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March 23, 2018

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Division of Decommissioning, Uranium Recovery, and Waste Programs
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SUBJECT: CONTRACT NO. DE-SC0014664
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNIT L1010102 AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN
RFTA No. 18-003; DCN 5299-SR-02-0

Dear Ms. Vaaler:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the subject report detailing the independent confirmatory surveys performed of survey unit L1010102 at the La Crosse Boiling Water Reactor. NRC's comments on the draft report have been incorporated into this final version.

Please feel free to contact me at 865.574.6273 or Erika Bailey at 865.576.6659 if you have any comments or concerns.

Sincerely,

Nick A. Altic, CHP
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ORAU

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N. A. Altic, CHP
and
S. T. Pittman, PhD
ORAU

FINAL REPORT

Prepared for the
U.S. Nuclear Regulatory Commission

MARCH 2018

NOTICES

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNIT L1010102 AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

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MARCH 2018

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ACRONYMS

AA	alternate action
BWR	boiling water reactor
Co-60	cobalt-60
cpm	counts per minute
Cs-137	cesium-137
CU	confirmatory unit
DCGL	derived concentration guideline level
DPC	Dairyland Power Cooperative
DQO	data quality objective
DS	decision statement
Eu-152	europium-152
Eu-154	europium-154
FESW	Fuel Element Storage Well
FRS	Final Radiation Survey
FSS	Final Status Survey
GPS	global positioning system
ISFSI	Independent Spent Fuel Storage Installation
LACBWR	La Crosse Boiling Water Reactor
LSE	LACBWR Site Enclosure
LTP	license termination plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
mrem/yr	millirem per year
NaI	sodium iodide
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities

ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
PSP	project-specific plan
PSQ	principal study question
Q	quantile
ROC	radionuclide of concern
SOF	sum of fractions
Sr-90	strontium-90
SU	survey unit
STS	Source Term Survey
TAP	total absorption peak
WRS	Wilcoxon Rank Sum

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNIT L1010102 AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

EXECUTIVE SUMMARY

At the request of the U.S. Nuclear Regulatory Commission (NRC), the Oak Ridge Institute for Science and Education (ORISE) performed an independent confirmatory survey of turbine building survey unit L1010102 during the period of January 15 through 18, 2018, at the La Crosse Boiling Water Reactor (LACBWR). The confirmatory survey consisted of visual inspections, gamma walkover scans, and surface soil sampling to independently assess the adequacy of the site's Final Status Survey (FSS) design and implementation for demonstrating compliance with the release criteria. Fourteen random soil samples and three judgmental samples, based on gamma walkover survey results, were collected for laboratory analysis and data comparison with the LACBWR results.

A direct comparison of the mean/median Cs-137 concentrations between the ORISE and LACBWR data using the Wilcoxon Rank Sum (WRS) test was not performed due to unequal variances between the two sample sets; an underlying assumption of the WRS test is that the sample sets have equal variances. It was also unnecessary to perform the WRS test for other radionuclides of concern (ROCs) because the majority of results, from both sample sets, had concentrations below the analytical minimum detectable concentration.

A comparison of the ORISE maximum ROC analytical concentrations with the LACBWR operational derived concentration guideline levels (DCGLs) for soil determined that all concentrations were at least an order of magnitude less than the respective operational DCGLs. Based on the confirmatory survey data, it is the opinion of ORISE that LACBWR's FSS design and implementation were appropriate and reported results were acceptable for demonstrating compliance with the release criteria.

However, based on a post-survey review of the gamma walkover maps, there is an apparent discrepancy between the planned survey unit boundary and the physical boundary observed in the field. For future surveys, ORISE recommends the NRC confirm that the boundaries of the survey units surrounding L1010102 share physical boundaries such that 100 percent of the soil area is investigated.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNIT L1010102 AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

1. INTRODUCTION

The La Crosse Boiling Water Reactor (LACBWR), a 50-megawatt electric boiling water reactor (BWR) located in Genoa, Wisconsin, was originally a demonstration plant funded by the U.S. Atomic Energy Commission. The plant was later sold to Dairyland Power Cooperative (DPC) with a provisional operating license. The BWR achieved initial criticality on July 11, 1967 and operated for 19 years until being permanently shut down on April 30, 1987. After shutdown, DPC's authority to operate LACBWR under Provisional Operating License DPR-45 (issued by the U.S. Nuclear Regulatory Commission [NRC] on August 28, 1973) was amended via License Amendment 56 (August 4, 1987) to possession only authority (LS 2016).

Dismantling unused and offline systems and waste disposal operations began in 1994. The Reactor Pressure Vessel (head, internals, and 29 control rods sealed with concrete), stored waste in the Fuel Element Storage Well (FESW), and other Class B/C wastes were shipped offsite for disposal in June 2007. Other systems and components—such as spent fuel storage racks, gaseous waste disposal systems (excluding the underground gas storage tanks), condensate and feedwater system (excluding condensate storage tank and condenser), the turbine and generator, and various components located in the Turbine Building (cooling water system pumps, heat exchangers, piping, etc.)—have also been removed. In September 2012, 333 irradiated fuel assemblies from the FESW were packaged in five dry casks and transferred to the site's Independent Spent Fuel Storage Installation (ISFSI) (LS 2016). In May 2016, the NRC consented to having the possession, maintenance, and decommissioning authorities of the LACBWR site transferred from DPC to LaCrosse*Solutions,* LLC.

LACBWR has recently submitted a License Termination Plan (LTP) to the NRC requesting the removal of all remaining open-land and structures, except for the fenced area surrounding the ISFSI, from License DPR-45. The LACBWR Administration Building, Crib House, and Transmission Sub-Station Switch House will remain intact. All other LACBWR buildings and structures will be demolished and removed to a depth of three feet below grade—corresponding to the 636-foot elevation—including the basements of the Reactor Building, Waste Treatment Building, Waste Gas Tank Vault, and other miscellaneous remaining basement structures.

The LTP requires a Final Radiation Survey (FRS) that will radiologically characterize the site and determine the potential for an average member of the critical group to receive a total effective dose equivalent greater than 25 millirem per year (mrem/yr). The FRS plan consists of two types of compliance surveys: a Final Status Survey (FSS) for open-land areas and buried piping based on NUREG-1575 (NRC 2000) and a Source Term Survey (STS) for the below-ground structures that will be backfilled prior to license termination.

NRC requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities to determine if the FSS and STS were performed in accordance with the FRS plan. This report summarizes the confirmatory survey activities associated with the FSS of survey unit L1010102 at LACBWR.

2. SITE DESCRIPTION

The LACBWR site is located approximately 1.6 kilometers (1 mile) south from the village of Genoa, Wisconsin on the eastern shore of the Mississippi River. The licensed site is shared with the non-nuclear Genoa-3 Fossil Station. The operational fossil plant's buildings and structures were classified as non-impacted and are not subject to the release surveys specified in the LTP (LS 2016). Figure 2.1 provides an aerial view of the licensed site and illustrates the open land area survey unit boundaries and FSS radiological contamination potential classifications based on the *Multi-Agency Radiation Survey and Site Investigation Manual* (*MARSSIM*).

The 10 CFR Part 50 licensed site comprises a total of 66.2 hectares (164 acres) within which is located the 0.61-hectare LACBWR Site Enclosure (LSE) area where confirmatory surveys of turbine building survey unit L1010102 were performed. The LSE is shaded red in Figure 2.1, and the survey unit is shown with its original structures in Figure 2.2. At the time of survey, the terrain was uneven with several flat levels descending in elevation toward a circular region northwest of the reactor building where a condensate pump had been excavated, leaving a crater approximately 10 meters across and 4 meters deep.

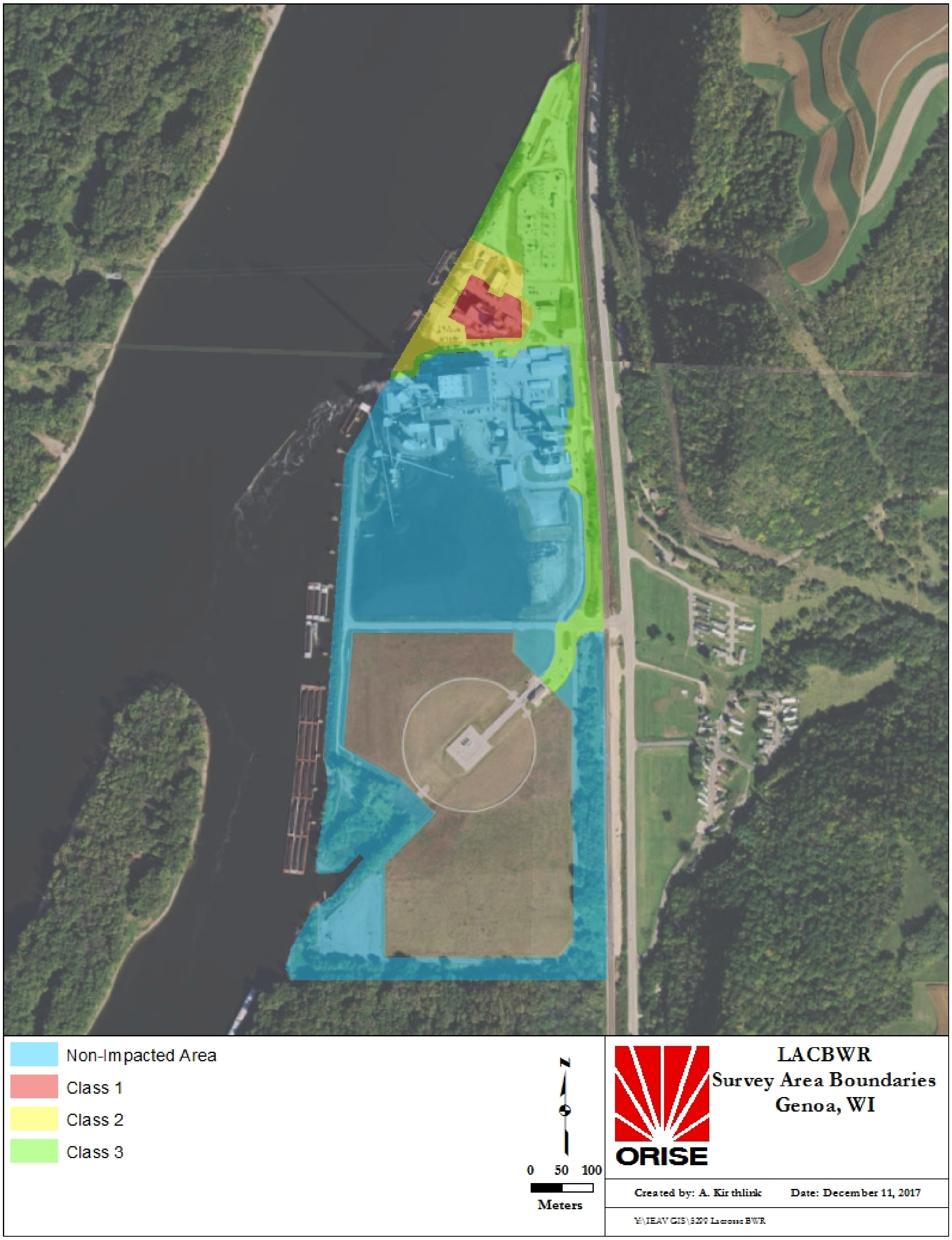

Figure 2.1. LACBWR Site Overview and Open Land Survey Area Boundaries and Classification

Figure 2.2. LACBWR Survey Unit L1010102

3. DATA QUALITY OBJECTIVES

The data quality objectives (DQOs) described herein are consistent with the *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) and provided a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected were adequate for the intended decision applications. The seven steps in the DQO process are as follows:

1. State the problem
2. Identify the decision/objective
3. Identify inputs to the decision/objective
4. Define the study boundaries
5. Develop a decision rule

6. Specify limits on decision errors
7. Optimize the design for obtaining data

3.1 State the Problem

The first step in the DQO process defined the problem that necessitated the study, identified the planning team, and examined the project budget and schedule. LACBWR is in the process of dismantling remaining structures and remediating remaining lands. As part of this process, LACBWR is conducting an FSS to demonstrate compliance with NRC's license termination criteria specified in 10CFR20.1402. NRC requested that ORISE perform confirmatory surveys at LACBWR to provide independent contractor documentation, and generate independent radiological data to assist the NRC in evaluating the adequacy and accuracy of LACBWR's FRS results. Therefore, the problem statement was as follows:

> Independent confirmatory surveys are necessary to assist the NRC in their assessment and determination of the adequacy of the FRS design, implementation, and results for demonstrating compliance with the release criteria.

3.2 Identify the Decision

The second step in the DQO process identified the principal study questions (PSQs) and alternative actions (AAs); developed decision statements; and organized multiple decisions, as appropriate. This was done by specifying AAs that could result from a "yes" response to the PSQs and combining the PSQs and AAs into decision statements. Given that the problem statement introduced in Section 3.1 is fairly broad, multiple PSQs arose and are detailed in the confirmatory survey project-specific plan (PSP) (ORISE 2017). The PSQ, AAs, and combined decision statement (DS) applicable to the survey efforts detailed in this report are presented in Table 3.1. For more information regarding the boundaries of this survey, see Section 3.4.

Table 3.1. LACBWR Confirmatory Survey Decision Process	
Principal Study Question	**Alternative Actions**
PSQ: Do LACBWR's FSS results adequately and accurately support the decision regarding the final radiological status of remaining soils at the La Crosse site?	**Yes**: Confirmatory survey results support the final radiological survey data for remaining soils generated by LACBWR—compile confirmatory survey data and present the results to NRC. **No**: Confirmatory results refute the final radiological survey data for remaining soils generated by LACBWR—summarize the discrepancies and provide technical comments to NRC.
Decision Statement	
LACBWR's FSS results for remaining surface soil do/do not adequately and accurately represent final radiological conditions.	

3.3 Identify Inputs to the Decision

The third step in the DQO process identified both the information needed and the sources of this information; determined the basis for action levels; and identified sampling and analytical methods to meet data requirements. For this effort, information inputs included the following:

- LACBWR characterization data
- LACBWR FSS data for remaining soils, provided by NRC (NRC 2018)
- LACBWR derived concentration guideline levels (DCGLs); discussed in Section 3.3.1
- LACBWR survey unit boundaries
- ORISE confirmatory survey results, including surface radiation scans and direct surface activity measurements
- ORISE confirmatory soil sample analytical results

3.3.1 Radionuclides of Concern

The primary radionuclides of concern (ROCs) identified for LACBWR are beta-gamma emitters—fission and activation products—resulting from reactor operation. An initial suite of ROCs was identified by LACBWR and is presented in Table 5-1 of the LTP. In order to demonstrate compliance with the 25 mrem/yr release criterion, site-specific $DCGL_W$s were developed and presented in the site's LTP. For the purposes of LACBWR decommissioning activities, ROC concentrations in soil that corresponded to 25 mrem/yr (above background) are referred to as $DCGL_W$s.

Based on site characterization results, several of the initial ROCs that contributed an insignificant receptor dose were de-selected from analysis in the subsequent FRS, and $DCGL_W$s for the final ROCs were presented in Table 6-19 of the LTP, adjusted [lowered] to account for the dose from insignificant ROCs. In response to an NRC request for additional information to complete their review of the LTP (NRC 2017), LACBWR further reduced its soil $DCGL_W$s to operational levels, and these are presented in units of picocuries per gram (pCi/g) for cobalt-60 (Co-60), strontium-90 (Sr-90), cesium-137 (Cs-137), europium-152 (Eu-152), and europium-154 (Eu-154) in Table 3.2.

Table 3.2. Operational DCGLs for Soil

ROC	Operational DCGL (pCi/g)
Co-60	3.83
Sr-90	1,970.45
Cs-137	17.39
Eu-152	8.51
Eu-154	7.89

The operational DCGLs have not yet been incorporated into a formal revision to the LTP. However, ORISE received approval from the NRC to compare confirmatory survey results with the current operational soil DCGLs adopted by LACBWR (ORISE 2018).

Because each individual $DCGL_W$ represents 25 mrem/yr, the sum-of-fractions (SOF) approach is used to demonstrate compliance with the dose limit. SOF calculations are performed as follows:

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

Where C_j is the concentration of ROC "j," and $DCGL_{W,j}$ is the $DCGL_W$ for ROC "j." Note that gross concentrations are considered here for conservatism.

3.4 DEFINE THE STUDY BOUNDARIES

The fourth step in the DQO process defined target populations and spatial boundaries; determined the timeframe for collecting data and making decisions; addressed practical constraints; and determined the smallest subpopulations, area, volume, and time for which separate decisions must be made.

Within the LSE, survey unit L1010102 was selected by NRC for this confirmatory survey effort. The boundaries of the survey unit were shown in Figure 2.2. The physical boundary of the study consisted of caution tape and netting, which outlined the perimeter of the survey unit. The temporal boundary of the survey was three full days.

3.5 DEVELOP A DECISION RULE

The fifth step in the DQO process specified appropriate parameters (e.g., mean, median); confirmed action levels were above detection limits; and developed an if…then… decision rule statement. For this survey effort, the parameter of interest was the mean ROC concentration in survey unit L1010012. The Wilcoxon Rank Sum (WRS) test was preliminarily selected for comparing the confirmatory survey and LACBWR mean ROC concentrations in the survey unit. Hypothesis testing adopts a scientific approach where the survey data are used to select between the baseline condition (the null hypothesis, H_0) and an alternative condition. The two population statistical test selected for this survey effort was analogous to the WRS test presented in *MARSSIM*—except for this study, the reference area was LACBWR's survey unit data, and the DCGL was replaced by what is considered a substantial difference from LACBWR's FSS data.

The null and alternative hypotheses were stated as:

> H_o: The ORISE-determined mean/median ROC concentration in a confirmatory unit (CU) (μ_{ORISE}) is greater than the LACBWR mean/median ROC concentration (μ_{LACBWR}) plus a substantial difference (S). Mathematically, H_0 is formulated as:

$$\mu_{ORISE} > \mu_{LACBWR} + S$$

H_A: The ORISE-determined mean/median ROC concentration in a CU is less than or equal to the LACBWR mean/median ROC concentration plus a substantial difference. Similarly, H_A is formulated as:

$$\mu_{ORISE} \leq \mu_{LACBWR} + S$$

In the hypotheses, the substantial difference was a limit on how much the ORISE-determined mean can vary before one can conclude that the two populations are different. For this study, the substantial difference was equal to two times the standard error of the LACBWR-determined mean ROC concentration.

The WRS test is a non-parametric statistical test that is not sensitive to individual sample results; therefore, individual results also had to be evaluated against a single pass/fail criterion. The project-specific plan specified that the 95% upper prediction limit would be used as the pass/fail criterion. However, since NRC approved ORISE to compare confirmatory survey results directly to the operation DCGLs, these values served as the pass/fail criterion for this survey.

Given the information presented previously, the decision rule can be stated as follows:

> If the null hypothesis is rejected and each individual sample concentration is below the operational DCGL for the respective ROC, then recommend acceptance of LACBWR's FSS data; otherwise, perform further evaluation(s) and provide technical comments and recommendations to the NRC.

3.6 SPECIFY LIMITS ON DECISION ERRORS

The sixth step in the DQO process specified the decision maker's limits on decision errors, which were then used to establish performance goals for the survey. There were two types of decision errors to consider: Type I (typically designated as alpha or α) and Type II (typically designated as beta or β). A Type I error occurs when the null hypothesis is rejected when it should not be, also known as a false positive, and reflects the confidence level in the decision. A Type II error is incorrectly failing to reject the null hypothesis when the alternative hypothesis is true. This is also known as a false negative. Two orders of control were implemented to minimize decision errors regarding the decision statement introduced in Table 3.1.

The first order of control was to select decision error rates that were conservative yet still allow for the project to be completed within the study boundaries. The Type I error rate was set to α=0.05, that is, there was a 5% chance of incorrectly rejecting the null hypothesis. The power of the WRS test, or the probability of the test to correctly reject the null hypothesis when it is false, is denoted as the quantity 1-β. Typically, a prospective power is defined by selecting a Type II error rate that is acceptable while not requiring an overly burdensome sample size. A prospective Type II error rate was not specified, as ORISE did not have influence over LACBWR's sample size. The prospective or actual power achieved by the WRS test is a function of the variability in the survey unit and the number of samples in each data set. Because ORISE had no control over the LACBWR sample size, ORISE collected a sample size equal to that of LACBWR for comparison with the WRS test. It should be noted that due to the manner in which the hypotheses were stated, the sample size only impacts the power of the test and not the Type I error rate, which is more detrimental in this case than committing a Type II error, that is incorrectly concluding that the ORISE-determined mean/median ROC concentration in a CU was less than or equal to the licensee's result. .

The second order of control was to optimize the confirmatory field measurement detection sensitivities and ensure that laboratory analytical minimum detectable concentrations (MDCs) were sufficient for decision making. Field scanning MDCs were minimized by following the procedures referenced in Section 4. The nominal analytical MDCs were less than 10% of the DCGLs.

3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA

The seventh step in the DQO process was used to review DQO outputs; develop data collection design alternatives; formulate mathematical expressions for each design; select the sample size to satisfy DQOs; decide on the most resource-effective design of agreed alternatives; and document requisite details. Survey design and laboratory analyses were optimized by implementing the procedures presented in Sections 4 and 5, respectively.

4. PROCEDURES

The ORISE survey team performed visual inspections, measurements, and sampling activities within the accessible portions of survey unit L1010102, west of the reactor building. Survey activities were conducted in accordance with the *ORAU Radiological and Environmental Survey Procedures Manual*, the

ORAU Environmental Services and Radiation Training Quality Program Manual, and the approved confirmatory survey PSP (ORAU 2016a, ORAU 2016b, and ORISE 2017).

4.1 Reference System

ORISE referenced confirmatory measurement/sampling locations to global positioning system (GPS) coordinates using the Wisconsin South 4803 state plane NAD 1987. Measurement and sampling locations were also documented on detailed survey maps. LACBWR provided ORISE with GIS files outlining the survey unit boundary prior to on-site activities.

4.2 Surface Scans

Surface scans were performed with Ludlum Model 44-10 sodium iodide (NaI) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Surface scans on the east side of the survey unit were conducted with a lead collimator attached to the 44-10 to limit potential gamma-shine from the reactor building area. Ratemeter-scalers were also coupled to GPS systems that enabled real-time gamma count rate and geo-referenced data capture. The survey unit was initially classified as a Class 1 unit; therefore, a high density scan was performed. Locations that exhibited elevated direct gamma radiation, as indicated by the increase in audible output from the ratemeter-scaler, were marked for further investigation by soil sampling.

4.3 Soil Sampling

Soil sample locations are provided in Figures A-1 through A-3. Fourteen surface soil sampling locations were randomly selected from the study area using Visual Sample Plan, Version 7.7a. Soil samples were collected from a depth of 0 to 15 cm using hand trowels. One-minute static NaI counts were performed at each sample location pre- and post-sample collection. The pre- and post-sampling static measurements were compared to assess the potential for contamination below 15 cm.

Three judgmental samples were collected from locations identified during surface scans with elevated direct gamma radiation levels distinguishable from local background. Sampling equipment was decontaminated in the field after the collection of each sample to prevent cross-contamination.

5. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples were transferred to the ORISE Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the *Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017). Soil samples were analyzed by solid-state high-resolution gamma spectroscopy for ROCs, including Cs-137, Co-60, Eu-152, and Eu-154. The spectra were also reviewed for other identifiable photopeaks.

The gamma spectroscopy results were evaluated, and the three samples with the highest gamma-emitting ROC SOFs were selected for Sr-90 analysis by chemical separation and low-background proportional counting.

Analytical results were reported in units of pCi/g and graphed in quantile-quantile (Q-Q) plots for assessment. The Q-Q plot is a graphical tool for assessing the distribution of a data set. In viewing the Q-Q plots provided, the Y-axis represents ROC concentrations in units of pCi/g. The X-axis represents the data quantiles about the median value. Values less than the median are represented in the negative quantiles, and the values greater than the median are represented in the positive quantiles. A normal distribution that is not skewed by outliers—i.e., a background population—will appear as a straight line, with the slope of the line subject to the degree of variability among the data population. More than one distribution, such as background plus contamination or other outliers, will appear as a step function.

6. FINDINGS AND RESULTS

The results of the confirmatory survey activities are discussed in the subsections below.

6.1 SURFACE SCANS

Surface scan maps for survey unit L1010102 are presented in Figures A-1 and A-2. Also shown in the figures are locations for the three judgmental soil samples, which will be discussed further in Section 6.2. Though a high scan density was conducted, due to various geographical and other site conditions, such as ice or building structures, complete scan coverage was not achieved.

Figure A-1 illustrates scan data for the collimated NaI detector. The collimated detector response ranged from approximately 2,000 to 5,000 counts per minute (cpm) with higher detector response on the eastern side of this area, closest to the reactor building. Gamma radiation "shine" interference reduced with distance from this building.

Figure A-2 illustrates scan data for the uncollimated NaI detector, which ranged from approximately 5,200 to 14,000 cpm. As with the collimated detector, counts tended to decrease toward the north western boundary. Detector response was also notably lower in the vicinity of the condensate pump excavation.

A portion of the survey unit along the southern border was not accessible for gamma walkover scans as the grade of the surface and snow cover precluded the surveyors walking on the area. Gamma scans of this area were performed from the bottom of the survey unit excavation with the surveyors passing the detector over accessible areas by hand. The surveyors could not reach the boundary of the survey unit at the top of the slope. Gamma scans of this area were performed with both the collimated and uncollimated NaI detector, depending on proximity to the reactor building. The total coverage of this area was estimated to be 75%, and scan ranges of 3,000 to 4,200 cpm and 7,000 to 8,500 cpm with the collimated and uncollimated NaI detector, respectively. No anomalies were identified in this area.

As indicated in Figure A-1, there are scan coverage gaps associated with the eastern and southern survey unit boundaries. However, surveyors noted that scans were performed along the physical boundaries established by LACBWR, with exception of the aforementioned inaccessible portion. Sample S0022, shown in Figure A-1, was collected from the corner of the physical boundary established by LACBWR, indicative of the identified discrepancy between the planned boundary—established in the GIS files—and the physical survey unit demarcation.

6.2 Radionuclide Concentration in Soil

General statistics for the ORISE and LACBWR soil sample data sets are provided in Table 6.1. Table B-1 provides individual soil sample results and the associated SOFs. The analytical results output from ORISE's Radiological and Environmental Analytical Laboratory Information Management System are also presented in Appendix B. Static NaI measurements did not indicate that any of the soil sampling locations exhibited residual radioactivity at depth.

Table 6.1. General Statistics for ORISE and LACBWR Random Samples (pCi/g)								
Parameter	Co-60		Cs-137		Eu-152		Eu-154	
	ORISE	LACBWR	ORISE	LACBWR	ORISE	LACBWR	ORISE	LACBWR
Mean	0.024	0.050	0.089	0.09	-0.003	-0.026	-0.022	-0.015
Median	0.007	0.04335	0.047	0.0711	-0.0025	-0.0267	-0.012	-0.01002
St. Dev.	0.040	0.026	0.107	0.057	0.014	0.018	0.026	0.015
Variance	0.002	0.001	0.011	0.003	0.000	0.000	0.001	0.000
Min	-0.002	0.0137	0.0042	0.0139	-0.032	-0.066	-0.078	-0.0414
Max	0.152	0.113	0.384	0.208	0.018	-0.00315	0.011	0.00971
SOF[a]	0.006	0.013	0.0051	0.005	0.0	0.00	0.0	0.00
Detects[b]	3	1	9	10	0	0	0	0

[a]Calculated using operational DCGLs
[b]Number of results above the MDC

The maximum observed Cs-137 concentration of 0.384 pCi/g in the random sample data was identified in sample S0029. This sample also had the highest Co-60 concentration of 0.152 pCi/g. For the three judgmental samples, the highest Co-60 concentration was 0.248 pCi/g in sample S0021. The highest judgmental sample Cs-137 concentration was 0.201 pCi/g in sample S0037. Eu-152 and Eu-154 were not identified in any of the judgmental samples.

Sr-90 analytical results are summarized in Table B-2; all sample concentrations were less than analytical MDC (approximately 0.3 pCi/g).

6.3 Evaluation of Analytical Data

Figure 6.1 presents an individual Q-Q plot for each ROC. Based on the Q-Q plot for Cs-137, the ORISE data set appears to contain two populations and a potential outlier. Two populations are indicated by the distinct separation between the data points; below 0.065 pCi/g and above 0.17 pCi/g, as well as the step-shape of the data set. The highest observation at 0.384 appears to be a potential outlier; however, a formal outlier test was not performed. The data set collected by LACBWR, however, appears to follow a normal distribution, as indicated by the relatively linear shape of the data points. Review of the Co-60 Q-Q plot reveals a similar trend to that of Cs-137. The Q-Q plots for Eu-152 and Eu-154 represent a fluctuation in instrument background as neither ROC had concentrations above the MDC.

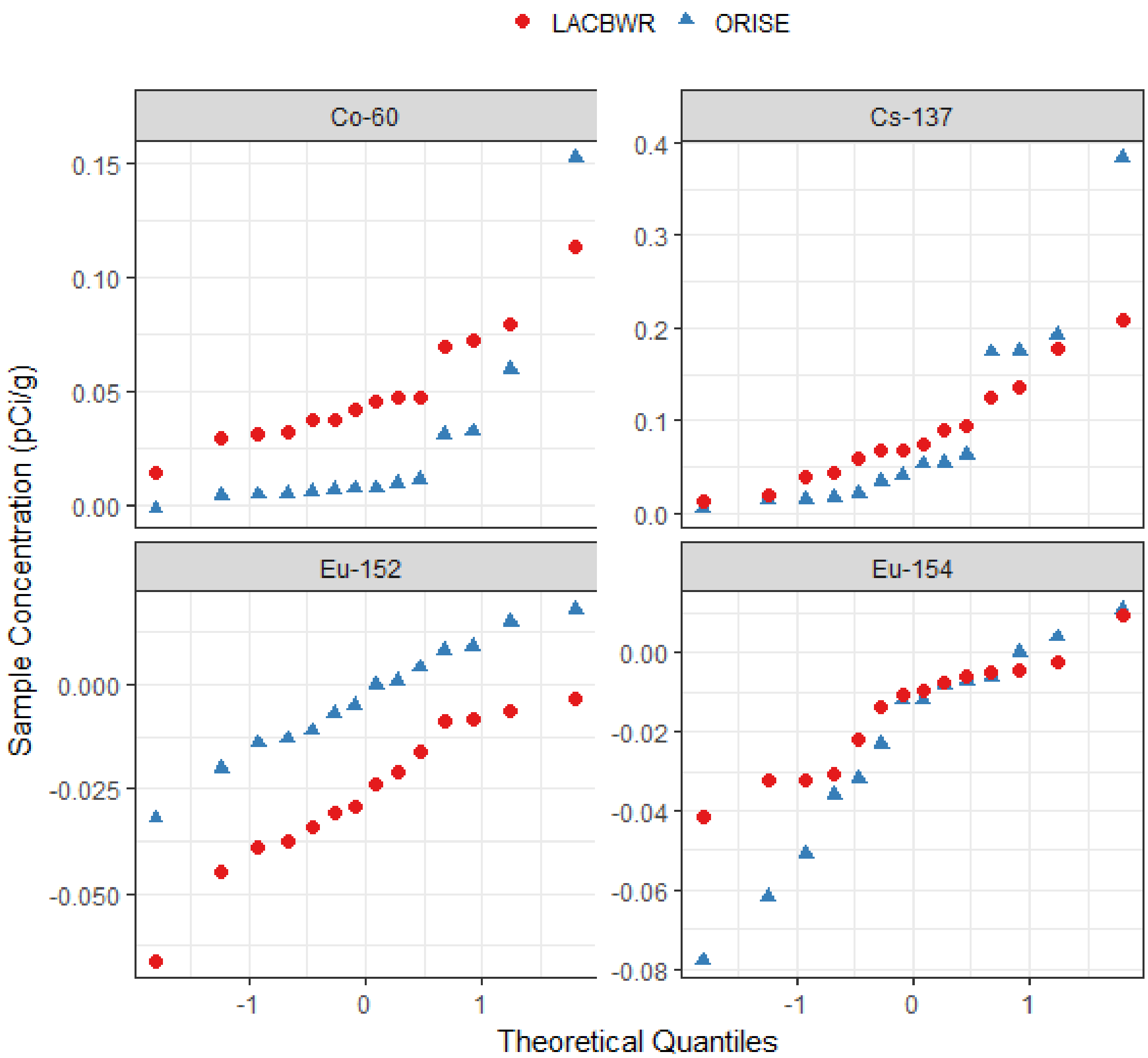

Figure 6.1. Q-Q Plot of ORISE Random Confirmatory Sample Results and LACBWR Sample Results by ROC

Due to the low number of detects for Co-60, Eu-152, and Eu-154, subsequent analysis with the WRS test was unnecessary and not appropriate for the Cs-137 sample sets. Based on the Cs-137 Q-Q plot review and general statistics in Table 6.1, it is apparent that the LACBWR sample set follows a normal distribution, whereas the ORISE sample set does not. Furthermore, the variance in the ORISE sample set is 4-times higher than that in the LACBWR data set, which violates a key assumption of the WRS test (the WRS test assumes that the sample sets have equal variance).

Although the WRS test was not performed as planned, confirmatory survey data for gamma-emitting ROCs were directly compared against the operational DCGLs via the SOF calculation. The largest individual SOF for a sample was 0.08, from judgmental sample S0021, indicating that all gamma-emitting ROCs were a small fraction (less than 10%) of the operational DCGLs.

7. CONCLUSIONS

During the period of January 15 through 18, 2018, ORISE performed an independent confirmatory survey of survey unit L1010102 at the LACBWR. The confirmatory survey consisted of visual inspections, gamma walkover scans, and surface soil sampling.

Fourteen random soil samples were collected, and based on gamma walkover scan results, an additional three judgmental soil samples were collected.

A direct comparison of the Cs-137 concentrations between the ORISE and LACBWR data using the Wilcoxon Rank Sum test could not be performed because the sample populations had distinctly different variances. It was also unnecessary to perform the WRS test for other ROCs because the majority of results, from both sample populations, had concentrations below the MDC.

However, a comparison of the upper limits of ROC concentrations measured by ORISE with the LACBWR operational DCGLs for soil revealed that ORISE concentrations are at least an order of magnitude smaller than the operational DCGLs. Based on the confirmatory survey data, it is the opinion of ORISE that LACBWR's FSS design and implementation were appropriate and reported results were acceptable for demonstrating compliance with the release criteria.

ORISE noted one LACBWR FRS implementation discrepancy based on the post-survey review of the confirmatory survey gamma walkover maps. The planned survey unit boundary provided in the site's GIS file did not coincide with the physical boundary observed in the field. For future surveys, ORISE recommends the NRC confirm that the L1010102 adjoining shared survey unit boundaries encompass the discrepant physical soil area.

8. REFERENCES

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APPENDIX A
FIGURES

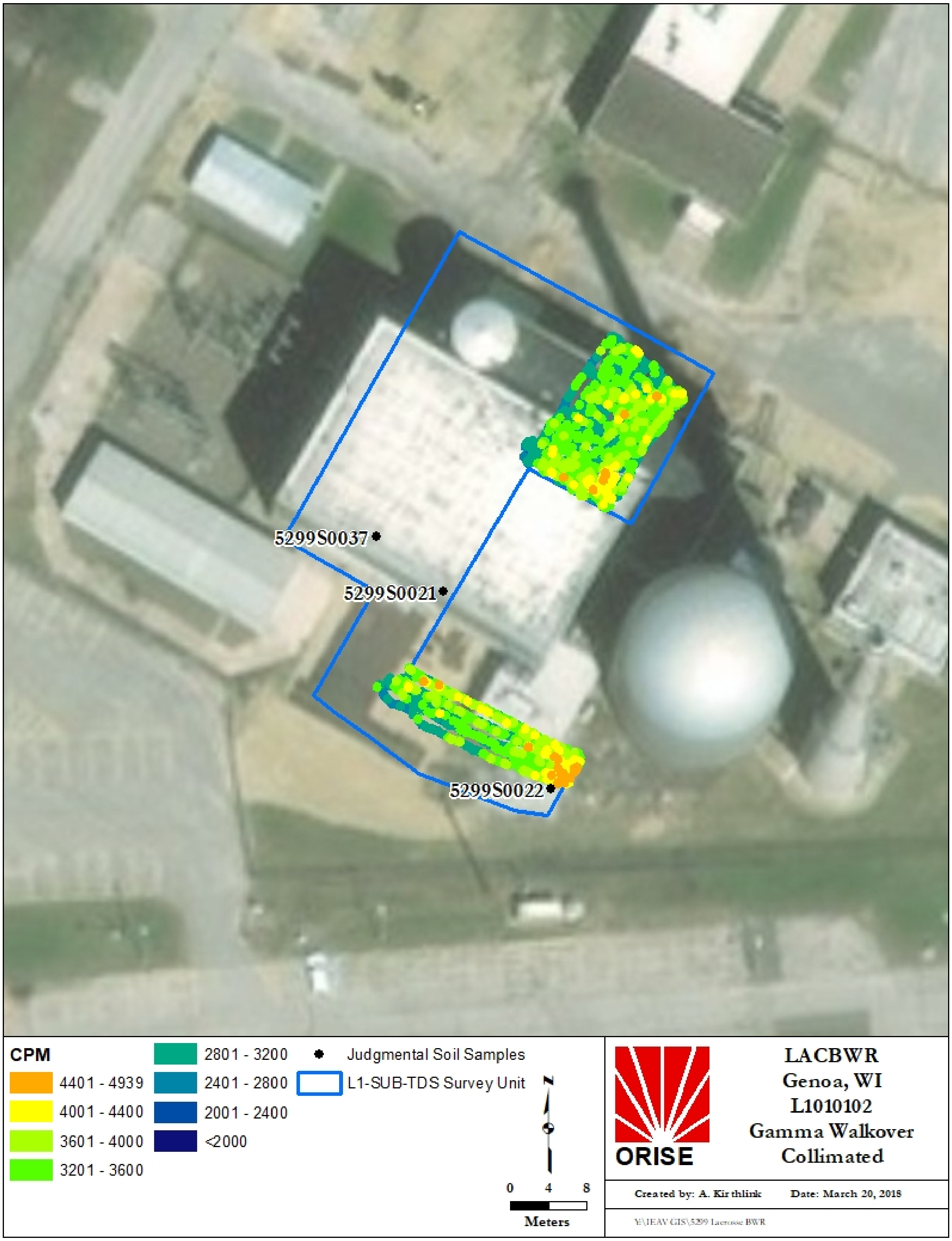

Figure A.1. Collimated Gamma Walkover Scan and Judgmental Soil Sampling Locations in SU L1010102

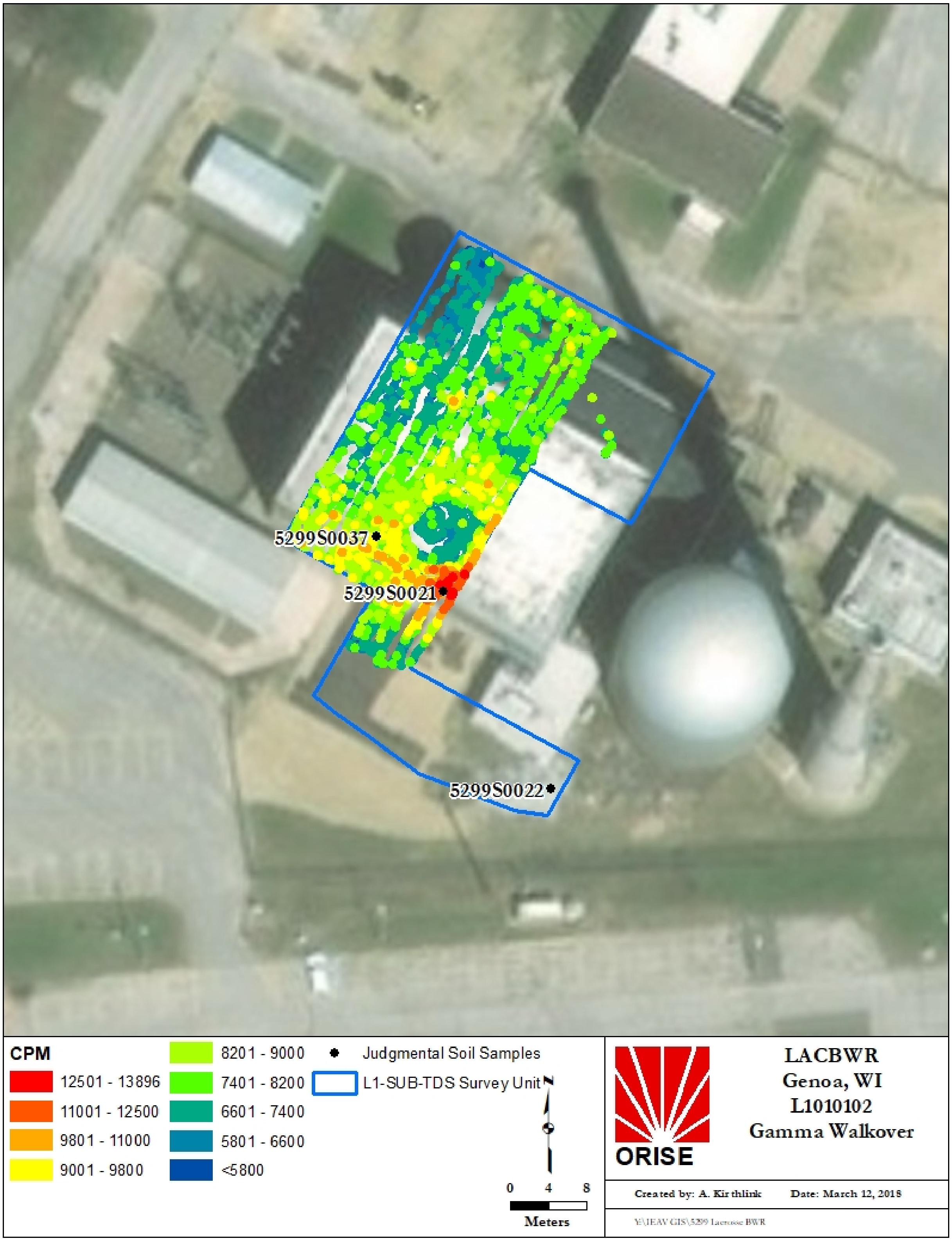

Figure A.2. Uncollimated Gamma Walkover Scan and Judgmental Soil Sampling Locations in SU L1010102

Figure A.3. Soil Sampling Locations in SU L1010102

APPENDIX B
SOIL SAMPLE ANALYTICAL RESULTS

Table B.1. ROC Concentrations (pCi/g) and SOFs for Random and Judgmental Soil Samples					
Sample ID	**Co-60**	**Cs-137**	**Eu-152**	**Eu-154**	**SOF[a]**
5299S0021[b]	0.248	0.186	-0.004	0.002	0.08
5299S0022[b]	0.0000	0.044	0.002	-0.020	0.00
5299S0023	0.007	0.174	-0.020	-0.078	0.01
5299S0024	0.059	0.175	-0.007	0.000	0.03
5299S0025	0.006	0.0335	0.001	-0.032	0.00
5299S0026	0.0044	0.054	-0.013	-0.008	0.00
5299S0027	0.011	0.017	0.000	-0.023	0.00
5299S0028	0.031	0.053	-0.005	-0.006	0.01
5299S0029	0.152	0.384	-0.032	-0.062	0.06
5299S0030	-0.002	0.041	-0.014	0.004	0.00
5299S0031	0.009	0.021	0.018	-0.051	0.01
5299S0032	0.0064	0.014	0.008	-0.036	0.00
5299S0033	0.032	0.193	0.009	-0.012	0.02
5299S0034	0.007	0.062	0.004	0.011	0.01
5299S0035	0.0049	0.0042	-0.011	-0.012	0.00
5299S0036	0.0037	0.015	0.015	-0.007	0.00
5299S0037[b]	0.163	0.201	-0.009	0.003	0.05

[a]Calculated using operational DCGLs
[b]Judgmental sample

Table B-2. Sr-90 Concentration in Confirmatory Soil Samples		
Sample ID	**Result (pCi/g)**	**MDC (pCi/g)**
5299S0021	0.14 ± 0.18	0.31
5299S0029	0.02 ± 0.17	0.31
5299S0037	0.16 ± 0.18	0.30

Gamma Spectrometry Summary Results By Analyte

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

ORAU Further. Together.

Report Date: January 30, 2018

Analyte:	Co-60	SOP (Rev. #)	CP1 (21)
Project Name:	La Crosse	Energy Signature:	1332.49 (KeV)
Project # :	201214041	SDG # :	201214041-1

Client Sample ID:	Lab Sample ID:	Result	TPU (2s)	MDC	Units	Qualifier Flag	Batch #
5299S0021	14041S0001	0.248	0.030	0.034	pCi/g		GS0659
	14041S0001Dup	0.266	0.031	0.028	pCi/g		GS0659
5299S0022	14041S0002	-0.0000	0.0045	0.0322	pCi/g	U	GS0659
5299S0023	14041S0003	0.007	0.023	0.050	pCi/g	U	GS0659
5299S0024	14041S0004	0.059	0.016	0.029	pCi/g		GS0659
5299S0025	14041S0005	0.006	0.014	0.033	pCi/g	U	GS0659
5299S0026	14041S0006	0.0044	0.0094	0.0227	pCi/g	U	GS0659
5299S0027	14041S0007	0.011	0.013	0.030	pCi/g	U	GS0659
5299S0028	14041S0008	0.031	0.016	0.031	pCi/g	U	GS0659
5299S0029	14041S0009	0.152	0.023	0.028	pCi/g		GS0659
5299S0030	14041S0010	-0.002	0.014	0.028	pCi/g	U	GS0659
5299S0031	14041S0011	0.009	0.015	0.036	pCi/g	U	GS0659
5299S0032	14041S0012	0.0064	0.0051	0.0169	pCi/g	U	GS0659
5299S0033	14041S0013	0.032	0.015	0.031	pCi/g		GS0659
5299S0034	14041S0014	0.007	0.017	0.039	pCi/g	U	GS0659
5299S0035	14041S0015	0.0049	0.0078	0.0186	pCi/g	U	GS0659
5299S0036	14041S0016	0.0037	0.0086	0.0283	pCi/g	U	GS0659
5299S0037	14041S0017	0.163	0.029	0.032	pCi/g		GS0659

Electronically Validated By:
John Cox- 1/25/2018 09:17

Electronically Approved By:

William Smith 1/30/2018 10:25

Qualifier Flags:
U = Analyte not detected (< MDC)

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

Gamma Spectrometry Summary Results By Analyte

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

ORAU Further. Together.

Report Date: January 30, 2018

Analyte:	Cs-137	SOP (Rev. #)	CP1 (21)
Project Name:	La Crosse	Energy Signature:	661.66 (KeV)
Project # :	201214041	SDG # :	201214041-1

Client Sample ID:	Lab Sample ID:	Result	TPU (2s)	MDC	Units	Qualifier Flag	Batch #
5299S0021	14041S0001	0.186	0.024	0.030	pCi/g		GS0659
	14041S0001Dup	0.186	0.025	0.033	pCi/g		GS0659
5299S0022	14041S0002	0.044	0.010	0.020	pCi/g		GS0659
5299S0023	14041S0003	0.174	0.029	0.039	pCi/g		GS0659
5299S0024	14041S0004	0.175	0.022	0.024	pCi/g		GS0659
5299S0025	14041S0005	0.0335	0.0039	0.0242	pCi/g		GS0659
5299S0026	14041S0006	0.054	0.014	0.025	pCi/g		GS0659
5299S0027	14041S0007	0.017	0.012	0.026	pCi/g	U	GS0659
5299S0028	14041S0008	0.053	0.018	0.033	pCi/g		GS0659
5299S0029	14041S0009	0.384	0.038	0.029	pCi/g		GS0659
5299S0030	14041S0010	0.041	0.014	0.026	pCi/g		GS0659
5299S0031	14041S0011	0.021	0.011	0.024	pCi/g	U	GS0659
5299S0032	14041S0012	0.014	0.010	0.023	pCi/g	U	GS0659
5299S0033	14041S0013	0.193	0.026	0.031	pCi/g		GS0659
5299S0034	14041S0014	0.062	0.018	0.032	pCi/g		GS0659
5299S0035	14041S0015	0.0042	0.0085	0.0205	pCi/g	U	GS0659
5299S0036	14041S0016	0.015	0.011	0.025	pCi/g	U	GS0659
5299S0037	14041S0017	0.201	0.028	0.033	pCi/g		GS0659

Electronically Validated By:
John Cox- 1/25/2018 09:17

Electronically Approved By:

William Smith 1/30/2018 10:25

Qualifier Flags:
U = Analyte not detected (< MDC)

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

Gamma Spectrometry Summary Results By Analyte

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

ORAU Further. Together.

Report Date: January 30, 2018

Analyte:	Eu-152	SOP (Rev. #)	CP1 (21)
Project Name:	La Crosse	Energy Signature:	344.28 (KeV)
Project # :	201214041	SDG # :	201214041-1

Client Sample ID:	Lab Sample ID:	Result	TPU (2s)	MDC	Units	Qualifier Flag	Batch #
5299S0021	14041S0001	-0.004	0.026	0.058	pCi/g	U	GS0659
	14041S0001Dup	0.007	0.029	0.070	pCi/g	U	GS0659
5299S0022	14041S0002	0.002	0.028	0.067	pCi/g	U	GS0659
5299S0023	14041S0003	-0.020	0.040	0.087	pCi/g	U	GS0659
5299S0024	14041S0004	-0.007	0.024	0.056	pCi/g	U	GS0659
5299S0025	14041S0005	0.001	0.032	0.073	pCi/g	U	GS0659
5299S0026	14041S0006	-0.013	0.024	0.051	pCi/g	U	GS0659
5299S0027	14041S0007	-0.000	0.027	0.063	pCi/g	U	GS0659
5299S0028	14041S0008	-0.005	0.035	0.079	pCi/g	U	GS0659
5299S0029	14041S0009	-0.032	0.028	0.059	pCi/g	U	GS0659
5299S0030	14041S0010	-0.014	0.027	0.061	pCi/g	U	GS0659
5299S0031	14041S0011	0.018	0.029	0.069	pCi/g	U	GS0659
5299S0032	14041S0012	0.008	0.016	0.053	pCi/g	U	GS0659
5299S0033	14041S0013	0.009	0.031	0.075	pCi/g	U	GS0659
5299S0034	14041S0014	0.004	0.033	0.075	pCi/g	U	GS0659
5299S0035	14041S0015	-0.011	0.024	0.052	pCi/g	U	GS0659
5299S0036	14041S0016	0.015	0.025	0.062	pCi/g	U	GS0659
5299S0037	14041S0017	-0.009	0.035	0.077	pCi/g	U	GS0659

Electronically Validated By:
John Cox- 1/25/2018 09:17

Electronically Approved By:

William Smith 1/30/2018 10:25

Qualifier Flags:
U = Analyte not detected (< MDC)

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

Gamma Spectrometry Summary Results By Analyte

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

ORAU Further. Together.

Report Date: January 30, 2018

Analyte:	Eu-154	SOP (Rev. #)	CP1 (21)
Project Name:	La Crosse	Energy Signature:	723.30 (KeV)
Project # :	201214041	SDG # :	201214041-1

Client Sample ID:	Lab Sample ID:	Result	TPU (2s)	MDC	Units	Qualifier Flag	Batch #
5299S0021	14041S0001	0.002	0.031	0.114	pCi/g	U	GS0659
	14041S0001Dup	-0.008	0.045	0.113	pCi/g	U	GS0659
5299S0022	14041S0002	-0.020	0.033	0.107	pCi/g	U	GS0659
5299S0023	14041S0003	-0.078	0.052	0.167	pCi/g	U	GS0659
5299S0024	14041S0004	0.000	0.029	0.103	pCi/g	U	GS0659
5299S0025	14041S0005	-0.032	0.057	0.135	pCi/g	U	GS0659
5299S0026	14041S0006	-0.008	0.033	0.108	pCi/g	U	GS0659
5299S0027	14041S0007	-0.023	0.041	0.099	pCi/g	U	GS0659
5299S0028	14041S0008	-0.006	0.045	0.150	pCi/g	U	GS0659
5299S0029	14041S0009	-0.062	0.046	0.107	pCi/g	U	GS0659
5299S0030	14041S0010	0.004	0.034	0.101	pCi/g	U	GS0659
5299S0031	14041S0011	-0.051	0.053	0.126	pCi/g	U	GS0659
5299S0032	14041S0012	-0.036	0.039	0.112	pCi/g	U	GS0659
5299S0033	14041S0013	-0.012	0.041	0.114	pCi/g	U	GS0659
5299S0034	14041S0014	0.011	0.044	0.132	pCi/g	U	GS0659
5299S0035	14041S0015	-0.012	0.039	0.111	pCi/g	U	GS0659
5299S0036	14041S0016	-0.007	0.030	0.094	pCi/g	U	GS0659
5299S0037	14041S0017	0.003	0.048	0.161	pCi/g	U	GS0659

Electronically Validated By:
John Cox- 1/25/2018 09:17

Electronically Approved By:

William Smith 1/30/2018 10:25

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MDC = Minimum Detectable Concentration

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(Tl) 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)

Low-Background Alpha/Beta Gas Proportional Counter
Series 5 XLB
(Canberra, Meriden, CT)
Used in conjunction with:
Eclipse Software
Dell Workstation
(Canberra, Meriden,CT)

APPENDIX D
SURVEY PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

ORISE performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2014, ORAU 2016c, 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.

Calibration of field instrumentation and laboratory equipment was performed in accordance with procedures from the following ORAU documents:

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017)

Quality control procedures included:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed-Analyte Performance Evaluation 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. Specific scan MDCs for the NaI scintillation detectors were not determined, as the instruments were used solely as a qualitative means to identify elevated gamma radiation levels in excess of local background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument.

D.3.3 SOIL SAMPLING

Surface soil samples (approximately 0.5 kilogram each) were collected, using a clean garden trowel, then transferred into a new sample container by ORISE personnel. ORISE personnel labeled each sample in accordance with ORISE survey procedures and completed the required custody documentation.

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 were:

Table D.1. Typical MDCs and TAPs for ROCs		
Radionuclide[a]	TAP (keV)	MDC (pCi/g)
Co-60	1332.49	0.06
Cs-137	661.66	0.05
Eu-152	344.28	0.10
Eu-154	723.30	0.15

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

D.4.2 Sr-90 Analysis

Sr-90 concentrations were quantified by total sample dissolution followed by radiochemical separation and counted on a low background gas proportional counter.

Samples were homogenized and dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cakes were dissolved and strontium is coprecipitated on lead sulfate. The strontium was separated from residual calcium and lead by reprecipitating strontium sulfate from EDTA at a pH of 4.0. Strontium was separated from barium by complexing the strontium in DTPA while precipitating barium as barium chromate. The strontium was ultimately converted to strontium carbonate and counted on a low-background gas proportional counter. The typical MDC for a one gram sample and a 60-minute count time was 0.3 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.