Final Status Survey Plan

Buffalo Materials Research Center

Prepared for:

University at Buffalo
The State University of New York

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Completed by:

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SUMMARY OF CHANGES

Revisions to the Final Status Survey Plan will be tracked when revisions are issued. Changed sections will be identified by special demarcation in the margin. A summary description of each revision will be noted in the following table.

Revision Number	Date	Description of Change
0	June 20, 2012	Initial Issue
1	September 20, 2012	Pages ii-vi: Updated Table of Contents, Tables, and Abbreviations/Acronyms. Page 15: Added reference to BMRC FSS standard deviation calculation method in Section 3.5.5. Pages 18-22: Reorganized and clarified Section 3.6 regarding instruments and detection limits. Added gamma walkover instrumentation to section. Page 23: Clarified selection of LBGR and corrected the number of required data points for a relative shift of 1.5.

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ABBREVIATIONS/ACRONYMS

μR/hr	microRoentgen per hour
2x2 NaI	2-inch by 2-inch sodium iodide detector
AEC	Atomic Energy Commission
BMRC	Buffalo Materials Research Center
Bq	Bequerels
cm^2	Centimeter Squared
cpm	counts per minute
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissionoing
DCGL	Derived Concentration Guideline Level
$DCGL_{emc}$	Derived Concentration Guideline Level Elevated Measurement Comparison
DOC	Design and Oversight Contractor
DP	Decommissioning Plan
DQO	Data Quality Objective
DPM or dpm	disintegrations per minute
FSS	Final Status Survey
FSSP	Final Status Survey Plan
kw	kilowatt
LBGR	Lower Bound of the Gray Region
m	meter
m^2	Meters square
MARSSIM	Multi-Agency Radiation Site Survey and Investigation Manual, NUREG-1575
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
MDC_{scan}	Minimum Detectable Concentration for scans
mrem	Millirem
NaI	Sodium Iodide
NELAP	National Environmental Laboratory Accreditation Program
NVLAP	National Voluntary Laboratory Accreditation Program
MWt	Megawatt thermal
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute for Science and Education

pCi/g	Picocuries per gram
PULSTAR	Pulse Training Assembled Reactor
QA/QC	Quality Assurance/Quality Control
SSC	Systems/Structures/Components
University	State University of New York at Buffalo
VSP	Visual Sample Plan ©
WRS	Wilcoxon Rank Sum

Radionuclide Abbreviations

Ag	Silver
C	Carbon
Co	Co-60
Cs	Cesium
H	Hydrogen
Pu	Plutonium
Sr	Strontium
Th	Thorium
ZnS	Zinc Sulfide

If the contaminant is not in the background or constitutes a small fraction of the DCGL, the Sign Test will be used. If background is a significant fraction of the DCGL, the WRS Test will be used. It is anticipated that the Sign Test will be the only statistical test applied to the collected data because of the small fraction of the DCGL that background radionuclides will contribute.

3.5.2 Establish Decision Errors

The probability of making decision errors is controlled by hypothesis testing. The survey results will be used to select between one condition of the environment (the null hypothesis) and an alternate condition (the alternative hypothesis). These hypotheses, chosen from MARSSIM Scenario A, are defined as follows:

- Null Hypothesis (H_0): The survey unit does not meet the release criteria.
- Alternate Hypothesis (H_a): The survey unit does meet the release criteria.

A Type I decision error would result in the release of a survey unit containing residual radioactivity above the release criteria. It occurs when the Null Hypothesis is rejected, but in reality is true. The probability of making this error is designated as "α."

A Type II decision error would result in the failure to release a survey unit when the residual radioactivity is below the release criteria. This occurs when the Null Hypothesis is accepted when it is not true. The probability of making this error is designated as "β."

Appendix E of NUREG-1727 recommends using a Type I error probability (α) of 0.05 and states that any value for the Type II error probability (β) is acceptable. Following the guidance, α will be set at 0.05. A β of 0.05 will initially be selected based on site-specific considerations. The β may be modified, as necessary, after weighing the resulting change in the number of required survey measurements against the risk of unnecessarily investigating and/or remediating survey units that are truly below the release criteria.

3.5.3 Relative Shift

The relative shift (Δ/σ) is a calculated value. Delta (Δ) is equal to the DCGL minus the lower boundary of the gray region (LBGR). The standard deviation (σ) used for the relative shift calculation may be recalculated based on the most current data obtained from post-remediation or post-demolition surveys; or from background reference areas, as appropriate. See Section 3.5.5 for the specific method of calculating the standard deviation for the BMRC FSS. The LBGR may be adjusted to obtain an optimal

Table 3-4: MARSSIM Table 5.4

Relative Shift	Sign p	Relative Shift	Sign p
0.1	0.539828	1.2	0.88493
0.2	0.57926	1.3	0.903199
0.3	0.617911	1.4	0.919243
0.4	0.655422	1.5	0.933193
0.5	0.691462	1.6	0.945201
0.6	0.725747	1.7	0.955435
0.7	0.758036	1.8	0.96407
0.8	0.788145	1.9	0.971284
0.9	0.81594	2	0.97725
1	0.841345	2.5	0.99379
1.1	0.864334	3	0.99865

Note: If relative shift > 3.0, use Sign p = 1.0

3.6 Instruments and Detection Limits

3.6.1 Survey Instruments

The FSS will consist of walkover surveys with gamma scintillation detectors, and soil sampling with off-site analysis, scans and direct measurements with floor monitors. The instruments proposed for use during the FSS and their applications are provided in Table 3-5 . If necessary, the DOC may substitute comparable instruments.

All instruments will be calibrated using NIST-traceable standards. Instruments will be checked at the beginning of each day to ensure they are operating properly. The daily check also reassures the validity of the previous day's measurements. The daily checks will include a background measurement and a source check. Instrument records, including dates of use, efficiencies, calibration due dates and source traceability, will be maintained in accordance with established procedures.

Table 3-5: FSS Instrumentation

Instrument	Detector Type	Radiation Detected	Calibration Source	Use
Ludlum Model 2221	Ludlum Model 44-10 2" x 2" NaI	Gamma	Cs-137	Gamma Walkover Surveys
Ludlum Model 2221	Ludlum Model 43-68 Gas Proportional (126 cm^2)	Beta	Tc-99	Surface Static Measurements; Beta scan measurements
Ludlum Model 2360	Ludlum Model 43-68 Gas Proportional (126 cm^2)	Alpha/Beta	Th-230/Tc-99	Alpha/Beta static measurements
Ludlum Model 2360	Ludlum Model 43-89 ZnS coated Plastic Scintillator (126 cm^2)	Alpha/Beta	Th-230/Tc-99	Alpha/Beta static measurements
Ludlum Model 3030E	Ludlum Model 43-10-1 ZnS internal detector	Alpha/Beta	Th-230/Tc-99	Swipe/smear counting
Ludlum Model 19	Internal NaI	Gamma	Cs-137	General area exposure rates

3.6.2 Minimum Detectable Concentration

The minimum detectable concentration (MDC) is the concentration of radioactivity that an instrument can be expected to detect at a 95 percent confidence level. For instruments performing direct measurements and for laboratory analyses, the MDC goal is 10-50 percent of applicable release criteria.

For static (direct) surface measurements, with conventional detectors, the MDC was calculated using the formula:

$$\text{MDC (dpm/100cm}^2\text{)} = \left[\frac{3 + 3.29\sqrt{(R_b)(T_s)(1 + T_s / T_b)}}{(T_s)(\varepsilon_t)}\right]$$

<u>Where:</u>

R_b = Background count rate (cpm)
T_b = Background count time (min)
T_d = Sample Run Time (min)
T_s = Sample Count Time (min)
ε_t = Total Instrument Efficiency (MARSSIM section 6.6.1)

The data used to calculate the MDC for the instrumentation is from data collected during the BMRC characterization process. The *a priori* MDC is listed in Table 3-6.

For gamma scan measurements in the gamma walkover survey, the minimum detectable count rate (MDCR) is calculated as the survey is used as a qualitative analysis for elevated concentrations also known as hot spots. The MDCR is calculated by first determining the minimum detectable net source counts using Formula 6-8 from the MARSSIM as below.

Minimum number of detectable source counts: $s_i = d'\sqrt{b_i}$

Where:

d' = value taken from Table 6.5 in the MARSSIM for applicable true and false positive rates

b_i = Number of background counts in a given time interval

The MDCR is calculated from Formula 6-9 in the MARSSIM:

Minimum detectable count rate: $MDCR = s_i * \frac{60}{i}$

Where:

i = Observed time interval

For beta scan measurements, the MDCR equation is used along with the detection efficiency and probe area correction factor to calculate the MDC for a beta scan measurement (MDC_{scan}) in standardized units (DPM/100-cm^2). The MDC_{scan} formula is the following:

Scan MDC: $$MDC_{scan} = \frac{MDCR}{\sqrt{\rho} * \varepsilon_i * \varepsilon_s * \frac{probearea}{100cm^2}}$$

Where:

ρ = Surveyor efficiency (value from a range between 0.5 and 0.75)

ε_i = Instrument efficiency

ε_s = Surface efficiency

probearea = active area of the detector face in cm^2

The value for ρ was developed in Draft NUREG/CR-6364 and NUREG-1507, it is a percentage estimate of the likelihood a surveyor will reliably detect an elevated count rate. A value of 0.5 will be used for the Surveyor Efficiency.

Table 3-6: Instrumentation MDC

Instrument	Detector Type	Radiation Detected	Typical Scan MDC (dpm/100 cm²)	Typical Static MDC (dpm/100 cm²)
Ludlum Model 2221	Ludlum Model 44-10	Gamma	See Section 3.6.3	N/A
Ludlum Model 2221	Ludlum Model 43-68	Beta	1736	271
Ludlum Model 2360	Ludlum Model 43-68	Alpha	N/A	59
		Beta	2981	393
Ludlum Model 2360	Ludlum Model 43-89	Alpha	N/A	47
		Beta	4292	612
Ludlum Model 3030E	Ludlum Model 43-10-1	Alpha	N/A	12
		Beta	N/A	159
Ludlum Model 19	Internal NaI	Gamma	N/A	N/A

3.6.3 Verification of Gamma Walkover Detection Limits for Ag-108m

Based on data presented in NUREG-1507 (Reference 7.6), the MDC_{scan} for a walkover survey with a 2x2 NaI detector is approximately 3.4 pCi/g and 6.4 pCi/g for Co-60 and Cs-137, respectively as shown in Table 6.4 of NUREG-1507 . There is no data listed for Ag-108m. However, based on the gamma photon energies of Ag-108m, the walk-over surveys should be capable of identifying the presence of residual contamination at levels below the DCGLs.

To verify that Ag-108m would be appropriately detected, the expected exposure rates for Co-60 and Ag-108m at their respective DCGLs were individually calculated using Microshield© with an infinite slab source geometry. Then by applying the instrument detection specifications for counts per minute (cpm) per µR/hr, the expected count rate at the DCGL was calculated.

The analysis for Co-60, presented in Attachment 8.1, shows that the expected exposure rate for soil containing 3.8 pCi/g Co-60 would be 11 µR/hr. Using the conversion factor of 430 counts per minute (cpm) per µR/hr from Reference 7.6, the required minimum detectable count rate (MDCR) to measure 3.8 pCi/g of Co-60 would be approximately 4,730 cpm.

Microshield was used in the same way to model Ag-108m. This analysis, presented in Attachment 8.2, shows that the expected exposure rate for soil containing 8.2 pCi/g Ag-108m would be 20.9 µR/hr. Based off the Microshield evaluation, the average weighted energy of Ag-108m is ~50 keV. The detection sensitivity for a 2x2 NaI detector at that energy range is approximately 3,600 cpm per µR/hr (Reference

7.7), therefore the required MDCR to measure 8.2 pCi/g of Ag-108m would be approximately 75,200 cpm.

Using the MDCR equation in Section 3.6.2 and estimating a background count rate of 8,000 cpm the expected MDCR is 1,352 net cpm (841 cpm less than the required MDCR) or approximately 9,350 gross cpm (depending on the true background rate on site). Using the MDC_{scan} (pCi/g) equation above, this MDCR correlates to an expected MDC_{scan} of about 3.1 pCi/g for Co-60 contamination in the soil.

3.7 Daily Instrument and Background Measurements

Daily instrument checks will be made according to written procedures. These measurements will be made in non-impacted areas using radioactive check sources. These measurements will be recorded for the purpose of ensuring that instruments are operating properly. An instrument control log will be used for each instrument to keep track of background counts and response checks.

Daily background measurements will also be made according to written procedures. These measurements will be made in non-impacted areas. Single background measurements used to estimate the mean background will be made for a minimum of 10 minutes for scaling instruments (scalers).

3.8 Reference Area Measurements

The radionuclides of concern at the BMRC fall into two distinct categories:

1) The DCGL is low and the radioisotope is generally not detectable in background samples (cobalt, silver, and europium), and
2) The DCGL is high compared to the expected background concentration (remaining isotopes)

Therefore, to simplify matters, the site release statistical tests will assume that none of the radioisotopes of concern are present in background. Based on this assumption, MARSSIM recommends the Sign Test for statistical comparisons. No reference area measurements are required for the Sign Test to release the site based on the soil sample results.

3.9 Projected Survey Units

The projected survey units and associated classes are shown in Table 3-7. The selected LBGR for each survey unit is based on empirical characterization data using the average of the characterization sample results that were reported as less than the radionuclide specific DCGL. Sample results greater than the radionuclide specific DCGL were not used in this calculation since remediation should occur in the immediate area of the sample. Using this method, the selected LBGRs are representative of the anticipated post-remediation radiological conditions.

Table 3-7: Survey Units

Survey Unit	Unit #	Class	Area (m^2)	Relative Shift	Required Data Points
N16	1	1	90	1.5	18
Tank Farm	2	1	105	1	29
Sub-Basement	3	1	300	1	29
Containment	4	1	420	1	29
Side slopes	5	2	1,230	3.0	14
Cooling Tower	6	2	105	1	29
Remainder	7	3	>2,000	3.0	14

3.9.1 Class 1 Survey Units

3.9.1.1 N16 Tank Area - Survey Unit 1

The N16 tank is known to have radioactivity greater than NRC and NYS Screening values for Co-60. Additionally, Ag-108m was elevated and has a high potential to be greater than the release criteria (Reference 7.5). The N16 tank area encompasses approximately 90 m^2.

A summary of the characterization data for the detected radionuclides of interest for this area is shown in the table below. This data summary excludes sample results greater than the relevant DCGL in order to properly calculate the relative shift.

Table 3-8: N16 Tank Area Characterization Results Summary

Radionuclide	LBGR	Standard Deviation	DCGL (pCi/g)	Calculated Relative Shift
Ag-108m	4.9	2.2	8.2	1.5
Co-60	2.54	0.84	3.8	15
Cs-137	1.86	1.75	11	5.2
Eu-152	0.54	0.86	6.9	7.3
Eu-154	0.34	0.37	8	20.7
H-3	4.8	2.4	110	43.8
Ni-63	33.7	25.1	2,100	82.3
Sr-90	0.14	0.13	1.7	12

The lowest relative shift calculated from this data is 1.5 which correlates to a minimum of 18 samples to meet MARSSIM data requirements.