Phase II Final Status Survey Report
Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 9

Project No. 137131 **Revision 0**

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

%	percent
σ	sigma; standard deviation
AECOM	AECOM Technical Services
bgs	below grade surface
C-T	columbium-tantalum
CFR	Code of Federal Regulations
cm	centimeters
DCGL	derived concentration guideline level
DP	decommissioning plan
DQO	data quality objectives
EMC	elevated measurement comparison
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GWS	gamma walk-over survey
m^2	square meters
MARSSIM	Multi-Agency Radiation and Site Investigation Manual (NUREG-1575)
mm	milli-meters
MDC	minimum detectable concentration
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
Ra	radium
SOF	sum of fractions
Th	thorium
U	uranium
WRS	Wilcoxon Rank Sum

9.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU03

This chapter of the Final Status Survey Report (FSSR) presents the results of the final status survey (FSS) and data assessment for Plant 5 subsurface survey unit SU03 in accordance with Columbium-Tantalum (C-T) Phase II Decommissioning Plan (DP) Section 14.5. The FSS for this Class 1 survey unit was completed by AECOM Technical Services (AECOM) in May and June of 2011. The SU03 data assessment was performed based on the assumptions, methods, and performance criteria established to satisfy the data quality objectives (DQOs) in accordance with the C-T Phase II DP Section 14.4.3.8. The summary statistics provide numerical values for measures of central tendency (i.e., mean, median), variation (i.e., standard deviation), and spread (i.e., minimum, maximum). Data evaluation and statistical analyses were performed and a separate decision was made for each survey unit of the C-T Plant as to its suitability for release for unrestricted use based upon the industrial use scenario release criterion as established in C-T Phase II DP Chapter 5.

9.1 OVERVIEW

SU03 is a Class 1 survey unit located in the northwest portion of C-T Plant 5. The survey unit is approximately 252 square meters (m^2) in size, which is less than the size limit of 3,000 m^2 for Class 1 survey units for subsurface material (per C-T Phase II DP, Table 14-4). Class 1 was the appropriate classification because the survey unit contained residual radioactivity that exceeded the $DCGL_W$ prior to remediation. Figure 9-1 shows the location of SU03 within the Plant 5 area.

Figure 9-2 is a photograph of SU03 that was taken during the FSS, following remediation. In Figure 9-2, as viewed from the east side of the survey unit looking west, shows the east wall of Building 250 in the background. SU02 (partially backfilled) appears next to Building 250. The southern edge of the survey unit coincides with a straight line extending from the red valve capping the fire suppression line (see Figure 9-2 upper left). The north edge of the survey unit coincides with the south edge of the concrete monolith in SU01 (see Figure 9-2 at right). C-T sewer lines that connected to the former Building 248 were encountered at about 4 feet (ft) below grade surface (bgs) and removed. Soil and related debris were removed from the area to an excavated depth of approximately 9 ft bgs.

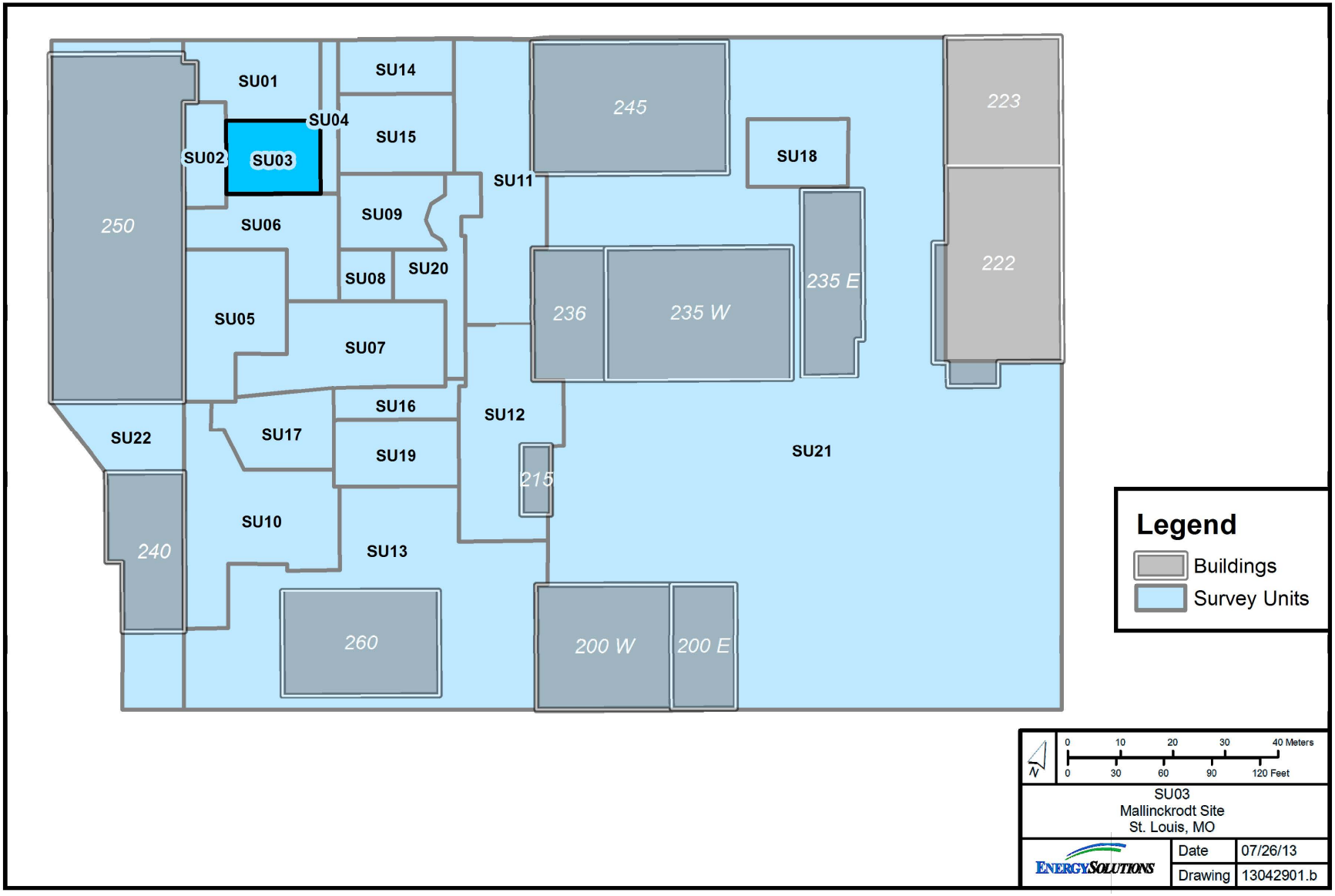

Figure 9-1 Location of Subsurface SU03 in C-T Plant 5

Figure 9-2 Photograph of SU03 from East Side Looking West

9.2 DATA COLLECTION

Data collection was performed based on the assumptions, methods, and performance criteria established to satisfy the DQOs in accordance with the C-T Phase II DP, Sections 14.4.1 and 14.4.3. Details regarding FSS design and quality assurance and quality control applicable to all survey units were discussed in Chapters 4 and 5, respectively, of this FSSR.

9.2.1 Gamma Scans

A gamma walk-over survey (GWS) was performed over 100% of the excavated area to locate radiation anomalies that might indicate areas with elevated residual radioactivity where further data collection (i.e., biased soil sampling) was warranted.

9.2.2 Soil Sampling

Soil samples to be used for the statistical test were collected at a frequency and at representative locations throughout SU03 such that a statistically sound conclusion regarding the radiological condition of the survey unit could be developed. Additional biased soil samples were also collected at locations of elevated residual radioactivity identified by GWS. Figure 9-3 provides the GWS results and soil sampling locations. A total of 17 (15 systematic and 2 GWS biased) soil samples were collected over the areal footprint SU03.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 9-1 provides the sample results and summary statistics for the 15 systematic samples. Table 9-2 provides the sample results for the 2 GWS biased samples.

Any remaining sieved material from each sample was analyzed separately to verify residual radioactivity was consistent with sample results. The radiological screening process did not identify any significant levels of radioactivity in the sieved materials removed from samples.

The C-T Phase II DP, Table 4-17, provided mean background activity levels of 1.3, 2.5, and 4.4 picoCuries per gram (pCi/g) for thorium-232 (^{232}Th), radium-226 (^{226}Ra), and uranium-238 (^{238}U), respectively. These values were used to calculate net sum of fractions (SOF) values—note that when measured activity concentration levels were less than the background mean resulting in a negative value, the net activity concentration was set equal to zero for the net SOF calculation.

To mitigate the risk of backfilling, the on-site laboratory analytical results were reviewed to determine the likelihood of the survey unit failing to meet the criteria for radiological release. The on-site laboratory, by design, reported conservative sample results.

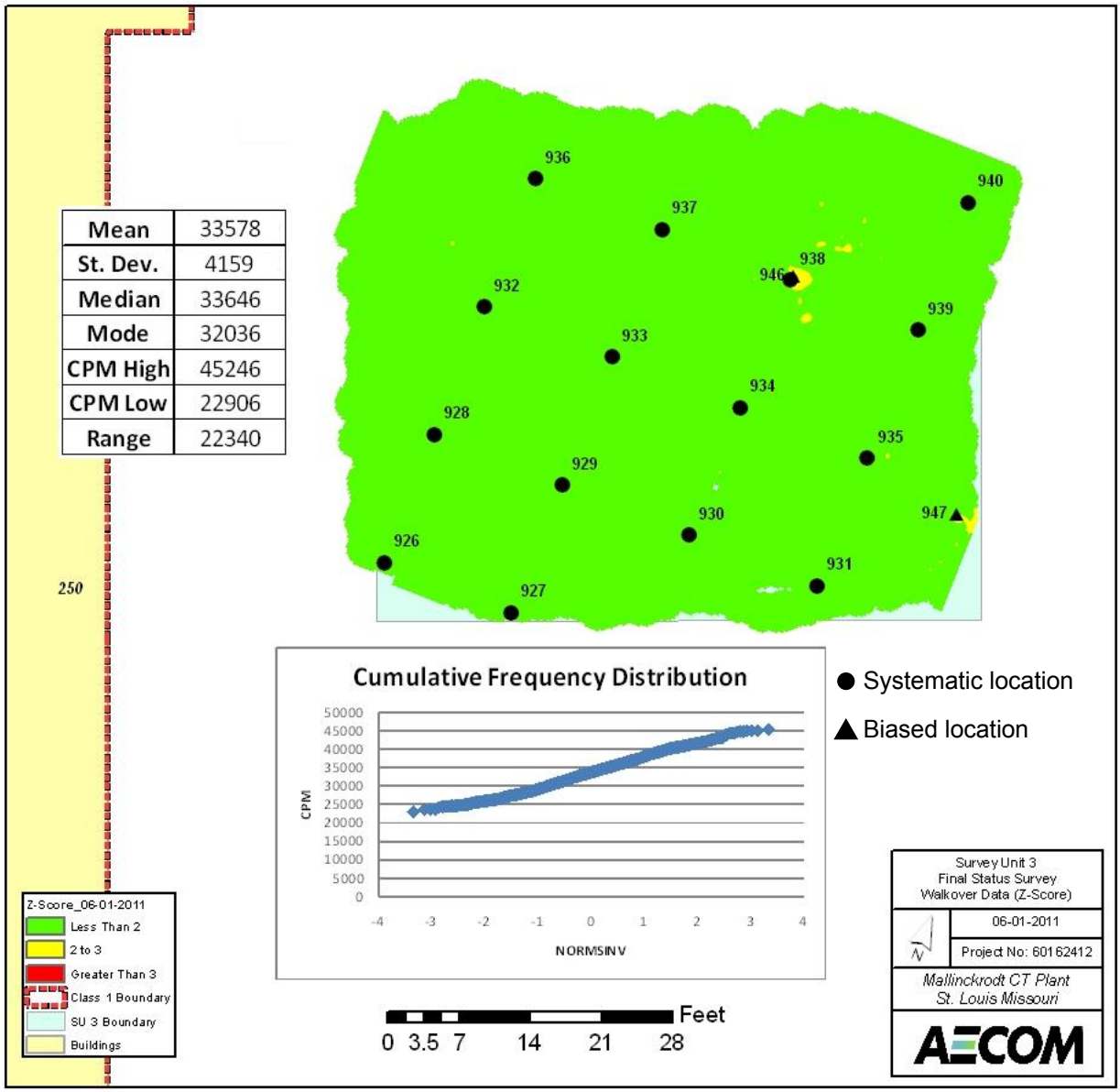

Figure 9-3 GWS and Soil Sampling Locations

Table 9-1 Gamma Spectroscopy Systematic Sample Analytical Results

Sample ID	Depth (ft bgs)	On-Site Results											Off-Site Results [a]										On-Site/ Off-Site Gross SOF Ratio
		Concentration (pCi/g)									SOF		Concentration (pCi/g)									SOF	
		^{232}Th			^{226}Ra			^{238}U					^{232}Th			^{226}Ra			^{238}U				
		Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [b]	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [b]	
0926	9	0.95	0.18	0.07	4.58	0.88	0.63	7.98	0.93	0.49	0.21	0.08	1.59	0.34	0.26	3.38	0.46	0.07	3.76	0.49	0.08	0.19	0.04	1.11
0927	9	1.23	0.22	0.08	4.12	1.00	0.75	10.36	0.87	0.45	0.21	0.06	1.67	0.46	0.40	4.48	0.62	0.11	4.79	0.63	0.12	0.23	0.08	0.90
0928	9	0.99	0.17	0.07	4.05	0.82	0.59	7.51	0.87	0.46	0.19	0.06	1.75	0.41	0.39	4.09	0.55	0.10	4.51	0.60	0.12	0.22	0.07	0.87
0929	9	0.69	0.14	0.05	2.56	0.73	0.55	6.63	0.78	0.40	0.13	0.01	0.93	0.31	0.31	2.33	0.32	0.09	2.60	0.34	0.10	0.12	0.00	1.03
0930	9	0.81	0.17	0.07	3.19	0.88	0.66	8.37	0.95	0.48	0.15	0.03	1.09	0.38	0.31	2.63	0.36	0.09	2.97	0.48	0.09	0.14	0.00	1.11
0931	9	1.01	0.18	0.07	4.43	0.83	0.59	6.22	0.81	0.45	0.20	0.07	1.85	0.38	0.37	4.40	0.61	0.10	4.72	0.62	0.11	0.23	0.09	0.86
0932	9	1.11	0.20	0.07	4.09	0.75	0.53	4.42	0.77	0.46	0.19	0.05	1.84	0.56	0.37	3.69	0.53	0.11	3.98	0.55	0.12	0.21	0.06	0.92
0933	9	0.71	0.13	0.05	1.32	0.42	0.31	1.52	0.45	0.28	0.08	0.00	0.97	0.24	0.24	1.28	0.18	0.07	1.50	0.20	0.08	0.09	0.00	0.89
0934	9	0.98	0.21	0.08	6.29	0.97	0.68	9.19	0.81	0.45	0.27	0.14	1.31	0.47	0.34	5.75	0.73	0.10	6.48	1.00	0.11	0.26	0.11	1.03
0935	9	0.92	0.18	0.07	3.72	0.85	0.62	5.35	0.67	0.40	0.17	0.04	1.51	0.45	0.39	4.16	0.55	0.10	4.48	0.71	0.11	0.21	0.07	0.82
0936	9	0.83	0.14	0.07	2.02	0.45	0.31	1.91	0.53	0.33	0.11	0.00	1.61	0.40	0.30	1.59	0.23	0.08	1.56	0.22	0.08	0.12	0.01	0.86
0937	9	1.01	0.18	0.06	4.03	0.74	0.52	3.91	0.72	0.43	0.18	0.05	1.55	0.41	0.34	3.46	0.48	0.10	3.74	0.50	0.10	0.19	0.04	0.98
0938	9	1.05	0.22	0.09	8.25	1.07	0.71	9.81	1.09	0.60	0.34	0.20	1.06	0.36	0.36	6.52	0.85	0.09	7.44	0.94	0.11	0.28	0.14	1.22
0939	9	1.12	0.16	0.07	4.31	0.75	0.52	5.32	0.62	0.38	0.20	0.06	1.48	0.51	0.34	3.27	0.46	0.09	3.53	0.47	0.11	0.18	0.03	1.13
0940	9	0.96	0.17	0.08	3.58	0.92	0.69	9.72	0.97	0.48	0.18	0.04	0.98	0.33	0.27	4.36	0.56	0.07	4.88	0.61	0.08	0.20	0.06	0.89
Summary Statistics																								
Count:		15			15			15			15	15	15			15			15			15	15	15
Average:		0.96			4.04			6.55			0.19	0.06	1.41			3.69			4.06			0.19	0.06	0.97
Median:		0.98			4.05			6.63			0.19	0.05	1.51			3.69			3.98			0.20	0.06	0.92
Standard Dev.:		0.15			1.65			2.80			0.06	0.05	0.33			1.41			1.60			0.05	0.04	0.12
Minimum:		0.69			1.32			1.52			0.08	0.00	0.93			1.28			1.50			0.09	0.00	0.82
Maximum:		1.23			8.25			10.36			0.34	0.20	1.85			6.52			7.44			0.28	0.14	1.22
Range:		0.54			6.93			8.84			0.26	0.20	0.92			5.24			5.94			0.19	0.14	0.41

[a] Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ^{226}Ra progeny equilibrium.
[b] Calculated as discussed in Section 9.2.2.

Table 9-2 Gamma Spectroscopy Biased Sample Analytical Results

Sample ID	Depth (ft bgs)	On-Site Results											Off-Site Results [a]										On-Site/ Off-Site Gross SOF Ratio
		Concentration (pCi/g)									SOF		Concentration (pCi/g)									SOF	
		^{232}Th			^{226}Ra			^{238}U					^{232}Th			^{226}Ra			^{238}U				
		Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [b]	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [b]	
GWS Biased Samples																							
0946	9	0.98	0.17	0.07	6.80	1.01	0.70	10.65	1.10	0.56	0.29	0.15	1.33	0.46	0.46	4.59	0.61	0.13	4.90	0.69	0.14	0.22	0.07	1.31
0947	9	0.75	0.14	0.20	7.50	1.16	0.80	12.76	1.35	0.68	0.30	0.18	1.58	0.47	0.34	4.43	0.57	0.09	5.13	0.80	0.09	0.22	0.08	1.36

[a] Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ^{226}Ra progeny equilibrium.
[b] Calculated as discussed in Section 9.2.2.

9.3 DATA ANALYSIS

The data analysis was performed based on the assumptions, methods, and performance criteria established to satisfy the DQOs in accordance with the C-T Phase II DP, Sections 14.4.1 and 14.4.3. Details regarding FSS design and quality assurance and quality control applicable to all survey units were discussed in Chapters 4 and 5, respectively, of this FSSR.

9.3.1 Elevated Area Evaluation

There were no elevated areas identified in SU03.

9.3.2 Data Set Screening Analysis

Table 9-3 summarizes the results of the screening tests performed in accordance with Pages 14-27 through 14-29 of the C-T Phase II DP. All applicable tests demonstrating compliance passed.

Table 9-3 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.26	PASS
Low Level	N/A	Not applicable; Class 1 survey unit
$DCGL_W$	N/A	Not applicable; Min/Max < 1
EMC Limit	N/A	Not applicable; No elevated areas

9.3.2.1 Min/Max

In accordance with Page 14-27 of the C-T Phase II DP, the Min/Max screening test value was calculated by subtracting the minimum reference area result from the maximum survey unit systematic result. Sample 0938 with a gross SOF of 0.28 (from Table 9-1) was the maximum survey unit systematic result. Sample BH-Z-08 with a calculated gross SOF of 0.02 (from C-T Phase II DP Table B-1) was the minimum reference area result. The Min/Max screening test value was calculated to be 0.26. Because the test value was less than one, no further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

9.3.2.2 Low Level

In accordance with Page 14-27 of the C-T Phase II DP, the Low Level screening test is not applicable to Class 1 survey units.

9.3.2.3 $DCGL_W$

In accordance with Page 14-28 of the C-T Phase II DP and because the Min/Max test value was less than one, the $DCGL_W$ screening test was not applicable to this survey unit.

9.3.2.4 EMC Limit

In accordance with Page 14-28 of the C-T Phase II DP, the elevated measurement comparison (EMC) Limit screening test was not applicable to this survey unit because no elevated areas were identified.

9.3.3 WRS Test

In accordance with Page 14-29 of the C-T Phase II DP and because the Min/Max test value was less than one, the WRS Test was not required to demonstrate compliance.

9.3.4 Retrospective Analysis

A retrospective analysis was performed of the FSS results to determine whether the results met the survey design objectives, in accordance with Page 14-30 of the C-T Phase II DP. Table 9-4 provides the results of the retrospective analysis. Because the actual sample size exceeded the retrospective value sample size, the conclusion is that the survey design objectives were met.

Table 9-4 Retrospective Analysis

Parameter	*A Priori* Value	Retrospective Value Based on FSS Results (Gross SOF)
Upper Bound of Gray Region	DCGL = 1	1
Lower Bound of Gray Region	0.5 x DCGL = 0.5	0.19
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.053
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	15.3
Calculated N/2 Sample Size	15 [a]	9
Actual N/2 Sample Size	--	15

[a] The *a priori* value of 15 for the N/2 sample size was determined to be a conservative value that would allow application of either the Sign or WRS test. The *a priori* value for N/2 is 10 based on MARSSIM Table 5.3.

9.4 DEVIATIONS

In accordance with the second bullet in Section 14.5 of the C-T Phase II DP, the FSSR is required to list changes made in the FSS from what was proposed in the DP. Only one deviation was noted. Page 14-27 of the C-T Phase II DP indicated that the "data set for the survey unit will be processed within a database using screening software developed and verified for the project." This database was not developed; instead, a combination of Microsoft® Excel® spreadsheets and hand calculations was utilized. This deviation is not significant and does not affect the data collection or assessment.

9.5 ORISE CONFIRMATORY SURVEY

The Oak Ridge Institute for Science and Education (ORISE), by NRC request, performed an independent evaluation of AECOM's FSS methods and results. It made two site visits - on April

28, 2011, and on June 1-2, 2011. During these visits, ORISE observed FSS activities and conducted confirmatory surveys of SU01 and SU03 (ORISE 2011).

Two specific issues were identified by ORISE:

1. The contractor (AECOM) sieved the soil samples resulting in the removal of contaminated slag material (greater than the sieve size) and the excess material/slag (potentially containing significant residual radioactivity) was left behind in the surveyed area.
2. The contractor (AECOM) technicians were not relying on the audible output of the instrument to pinpoint judgmental locations real time. Instead their process was to post process the data and go back and investigate the suspect locations.

In response to the issues identified by ORISE, AECOM performed an assessment of its GWS and soil sampling methodology. The assessment is found in Appendix H of AECOM's Preliminary FSSR (AECOM 2012), and is summarized below.

Regarding ORISE's second issue, the GWS process was not modified to rely on the surveyor responding to an audible output of the instrument to pinpoint judgmental locations in real time. There are several reasons. A GWS data set collected uniformly over the surface of a survey unit, based on the rate at which data are logged (at 1-second intervals), is believed to more likely capture indications of an anomalous or subtle trending count rate than a surveyor responding to an audible indication. In addition, an evaluation of the GWS data set using both statistical and graphical methods (see Section 4.4.1.4 of this FSSR) is believed to provide superior information than a subjective response by a surveyor to an audible indication. For example, a cumulative frequency distribution provides information on the general shape of the data distribution, whether the population is normally or non-normally distributed, whether there are multiple populations present or individual outliers that may represent locations for further investigation. Another example is the z-score contouring process, which tends to smooth over single data points with slightly elevated values while accentuating clustered areas or single locations with significantly elevated values. This is the desired effect which aids in the data analysis by focusing attention on those areas most likely to have elevated residual radioactivity. These advantages are among those lost in a data set that is subjectively collected.

Table 9-5 lists the changes implemented by AECOM to improve the FSS survey and sampling methods.

Table 9-5 Changes to AECOM Survey and Sampling Methods

FSS Method	Change to Method	Rationale for Change
Perform single pass GWS	Perform double pass GWS with 2nd pass performed perpendicular to 1st pass.	A double pass increases data density and improves likelihood of detecting presence of small areas of elevated residual radioactivity.
Collect soil samples to a depth of 15 cm.	Collect soil samples to a depth of 30 cm.	External exposure is primary exposure pathway. The depth of contamination continues to affect external exposure up to 30 cm, beyond which impact is negligible.
Field screen soil samples using a ¼ inch sieve; discard plus ¼ inch material.	Collect all sample material. Do not field screen sample.	Radioactive material larger than 1/4 inch soil may exist.
Prepare soil samples by drying, screening using a No. 4 sieve, and mixing; discard plus No.4 (4.75 mm) material.	Prepare soil samples by drying, screening using No. 4 sieve, and mixing; retain plus No. 4 material.	Sample preparation preserves counting assumptions (uniformity, density, geometry) and comparability of onsite and offsite results.
Perform gamma spec count of prepared soil sample.	Perform gamma spec count of prepared soil sample; perform screening count of plus No. 4 material; investigate if above 0.5 x DCGL.	Radioactive material larger than No. 4 soil will be monitored with minimal impact on sampling process.

9.6 NRC INSPECTIONS

A summary of NRC inspections applicable to the FSS are provided in Section 5.8 of this FSSR. The scope of the inspections included, but was not limited to: review of project plans, interviewing of project personnel, evaluation of the on-site laboratory, observation of FSS field activities, and independent confirmatory surveys conducted by the NRC prior to and after backfilling. No violations were identified. No findings of significance were identified.

9.7 CONCLUSION

FSS data were verified to be reliable, appropriately documented, and technically defensible. Specifically, the following conclusions are made:

- The instruments used to collect the data were capable of detecting the radiation type (i.e., gamma) at or below the release criteria (described in Sections 4.4 and 4.5 of this FSSR).

- The calibration of the instruments used to collect the data was current and radioactive sources used for calibration were National Institute of Standards and Technology (NIST) traceable (described in Section 5.4 of this FSSR). Specific records available upon request.
- Instrument response was checked before instrument use each day, at minimum (described in Section 5.4 of this FSSR). Specific records available upon request.
- The survey methods used to collect the data were appropriate for the media and type of radiation being measured (described in Sections 4.4, 4.5, and 4.6 of this FSSR).
- The custody of samples collected for laboratory analysis was tracked from the point of collection until final results were obtained (described in Section 5.5.2 of this FSSR). Specific records available upon request.
- The survey data consist of qualified measurement results that are representative of the area of interest.
- Areas identified with elevated residual radioactivity (i.e. SOF > 1.0) were appropriately investigated and the $DCGL_{EMC}$ properly applied.

All the applicable screening tests passed, the retrospective analysis found that the survey design objectives were met, and additional subsurface contamination was not reasonably suspected. SU03 meets the industrial use scenario release criterion as established in the C-T Phase II DP Chapter 5; and therefore, satisfies the unrestricted release provisions of Title 10, Code of Federal Regulations (CFR), Part 20, Subpart E.

9.8 REFERENCES

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