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March 15, 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 INTERIM REPORT—INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSAs 02-01, 02-02, AND 02-03 FOR THE HEMATITE DECOMMISSIONING PROJECT, FESTUS, MISSOURI (RFTA NO. 14-003); DCN 5184-SR-06-0

Dear Mr. Smith:

ORAU is pleased to provide the enclosed final interim report detailing the independent confirmatory survey activities of Survey Units LSAs 02-01, 02-02, and 02-03 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 September 1–3, 2015. Comments on the draft report have been incorporated into this final 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:fs

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSAs 02-01, 02-02, AND 02-03 FOR THE HEMATITE DECOMMISSIONING PROJECT, FESTUS, MISSOURI

FINAL INTERIM REPORT

Prepared by
Evan M. Harpenau

MARCH 2016

Prepared for the
U.S. Nuclear Regulatory Commission

Prepared by ORAU under the Oak Ridge Institute for Science and Education contract, number DE-AC05-06OR23100, 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 02-01, 02-02, AND 02-03 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), and its decommissioning contractor are 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) 02-01, 02-02, and 02-03 for unrestricted use.

ORAU performed independent assessment activities including gamma and beta radiation surveys and soil sampling during the period of September 1–3, 2015. Confirmatory survey activities included surveys of three soil survey units and one concrete dam and the collection and analysis of 18 random and 8 judgmental soil samples. The results of ORAU's gamma and beta radiation surveys, combined with laboratory analytical results of soil samples, and concurrence that the NRC follow-up surveys in LSA 02-01 found no additional discreet pieces of low-level waste support the conclusion that LSAs 02-01, 02-02, and 02-03 satisfy the NRC-approved activity derived concentration guideline levels (DCGLs) described in WEC's decommissioning plan (DP).

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSAs 02-01, 02-02, AND 02-03 FOR THE HEMATITE DECOMMISSIONING PROJECT, FESTUS, MISSOURI

1. INTRODUCTION

The 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 permitted license 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 02-01, 02-02, and 02-03. These survey units were associated with the site pond in the southwestern portion of the overall site (Figure A-2). 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 a secondary ROC found in lesser quantities but could have accumulated due to site runoff (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 ($DCGL_W$s) (WEC 2011).

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 $DCGL_W$s 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 were evaluated and compared to the applicable uniform stratum DCGL (uniform $DCGL_W$) presented in Table 2.1.

Table 2.1. Adjusted Site-specific Soil $DCGL_W$s 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
[a]Table 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.
[d]$DCGL_W$s represents net concentration in soil for each CSM.

3. PROCEDURES

The confirmatory survey activities were conducted September 1–3, 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 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 survey unit (SU). Walkover scans were performed 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 02-01, 02-02, and 02-03, respectively.

In addition to the soil walkover surveys, ORAU performed high-density beta scans on the concrete dam separating LSAs 02-02 and 02-03 using a Ludlum Model 44-142 plastic scintillation detector

coupled to a ratemeter-scaler with audible indicator and a GPS receiver. The spatially-oriented beta scan data are provided in Figure A-6.

A ranked set sampling (RSS) design was used to estimate the mean radionuclide concentration in the SUs (EPA 2002). FSS sample data were not available prior to the confirmatory survey, so the number of locations to evaluate and sample within each SU were determined by associating the licensee's FSS results and walkover survey count rates from previous SUs with the walkover survey and Z score results for LSAs 02-01, and 02-02 (WEC 2015a, 2015b, 2015c, and 2015d). Visual Sample Plan software, version 7.4 was then used to plot the confirmatory locations for LSAs 02-01, 02-02, and 02-03. As a result of the sample planning inputs, 18 ranking locations were evaluated in each of the three SUs. Following completion of walkover surveys, the RSS locations were laid out as illustrated in Figures A-7 through A-9. A one-minute static gamma measurement was made with the NaI detector at each ranking location. The surface measurements were then ranked, which resulted in the selection of six locations per SU for sampling. The six sample locations are presented in Figures A-10 through A-12 for LSAs 02-01, 02-02 and 02-03, respectively. Additionally, the location with the highest gamma count rate in each SU was selected for judgmental sampling. Multiple locations exhibiting elevated gamma count rates, greater than 4,000 counts per minute above the average for the unit, were observed in LSA 02-01 resulting in the collection of additional judgmental samples. In total, 18 samples were collected using the RSS process and 8 judgmental samples collected based on elevated gamma count rates (see Figures A-10 through A-12).

Soil samples were sent to the Radiological and Environmental Analytical Laboratory 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 enriched uranium at levels above 3.5% in six of the confirmatory samples which prompted alpha spectroscopic analysis to provide greater confidence of the actual uranium concentrations. 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 (Table B-1).

4. RESULTS

4.1 SURFACE SCANS

Elevated direct gamma radiation in excess of the background count variability was observed in each of the three soil LSAs. In the northern portion of LSA 02-01, elevated gamma radiation levels were observed over discreet pieces of solid material located on the soil surface as well as locations associated with drain lines that had been remediated. ORAU placed pin-flags at each discreet particle location and other elevated soil areas 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 36,900 gross counts per minute (cpm) with a mean count rate of approximately 10,500 cpm and background of approximately 10,000 cpm (Figure A-3).

A majority of the observed instrument responses for LSA 02-02 were within the background count variability for all areas of the SU with the exception of the southern boundary near the dam where count rates exceeded 17,400 cpm. Similarly, a majority of the observed instrument responses for LSA 02-03 were within the background count variability for all areas except a depression in the base of the large trench near the northern boundary of the SU where count rates exceeded 15,100 cpm. Walkover survey data are illustrated in Figures A-3 through A-5.

No elevated beta radiation above 833 cpm was observed during the beta scan of the dam separating LSAs 02-02 and 02-03. However, ORAU personnel noted instrument cable electronic spikes that caused the recording of false positive data above 833 cpm. Those false positive data were removed for presentation in Figure A-6. The observed beta count rates were indicative of typical background responses for a plastic scintillation detector on concrete and thus did not warrant additional evaluation.

4.2 VOLUMETRIC SAMPLING

The random sample results for LSAs 02-01, 02-02, and 02-03 were all below the established $DCGL_W$s, as well as having SOFs less than unity. From the random sample results, only sample 5184S0114 from LSA 02-01 exhibited an elevated concentration of Tc-99 at 16.32 pCi/g, which

resulted in the highest calculated SOF value of 0.69. The ROC concentrations in all other random confirmatory samples were minimal and the SOF calculation did not exceed 0.20.

Five of the six judgmental samples from LSA 02-01 had low concentrations (relative to background?) of the ROCs with SOFs less than 0.30. However, judgmental sample 5148S0122, a discreet piece of solid material, was showed by gamma spectroscopic and radiochemical separation analyses to contain 13.74 pCi/g of Tc-99, 5,082 pCi/g of U-234 (inferred), 195 pCi/g of U-235, and 21.7 pCi/g of U-238, resulting in an SOF calculation greater than 30. Additionally, the 0.11 grams of U-235 in the sample were enriched to approximately 58% (ORAU 2015d). The calculation for interpolating enrichment using Table 14-5 from the licensee's DP showed the sample to contain 59% enriched U-235 which is in statistical agreement with ORAU's internal analytical determination. Sample 5184S0122 was further analyzed through alpha spectroscopy with the following uranium results: 6,810 pCi/g of U-234, 208 pCi/g of U-235 at 46% enrichment, and 37 pCi/g of U-238 (ORAU 2015e). At the NRC's request, sample 5148S0122 was sent to a third party laboratory for material identification. ORAU transferred the sample to Southwest Research Institute (SwRI) in San Antonio, Texas to perform that analysis. SwRI is accredited by the National Environmental Laboratory Accreditation Conference (NELAC) and ISO 9001 certified. The materials identification analysis concluded that the sample contained rock-like materials and roofing felt consistent with roofing material (SwRI 2015).

The judgmental sample collected in LSA 02-02, 5184S0119, contained elevated concentrations of U-234, U-235, and U-238. Though elevated, the reported concentrations did not exceed the respective $DCGL_W$s and the SOF was 0.60. Judgmental sample 5184S0118 from LSA 02-03 contained minimal concentrations of the ROCs and had an SOF of 0.10.

A comprehensive summary of the Radiological and Environmental Analytical Laboratory sample results for site-related ROCs (excluding Pu-239/240, Am-241, and Np-237) is provided in Table B-2. Table 4.1 summarizes the ROC concentrations reported in Table B-2. Additionally, six samples containing enriched U-235 at concentrations above 3.5% via gamma spectroscopy were subjected to alpha spectroscopy analysis to provide higher confidence of the uranium concentrations. The alpha spectroscopy results for those samples are provided in Table B-3.

The analytical results were evaluated and compared to the applicable uniform $DCGL_W$ presented in Table 2.1. Comparisons to the uniform $DCGL_W$s 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 sample 5184S0122, were below the individual uniform stratum $DCGL_W$, and the SOF calculations were less than unity.

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

ROC	Gross Soil Activity Concentration Range		
U-234[a]	1.18[a]	to	6,810[b]
U-235	-0.02	to	208[b]
U-238	0.74	to	37[b]
Tc-99	0.01	to	16.32
Th-232	0.32	to	1.18
Ra-226	0.29	to	1.28

[a]U-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.

[b]Concentrations as determined through alpha spectroscopic analysis.

Table 4.2. SOF Statistical Comparison of Random Samples						
SOF[a]	LSA 02-01		LSA 02-02		LSA 02-03	
	ORAU	WEC[b]	ORAU	WEC[b]	ORAU	WEC[b]
Average	0.20	0.10	0.11	0.17	0.09	0.12
Standard Deviation[c]	0.25	0.09	0.06	0.08	0.07	0.08
Minimum	0.04	0.01	0.05	0.03	0.02	0.01
Maximum	0.69	0.27	0.20	0.32	0.18	0.27

[a]Sum 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).
[b]WEC values calculated from WEC offsite summary data with ingrowth (WEC 2015e, 2015f, 2015g)
[c]95% 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 September 1–3, 2015. The survey activities included document reviews, beta scans, gamma walkover surveys, soil sampling, and laboratory analysis of confirmatory soil samples. All confirmatory survey ROC concentrations from the LSA 02-01, LSA 02-02 and LSA 02-03 soil samples, except sample 5184S0122 which was remediated through sampling, were below the individual uniform stratum $DCGL_W$ 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 02-01 with an elevated concentration of Tc-99 that skewed the SOF data presented in Table 4.2.

In addition, ORAU reviewed the licensee's inter-office memorandum for the *Discreet Contaminated Items Identified in Site Pond LSA 02-01 by ORAU* (WEC 2015h). The licensee provided extensive detail about site remediation activities and weather events that led them to conclude the 15 discreet particles identified in LSA 02-01 were from roofing material deemed as low-level waste (LLW) that had been staged for offsite disposal in the SU adjacent to LSA 02-01. Based on the information provided by the licensee and the material identification report from SwRI, ORAU is of the opinion that the licensee's conclusion is plausible and the discreet LLW items were most likely remnants from the staging area in LSA 05-04 that washed into the SU following FSS activities as opposed to

material that was not identified during FSS activities.

Based on the findings of the confirmatory survey, and provided the NRC's follow-up walkover survey concluded that the licensee had remediated all contaminated roofing material from LSA 02-01, ORAU is of the opinion that the licensee has adequately demonstrated that survey units LSA 02-01, 02-02 and 02-03 meet the site-approved release criteria.

5. REFERENCES

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WEC 2015d. *LSA_02_02_A_ZSCORE(final)*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. August 14.

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WEC 2015g. *Copy of LSA 02-03 FSSDE*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. November 5.

WEC 2015h. *Appendix G-2: Final Status Investigations for Soil Survey Units*. Hematite Decommissioning Project Procedure. HDP-PR-FSS-721, Rev 5: Final Status Survey Data Evaluation. Westinghouse Electric Company, LLC. Festus, Missouri. September.

APPENDIX A
FIGURES

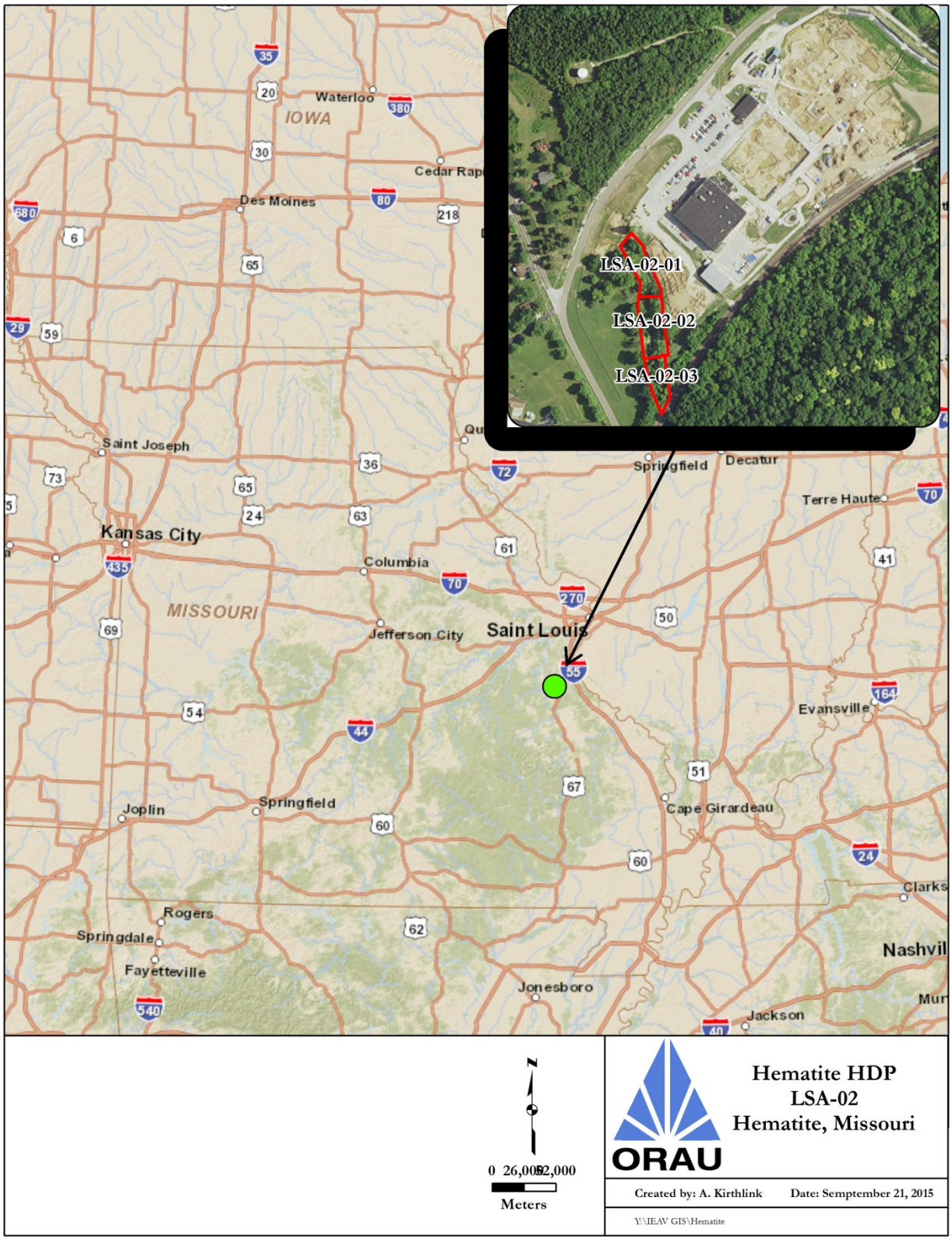

Figure A-1. Location of Hematite Decommissioning Project, Festus, Missouri

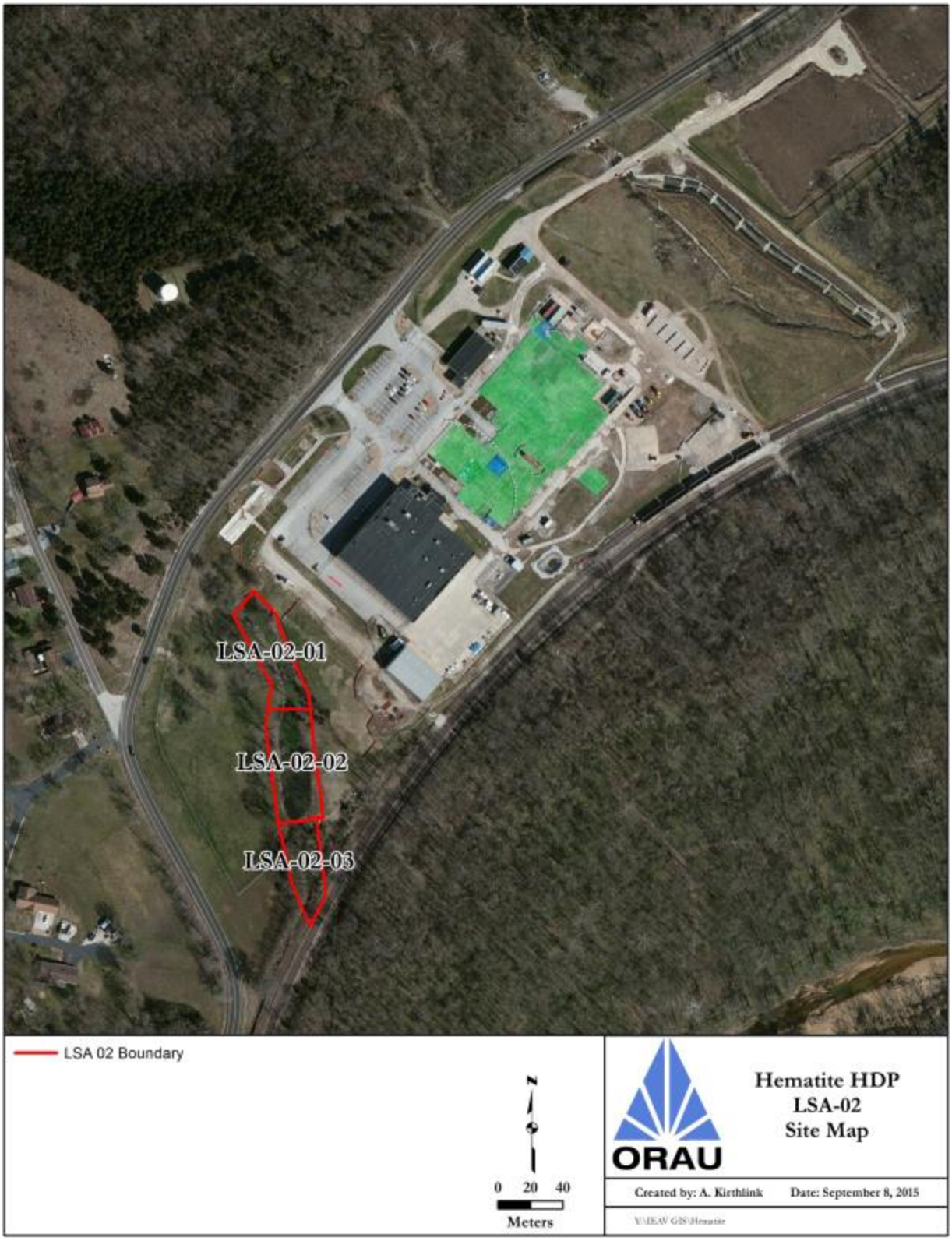

Figure A-2. Plot Plan of LSAs 02-01, 02-02, and 02-03 at the Hematite Decommissioning Project

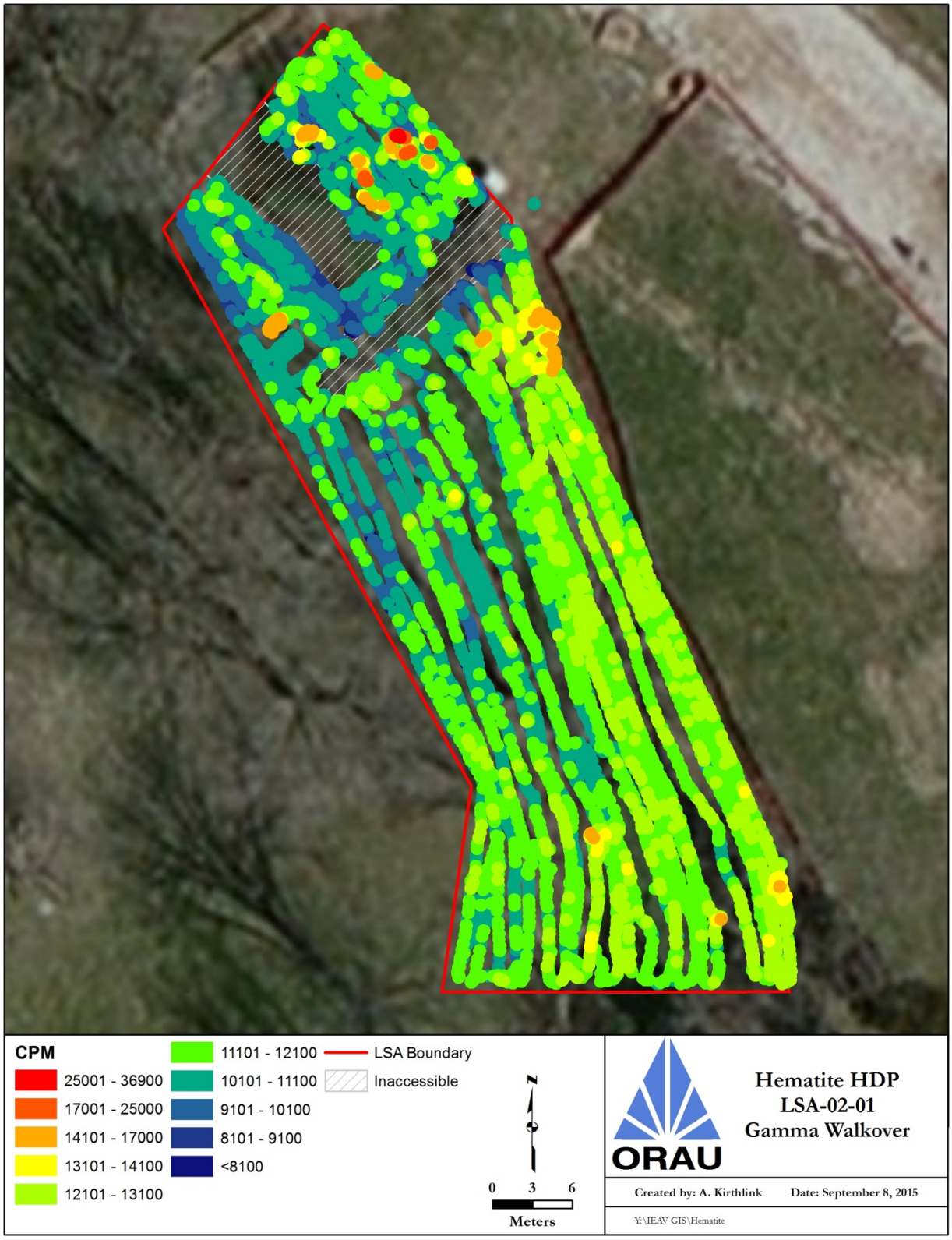

Figure A-3. LSA 02-01—Gamma Walkover Scans

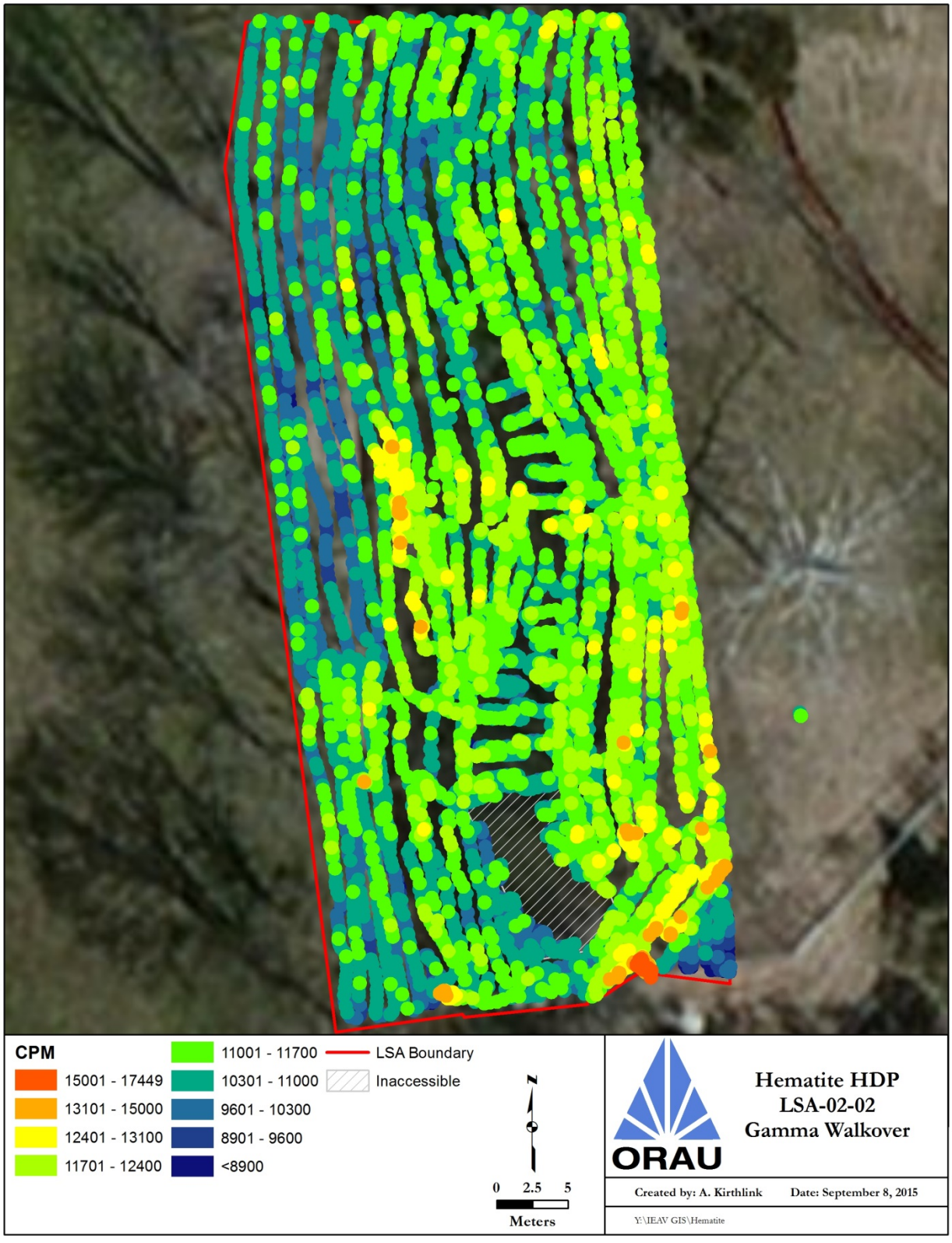

Figure A-4. LSA 02-02—Gamma Walkover Scans

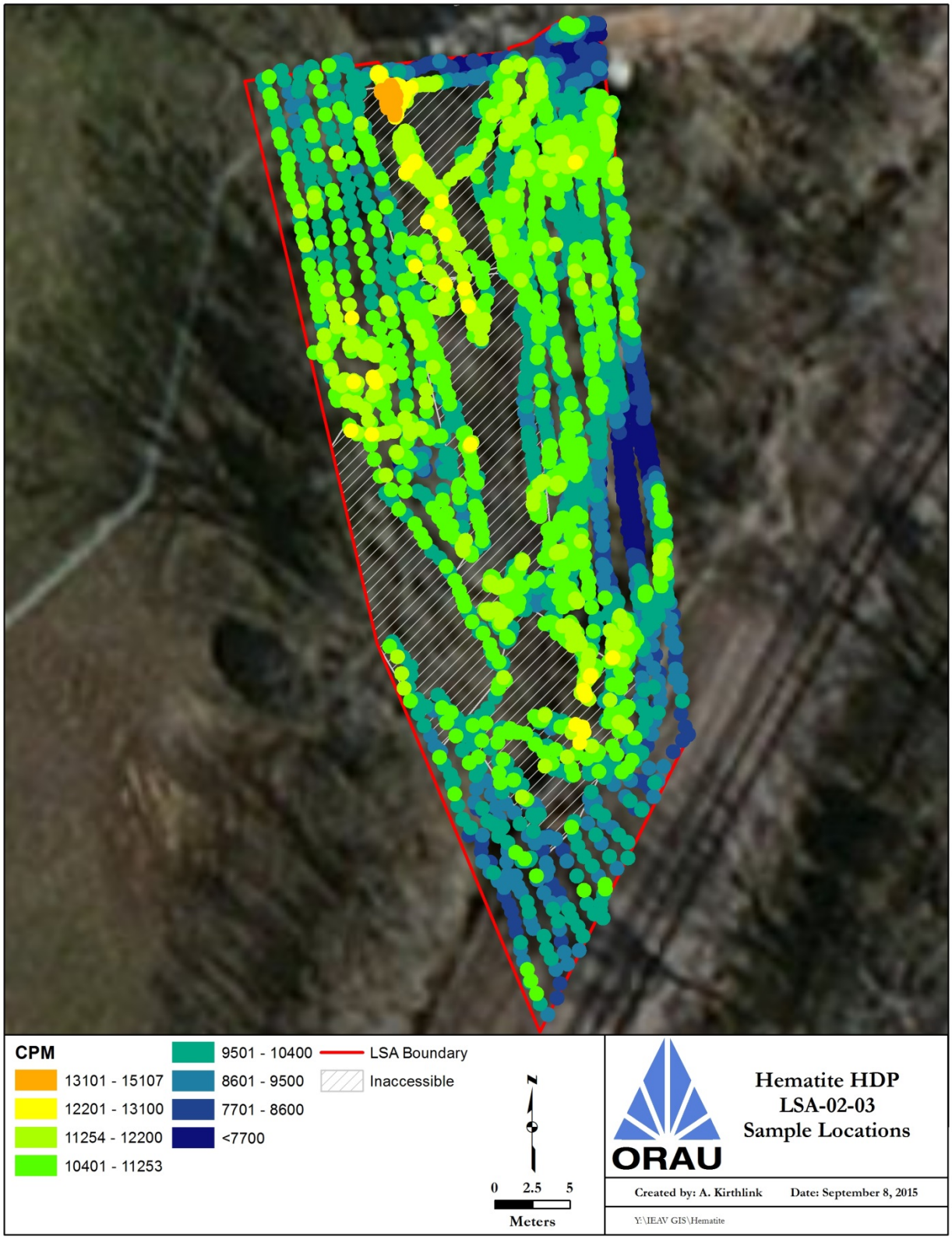

Figure A-5. LSA 02-03—Gamma Walkover Scans

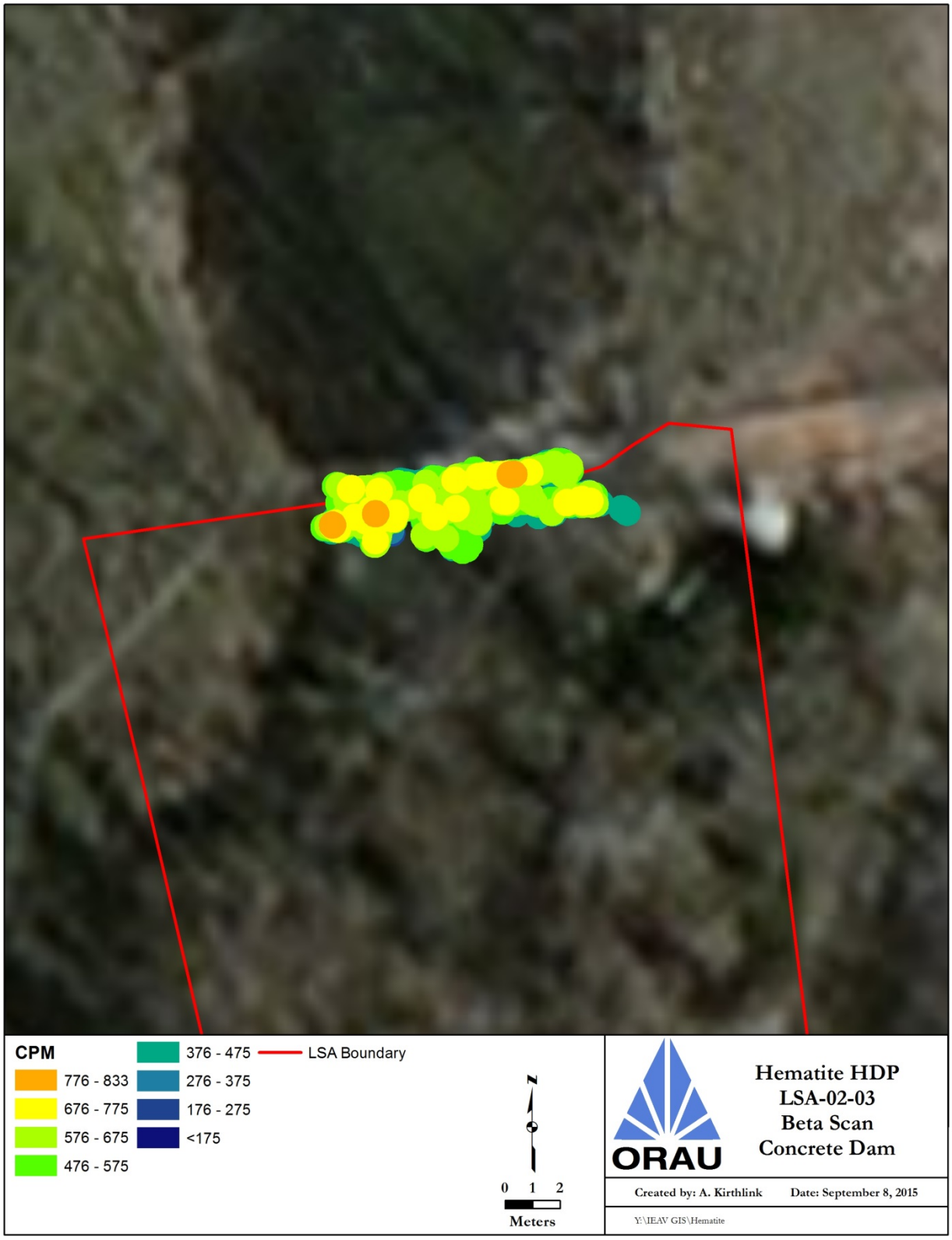

Figure A-6. Concrete Dam between LSA 02-2 and LSA 02-03—Beta Scan

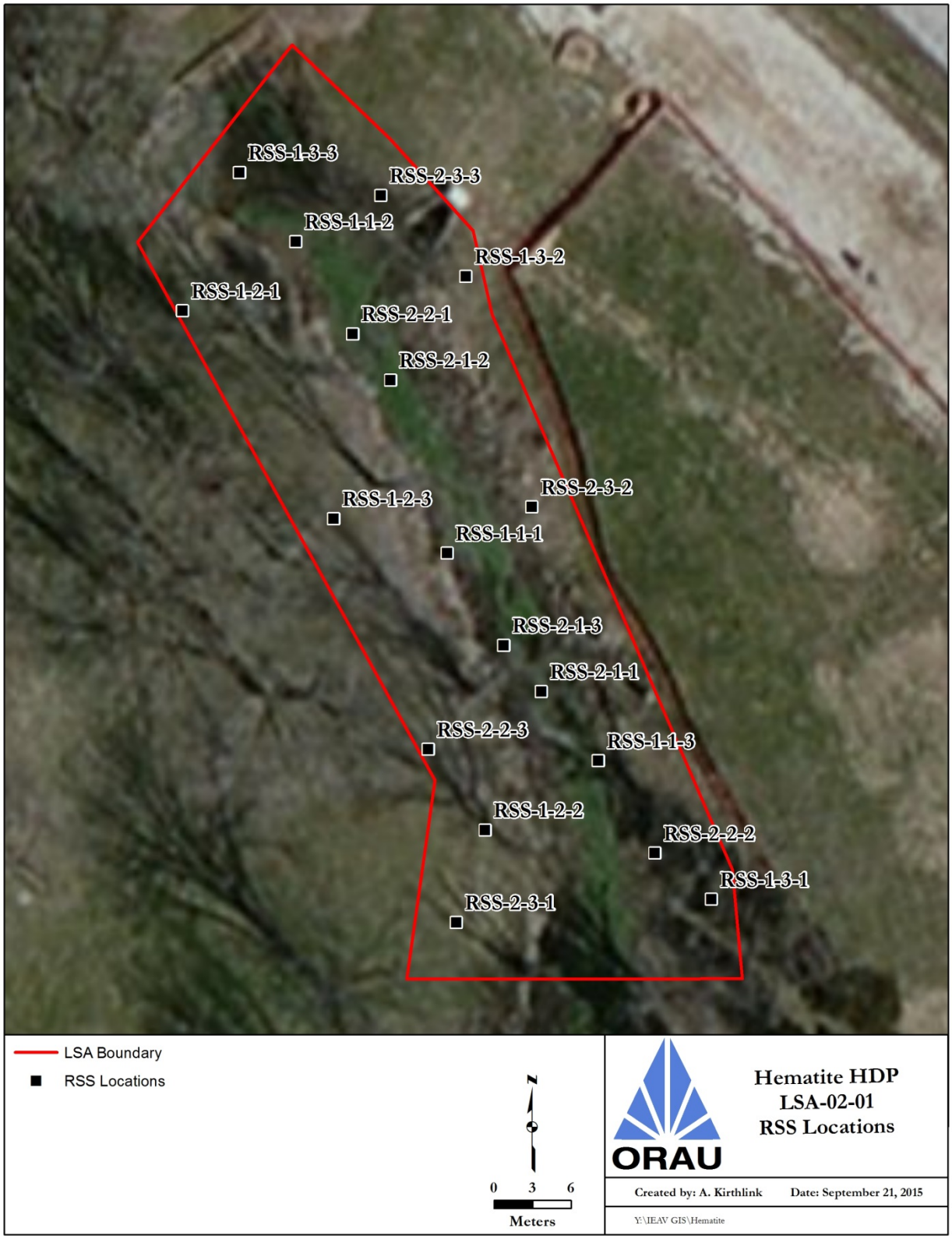

Figure A-7. LSA 02-01—Ranked Set Sampling Measurement Locations

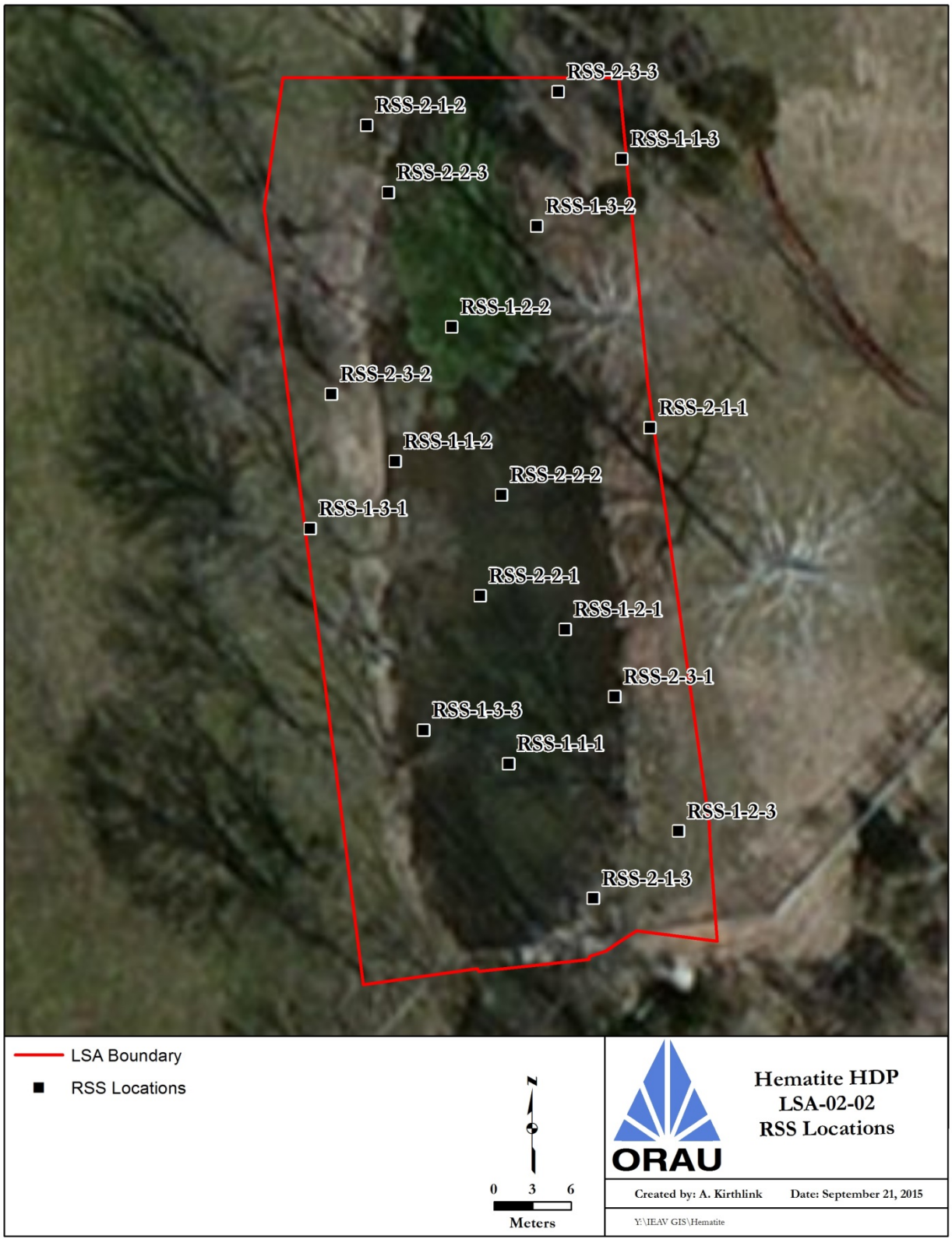

Figure A-8. LSA 02-02—Ranked Set Sampling Measurement Locations

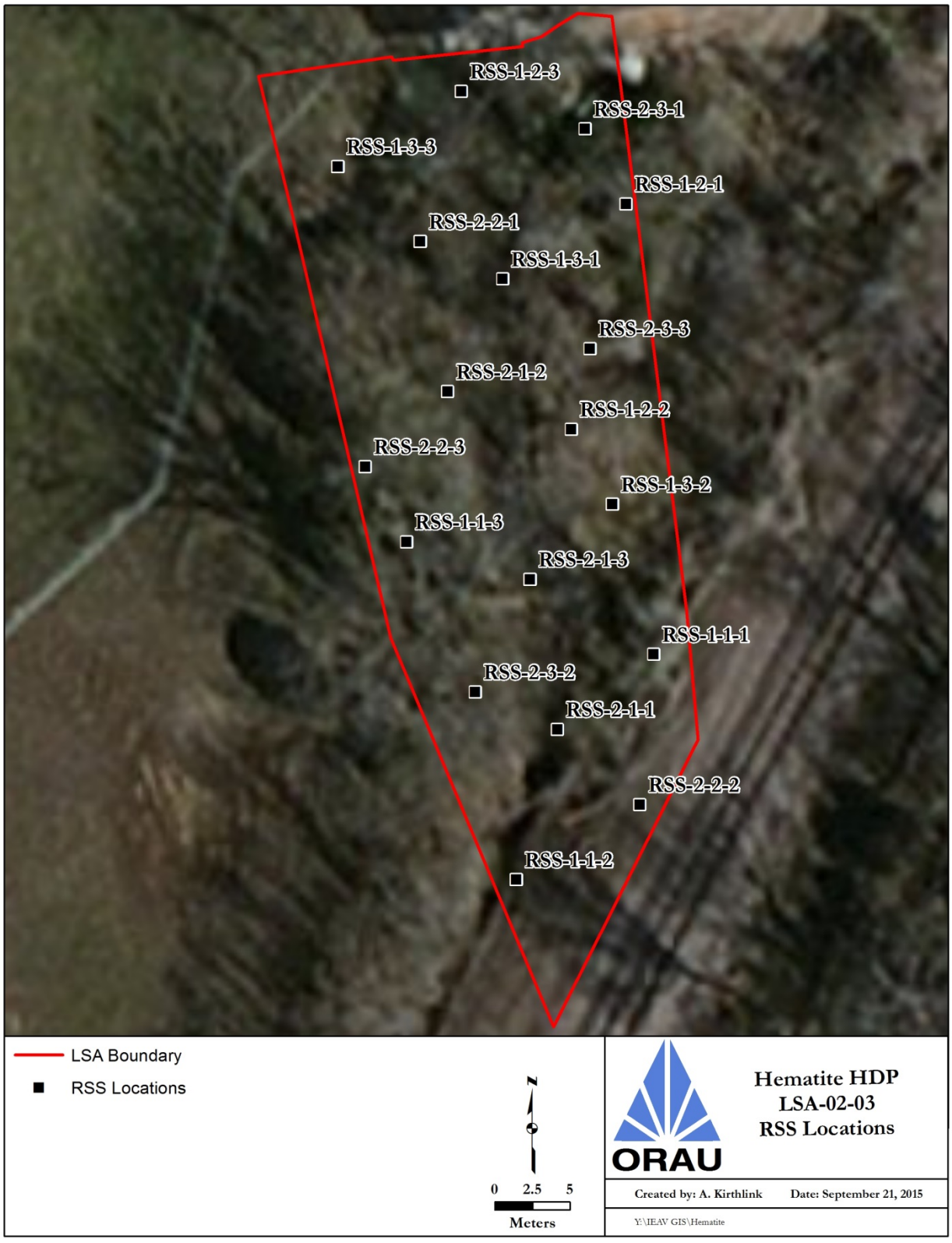

Figure A-9. LSA 02-03—Ranked Set Sampling Measurement Locations

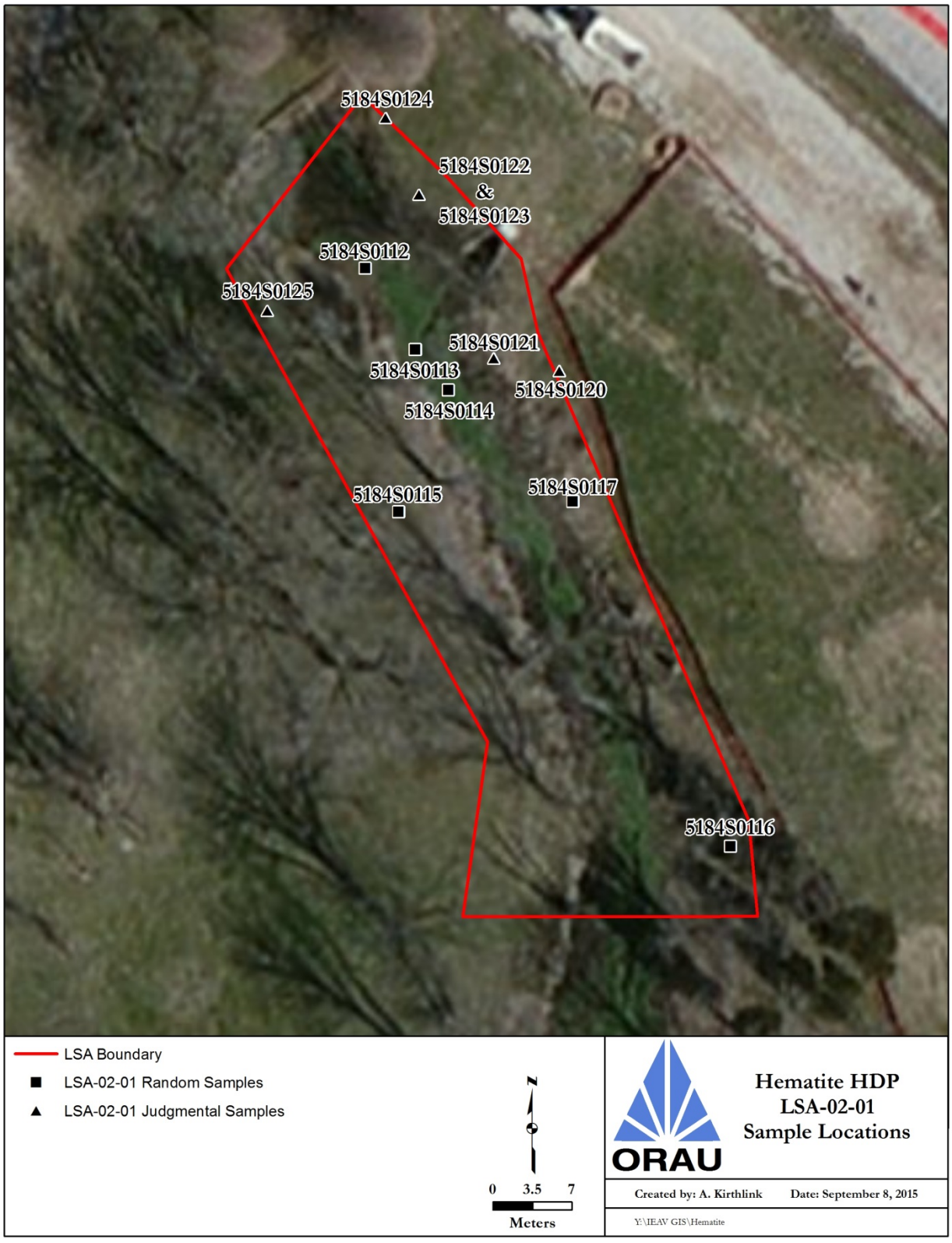

Figure A-10. LSA 02-01—Soil Sampling Locations

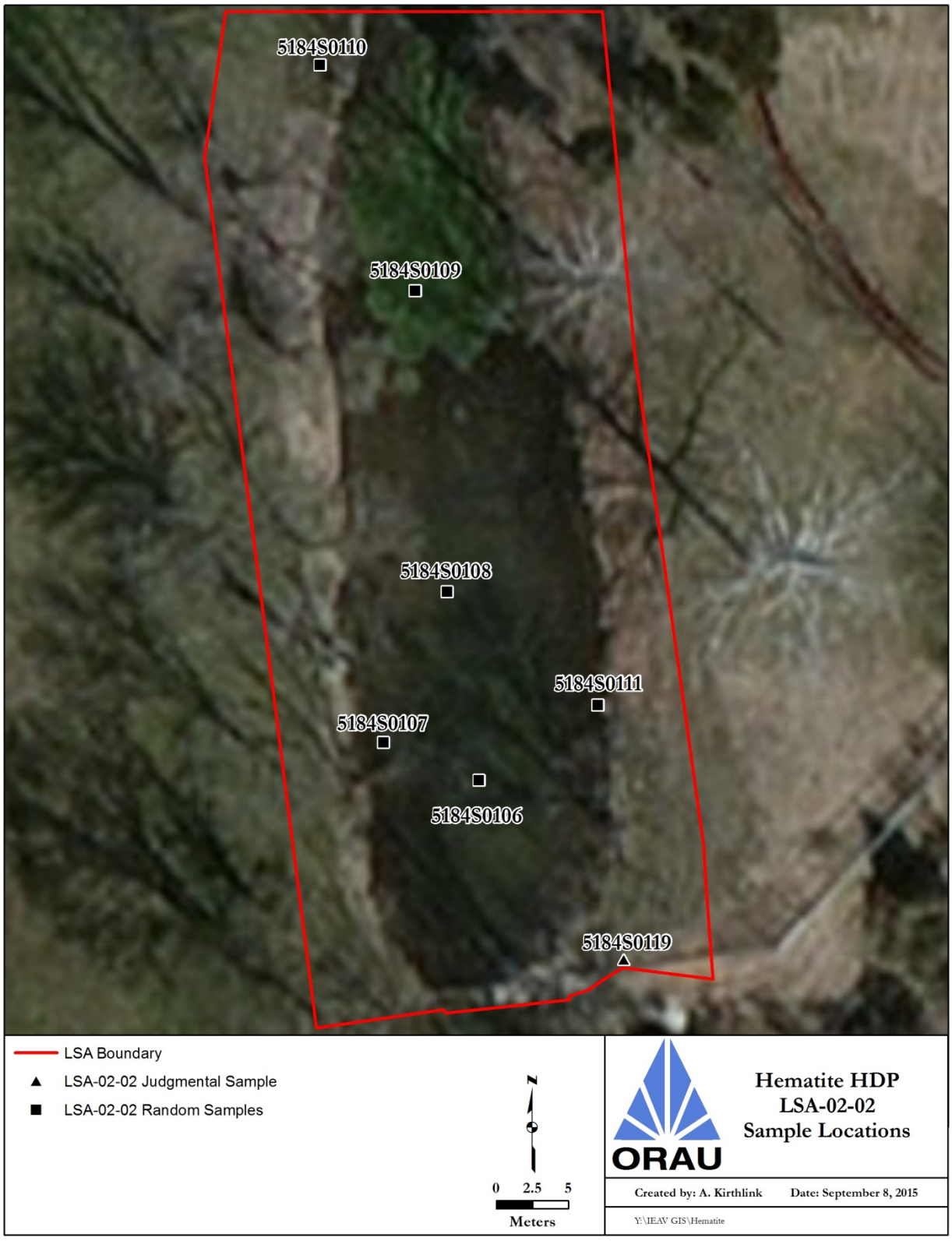

Figure A-11. LSA 02-02—Soil Sampling Locations

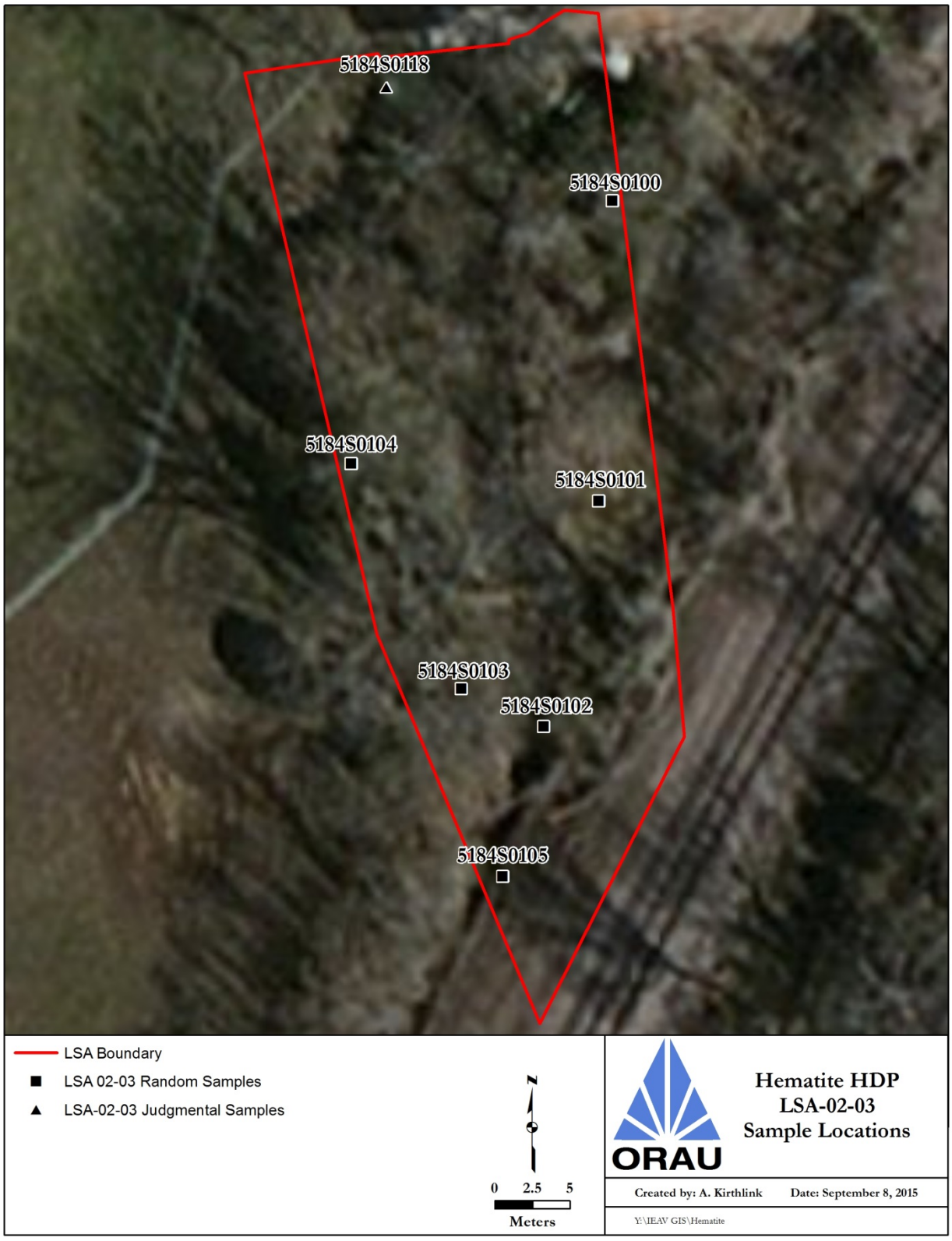

Figure A-12. LSA 02-03—Soil Sampling Locations

APPENDIX B
DATA TABLES

Table B-1. U-234 Calculations from U-238 and U-235 for LSA-02-01, 02-02, and 02-03 Soil Samples Hematite Decommissioning Project Festus, Missouri						
Sample	U-238 (pCi/g)	U-235 (pCi/g)	U-238/U-235 Ratio	U-234/U-235[a] Ratio	Enrichment (% U-235)[b]	U-234 (pCi/g)
	Result	Result				Result
5184S0100	1.32 ± 0.45[c]	0.100 ± 0.067	13.20	19.46	1.2	1.95 ± 1.46
5184S0101	1.36 ± 0.66	0.16 ± 0.13	8.50	18.67	1.8	2.99 ± 2.83
5184S0102	1.02 ± 0.44	0.07 ± 0.13	14.57	19.70	1.8	1.38 ± 2.63
5184S0103	0.74 ± 0.75	0.14 ± 0.15	5.29	18.23	2.9	2.55 ± 3.76
5184S0104	1.14 ± 0.42	0.103 ± 0.066	11.07	19.09	1.4	1.97 ± 1.45
5184S0105	0.78 ± 0.39	0.098 ± 0.058	7.96	18.58	1.9	1.82 ± 1.41
5184S0106	2.27 ± 0.64	0.49 ± 0.11	4.63	18.16	3.3	8.90 ± 3.21
5184S0107	1.55 ± 0.68	0.178 ± 0.099	8.71	18.71	1.8	3.33 ± 2.36
5184S0108	1.48 ± 0.47	0.143 ± 0.077	10.35	18.97	1.5	2.71 ± 1.70
5184S0109	1.18 ± 0.79	-0.02 ± 0.14	—	—	—	1.18 ± 1.59[d]
5184S0110	1.55 ± 0.64	0.208 ± 0.092	7.45	18.51	2	3.85 ± 2.33
5184S0111	1.90 ± 0.53	0.235 ± 0.080	8.09	18.60	1.9	4.37 ± 1.92
5184S0112	1.65 ± 0.74	0.69 ± 0.11	2.39	18.18	6.1	12.54 ± 5.97
5184S0113	1.25 ± 0.44	0.128 ± 0.080	9.77	18.87	1.6	2.42 ± 1.73
5184S0114	1.28 ± 0.59	0.328 ± 0.095	3.90	18.12	3.8	5.94 ± 3.23
5184S0115	1.83 ± 0.53	0.130 ± 0.064	14.08	19.62	1.1	2.55 ± 1.46
5184S0116	1.40 ± 0.82	0.15 ± 0.11	9.66	18.86	1.6	2.73 ± 2.62
5184S0117	1.60 ± 0.62	0.118 ± 0.076	13.56	19.53	1.1	2.30 ± 1.73
5184S0118	1.72 ± 0.55	0.170 ± 0.087	10.12	18.93	1.5	3.22 ± 1.94
5184S0119	10.9 ± 2.4	4.59 ± 0.31	2.37	18.18	3.1	83.46 ± 19.22
5184S0120	2.01 ± 0.58	0.326 ± 0.096	6.17	18.33	2.5	5.98 ± 2.46
5184S0121	3.80 ± 0.93	0.93 ± 0.12	4.09	18.12	3.7	16.85 ± 4.66
5184S0122	21.7 ± 5.5	195 ± 11	0.11	26.06	59	5,082 ± 1,319
5184S0123	0.83 ± 0.45	0.429 ± 0.086	1.93	18.31	7.5	7.85 ± 4.54
5184S0124	1.21 ± 0.79	0.06 ± 0.15	20.17	20.72	0.8	1.24 ± 3.21

Table B-1. U-234 Calculations from U-238 and U-235 for LSA-02-01, 02-02, and 02-03 Soil Samples Hematite Decommissioning Project Festus, Missouri						
Sample	U-238 (pCi/g)	U-235 (pCi/g)	U-238/U-235 Ratio	U-234/U-235[a] Ratio	Enrichment (% U-235)[b]	U-234 (pCi/g)
	Result	Result				Result
5184S0125	1.59 ± 0.80	0.23 ± 0.11	6.91	18.43	2.2	4.24 ± 2.94

[a]U-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.

[b]From Table 14-5 "Radioactivity and Isotopic Ratios Relative to Enrichment" in the Hematite DP Rev 1.2.

[c]Two sigma uncertainty is presented.

[d]The concentration of U-234 was assumed to be in equilibrium with U-238 due to the absence of U-235 in the sample. The 95% TPU for natural uranium/U-234 was calculated from: $\sqrt{(\sigma_{U-234})^2 + (\sigma_{U-235})^2 + (\sigma_{U-235})^2}$

Table B-2. Radionuclide Concentrations in LSA 02-01, 02-02 and 02-03 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 $DCGL_W$[d]			25.1	1.9	2.0	195.4	51.6	168.8	<1
LSA 02-01[e]									
5184S0112	826671	864512	0.75	0.76	0.88	12.54	0.69	1.65	0.12
5184S0113	826686	864489	0.10	0.97	1.14	2.42	0.13	1.25	0.13
5184S0114	826696	864477	16.32	0.86	0.84	5.94	0.33	1.28	0.69
5184S0115	826681	864441	0.30	0.87	0.86	2.55	0.13	1.83	0.04
5184S0116	826778	864344	0.15	0.95	1.16	2.73	0.15	1.40	0.14
5184S0117	826732	864444	0.19	0.86	1.09	2.30	0.12	1.60	0.08
LSA 02-01 Judgmental Samples[e]									
5184S0120	826728	864482	0.83	0.89	1.15	5.98	0.33	2.01	0.16
5184S0121	826709	864486	0.36	0.99	1.18	16.85	0.93	3.80	0.28
5184S0122[f]	826687	864534	13.74	0.29	0.32	5082	195	21.7	30.5

Table B-2. Radionuclide Concentrations in LSA 02-01, 02-02 and 02-03 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	
5184S0123	826687	864534	0.01	0.59	0.745	7.85	0.43	0.83	0.05
5184S0124	826677	864556	0.05	1.28	1.14	1.24	0.06	1.21	0.29
5184S0125	826643	864499	0.33	0.92	1.11	4.24	0.23	1.59	0.11
LSA 02-02[g]									
5184S0106	826758	864148	0.78	0.76	1.09	8.90	0.49	2.27	0.14
5184S0107	826736	864157	0.02	1.08	1.14	3.33	0.18	1.55	0.20
5184S0108	826750	864191	0.12	0.93	1.01	2.71	0.14	1.48	0.05
5184S0109	826743	864260	0.16	0.95	1.07	1.18	-0.02	1.18	0.08
5184S0110	826721	864311	0.18	0.93	1.00	3.85	0.21	1.55	0.05
5184S0111	826785	864166	1.09	0.95	1.01	4.37	0.24	1.90	0.11
LSA 02-02 Judgmental Samples[g]									
5184S0119	826791	864107	0.19	0.83	1.02	83.46	4.59	10.90	0.60
LSA 02-03[h]									
5184S0100	826801	864064	0.14	0.88	1.03	1.95	0.10	1.32	0.04
5184S0101	826798	863998	0.10	0.87	0.87	2.99	0.16	1.36	0.03
5184S0102	826786	863949	0.23	1.00	1.12	1.38	0.07	1.02	0.13
5184S0103	826768	863957	0.07	1.09	1.11	2.55	0.14	0.74	0.18
5184S0104	826744	864007	0.01	1.01	1.12	1.97	0.10	1.14	0.14
5184S0105	826777	863916	0.07	0.70	0.540	1.82	0.10	0.78	0.02
LSA 02-03 Judgmental Samples[h]									
5184S0118	826751	864088	0.37	0.78	1.11	3.22	0.17	1.72	0.10

[a]These values are gross concentrations; background concentrations have not been subtracted.

[b]U-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-1.

[c]Sum 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).

[d]$DCGL_W$ values are from the uniform stratum column in Table 2.1.

[e]Refer to Figure A-10.

[f]Sample consisted of a discrete disc-shaped piece of roofing material.

[g]Refer to Figure A-11. [h]Refer to Figure A-12.

Table B-3. Radionuclide Concentrations in LSA 02-01, 02-02 and 02-03 Soil 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**	
Uniform Stratum $DCGL_W$[d]			195.4	51.6	168.8	<1
5184S0112	826671	864512	14.4 ± 1.5	0.468 ± 0.075	1.31 ± 0.16	0.12
5184S0114	826696	864477	5.46 ± 0.59	0.256 ± 0.054	1.52 ± 0.19	0.69
5184S0119	826791	864107	105 ± 11	4.22 ± 0.51	10.9 ± 1.2	0.70
5184S0121	826709	864486	26.7 ± 2.7	1.04 ± 0.14	3.62 ± 0.40	0.33
5184S0122	826687	864534	6810 ± 700	208 ± 30	37.5 ±9.0	40
5184S0123	826687	864534	4.30 ± 0.47	0.130 ± 0.035	0.79 ± 0.11	0.03

[a]These values are gross concentrations; background concentrations have not been subtracted.

[b]Alpha spectroscopy results reported for uranium isotopes.

[c]Sum 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-2 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).

[d]$DCGL_W$ values are from the uniform stratum column in Table 2.1.