



May 20, 2016

James Smith, Project Manager
U.S. Nuclear Regulatory Commission
Division of Decommissioning, Uranium Recovery, and Waste Programs
Material Decommissioning Branch
TWFN Mail Stop T-8F5
Rockville, MD 20852

**SUBJECT: FINAL REPORT—INDEPENDENT CONFIRMATORY SURVEY
SUMMARY AND RESULTS FOR SURVEY UNITS LSAs 08-06, 08-11, AND
08-17 FOR THE HEMATITE DECOMMISSIONING PROJECT,
FESTUS, MISSOURI
(RFTA NO. 14-003); DCN 5184-SR-07-0**

Dear Mr. Smith:

ORAU is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of Survey Units LSAs 08-06, 08-11, and 08-17 at the Hematite Decommissioning Project in Festus, Missouri. This report provides the summary and results of activities performed by ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, during the period of December 15–18, 2015. Comments on the draft report have been incorporated into this version.

You may contact me at 865.241.8793 or Erika Bailey at 865.576.6659 if you have any questions.

Sincerely,

Evan M. Harpenau
Health Physicist
ORAU

EMH:dg

Enclosure

electronic distribution: G. Bonano, NRC M. LaFranzo, NRC
 G. Chapman, NRC S. Roberts, ORAU
 T. Vitkus, ORAU E. Bailey, ORAU
 File/5184

Distribution approval and concurrence:	Initials
Laboratory Review	
Technical/Group Manager Review	
Quality Review	GI for Paige

**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS
FOR SURVEY UNITS LSAs 08-06, 08-11, AND 08-17
FOR THE HEMATITE DECOMMISSIONING PROJECT,
FESTUS, MISSOURI**

FINAL REPORT



Prepared by
Evan M. Harpenau

MAY 2016

Prepared for the
U.S. Nuclear Regulatory Commission

Prepared by ORAU under the Oak Ridge Institute for Science and Education contract, number DE-SC0014664, with the U.S. Department of Energy under interagency agreement (NRC FIN No. F-1244) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.



**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS
FOR SURVEY UNITS LSAs 08-06, 08-11, AND 08-17
FOR THE HEMATITE DECOMMISSIONING PROJECT,
FESTUS, MISSOURI**

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that ORAU, working under the Oak Ridge Institute for Science and Education (ORISE) contract, perform an independent confirmatory survey at the Hematite Decommissioning Project (HDP) in Festus, Missouri. Westinghouse Electric Company, LLC (WEC) is currently engaged in the decontamination and decommissioning of the approximate 10 acre Central Tract. This report focuses on confirmatory survey activities performed in support of the release of Land Survey Areas (LSAs) 08-06, 08-11, and 08-17 for unrestricted use.

ORAU's field activities included gamma walkover surveys, beta static measurements, and soil sampling within three soil survey units during the period of December 15–18, 2015. Confirmatory activities also included document reviews and laboratory analysis of the 18 random, 8 judgmental soil samples, and 1 discreet particle sample collected. The results of ORAU's onsite confirmatory surveys, combined with the laboratory analytical results of soil samples, and proper disposal of sample 5184M0002 support the conclusion that LSAs 08-06 and 08-11 satisfy the NRC-approved soil and surface activity derived concentration guideline levels (DCGLs) described in WEC's decommissioning planning documents. However, the confirmatory scans identified six discreet locations above the licensee's gamma surface activity investigation level. Additionally, confirmatory sample analysis indicated that LSA 08-17 contains soil contamination in excess of the uniform stratum DCGL_{ws}.

The licensee provided an explanatory document and a MARSSIM-based elevated measurement comparison DCGL (DCGL_{EMC}) calculation for the biased sample representing the highest sum-of-fraction value in excess of unity for LSA 08-17. Overall, ORAU did not find any issues in the methodology used for the calculation to dispute the licensee's determination. This conclusion along with the consideration that scans only identified six discreet locations above the gamma investigation level within the survey unit, leads ORAU to the opinion that the licensee has adequately demonstrated that LSA 08-17 also satisfies the NRC-approved soil and surface activity DCGLs.



**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS
FOR SURVEY UNITS LSAs 08-06, 08-11, AND 08-17
FOR THE HEMATITE DECOMMISSIONING PROJECT,
FESTUS, MISSOURI**

1. INTRODUCTION

Westinghouse Electric Company, LLC (WEC) is in the process of removing radiologically contaminated materials from a former nuclear fuel fabrication facility near Festus, Missouri now known as the Hematite Decommissioning Project (HDP). From its inception in 1956 through 1974, the facility was used primarily in support of government contracts that required the production of highly enriched uranium products. From 1974 through plant closure in 2001, the focus changed from government contracts to commercial fuel production. Specifically, operations included the conversion of uranium hexafluoride gas of various uranium enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. Secondary operations included research and development and uranium scrap recovery processes.

The site is located in Jefferson County, Missouri, less than four miles west of the town of Festus, Missouri, and 35 miles south of the city of St. Louis. It is surrounded by forest, agricultural lands, and low-density residential housing (Figure A-1). The entire site consists of approximately 228 acres; however, the impacted portion of the site—referred to as the central tract—includes approximately 10 acres.

The U.S. Nuclear Regulatory Commission (NRC) is responsible for oversight of licensed activities that are currently being conducted at the HDP. The NRC requested that ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, perform confirmatory surveys of final status survey (FSS) units LSAs 08-06, 08-11, and 08-17. The soils in these survey units are associated with the former septic system, the leach field, evaporation ponds, and soils under the radioactive material storage vault, (Figure A-2) (WEC 2009, 2015a). Confirmatory activities included document reviews and the collection of independent survey and sample data for the NRC's use in assessing the adequacy of the licensee's FSS process.

2. APPLICABLE SITE GUIDELINES

The primary radionuclides of concern (ROCs) at the HDP are technetium-99 (Tc-99), thorium-232 (Th-232), uranium-234 (U-234), U-235, and U-238. Radium-226 (Ra-226) is also considered to be a ROC within the Burial Pit Area (WEC 2011). The balance of ROCs—neptunium-237 (Np-237), plutonium-239/240 (Pu-239/240), and americium-241 (Am-241)—are considered to be insignificant based on the aggregate dose of these radionuclides being less than 10% of the total effective dose equivalent (TEDE) for each conceptual site model (CSM). However, their dose contributions have been accounted for in the adjusted derived concentration guideline levels (DCGL_ws) accordingly (WEC 2011). A DCGL_w is a radionuclide-specific activity concentration corresponding to a release criterion based on the spatial distribution of a contaminant as derived for the nonparametric statistical test.

Each radionuclide-specific DCGL_w represents the concentration above background of a residual radionuclide that would result in a radiological dose of 25 millirem per year (mrem/yr) to the average member of the critical group (WEC 2013). For conservatism, the licensee has opted to compare the DCGL_ws to gross soil concentrations with the exception of Ra-226 and Th-232. For consistency, ORAU's analytical data are presented and assessed in the same manner. Because each of the individual DCGL_w represents 25 mrem/yr, the sum-of-the-fractions (SOF) approach is used to demonstrate compliance with the dose limit. SOF calculations are performed as follows:

$$SOF_{TOTAL} = \sum_{j=0}^n SOF_j = \sum_{j=0}^n \frac{C_j}{DCGL_{w,j}}$$

Where C_j is the concentration of ROC “j,” and $DCGL_{w,j}$ is the DCGL_w for ROC “j.”

The analytical results for LSAs 08-06 and 08-17 were evaluated and compared to the applicable uniform stratum DCGL (uniform DCGL_w) presented in Table 2.1. Sample results for LSA 08-11 were compared to the three-layer DCGL_w values—shallow stratum, root stratum, and excavation scenario—due to the way remediation was performed around the natural gas pipeline that passes through the survey unit (SU) and for the evaporation ponds (WEC 2015a).

Table 2.1. Adjusted Site-specific Soil DCGL_{ws} by CSM^a

Radionuclide	DCGL _w By Conceptual Site Model (pCi/g)				
	Shallow Stratum	Root Stratum	Deep Stratum	Excavation Scenario	Uniform Stratum
Uranium-234	508.5	235.6	2,890	872.4	195.4
Uranium-235+D ^b	102.3	64.1	3,034	208.1	51.6
Uranium-238+D ^b	297.6	183.3	3,028	551.1	168.8
Technetium-99	151.0	30.1	98,649	74.0	25.1
Thorium-232+C ^{c, d}	4.7	2.0	9,279	5.2	2.0
Radium-226+C ^{c, d}	5.0	2.1	13,029	5.4	1.9

CSM = conceptual site model

^aTable populated from WEC 2013 Table 14-4.

^b+D indicates the DCGL_w includes short-lived (half-life ≤ 6 mo.) decay products.

^c+C indicates the DCGL_w includes all radionuclides in the associated decay chain.

^dDCGL_{ws} represents net concentration in soil for each CSM.

3. PROCEDURES

The confirmatory survey activities were conducted December 15–18, 2015, in accordance with a project-specific confirmatory survey plan approved by the NRC, the ORAU *Radiological and Environmental Survey Procedures Manual*, the ORAU *Radiological and Environmental Analytical Laboratory Procedures Manual*, and the ORAU *Environmental Services and Radiation Training Quality Program Manual* (ORAU 2013, 2015a, 2015b, and 2015c).

ORAU performed high-density gamma radiation scans of the accessible soil surfaces within each SU. High-density walkover scans were performed in 1-meter intervals using Ludlum Model 44-10 sodium iodide (NaI) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. The ratemeter-scalers were also coupled to global positioning systems (GPS) that enabled real-time gamma count rate and spatial data capture. Figures A-3 through A-5 show the spatially-oriented gamma walkover surveys for SUs LSA 08-06, 08-11, and 08-17, respectively. One thing to note is that some areas within each SU were deemed inaccessible due to the presence of non-traversable mud and generally slippery conditions.

A ranked set sampling (RSS) design was used to estimate the mean radionuclide concentration in the SUs (EPA 2002). FSS sample data were only available for LSA 08-17 prior to the confirmatory survey (WEC 2015b). Review of that FSS data showed that mean ROC concentrations and their associated standard deviations were consistent with FSS data reviewed for prior confirmatory surveys, thus suggesting the RSS design for LSA 08-17 would be adequate to also use for LSAs 08-06 and 08-11. Review of the gamma walkover survey data for LSAs 08-11 and 08-17 reinforced the theory that the FSS sample data from LSA 08-17 would be adequate for the RSS design (WEC 2015c, 2015d, 2015e, and 2015f). Visual Sample Plan software, version 7.4 was then used to plot the confirmatory locations for LSAs 08-06, 08-11, and 08-17. As a result of the sample planning inputs, 18 ranking locations were evaluated in each of the three SUs. Following completion of the confirmatory walkover surveys, the RSS locations were laid out as illustrated in Figures A-6 through A-8. A one-minute static gamma measurement was made with the NaI detector in conjunction with a static beta measurement using a plastic scintillation detector at each ranking location. The surface measurements were then ranked, which resulted in the selection of six locations per SU for sampling (Tables B-1, B-2, and B-3). The six sample locations are presented in Figures A-9 through A-11 for LSAs 08-06, 08-11 and 08-17, respectively. Additionally, multiple locations exhibiting elevated gamma count rates of concern were observed in LSAs 08-11 and 08-17 resulting in the collection of judgmental samples. In total, 18 samples were collected using the RSS process, along with 8 judgmental soil samples and 1 discrete particle sample collected based on elevated gamma count rates (see Figures A-9 through A-11).

Soil samples were returned to the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee for laboratory analysis. Sample analyses were performed in accordance with the laboratory procedures manual (ORAU 2015b). Samples were analyzed by solid-state gamma spectroscopy for gamma-emitting ROCs. Tc-99 was quantified by radiochemical separation using extraction chromatography and counted by liquid scintillation. Analytical results were reported in units of picocuries per gram (pCi/g). Gamma spectroscopic analysis identified elevated levels of enriched U-235 in eight samples which prompted alpha spectroscopic analysis to provide greater confidence of the actual uranium concentrations. Otherwise, the U-234 concentrations were calculated using the ORAU U-238/U-235 analytical concentration ratios from gamma spectroscopic analysis and then interpolating those data with Table 14-5 of the HDP decommissioning plan

(WEC 2009) to calculate the U-234/U-235 ratio. The U-234/U-235 ratio was then multiplied by the U-235 concentration, resulting in an inferred U-234 concentration.

4. RESULTS

4.1 SURFACE SCANS

Elevated direct gamma radiation in excess of the background count variability was observed in LSAs 08-11 and 08-17. The background count variability relates to data that is within $\pm 3\sigma$ (sigma) of the mean as long as the mean is consistent with the predetermined background for the site while also considering surface geometry can cause a shift in background levels. Elevated gamma radiation levels were observed along the natural gas pipeline and the former evaporation ponds in LSA 08-11. ORAU placed pin-flags at nine elevated soil locations during the walkover surveys to facilitate follow-up investigations and judgmental sampling. Overall instrument response in this SU ranged from less than 8,100 to 20,000 counts per minute (cpm) with a mean count rate of approximately 13,000 cpm and background of approximately 10,000 cpm (Figure A-4).

A majority of the observed instrument responses for LSA 08-17 were within the background count variability for all areas of the SU with the exception of several discreet locations along the trench that bisected the SU from northeast to southwest and in the soils beneath the former radioactive materials storage vault that was connected to Building 230. A total of nine locations exhibiting elevated gamma radiation levels were marked with pin-flags for further evaluation. The instrument response in LSA 08-17 ranged from less than 8,500 to 14,500 cpm with a background of approximately 10,000 cpm.

Similarly, a majority of the observed instrument responses for LSA 08-06 were within the background count variability for all areas. The highest instrument responses were observed around the perimeters of two separate excavations within the unit. Technicians paused at each observed elevated response but were unable to locate a consistent count rate to warrant follow-up evaluations. The instrument responses in LSA 08-06 ranged from less than 8,300 to 15,000 cpm with a background near 11,000 cpm. The approximate 1,000 cpm shift in the background count rate was consistent with typical geometric effects on the detector for surveys performed in excavations. Walkover survey data for each SU are illustrated in Figures A-3 through A-5.

4.2 VOLUMETRIC SAMPLING

The random sample results for LSAs 08-06, 08-11, and 08-17 were all below the established $DCGL_{ws}$, as well as having SOFs less than unity. The SOFs for all but one of the 18 random samples were equal to or less than 0.34. The highest random sample SOF value, 0.64, was associated with sample 5184S0139 in LSA 08-11, and the increased SOF was attributed to the elevated Tc-99 concentration of 8.82 pCi/g with respect to the root stratum $DCGL_{wv}$ value of 30.1 pCi/g.

The ROC concentrations for four of the five judgmental samples from LSA 08-11 were low in comparison to their respective $DCGL_{ws}$ with SOFs equal to or less than 0.36. However, judgmental sample 5184M0002, initially collected as 5184S0142, was comprised of a discreet piece of solid material that was determined to be the source of the elevated gamma response. During the field investigation, there was no indication that the soil contained any elevated activity, and therefore was returned to the SU. The solid material which was presumed to be part of a uranium fuel pellet was retained as sample 5184M0002 for analytical assessment. The gamma spectroscopic and radiochemical separation analyses of the pellet showed it contained 45 pCi/g of Tc-99 and $4.84E+05$ pCi/g of U-235 resulting in an SOF calculation greater than 2,300. The high concentration of U-235 and significant degree of count variability prevented accurate reporting of the remaining ROCs via gamma spectroscopy. Sample 5184M0002 was then subjected to alpha spectroscopic analysis to provide more accurate uranium concentrations and facilitate the enrichment calculation. The calculation for interpolating enrichment using Table 14-5 from the licensee's decommissioning plan (DP) showed the sample to contain 64.5% enriched U-235 which is in statistical agreement with ORAU's internal analytical determination. The uranium concentrations observed from alpha spectroscopic analysis showed: $1.23 E+07$ pCi/g of U-234, $4.36 E+05$ pCi/g of U-235 at 64% enrichment, and $3.7 E+04$ pCi/g of U-238. In addition, a dose calculation was performed from the reported ROC concentrations in sample 5184M0002 using the RESRAD computer code Version 7.0 developed at Argonne National Laboratory. Using the conservative assumptions of the source positioned on the surface of the ground, and a worker positioned directly over the source for 2339 hours/year as described in NUREG 5512 Volume 4 (NRC 1999), the worker would receive a total dose of 179 mrem/year.

Of the four judgmental samples collected in LSA 08-17, three (5184S0132, 5184S0133, and 5184S0152) had SOFs greater than 1. Each of those three samples contained elevated

concentrations of U-234, U-235, and U-238. Elevated concentrations of Th-232 were also observed in samples 5184S0133 and 5184S0152. Sample 5184S0152 was collected from the same location as 5184S0133 but from a depth of 15-30 centimeters after WEC's preliminary onsite analysis suggested that the SOF value from the surface sample would exceed unity.

A comprehensive summary of the REAL sample results for site-related ROCs (excluding Pu-239/240, Am-241, and Np-237) is provided in Tables B-4, B-5, and B-6. Table 4.1 summarizes the ROC concentrations reported in those tables. The results of the U-234 calculations described in Section 3 of this report are provided in Table B-7. Additionally, eight samples containing enriched U-235 as determined through gamma spectroscopic analysis were subjected to alpha spectroscopic analysis to provide higher confidence of the uranium concentrations. The alpha spectroscopy results for those samples along with the adjusted SOF are provided in Table B-8.

Table 4.1. ORAU ROC Concentration Range Summary in pCi/g

ROC	Gross Soil Activity Concentration Range		
U-234	1.9 ^a	to	12,300,000 ^b
U-235	0.10	to	436,000 ^b
U-238	0.57	to	37,000 ^b
Tc-99	0.14	to	45
Th-232	0.31	to	2.13 ^c
Ra-226	0.37	to	1.40 ^c

^aU-234 concentrations as calculated by determining the gamma spectroscopy U-238/U-235 ratio, then using Table 14-5 from the DP to determine the U-234/U-235 ratio (using interpolation) and hence the enrichment percentage. The U-235 value is then multiplied by the U-234/U-235 ratio to determine the U-234 concentration result. The U-234 error was propagated by assuming the U-234/U-235 ratio did not have an error.

^bConcentrations as determined through alpha spectroscopic analysis.

^cCompliance with the release criteria was determined after background contributions were subtracted from the gross concentrations.

The analytical results were evaluated and compared to the applicable DCGL_{ws} presented in Table 2.1. Comparisons to the DCGL_{ws} were made using gross concentrations—i.e., the concentrations were not adjusted for soil background—with the exception of Ra-226 and Th-232, which were corrected for background concentrations of 0.9 and 1.0 pCi/g, respectively (WEC 2012). The SOF for each sample was then calculated to evaluate compliance with the 25 mrem/year release

criteria. WEC's analytical results and SOF averages were evaluated against the confirmatory sample results to determine if the radionuclide concentrations reported from FSS activities were consistent with the results of the confirmatory surveys for each SU. The average SOF values of the random samples reported by WEC and for ORAU confirmatory samples are presented in Table 4.2 for comparison. All of the ROC concentrations in confirmatory soil samples, except judgmental samples 5184M0002, 5184S0132, 5184S0133, and 5184S0152 were below their respective $DCGL_w$ s, and the SOF calculations were less than unity.

Table 4.2. SOF Statistical Comparison of Random Samples						
SOF ^a	LSA 08-06		LSA 08-11		LSA 08-17	
	ORAU	WEC ^b	ORAU	WEC ^b	ORAU	WEC ^b
Average	0.20	0.13	0.27	0.15	0.22	0.15
Standard Deviation^c	0.10	0.07	0.19	0.08	0.11	0.07
Minimum	0.07	0.03	0.08	0.04	0.03	0.07
Maximum	0.32	0.24	0.64	0.33	0.34	0.29

^aSum-of-fractions (SOF) calculated using the unity rule for each radionuclide-of-concern. Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the WEC analyses, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

^bWEC values calculated from WEC off-site lab data with ingrowth (WEC 2016a, 2016b, 2016c)

^c95% confidence interval.

5. CONCLUSION

At NRC's request, ORAU completed confirmatory surveys of three FSS survey units at the Hematite Decommissioning Project during the period of December 15–18, 2015. The survey activities included document reviews, gamma walkover surveys, sampling activities, and laboratory analysis of confirmatory samples. All confirmatory survey ROC concentrations from the LSA 08-06, LSA 08-11 and LSA 08-17 soil samples, except samples 5184M0002, 5184S0132, 5184S0133, and 5184S0152, were below their respective $DCGL_w$ limits and also satisfied the SOF $DCGL_w$ criteria. The average SOF concentrations between the ORAU and WEC sample populations for all three SUs were in statistical agreement with the exception of one confirmatory sample in LSA 08-11 with an elevated concentration of Tc-99 that skewed the SOF data presented in Table 4.2.



Based on the findings of the confirmatory survey and proper disposal of sample 5184M0002, ORAU is of the opinion that the licensee has adequately demonstrated that survey units LSA 08-06 and 08-11 meet the site-approved release criteria. However, the results of three judgmental samples collected in LSA 08-17 suggested that the survey unit did not satisfy the uniform $DCGL_w$ criteria applied to the unit.

The licensee provided an explanatory document and a MARSSIM-based elevated measurement comparison DCGL ($DCGL_{EMC}$) calculation for biased sample 3430-SS-151215-09-01, a split of confirmatory sample 5184S0132, which represented the licensee's highest sum-of-fraction value in excess of unity (WEC 2016d and 2016e). Although ORAU's SOF value for this sample location was higher than the licensee's (1.42 vs 1.16), this is an understandable variation based upon the homogeneity of ROC particulates within the sample matrix. Overall, ORAU did not find any issues in the methodology used for the calculation to dispute the licensee's determination. This conclusion along with the consideration that confirmatory scans only identified six discreet locations above the gamma investigation level within the survey unit, leads ORAU to the opinion that the licensee has adequately demonstrated that LSA 08-17 also satisfies the NRC-approved soil and surface activity DCGLs.



5. REFERENCES

EPA 2002. *Guidance on Choosing a Sampling Design for Environmental Data Collection*. EPA QA/G-5S. U.S. Environmental Protection Agency Washington, DC. December.

NRC 1999. Comparison of the Models and Assumptions used in the DandD 1.0, RESRAD 5.61, and RESRAD-Build 1.50 Computer Codes with Respect to the Residential Farmer and Industrial Occupant Scenarios Provided in NUREG/CR-5512. U.S. Nuclear Regulatory Commission, Washington, DC. October 1999.

ORAU 2013. *Final—Project-Specific Plan for Independent Confirmatory Survey Activities for the Hematite Decommissioning Project, Festus, Missouri*. 5184-PL-02-0. Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. Oak Ridge, Tennessee. March 20.

ORAU 2015a. *ORAU Radiological and Environmental Survey Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. August 6.

ORAU 2015b. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*. Oak Ridge Institute for Science and Education, managed and operated by ORAU. Oak Ridge, Tennessee. May 7.

ORAU 2015c. *ORAU Environmental Services and Radiation Training Quality Program Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. August 7.

WEC 2009 *Hematite Decommissioning Plan*. D0-08-004; Revision 0.0. Westinghouse Electric Company, LLC. Festus, Missouri. August.

WEC 2011. *Final Supplemental Response to NRC Request for Additional Information on the Hematite Decommissioning Plan and Related Revision to a Pending License Amendment Request (License No. SNM-00033, Docket No. 070-00036)*. HEM-11-96. Westinghouse Electric Company, LLC. Festus, Missouri. July 5.

WEC 2012. *Final Status Survey Plan Development*. Hematite Decommissioning Project. HDP-PR-FSS-701; Revision 0. Westinghouse Electric Company, LLC. Festus, Missouri. January 16.

WEC 2013 *Hematite Decommissioning Plan Chapter 14: HEM 13-10*; Revision 1.2. Westinghouse Electric Company, LLC. Festus, Missouri. February 12.

WEC 2015a. *Final Status Survey Plan Development*. Hematite Decommissioning Project. HDP-PR-FSS-701; Revision 8 (LSA 08-11). Westinghouse Electric Company, LLC. Festus, Missouri. October 22.

WEC 2015b. *LSA 08-17 FSSDE WorksheetsUniform_R10*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. December 3.

WEC 2015c. *LSA 08-11 Gamma Walkover Coverage Map*. Adobe PDF. Hematite Decommissioning Project. Westinghouse Electric Company, LLC. Festus, Missouri. December 2.

WEC 2015d. *LSA 08-17 Gamma Walkover Coverage Map (Final)*. Adobe PDF. Hematite Decommissioning Project. Westinghouse Electric Company, LLC. Festus, Missouri. December 2.



WEC 2015e. *LSA 08-11 Z Score Map (w sidewall biased)*. Adobe PDF. Hematite Decommissioning Project. Westinghouse Electric Company, LLC. Festus, Missouri. December 2.

WEC 2015f. *LSA 08-17 Z Score Map (w sidewall biased)*. Adobe PDF. Hematite Decommissioning Project. Westinghouse Electric Company, LLC. Festus, Missouri. December 3.

WEC 2016a. *LSA 08-06 FSSDE WorksheetsUniform_R10_NRC*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. January 5.

WEC 2016b. *LSA 08-11 FSSDE Worksheets_3-Layer_R10_NRC*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. December 3.

WEC 2016c. *LSA 08-17 FSSDE WorksheetsUniform_R10_NRC*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. December 3.

WEC 2016d. *ORAU Split Sample Summary*. Microsoft Word Document. Westinghouse Electric Company, LLC. Festus, Missouri. May 17.

WEC 2016e. *LSA 08-17 FSSDE WorksheetsUniform_R10(draft for ORAU)*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. May 17.

APPENDIX A FIGURES



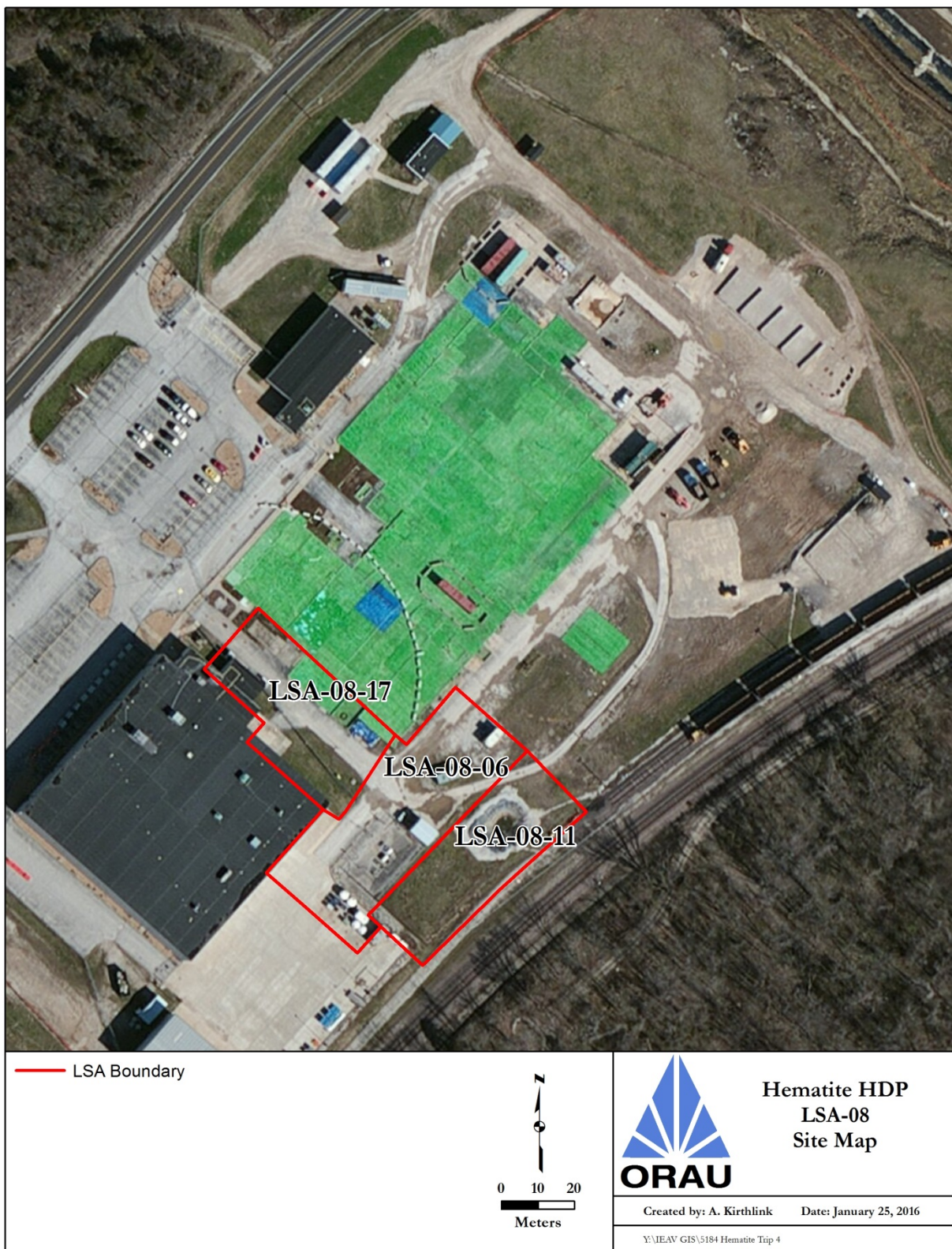


Figure A-2. Site Map of LSAs 08-06, 08-11, and 08-17 at the Hematite Decommissioning Project

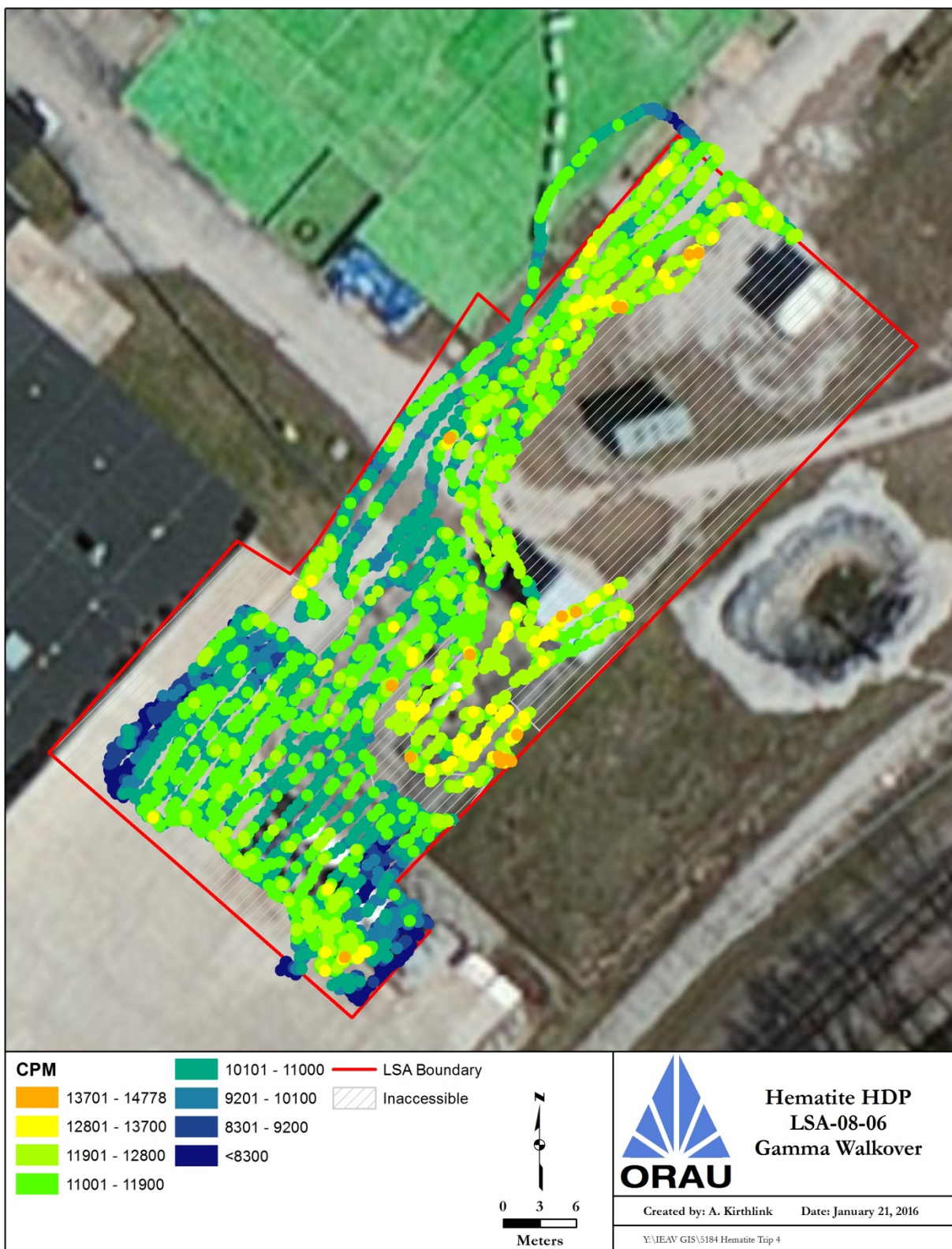


Figure A-3. LSA 08-06—Gamma Walkover Scans

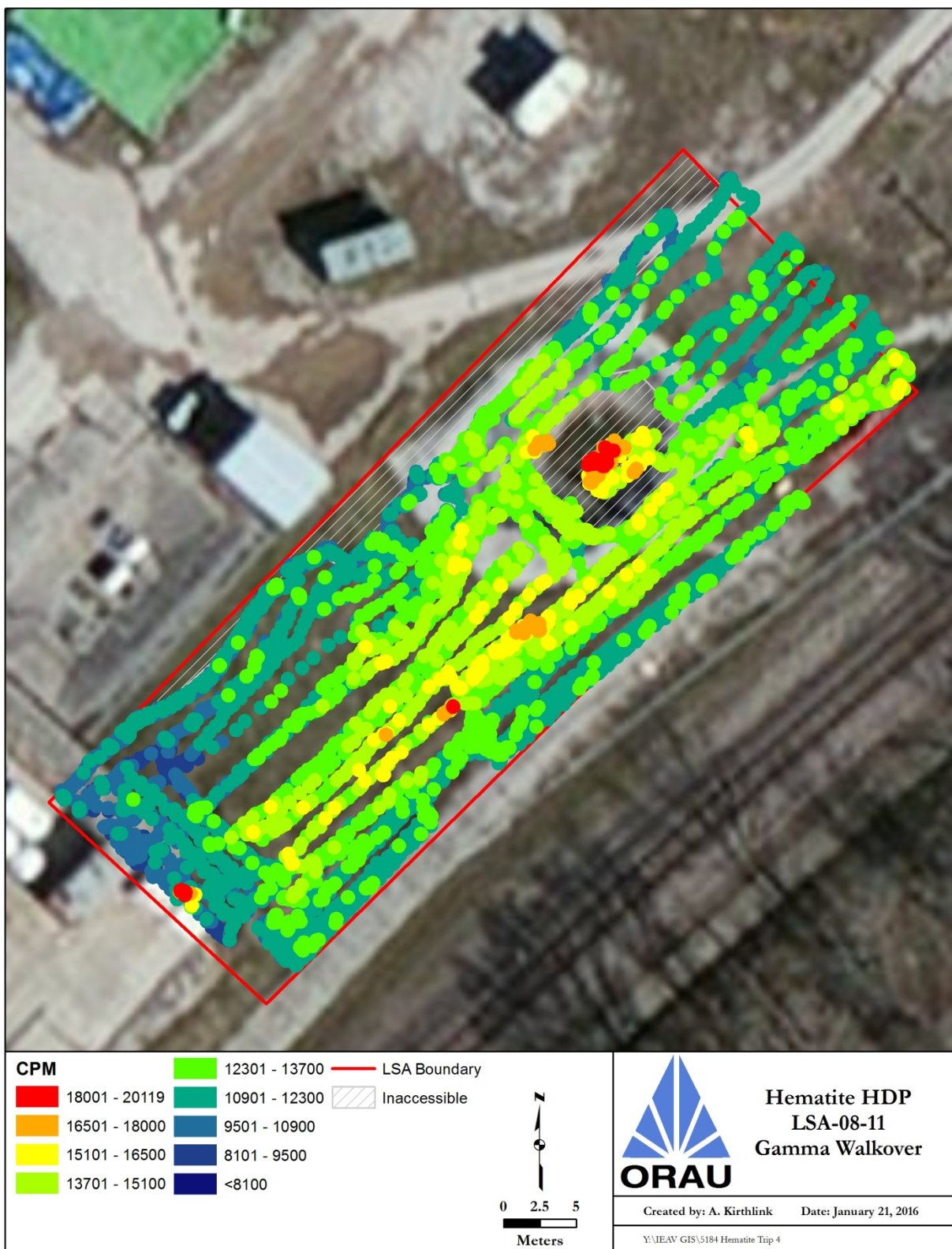


Figure A-4. LSA 08-11—Gamma Walkover Scans

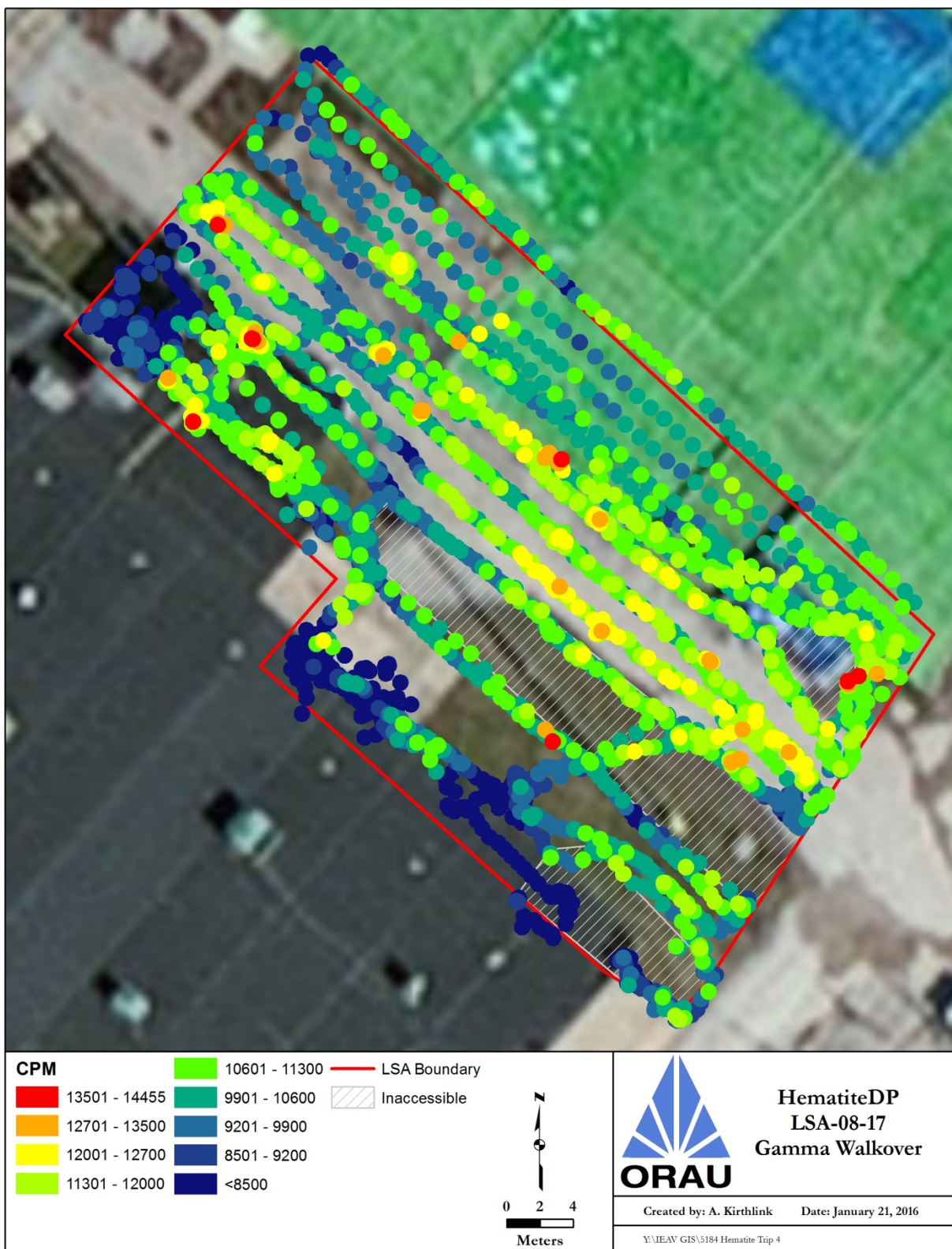


Figure A-5. LSA 08-17—Gamma Walkover Scans

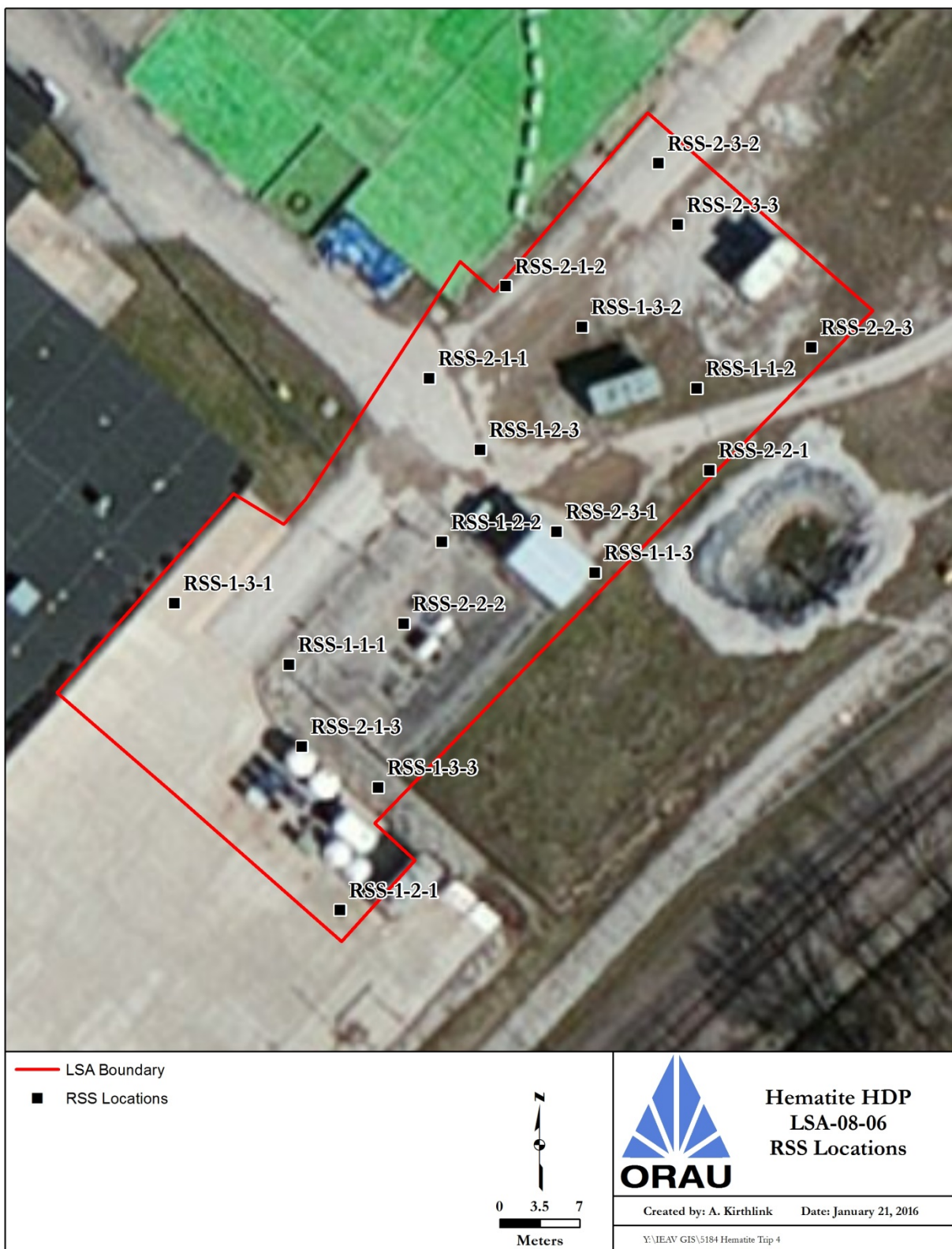


Figure A-6. LSA 08-06—Ranked Set Sampling Measurement Locations

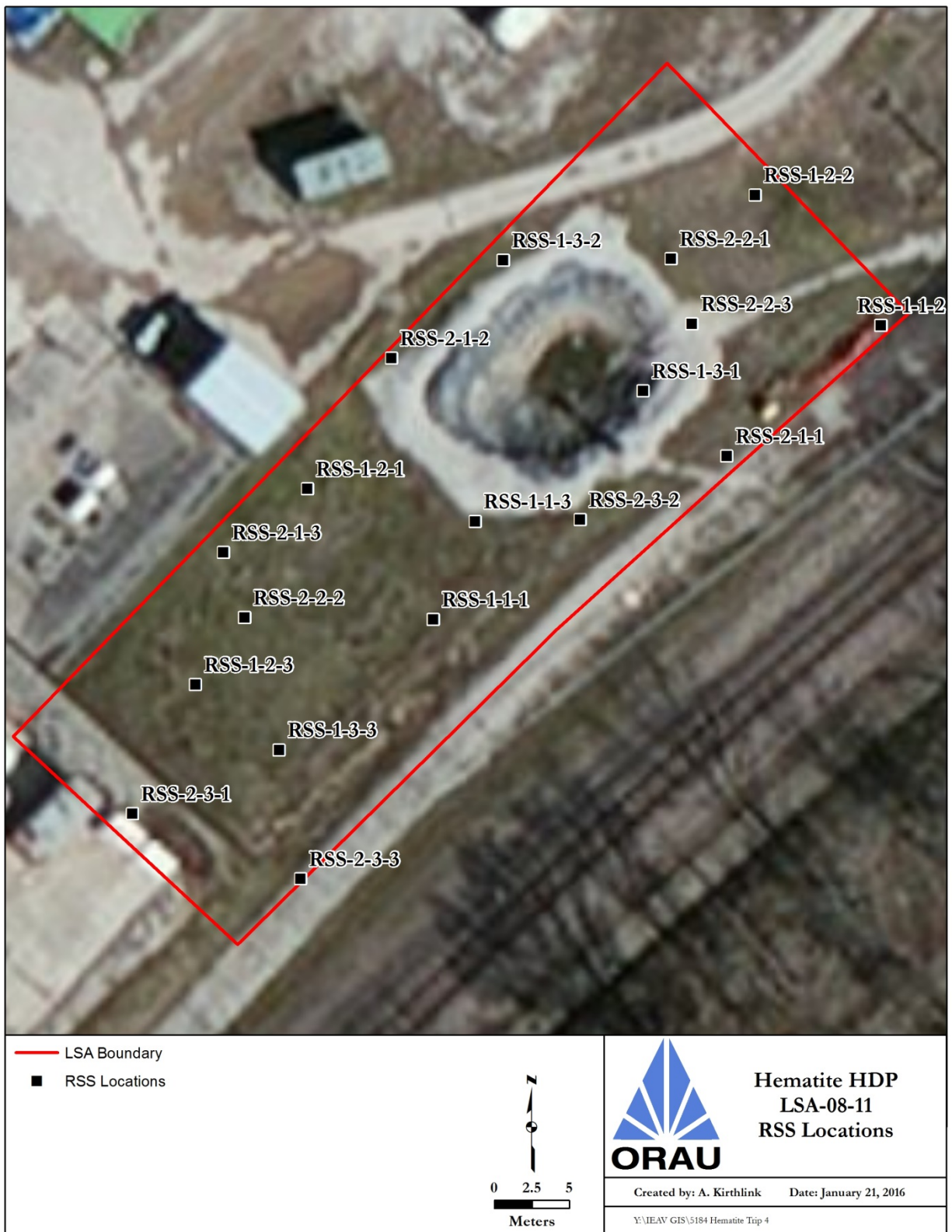


Figure A-7. LSA 08-11—Ranked Set Sampling Measurement Locations

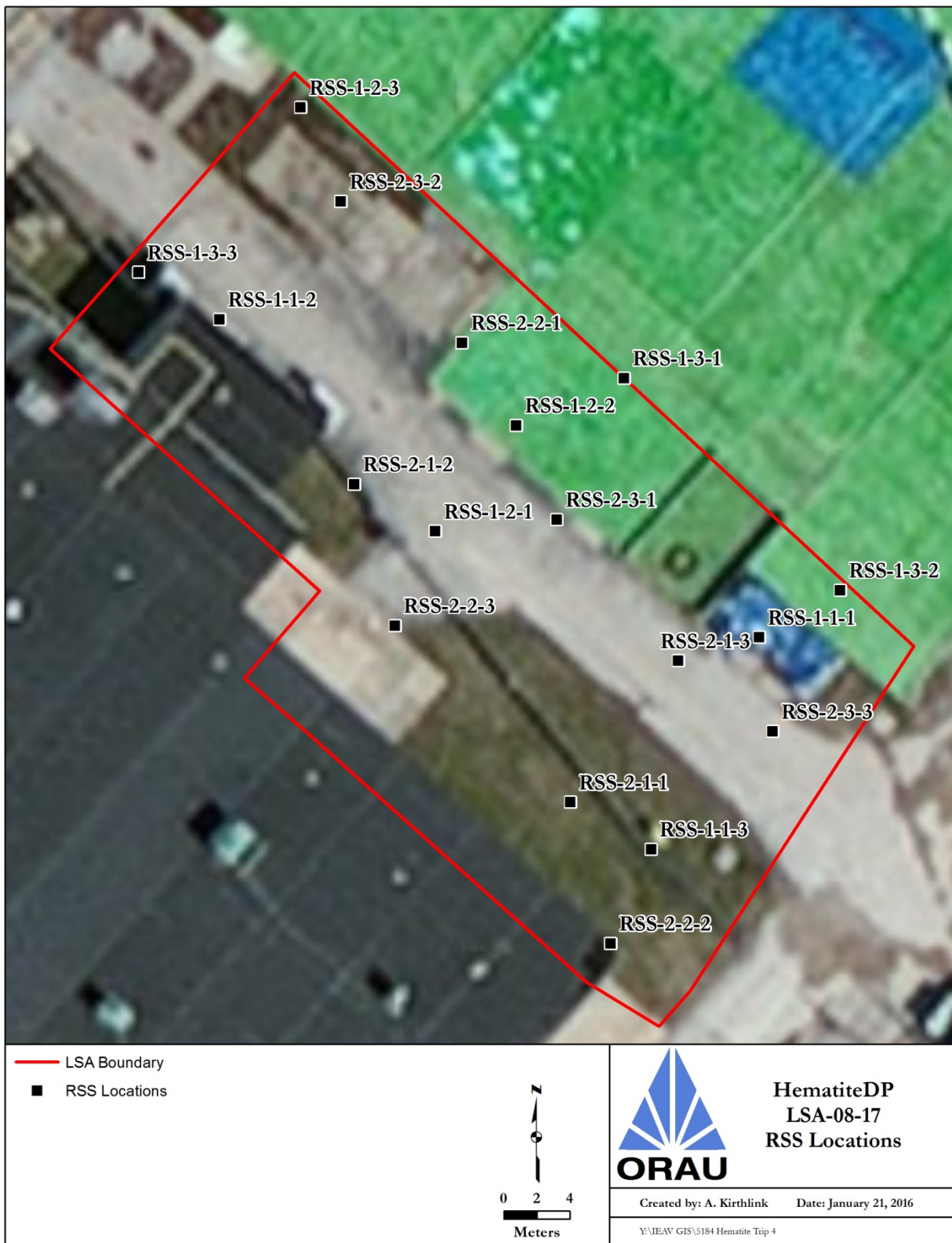


Figure A-8. LSA 08-17—Ranked Set Sampling Measurement Locations

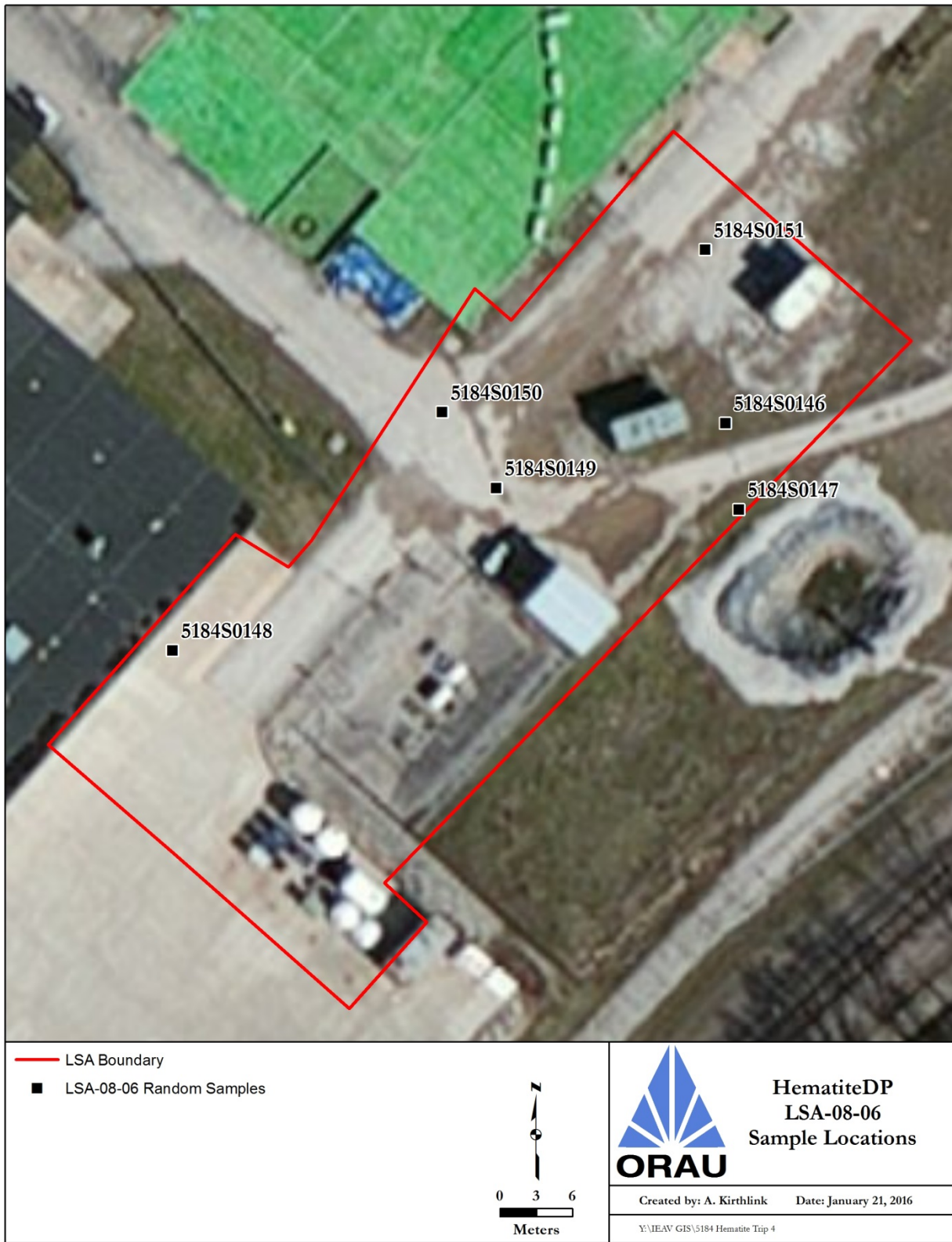


Figure A-9. LSA 08-06—Soil Sampling Locations

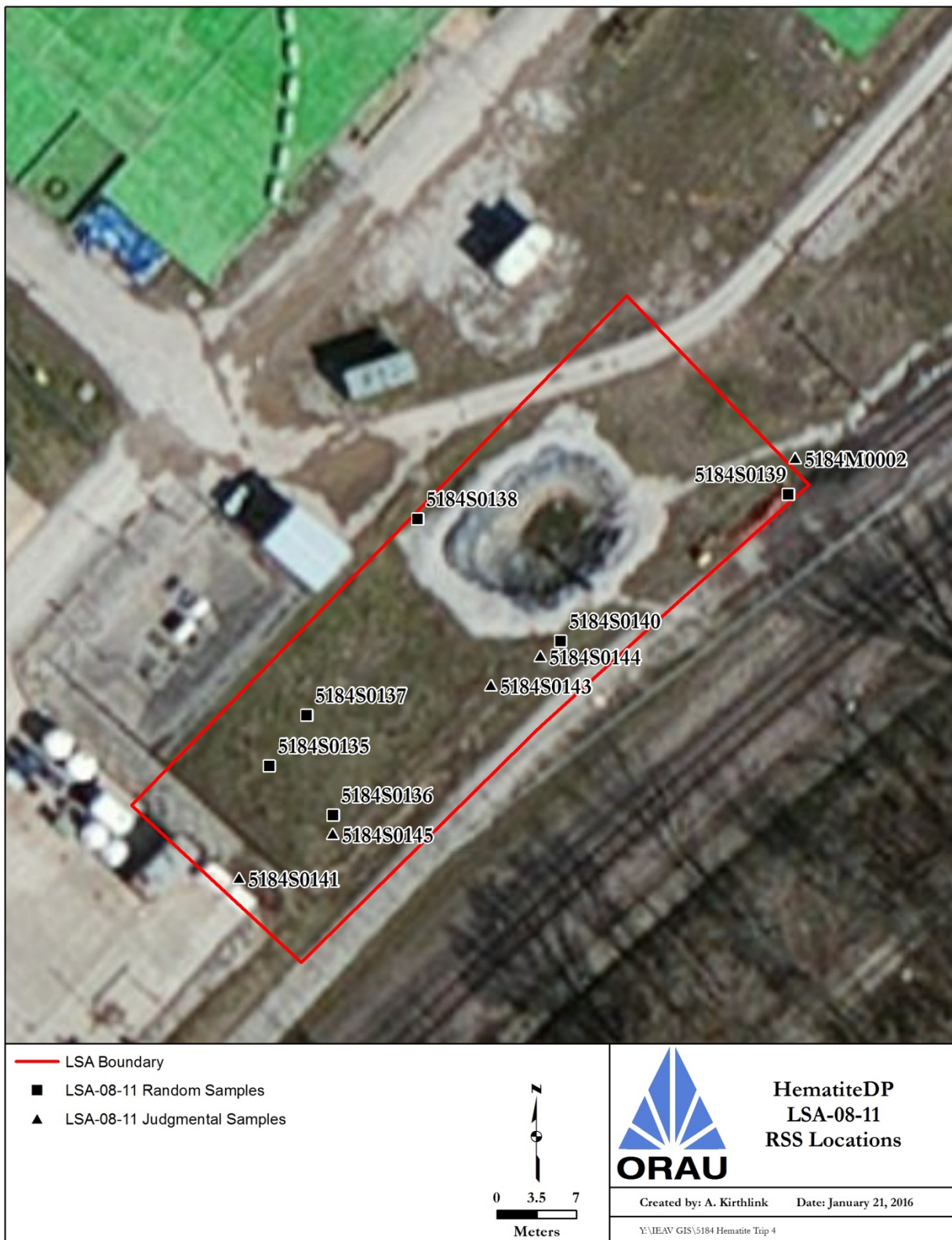




















Figure A-10. LSA 08-11—Soil Sampling Locations



Figure A-11. LSA 08-17—Soil Sampling Locations



















APPENDIX B DATA TABLES

Table B.1. Hematite Decommissioning Project RSS Soil Sampling Form

Project/Task	201208997 / 5184	Area / SU	LSA 08-06			Date	12/17/2015				
Surveyors / Samplers	Kithlink, Edds				Coordinate System					Missouri East 2401	
	Type (α , β , γ)	Instrument		Detector		Background (cpm)					
	γ	2221#	252	44-10#	868	8687					
	β	2221#	561	44-142#	690	297					
	GPS	GeoXH#	1122								
Coordinate (X or Easting)	Coordinate (Y or Northing)	RSS Measurement Location				Pre (cpm)		Weighted Msmt.	Value	Post (cpm)	Soil Sample # (0-15 cm)
		Cycle	Set	#	Symbol	Gamma	Beta			Gamma	
827129	864586	1	1	1		10,787	517	2.98	L		
827247	864665	1	1	2		10,477	462	2.76	L	10500	5184S0146
827217	864612	1	1	3		10,946	464	2.82	L		
827144	864515	1	2	1		10326	509	2.90	M		
827173	864621	1	2	2		11,189	515	3.02	M		
827184	864648	1	2	3		12,072	479	3.00	M	12166	5184S0149
827096	864603	1	3	1		9,071	451	2.56	H	9614	5184S0148
827214	864683	1	3	2		NC	NC	--	H		
827155	864550	1	3	3		8,750	441	2.49	H		
827170	864668	2	1	1		10,348	470	2.77	L	10748	5184S0150
827192	864695	2	1	2		10,019	485	2.79	L		
827133	864562	2	1	3		10,708	522	2.99	L		
827251	864642	2	2	1		11,376	493	2.97	M	11674	5184S0147
827162	864597	2	2	2		11,481	503	3.02	M		
827280	864677	2	2	3		10,679	514	2.96	M		
827206	864624	2	3	1		11,532	494	2.99	H		
827236	864730	2	3	2		10,740	499	2.92	H		
827241	864712	2	3	3		12,465	466	3.00	H	12568	5184S0151

NC = Measurement not collected due to inaccessibility and standing water at location

Table B.2. Hematite Decommissioning Project RSS Soil Sampling Form

Project/Task	201208997 / 5184	Area / SU	LSA 08-11	Date	12/16/2015						
Surveyors / Samplers	Harpenau, Brown, J. Bailey			Coordinate System						Missouri East 2401	
	Type (α , β , γ)	Instrument		Detector		Background (cpm)					
	γ	2221#	252	44-10#	868	10021					
	β	2221#	561	44-142#	690	281					
	GPS	GeoXH#	1122								
Coordinate (X or Easting)	Coordinate (Y or Northing)	RSS Measurement Location				Pre (cpm)		Weighted Msmt.	Value	Post (cpm)	Soil Sample # (0-15 cm)
		Cycle	Set	#	Symbol	Gamma	Beta			Gamma	
827246	864566	1	1	1		14,057	631	3.65	L		
827344	864630	1	1	2		12,635	552	3.23	L	13022	5184S0139
827255	864587	1	1	3		14,804	776	4.24	L		
827219	864594	1	2	1		11,220	380	2.47	M		
827317	864659	1	2	2		12,415	536	3.15	M		
827194	864552	1	2	3		11,536	548	3.10	M	12480	5184S0135
827292	864616	1	3	1		13,927	709	3.91	H		
827261	864644	1	3	2		13,003	680	3.72	H		
827212	864537	1	3	3		15,827	852	4.61	H	16569	5184S0136
827311	864602	2	1	1		11,826	497	2.95	L		
827237	864623	2	1	2		11,282	512	2.95	L	12091	5184S0138
827200	864580	2	1	3		12,138	516	3.05	L		
827298	864645	2	2	1		12,172	582	3.29	M		
827205	864566	2	2	2		13,091	640	3.58	M	13120	5184S0137
827303	864630	2	2	3		13,847	648	3.69	M		
827180	864523	2	3	1		9,844	470	2.65	H		
827278	864588	2	3	2		13,061	554	3.27	H	13917	5184S0140
827217	864509	2	3	3		12,672	480	2.97	H		
827185	864519	Judgmental 1				18,842	570			19186	5184S0141

827212	864532	Judgmental 2	19,228	NC		17072	5184S0145
827258	864575	Judgmental 5	15,561	1036		16222	5184S0143
827272	864583	Judgmental 6	18,558	960		19129	5184S0144
827346	864640	Judgmental 9	47,395	640		12158	5184M0002

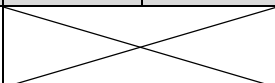
NC = Measurement not collected due to standing water at location

Table B.3. Hematite Decommissioning Project RSS Soil Sampling Form

Project/Task	201208997 / 5184	Area / SU	LSA 08-17			Date		12/15/15			
Surveyors / Samplers	Harpenau, Brown, Bailey				Coordinate System				Missouri East 2401		
	Type (α , β , γ)	Instrument		Detector		Background (cpm)					
	γ	2221#	252	44-10#	868	8412					
	β	2221#	561	44-142#	690	297					
	GPS	GeoXH#	1122								
Coordinate (X or Easting)	Coordinate (Y or Northing)	RSS Measurement Location				Pre (cpm)		Weighted Msmt.	Value	Post (cpm)	Soil Sample # (0-15 cm)
		Cycle	Set	#	Symbol	Gamma	Beta			Gamma	
827148	864703	1	1	1	■	11,744	460	2.94	L		
827040	864767	1	1	2	■	10,215	451	2.73	L	10,802	5184S0126
827126	864661	1	1	3	■	10,344	454	2.76	L		
827083	864725	1	2	1	▲	11,373	499	3.03	M		
827099	864746	1	2	2	▲	10,595	476	2.86	M	11,665	5184S0128
827056	864809	1	2	3	▲	10,318	421	2.64	M		
827121	864755	1	3	1	●	11,419	482	2.98	H	12,219	5184S0129
827164	864713	1	3	2	●	10,876	448	2.80	H		
827024	864776	1	3	3	●	7,092	322	1.93	H		
827110	864671	2	1	1	■	10,506	510	2.97	L		
827067	864734	2	1	2	■	7,720	390	2.23	L	6,664	5184S0131
827132	864699	2	1	3	■	11,279	454	2.87	L		
827089	864762	2	2	1	▲	10,228	409	2.59	M	11,642	5184S0127
827118	864643	2	2	2	▲	7,957	354	2.14	M		
827075	864706	2	2	3	▲	10,444	489	2.89	M		
827108	864727	2	3	1	●	11,501	448	2.88	H		
827065	864790	2	3	2	●	10,334	483	2.85	H		
827150	864685	2	3	3	●	11,258	495	3.00	H	12,450	5184S0130
827028	864753	Judgmental 5				16,439	551			15,974	5184S0132

Table B.3. Hematite Decommissioning Project RSS Soil Sampling Form

Project/Task	201208997 / 5184	Area / SU	LSA 08-17				Date		12/15/15		
Surveyors / Samplers	Harpenau, Brown, Bailey				Coordinate System					Missouri East 2401	
	Type (α, β, γ)	Instrument		Detector		Background (cpm)					
	γ	2221#	252	44-10#	868	8412					
	β	2221#	561	44-142#	690	297					
	GPS	GeoXH#	1122								
Coordinate (X or Easting)	Coordinate (Y or Northing)	RSS Measurement Location				Pre (cpm)		Weighted Msmt.	Value	Post (cpm)	Soil Sample # (0-15 cm)
		Cycle	Set	#	Symbol	Gamma	Beta			Gamma	
827108	864737	Judgmental 2				20,011	857			16,154	5184S0133
827162	864693	Judgmental 8				15,502	565			15,640	5184S0134
827108	864737	Judgmental 2 (6"-12")				--	1,000			15,129	5184S0152

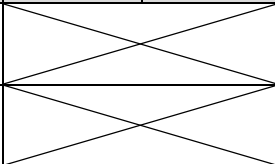
Table B-4. Radionuclide Concentrations in LSA 08-06 Soil Samples Hematite Decommissioning Project Festus, Missouri									
Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g) ^a						SOF ^c
	East	North	Tc-99	Ra-226	Th-232	U-234 ^b	U-235	U-238	
Uniform Stratum DCGL _W			25.1	1.9	2	195.4	51.6	168.8	<1
LSA 08-06 ^d									
5184S0146	827247	864665	2.24	0.98	1.25	7.85	0.43	2.95	0.32
5184S0147	827251	864642	0.62	1.13	1.24	4.51	0.24	2.20	0.31
5184S0148	827096	864603	0.53	0.84	0.97	6.17	0.34	2.14	0.07
5184S0149	827184	864648	0.22	0.96	1.17	2.80	0.14	1.96	0.15
5184S0150	827170	864668	0.69	0.99	1.10	7.85	0.43	2.39	0.19
5184S0151	827241	864712	0.60	0.93	1.19	2.79	0.15	1.29	0.16

^aThese values are gross concentrations; background concentrations have not been subtracted.

^bU-234 concentrations and uncertainties calculated from the U-238/U-235 ratios and using Table 14-5 in the Hematite DP, Rev. 1.2. Full details of calculations are provided in Table B-7.

^cSum-of-fractions (SOF) calculated using the unity rule for each radionuclide of concern (ROC). Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the HDP FSS data for Reuse Stockpile 2, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

^dRefer to Figure A-9.

Table B-5. Radionuclide Concentrations in LSA 08-11 Soil Samples Hematite Decommissioning Project Festus, Missouri									
Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g) ^a						SOF ^c
	East	North	Tc-99	Ra-226	Th-232	U-234 ^b	U-235	U-238	
Root Stratum DCGL _W			30.1	2.1	2	235.6	64.1	183.3	<1
Excavation Scenario DCGL _W			74	5.4	5.2	872.4	208.1	551.1	<1
LSA 08-11 ^d									
5184S0135 ^e	827194	864552	12.97	0.94	1.15	18.91	1.04	5.20	0.25
5184S0136 ^{e,g}	827212	864537	1.77	1.25	1.29	55.30	2.31	11.30	0.24
5184S0137 ^e	827205	864566	0.77	1.20	1.50	28.16	1.54	8.90	0.22
5184S0138 ^e	827237	864623	1.18	1.02	1.19	4.26	0.23	1.77	0.08
5184S0139 ^f	827344	864630	8.82	0.91	1.31	29.21	1.61	6.90	0.64
5184S0140 ^e	827278	864588	0.85	1.40	1.17	32.07	1.75	10.70	0.20
LSA 08-11 Judgmental Samples ^d									
5184S0141 ^f	827185	864519	0.60	0.88	1.15	5.26	0.28	2.16	0.13
5184M0002 ^{e,g}	827346	864640	45.00	0.00	0.00	12,300,000	436,000	37,000	16,262
5184S0143 ^{e,g}	827258	864575	1.77	1.18	1.24	142	5.5	25.0	0.36
5184S0144 ^{e,g}	827272	864583	1.55	1.27	1.22	109	4.2	21.0	0.31
5184S0145 ^{e,g}	827212	864532	1.67	1.12	1.21	149	6.2	32.3	0.36

^aThese values are gross concentrations; background concentrations have not been subtracted.

^bU-234 concentrations and uncertainties calculated by determining the gamma spectroscopy U-238/U-235 ratios and using Table 14-5 in the Hematite DP, Rev. 1.2. Full details of calculations are provided in Table B-7.

^cSum-of-fractions (SOF) calculated using the unity rule for each radionuclide of concern (ROC). Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the HDP FSS data for Reuse Stockpile 2, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

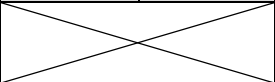
^dRefer to Figure A-10.

^eDCGL_W values are from the excavation stratum column in Table 2.1.

^fDCGL_W values are from the root scenario column in Table 2.1.

^gReported uranium concentrations represent results from alpha spectroscopic analysis.

Negative reported concentrations are represented as zero "0" values.

Table B-6. Radionuclide Concentrations in LSA 08-17 Soil Samples Hematite Decommissioning Project Festus, Missouri									
Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g) ^a						SOF ^c
	East	North	Tc-99	Ra-226	Th-232	U-234 ^b	U-235	U-238	
Uniform Stratum DCGL _W			25.1	1.9	2	195.4	51.6	168.8	<1
LSA 08-17 ^d									
5184S0126	827040	864767	1.12	0.94	1.10	16.71	0.92	2.33	0.23
5184S0127	827089	864762	0.69	0.99	1.04	14.79	0.81	1.66	0.19
5184S0128	827099	864746	0.14	1.07	1.27	1.90	0.10	1.45	0.25
5184S0129	827121	864755	0.15	1.11	1.22	6.18	0.33	2.90	0.28
5184S0130	827150	864685	0.57	1.05	1.42	3.05	0.16	2.14	0.34
5184S0131	827067	864734	0.28	0.37	0.31	2.79	0.15	0.57	0.03
LSA 08-17 Judgmental Samples ^d									
5184S0132 ^e	827028	864753	0.26	1.10	1.22	201.00	7.50	3.20	1.42
5184S0133 ^e	827108	864737	1.09	0.94	1.71	111.00	4.10	20.30	1.19
5184S0134	827162	864693	0.48	1.00	1.20	8.40	0.46	2.58	0.24
5184S0152 ^e	827108	864737	0.76	1.11	2.13	66.80	2.80	22.50	1.24

^aThese values are gross concentrations; background concentrations have not been subtracted.

^bU-234 concentrations and uncertainties calculated from the U-238/U-235 ratios and using Table 14-5 in the Hematite DP, Rev. 1.2. Full details of calculations are provided in Table B-7.

^cSum-of-fractions (SOF) calculated using the unity rule for each radionuclide of concern (ROC). Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the HDP FSS data for Reuse Stockpile 2, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

^dRefer to Figure A-11.

^eReported uranium concentrations represent results from alpha spectroscopic analysis.

**Table B-7. U-234 Calculations for LSA-08-06, 08-11, and 08-17 Soil Samples
Hematite Decommissioning Project
Festus, Missouri**

Sample	U-238 (pCi/g)	U-235 (pCi/g)	U-238/ U-235	U-234/ U-235 ^a	Enrichment (% U-235) ^b	U-234 (pCi/g)
	Result	Result				Result
5184M0002	-700 ± 9000 ^c	484000 ± 30000	0.08 ^d	26.90	64.5	11726640 ± 6729315
5184S0126	2.33 ± 0.72	0.92 ± 0.12	2.53	18.16	5.7	16.71 ± 5.6
5184S0127	1.66 ± 0.49	0.81 ± 0.11	2.05	18.27	7.1	14.79 ± 4.81
5184S0128	1.45 ± 0.47	0.096 ± 0.085	15.10	19.80	1	1.9 ± 1.79
5184S0129	2.9 ± 1.1	0.33 ± 0.11	8.79	18.72	1.7	6.18 ± 3.12
5184S0130	2.14 ± 0.65	0.156 ± 0.089	13.72	19.55	1.1	3.05 ± 1.97
5184S0131	0.57 ± 0.21	0.154 ± 0.046	3.70	18.11	4	2.79 ± 1.32
5184S0132	3.8 ± 1.5	7.84 ± 0.55	0.48	20.69	24.5	162.19 ± 65.02
5184S0133	40.3 ± 8.8	41.5 ± 2.6	0.97	19.12	13.75	793.5 ± 180.26
5184S0134	2.58 ± 0.79	0.46 ± 0.13	5.61	18.26	2.7	8.4 ± 3.5
5184S0135	5.2 ± 1.2	1.04 ± 0.12	5.00	18.18	3.1	18.91 ± 4.88
5184S0136	16.3 ± 3.6	2.98 ± 0.27	5.47	18.25	2.75	54.38 ± 12.98
5184S0137	8.9 ± 2.2	1.54 ± 0.19	5.78	18.28	2.6	28.16 ± 7.78
5184S0138	1.77 ± 0.89	0.23 ± 0.11	7.70	18.54	2	4.26 ± 2.96
5184S0139	6.9 ± 1.6	1.61 ± 0.17	4.29	18.14	3.5	29.21 ± 7.44
5184S0140	10.7 ± 2.4	1.75 ± 0.18	6.11	18.33	2.5	32.07 ± 7.91
5184S0141	2.16 ± 0.62	0.284 ± 0.082	7.61	18.53	2	5.26 ± 2.14
5184S0143	28.2 ± 6.2	6.23 ± 0.44	4.53	18.15	3.3	113.06 ± 26.11
5184S0144	23.8 ± 5.2	4.47 ± 0.33	5.32	18.23	2.8	81.5 ± 7.91
5184S0145	40.5 ± 8.8	7.55 ± 0.49	5.36	18.24	2.8	137.68 ± 2.14
5184S0146	2.95 ± 0.78	0.426 ± 0.09	6.92	18.43	2.2	7.85 ± 26.11
5184S0147	2.2 ± 1	0.24 ± 0.13	9.17	18.77	1.7	4.51 ± 18.8
5184S0148	2.14 ± 0.6	0.336 ± 0.088	6.37	18.36	2.4	6.17 ± 31.22
5184S0149	1.96 ± 0.58	0.143 ± 0.084	13.71	19.55	1.1	2.8 ± 2.66
5184S0150	2.39 ± 0.71	0.43 ± 0.12	5.56	18.26	2.7	7.85 ± 3.19
5184S0151	1.29 ± 0.44	0.149 ± 0.074	8.66	18.70	1.8	2.79 ± 2.37

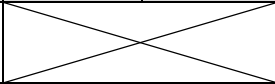
Table B-7. U-234 Calculations for LSA-08-06, 08-11, and 08-17 Soil Samples Hematite Decommissioning Project Festus, Missouri						
Sample	U-238 (pCi/g)	U-235 (pCi/g)	U-238/ U-235	U-234/ U-235 ^a	Enrichment (% U-235) ^b	U-234 (pCi/g)
	Result	Result				Result
5184S0152	25.6 ± 6	10.85 ± 0.75	2.36	18.19	6.2	197.34 ± 48.22

^aU-234 concentrations are calculated by determining the gamma spectroscopy U-238/U-235 ratio, then using Table 14-5 from the DP to determine the U-234/U-235 ratio (using interpolation) and hence the Enrichment percentage. The U-235 value is then multiplied by the U-234/U-235 ratio to determine the U-234 concentration result. The U-234 error was propagated by assuming the U-234/U-235 ratio did not have an error.

^bFrom Table 14-5 "Radioactivity And Isotopic Ratios Relative To Enrichment" in the Hematite DP Rev 1.2.

^cTwo sigma uncertainty is presented.

^dValue represents ratio as determined by alpha spectroscopy because of the negative U-238 concentration reported by gamma spectroscopy.

Table B-8. Radionuclide Concentrations in LSA 08-11 and 08-17 Samples Hematite Decommissioning Project Festus, Missouri						
Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g) ^{a, b}			Adjusted SOF ^c
	East	North	U-234	U-235	U-238	
Excavation Scenario DCGL _W			872.4	208.1	208.1	<1
Uniform Stratum DCGL _W			195.4	51.6	168.8	<1
LSA 08-11 ^d						
5184S0136	827212	864537	55.3 ± 6.3	2.31 ± 0.6	11.3 ± 1.6	0.24
5184M0002	827346	864640	12300000 ± 1300000	436000 ± 84000	37000 ± 20000	16,262
5184S0143	827258	864575	142 ± 17	5.5 ± 1.6	25 ± 3.9	0.36
5184S0144	827272	864583	109 ± 13	4.2 ± 1.3	21 ± 3.3	0.31
5184S0145	827212	864532	149 ± 17	6.2 ± 1.6	32.3 ± 4.6	0.36
LSA 08-17 ^e						
5184S0132	827028	864753	201 ± 23	7.5 ± 1.8	3.2 ± 1	1.42
5184S0133	827108	864737	111 ± 13	4.1 ± 1.3	20.3 ± 3.3	1.19
5184S0152	827108	864737	66.8 ± 8.2	2.8 ± 1	22.5 ± 3.4	1.24

^aThese values are gross concentrations; background concentrations have not been subtracted.

^bAlpha spectroscopy results reported for uranium isotopes.

^cSum-of-fractions (SOF) calculated using the unity rule for each radionuclide of concern (ROC). Though not shown here, Tc-99, Ra-226, and Th-232 concentrations from Table B-5, and B-6 were included in the adjusted SOF calculation. Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the HDP FSS data for Reuse Stockpile 2, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

^dDCGL_W values are from the excavation scenario column in Table 2.1.

^eDCGL_W values are from the uniform stratum column in Table 2.1.