March 16, 2017

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: CONTRACT NO. DE-SC0014664
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSA 01-01, LSA 01-02, AND LSA 01-03 AT THE HEMATITE DECOMMISSIONING PROJECT
FESTUS, MISSOURI
RFTA NO. 14-003; DCN 5184-SR-08-1

Dear Mr. Smith:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the subject revised final report that details the confirmatory survey activities performed during the period of January 12 through 14, 2016, and September 19 through 21, 2016, at the Hematite Decommissioning Project in Festus, Missouri. The revised final version of this report includes revisions based on comments submitted by U.S. Nuclear Regulatory Commission Region III staff.

Please feel free to contact me at 865.574.6273 or Tim Vitkus at 865.576.5073 if you have any questions or comments.

Sincerely,

Nick A. Altic
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Nick A. Altic

FINAL REPORT

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Prepared for U.S. Nuclear Regulatory Commission

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MARCH 2017

FINAL REPORT

Prepared for the
U.S. Nuclear Regulatory Commission

This document was prepared for the U.S. Nuclear Regulatory Commission (NRC) by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement (NRC FIN No. F-1244) between the NRC and the U.S. Department of Energy (DOE). ORISE is managed by Oak Ridge Associated Universities under DOE contract number DE-SC0014664.

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

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FINAL REPORT

MARCH 2017

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ACRONYMS

cpm	counts per minute
CSM	conceptual site model
$DCGL_{EMC}$	derived concentration guideline level for use with the elevated measurement comparison
$DCGL_W$	derived concentration guideline level over a wide area
DOE	U.S. Department of Energy
DP	decommissioning plan
EPA	U.S. Environmental Protection Agency
FSS	final status survey
GPS	global positioning system
HDP	Hematite Decommissioning Project
IL	investigation level
MDC	minimum detectable concentration
keV	kilo electron volt
NaI	sodium iodide
$MDCR_{Surveyor}$	minimum detectable count rate for the surveyor
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
ROC	radionuclide of concern
RSS	ranked set sampling
SOF	sum of fractions
TAP	total absorption peak
TEDE	total effective dose equivalent
WEC	Westinghouse Electric Company

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

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE) perform an independent confirmatory survey at the Hematite Decommissioning Project (HDP) in Festus, Missouri. The survey units investigated during this confirmatory survey included LSA 01-01, 01-02, and 01-03. These survey units consisted of land areas containing the site creek and a portion of Joachim Creek, which is outside of the Hematite property.

ORISE performed confirmatory survey activities, including gamma walkover surveys, surface soil and sediment sampling, and sediment core sampling, during the period of January 12 through 14, 2016, and September 19 through 21, 2016. ORISE collected a total of 30 samples consisting of 11 sediment cores, 11 surface sediment samples, and 8 surface soil samples. The results of the ORISE gamma surveys, combined with laboratory analytical results, support the survey unit classification determined by the licensee was appropriate (i.e., Class 1, Class 2 and Class 3 for LSA 01-03, 01-02, and 01-01—respectively). Confirmatory survey activities did not identify any site-related contaminants above their respective derived concentration guideline level in LSA 01-01, 01-02, or 01-03.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSA 01-01, LSA 01-02, AND LSA 01-03 AT 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 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 ORISE perform confirmatory surveys of final status survey (FSS) units LSA 01-01, 01-02, and 01-03.

2. SITE DESCRIPTION

The Hematite facility is located in Jefferson County Missouri, less than 4 miles west of the town of Festus, Missouri and 35 miles south of the city of St. Louis. The site location is presented in Figure 2.1 below. The site is surrounded by forest, agricultural lands, and low-density residential housing (also shown in Figure A-1). The entire site consists of approximately 228 acres; however, the impacted portion of the site, referred to as the central tract, only includes approximately 19 acres. The central tract of the site is bounded by State Road P to the north, the northeast site creek to the east, Union-Pacific railroad tracks to the south, and the site creek/pond to the west.

Survey units LSA 01-01, 01-02, and 01-03 are located approximately to the south of the HDP structures as shown in Figure A-1. WEC has classified these survey units based on the guidance found in the *Multi-Agency Radiation Site Survey and Investigation Manual* (NRC 2000). Survey unit classifications are specified in Table 2.1.

Table 2.1. Survey Unit Classification	
Survey Unit	**Classification**
LSA 01-01	Class 3
LSA 01-02	Class 2
LSA 01-03	Class 1

LSA 01-03 and 01-02 are wooded land areas that contain the site creek that terminates into Joachim Creek. LSA 01-01 consists of Joachim Creek, which depth varies based on environmental factors such as precipitation. LSA 01-01 also includes a small portion of the site creek, which is still on the HDP property.

Figure 2.1. Location of the HDP Site and the Survey Units Investigated

The primary radionuclides of concern (ROCs) at the HDP are technetium-99 (Tc-99), thorium-232 (Th-232), uranium-234 (U-234), radium-226 (Ra-226), uranium-235 (U-235), and uranium (U-238). 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 over a wide area ($DCGL_W$s) accordingly (WEC 2013).

Each radionuclide-specific $DCGL_W$ represents the concentration above background of a residual radionuclide that would result in a radiological dose of 24.75 millirem per year (mrem/yr) to the average member of the critical group (WEC 2013). The $DCGL_W$s for individual ROCs at the Hematite site are presented in Table 2.2. Because each individual $DCGL_W$ in Table 2.2 represents 24.75 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." For conservatism, the licensee has opted to use gross soil concentrations with the exception of Ra-226 and Th-232, for the SOF calculation. For consistency, ORISE's analytical data were assessed in the same manner.

Table 2.2. 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 represent net concentration in soil for each CSM.

3. OBJECTIVES

The objectives of the confirmatory surveys were to provide independent contractor field data reviews and to generate independent radiological data for use by the NRC in evaluating the accuracy and adequacy of the licensee's procedures and FSS results.

4. PROCEDURES

During the period of January 12 through 14, 2016, and September 19 through 21, 2016, ORISE performed confirmatory survey activities within Survey Units LSA 01-01, 01-02, and 01-03. The activities were in accordance with a project-specific plan and subsequent addendum, submitted to and approved by the NRC (ORISE 2013 and ORISE 2016). The confirmatory survey activities were also conducted in accordance with the *ORAU Radiological and Environmental Survey Procedures Manual* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2016a and ORAU 2016b). This report summarizes the procedures and results of the survey.

4.1 REFERENCE SYSTEM

ORISE referenced confirmatory sampling locations to the licensee's reference system using global positioning system (GPS) coordinates (NAD 1983 Missouri State Plane measured in feet).

4.2 SURFACE SCANS

Surface scans were performed using Ludlum Model 44-10 sodium iodide (NaI) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Ratemeter-scalers were coupled to GPS systems that enable real-time gamma count rate and spatial data capture. Locations of elevated direct gamma radiation, suggesting the presence of residual contamination, were marked and identified for further investigation. Medium- to high-density surface scans were performed over the Class 1 and Class 2 land areas (approximately 80% total coverage), and low-density scans were performed in Class 3 land area (less than 10% total coverage). Surface scan results were compared to an investigation level (IL) of 8,800 net counts per minute (cpm) for LSA 01-03 and 2,000 net cpm in LSA 01-01 and 01-02. The ILs correspond to an expected NaI detector response from 75% enriched uranium at a concentration equal to the derived concentration guideline level for use with the elevated measurement comparison ($DCGL_{EMC}$) for LSA 01-03 and the $DCGL_W$ for LSA 01-01 and 01-02.

Scans of the creek bed sediment were performed using the aforementioned NaI detector placed in a PVC tube with a sealed end-cap to prevent water intrusion.

4.3 SOIL AND SEDIMENT SAMPLING

A ranked set sampling (RSS) process, following U.S. Environmental Protection Agency (EPA) guidance, was used to select the random locations from which soil samples were collected (EPA 2002). RSS provides a methodology to determine the necessary number of soil samples to estimate the mean concentration of a population; however, it does not require the assumption of a normal distribution. The process combines random sampling with the use of a field screening method capable of distinguishing the relative magnitude of a parameter of interest in a population in combination with professional judgment to select sampling locations. For this project, one-minute static NaI gamma radiation count rate data collected at randomly selected locations provided the measurable field screening method that correlates with the relative concentrations of the gamma-emitting ROCs. The professional judgment component was the ability to assess the magnitude of gamma radiation levels (count rates) between randomly selected locations. The count rate data obtained from the population of random gamma measurement locations were then used to select specific locations for collecting the confirmatory soil samples

The RSS systematic planning process uses a replication method on a larger random population from which the locations for the resulting samples were selected. Replication refers to the number of cycles(r) for performing a set size (m) of field measurement. The set size was maintained at three locations ($m = 3$) to minimize ranking errors. The number of assessment locations per cycle is dependent on the set size and is simply m^2. Therefore, in a given cycle, samples were collected from each set based on the following ranking criteria:

- **Set 1:** The lowest of three gamma measurement locations within Set 1 is sampled.
- **Set 2:** The medium of three gamma measurement locations within Set 2 is sampled.
- **Set 3:** The highest of three gamma measurement locations within Set 3 is sampled.

The number of repetitive cycles is dependent on the total number of soil samples (n) required and is a function of n and m—simply defined as $n = m \times r$. Visual Sample Plan was used to determine the required number of samples based on Westinghouse's preliminary FSS data. It was determined that three soil samples would be required from each survey unit; however, six soil samples from each survey unit were conservatively chosen to optimize the confidence of the sampling design (i.e., $n = 6$). Therefore, with six required soil samples, the number of repetitive cycles was two ($r = n/m = 6/3 = 2$). The total number of assessment locations per survey unit is defined as $m^2 \times r$ *(where $r = 2$ in this case)*, and for this project was $3^2 \times 2 = 18$. The field ranking measurements are provided in Appendix D.

The initial sampling effort, performed in January of 2016, consisted of collecting surface soil or sediment samples—depending if the sample was collected from the creek. For each survey unit, 6 surface soil/sediment samples were collected. The sample locations were selected based on field measurements from 18 randomly ranked locations. Surface samples were collected from the top 15 cm of soil/sediment using hand tools. Additionally, one sample was collected based on the terrain of LSA 01-03 (Sample ID: 5184S0153). This sample was located in a pool formed by site drainage that could potentially accumulate site-related ROCs. A total of 19 surface soil/sediment samples were collected during the January 2016 survey, which includes one judgmental sample.

In September 2016, ORISE staff returned to the site and collected sediment cores at previously identified sampling locations that fell within the site creek. Every effort was made to collect sediment cores in Joachim Creek at the previously identified RSS locations. However, due to the abundance of large rocks that prevented sample collection, alternative core samples were collected at other RSS locations near the site creek boundary that were accessible. A total of 11 sediment core samples were collected during this effort, 3 of which were judgmental samples that were collected from the Joachim Creek bank based on an increase in audible output of the ratemeter from the bank relative to the creek bed sediment. These three judgmental samples were selected to confirm presence/absence of site-related ROCs accumulating in creek bank soils from site runoff during rain events that cause periods of high water elevation.

Sediment cores were collected to a depth of one meter, or until refusal, using a stainless steel sediment corer with plastic sample tube inserts. The corer was manually advanced to the one-meter depth using a slide-hammer. Once the core sample was collected, the sample tube was capped and sealed at both ends and prepared for shipping. After the core sample was prepared for shipping, it was field screened with the 44-10 NaI detector. The scans were performed to identify elevated direct gamma radiation distinguishable from background. The properties of each sample collected are summarized in Appendix B, Table B-1.

5. SAMPLE ANALYSIS AND DATA INTERPRETATION

All confirmatory field data and samples collected onsite were transported to the ORISE facility in Oak Ridge, Tennessee, for analysis and interpretation. Samples collected for radiological analysis were delivered to the ORISE Radiological and Environmental Analytical Laboratory under chain-of-custody. Sample analyses were performed in accordance with the ORAU *Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017). Samples were analyzed by gamma spectroscopy for gamma-emitting radionuclides; results were reported in units of picocuries per gram (pCi/g).

Alpha spectroscopy was not performed; therefore, Uranium-234 was calculated based on the U-238 to U-235 concentration ratio. Uranium-234 was calculated in the same manner as described in Section 14.1.4.3.3 of the licensee's decommissioning plan (DP) (WEC 2013). See Appendix D.4 for additional details on the U-234 calculation.

Samples were analyzed for Tc-99 by chemical separation and quantified by liquid scintillation counting. Analytical results were reported in pCi/g.

All confirmatory soil/sediment samples were compared directly with the uniform stratum $DCGL_W$s presented in Table 2.2. The SOF for each sample was calculated as discussed in Section 2. For the SOF calculation, a background concentration of 0.9 pCi/g and 1.0 pCi/g for Ra-226 and Th-232, respectively, were subtracted from the gross laboratory results. These background concentrations were determined by the licensee and specified in the HDP *Final Status Survey Plan Development* procedure (WEC 2015a).

6. FINDINGS AND RESULTS

6.1 SURFACE SCANS

Gamma walkover survey maps for LSA 01-01, 01-02, and 01-03 are provided in Figures A-5, A-6, and A-7, respectively. NaI detector response was significantly higher towards the northern boundary of LSA 01-03 than the remainder of the survey unit. The detector response ranged from approximately 7,000 to 19,000 cpm, with an overall average of approximately 12,000 cpm. This increase in direct gamma radiation was attributed to naturally occurring radioactive material in the rock associated with the railroad tracks transecting the northern portion of LSA 01-03. The survey team identified two distinct gamma count rate populations associated with the railroad rock and the remaining soil and detector responses for these two populations were less than the IL. Therefore, a judgmental sample was not collected as both populations represented background.

NaI detector response in LSA 01-02 ranged from approximately 5,200 to 15,000 cpm, with an average of 8,300 cpm. Based on the electronically captured scan data, there was a single outlier data point electronically captured above the IL. However, there were no audible indications in the area that would result in the surveyor pausing to investigate, nor do the data plots indicate any elevated gamma levels in the vicinity. Thus, the single spot was not sampled.

NaI detector response in LSA 01-01 ranged from approximately 600 to 7,000 cpm, with an average of approximately 2,400 cpm. Based on an increase in audible output from the ratemeter, three areas in Joachim Creek were marked for further investigation by soil/sediment sampling (LSA 01-01). The field technician noted that instrument response increased towards the bank of the creek. This increase was due to terrestrial and cosmogenic influences that were shielded by water during the scans over the creek bed. Three judgmental sample cores were collected to confirm the increase was not due to the presence of site-related ROCs.

6.2 RADIONUCLIDE CONCENTRATIONS IN SOIL AND SEDIMENT

Individual surface sample/sediment results for the ROCs that Westinghouse has identified as site-related contaminants are presented in Appendix B Table B-2. Individual sample results for Th-232 and Ra-226 were not corrected for background contribution and were below their respective $DCGL_W$s; however, the SOF calculations were corrected for background as specified in Section 5. A summary of the ROC concentration ranges in each of the survey units is provided in Table 6.1 below. Technetium-99 was identified above the analytical minimum detectable concentration (MDC) in all three survey units. However, it should be noted that only one sample, 5184S0168, from the Joachim Creek survey unit (01-01) was above the Tc-99 MDC. This sample was located in the site creek before joining with Joachim Creek (i.e., still on the HDP property). A sediment core, sample ID 5184S0178, was collected from a random RSS location near the LSA 01-02 and LSA 01-01 boundary in Joachim Creek. This RSS location was not selected based on ranking field measurement data but due to the proximity of the site creek. The SOF calculated for this sample was 0.01 and did not contain Tc-99 above the MDC.

Similarly, sample 5184S0153—which was located in the site creek—was not selected based on ranking field measurements. This sample location was in a pool formed by drainage from the site. The SOF for this sample was 0.12 and contained Tc-99 at a concentration of 0.45 pCi/g, slightly above the MDC.

The highest result—by SOF—was from sample 5184S0158 in LSA 01-03, which would be expected based on the Class 1 status of this survey unit. The SOF for this sample was 0.72, due mostly to the presence of Tc-99 at 10.93 pCi/g.

Table 6.1 Range of Radionuclide Concentration in Surface Soil and Sediment (pCi/g)[a]

ROC	LSA 01-01			LSA 01-02			LSA 01-03		
Tc-99	-0.04	to	0.82	-0.01	to	3.83	0.03	to	10.93
U-234[b]	0.33	to	5.34	1.12	to	3.78	0.33	to	34.4
U-235	-0.046	to	0.293	0.053	to	0.207	0.014	to	1.89
U-238	0.22	to	1.52	0.94	to	1.6	0.51	to	9.6
Th-232	0.07	to	1.08	0.483	to	0.95	0.397	to	1.07
Ra-226	0.191	to	0.94	0.508	to	0.891	0.675	to	1.093
SOF[c]	0.00	to	0.14	0.01	to	0.18	0.01	to	0.72

[a]Only the SOF values were corrected for background, as discussed in Section 5.
[b]Appendix D provides the details for the calculation of U-234 concentration.
[c]Values for SOF are dimensionless.

Individual sediment core sample results for the site-related contaminants are presented in Appendix B Table B-3. A summary of the ROC concentration ranges in each of the survey units is provided in Table 6.2 below. Individual sample results for Th-232 and Ra-226 were not corrected for background contribution; however, the SOF calculations were corrected for background as specified in Section 5.

The highest result—by SOF—for the sediment cores was from sample 5184S0175 in LSA 01-02. The SOF for this sample was 0.24, due mostly to the presence of Tc-99 and U-234 at concentrations of 2.12 pCi/g and 21.4 pCi/g, respectively.

Table 6.2 Range of Radionuclide Concentration in Sediment Cores (pCi/g)[a]

ROC	LSA 01-01			LSA 01-02			LSA 01-03		
Tc-99	-0.16	to	0.09	0.45	to	2.12	-0.04	to	0.27
U-234[c]	0.75	to	2.37	3.34	to	21.36	2.07	to	3.03
U-235	0.04	to	0.13	0.17	to	1.18	0.106	to	0.16
U-238	0.09	to	1.07	2.42	to	4.1	1.17	to	1.6
Th-232	0.129	to	0.63	0.34	to	0.98	0.83	to	1.09
Ra-226	0.166	to	0.621	0.515	to	0.927	0.714	to	1.08
SOF[c]	0.01	to	0.02	0.07	to	0.24	0.03	to	0.13

[a]Only the SOF values were corrected for background, as discussed in Section 5.
[b]Appendix D provides the details for the calculation of U-234 concentration.
[c]Values for SOF are dimensionless.

For convenience, the analysis results of the surface and core sediment samples are presented together in Appendix B Table B-4.

7. SUMMARY AND CONCLUSION

At NRC's request, ORISE conducted independent confirmatory surveys of the Joachim Creek area and associated site creek survey units. The surveys were conducted over the course of two site visits during the period of January 12 through 14, 2016, and September 19 through 21, 2016. The survey activities included measurement and sampling activities.

All individual confirmatory measurement results were below the respective uniform stratum $DCGL_W$ values (most restrictive) for the ROCs specified in the in the licensee's DP. Surface Soil and sediment sample SOFs were below 72% of the $DCGL_W$ (unity). ORISE's survey data verifies that the classifications determined by the licensee for survey units LSA 01-01, 01-02, and 01-03 were appropriate. Confirmatory survey activities did not identify any site-related contaminants above their respective $DCGL_W$ in survey units LSA 01-01, 01-02, or 01-03.

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APPENDIX A
FIGURES

Figure A-1. Survey Unit Location Relative to the Hematite Site

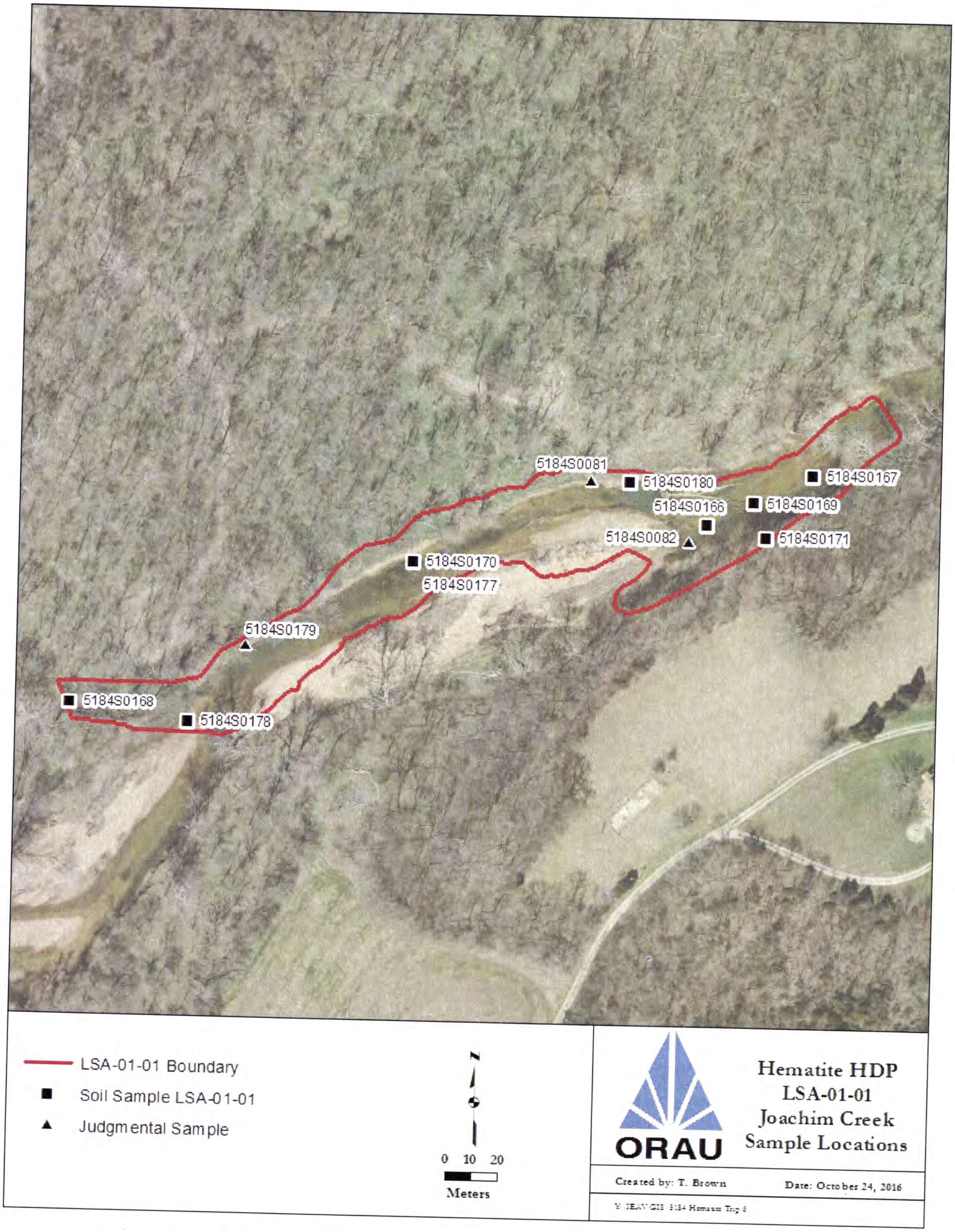


Figure A-2. Confirmatory Soil/Sediment Sample Locations in LSA 01-01

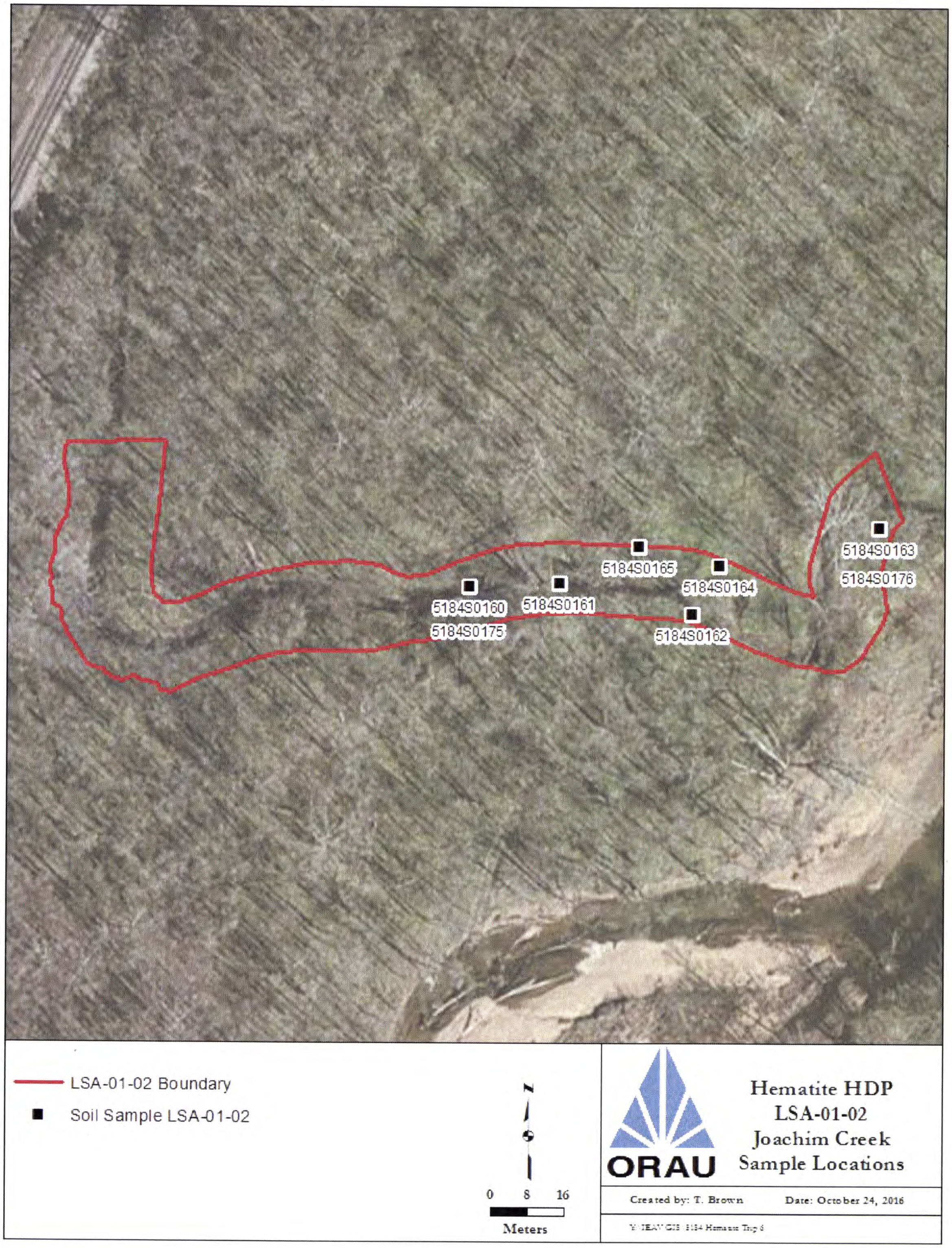


Figure A-3. Confirmatory Soil/Sediment Sample Locations in LSA 01-02

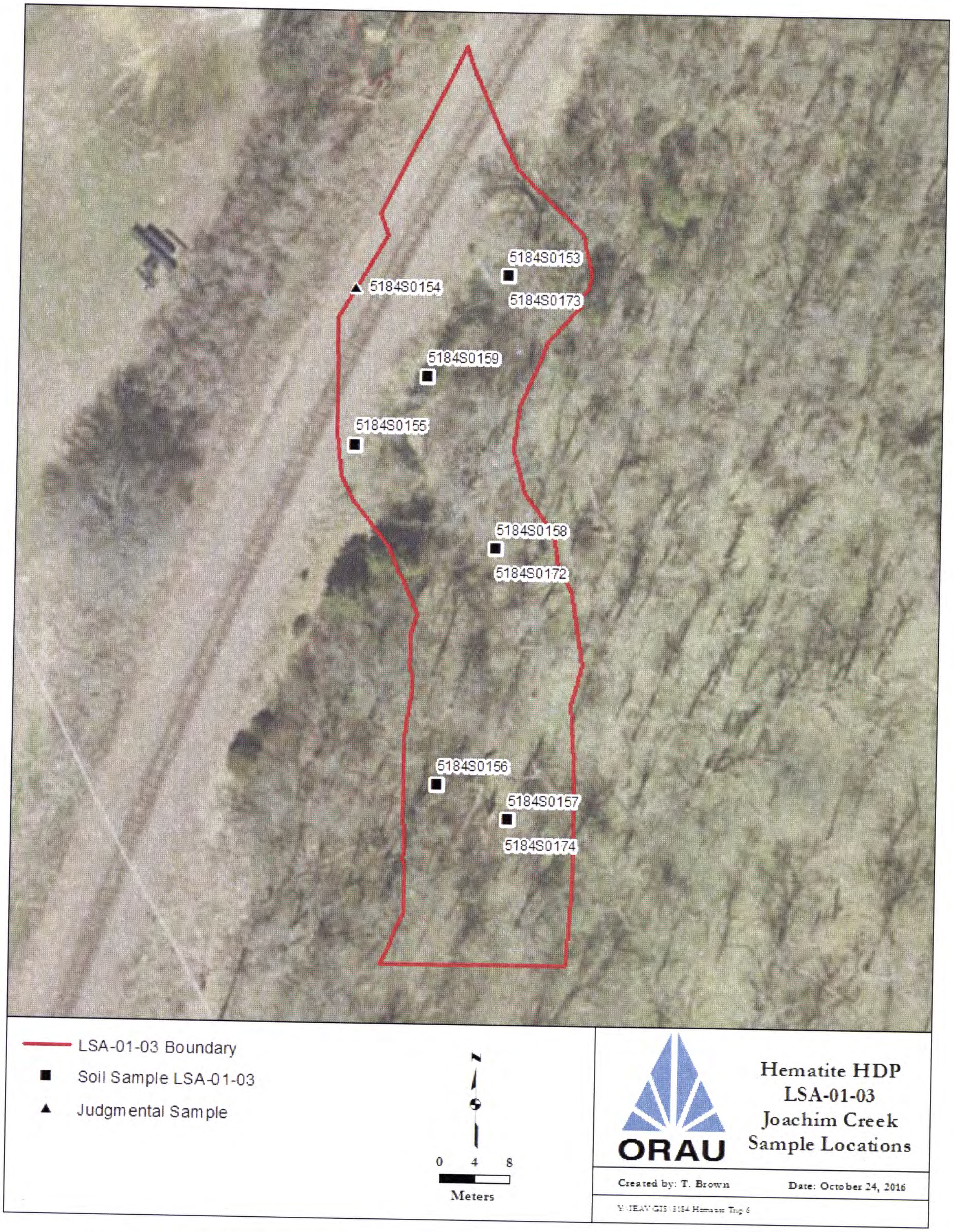


Figure A-4. Confirmatory Soil/Sediment Sample Locations in LSA 01-03

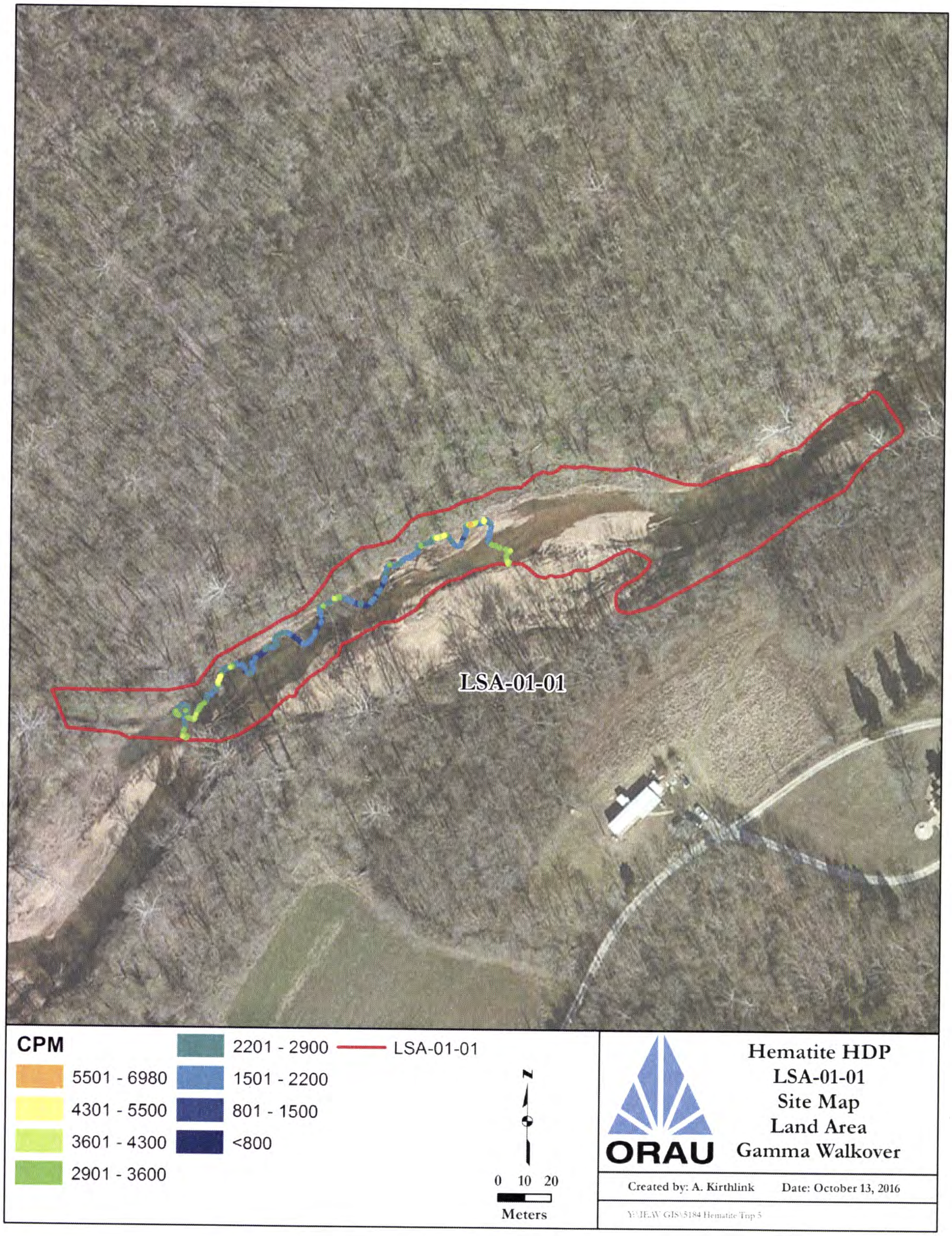


Figure A-5. Gamma Walkover Results of LSA 01-01

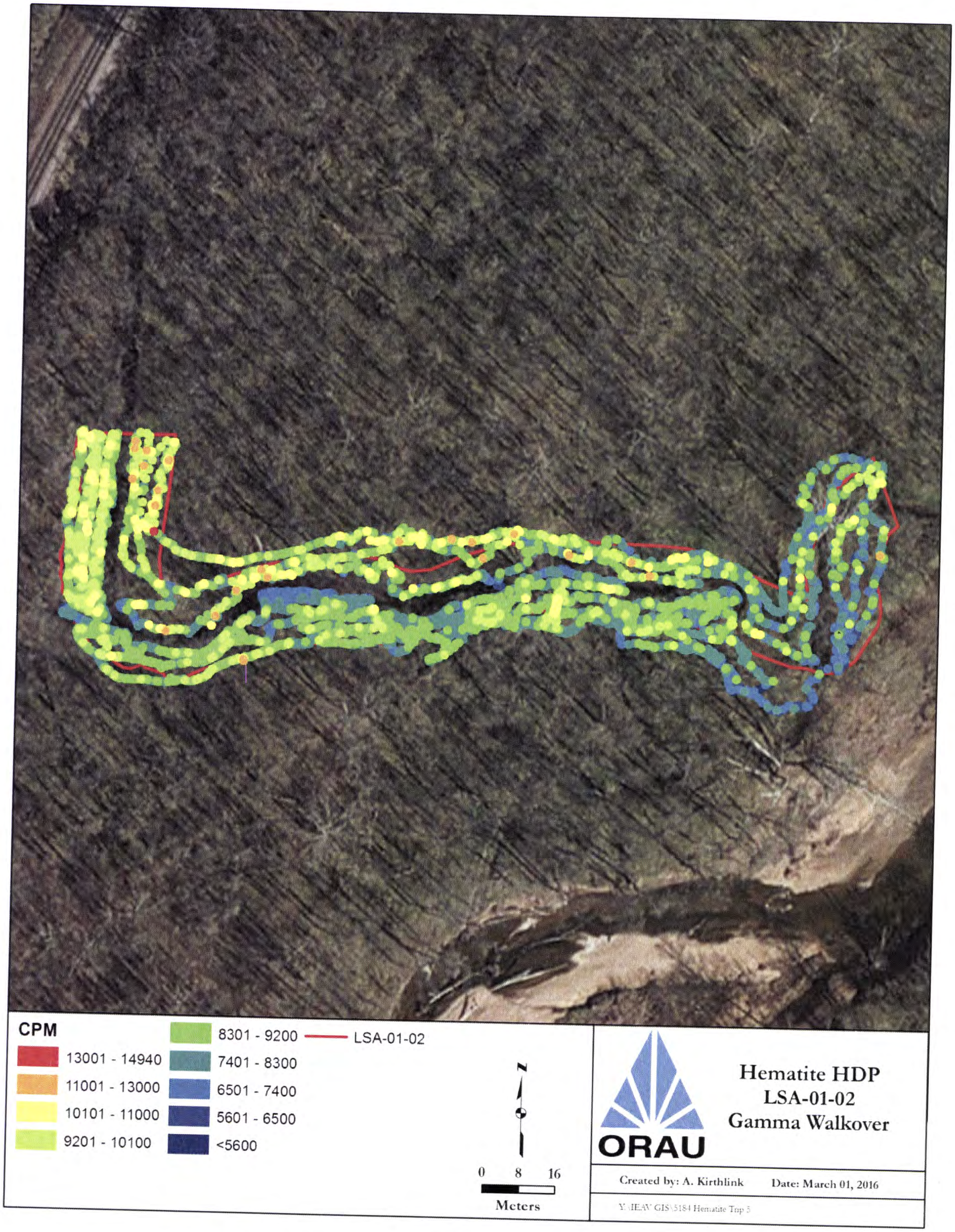


Figure A-6. Gamma Walkover Results for LSA 01-02

Figure A-7. Gamma Walkover Results for LSA 01-03

APPENDIX B
TABLES

Table B-1. Confirmatory Sample Properties					
Sample ID	Sample Type	Location	Sample Matrix	Surface/Core	Sample Recovery Depth (m)[a]
		LSA 01-01			
5184S0166	Random	RSS-1-1-2	Sediment	Surface	
5184S0167	Random	RSS-1-2-1	Sediment	Surface	
5184S0168	Random	RSS-1-3-3	Sediment	Surface	
5184S0169	Random	RSS-2-1-2	Sediment	Surface	
5184S0170	Random	RSS-2-2-2	Sediment	Surface	
5184S0177	Random	RSS-2-2-2	Sediment	Core	0.3
5184S0178	Random	RSS-2-3-2	Sediment	Core	0.3
5184S0171	Random	RSS-2-3-3	Sediment	Surface	
5184S0179	Judgmental[b]	Creek Bank	Sediment	Core	--[c]
5184S0180	Random	RSS-1-2-3	Sediment	Core	0.3
5184S0181	Judgmental[b]	Creek Bank	Sediment	Core	0.4
5184S0182	Judgmental[b]	Creek Bank	Sediment	Core	0.3
		LSA 01-02			
5184S0160	Random	RSS-1-1-2	Sediment	Surface	
5184S0175	Random	RSS-1-1-2	Sediment	Core	--[c]
5184S0161	Random	RSS-2-2-2	Soil	Surface	
5184S0162	Random	RSS-1-2-1	Soil	Surface	
5184S0163	Random	RSS-2-3-2	Sediment	Surface	
5184S0176	Random	RSS-2-3-2	Sediment	Core	0.6
5184S0164	Random	RSS-2-1-3	Soil	Surface	
5184S0165	Random	RSS-1-3-3	Soil	Surface	
		LSA 01-03			
5184S0153	Judgmental[d]	RSS-2-2-2	Sediment	Surface	
5184S0173	Judgmental[d]	RSS-2-2-2	Sediment	Core	0.3
5184S0154	Judgmental[e]	Near RSS-1-3-3	Soil	Surface	
5184S0155	Random	RSS-1-2-2	Soil	Surface	
5184S0156	Random	RSS-2-2-3	Soil	Surface	
5184S0157	Random	RSS-2-1-1	Sediment	Surface	
5184S0174	Random	RSS-2-1-1	Sediment	Core	0.6
5184S0158	Random	RSS-1-1-2	Sediment	Surface	
5184S0172	Random	RSS-1-1-2	Sediment	Core	0.5
5184S0159	Random	RSS-2-3-2	Soil	Surface	

[a]Sample recovery depth is not applicable to surface samples.
[b]Sample collected based on an increase in audible response from the ratemeter
[c]Sample was not solid enough to be collected in a sample tube and was therefore collected in a bag.
[d]Sample was not selected during the field measurement ranking but was collected based on the potential to accumulate site-related ROCs.
[e]Sample location was relocated due to large railroad rocks at RSS-1-3-3

Table B-2. ROC Concentration in Surface Soil/Sediment Samples (pCi/g)[a, b]

Sample ID[c]	Tc-99	MDC	U-234[d]	U-235	MDC	U-238	MDC	Th-232	MDC	Ra-226	MDC	SOF[e]
LSA 01-01												
5184S0166	-0.02 ± 0.17	0.31	0.4 ± 1.5	-0.046 ± 0.071	0.163	0.41 ± 0.28	0.59	0.070 ± 0.040	0.086	0.273 ± 0.033	0.042	0.00
5184S0167	0.16 ± 0.18	0.31	0.86 ± 0.81	0.047 ± 0.044	0.110	0.31 ± 0.15	0.30	0.135 ± 0.037	0.045	0.191 ± 0.026	0.028	0.01
5184S0168	0.82 ± 0.23	0.33	5.3 ± 1.8	0.293 ± 0.096	0.199	1.52 ± 0.52	0.86	1.08 ± 0.16	0.15	0.940 ± 0.091	0.082	0.14
5184S0169	0.02 ± 0.18	0.32	0.33 ± 0.87	0.017 ± 0.045	0.108	0.22 ± 0.13	0.28	0.088 ± 0.032	0.058	0.278 ± 0.029	0.026	0.00
5184S0170	0.13 ± 0.18	0.31	0.39 ± 0.77	0.019 ± 0.038	0.090	0.34 ± 0.18	0.36	0.132 ± 0.041	0.059	0.308 ± 0.036	0.033	0.01
5184S0171	-0.04 ± 0.17	0.31	1.5 ± 2.7	-0.02 ± 0.13	0.30	1.51 ± 0.61	1.14	0.90 ± 0.12	0.15	0.757 ± 0.068	0.071	0.02
LSA 01-02												
5184S0160	3.83 ± 0.34	0.31	3.8 ± 1.1	0.207 ± 0.061	0.125	1.12 ± 0.35	0.52	0.483 ± 0.075	0.089	0.508 ± 0.047	0.043	0.18
5184S0161	0.59 ± 0.20	0.30	2.5 ± 1.5	0.129 ± 0.081	0.186	1.35 ± 0.56	1.04	0.79 ± 0.10	0.12	0.787 ± 0.067	0.070	0.05
5184S0162	0.23 ± 0.19	0.19	1.1 ± 1.3	0.053 ± 0.063	0.147	1.16 ± 0.37	0.59	0.81 ± 0.11	0.13	0.859 ± 0.071	0.062	0.02
5184S0163	0.14 ± 0.19	0.32	1.8 ± 1.1	0.091 ± 0.056	0.127	1.09 ± 0.35	0.57	0.90 ± 0.11	0.12	0.891 ± 0.052	0.051	0.02
5184S0164	0.09 ± 0.19	0.32	2.3 ± 2.7	0.12 ± 0.14	0.34	1.60 ± 0.87	1.78	0.95 ± 0.13	0.14	0.709 ± 0.069	0.068	0.03
5184S0165	-0.01 ± 0.18	0.31	1.2 ± 1.6	0.060 ± 0.080	0.189	0.94 ± 0.34	0.58	0.732 ± 0.100	0.111	0.831 ± 0.066	0.053	0.01
LSA 01-03												
5184S0153	0.45 ± 0.20	0.31	2.8 ± 1.4	0.149 ± 0.075	0.165	1.23 ± 0.44	0.76	0.93 ± 0.15	0.18	1.051 ± 0.091	0.077	0.12
5184S0154	0.03 ± 0.17	0.31	0.3 ± 1.6	0.014 ± 0.067	0.158	0.51 ± 0.20	0.35	0.397 ± 0.068	0.094	0.675 ± 0.042	0.043	0.01
5184S0155	0.14 ± 0.18	0.30	2.3 ± 1.4	0.122 ± 0.072	0.162	1.44 ± 0.43	0.62	1.07 ± 0.14	0.15	1.018 ± 0.081	0.067	0.13
5184S0156	0.20 ± 0.18	0.30	2.7 ± 1.7	0.145 ± 0.090	0.205	1.22 ± 0.59	1.19	1.05 ± 0.13	0.15	0.874 ± 0.074	0.070	0.06
5184S0157	0.71 ± 0.20	0.29	5.6 ± 1.6	0.302 ± 0.086	0.176	2.20 ± 0.60	0.71	0.87 ± 0.13	0.16	0.865 ± 0.077	0.068	0.08
5184S0158	10.93 ± 0.54	0.30	34.4 ± 3.6	1.89 ± 0.20	0.27	9.6 ± 2.2	1.1	1.02 ± 0.17	0.18	0.880 ± 0.093	0.095	0.72
5184S0159	3.99 ± 0.34	0.30	5.7 ± 1.2	0.313 ± 0.064	0.126	1.18 ± 0.34	0.49	0.732 ± 0.096	0.098	1.093 ± 0.076	0.046	0.30

[a]Uncertainties represent the total propagated uncertainties reported at the 95% confidence level.
[b]Individual sample results are not corrected for background contributions.
[c]Refer to Figure A-2 through A-4 for sample locations.
[d]Appendix D provides the details for the calculation of U-234 concentration.
[e]Th-232 and Ra-226 were corrected for background in the SOF calculation, as described in Section 5.

Table B-3. ROC Concentration in Sediment Cores (pCi/g)[a, b]												
Sample ID[c]	Tc-99	MDC	U-234[d]	U-235	MDC	U-238	MDC	Th-232	MDC	Ra-226	MDC	SOF[e]
LSA 01-01												
5184S0177	0.09 ± 0.19	0.33	1.6 ± 1.2	0.090 ± 0.067	0.153	0.49 ± 0.29	0.61	0.140 ± 0.078	0.158	0.412 ± 0.065	0.108	0.02
5184S0178	-0.15 ± 0.18	0.34	0.8 ± 1.9	0.04 ± 0.10	0.25	0.36 ± 0.26	0.58	0.129 ± 0.091	0.196	0.246 ± 0.055	0.099	0.01
5184S0179	-0.02 ± 0.18	0.31	1.9 ± 3.9	0.10 ± 0.21	0.49	0.81 ± 0.59	1.31	0.62 ± 0.17	0.31	0.612 ± 0.092	0.155	0.02
5184S0180	-0.13 ± 0.17	0.31	0.8 ± 1.2	0.044 ± 0.063	0.149	0.09 ± 0.21	0.50	0.20 ± 0.11	0.28	0.216 ± 0.049	0.090	0.01
5184S0181	-0.13 ± 0.17	0.32	1.4 ± 1.2	0.074 ± 0.064	0.148	1.07 ± 0.38	0.64	0.63 ± 0.11	0.15	0.621 ± 0.055	0.070	0.01
5184S0182	-0.16 ± 0.18	0.32	2.4 ± 3.3	0.13 ± 0.18	0.43	0.65 ± 0.48	1.06	0.21 ± 0.13	0.27	0.166 ± 0.070	0.154	0.02
LSA 01-02												
5184S0175	2.12 ± 0.27	0.31	21.4 ± 3.3	1.18 ± 0.18	0.30	4.1 ± 1.1	1.2	0.34 ± 0.14	0.29	0.515 ± 0.084	0.148	0.24
5184S0176	0.45 ± 0.20	0.31	3.3 ± 2.2	0.17 ± 0.11	0.24	2.42 ± 0.95	1.67	0.98 ± 0.14	0.15	0.927 ± 0.083	0.075	0.07
LSA 01-03												
5184S0172	-0.04 ± 0.18	0.33	2.1 ± 1.2	0.106 ± 0.060	0.136	1.44 ± 0.42	0.60	1.09 ± 0.13	0.12	0.908 ± 0.054	0.056	0.07
5184S0173	0.27 ± 0.21	0.35	3.0 ± 2.1	0.16 ± 0.11	0.26	1.60 ± 0.57	0.98	0.83 ± 0.20	0.34	1.08 ± 0.12	0.17	0.13
5184S0174	0.13 ± 0.20	0.34	2.3 ± 1.3	0.119 ± 0.070	0.158	1.17 ± 0.38	0.60	0.97 ± 0.13	0.12	0.714 ± 0.065	0.058	0.03

[a] Uncertainties represent the total propagated uncertainties reported at the 95% confidence level.
[b] Individual sample results are not corrected for background contributions.
[c] Refer to Figure A-2 through A-4 for sample locations.
[d] Appendix D provides the details for the calculation of U-234 concentration.
[e] Th-232 and Ra-226 were corrected for background in the SOF calculation, as described in Section 5.

Table B-4. ROC Concentration in Surface and Core Sediment Samples (pCi/g)[a, b]

Sample ID (Surface/Core)[c]	Tc-99	MDC	U-234[d]	U-235	MDC	U-238	MDC	Th-232	MDC	Ra-226	MDC	SOF[e]
LSA 01-01												
5184S0170/ 5184S0177	0.13 ± 0.18	0.31	0.39 ± 0.77	0.019 ± 0.038	0.090	0.34 ± 0.18	0.36	0.132 ± 0.041	0.059	0.308 ± 0.036	0.033	0.01
	0.09 ± 0.19	0.33	1.6 ± 1.2	0.090 ± 0.067	0.153	0.49 ± 0.29	0.61	0.140 ± 0.078	0.158	0.412 ± 0.065	0.108	0.02
LSA 01-02												
5184S0160/ 5184S0175	3.83 ± 0.34	0.31	3.8 ± 1.1	0.207 ± 0.061	0.125	1.12 ± 0.35	0.52	0.483 ± 0.075	0.089	0.508 ± 0.047	0.043	0.18
	2.12 ± 0.27	0.31	21.4 ± 3.3	1.18 ± 0.18	0.30	4.1 ± 1.1	1.2	0.34 ± 0.14	0.29	0.515 ± 0.084	0.148	0.24
5184S0163/ 5184S0176	0.14 ± 0.19	0.32	1.8 ± 1.1	0.091 ± 0.056	0.127	1.09 ± 0.35	0.57	0.90 ± 0.11	0.12	0.891 ± 0.052	0.051	0.02
	0.45 ± 0.20	0.31	3.3 ± 2.2	0.17 ± 0.11	0.24	2.42 ± 0.95	1.67	0.98 ± 0.14	0.15	0.927 ± 0.083	0.075	0.07
LSA 01-03												
5184S0153/ 5184S0173	0.45 ± 0.20	0.31	2.8 ± 1.4	0.149 ± 0.075	0.165	1.23 ± 0.44	0.76	0.93 ± 0.15	0.18	1.051 ± 0.091	0.077	0.12
	0.27 ± 0.21	0.35	3.0 ± 2.1	0.16 ± 0.11	0.26	1.60 ± 0.57	0.98	0.83 ± 0.20	0.34	1.08 ± 0.12	0.17	0.13
5184S0157/ 5184S0174	0.71 ± 0.20	0.29	5.6 ± 1.6	0.302 ± 0.086	0.176	2.20 ± 0.60	0.71	0.87 ± 0.13	0.16	0.865 ± 0.077	0.068	0.08
	0.13 ± 0.20	0.34	2.3 ± 1.3	0.119 ± 0.070	0.158	1.17 ± 0.38	0.60	0.97 ± 0.13	0.12	0.714 ± 0.065	0.058	0.03
5184S0158/ 5184S0172	10.93 ± 0.54	0.30	34.4 ± 3.6	1.89 ± 0.20	0.27	9.6 ± 2.2	1.1	1.02 ± 0.17	0.18	0.880 ± 0.093	0.095	0.72
	-0.04 ± 0.18	0.33	2.1 ± 1.2	0.106 ± 0.060	0.136	1.44 ± 0.42	0.60	1.09 ± 0.13	0.12	0.908 ± 0.054	0.056	0.07

[a]Uncertainties represent the total propagated uncertainties reported at the 95% confidence level.
[b]Individual sample results are not corrected for background contributions.
[c]Refer to Figure A-2 through A-4 for sample locations.
[d]Appendix D provides the details for the calculation of U-234 concentration.
[e]Th-232 and Ra-226 were corrected for background in the SOF calculation, as described in Section 5.

APPENDIX C
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

C.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

C.1.1 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, California)

C.2 LABORATORY ANALYTICAL INSTRUMENTATION

High-Purity, Extended Range Intrinsic Detector
CANBERRA/Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-45200-5
Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-30P4
Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)

Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. CDG-SV-76/GEM-MX5970-S
Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)

Tri-Carb Liquid Scintillation Analyzer
Model 3100
(Packard Instrument Co., Meriden, Connecticut)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

ORISE performed all survey activities in accordance with the *ORAU Health and Safety Manual*, the *ORAU Radiation Protection Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016c, ORAU 2014, and ORAU 2016a). Prior to on-site activities, a work-specific hazard checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk-down of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORISE have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)or the project's work-specific hazard checklist for the planned survey and sampling procedures, work would not have been initiated or continued until it was addressed by an appropriate job hazard analysis and hazard controls.

D.2 CALIBRATION AND QUALITY ASSURANCE

Calibration of all field instrumentation was based on standards/sources, traceable to National Institute of Standards and Technology (NIST).

Field survey activities were conducted in accordance with procedures from the following ORAU documents:

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2016b)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017)

The procedures contained in these manuals were developed to meet the requirements of the U.S. Department of Energy (DOE) Order 414.1D and the U.S. Nuclear Regulatory Commission (NRC) *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.

- Participation in Mixed-Analyte Performance Evaluation Program, NIST Radiochemistry Intercomparison Testing Program, and Intercomparison Testing Program Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

D.3 SURVEY PROCEDURES

D.3.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a minimum. In order to evaluate surface scan results, investigation levels (ILs) were calculated based on the guidance provided in NUREG-1507(NRC 1998). ILs represent the expected sodium iodide (NaI) detector response due to a hypothesized 0.25 square meter area that is 0.15 cm thick (default value assumed in NUREG-1507) and of varying concentrations. The assumed radionuclide was total uranium, with a 75% enrichment of uranium-235, and concentrations were equal to the derived concentration guideline level for the elevated measurement comparison ($DCGL_{EMC}$) for LSA 01-03 and the derived concentration guideline level over a wide area ($DCGL_{W}$) for LSA 01-01 and 01-02. The $DCGL_{EMC}$ was computed using the licensee's area factors identified in Chapter 14 of their Decommissioning plan and the licensee's area represented by a soil sample specified in their final status survey plan development checklist for LSA 01-03 (WEC 2013 and WEC 2015b). The expected NaI detector response (i.e., the IL) was back-calculated based on a weighted counts per minute per micro-Roentgen per hour (cpm per µR/hr) determined using MicroShield®. A uranium-235 enrichment of 75% was chosen because this enrichment percentage yields a conservative weighted cpm per µR/hr. The ILs were equal to the 8,800 net cpm for LSA 01-03 and 2,000 net cpm for LSA 01-01 and 01-02.

An *a priori* minimum detectable count-rate for the surveyor ($MDCR_{Surveyor}$) was calculated based on standard ORAU gamma walkover survey procedures. The $MDCR_{Surveyor}$ was calculated by:

$$\mathrm{MDCR_{Surveyor}} = \frac{d'\sqrt{b(i/60s)}\,(60s/i)}{\sqrt{p}}$$

Where:

d' = index of sensitivity;
i = observation interval; and
p = surveyor efficiency.

For the $MDCR_{Surveyor}$ calculation an index of sensitivity of 1.96—corresponding to a true positive and false positive rate of 0.90 and 0.25, respectively—was used. A background observation interval of one second and a surveyor efficiency of 0.5 was used. With the aforementioned inputs and a background of 8,000 cpm the $MDCR_{Surveyor}$ was 1,900 cpm. Surface scans consisted of two phases. The first phase relies on an increase in audible signal from the indicating instrument that triggers the surveyor to pause and allow the instrument response to stabilize—i.e., the second stage.

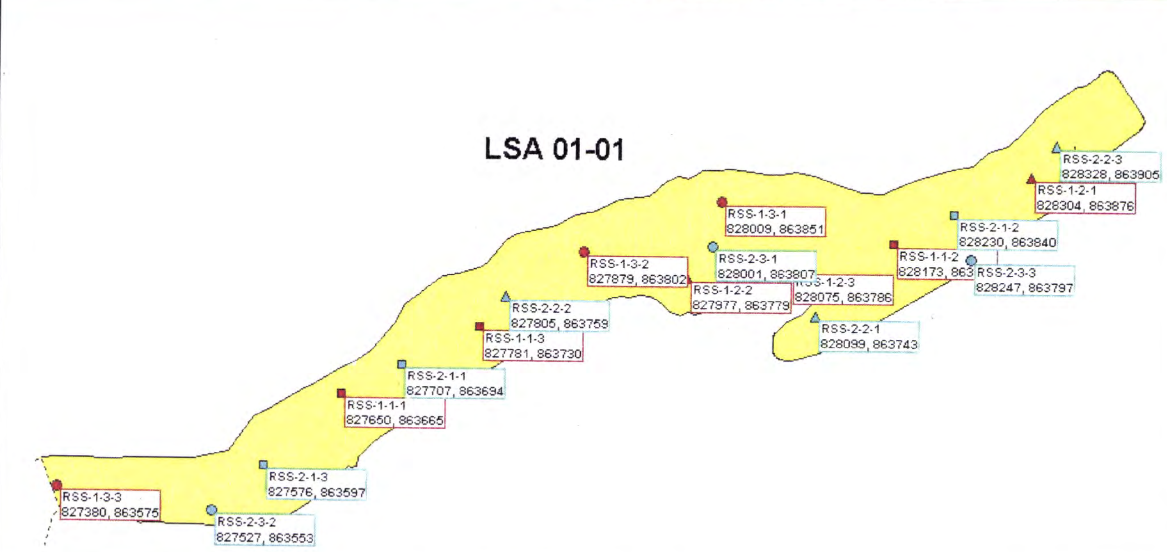
The housing used to scan the creek bed sediment was constructed using three-inch diameter schedule 40 PVC tubing with the corresponding endcap. The endcap was joined to the tube using a PVC bonding compound to form a watertight seal.

D.3.2 RANKED SET SAMPLING

Tables D-1 through D-3 provide the RSS field measurement data for LSA 01-01, 01-02, and 01-03—respectively. Note that in set #2 of cycle # 2 of LSA 01-01, the surveyor should have collected the sample from measurement location 3 instead of 2. However, since the sample was collected at the location with the largest NaI count rate in the set, the overall average would be conservatively biased high.

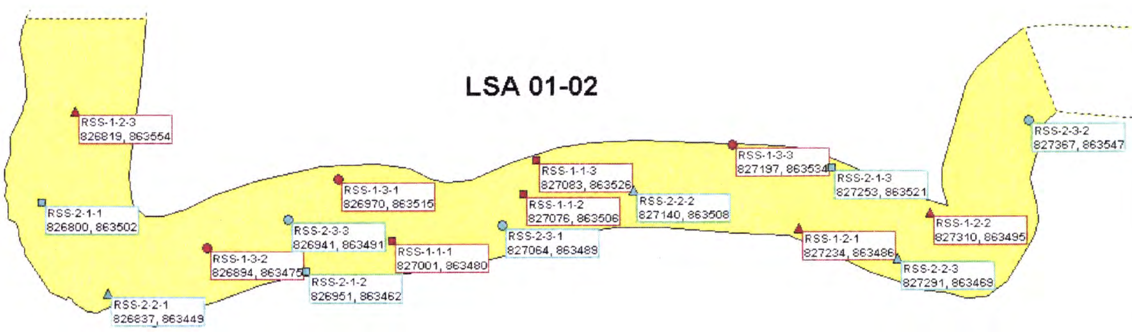
Measurement location 3 in set #1 of cycle #2 of LSA 01-03 was selected for sampling based on the gamma count rate. However, this location was on the railroad tracks and was covered by rock. With NRC concurrence, this location was relocated to the nearest soil area.

Table D-1. RSS Measurements for LSA 01-01



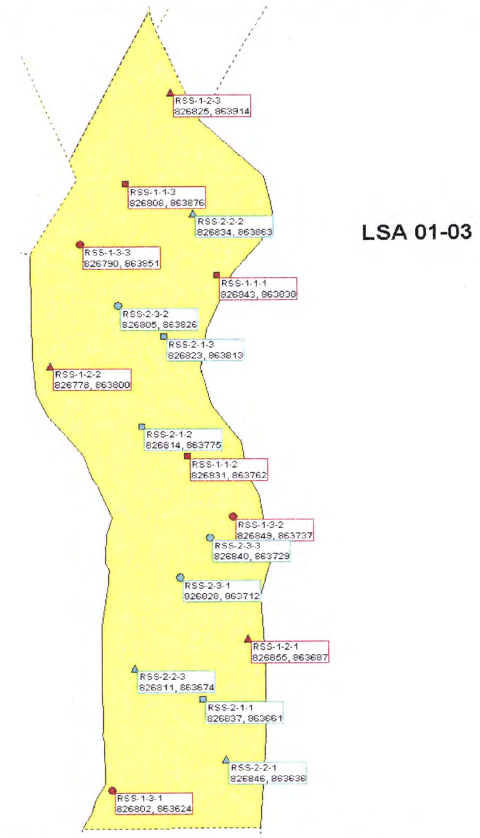
Coordinates (m)		RSS Measurement Location				Pre (cpm)	Value	Soil Sample ID (0-15 cm)
Easting	Northing	Cycle	Set	#	Symbol	Gamma		
252267	263245	1	1	1	■	4536	L	
252427	263289	1	1	2	■	4533	L	5184S0166
252307	263265	1	1	3	■	4578	L	
252467	263309	1	2	1	▲	4470	M	5184S0167
252367	263280	1	2	2	▲	4505	M	
252397	263282	1	2	3	▲	4385	M	
252377	263301	1	3	1	●	4650	H	
252337	263287	1	3	2	●	4539	H	
252185	263217	1	3	3	●	4838	H	5184S0168
252285	263254	2	1	1	■	4505	L	
252444	263298	2	1	2	■	4465	L	5184S0169
252245	263224	2	1	3	■	4571	L	
252404	263269	2	2	1	▲	4486	M	
252315	263273	2	2	2	▲	4722	M	5184S0170
252474	263318	2	2	3	▲	4551	M	
252374	263288	2	3	1	●	4444	H	
252230	263211	2	3	2	●	4662	H	
252449	263285	2	3	3	●	4923	H	5184S0171

Table D-2. RSS Measurements for LSA 01-02



Coordinates (m)		RSS Measurement Location				Pre (cpm)	Value	Soil Sample # (0-15 cm)
Easting	Northing	Cycle	Set	#	Symbol	Gamma		
252070	263188	1	1	1	■	8688	L	
252092	263196	1	1	2	■	4432	L	5184S0160
252095	263202	1	1	3	■	9374	L	
252141	263190	1	2	1	▲	8459	M	5184S0162
252164	263193	1	2	2	▲	7975	M	
252014	263211	1	2	3	▲	9113	M	
252060	263199	1	3	1	●	8202	H	
252037	263187	1	3	2	●	3828	H	
252129	263205	1	3	3	●	8366	H	5184S0165
252008	263195	2	1	1	■	9368	L	
252054	263183	2	1	2	■	8955	L	
252146	263201	2	1	3	■	8535	L	5184S0164
252020	263179	2	2	1	▲	8923	M	
252112	263197	2	2	2	▲	8890	M	5184S0161
252158	263185	2	2	3	▲	4400	M	
252089	263191	2	3	1	●	6868	H	
252181	263209	2	3	2	●	8520	H	5184S0163
252051	263192	2	3	3	●	7617	H	

Table D-3. RSS Measurements for LSA 01-03



Coordinates (m)		RSS Measurement Location				Pre (cpm)	Value	Soil Sample # (0-15 cm)
Easting	Northing	Cycle	Set	#	Symbol	Gamma		
252021	263298	1	1	1	■ (red)	10349	L	
252018	263274	1	1	2	■ (red)	10198	L	5184S0158
252011	263309	1	1	3	■ (red)	17805	L	
252025	263251	1	2	1	▲ (red)	9874	M	
252002	263286	1	2	2	▲ (red)	11949	M	5184S0155
252016	263321	1	2	3	▲ (red)	15347	M	
252009	263232	1	3	1	● (red)	9322	H	
252023	263267	1	3	2	● (red)	10180	H	
252005	263301	1	3	3	● (red)	15758	H	On Rail Rock
252020	263244	2	1	1	■ (green)	8685	L	5184S0157
252013	263278	2	1	2	■ (green)	9493	L	
252015	263290	2	1	3	■ (green)	10170	L	
252022	263236	2	2	1	▲ (green)	9103	M	
252019	263305	2	2	2	▲ (green)	11324	M	5184S0153
252012	263248	2	2	3	▲ (green)	9986	M	5184S0156
252017	263259	2	3	1	● (green)	10129	H	
252010	263294	2	3	2	● (green)	10284	H	5184S0159
252021	263264	2	3	3	● (green)	9246	H	
252001	263303	Replacement for 1-3-3				7909	Biased	5184S0154

D.3.3 SOIL AND SEDIMENT SAMPLING

Surface soil and sediment samples (approximately 0.5 kilogram each) were collected, using a clean garden trowel, then transferred into a new sample container by ORISE personnel. The samples were not field sieved and were delivered to the laboratory as collected. Sediment cores were collected using a steel core sampling system with a manual slide hammer. The coring system was manually advanced to a depth of one meter, or until refusal. The sediment core was collected in a 2.54 cm diameter sample tube, loaded into the coring system prior to sampling. After the core was collected, the sample tube was capped at both ends and sealed with electrical tape.

D.4 RADIOLOGICAL ANALYSIS

D.4.1 GAMMA SPECTROSCOPY

Samples were analyzed as received, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic, high purity, germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the ROCs were reviewed for consistency of activity. Spectra were also reviewed for other identifiable TAPs. TAPs used for determining the activities of ROCs and the typical associated MDCs for a one-hour count time are presented in Table D-4, below.

Table D-4. Typical MDCs

Radionuclide[a]	TAP (keV)	MDC (pCi/g)
U-235	143.76	0.24
U-238 by Th-234	63.29	0.75
Th-232 by Ac-228	911.20	0.12
Ra-226 by Pb-214	351.92[b]	0.24

[a]Spectra were also reviewed for other identifiable TAPs.

D.4.2 TC-99 ANALYSIS

Technetium-99 was analyzed by using REAL procedure AP5 and CP4. The samples were processed such that any technetium was converted into the pertechnatate anion. The pertechnatate anion was selectively absorbed on a chromatographic resin. Interfering elements were not retained under the correct conditions. The resin was counted with an appropriate Liquid Scintillation Counting cocktail. The typical MDC for this procedure was 0.28 pCi/g.

D.4.3 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 95% confidence level. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

D.4.4 U-234 CALCULATION

The U-234 concentration was calculated by using the method specified in WEC 2013. First, the U-238 to U-235 ratio was calculated. The corresponding U-234 to U-235 ratio, determined using Table 14-5 in Chapter 14 of the HDP DP, was multiplied by the U-235 concentration to yield the U-234 concentration. If the U-238 to U-235 ratio was not specified in Table 14-5, the U-234 to U-235 value was linearly interpolated. If the U-235 value was negative, a U-234 to U-235 ratio of 21.07 was assumed—the ratio for natural uranium. The uncertainty for the calculated U-234 value was propagated assuming the U-234 to U-235 ratio had no uncertainty. The uranium enrichment was determined based on the U-238 to U-235 ratio in the same manner as the U-234 to U-235 ratio. Table D-5, presented below, details the calculation of U-234.

Table D-5. U-234 Concentration Calculation												
Sample ID	**U-235**			**U-238**			**U-238/ U-235**	**U-234/ U-235**	**Enric. (%)**	**U-234**		
5184S0166	-0.046	±	0.071	0.41	±	0.28	-8.91	21.07	0.7	0.41	±	1.50
5184S0167	0.047	±	0.044	0.31	±	0.15	6.60	18.39	2.3	0.86	±	0.81
5184S0168	0.293	±	0.096	1.52	±	0.52	5.19	18.22	2.9	5.34	±	1.75
5184S0169	0.017	±	0.045	0.22	±	0.13	12.94	19.41	1.1	0.33	±	0.87
5184S0170	0.019	±	0.038	0.34	±	0.18	17.89	20.31	0.8	0.39	±	0.77
5184S0171	-0.02	±	0.13	1.51	±	0.61	-75.50	21.07	0.7	1.51	±	2.74
5184S0160	0.207	±	0.061	1.12	±	0.35	5.41	18.24	2.7	3.78	±	1.11
5184S0161	0.129	±	0.081	1.35	±	0.56	10.47	18.99	1.4	2.45	±	1.54
5184S0162	0.053	±	0.063	1.16	±	0.37	21.89	21.04	0.7	1.12	±	1.33
5184S0163	0.091	±	0.056	1.09	±	0.35	11.98	19.25	1.2	1.75	±	1.08
5184S0164	0.12	±	0.14	1.60	±	0.87	13.33	19.48	1.1	2.34	±	2.73
5184S0165	0.06	±	0.08	0.94	±	0.34	15.67	19.90	0.9	1.19	±	1.59
5184S0153	0.149	±	0.075	1.23	±	0.44	8.26	18.63	1.8	2.78	±	1.40
5184S0154	0.014	±	0.067	0.51	±	0.20	36.43	23.76	0.4	0.33	±	1.59
5184S0155	0.122	±	0.072	1.44	±	0.43	11.80	19.22	1.3	2.34	±	1.38
5184S0156	0.145	±	0.090	1.22	±	0.59	8.41	18.66	1.8	2.71	±	1.68
5184S0157	0.302	±	0.086	2.2	±	0.6	7.28	18.48	2	5.58	±	1.59
5184S0158	1.89	±	0.20	9.6	±	2.2	5.08	18.21	2.9	34.41	±	3.64
5184S0159	0.313	±	0.064	1.18	±	0.34	3.77	18.11	3.9	5.67	±	1.16
5184S0172	0.106	±	0.060	1.44	±	0.42	13.58	19.53	1.1	2.07	±	1.17
5184S0173	0.16	±	0.11	1.6	±	0.57	10.00	18.91	1.5	3.03	±	2.08
5184S0174	0.119	±	0.070	1.17	±	0.38	9.83	18.89	1.5	2.25	±	1.32
5184S0175	1.18	±	0.18	4.1	±	1.1	3.47	18.10	4.2	21.36	±	3.26
5184S0176	0.17	±	0.11	2.42	±	0.95	14.24	19.65	1	3.34	±	2.16
5184S0177	0.090	±	0.067	0.49	±	0.29	5.44	18.24	2.7	1.64	±	1.22
5184S0178	0.04	±	0.10	0.36	±	0.26	9.00	18.75	1.6	0.75	±	1.88
5184S0179	0.10	±	0.21	0.81	±	0.59	8.10	18.60	1.8	1.86	±	3.91
5184S0180	0.044	±	0.063	0.09	±	0.21	2.05	18.27	7	0.80	±	1.15
5184S0181	0.074	±	0.064	0.09	±	0.38	1.22	18.79	11	1.39	±	1.20
5184S0182	0.13	±	0.18	0.65	±	0.48	5.00	18.20	3	2.37	±	3.28