Phase II Final Status Survey Report
Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 14

Project No. 137131 **Revision 0**

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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
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)
MDC	minimum detectable concentration
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
pCi/g	picoCuries per gram
Ra	radium
SOF	sum of fractions
Th	thorium
U	uranium
WRS	Wilcoxon Rank Sum

14.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU08

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 SU08 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 November 2011. The SU08 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.

14.1 OVERVIEW

SU08 is a Class 1 survey unit located in the central portion of C-T Plant 5. The survey unit is approximately 101 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 14-1 shows the location of SU08 within the Plant 5 area. Figure 14-2 depicts the AECOM grids within and surrounding SU08.

Figure 14-3 is a photograph of SU08 that was taken during the FSS, following remediation. The survey unit is bounded on the west by SU06, the south by SU07, the east by SU20, and the north by SU09. The survey unit is comprised entirely of AECOM grid D5. Soil and related debris, including wooden and clay pipe, were removed from the area to an excavated depth range of approximately 14.5 feet (ft) below grade surface (bgs).

Major concerns were raised on November 17, 2011 regarding the previously constructed east/west berm across SU07 forming the impoundment for the accumulating untreated water in the excavation, as pictured in Figure 14-3. The berm began showing evidence of saturation through the bottom and into the area north of the berm being prepared for FSS. The decision was made to install a buttress of compacted clean fill approximately 5 to 7 ft thick and 35 ft wide against the base of the saturated berm. Construction on the buttress began that day.

Soil samples were collected across AECOM grid D5 immediately prior to commencing construction of the buttress. The purpose of the sample collection was to acquire data of sufficient quality and quantity so as to preclude the need to remove the clean fill material at a later date and perform the FSS. Remediation in AECOM grid D5 had been completed. Soil sampling, including at-depth (auger) sampling, had been performed, which indicated no additional remediation was required. The FSS of the area was awaiting completion of the remediation of other grids north and east of AECOM grid D5.

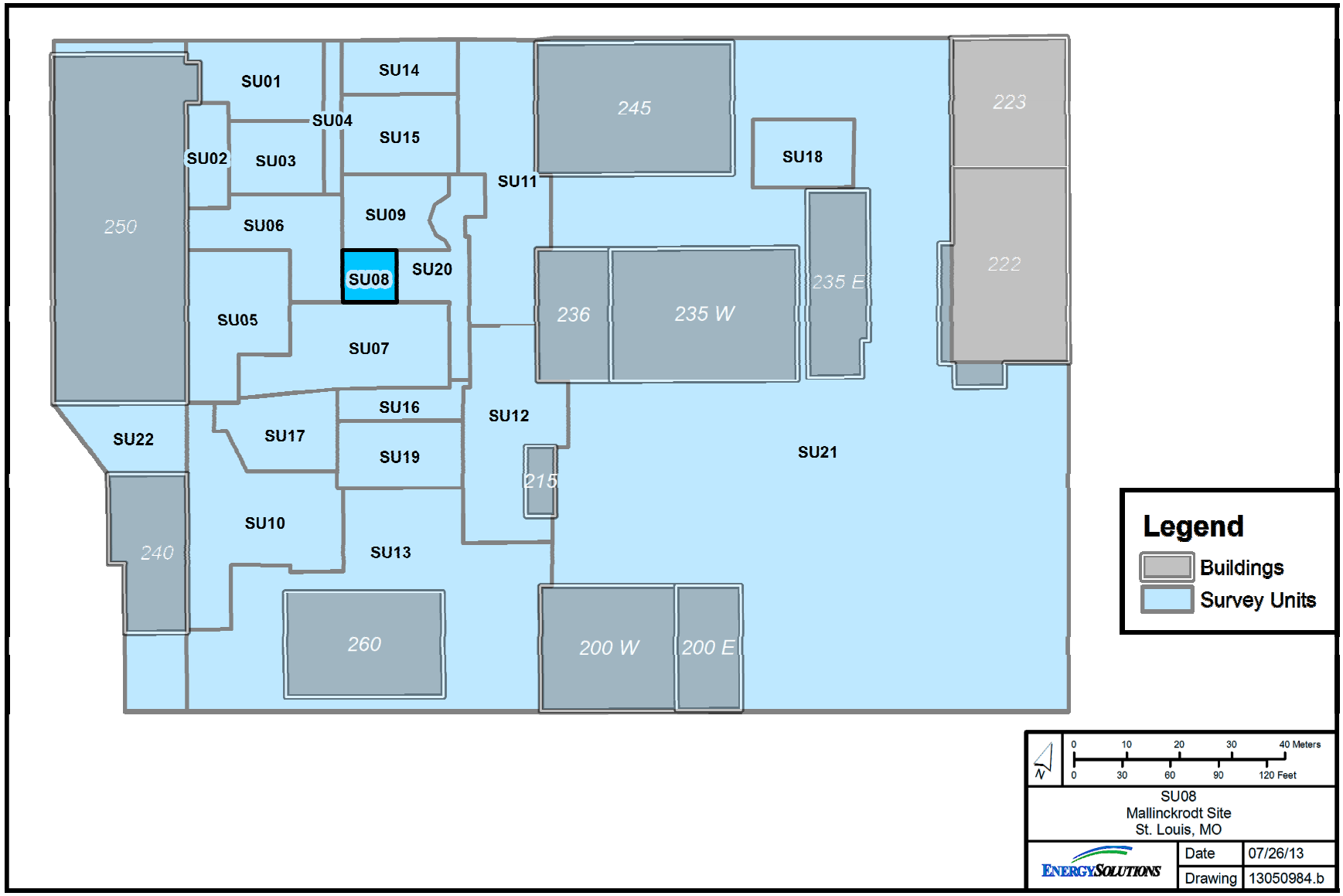

Figure 14-1 Location of Subsurface SU08 in C-T Plant 5

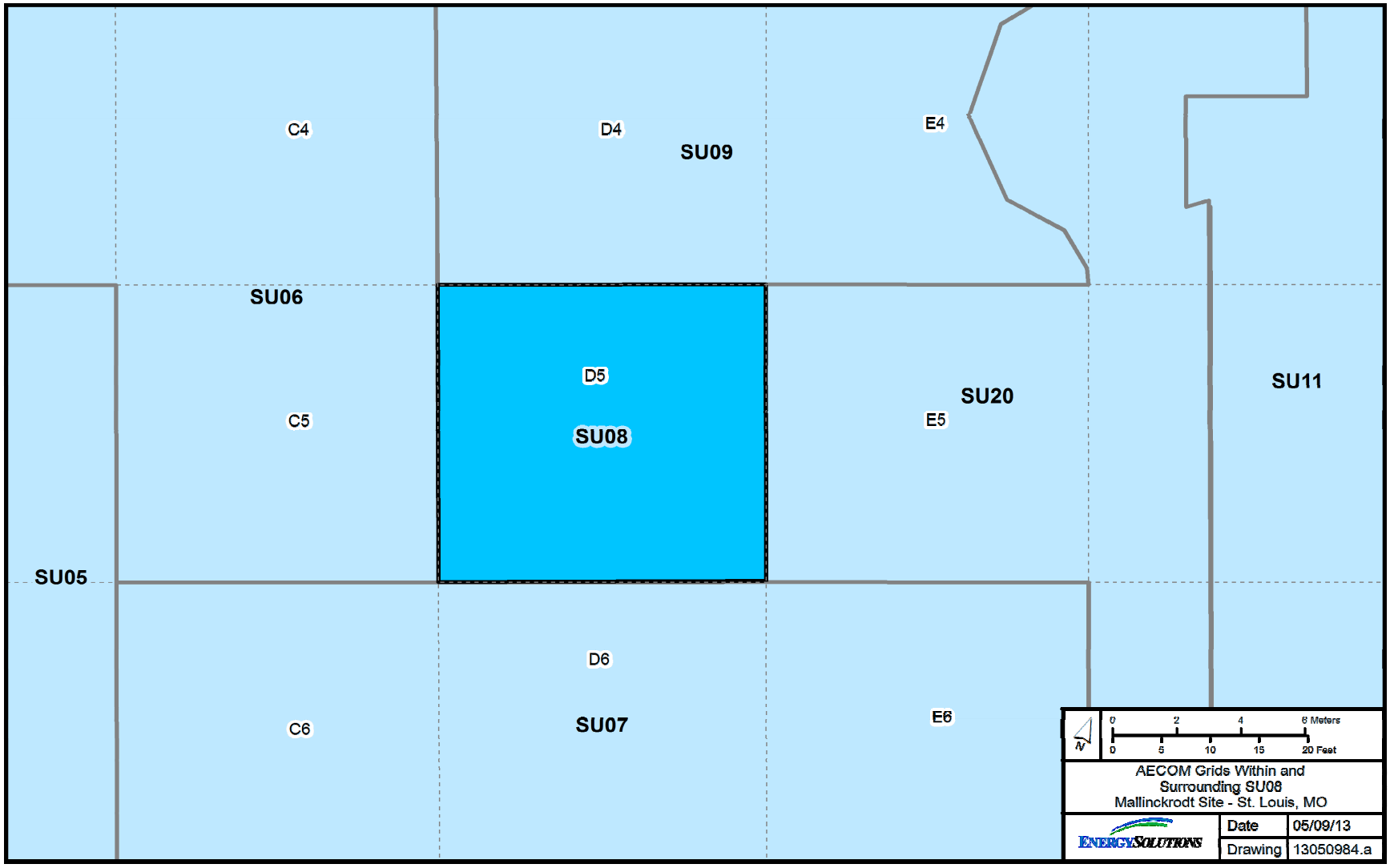

Figure 14-2 AECOM Grids Within and Surrounding SU08

Figure 14-3 Photograph Looking Southeast Towards SU08

14.2 REMEDIAL ACTION AND RADIOLOGICAL SAMPLING SUMMARY

Post-remediation surface soil sampling was performed, which indicated successful remediation of the area. Surface soil samples were collected at the grid center and at the midpoints of the northern, western, and southern edges of AECOM grid D5. In addition, at-depth (auger) sampling was performed in the center of AECOM grid D5 from the floor of the excavation at 14.5 ft bgs to approximately 18.5 ft bgs. A total of four auger samples were collected. Sampling locations are shown in Figure 14-4. Table 14-1 provides the results of those samples.

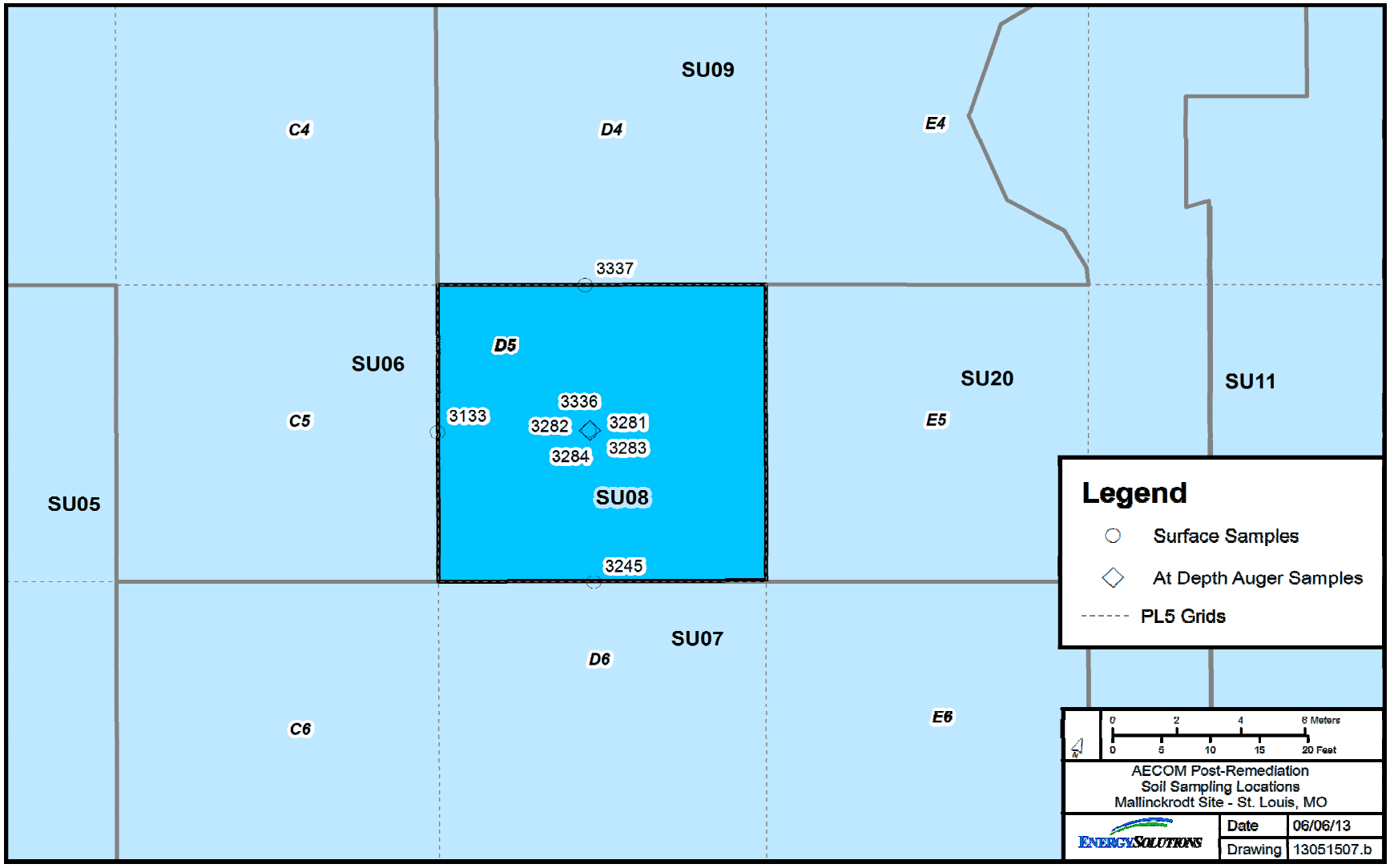

Figure 14-4 Post-Remediation Soil Sampling Locations

Table 14-1 Post-Remediation Sampling Analytical Results

Sample ID	Depth (ft bgs)	On-Site Results			
		Concentration (pCi/g)			Gross SOF
		^{232}Th	^{226}Ra	^{238}U	
Surface Samples					
3133	13.5	1.30	2.16	4.15	0.13
3245	16	0.82	1.13	3.36	0.08
3336	14.5	1.15	1.52	13.91	0.12
3337		0.94	1.26	0.86	0.08
At-Depth (Auger) Samples					
3281	14.5	7.51	7.25	9.17	0.58
3282	15.5	1.01	2.55	3.18	0.18
3283	16.5	1.86	2.28	6.33	0.17
3284	17.5	2.25	3.78	5.19	0.23

14.3 DATA COLLECTION

Soil samples were collected across AECOM grid D5 immediately prior to commencing construction of the buttress. Due to the urgency for construction, data collection was not necessarily 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; however, Section 14.5 discusses the deviations and how the intent of the DQOs were met. 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.

14.3.1 Gamma Scans

Because the previously constructed berm was showing signs of saturation and groundwater was entering the survey unit, a gamma walk-over survey (GWS) was not performed due to the urgency for the buttress construction to begin.

14.3.2 Soil Sampling

Soil samples to be used for the statistical test were collected at systematic locations distributed across the survey unit. Systematic locations were selected based on the orientation of the AECOM grid system over the entire excavation area. The 4 surface samples previously collected, as shown in Table 14-1, were included in the systematic locations. No random-start location specific to the survey unit was identified. Figure 14-5 provides the soil sampling locations. A total of 11 systematic soil samples were collected over the areal footprint SU08.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 14-2 provides the sample results and summary statistics for the 11 systematic samples.

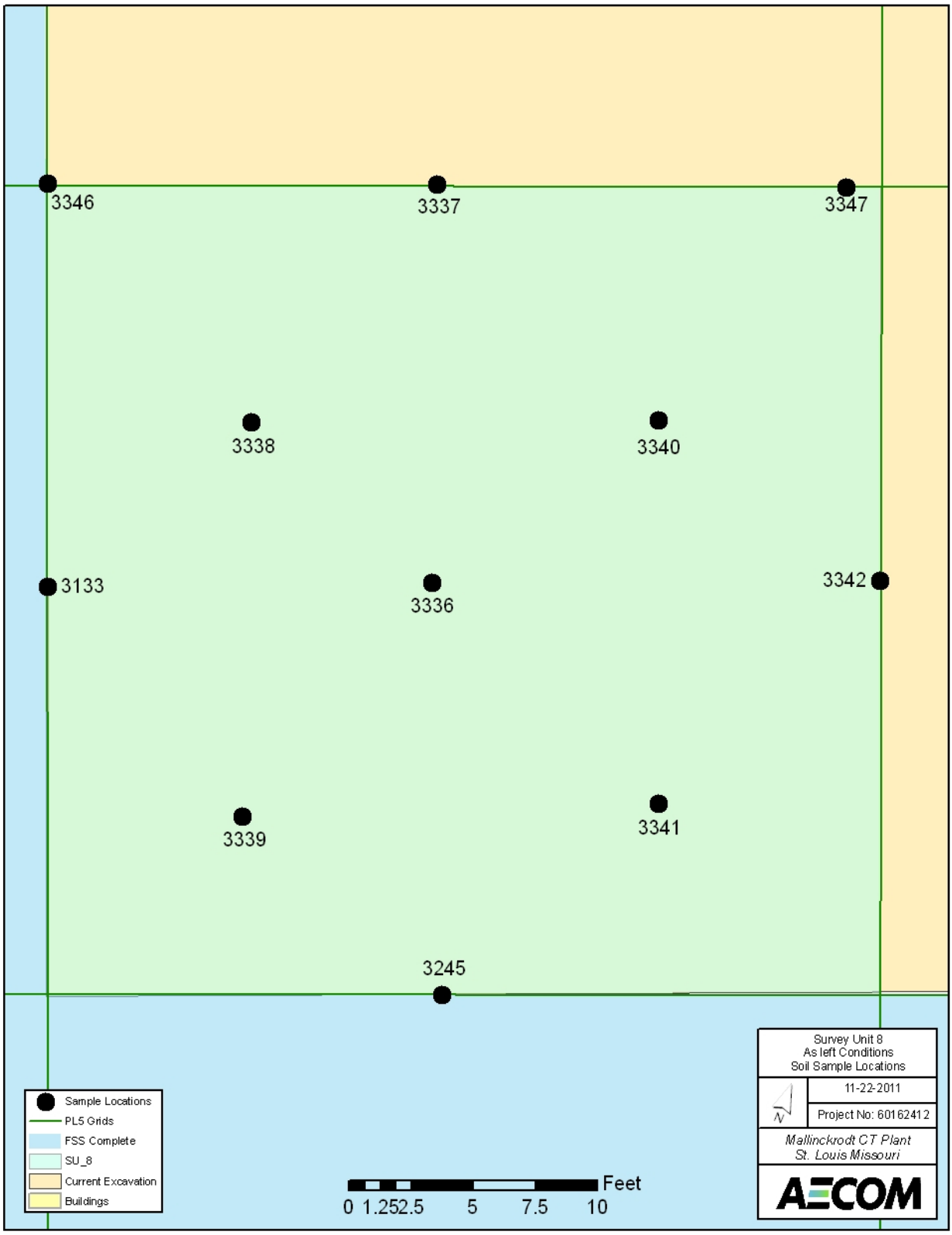

Figure 14-5 As-Left Soil Sampling Locations

Table 14-2 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]	
3133	13.5	1.30	0.27	0.07	2.16	1.02	0.75	4.15	0.91	0.57	0.13	0.00	1.66	0.35	0.22	1.45	0.22	0.07	1.60	0.23	0.07	0.12	0.02	1.10
3245	16	0.82	0.15	0.08	1.13	0.94	0.73	3.36	0.94	0.56	0.08	0.00	1.12	0.34	0.25	0.84	0.15	0.07	0.96	0.17	0.08	0.08	0.00	1.01
3336	14.5	1.15	0.21	0.04	1.52	1.38	1.10	13.91	1.43	0.68	0.12	0.01	1.36	0.31	0.22	1.13	0.17	0.06	1.29	0.18	0.06	0.10	0.00	1.22
3337	14.5	0.94	0.22	0.07	1.26	0.83	0.54	0.86	0.67	0.48	0.08	0.00	1.40	0.41	0.29	1.34	0.23	0.08	1.36	0.23	0.09	0.11	0.00	0.79
3338	14.5	2.19	0.36	0.13	4.59	1.73	1.30	11.61	1.88	1.03	0.26	0.12	3.08	0.54	0.39	5.63	0.74	0.10	6.39	0.81	0.11	0.33	0.18	0.80
3339	14.5	1.20	0.22	0.09	1.28	0.95	0.73	4.24	1.00	0.59	0.10	0.00	1.54	0.40	0.35	1.29	0.22	0.10	1.51	0.25	0.09	0.11	0.01	0.90
3340	14.5	0.89	0.23	0.06	1.12	0.88	0.62	1.91	0.81	0.50	0.08	0.00	1.02	0.24	0.17	0.92	0.14	0.06	1.08	0.16	0.05	0.08	0.00	1.03
3341	14.5	0.88	0.21	0.07	1.29	0.81	0.54	1.29	0.80	0.50	0.08	0.00	0.91	0.21	0.20	0.86	0.14	0.06	0.95	0.14	0.06	0.07	0.00	1.19
3342	14.5	1.28	0.30	0.10	2.99	0.97	0.66	2.12	1.06	0.66	0.16	0.02	1.71	0.43	0.37	2.49	0.38	0.11	2.51	0.37	0.11	0.16	0.02	0.99
3346	14.5	1.27	0.29	0.09	1.61	1.12	0.86	5.14	1.61	0.67	0.12	0.00	1.34	0.25	0.22	1.66	0.23	0.06	1.76	0.24	0.06	0.11	0.00	1.00
3347	14.5	0.86	0.19	0.10	2.78	1.28	0.97	10.90	1.45	0.71	0.15	0.02	0.97	0.29	0.28	1.03	0.17	0.07	0.98	0.16	0.08	0.08	0.00	1.90
Summary Statistics																								
Count:		11			11			11			11	11	11			11			11			11	11	11
Average:		1.16			1.98			5.41			0.12	0.02	1.46			1.69			1.85			0.12	0.02	1.09
Median:		1.15			1.52			4.15			0.12	0.00	1.36			1.29			1.36			0.11	0.00	1.01
Standard Dev.:		0.39			1.09			4.57			0.05	0.04	0.60			1.39			1.57			0.07	0.05	0.30
Minimum:		0.82			1.12			0.86			0.08	0.00	0.91			0.84			0.95			0.07	0.00	0.79
Maximum:		2.19			4.59			13.91			0.26	0.12	3.08			5.63			6.39			0.33	0.18	1.90
Range:		1.37			3.47			13.05			0.19	0.12	2.17			4.80			5.44			0.26	0.18	1.11

[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 14.3.2.

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.

14.3.3 Core Boring

The C-T Phase II DP, Table 4-7, provided characterization borehole results. Of the locations provided in the table, two were collected within the extent of SU08: BH-015 and BH-015A. Table 14-3 provides the data for these locations. The results indicate that beyond the excavation extent, additional subsurface contamination is not reasonably expected. Therefore, in accordance with Page 14-22 of the C-T Phase II DP, FSS core sampling or measurements were not performed.

Table 14-3 Characterization Borehole Results

Location ID	Sample Depth (ft)	Activity Concentration (pCi/g) [a]			SOF [b]	
		^{232}Th	^{226}Ra	^{238}U	Gross	Net [c]
BH-015	5 - 6	11.10	327.40	16.30	**11.62**	**11.48**
BH-015A	9 - 10	48.20	744.60	71.70	**27.44**	**27.30**
	11 - 12	0.93	667.00	210.00	**23.02**	**22.89**
	14 - 15	2.20	462.00	75.00	**15.91**	**15.76**
	15 - 16	2.20	*0.43*	9.70	0.12	0.05

[a] Italicized results indicate <MDC.
[b] **Bolded red** SOF values indicate a result >1.
[c] Calculated as discussed in Section 14.3.2.

14.4 DATA ANALYSIS

Collected data were reviewed for suitability for use as FSS data and 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.

14.4.1 Elevated Area Evaluation

There were no elevated areas identified in SU08.

14.4.2 Data Set Screening Analysis

Table 14-4 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 14-4 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.31	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

14.4.2.1 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 3338 with a gross SOF of 0.33 (from Table 14-2) 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 0.31. Because the test value was less than one, no further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

14.4.2.2 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.

14.4.2.3 $DCGL_W$

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.

14.4.2.4 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.

14.4.3 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.

14.4.4 Retrospective Analysis

A retrospective analysis was performed of the survey 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 14-5 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 14-5 Retrospective Analysis

Parameter	*A Priori* Value	Retrospective Value Based on Actual Results (Gross SOF)
Upper Bound of Gray Region	DCGL = 1	1
Lower Bound of Gray Region	0.5 x DCGL = 0.5	0.12
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.074
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	11.9
Calculated N/2 Sample Size	15 [a]	9
Actual N/2 Sample Size	--	11

[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.

14.5 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. Three deviations are discussed below.

1. A GWS is performed to locate radiation anomalies that might indicate areas with elevated residual radioactivity where further data collection (i.e., biased soil sampling) is warranted. However, an FSS GWS was not performed due to urgency to complete construction of the buttress. Although the saturated soils prevented an accurate/useable GWS, AECOM was able to collect soil samples without placing backfill over the area for access, which is permitted per footnote 20 of Section 14.4.3.7 of the C-T Phase II DP. A total of 11 soil samples were collected at a spacing of approximately 3.5 m with an average sampling density of one sample per 9.1 m^2. The maximum sample density allowed would have been the calculated sample size of 9 from Table 14-5 over the maximum allowed Class 1 area size of 3,000 m^2, or one sample per approximately 333 m^2. Because the actual sample density was over 35 times greater than what was necessary per the C-T Phase II DP, the consequence of not performing the GWS portion of the FSS is mitigated by the high surface sample density. Consequently the survey unit was evaluated as acceptably meeting the C-T Phase II DP objectives.
2. A random-start, systematic sampling pattern is required for Class 1 survey units by C-T Phase II DP, Section 14.4.3.6. No random-start location was identified within the survey unit itself; however, samples were collected using a systematic pattern based on the AECOM grid system used over the entire excavation. There was no judgmental

discretion used in the placement of the AECOM grid or in the selection of the sample locations themselves relative to the area surveyed; therefore, the intent of the random-start requirement to eliminate judgmental discretion was satisfied.

3. 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.

14.6 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, and independent confirmatory surveys conducted by the NRC after backfilling. No violations were identified. No findings of significance were identified.

14.7 CONCLUSION

Collected data were reviewed for suitability for use as FSS data. The review concluded that the data collected were adequate to serve as FSS data and 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. SU08 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.

14.8 REFERENCES

Mallinckrodt, *Mallinckrodt Columbium-Tantalum Phase II Decommissioning Plan*, Revision 2, August 2008.