Phase II Final Status Survey Report
Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 6

Project No. 137131 **Revision 0**

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ABBREVIATIONS AND ACRONYMS

β	beta
AECOM	AECOM Technical Services
C-T	columbium-tantalum
CFR	Code of Federal Regulations
cpm	counts per minute
DCGL	derived concentration guideline level
DP	decommissioning plan
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
DQO	data quality objectives
EMC	elevated measurement comparison
Energy*Solutions*	Energy*Solutions*, LLC
FSS	Final Status Survey
FSSR	Final Status Survey Report
m^2	square meters
MARSSIM	Multi-Agency Radiation and Site Investigation Manual (NUREG-1575)
MDA	minimum detectable activity
MDC	minimum detectable concentration
min	minute
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
WRS	Wilcoxon Rank Sum

6.0 RESULTS SUMMARY FOR PLANT 5 PAVEMENT

This chapter of the Final Status Survey Report (FSSR) presents the results of the final status survey (FSS) and data assessment for Plant 5 pavement survey units SUA and SUB in accordance with Columbium-Tantalum (C-T) Phase II Decommissioning Plan (DP) Section 14.5. SUA consists of the exposed asphalt and concrete surfaces east of the 7th Street alley in the eastern half of Plant 5. SUB consists of the exposed asphalt and concrete surfaces west of the 7th Street alley in the western half of Plant 5. The pavement was divided into two survey units due to operation considerations. The FSS for SUA was completed by AECOM Technical Services (AECOM) in November and December of 2011. The FSS for SUB was completed by Energy*Solutions*, LLC (Energy*Solutions*) in November of 2013. The data assessments for both survey units were 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.

6.1 OVERVIEW

C-T Phase II DP Figure 14-1A shows the initial classification of the Plant 5 pavement. All portions of the Class 1 and Class 2 along with some surrounding Class 3 pavement have been removed during subsurface remediation site activities. SUA and SUB are survey units comprising the remaining Class 3 pavement of Plant 5. The survey units consist of asphalt and concrete. SUA and SUB are approximately 6,784 square meters (m^2) and 2,406 m^2 in size, respectively. C-T Phase II DP Table 14-4 notes no size limitation for Class 3 survey units. Class 3 was the appropriate classification for the remaining pavement because the survey units had potential residual radioactivity that was not expected to exceed a small fraction of the derived concentration guideline level ($DCGL_W$). Figure 6-1 shows the location of SUA and SUB within the Plant 5 area.

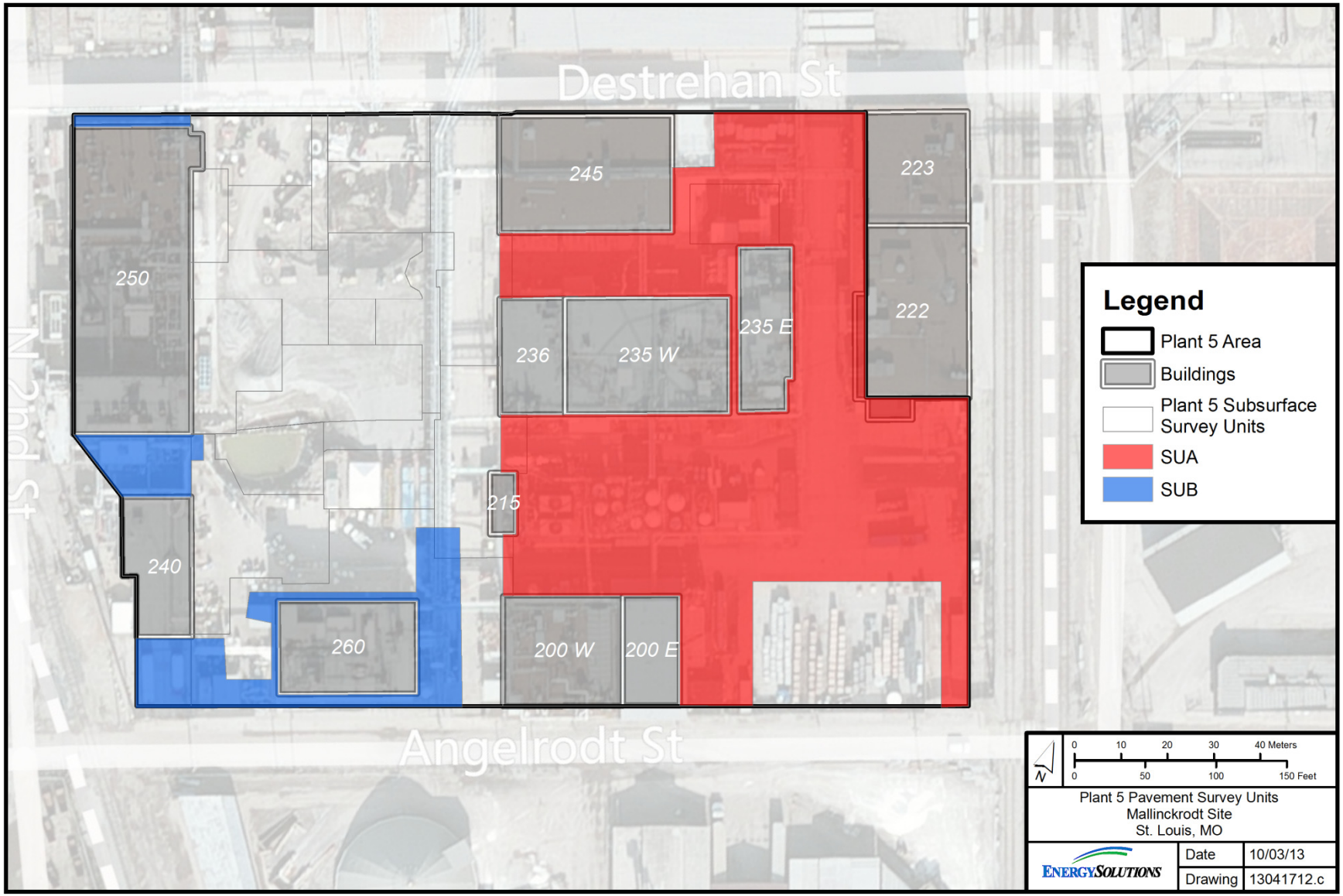


Figure 6-1 Plant 5 Pavement Survey Units

6.2 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.

6.2.1 Beta Surface Activity Scans

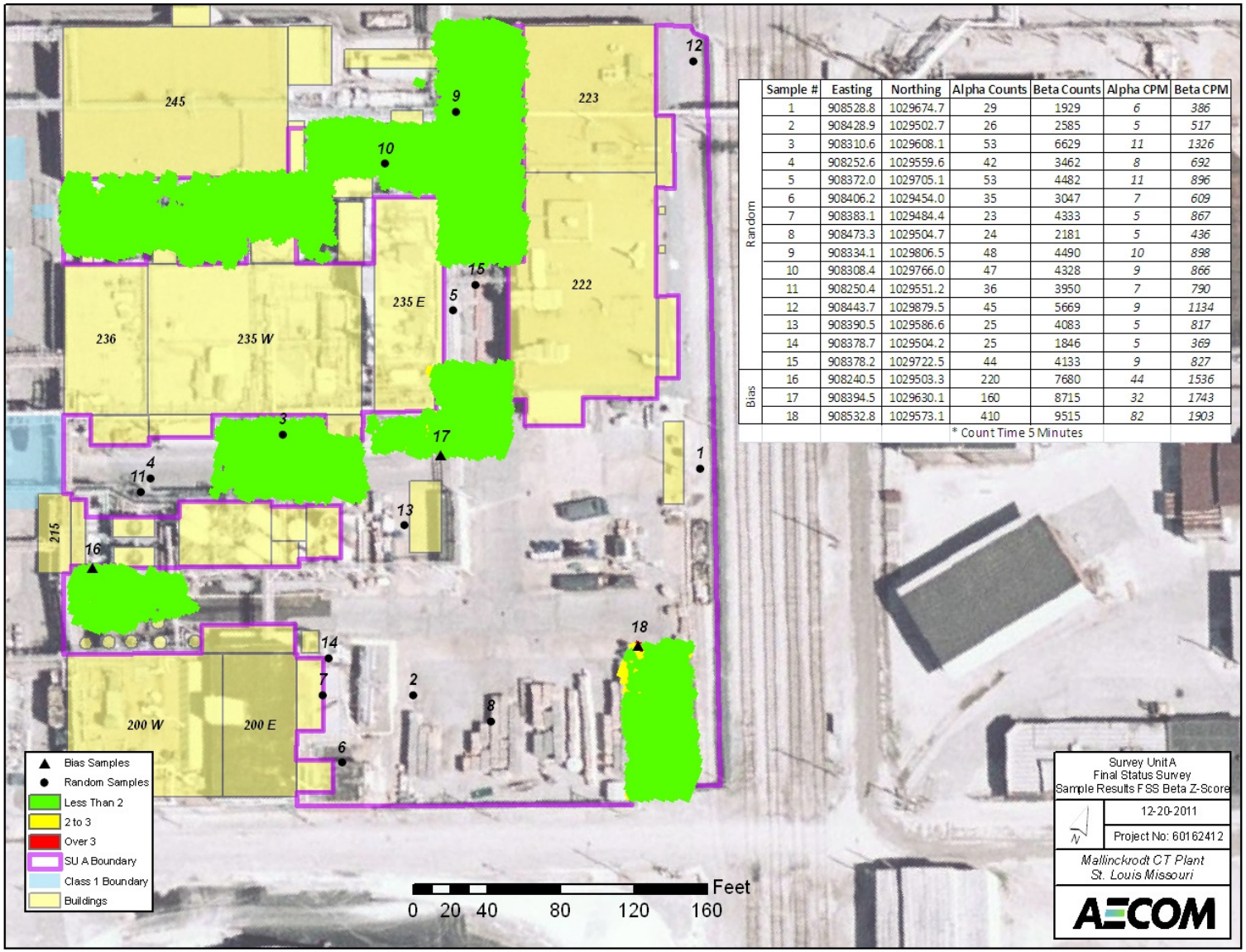
A beta surface scan was performed over the pavement surfaces of SUA and SUB to locate radiation anomalies that might indicate areas with elevated residual radioactivity where further data collection (i.e., biased measurement) was warranted.

6.2.2 Surface Activity Measurements

Surface activity measurements to be used for the statistical test were collected at a frequency and at representative locations throughout SUA and SUB such that a statistically sound conclusion regarding the radiological condition of each survey unit could be developed. Additional biased surface activity measurements were also collected at locations of elevated residual radioactivity identified by the beta surface activity scans.

Figure 6-2 provides the beta surface activity scan results and surface activity measurement locations for SUA. A total of 18 (15 systematic and 3 biased locations based on beta surface scans) surface activity measurements were performed on the pavement surfaces.

Figure 6-3 provides the beta surface activity scan results and surface activity measurement locations for SUB. A total of 20 (17 random and 3 biased locations based on beta surface scans) surface activity measurements were performed on the surface of the remaining “old” pavement surfaces.



	Sample #	Easting	Northing	Alpha Counts	Beta Counts	Alpha CPM	Beta CPM
Random	1	908528.8	1029674.7	29	1929	6	386
	2	908428.9	1029502.7	26	2585	5	517
	3	908310.6	1029608.1	53	6629	11	1326
	4	908252.6	1029559.6	42	3462	8	692
	5	908372.0	1029705.1	53	4482	11	896
	6	908406.2	1029454.0	35	3047	7	609
	7	908383.1	1029484.4	23	4333	5	867
	8	908473.3	1029504.7	24	2181	5	436
	9	908334.1	1029806.5	48	4490	10	898
	10	908308.4	1029766.0	47	4328	9	866
	11	908250.4	1029551.2	36	3950	7	790
	12	908443.7	1029879.5	45	5669	9	1134
	13	908390.5	1029586.6	25	4083	5	817
	14	908378.7	1029504.2	25	1846	5	369
	15	908378.2	1029722.5	44	4133	9	827
Bias	16	908240.5	1029503.3	220	7680	44	1536
	17	908394.5	1029630.1	160	8715	32	1743
	18	908532.8	1029573.1	410	9515	82	1903

* Count Time 5 Minutes

Figure 6-2 Beta Surface Activity Scans and Measurement Locations for SUA

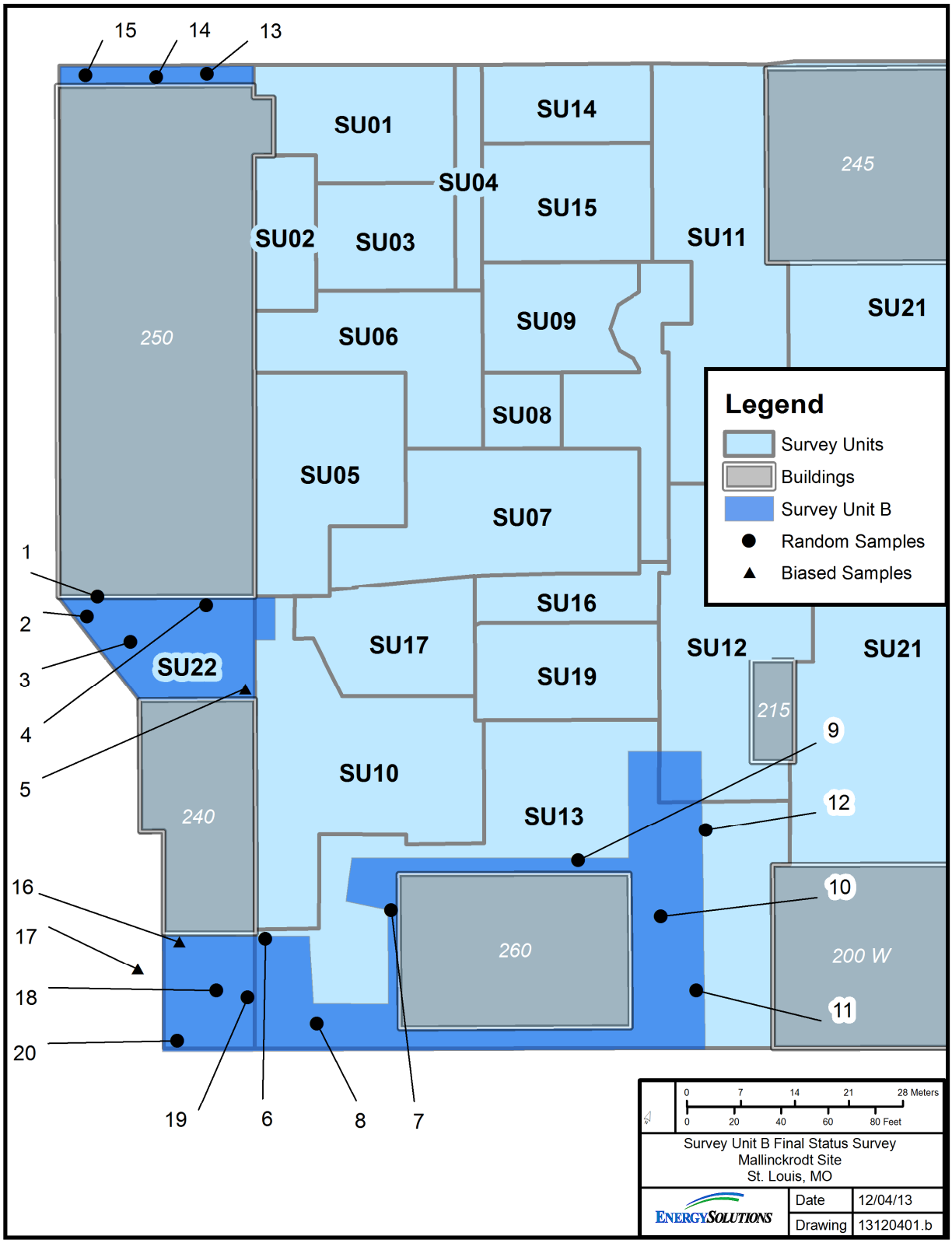


Figure 6-3 Beta Surface Activity Scans and Measurement Locations for SUB

Table 6-1 provides the surface activity measurement results and summary statistics, in counts per minute (cpm) and disintegrations per minute per 100 square centimeters (dpm/100 cm^2), for the 15 systematic measurements for SUA. Table 6-2 provides the surface activity measurements results for the 3 beta surface activity scan biased measurement locations for SUA. In evaluating the data, background contributions were not accounted for in calculating surface activity. Alpha surface activity measurements were performed by AECOM, presumably for informational purposes, and are provided in the tables.

Table 6-1 Systematic Surface Activity Results for SUA

Location	Alpha Counts [a]	Beta Counts [a]	Alpha cpm	Beta cpm	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2) [b]
1	29	1,929	6	386	12	555
2	26	2,585	5	517	11	744
3	53	6,629	11	1,326	23	1,909
4	42	3,462	8	692	18	997
5	53	4,482	11	896	23	1,291
6	35	3,047	7	609	15	877
7	23	4,333	5	867	10	1,248
8	24	2,181	5	436	10	628
9	48	4,490	10	898	21	1,293
10	47	4,328	9	866	20	1,246
11	36	3,950	7	790	15	1,137
12	45	5,669	9	1,134	19	1,632
13	25	4,083	5	817	11	1,176
14	25	1,846	5	369	11	532
15	44	4,133	9	827	19	1,190
				Average:	16	1,097
				Median:	15	1,176
				Standard Deviation:	5	387
				Minimum:	10	532
				Maximum:	23	1,909

[a] Total count time of five minutes.

[b] Surface activity measurements were performed using an 821 cm^2 detector and reported values include a geometry correction factor of 8.21 (821 cm^2 / 100 cm^2). For the surface activity measurements, it could be conservatively assumed that all of the activity was concentrated into a 100 cm^2 area within the detector's field of view and the remaining area had no activity (background levels). With that assumption, the calculated range without using the geometry correction factor was 4,364 to 15,671 dpm/100 cm^2. These results did not exceed the $DCGL_W$ of 180,000 β/min/100 cm^2.

Table 6-2 Biased Surface Activity Results for SUA

Location	Alpha Counts [a]	Beta Counts [a]	Alpha cpm	Beta cpm	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2) [b]
16	220	7,680	44	1,536	94	2,211
17	160	8,715	32	1,743	68	2,509
18	410	9,515	82	1,903	175	2,740

[a] Total count time of five minutes.

[b] Surface activity measurements were performed using an 821 cm^2 detector and reported values include a geometry correction factor of 8.21 (821 cm^2 / 100 cm^2). For the surface activity measurements, it could be conservatively assumed that all of the activity was concentrated into a 100 cm^2 area within the detector's field of view and the remaining area had no activity (background levels). With that assumption, the calculated range without using the geometry correction factor was 18,156 to 22,494 dpm/100 cm^2. These results did not exceed the $DCGL_W$ of 180,000 β/min/100 cm^2.

Table 6-3 provides the surface activity measurement results and summary statistics for the 17 systematic measurements for SUB. Table 6-4 provides the surface activity measurements results for the 3 beta surface activity scan biased measurement locations for SUB. In evaluating the data, background contributions were not accounted for in calculating surface activity. Because alpha surface activity measurements were performed by AECOM, Energy*Solutions* also performed them and they are provided in the tables.

Table 6-3 Random Surface Activity Results for SUB

Location	Alpha Counts [a]	Beta Counts [a]	Alpha cpm	Beta cpm	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2)
1	2	215	2	215	22	1,732
2	4	194	4	194	43	1,563
3	2	242	2	242	22	1,950
4	5	213	5	213	54	1,716
6	3	211	3	211	32	1,700
7	4	233	4	233	43	1,877
8	6	220	6	220	65	1,773
9	3	217	3	217	32	1,748
10	1	290	1	290	11	2,337
11	4	221	4	221	43	1,781
12	1	236	1	236	11	1,902
13	6	208	6	208	65	1,676
14	5	211	5	211	54	1,700
15	7	240	7	240	75	1,934
18	3	266	3	266	32	2,143
19	4	235	4	235	43	1,893
20	7	249	7	249	75	2,006
				Average:	42	1,849
				Median:	43	1,781
				Standard Deviation:	20.2	190
				Minimum:	11	1,563
				Maximum:	75	2,337

[a] Total count time of one minute.

Table 6-4 Biased Surface Activity Results for SUB

Location	Alpha Counts [a]	Beta Counts [a]	Alpha cpm	Beta cpm	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2)
5	7	697	7	697	75	5,616
16	7	1143	7	1143	75	9,210
17	6	1023	6	1023	65	8,243

[a] Total count time of one minute.

6.3 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.

6.3.1 Elevated Area Evaluation

There were no elevated areas identified in SUA or SUB.

6.3.2 Data Set Screening Analysis

Table 6-5 summarizes the results of the screening tests performed for SUA and SUB in accordance with Pages 14-27 through 14-29 of the C-T Phase II DP. All applicable tests demonstrating compliance passed.

Table 6-5 Screening Tests Results

Screening Test	Test Value	Conclusion
SUA		
Min/Max	1,909	PASS
Low Level	0	PASS
$DCGL_W$	N/A	Not applicable; Min/Max < $DCGL_W$
EMC Limit	N/A	Not applicable; No elevated areas
SUB		
Min/Max	2,337	PASS
Low Level	0	PASS
$DCGL_W$	N/A	Not applicable; Min/Max < $DCGL_W$
EMC Limit	N/A	Not applicable; No elevated areas

6.3.2.1 Min/Max

Page 14-27 of the C-T Phase II DP describes calculating the Min/Max screening test value by subtracting the minimum reference area result from the maximum survey unit systematic result. Background was not accounted for in the surface activity measurements; therefore, the Min/Max screening test value was equal to the maximum survey unit result. For SUA, Location 3 with a beta surface activity result of 1,909 dpm/100 cm^2 (from Table 6-1) was the maximum survey unit

systematic result, which is the Min/Max screening test value. For SUB, Location 10 with a beta surface activity result of 2,337 dpm/100 cm^2 (from Table 6-3) was the maximum survey unit systematic result. Because both test values were less than 180,000 β/min/100 cm^2, no further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

6.3.2.2 Low Level

In accordance with Page 14-27 of the C-T Phase II DP, the Low Level screening test was conducted for these Class 3 survey units. The Low Level screening test limit is calculated as the maximum of 0.1 × $DCGL_W$ plus mean of the background reference area, including uncertainty of the background reference area, or the minimum detectable activity (MDA), according to the stationary investigation level equation provided in Table 14-5 of the C-T Phase II DP. Minimum detectable activities for beta surface measurements were typical small fractions of the DCGLs (<1,000 dpm/100 cm^2). A background reference area was not used; therefore, the Low Level screening test limit could not be calculated per the equation provided in Table 14-5 of the C-T Phase II DP. Instead, the Low Level screening test limit was set to 10% of the $DCGL_w$, or 18,000 β/min/100 cm^2. This is a conservative application of the Low Level test. As shown in Table 6-1 through Table 6-4, no beta measurements exceeded the Low Level screening test limit of 18,000 β/min/100 cm^2.

6.3.2.3 $DCGL_W$

In accordance with Page 14-28 of the C-T Phase II DP and because the Min/Max test value was less than 180,000 β/min/100 cm^2, the $DCGL_W$ screening test was not applicable to SUA or SUB.

6.3.2.4 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 either SUA or SUB because no elevated areas were identified.

6.3.3 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 180,000 β/min/100 cm^2, the WRS Test was not required to demonstrate compliance for either SUA or SUB.

6.3.4 Retrospective Analysis

A retrospective analysis was performed of the FSS results for SUA and SUB to determine whether the results met the survey design objectives, in accordance with Page 14-30 of the C-T Phase II DP. Table 6-6 provides the results of the retrospective analysis. The Sign test was used instead of the WRS test in the retrospective analysis because background was not accounted for during surface activity measurements in SUA and SUB. Because the actual sample size exceeded the retrospective value sample size for both SUA and SUB, the conclusion is that the survey design objectives were met.

Table 6-6 Retrospective Analysis

Parameter	*A Priori* Value	Retrospective Value Based on FSS Results (dpm/100 cm^2)
SUA		
Upper Bound of Gray Region	DCGL = 180,000 β/min/100 cm^2	180,000
Lower Bound of Gray Region	0.5 x DCGL = 90,000 β/min/100 cm^2	1,097
Spatial Variability (standard deviation)	1/6 x DCGL = 30,000 β/min/100 cm^2	387
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	462
Calculated N Sample Size	15 [a]	14
Actual N Sample Size	--	15
SUB		
Upper Bound of Gray Region	DCGL = 180,000 β/min/100 cm^2	180,000
Lower Bound of Gray Region	0.5 x DCGL = 90,000 β/min/100 cm^2	1,849
Spatial Variability (standard deviation)	1/6 x DCGL = 30,000 β/min/100 cm^2	190
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	938
Calculated N Sample Size	15 [a]	14
Actual N Sample Size	--	17

[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 is 14 based on MARSSIM Table 5.5.

6.4 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.

6.5 NRC INSPECTIONS

A summary of U.S. Nuclear Regulatory Commission (NRC) inspections applicable to the FSS are provided in Section 5.8 of this FSSR. None of the inspections applied to the Plant 5 pavement final status surveys.

6.6 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 and 4.5 of this FSSR).
- The survey data consist of qualified measurement results that are representative of the area of interest.

All the applicable screening tests passed, the retrospective analysis found that the survey design objectives were met. SUA and SUB meet 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.

6.7 REFERENCES

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