Guidelines computer code, *RESRAD*, based on BNL site-specific conditions and a residential land use scenario following 50 years of institutional control of the site. Cleanup criteria for radionuclides that might be present are identified in Table 1 of the *Remedial Action Work Plan AOC 10 Building 811 Waste Concentration Facility* (BNL, 2001).

While many radionuclides have been detected in the remediation area, the primary radionuclides of concern for AOC 10 are cesium-137 and strontium-90 (see section 1.5.1, Historical Data Summary, in the *Remedial Action Work Plan for AOC 10*). These radionuclides are identified specifically in the following sections when examples are provided, but analyses and interpretations will be performed for all radionuclide contaminants of concern.

3.0 DATA NEEDS AND SAMPLING OBJECTIVES

The sampling program for the AOC 1O Remedial Action has been primarily developed to confirm the removal of all Cs-137 and Sr-90 contaminated soil (Cs-137 > 23 pCi/g and Sr-90 > 15 pCi/g) within the AOC 10 areas. Data needs and data quality objectives are defined in the following sections.

3.1 QA OBJECTIVES FOR MEASUREMENT

The QA objectives for measurement, the means by which quality will be measured and documented, will be achieved through the measurement of the following quality indicators:

3.1.1 PRECISION

Precision is a measure of the agreement between a set of replicate sample results. Precision is assessed by means of duplicate sample analyses including matrix spikes and matrix spike duplicates, laboratory control samples and laboratory control sample duplicates, laboratory duplicates, and field duplicate results compared with results of the original sample. Precision is generally expressed in terms of relative percent difference (RPD) as defined below:

$$RPD = \frac{|X_1 - X_2|}{(X_1 + X_2)/2} x100$$

where X_1 and X_2 are the two duplicate results.

3.1.2 ACCURACY

Accuracy is defined as the nearness of a measurement to its true value. Accuracy measures the average or systematic error of a method. Laboratory accuracy is assessed by spiking samples with known standards and calculating the percent recovery. Three types of recoveries are measured including matrix spikes, laboratory control spikes, and blind quality control spikes. Laboratory accuracy will be evaluated during the data validation process. Accuracy is reported in terms of percent recovery as defined below.

$$\%Recovery = \frac{|R - U|}{S} x100$$

where S = actual concentration of spike added
U = measured concentration in unspiked aliquot
R = measured concentration in spiked aliquot

3.1.3 REPRESENTATIVENESS

Representativeness expresses the degree to which sampling data represent the characteristics that are being measured. Field planning meetings, technical system audits, and oversight will provide opportunities to check that field procedures are being correctly implemented, thus helping to ensure the representativeness of the collected field data.

3.1.4 COMPARABILITY

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sample data will be comparable with other measurement data for similar samples and sample conditions. Data comparability will be maintained by using consistent standardized methods and units of measurement.

3.1.5 COMPLETENESS

Completeness is a measure of the amount of valid data obtained from the field investigation in comparison with the total amount of data that was collected. A minimum goal of 90 percent completeness for chemical and radiological data will be acceptable for data quality requirements.

3.1.6 SENSITIVITY

Sensitivity relates to the method detection limit necessary for each parameter. The detection limits must be low enough to meet the requirements for the contaminants of concern. The detection limits are specified in the BNL *Technical Specifications for Hazardous Chemical and Radiochemical Analytical Laboratory Services* (December, 1999).

3.1.7 DATA VALIDATION

Data validation is the procedure where analytical data is reviewed against established criteria to assure that results comply with analytical method and any other specified requirements. Data validation will be in accordance with the BNL *Technical Specifications for Hazardous Chemical and Radiochemical Analytical Laboratory Services* (December, 1999).

3.2 QUALITY ASSURANCE/QUALITY CONTROL SAMPLES (QA/QC)

QA/QC samples will be collected in accordance with BNL's Collection and Frequency of Field Quality Control Samples, which is provided in Appendix A. These samples will be analyzed in the same manner as the field samples. Each type of QC sample is described below.

3.2.1 FIELD DUPLICATES

Field duplicate samples will be collected and analyzed to assess the overall precision of the field sampling technique. Field duplicates samples will be collected at a rate of five percent, or one per 20 environmental samples collected. These duplicates will be submitted "blind" to the laboratory by using sample ID/UID (see Chain of Custody procedure provided in Appendix A) that are different from the associated environmental samples.

3.2.2 RINSATE BLANKS

Rinsate blanks, also known as field blanks or equipment blanks, will be used to assess the effectiveness of equipment decontamination. The frequency for rinsate blanks will be one per every 20 samples collected for each equipment type and for each sample matrix. Field blanks will be analyzed for the same constituents as the environmental samples and will be generated by pouring demonstrated analyte-free water over the decontaminated sampling tool.

4.0 SAMPLING REQUIREMENTS AND SURVEY METHODS

This section establishes the sample locations, number of samples required, and sampling procedures to ensure that all contaminated materials have been excavated. This information will then be used to substantially evaluate the attainment of remedial goals and determine project completeness.

This section also addresses the controls on protective equipment, instruments, and wastes to be implemented during sampling operations. Prior to the commencement of any remedial activities, a meeting will be held with the project team to review the requirements of the Work Plan, Field Sampling Plan, the HASP, and BNL's Pollution Prevention/Waste Minimization Plan, and to ensure that all supporting documentation has been completed.

4.1 CONFIRMATORY SAMPLING

While many radionuclides have been detected in the remediation area, the primary radionuclides of concern for AOC 10 are cesium-137 and strontium-90. These radionuclides are identified and discussed specifically in the following sections when examples are provided.

A two-step approach confirmation sampling following the MARSSIM approach will be conducted at the AOC 10 excavation areas. The first step will consist of an initial NaI detector walkover survey and the second will be analysis of systematic position samples using the ISOCS system for *in situ* gamma spectroscopy and the BetaScint instrument for Sr-90 analysis. Sampling and analysis will be performed in accordance with the Standard Operating Procedures provided in Appendix B.

For surveys of areas with Sr-90, the MARSSIM suggests using an easily detected radionuclide such as Cs-137 as a surrogate for Sr-90, which can be difficult or costly to analyze and detect. However, availability of the BetaScint™ instrument at BNL allows direct, economical and rapid analysis for Sr-90 on-site. Thus, in this analysis, Cs-137 and Sr-90 will each be analyzed for in each sample, and the conventional MARSSIM method of evaluating multiple radionuclides with individual measurements will be used. The Cs-137 activity will be used as a surrogate for Sr-90 in the walkover or surface scanning survey, where Sr-90 is not directly detected (see Section 4.1.1.2).

4.1.1 RADIOLOGICAL FINAL STATUS SURVEY

A final status survey will be performed to demonstrate that residual radioactivity in excavated areas satisfies the predetermined clean up goal. This radiological survey of the AOC 10 remediated areas will include two elements; a final status survey performed by BNL personnel and a verification of cleanup attainment by an independent authority. The Oak Ridge Institute for Science and Education (ORISE) will serve as an independent verification contractor for the project. ORISE will prepare a separate survey plan and will perform an independent field sampling survey to verify that cleanup goals are being met.

4.1.1.1 FINAL STATUS SURVEY DESIGN

The design of the final status survey was based on guidance provided in the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM). The survey has an integrated design, combining:

- A surface scanning meter survey to identify localized areas of elevated activity (100% of Class 1 and 25% of Class 2 areas);
- Measurements at systematic positions on a triangular grid to determine the average concentration of activity distributions in relatively large areas (Class 1, Class 2 and Reference areas); and
- Analysis of soil samples to confirm instrument readings (100% of high readings) or to verify on-site analysis (10% of *in situ* positions and samples analyzed on site will be sent to off site laboratory).

4.1.1.2 SURFACE SCANNING SURVEY

A walkover surface scan survey of each excavated area will be performed using a 2" x 2" sodium iodide (NaI) detector and the Eberline E600 ratemeter. The NaI detectors have been correlated to measure Cs-137 concentration in the surface soil by comparing instrument response to locations of elevated soil activity, which were then sampled and analyzed at an off-site laboratory. For the Eberline E600 meter, 20,000 counts per minute (cpm) or 20 kcpm is approximately equal to the cleanup goal. A graph of the instrument response to Cs-137 soil concentration is provided in Appendix C.

To facilitate data recording and to ensure uniform coverage of the surface, each area will be flagged with the triangular grid used for the systematic measurement survey. The final walkover survey will consist of a 100% surface scan of the excavated Class 1 areas and a 25% surface scan of Class 2 areas using an Eberline E600 with 2" x 2" Sodium Iodide detector. When the instrument indicates a response above background (approximately 1,000 cpm above the background in the reference area), the scan will be halted, the position of highest response will be located, and a stationary reading will be performed (with the detector within 1 in or 2 cm of the surface). The action level is determined by instrument alarm, set at 1,000 cpm above background. If the action level is met, a soil sample will be collected to quantify the activity. A discussion of the minimum detectable concentration detectable with the scanning instrument is provided in Appendix C. Position coordinates using a global positioning system will be recorded.

Since the NaI detector is insensitive to the Sr-90 contaminant, a ratio of Sr-90 to Cs-137 will be established based on the sampling analysis described in the next section. This ratio will enable the measurement of Cs-137 to be a surrogate for measuring Sr-90 during the surface scanning. The best estimate of the Sr-90 to Cs-137 ratio will be established using the DQO review process when sample analysis results are available.

4.1.1.3 SYSTEMATIC MEASUREMENT SURVEY

Using the methods recommended in MARSSIM, Chapter 5, the calculation of number and spacing for a systematic sampling pattern will be performed following remediation. This number of systematic samples, and the corresponding grid spacing between the samples, assures a statistically sufficient database for determining whether the average radioactivity concentration in each of the survey units meets or exceeds the cleanup goal.

Samples analyzed during the remediation efforts will be used to establish a Cs-137:Sr-90 ratio to enable use of the Cs-137 as a surrogate indicator of Sr-90. After remediation, the actual survey/sampling results will be used to develop a modified cleanup goal for Cs-137 using the methods in MARSSIM, §4.3.2. For example, for the case of contaminants present at a post-remediation Cs-137 to Sr-90 ratio of 4:1, the modified clean-up goals would be 16.6 pCi/g for Cs-137 and 4.15 pCi/g of Sr-90.

a. Classifying survey units

Areas within AOC10 were categorized using MARSSIM methods to define the survey design.

- *Class 1 Areas* are those areas with contamination levels greater than the clean-up goal. The areas in AOC 10A that are designated for excavation (see Appendix A of the Remedial Action Work Plan) constitute the Class 1 survey unit (see Table 1). This area has been sampled and shown to have levels of contaminants significantly greater than the remediation clean-up goals (23 pCi/g of Cs-137 and 15 pCi/g of Sr-90).
- *Class 2 Areas* are those areas which have been found to be contaminated but at levels below the clean-up goals. The area of the AOC periphery around the designated excavation area is considered to constitute the Class 2 survey unit. Previous sampling of these areas showed the average concentration of Cs-137 to be approximately 6.2 pCi/g with a standard deviation of approximately 6.8 pCi/g, while the average concentration of Sr-90 is approximately 0.14 pCi/g with a standard deviation of approximately 0.05 pCi/g (see data in Appendix C).
- *Class 3 Areas* are those considered to be uncontaminated or minimally affected by contaminants. Because the remainder of Brookhaven National Laboratory (BNL) is under institutional controls, these areas will be evaluated at a later date, and surveys of Class 3 areas for this remedial action will not be performed.
- A site radiological *reference area* (background area) is defined as an area that has similar physical, chemical, radiological, and biological characteristics as the site area being remediated, but which has not been contaminated by site activities. The distribution and concentration of background radiation in the reference area should be the same as that which would be expected on the *site* if that *site* had never been contaminated. The BNL Helipad is the reference area, from which representative reference measurements will be compared to measurements performed in AOC 10A survey units. Data from measurements in the Helipad area are available from prior remedial efforts and will not be repeated.

This classification resulted in one Class 1 survey unit, one Class 2 survey unit, and one reference area, as indicated in Table 1.

Table 1: Parameters Used to Classify Survey Units for MARSSIM-Based Survey

Survey Unit	10A-1 (note 1)		10A-2 (note 2)	10A-R
Class	1		2	Reference
Description	Former "D" Tank Area, "A" & "B" Tank Area West and North of Bldg 811		Periphery of Excavated Areas Bldg 811 vicinity	BNL Helipad
Area	15,000 ft^2 / 1,400 m^2		20,000 ft^2 / 1,850 m^2	N/A
Contaminant	Cs-137	Cs Surrogate For ratio 4:1	Cs Surrogate For ratio 40:1	N/A
DCGL (pCi/g)	23	16.6	22.2	N/A
LBGR (pCi/g)	15	12	6.22	N/A
Mean Activity (pCi/g) following remediation			Cs-137: 6.22 Sr-90: 0.14	Cs-137: 0.47 Sr-90: < 0.14
Variability (σ) (pCi/g)			Cs-137: 6.75 (14 values)	Cs-137: 0.21 (20 values) Sr-90: 0.05 (5 values)
Relative Shift Δ / σ	See Note 1		2.37	N/A
P_r (Table 5-1)			0.97725	N/A
N/2 (Table 5-3)			Sign Test 15	Sufficient to meet selected value for test of survey unit
Triangular grid node separation			39 ft 12 m	N/A Random

Note 1: At this time calculation of the number of samples and grid spacing for the Class 1 area (Survey Unit 10A-1can not be performed. For planning purposes, surrogate ratio is assumed Cs-Sr = 4:1, with other radionuclides at insignificant levels, if present; final concentration of Cs-137 following remediation will most likely be a small fraction of the DCGL. Final calculation using methods in *MARSSIM* Chapter 5 will be performed following remediation when actual values of concentration of Cs-137 and Sr-90 and other radionuclides in the remediated soil will be available. The calculated value indicating the greatest number of samples to satisfy the statistics will be selected. Each sample will be analyzed for Cs-137 and Sr-90 on site. In addition, 10% of samples will be sent to an off-site laboratory for analytical verification. All final samples will be analyzed for gross alpha, gross beta, isotopic thoriums, isotopic uraniums, and isotopic plutoniums.

Note 2: Sampling has indicated that Sr-90 is essentially **Not Detected** in the Class 2 area (Survey Unit 10A-2) and in the reference area (ave = 0.14, less than MDA; ratio Cs:Sr = 40:1), so that survey of Class 2 is only necessary for Cs-137. However, the number of samples indicated for Cs-137 analysis also will be analyzed on-site for Sr-90, and 10% of samples will be sent to an off-site laboratory for analytical verification.

Note 3: Analysis for site release for Sr-90 will be performed with Sign Test (against the Non Detect/less than MDA data that shows contaminant not present in the background) and with the WRS Test (against the actual small numerical average value) to verify that site meets release criteria.

b. Statistical Test Selection

Since Cs-137 and Sr-90, the primary contaminants of concern, appear in background soils due to atmospheric fallout, the MARSSIM recommends a statistical analysis based on the Wilcoxon Rank Sum (WRS) Test. At BNL, Sr-90 is observed at levels below the laboratory Minimum Detectable Activity (MDA) so that the Sign Test may be more appropriate. The post-remediation data will be assessed using both statistical tests, when possible, to assure conformance to the most restrictive case.

c. Determining the sampling grid size and number of samples

The number of samples needed to perform the statistical test will be based upon the selection of a remediation guideline, the specification of acceptable decision error rates, and the standard deviation(s) of the contamination of interest in the remediation area and in the reference background area.

- A Derived Concentration Guideline Level (DCGL) and a Lower Bound of the Gray Region (LBGR) level need to be selected. In this case it is assumed the DCGL will be the remediation cleanup goal of 23 pCi/g for Cs-137 and 15 pCi/g for Sr-90, for individual nuclides and a surrogate DCGL when the Cs:Sr ratio has been determined. MARSSIM recommends initially selecting a LBGR at one-half the DCGL.
- The acceptable probability of making decision errors decision errors has been established:

  $\alpha = 0.05$ for Type I, False Positive or False Rejection decision error, and

  $\beta = 0.05$ for Type II, False Negative or False Acceptance decision error.
- An estimate of the contaminant variability (σ) in the background (σ_r) and in the remediation (σ_s) area will be performed. When σ_r is different than σ_s the larger of the two values will be used for calculating the number of samples. In this case for soils, the units for the activity concentration parameters will be in pCi/g (or Bq/kg).
- In prior measurements of the reference area, the background mean for Cs-137 is 0.47 pCi/g with a standard deviation (σ_r) of 0.21 pCi/g.

d. Relative Shift Calculations

A relative shift is calculated by dividing the difference or shift (Δ) between the DCGL and LBGR by the estimated standard deviation of the survey area. MARSSIM recommends that the relative shift be maintained between 1 and 3. This can be accomplished by altering the selected LBGR, if necessary.

For the Class 2 survey unit, the sample results from the *Engineering Evaluation / Cost Analysis for D Tanks Removal Action* (Dames and Moore, 1993) were used to calculate an approximate mean and standard deviation. This was done because it is not expected that these units will be remediated. Consequently, the distribution of the contaminants within the Class 2 Survey units is not expected to change appreciably upon completion of the remediation activities.

The number of sample data points is determined by using either the following equation, Table 5.3 from the MARSSIM document, or the *COMPASS* software utility.

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

Where

$Z_{1-\alpha}$ = Decision Error Percentile for False Positves

$Z_{1-\beta}$ = Decision Error Percentile for False Negative

α = The specified maximum probability of a Type I error; reject the null hypothesis of contamination being present when it is true

β = The specified maximum probability of a Type II error; accept the null hypothesis of contamination being present when it is false

P_r = probability that a random measurement from the suvey unit exceed a random measurement from background reference area by less than the DCGL

N is the total number of sample points for each survey unit/reference area combination. N/2 becomes the number of samples for the reference area and also for the survey unit.

There is already data available for the BNL Helipad, which can be used for the reference area so it will not be necessary to perform reference area samples. Their inclusion in the tables is simply for information and table calculation completeness.

The number of calculated survey locations n (n = N/2) is used to determine the grid spacing, L, of the systematic sampling pattern. The grid area that is bounded by these survey locations is given by $A = 0.866 * N/2 * L^2$. The distance between each sample point is determined by $L = [A/(N/2*0.866)]^{1/2}$. An initial sample co-ordinate is randomly selected and sample locations determined by triangular spacing (L) from the start of the randomly selected co-ordinate.

4.1.1.4 COLLECTING CONFIRMATORY SAMPLES FOR LABORATORY ANALYSIS

Soil samples of the surface soil will be obtained for laboratory analysis to confirm the results of instrument surveys and *in situ* gamma and beta analyses. Samples will be collected randomly at 10% of the *in situ* locations, with a minimum of one confirmation sample per survey unit. Laboratory samples will be analyzed for Cs-137 and Sr-90, the contaminants of concern at AOC 10.

In the event that sampling results show Cs-137 and Sr-90 concentrations above the cleanup levels of 23 pCi/g and 15 pCi/g, excavation will continue in one-foot increments (vertically and/or horizontally), and sampling and analysis will be repeated until cleanup goals are achieved. In addition, Oak Ridge Institute for Science and Education (ORISE) will be retained as an Independent Verification Contractor (IVC). ORISE will prepare an independent survey plan and perform an additional field verification sampling survey to document that cleanup goals have been met. Subsequent to the backfilling activities, a post closure dose assessment will be performed on the "as built" site conditions to measure post closure dose exposures for each remediated area.

Excavation of contaminated soil will be considered complete when both field and laboratory analysis results demonstrate that remediation requirements have been met.

4.1.2 PERFORMING ON SITE CS-137 AND SR-90 MEASUREMENTS

The MARSSIM method of survey design establishes a number of and location for finite samples to be obtained for contaminant quantification. In this final status survey, *in situ* gamma spectrum and *ex situ* sample analysis for Cs-137 and Sr-90 will be performed in accordance with the Standard Operating Procedures provided in Appendix B in addition to the collection and analysis of physical samples.

4.1.2.1 ON SITE GAMMA SPECTROSCOPY

In situ analysis has the advantage of the availability of results in real-time, as well as the elimination of effort, materials, and shipping and analysis expenses of physical samples. One disadvantage is that *in situ* analysis of surface soil usually reports a concentration value less than the laboratory sample, since *in situ* analysis is based on field samples that contain ambient moisture as well as non-radioactive rocks and biomass that are removed prior to laboratory analysis.

The BNL gamma spectrometer (Canberra ISOCS) was calibrated to Cs-137 in surface soil by acquiring gamma ray spectra *in situ* at locations of elevated activity on site at BNL prior to remediation. Samples were obtained from the *in situ* locations, and the samples were submitted for laboratory gamma spectrum analysis. The correlation curve of *in situ* instrument response to measured Cs-137 soil activity is provided in Figure 1. The correlation curve exhibits a strong linear response relation between the two methods. The slope of the line (0.70) is indicative of the under-response of the *in situ* measurement; the results are made comparable by adjusting upwards the *in situ* results (divide the reported *in situ* results by 0.70).

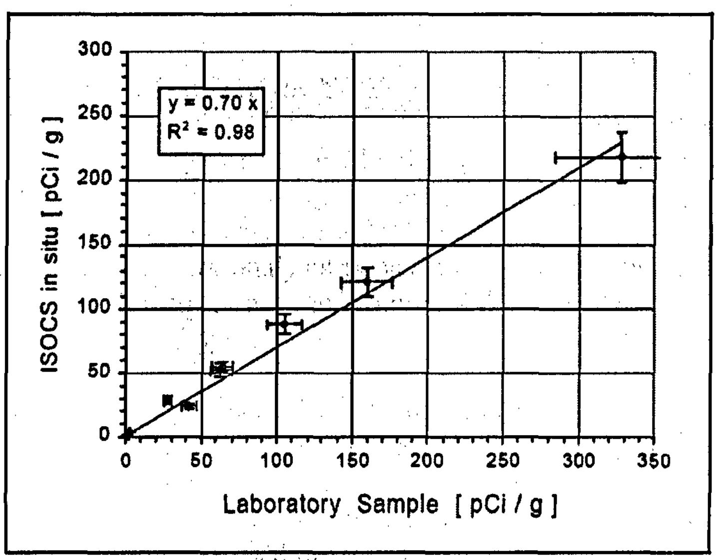

Figure 1. Correlation between ISOCS *in situ* and laboratory sample analysis

4.1.2.2 ON SITE BETA SPECTROSCOPY

Quantification of strontium-90 using conventional EPA laboratory methods typically takes a minimum of two weeks (accelerated turnaround) or a month (standard turnaround). As a potential solution to this time delay, use of the BetaScint™ fiber-optic sensor has been applied and evaluated at BNL as a technique to rapidly quantify strontium-90 in soil samples. The preliminary results of this evaluation indicate that the BetaScint™ system produces accurate and precise results with a quick turnaround time (approximately 20-30 minutes) and a detection sensitivity of approximately 1 pCi/gram. The operating procedures for the BetaScint™ are provided in Appendix B.

The BetaScint™ system consists of a multi-layer beta scintillation detector array with a beta radiation entrance window measuring 30-cm by 60-cm (DOE, 1998). Scintillating fibers are fashioned into ribbons, which are stacked vertically. Soil samples are prepared, transferred to large area counting trays, and positioned beneath the system entrance window for analysis. Beta particles that pass through the entrance window excite electrons in the scintillating ribbons resulting in the emission of light pulses, which are counted by photo-multiplier tubes.
The BetaScint™ system relies on the relatively high energy of the beta particle emitted from yttrium-90 as a result of strontium-90 decays to quantify Sr-90 in the presence of other beta-emitting radionuclides and ambient background radiation. For calibration and operation, a 1 to 2 pound soil sample is typically dried, sieved to remove organic matter and rocks over 0.25 inches in size, and spread evenly over a large area counting tray. The sample is then positioned beneath the radiation entrance window of the detector and counted for five minutes. Following the analysis, the system reports the measured strontium-90 activity concentration in the soil, based the detection efficiency established using spiked site soils.

Routine daily operations of the BetaScint™ system include the performance of daily quality control checks and background measurements. Quality control checks consist of analysis of a calibration standard of known activity. The results of the quality control checks are compared against established acceptance criteria to determine whether the instrument is functioning properly. Background checks are performed by counting without a sample in place (i.e., blank sample tray.) These measurements, which are performed daily at a minimum, are subtracted from gross sample counts to establish net detector response.

4.1.3 INTERPRETATION OF SURVEY RESULTS

Decision criteria and survey components are discussed further in the following sections. Excavation of contaminated soil will be considered complete when both field and laboratory analysis demonstrate that remediation requirements are met.

4.1.3.1 EVALUATION OF MULTIPLE RADIONUCLIDES

Each radionuclide's Wilcoxon Test Cleanup Goal (CGw) corresponds to the site release criterion that results in the regulatory limit dose or risk. However, in the presence of multiple radionuclides, the total of the CGw for all radionuclides could exceed the release criterion. In this case, the individual CGw need to be adjusted to account for the presence of multiple radionuclides contributing to the total dose. The MARSSIM suggests the use of the unity rule as one method to adjust the evaluation for the presence of multiple radionuclides. For the situation of the AOC 10 remediation, where there may be multiple radionuclide contaminants present, including Cs-137 and Sr-90, the unity rule takes the form:

$$[C_{Cs\text{-}137} / CGw_{Cs\text{-}137}] + [C_{Sr\text{-}90} / CGw_{Sr\text{-}90}] + \ldots [C_n / CGw_n] \leq 1$$

where

C = measured concentration
CGw = guideline value for each individual radionuclide (1, 2, ..., n)

The unity rule, represented in the expression above, is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one. This unity rule is applied separately for each of the dose limit criteria (all pathways and drinking water pathway).

4.1.3.2 ELEVATED MEASUREMENT COMPARISON

The MARSSIM statistical tests on the results of the systematic sampling evaluate whether or not the average residual radioactivity in a survey unit exceeds the cleanup goal (CG_W), which is 23 pCi/g for Cs-137. Since the average includes values that are higher and lower than the cleanup goal, there should be a reasonable level of assurance that any small areas of elevated residual radioactivity are not too high. In MARSSIM, the process of determining the value that is "too high" is termed the cleanup goal elevated measurement comparison CG_{EMC}.

One method for determining values for the CG_{EMC} is to modify the CG_W using a correction factor that accounts for the difference in area and the resulting change in dose or risk. That is, as the concentration of Cs-137 is elevated, the area must be reduced to keep the risk from rising. The area factor (AF) is the magnitude by which the concentration within the small area of elevated activity can exceed CG_W while maintaining compliance with the dose-based release criteria.

Table 2 provides area factors. The AFs were generated using the RESRAD exposure pathway model for a unit concentration of 37 Bq/kg (1 pCi/g). For consistency with the assumptions for post remediation residential land use, the meat, milk, and aquatic foods ingestion pathways were suppressed, and the thickness of the residual contamination layer was assumed to be 0.15 m (0.5 ft). The area of contamination in RESRAD defaults to 10,000 m^2; for this AF calculation, the area was varied to values of 9, 16, 25, 50, 100, 400, 900, or 5,000 m^2. Other parameter values for the RESRAD code were not changed from the default values. The area factors were then computed by taking the ratio of the dose (or risk) generated by RESRAD for the default 10,000 m^2 to the dose generated for the other areas listed. If the CG_W for residual radioactivity distributed over 10,000 m^2 is multiplied by this AF value, the resulting concentration distributed over the specified smaller area delivers the same calculated radiation dose.

Table 2: Outdoor Area Dose Factor for BNL Surface Soils Containing Cs-137

Area of Elevated Activity	(m^2)	9	16	25	50	100	400	900	5,000	10,000
	(ft^2)	100	170	270	540	1,075	4,300	9,700	53,800	107,600
Area Factor		2.5	1.9	1.7	1.4	1.2	1.1	1.0	1.0	1.00

For example, from Table 2, an area factor of approximately 1.7 is calculated for Cs-137 for an area of 25 m^2. Thus, for the cleanup goal of 23 pCi/g which corresponds to the annual dose criterion, an area of activity up to 39 pCi/g (1.7 x 23) will not exceed the annual dose criterion, if the elevated area is limited to 25 m^2 or less.

If residual radioactivity is found as an isolated area of elevated activity, in addition to residual radioactivity distributed relatively uniformly across the survey unit, the unity rule can be used to ensure that the total dose is within the release criterion [MARSSIM Equation 8-2]:

$$\frac{\delta}{CG_W} + \frac{(\text{average concentration in elevated area} - \delta)}{(\text{area factor for elevated area}) \times CG_W} < 1 ,$$

where δ = the average concentration in the survey unit.

If there is more than one elevated area in a survey unit, a separate term can be included for each.

4.2 PERSONAL PROTECTIVE EQUIPMENT

Sampling personnel will be required to wear Personal Protective Equipment (PPE) appropriate to the anticipated hazard of operation. PPE will be selected in accordance with the AOC 10 Health and Safety Plan prepared by the contractor.

4.3 DECONTAMINATION

Decontamination of BNL's and the contractor's equipment and tools will be the responsibility of BNL and the contractor, respectively. Decontamination activities will be performed within the contamination areas. All tools and equipment will be decontaminated with dry methods, utilizing brooms, wire brushes and putty knives. Decontamination of sampling equipment will be performed in accordance with BNL's Decontamination of Environmental Sampling Equipment Procedure provided in Appendix D. Decontamination water will be collected and managed as waste.

4.4 EQUIPMENT

Each piece of field equipment used for measuring, monitoring, or analytical purposes will be periodically calibrated and maintained to assure accuracy within specified limits. Each piece of equipment will be checked on a daily basis, prior to any usage. Field personnel will be required to calibrate and field check the equipment. At a minimum, field equipment will be calibrated at the frequency recommended by the manufacturer. Information related to the field calibration will be noted in the field logbook. This information should include, at minimum, the instrument identification number, date and time of calibration, the person performing calibration, adjustments made, any problems noted during calibration, and a record of calibration measurements. BNL Facilities Support Services will be responsible for the releasing of all equipment and tools.

4.5 HANDLING AND DISPOSITION OF WASTES

Waste generated during the remediation activities will be characterized, segregated, stored, and disposed off in accordance with BNL's Pollution Prevention/Waste Minimization Plan and the *Bulk Waste Characterization for Off-site Disposal Sampling Procedure* (August, 2000) provided in Appendix E.

Handling and disposition of investigation-derived wastes is discussed in detail in Section 4.0 "WASTE MANAGEMENT AND DISPOSAL" of the Remedial Action Work Plan.

5.0 SAMPLING DOCUMENTATION

This section establishes the guidelines for documenting the possession of the samples from the point of collection to receipt by the analytical laboratory.

5.1 SAMPLING AND RECORDING

Appendix A contains BNL's Chain-of-Custody Procedure, which describes the procedures to properly document all collected samples.

Each sample will be identified with a set of information relating individual sample characteristics. The required information consists of Sample ID/UID, Depth, Date, Time, and Matrix, which are further detailed in Appendix A.

6.0 DOCUMENTATION MANAGEMENT AND SAMPLE CONTROL

Each submittal of samples for analysis will be properly documented in accordance with BNL's Chain-of-Custody Procedure (Appendix A) to ensure timely, correct, and complete analysis and to support the use of analytical data in potential enforcement actions. The documentation system provides the means to individually identify, track and monitor each sample from the point of collection through final data reporting. Project documentation also includes proper documentation of changes to approved project plans and maintaining the field logbooks.

6.1 DOCUMENTATION MANAGEMENT

All field documents and records will be maintained and all required documents will be submitted to BNL for review and approval. All entries will be made in ink. Incorrect entries will be crossed out with a single strike mark, initialed and dated.

6.1.1 SAMPLE CONTAINER LABELS

One adhesive label stating the project name, sample ID/UID, date and time of sample collection, matrix, requested analysis, preservatives added, and initials of the individual(s) who collected the sample will be affixed to each sample container. To protect the label from water damage, each label will be completed with indelible ink and covered with clear, waterproof tape.

6.1.2 FIELD LOGBOOKS

Maintenance of the site-specific field logbook by field personnel is required for this project. Military time will be used. All pages in the book and all books used during the fieldwork will be numbered sequentially. At the beginning of each day of field activity, the following information will be recorded: the date, start time, weather including wind speed and direction, all field personnel present and their affiliations, level of personal protection being used on site, and the signature of the person making the entry. The individual writing the entry must initial all pages.

Other information that will be recorded in the project field logbook will include:

Schedule for the day;
Sample container and demonstrated analyte-free water shipment lot numbers (as received);
Equipment used (record ID number) and calibration information;
Equipment decontamination procedures;
Description of any photographs taken and photolog entries
Deviations or problems encountered;
Notes of conversations with project coordinators;
Visitor log;
List of site contacts.

For each sample collected and shipped, the following information will be recorded in the field logbook:

Names of field personnel;
Sample ID/UID and location;
Date and time sampled;
All QC samples;
Date shipped;
Media type;
Type of analysis to be performed;
Sample volume and containers;
Any unusual discoloration or evidence of contamination;
Equipment calibration information;
Preservatives added to the sample (if any);
Courier air bill number and means of delivery to the laboratory;
COC number; and
General observations.

6.2 SAMPLE HANDLING

Samples collected for analysis will be collected in precleaned containers. Collection of soil samples will be performed as described in Appendix E, BNL Collection of Soil Samples Procedure.

Samples destined for an off-site laboratory will be packaged according to American Society for Testing and Materials or EPA-recommended procedures. Off-site analysis will be performed by independent, qualified, and BNL-approved analytical and testing laboratories.

6.2.1 SAMPLE PRESERVATION

Preservation of water samples will be performed immediately upon sample collection. If required for preservation, acid may be added to the bottles prior to sampling. No samples require controlled temperatures for shipment.

6.2.2 TRANSPORTATION OF SAMPLES

Samples will be shipped in accordance with DOT (49 CFR Parts 171 through 179), EPA sample handling, packaging, and shipping methods (40 CFR 262 Subpart C and 40 CFR 263).

6.2.2.1 CUSTODY SEALS

Signed and dated custody seals will be placed on all shipping containers in such a way as to ensure that sample integrity is not compromised by tampering or unauthorized opening. Clear, plastic tape will be placed over the seals to ensure that the seals are not damaged during shipment.

6.2.2.2 ON-SITE AND OFF-SITE SHIPPING

On-site shipment will be considered as any transfer of material within BNL. Site-specific as well as DOT requirements will be followed for on-site shipment. Off-site sample shipment will be coordinated with all involved personnel and will conform to all applicable DOT requirements.

7.0 REFERENCES

Brookhaven National Laboratory, Environmental Restoration Division, *Draft OU II/VII Supplemental Sampling Report,* July 15, 1999.

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CDM Federal Programs Corporation, *Final Feasibility Study Report, Operable Unit I and Radiological-Contaminated Soils,* March 1999.

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Science Application International Corporation (SAIC), *Brookhaven National Laboratory Response Strategy Document,* 1992.

Chain-of-Custody Procedure (BNL, EM-SOP-109, October, 1999).

BNL, *Review and Acceptance of Non-Contract Laboratory Program Analytical Data.*

Technical Specifications for Hazardous Chemical and Radiochemical Analytical Laboratory Services (BNL, November, 1999).

Collection and Frequency of Field Quality Control Samples (BNL, EM-SOP-200, September, 1999

Standard Operating Procedure for Gamma Spectrum Acquisition Using Canberra ISOCS System (BNL, March, 2000).

Standard Operating Procedure: Analysis of Gamma Spectrum Files Using Canberra ISOCS System [software version 3.0] (BNL, March 2000).

Decontamination of Sampling Equipment (BNL, EM-SOP-801, October, 1999).

Collection of Soil Samples Procedure (BNL, EM-SOP-601, October, 1999).

Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) NUREG-1575, EPA 402-R-97-016, December, 1997.

Engineering Evaluation / Cost Analysis for D Tanks Removal Action (Dames and Moore, 1993).

BetaScint ™ Fiber-Optic Sensor for Detecting Strontium-90 and Uranium-238 (Innovative Technology Summary Report, OST Reference #70, DOE, December 1998).

APPENDIX C

DETERMINATION OF SCANNING SENSITIVITY

APPENDIX C

DETERMINATION OF SCANNING SENSITIVITY

C.0 Introduction

Scanning is often performed during radiological surveys in support of decommissioning to identify the presence of any locations of elevated direct radiation (hot spots). The probability of detecting residual contamination in the field is not only affected by the sensitivity of the survey instrumentation when used in the scanning mode of operation, but also by the surveyor's ability. The surveyor must decide whether the signals represent only the background activity, or whether they represent residual contamination in excess of background.

The minimum detectable concentration of a scan survey (scan MDC) depends on the intrinsic characteristics of the detector (efficiency, window area, etc.), the nature (type and energy of emissions) and relative distribution of the potential contamination (point versus distributed source and depth of contamination), the scan rate and other characteristics of the surveyor. Some factors that may affect the surveyor's performance include the costs associated with various outcomes—e.g., cost of missed contamination versus cost of incorrectly identifying areas as being contaminated —and the surveyor's *a priori* expectation of the likelihood of contamination present. For example, if the surveyor believes that the potential for contamination is very low, as in an unaffected area, a relatively large signal may be required for the surveyor to conclude that contamination is present.

A discussion of the calculation of scanning minimum detectable concentration (MDC) and the scanning minimum detectable count rate (MDCR) is provided in the *MARSSIM.* More detail on signal detection theory and instrument response is provided in NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, December 1997, from which the following discussion is drawn.

C.1 Minimum Detectable Count Rate and Surveyor Efficiency

The framework for determining the scan sensitivity is based on the premise that there are two stages of scanning. That is, surveyors do not make decisions on the basis of a single indication, rather, upon noting an increased number of counts, they pause briefly and then decide whether to move on or take further measurements. Thus, scanning consists of two components: continuous monitoring and stationary sampling. In the first component, characterized by continuous movement of the probe, the surveyor has only a brief "look" at potential sources, determined by the scan speed. The surveyor's willingness to decide that a signal is present at this stage is likely to be liberal, in that the surveyor should respond positively on scant evidence, since the only "cost" of a false positive is a little time. The second component occurs only after a positive response was made at the first stage. This response is marked by the surveyor interrupting his scanning and holding the probe stationary for a period of time, while comparing the instrument output signal during that time to the background counting rate. Owing to the longer observation interval, sensitivity is relatively high. For this decision, the criterion should be more strict, since the cost of a "yes" decision is to spend considerably more time taking a static measurement or a sample.

Since scanning can be divided into two stages, it is necessary to consider the survey's scan sensitivity for each of the stages. Typically, the minimum detectable count rate (MDCR) associated with the first scanning stage will be greater due to the brief observation intervals of continuous monitoring—provided that the length of the pause during the second stage is significantly longer. Typically, observation intervals during the first stage are on the order of 1 or 2 seconds, while the second stage pause may be several seconds long. The greater value of MDCR from each of the scan stages is used to determine the scan sensitivity for the surveyor.

The minimum detectable number of net source counts in the interval is denoted by s_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in d') as shown in [Equation 6-8, MARSSIM]:

$$s_i = d'(b_i)^{1/2}$$

where the value of d' is selected from MARSSIM Table 6.5 based on the required true positive and false positive rates and b_i is the number of background counts in the interval.

The minimum detectable source count rate (*MDCR*), in cpm, detectable during the observation interval *i*, in seconds, by an "ideal" surveyor may be calculated by [Equation 6-9, MARSSIM]:

$$MDCR = s_i \times (60 / i)$$

For the case of real surveyors who are not equivalent to the "ideal" construct, MARSSIM recommends assuming an efficiency value at the lower end of the observed range of 0.75 – 0.50 (*i.e.*, p = 0.5) when making MDCR estimates. Thus, the required number of net source counts for the surveyor, $MDCR_{surveyor}$, is determined by dividing the MDCR by the square root of p.

Consider the calculation of the MDCR for the case of 2 inch by 2 inch NaI(Tl) scintillation detector used in the walkover scan performed in this project. The observed background level is 8,000 cpm. The desired level of performance, 95% correct detections and 60% false positive rate, results in a d' of 1.38 [Table 6-5, MARSSIM]. The scan rate of 0.5m/s at an observation interval of 1-second, results in a diameter of about 50 cm for the area of activity observed. The $MDCR_{surveyor}$ may be calculated assuming a surveyor efficiency (p) of 0.5 as follows:

1) b_i = (8,000 cpm) × (1 sec) × (1 min/60 sec) = 133 counts
2) MDCR = (1.38) × $(133)^{1/2}$ / (1 sec) × (60 sec/1 min) = 956 cpm
3) $MDCR_{surveyor}$ = 956 / $(0.5)^{1/2}$ = 1,352 cpm net above background

The minimum number of source counts required to support a given level of performance for the final detection decision (second scan stage) can be estimated using the same method. As explained earlier, the performance goal at this stage will be more demanding. The required rate of true positives remains high *(e.g.*, 95%), but fewer false positives *(e.g.*, 20%) can be tolerated, such that *d'* (from Table 6.5) is now 2.48. For this second stage of the scan survey, the surveyor typically stops the probe over a suspect location for about 4 seconds before making a decision,

1) b_i = (8,000 cpm) × (4 sec) × (1 min/60 sec) = 533 counts
2) MDCR = (2.48) × (533) $^{1/2}$ / (4 sec) × (60 sec/1 min) = 859 cpm
3) $MDCR_{surveyor}$ = 859 / (0.5) $^{1/2}$ = 1,215 cpm net above background

The greater of the calculated $MDCR_{surveyor}$ values is 1,352 cpm above background or approximately 9,350 cpm gross. This is the value chosen for the $MDCR_{surveyor}$.

C.2 Scanning Minimum Detectable Concentration

Having determined an estimate of the minimum instrument count rate detected by a real observer in the field, the count rate must be translated to the units corresponding to those of the DCGL (pCi/g). In the Bldg 811 Waste Concentration Facility remediation, the scanning survey will be performed with an Eberline E-600 ratemeter and a 2x2 NaI detector. Data relating this instrument response to Cs-137 in surface soil are provided in Figure C-1. The greater of the $MDCR_{surveyor}$ values calculated in the previous section is 1,352 cpm above background or approximately 9,350 cpm gross. From the graph of the Figure C-1 and the correlation equation, it is seen that an instrument response of 9,350 cpm corresponds to a surface soil concentration of approximately 7 pCi/g Cs-137. This is then the scanning minimum detectable concentration that corresponds to the $MDCR_{surveyor}$.

Since the $MDCR_{surveyor}$, corresponding to a scanning MDC of 7 pCi/g, is less than the $DCGL_W$, it will be less than any $DCGL_{EMC}$, and the MARSSIM statistical method of number of samples for the systematic survey need not be adjusted. There is assurance that

1) the statistics of the method will demonstrate whether or not the residual activity in an area exceeds 23 pCi/g ($DCGL_W$) and
2) any areas of elevated residual radioactivity ($DCGL_{EMC}$ will be greater than 23 pCi/g) will not be missed during the final status survey.

For the case of the Bldg 811 Waste Concentration Facility remediation, the $DCGL_W$ for Cs-137 will be modified so that it can be used as a surrogate indicator for the presence of Sr-90. This value of $DCGL_{Mod}$ will be less than 23 pCi/g, and following remediation, a definitive value will be calculated from Cs-137 to Sr-90 ratios observed in the soils. The scanning MDC of 7 pCi/g is low, will be below realistic values of $DCGL_{Mod}$, and therefore it should not impact on the number of sample positions calculated for the systematic survey.

C.3 Implementation at Bldg 811 Waste Concentration Facility remediation

The previous discussion is based on prior experimental observations of experienced surveyors reacting to the audible response of the scanning instrument to varying concentrations and distributions of radioactivity (NUREG-1507). The MARSSIM, in Section 6.7.2.1, p. 6-45, recognizes that there is considerable uncertainty in the development of the scan MDC:

> It must be emphasized that while a single scan MDC value can be calculated for a given radionuclide—other scan MDC values may be equally justifiable depending on the values chosen for the various factors, including the MDCR (background level, acceptable performance criteria, observation interval), surveyor efficiency, detector parameters and the modeling conditions of the contamination.

The implementation of the surface scan at BNL differs from the previous discussion and derivation of scan MDC in that the survey instrument to be used is the Eberline E-600 with a 2x2 NaI probe. The high background with this instrument and detector (8,000 cpm) is incompatible with the use of variation in the audible response to alert the surveyor. To ensure that the surveyor is alerted, the instrument's audible alarm will be set to sound at 1,000 cpm above the background measured in the reference area.

The use of the audible alarm relies on electronic signal processing that was not included in the derivation of the scan MDC. With the use of modern integrated circuits, the difference in time between the production of an audible "click" as a result of a "single" detection and the production of an audible "alarm" as a result of "multiple" detections should not be significant. To compensate for any electronic lag time, we have tightened the initial response trigger for the first phase scan, from the operator subjective recognition of 1,215 cpm to a preset instrument alarm set at 1,000 cpm. Thus the alarm set point is more "liberal" than the calculated $MDCR_{surveyor}$, and the surveyor will pause more frequently to take an extended time reading. Upon alarm, the surveyor will interrupt the scanning and hold the probe stationary for a period of time (approximately 4 seconds), while comparing the instrument output signal during that time to the background counting rate. Owing to the longer observation interval, sensitivity is relatively high; as shown on Figure C-1, 17,500 cpm corresponds to the $DCGL_W$ of 23 pCi/g for Cs-137 as a lone contaminant.

To validate the appropriateness of the practical scan MDC, the residual radioactivity in soil concentrations levels identified during investigations performed as a result of scanning surveys will be tracked. Measurements performed during the scanning surveys as a part of this SAP will be used to verify that assumptions on surveyor performance are met in the field. The measurements performed during these investigations may provide an *a posteriori* estimate of the scan MDC that can be used to validate the *a priori* scan MDC used to design the survey.

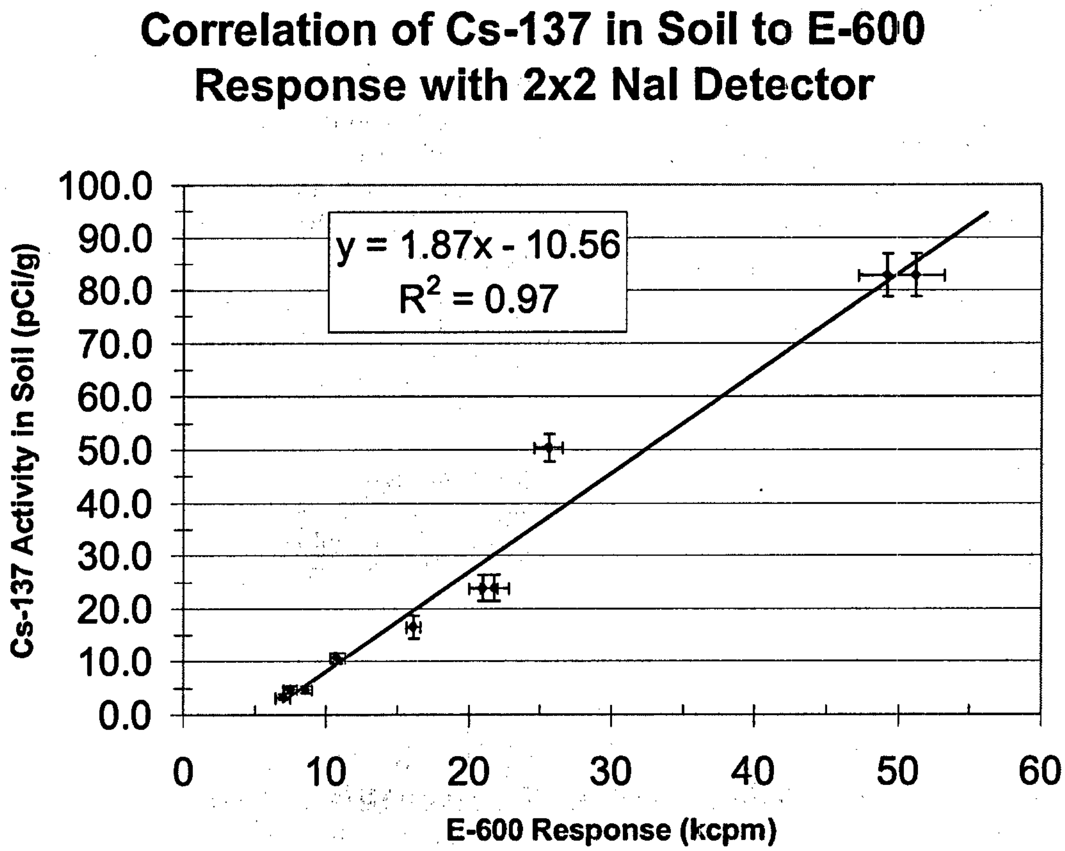

Figure C-1. Correlation of Cs-137 concentration in Surface soil to E-600 Response