ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Managed by ORAU for the U.S. Department of Energy

July 24, 2012

Mr. John Glenn
U.S. Department of Energy
Oak Ridge Office
P.O. Box 2001
Oak Ridge, TN 37831-0117

DOE CONTRACT NO. DE-AC05-06OR23100
SUBJECT: INDEPENDENT VERIFICATION OF THE CENTRAL CAMPUS AND SOUTHEAST LAB COMPLEX BUILDING SLABS, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE
DCN: 5086-SR-03-0

Dear Mr. Glenn:

Oak Ridge Associated Universities/Oak Ridge Institute for Science and Education (ORAU/ORISE) has completed the independent verification survey of the Central Campus and Southeast Lab Complex Building Slabs. The results of this effort are provided in the enclosed report.

Please direct any additional questions you may have to me via my information below, Evan Harpenau at 865.241.8793, or Kathy Rollow at 865.574.4390.

Sincerely,

Phyllis C. Weaver
Health Physicist Project Manager
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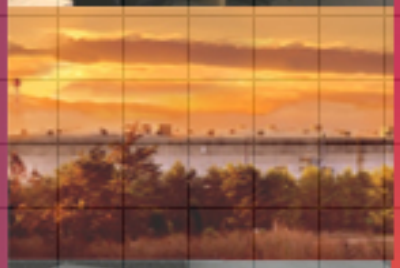

INDEPENDENT VERIFICATION OF THE CENTRAL CAMPUS AND SOUTHEAST LABORATORY COMPLEX BUILDING SLABS AT OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

P.C. Weaver

Prepared for the
U.S. Department of Energy

ORISE

The Oak Ridge Institute for Science and Education (ORISE) is a U.S. Department of Energy institute focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities.

INDEPENDENT VERIFICATION OF THE CENTRAL CAMPUS AND SOUTHEAST LABORATORY COMPLEX BUILDING SLABS AT OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

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Prepared for the
U.S. Department of Energy

JULY 2012

Prepared by Oak Ridge Associated Universities under the Oak Ridge Institute for Science and Education contract, number DE-AC05-06OR23100, with the U.S. Department of Energy.

5086-SR-03-0

INDEPENDENT VERIFICATION OF THE CENTRAL CAMPUS AND SOUTHEAST LABORATORY COMPLEX BUILDING SLABS AT OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

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JULY 2012

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ACRONYMS

cpm	counts per minute
DOE	U.S. Department of Energy
dpm/100cm^2	disintegration per minute per 100 square centimeters
ELCR	excess lifetime cancer risk
GM	General Maintenance
GPS	global positioning system
HPS	Health Physics Society
IV	independent verification
NaI	sodium iodide
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
Q	quantile
ROD	Record of Decision
SEC	Safety and Ecology Corporation
VSP	Visual Sample Plan

INDEPENDENT VERIFICATION OF THE CENTRAL CAMPUS AND SOUTHEAST LABORATORY COMPLEX BUILDING SLABS AT OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

1. INTRODUCTION

Oak Ridge Associated Universities (ORAU), working under the Oak Ridge Institute for Science and Education (ORISE) contract with the U.S. Department of Energy (DOE), has performed independent verification (IV) of Central Campus and Southeast Laboratory Complex building slabs located at Oak Ridge National Laboratory (ORNL). Safety and Ecology Corporation (SEC) has submitted final status survey data indicating completion of removal actions to meet site requirements for the following building slabs or structures: Buildings 3085, 3098, 3119, 3503, 3504, 3508, 3541, 3543, 3592, and 3605, and sub-grade containment structures 3102 and 3117A. All above-grade building structures, tanks, and systems have been characterized, demolished, and disposed as part of the American Recovery and Reinvestment Act of 2009. Any residual contamination that remains on the slabs or containment structures must meet contractual end-point criteria in accordance with the limits defined in the Bethel Valley Record of Decision (ROD) (DOE 2002).

ORAU survey teams conducted survey activities during the period between January and June, 2012 on behalf of DOE to verify the final radiological condition reported by SEC is reproducible. The DOE requires that the "as left" status of the slab condition be verified to ensure that the residual radioactivity does not exceed the guidance provided in the Bethel Valley ROD and that any issues of conflict can be addressed immediately. The potential radiological inventory, based on process knowledge, includes Cs-137, Sr-90, Th-232, U-235, U-238, Pu-239/240, and Am-241.

2. SITE DESCRIPTION

ORNL is located in Oak Ridge, Tennessee, approximately 25 miles west of Knoxville at the western end of Bethel Valley Road. The site occupies approximately 10,000 acres of the Oak Ridge Reservation and is bounded to the south by the Clinch River and to the north by Bethel Valley Road. The former Central Campus facilities were centrally located on the main ORNL campus to the north of Central Avenue and the former Southeast Laboratory Complex facilities are located

south of Central Avenue (as shown in Fig. 1). These facilities were utilized to house various offices and laboratories, and fabrication, operational, and support processes.

3. OBJECTIVE

The objective of this verification survey was to provide independent review and field assessment of remediation actions conducted by SEC, and to independently assess whether the final radiological condition of the slabs met the release guidelines as referenced in the ROD.

4. PROCEDURES

ORAU survey activities were performed in accordance with the final *Project-Specific Plan for Independent Verification of Building Slabs at Oak Ridge National Laboratory* (ORISE 2011). Procedures supporting the field implementation of the plan were obtained from the ORISE Survey Procedures Manual and the ORAU Quality Program Manual (ORISE 2012a and ORAU 2012).

4.1 DOCUMENT REVIEW

SEC provided ORAU final status survey data for each slab. These data were reviewed as a part of the overall assessment to ensure that actions by the contractor had met the specified criteria.

4.2 REFERENCE SYSTEM

ORAU used a global positioning system (GPS) for tracking survey data and identifying measurement and sampling locations. In most cases, GPS units were integrated with a ratemeter-scaler and detector to collect position and radiation count rate data. The specific geographic coordinate system required for documentation was the Tennessee State Plane Coordinate System. GPS coordinates are typically accurate to within one meter of any given position. When GPS units were not used, a hand-held distance meter was used to establish coordinate locations to identify sampling and measurement locations for several of the smaller slabs. In other cases when scan data could not be electronically captured, the scan ranges were observed and recorded in the site logbook and/or on slab drawings. Measurement locations were either geo-referenced or referenced to a prominent site feature. Standard orientation for measurement positions is referenced to the SW corner of a building slab.

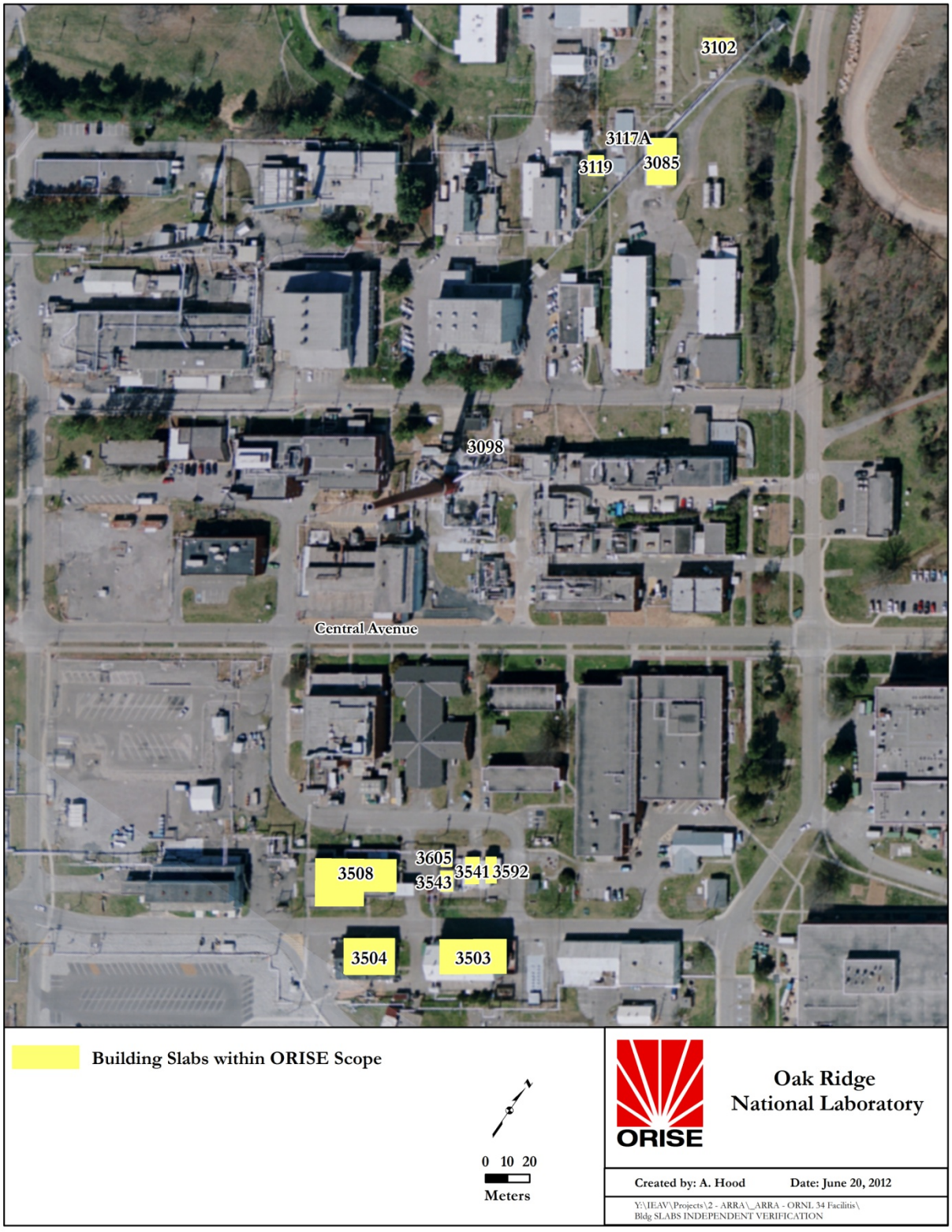

Fig. 1. Overview of Oak Ridge National Laboratory Central Campus and Southeast Laboratory Complex

4.3 SURFACE SCANS

High-density scans were performed for alpha, alpha-plus-beta, and gamma radiation on the slabs' surfaces, with the exception of slabs that had been re-covered with new concrete. Particular attention was given to areas with the highest potential for contamination (i.e., cracks, joints, and surface run-off pathways).

A large-area gas proportional detector was used for alpha and alpha-plus-beta radiation, and gamma radiation scans were performed using a 2 inch × 2 inch sodium iodide, thallium-activated (NaI[Tl]) detector. Detectors were coupled to ratemeter-scalers that supported data logging capabilities with audible indication. The data loggers electronically captured the count rates each second and converted the data to counts per minute (cpm) equivalents. ORAU field personnel relied on audio output for real-time identification of locations of elevated direct radiation that might suggest the presence of residual contamination. These judgmental locations were marked and identified for further investigation.

4.4 SURFACE ACTIVITY MEASUREMENTS

Direct static measurements of alpha and alpha-plus-beta surface activity were obtained at predetermined randomly-generated locations based on a statistical sampling design facilitated by using Visual Sample Plan (VSP) software (version 6.0 or greater). The number of measurement locations was adjusted based on the size or condition of the pad. The typical number of predetermined locations was 11, based on a non-parametric statistical determination of the number of samples required to estimate and quantify the mean activity level. Non-parametric statistics do not require the assumption of a normal distribution for the population of interest (i.e., surface activity). These predetermined measurement locations were supplemented by the addition of judgmental measurement locations. The judgmental data are used to assess locations of elevated radiation identified by surface scans that could potentially be above acceptable surface contamination guidelines. Smears (47-mm diameter numbered filter paper discs) were used to sample an area of 100 cm^2 at each static measurement location for removable gross alpha and beta contamination. Direct measurement locations are provided for individual slabs in Appendix A.

4.5 SAMPLE ANALYSIS AND DATA INTERPRETATION

Smear samples and data were returned to the ORAU/ORISE facility in Oak Ridge, Tennessee for analysis and interpretation. Smears were analyzed, in accordance with the ORISE Laboratory Procedures Manual, for gross alpha and beta activity using a low-background proportional counter (ORISE 2012b). Total and removable surface activity measurement results were corrected for background, then converted to units of disintegration per minute per 100 square centimeters (dpm/100 cm^2). The gross count rates for alpha, alpha-plus-beta, and gamma radiation surface scan data for each slab were prepared for report presentation using Quantile (Q) plots. The Q-plot is a graphical technique for determining if there is a common distribution in data sets. The advantage of the Q-plot is that population distributional aspects can be evaluated simultaneously. The detectable aspects include:

- Shifts in scale
- Changes in symmetry (skewness of the data)
- The presence of outliers

Q-plots were generated by uploading the survey area data into the U.S. Environmental Protection Agency's ProUCL software. In the Q-plots provided in Appendix A, the Y-axis represents observed count rates in cpm. The X-axis represents the data quantiles about the mean value. A normal distribution that is not skewed by outliers will appear as a straight line with the slope of the line subject to the degree of variability among the data population (i.e., a background radiation population). Values less than the mean are represented in the negative quantiles, and values greater than the mean are represented in the positive quantiles. The presence of more than one population—e.g., background radiation population and contamination—would display on a Q-plot as a step function. Small areas of localized contamination will appear on the Q-plot as outlier points in the upper right quadrant.

5. APPLICABLE RESIDUAL CONTAMINATION GUIDELINES

For structural surfaces that may remain in place, the "as left" condition must meet industrial surface criteria derived to achieve the same average excess lifetime cancer risk (ELCR) of 1×10^{-4} and the maximum risk level at ten times the average as defined in the ROD. The industrial surface criteria are applicable to the entire exposed surface of the slab (DOE 2002).

Surface criteria cited in the ROD have been derived based on American National Standard Institute /Health Physics Society (HPS) HPS N13.12-1999 (HPS 1999). This standard specifies screening levels for clearance of surfaces containing residual radioactive materials, based on a dose limit of 1 mrem/year, for several groups of radionuclides. Clearance, as defined by the standard, is "the removal of items or materials that contain residual levels of radioactive materials within authorized practices from any further control of any kind" (DOE 2002). The primary radionuclides of concern specified for building surfaces in Bethel Valley (ORNL) are classified in Group 2, per the standard (DOE 2002). This includes uranium and selected high-dose beta-gamma emitters. However, recent characterization data indicate that Group 1 radionuclides radium, thorium, and transuranics (Th-232, Pu-239/240, and Am-241) are present in the radionuclide mix. The surface activity screening level for Group 1 radionuclides is specified at 600 dpm/100 cm^2, and for Group 2 radionuclides the level is 6,000 dpm/100 cm^2 (HPS 1999). This screening level has been used to derive a risk-based surface concentration limit as follows (DOE 2002):

$RLsurf = TR / [DL/SL \times R \times ED] = 1 \times 10^{-4}$ ELCR / [(1 mrem/yr)/(6,000 dpm/100 cm^2) × 6×10^{-7} ELCR/mrem × 25 years] = 40,000 dpm/100 cm^2

where:

- RLsurf = remediation levels for residual building surfaces
- TR = target risk level = 1×10^{-4} ELCR
- DL = dose limit used to derive surface screening level = 1 mrem/year
- SL = surface activity screening level for Group 2 radionuclides = 6,000 dpm/100 cm^2
- R = cancer risk per unit dose for surface-deposited radioactivity (conservatively based on radionuclide-specific slope factor and external dose coefficient for ^{137}Cs+D) = 6×10^{-7} ELCR/mrem
- ED = exposure duration = 25 years for industrial scenario. This calculation is equivalent for Group 1 radionuclides using the specified 600 dpm/100 cm^2 surface activity screening value.

NOTE: The derived RLsurf value is based on the assumption that a worker could potentially be located directly above the building surfaces for 2,000 hours per year. Since it is unlikely that any worker would actually occupy this location for such an extended period of time, this estimate is considered conservative and any actual risk may be well below the target level of 1×10^{-4} ELCR. Additional conservative assumptions are the absence of any consideration of the decreasing concentrations of radionuclides on the building surfaces due to radioactive decay or the shielding effects from backfill of basements and other subsurface structures (DOE 2002).

6. FINDINGS AND RESULTS

The results of the IV surveys of the slabs are discussed below. Appendix A provides the data summaries for each individual slab. Data summaries include surface walkover scan results for each radiation type collected for the slab, Q-Plots, static measurement and smear sample location maps, and results tables of total and removable surface activity levels. Direct field measurement data are compared to the criteria specified in the ROD to determine if the "as left" conditions have been met. Removable surface activity results are evaluated against DOE Order 458.1, which references DOE Order 5400.5, for allowable alpha and beta removable activity (DOE 1993, 2002, and 2011).

6.1 SURFACE SCANS

Scan density schematics for each building slab is provided in Appendix A with the exception of the 3102 and 3117A slabs. The Building 3102 and 3117A Slabs are both subgrade structures with all four walls inplace; however, 3102 had a new concrete pour that covered the original slab and the 3117A structure was too small to use the spatial data loggers. Alpha activity scans ranged from 0 cpm to 860 cpm and alpha-plus-beta activity scans ranged from 0 cpm to 48,000 cpm. Gamma radiation scans over the surface of the slabs ranged from less than 6,000 cpm up to 330,000 cpm. Scan data were used as a qualitative indication of areas where radioactivity levels required additional investigations.

6.2 TOTAL AND REMOVABLE SURFACE ACTIVITY LEVELS

Surface activity measurement results are summarized in Table 1. Total alpha measurements ranged from -16 to 32,000 dpm/100 cm^2 and alpha plus beta from -340 to 96,000 dpm/100 cm^2. The

highest total and removable activity was measured on the Building 3508 slab. The Building 3508 slab had the highest removable alpha activity at 27 dpm/100 cm^2.

Table 1. Surface Activity Measurement Ranges for the Central Campus and Southeast Lab Complex Building Slabs Oak Ridge National Laboratory Oak Ridge, Tennessee

Building Slab	Direct Measurements		Removable Measurements	
	Alpha Activity (dpm/100cm²)	Alpha-plus-Beta Activity (dpm/100cm²)	Gross Alpha Activity (dpm/100cm²)	Gross Beta Activity (dpm/100cm²)
3085	8 to 330	91 to 61,000	0 to 1	-1 to 7
3098	0 to 65	-340 to 470	0 to 1	-2 to 5
3102	16 to 150	-15 to 190	0 to 4	-2 to 4
3117A	-8 to 73	-160 to 190	0 to 1	-1 to 4
3119	-16 to 41	-79 to 590	0 to 1	-3 to 5
3503	-8 to 110	330 to 12,000	0 to 1	-3 to 3
3504	0 to 110	450 to 12,000	0 to 4	-3 to 5
3508	-16 to 32,000	500 to 96,000	0 to 27	0 to 7
3541	-8 to 24	380 to 720	0 to 3	-2 to 6
3543	16 to 620	360 to 1,400	0 to 1	0 to 5
3592	-8 to 110	740 to 10,000	0 to 1	-3 to 6
3605	-8 to 57	500 to 760	0 to 1	-2 to 4

6.3 COMPARISON OF RESULTS WITH GUIDELINES

The remediation level guideline for Group 2 radionuclides is 40,000 dpm/100 cm^2 for allowable fixed activity. Total surface activity levels on ten of the twelve slabs were within the remediation level guideline of 40,000 dpm/100 cm^2 for remaining fixed contamination. The surface activity levels on Building 3085 and 3508 slabs were as high as 61,000 dpm/100 cm^2 and 96,000 dpm/100 cm^2, respectively. The detection of measurable fixed alpha activity concludes that Group 1 radionuclides are present. The Group 1 radionuclides guideline is 4,000 dpm/100 cm^2 when using the surface activity screening level for Group 1 radionuclides of 600 dpm/100 cm^2 to calculate the derived risk-based surface concentration. The highest fixed alpha contamination was found on the Building 3508 slab at 32,000 dpm/100 cm^2.

Neither the ROD nor HPS N13.12-1999 provide remediation guidelines for removable activity. Therefore, removable contamination activity levels were compared with the DOE Order 5400.5 guidance for acceptable activity levels. The most restrictive alpha and beta removable surface activity per DOE Order 5400.5 are 20 and 200 dpm/100 cm^2, respectively. Based on the results, removable alpha contamination exceeding the guidance was identified on the slab of Building 3508 at 27 dpm/100 cm^2.

7. SUMMARY

During the period between February 2012 and June 2012, ORAU performed verification surveys on former Central Campus and Southeast Laboratory Complex building slabs at ORNL. The survey included direct radiation surface scans, total surface activity measurements, and the collection of smear samples for determining removable surface activity levels. Scans for alpha and alpha-plus-beta radiation levels identified radiation activity levels exceeding the 40,000 dpm/100 cm^2 Group 2 radionuclide surface remediation level guidelines on the Building 3085 and 3508 slabs. The high activity levels were found in small localized areas (i.e., divets, holes, and cracks). One smear collected from the 3508 slab exceeded the DOE Order 5400.5 guidance for removable activity. ORAU field personnel notified SEC of the survey findings for immediate action. A recheck of the these locations determined that SEC grouted areas on both pads that had been marked by ORAU. Activity levels were then verified by ORAU to be within the guidelines. Therefore, ORAU is of the opion that the Central Campus and Southeast Laboratory Complex building slabs meet the "as left" condition per the ROD for fixed radioactivity.

8. REFERENCES

HPS 1999. *Surface and Volume Radioactivity Standards for Clearance.* Health Physics Society. McLean, Virginia. August 31.

ORAU 2012. *Quality Program Manual for the Independent Environmental Assessment and Verification Program*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. June 28.

ORISE 2012b. *Survey Procedures Manual for the Independent Environmental Assessment and Verification Program*. Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. Oak Ridge, Tennessee. May 11.

ORISE 2011a. *Project-Specific Plan for the Independent Verification of Building Slabs and Concrete Structures at Oak Ridge National Laboratory, Oak Ridge, Tennessee.* Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. 5086-PL-01-0. July.

ORISE 2012c. *Laboratory Procedures Manual for the Independent Environmental Assessment and Verification Program*. Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. Oak Ridge, Tennessee. April 25.

DOE 1993. ***DOE*** *Order 5400.5 Radiation Protection of the Public and the Environment.* U.S. Department of Energy. Washington, DC. January 7.

DOE 2002. *Record of Decision for Interim Actions in Bethel Valley*. U.S. Department of Energy. Oak Ridge, Tennessee. May.

DOE 2011. *DOE Order 458.1, Chg 1, Radiation Protection of the Public and the Environment.* U.S. Department of Energy. Washington, D.C. March 8.

APPENDIX A
DATA PACKAGES FOR INDIVIDUAL BUILDING SLABS

3085 BUILDING SLAB

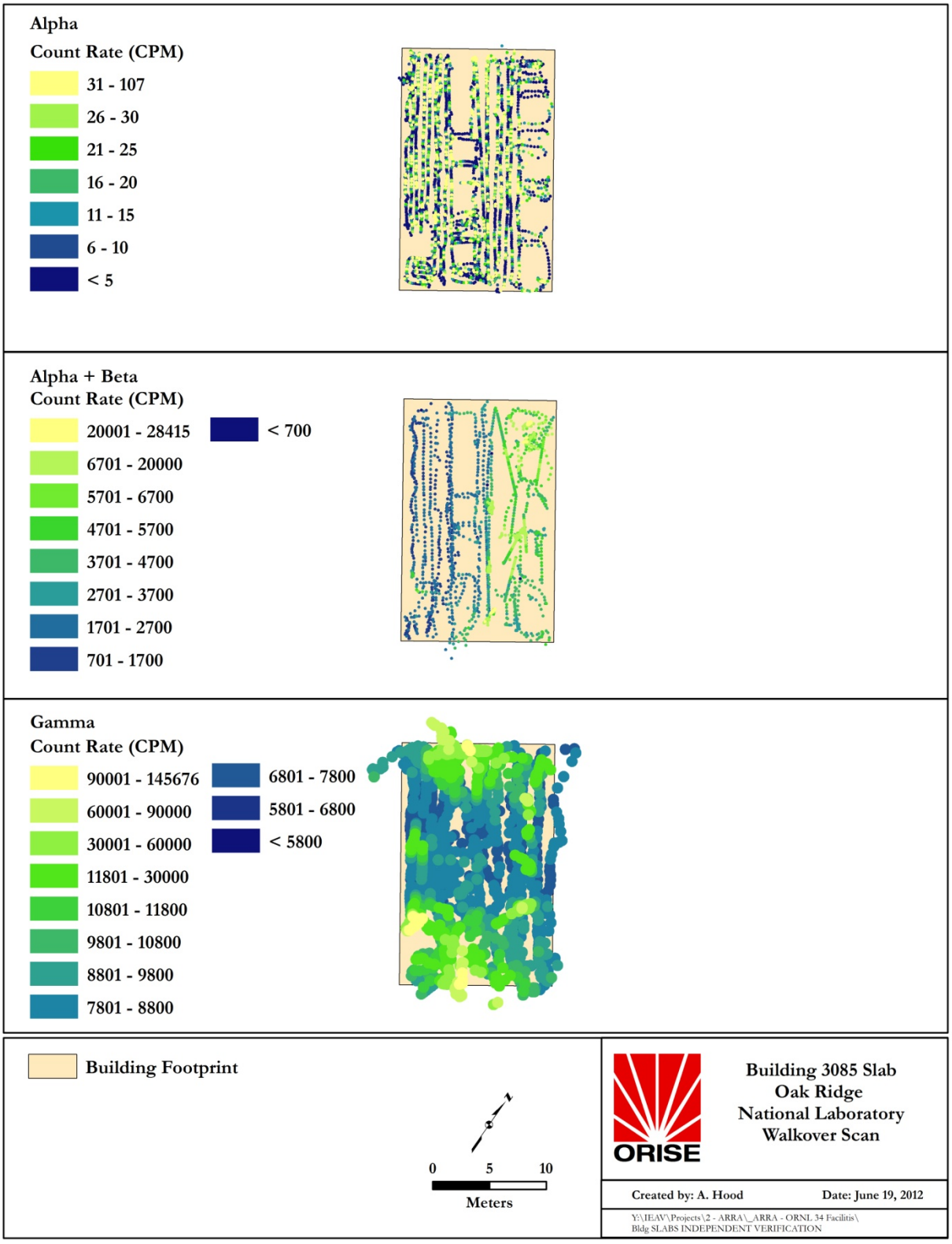

Fig. A-1. Surface Radiation Scans for the Building 3085 Slab

Building 3085 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	3,719	0	107	16	10	17
Alpha-plus-Beta	1,972	0	28,415	5,060	3,602	5,077

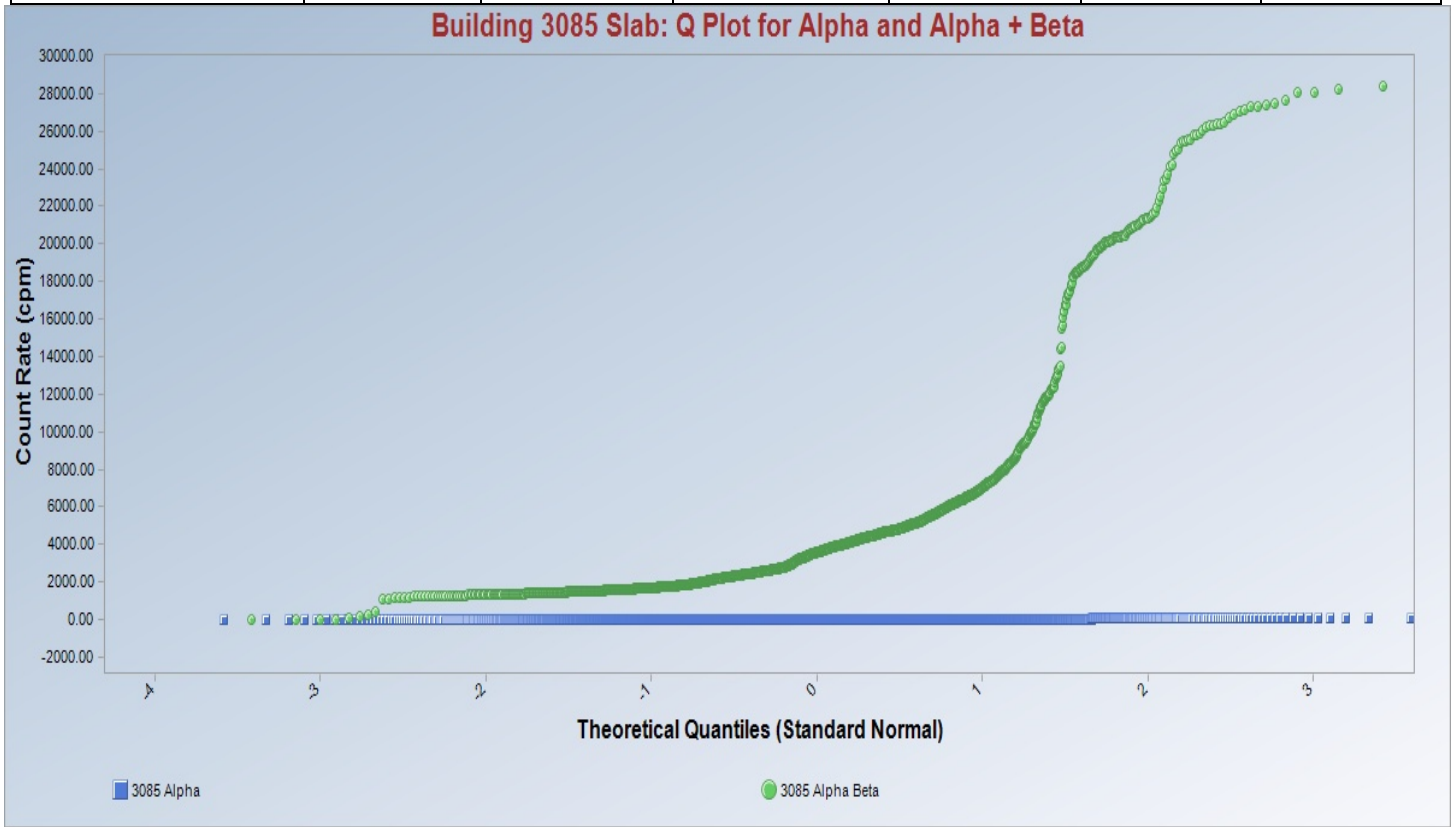

Fig. A-2. Alpha and Alpha-plus-Beta Scans Q-Plot for the Building 3085 Slab

Building 3085 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	1,685	6610	145,676	16,916	9,644	20,353

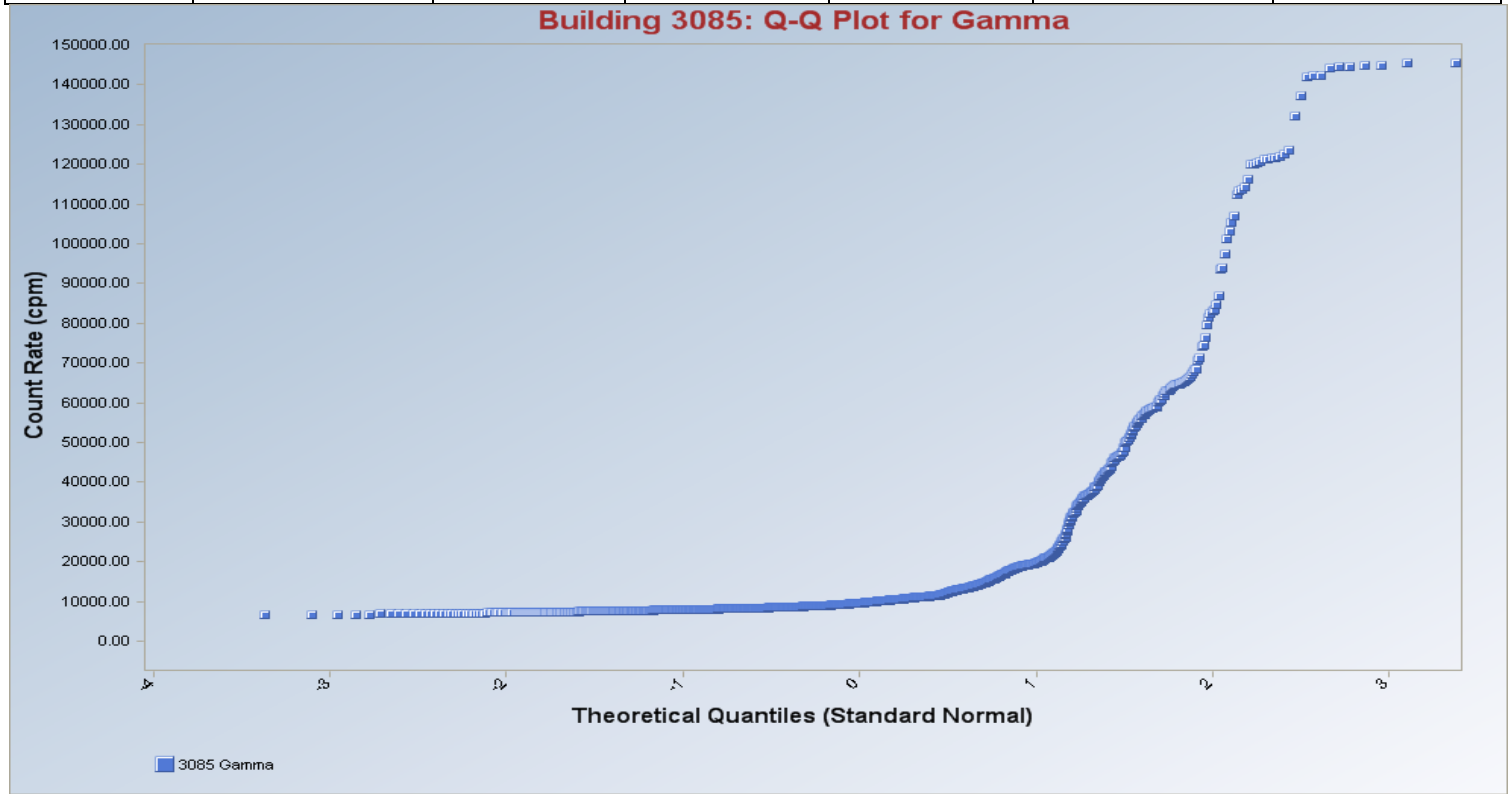

Fig. A-3. Gamma Scan Q-Plot for the Building 3085 Slab

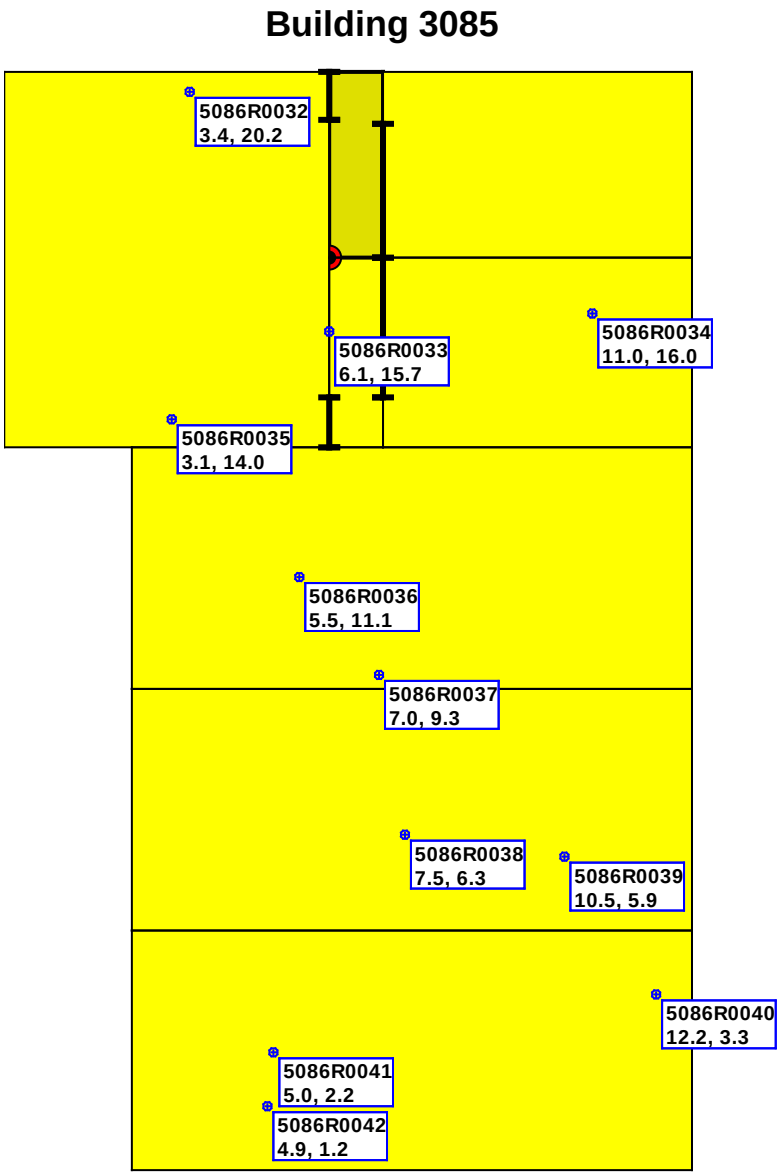

Fig. A-4. Sampling and Direct Measurement Locations for the Building 3085 Slab

Table A-1. Surface Activity Measurements for the Central Campus Building 3085 Slab
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Measurement Location/Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3085 Slab						
5086R0032	17	110	453	390	0	1
5086R0033	20	140	350	91	0	0
5086R0034	25	180	394	220	0	2
5086R0035	33	240	363	130	1	0
5086R0036	24	170	479	470	0	3
5086R0037	43	330	399	240	1	0
5086R0038	31	230	402	240	1	1
5086R0039	13	81	554	690	0	2
5086R0040	4	8	367	140	0	1
5086R0041	5	16	377	170	0	0
5086R0042	8	41	397	230	1	2
5086R0134	21	150	5,993	17,000	0	7
5086R0135	7	33	21,147	61,000	0	0

3098 BUILDING SLAB

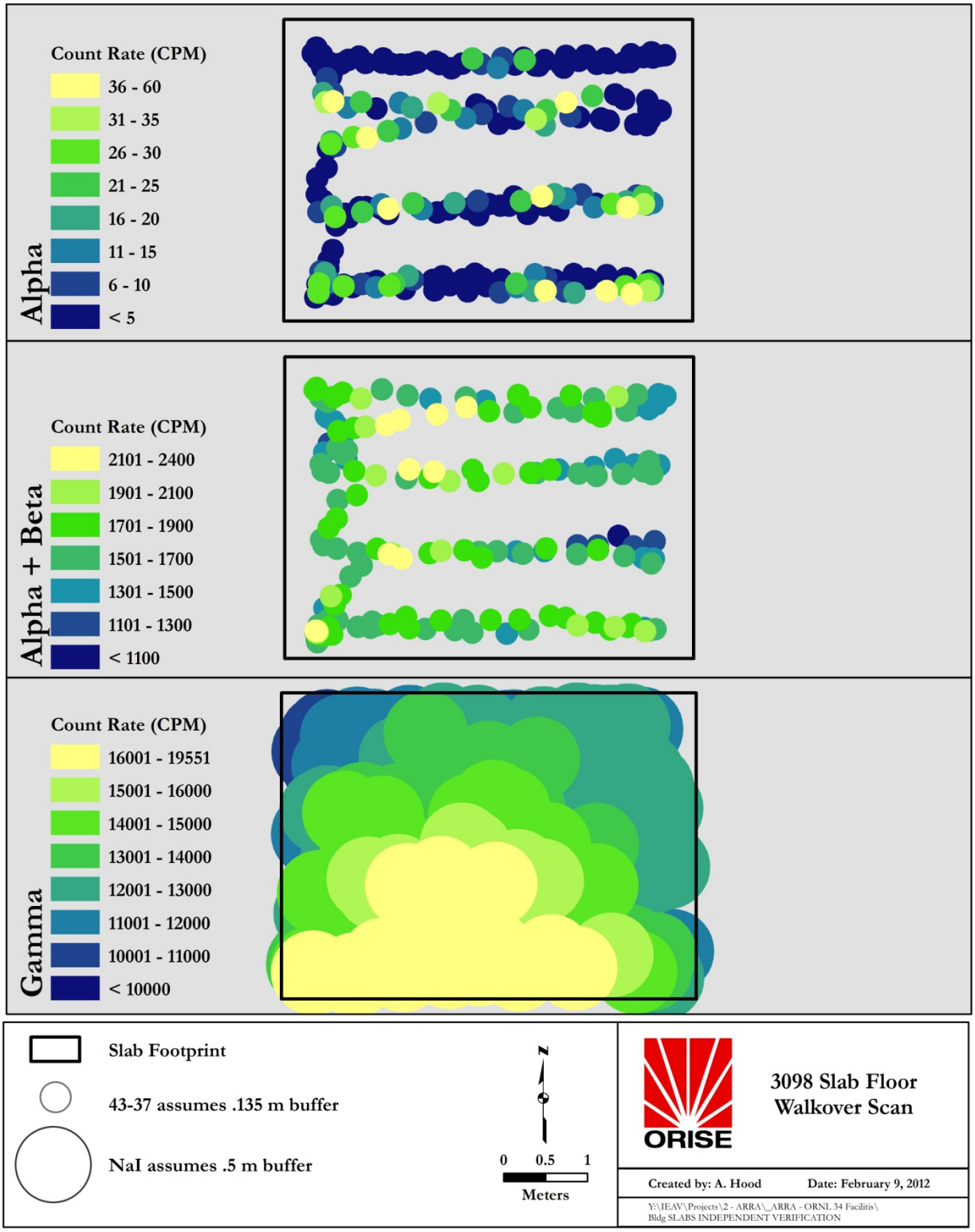

Fig. A-5. Surface Radiation Scans for the Building 3098 Slab

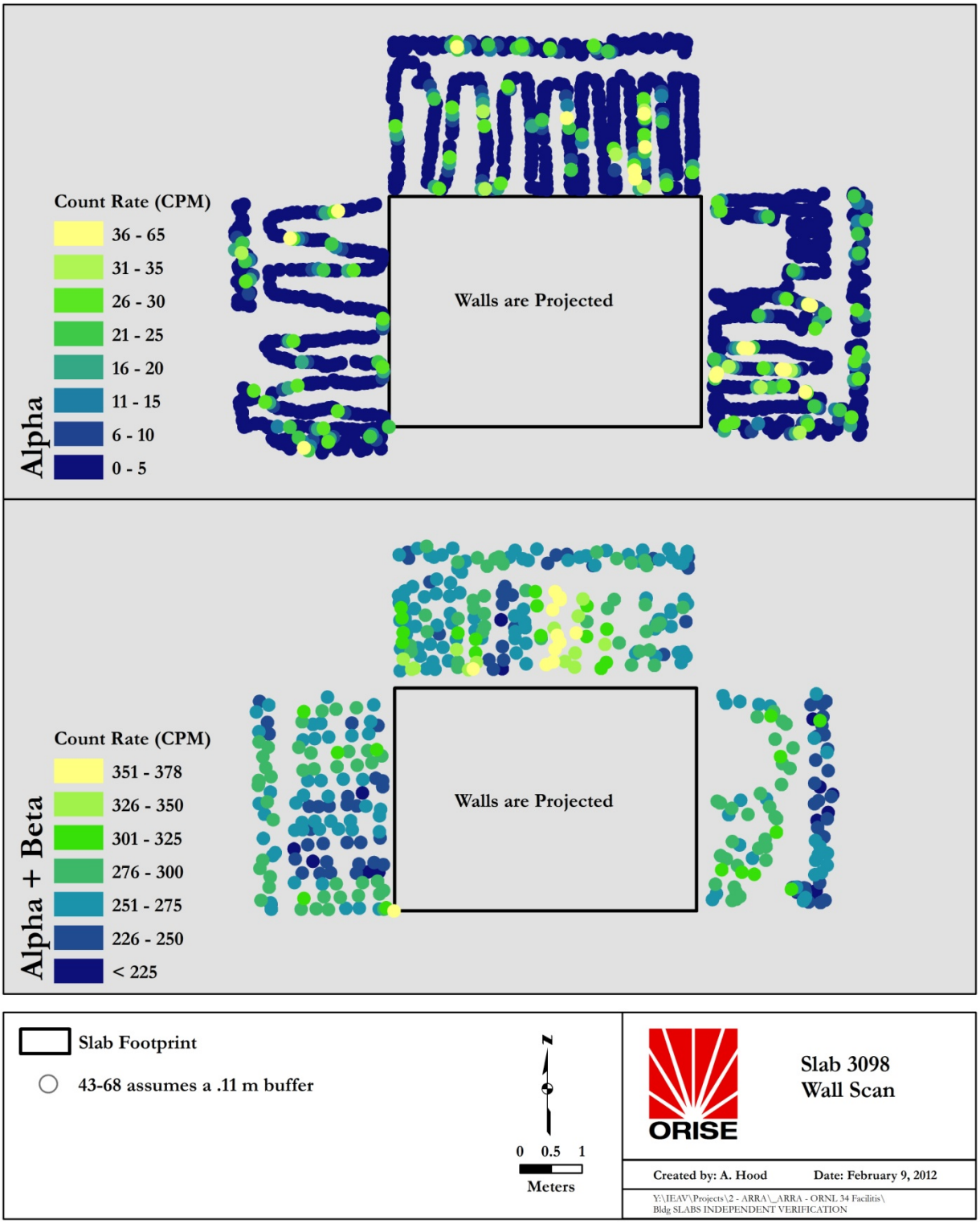

Fig. A-6. Surface Radiation Scans for the Building 3098 Remaining Walls

Building 3098 Slab Alpha and Alpha +Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Alpha Floor	218	0	60	9	3	12
Alpha Wall	1,353	0	65	4	0	9
Alpha-plus-Beta Floor	180	1,099	2,385	1,670	1,665	226
Alpha-plus-Beta Wall	512	209	378	272	269	32

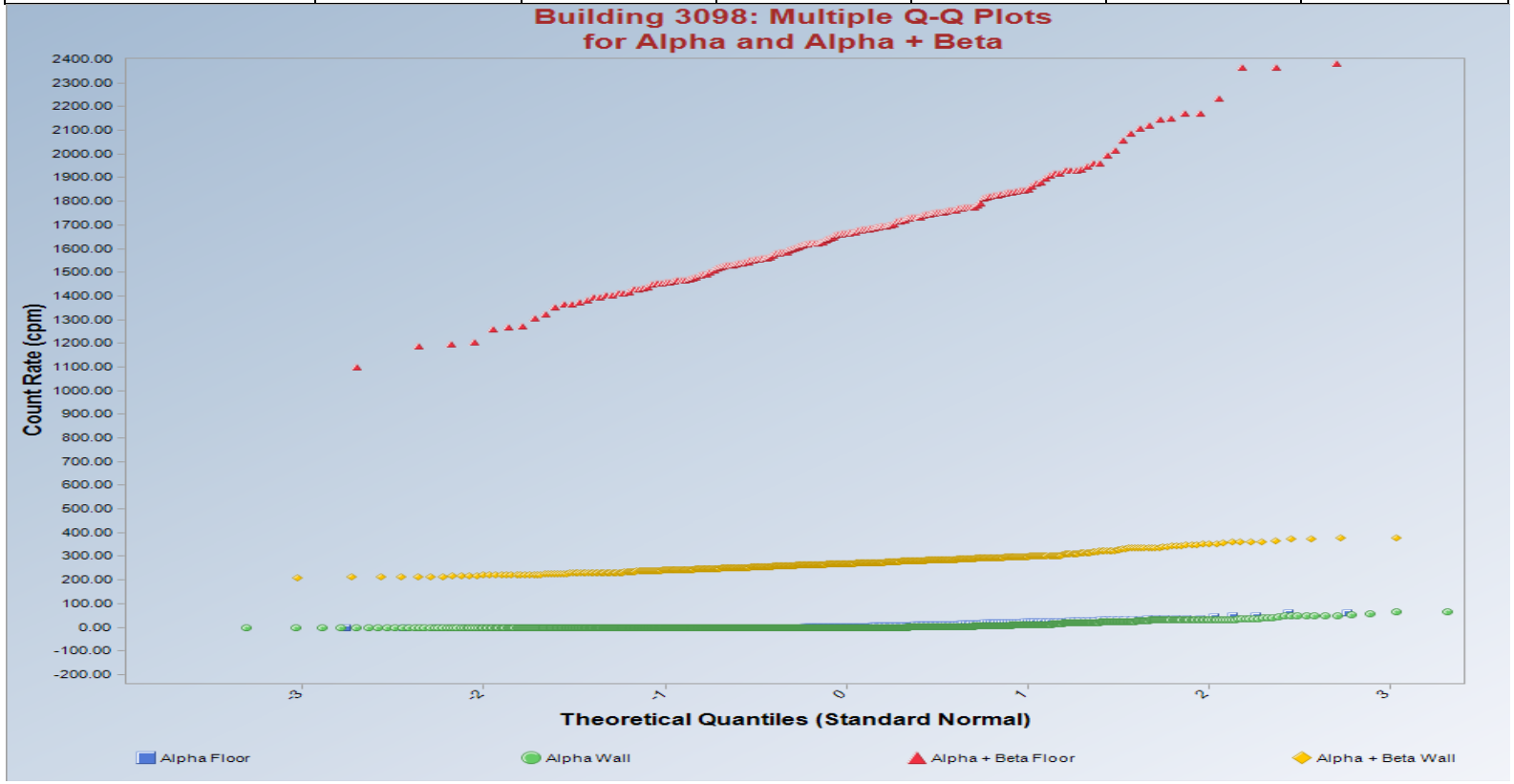

Fig. A-7. Alpha and Alpha-Plus-Beta Scan Q-Plot for the Building 3098 Slab

Building 3098 Slab Gamma Q-Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Gamma	144	9,981	19,551	13,641	13,277	1,966

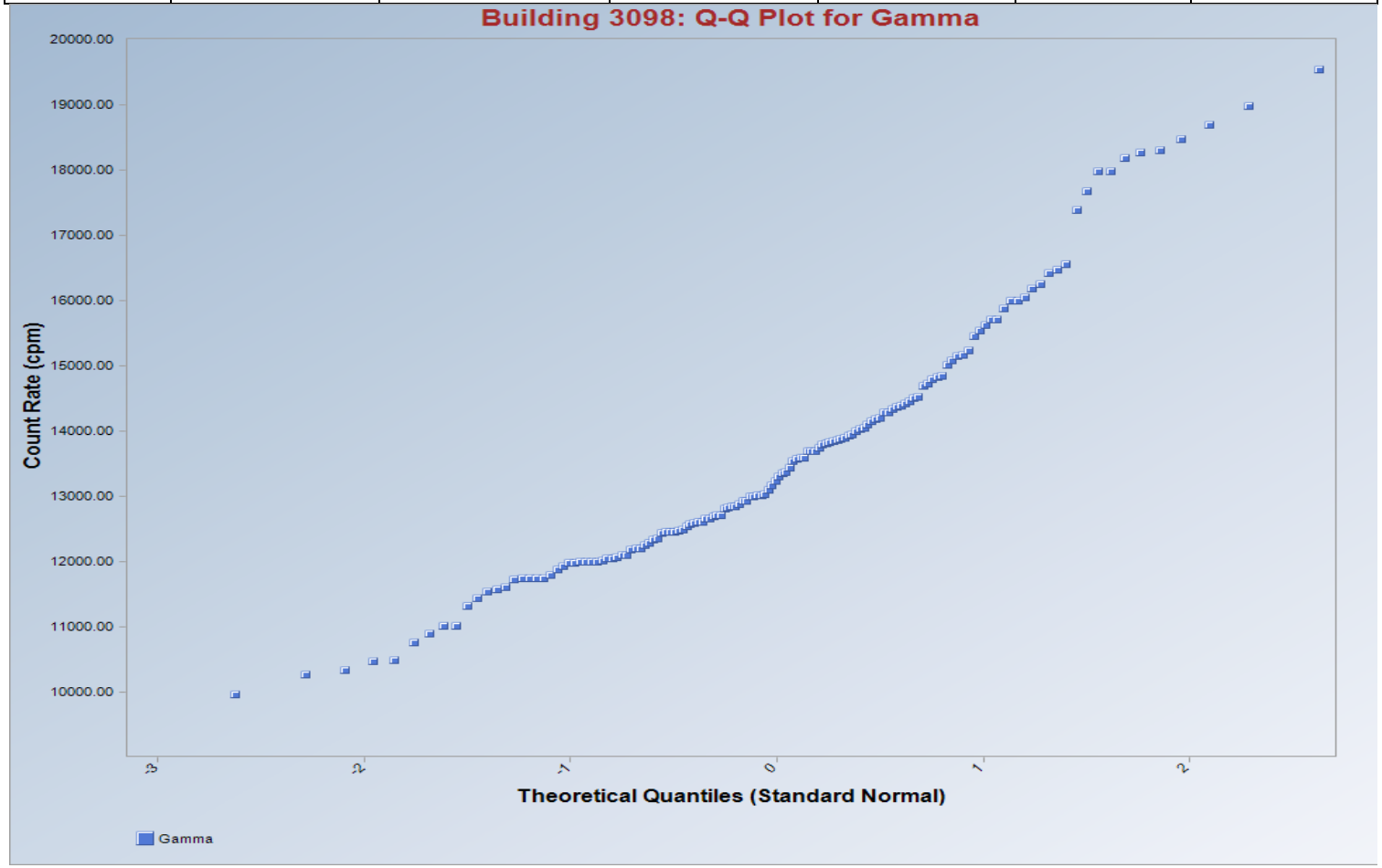

Fig. A-8. Gamma Scan Q-Plot for the Building 3098 Slab

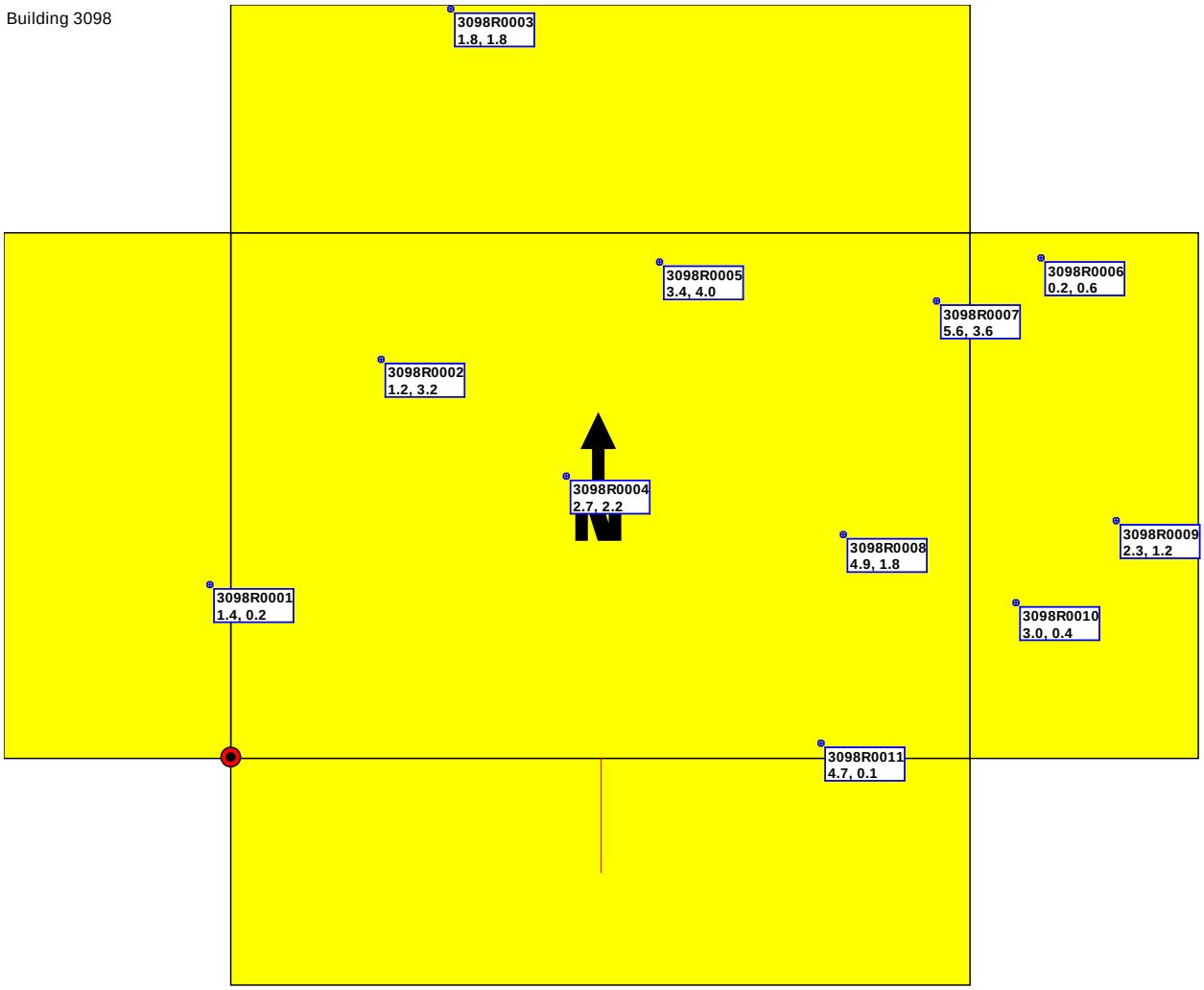

Fig. A-9. Sampling and Direct Measurement Locations for the Building 3098 Slab

Table A-2. Radionuclide Surface Activity Measurements for the Central Campus Building 3098 Slab
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Measurement Location/Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3098 Slab						
3098R0001	6	24	357	68	0	0
3098R0002	11	65	493	470	1	0
3098R0003	7	33	278	-160	0	1
3098R0004	8	41	478	420	0	4
3098R0005	6	24	492	460	0	2
3098R0006	9	49	252	-240	0	0
3098R0007	7	33	409	220	1	0
3098R0008	5	16	491	460	1	0
3098R0009	3	0	219	-340	1	5
3098R0010	8	41	253	-240	1	2
3098R0011	5	16	459	370	0	0

BUILDING 3102 SLAB

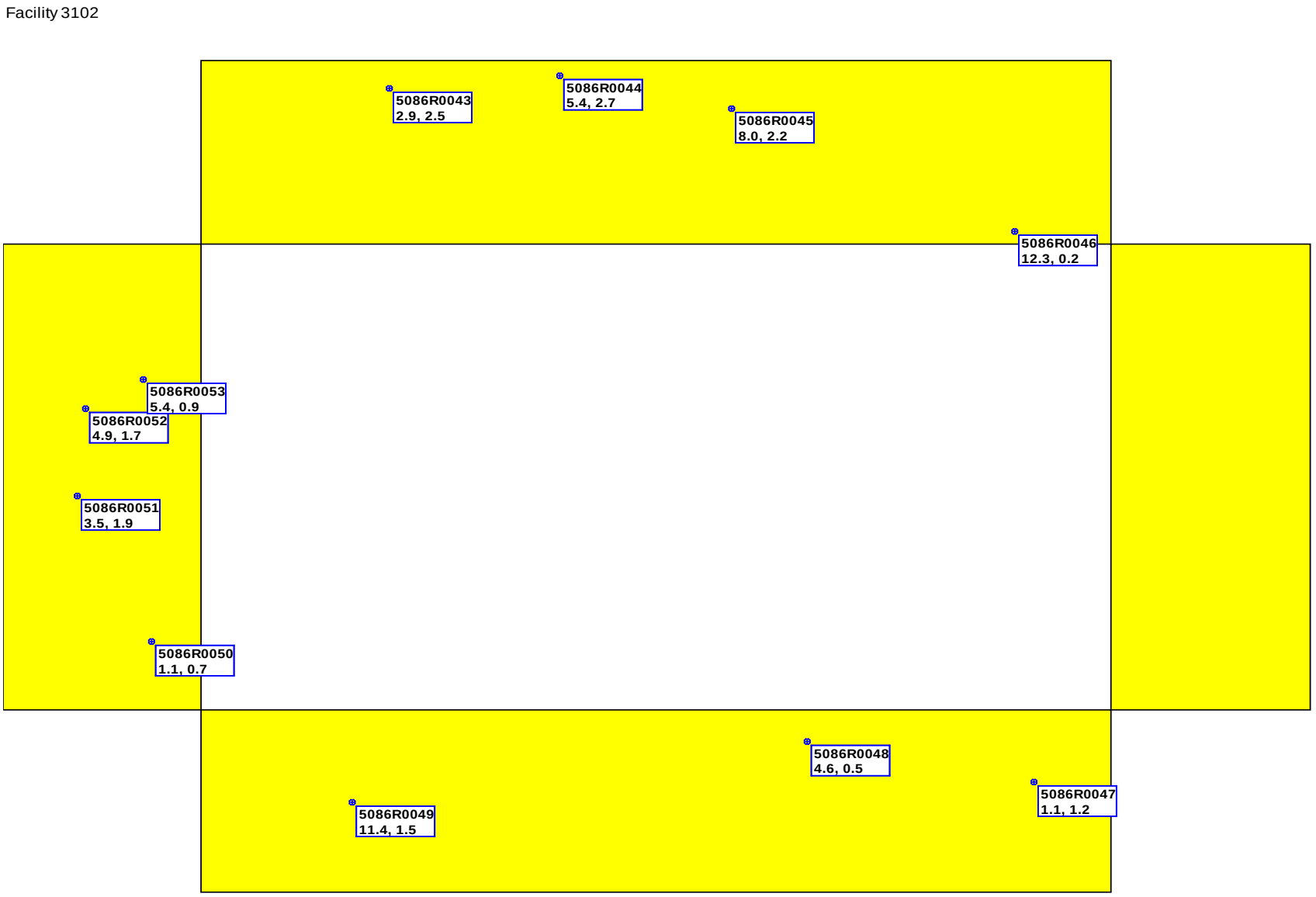

Fig. A-10. Sampling and Direct Measurement Locations for the Building 3102 Slab

Table A-3. Radionuclide Surface Activity Measurements for the Central Campus Building 3102 Slab
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Measurement Location/Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm^2)	Gross cpm	Activity (dpm/100cm^2)	Alpha Activity (dpm/100cm^2)	Beta Activity (dpm/100cm^2)
3102 Slab						
5086R0043	13	81	356	110	4	0
5086R0044	13	81	373	160	0	1
5086R0045	10	57	360	120	0	1
5086R0046	10	57	315	-12	0	4
5086R0047	10	57	373	160	0	0
5086R0048	5	16	336	50	4	0
5086R0049	8	41	384	190	1	0
5086R0050	12	73	323	12	1	1
5086R0051	22	150	320	3	4	1
5086R0052	11	65	339	59	0	2
5086R0053	12	73	314	-15	4	1

BUILDING 3117A SLAB

3117A

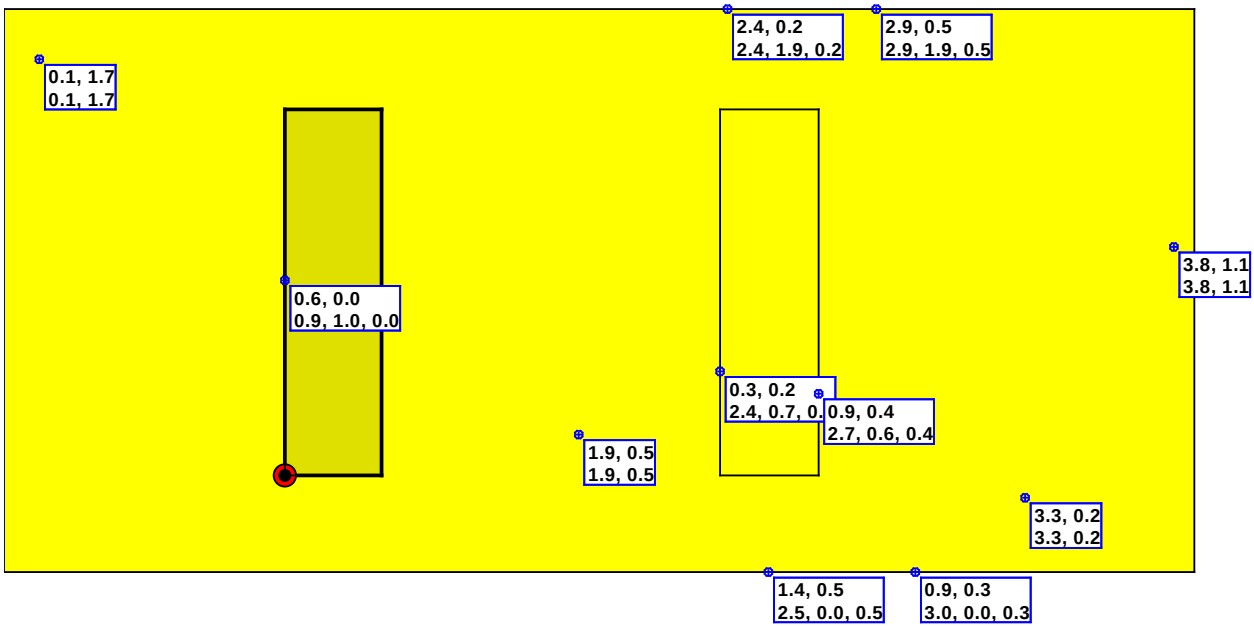

Fig. A-11. Sampling and Direct Measurement Locations for the Building 3117A Slab

Table A-4. Radionuclide Surface Activity Measurements for the Central Campus Building 3117A Slab
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha and Beta Activity	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Activity (dpm/100cm²)	Activity (dpm/100cm²)
3117A Slab						
5086R0054	5	16	336	50	0	2
5086R0055	2	-8	315	-12	1	1
5086R0056	4	8	278	-120	1	1
5086R0057	7	33	353	100	0	0
5086R0058	4	8	282	-110	0	1
5086R0059	2	-8	317	-10	0	0
5086R0060	11	65	384	190	0	0
5086R0061	7	33	327	20	0	4
5086R0062	12	73	317	-6	0	0
5086R0063	8	41	266	-160	0	0
5086R0064	8	41	308	-32	0	2

BUILDING 3119 SLAB

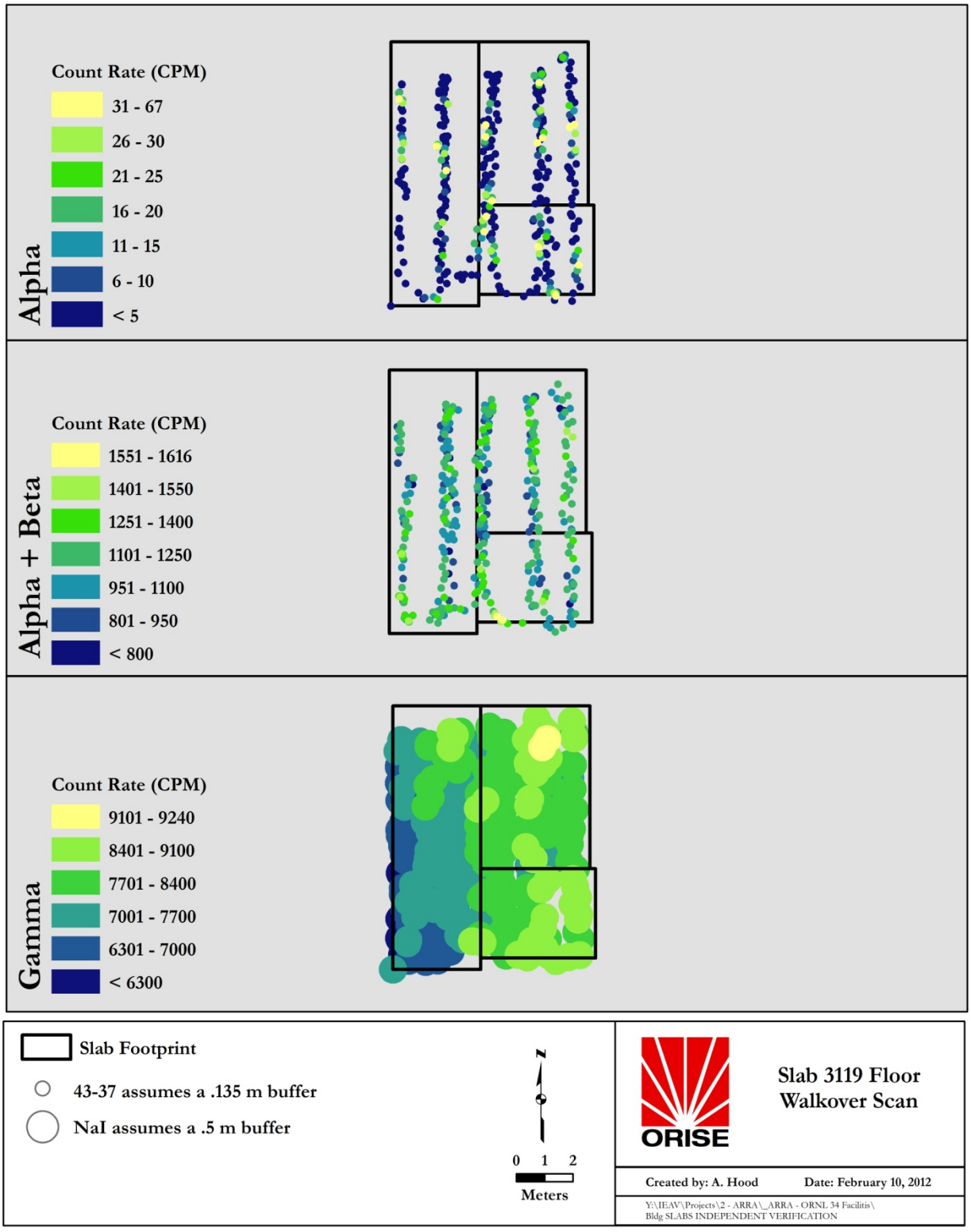

Fig. A-12. Surface Radiation Scans for the Building 3119 Slab

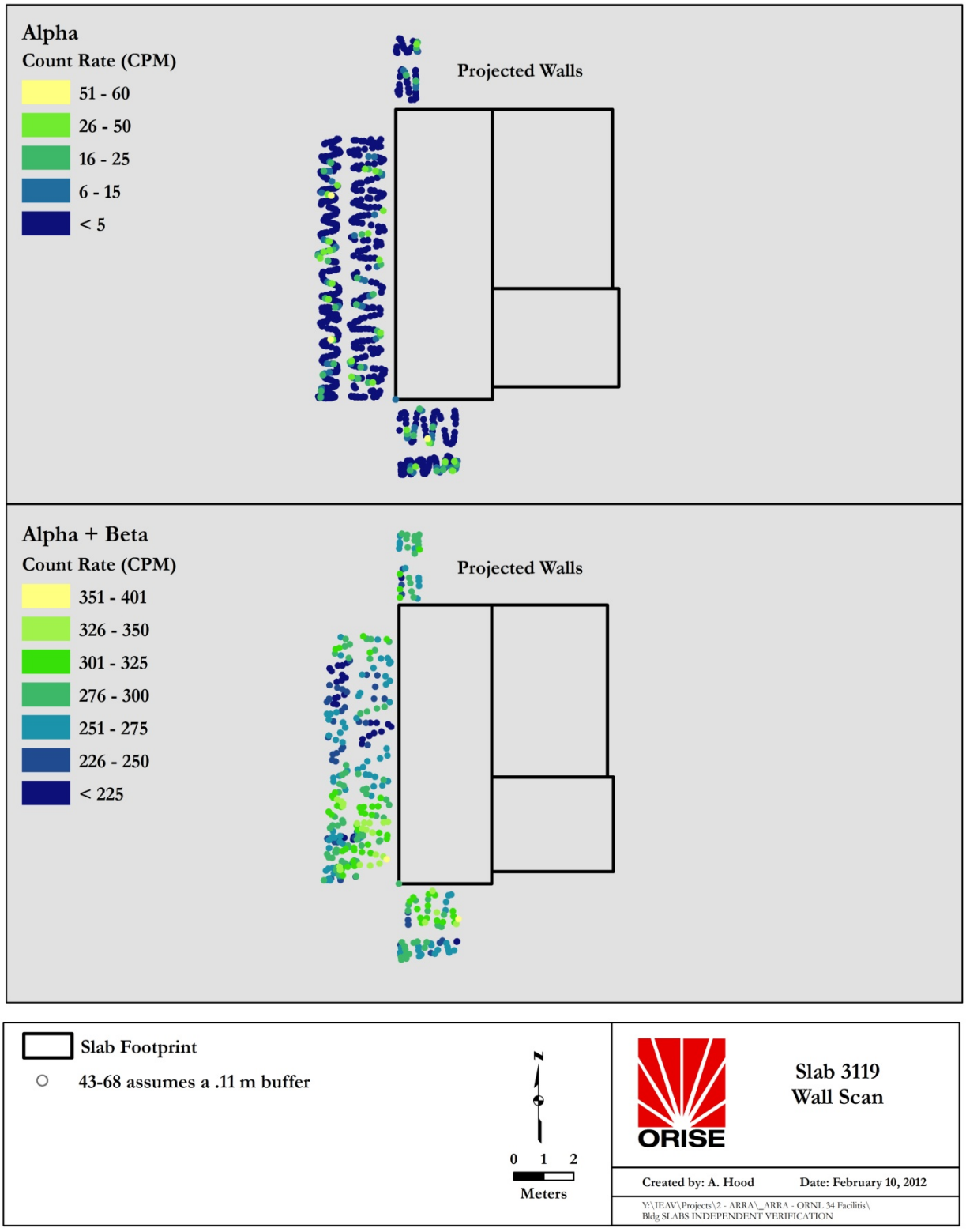

Fig. A-13. Surface Radiation Scans for the Building 3119 Slab

Building 3119 Slab Gamma Q-Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Alpha Floor	371	0	67	6.8	1	11
Alpha Wall	760	0	60	4.0	0	8.4
Alpha-plus-Beta Floor	368	734	1,616	1,106	1107	161.9
Alpha-plus-Beta Wall	537	172	401	271	269	35.48

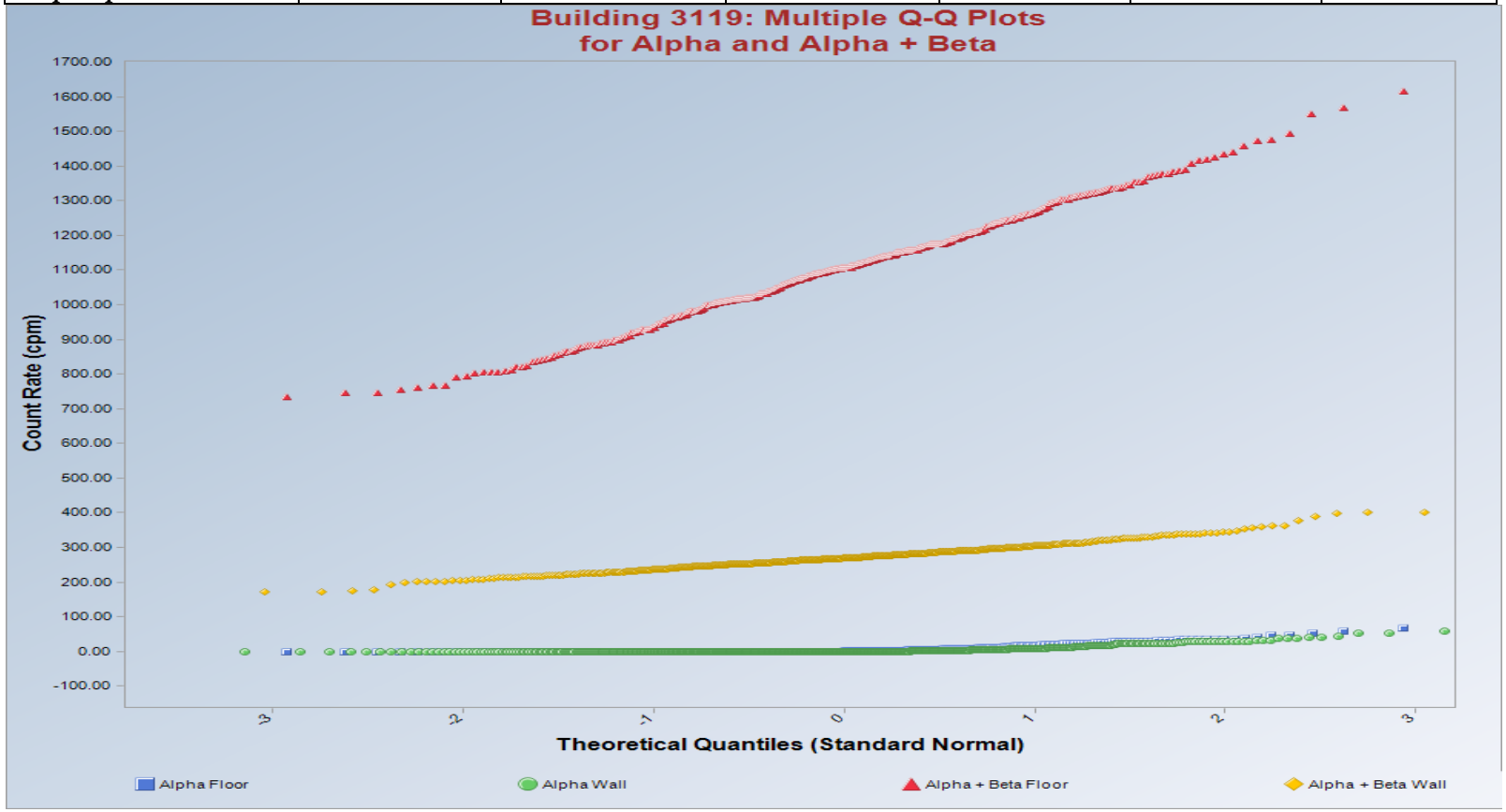

Fig. A-14. Alpha and Alpha-plus-Beta Scans Q-Plot for the Building 3119 Slab and Remaining Walls

Building 3119 Slab Gamma Q-Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Gamma	296	5,838	9,240	7,696	7,798	701.9

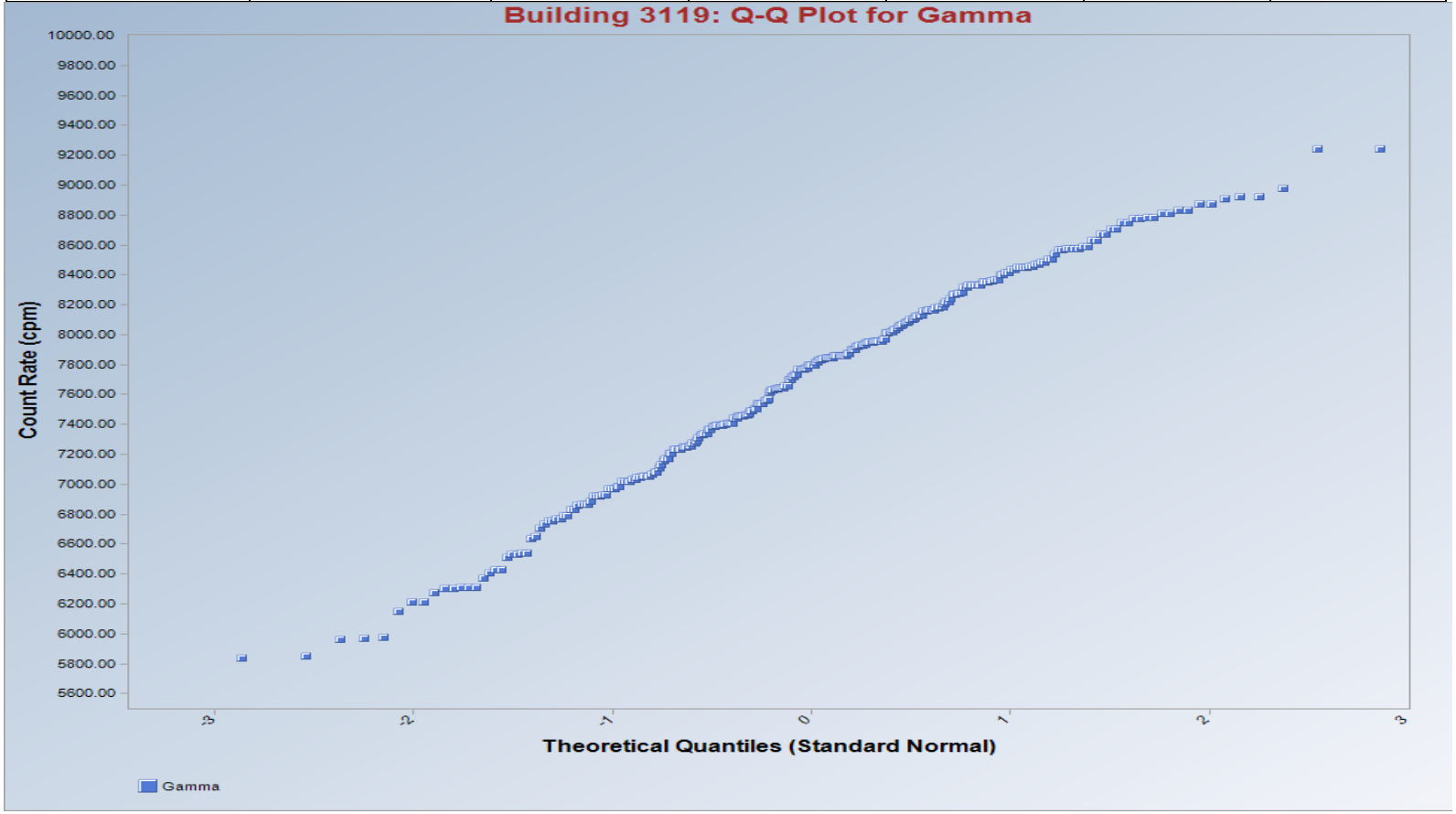

Fig. A-15. Gamma Scan Q-Plot for the Building 3119 Slab

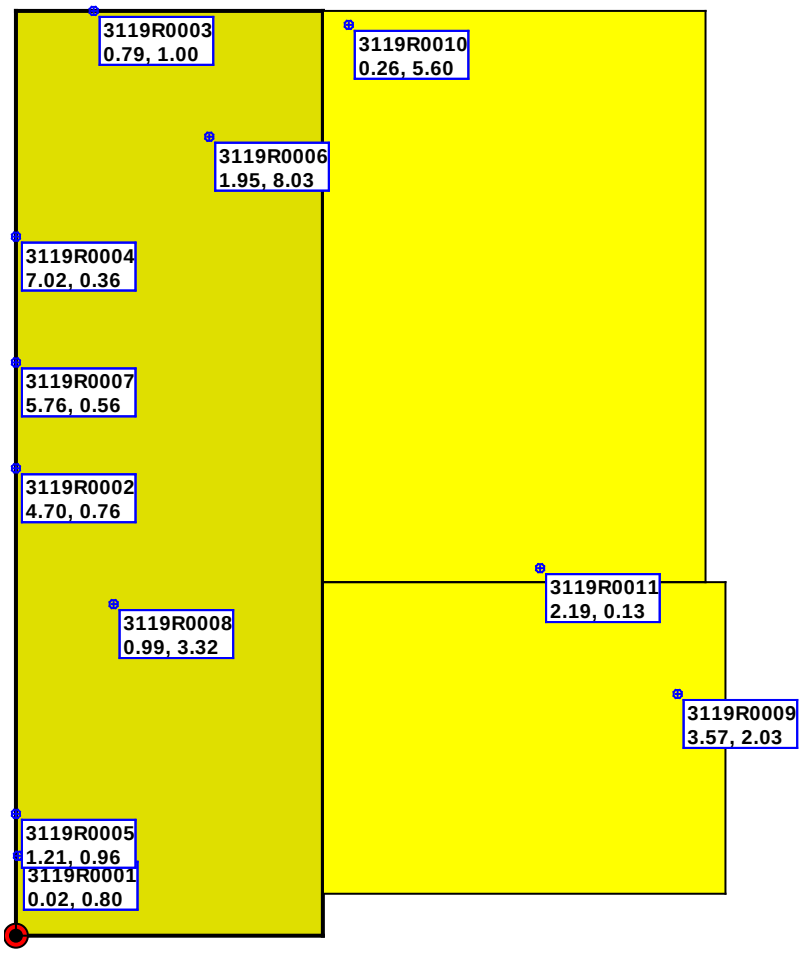

Fig. A-16. Sampling and Direct Measurement Locations for the Building 3119 Slab and Remaining Walls

Table A-5. Radionuclide Surface Activity Measurements for the Central Campus Building 3119 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha and Beta Activity	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Activity (dpm/100cm²)	Activity (dpm/100cm²)
3119 Slab						
3119R0001	6	24	328	-20	0	1
3119R0002	6	24	414	280	0	1
3119R0003	4	8	374	140	0	0
3119R0004	3	0	373	130	0	2
3119R0005	2	-8	349	52	0	5
3119R0006	8	41	413	270	1	0
3119R0007	4	8	389	190	1	0
3119R0008	8	41	305	-100	0	0
3119R0009	7	33	363	100	0	5
3119R0010	3	0	477	490	0	0
3119R0011	7	33	290	-150	0	0

BUILDING 3503 SLAB

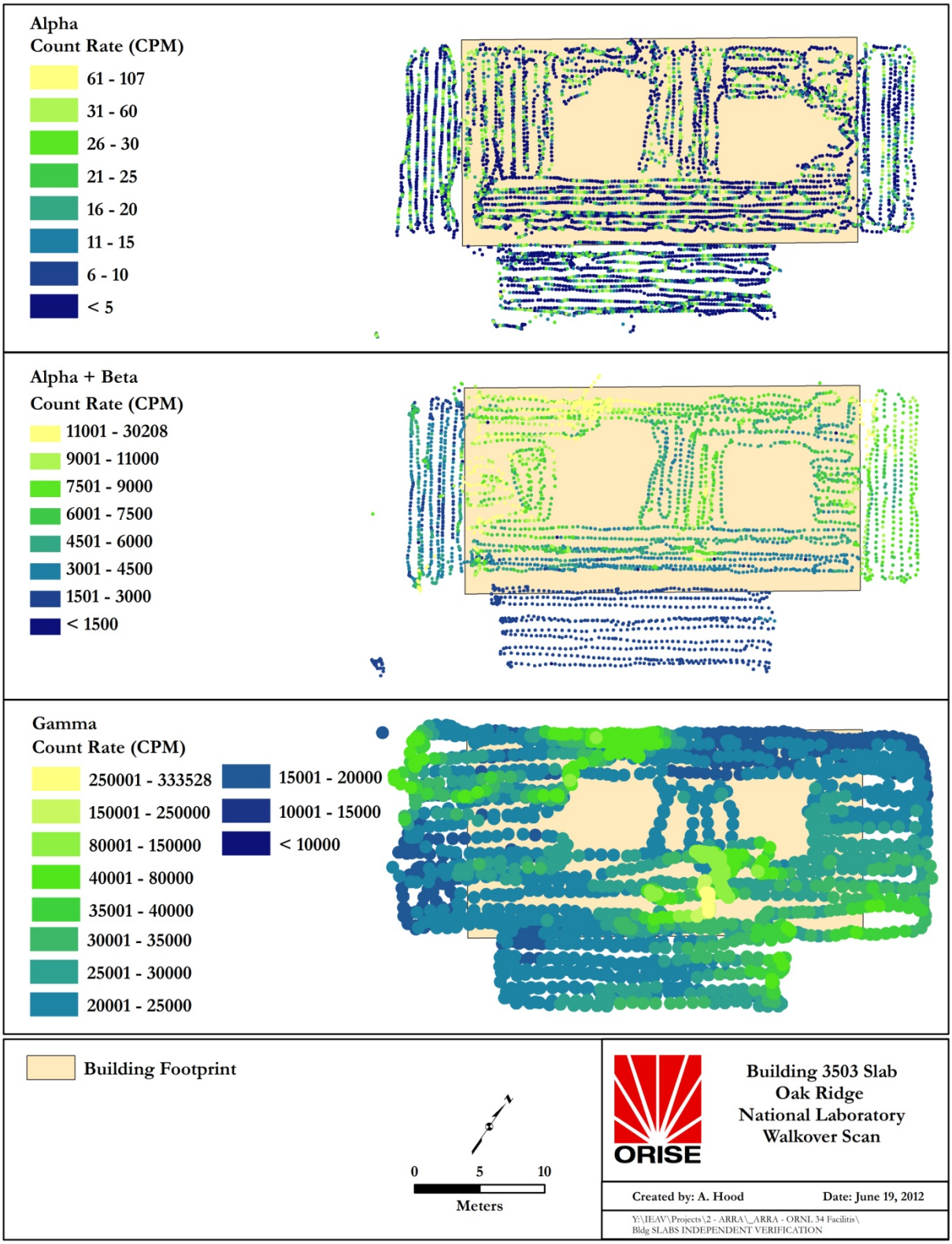

Fig. A-17. Surface Radiation Scans for the Building 3503

Building 3503 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	5,761	0	107	11	5	14
Alpha-plus-Beta	4,317	0	30,208	6,152	5,490	3,729

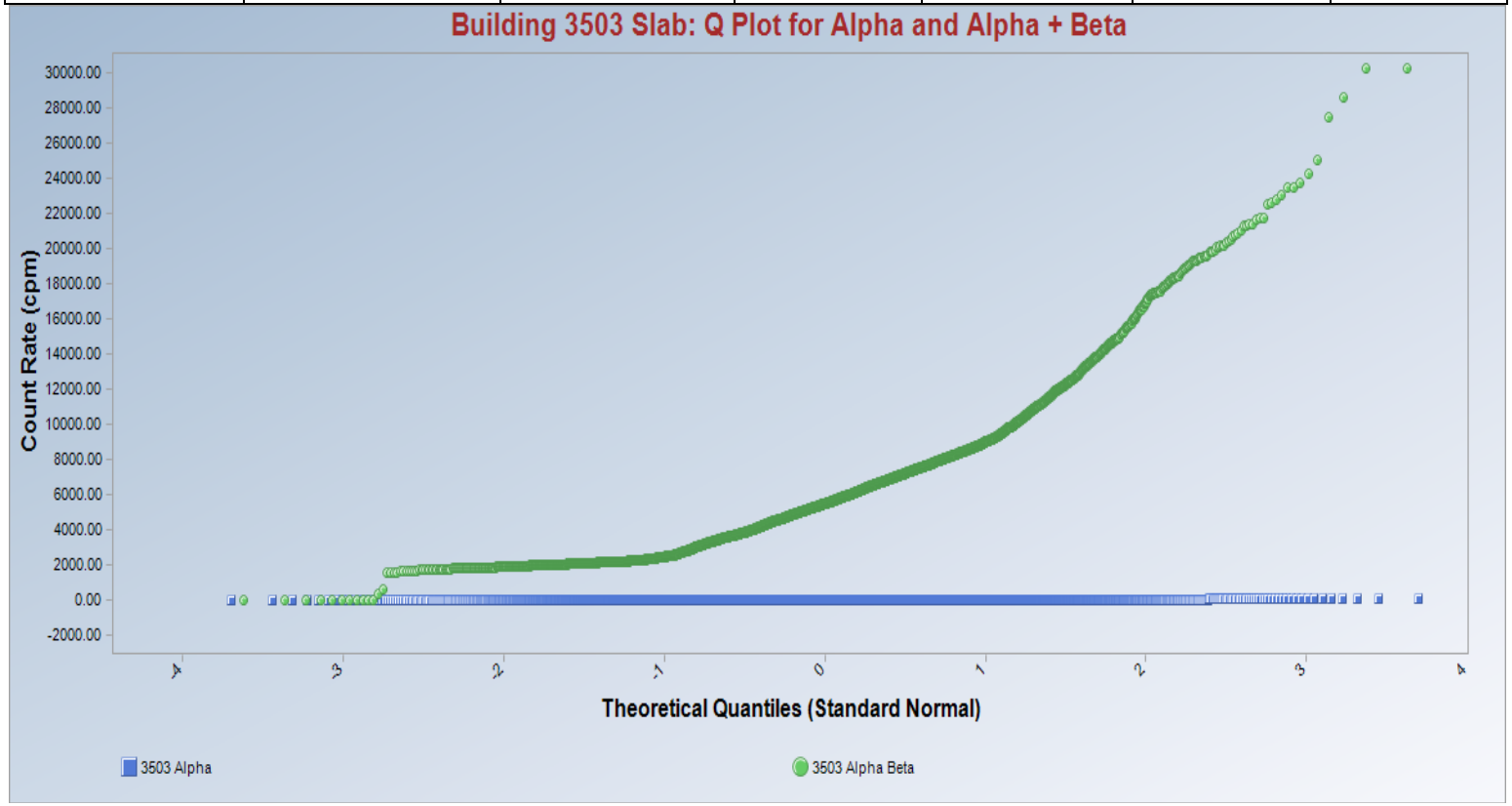

Fig. A-18. Alpha and Alpha-plus-Beta Scans Q-Plot for the Building 3503 Slab

Building 3503 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	2,209	14,920	333,528	39,888	25,143	44,303

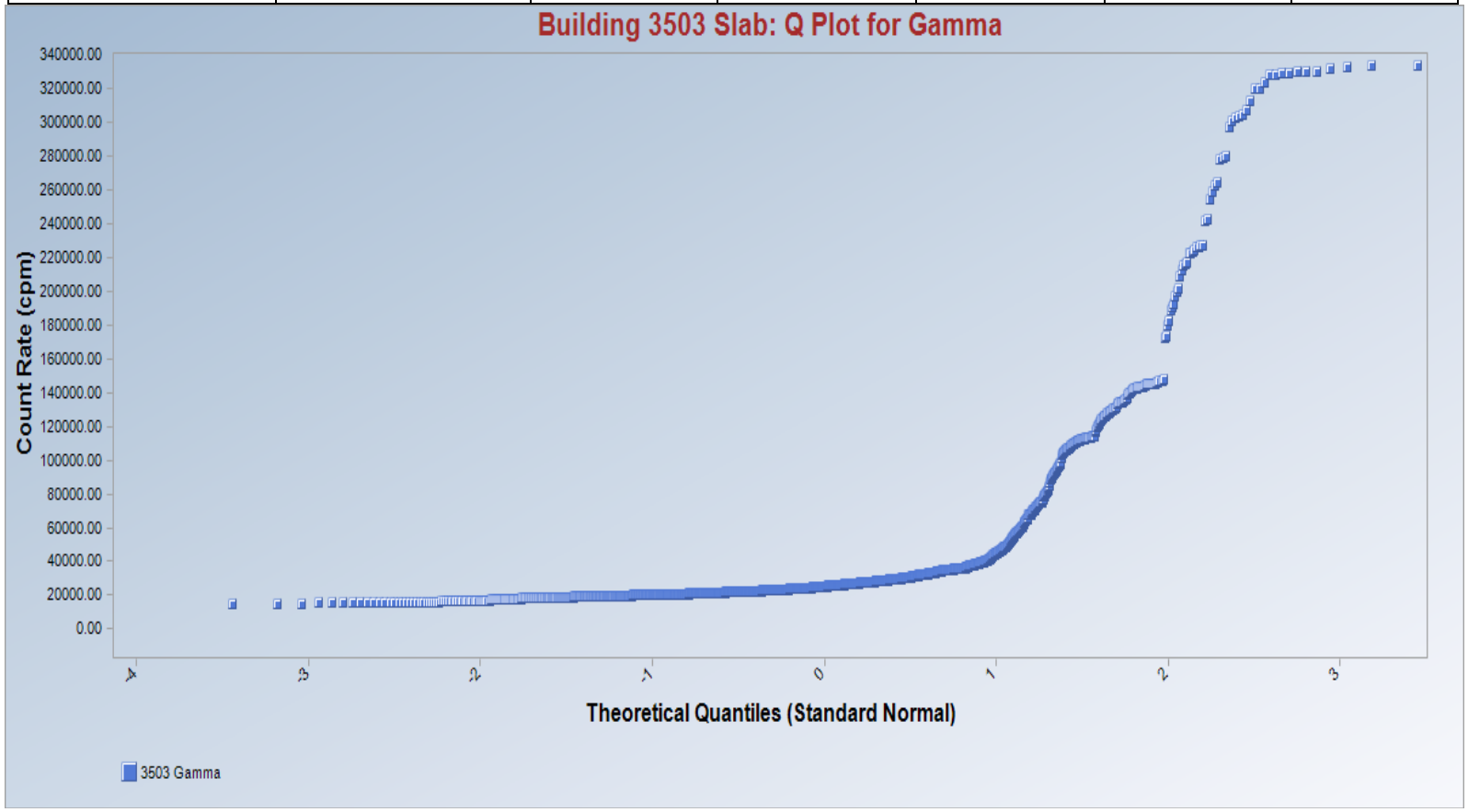

Fig. A-19. Gamma Q-Plot for the Building 3503 Slab

Building 3503

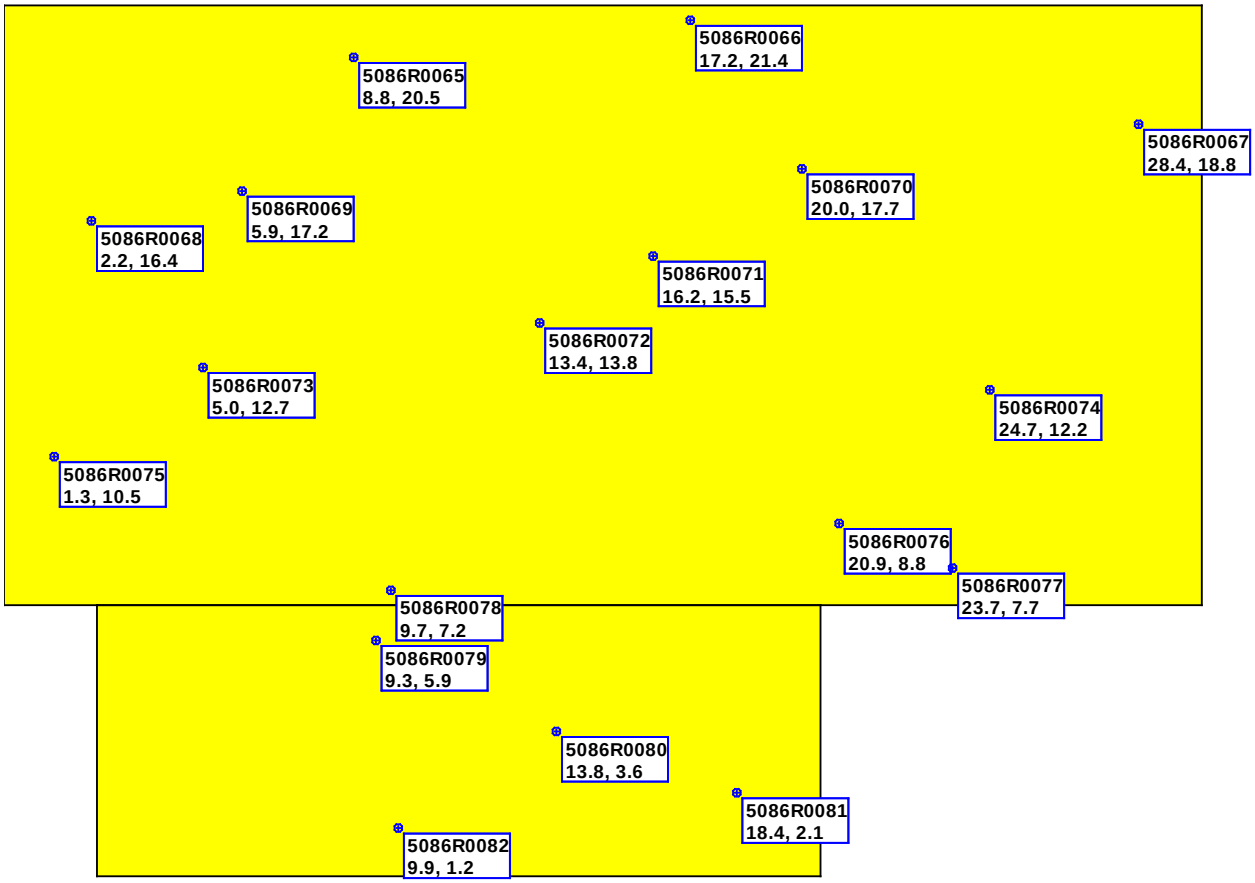

Fig. A-20. Sampling and Direct Measurement Locations for the Building 3503 Slab

Table A-6. Radionuclide Activities for the Southeast Laboratory Complex Building 3503 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3503						
5086R0065	4	8	1,299	2,900	0	0
5086R0066	2	-8	431	330	0	0
5086R0067	3	0	431	330	5	2
5086R0068	8	41	509	560	1	0
5086R0069	8	41	495	520	6	2
5086R0070	5	16	476	460	0	2
5086R0071	10	57	501	530	0	0
5086R0072	2	-8	581	770	1	2
5086R0073	16	110	514	570	0	0
5086R0074	9	49	439	350	0	3
5086R0075	5	16	449	380	0	0
5086R0076	2	-8	604	840	1	0
5086R0077	4	8	495	520	0	0
5086R0078	3	0	458	410	0	0
5086R0079	10	57	522	600	0	0
5086R0080	5	16	554	690	1	2
5086R0081	3	0	554	690	1	0
5086R0082	3	0	488	500	0	2
5086R0133	5	16	4,333	12,000	0	2

BUILDING 3504 SLAB

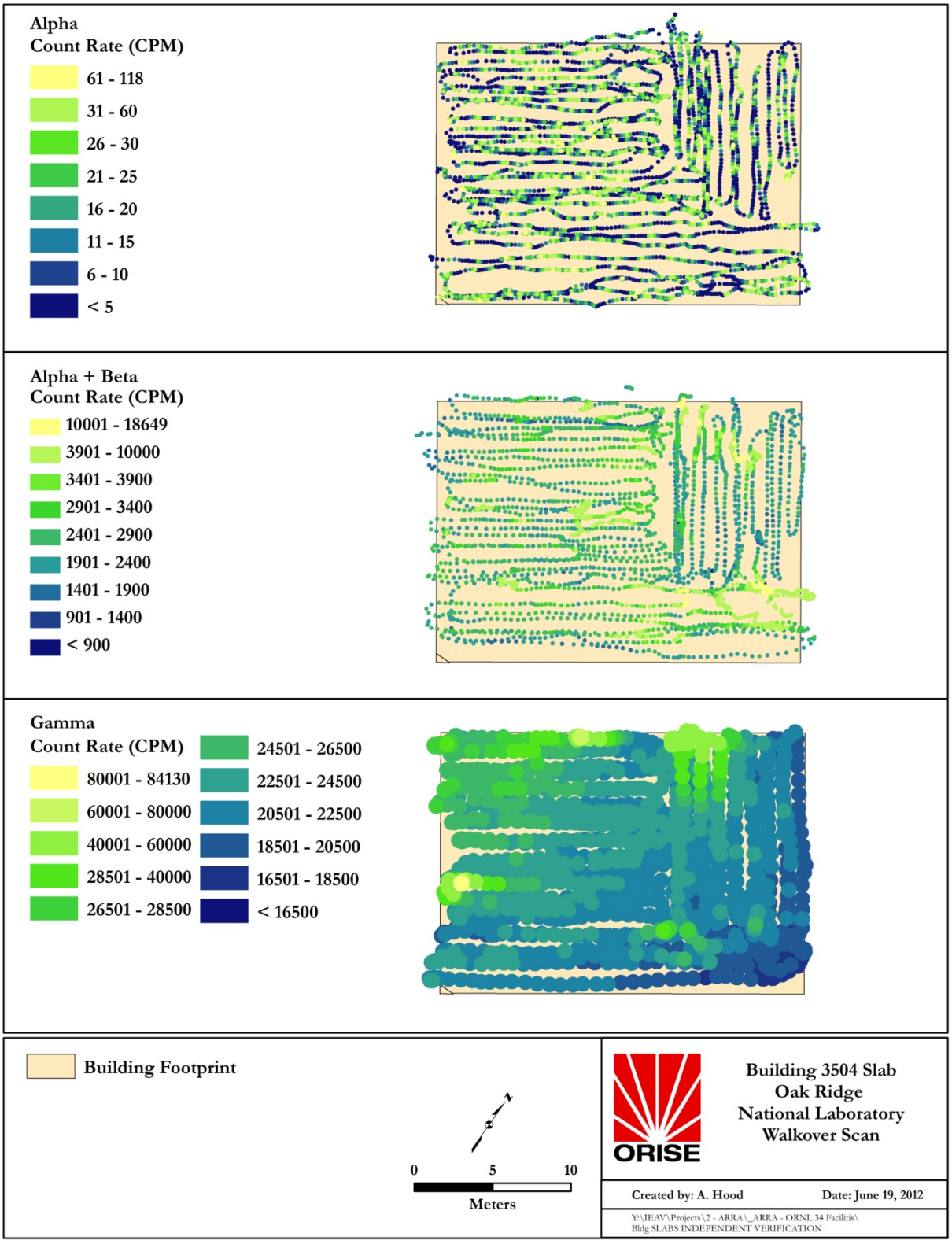

Fig. A-21. Surface Radiation Scans for the Building 3504 Slab

Building 3504 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	4,147	0	118	17	12	18
Alpha-plus-Beta	3,439	0	18,649	3,749	2,704	2,722

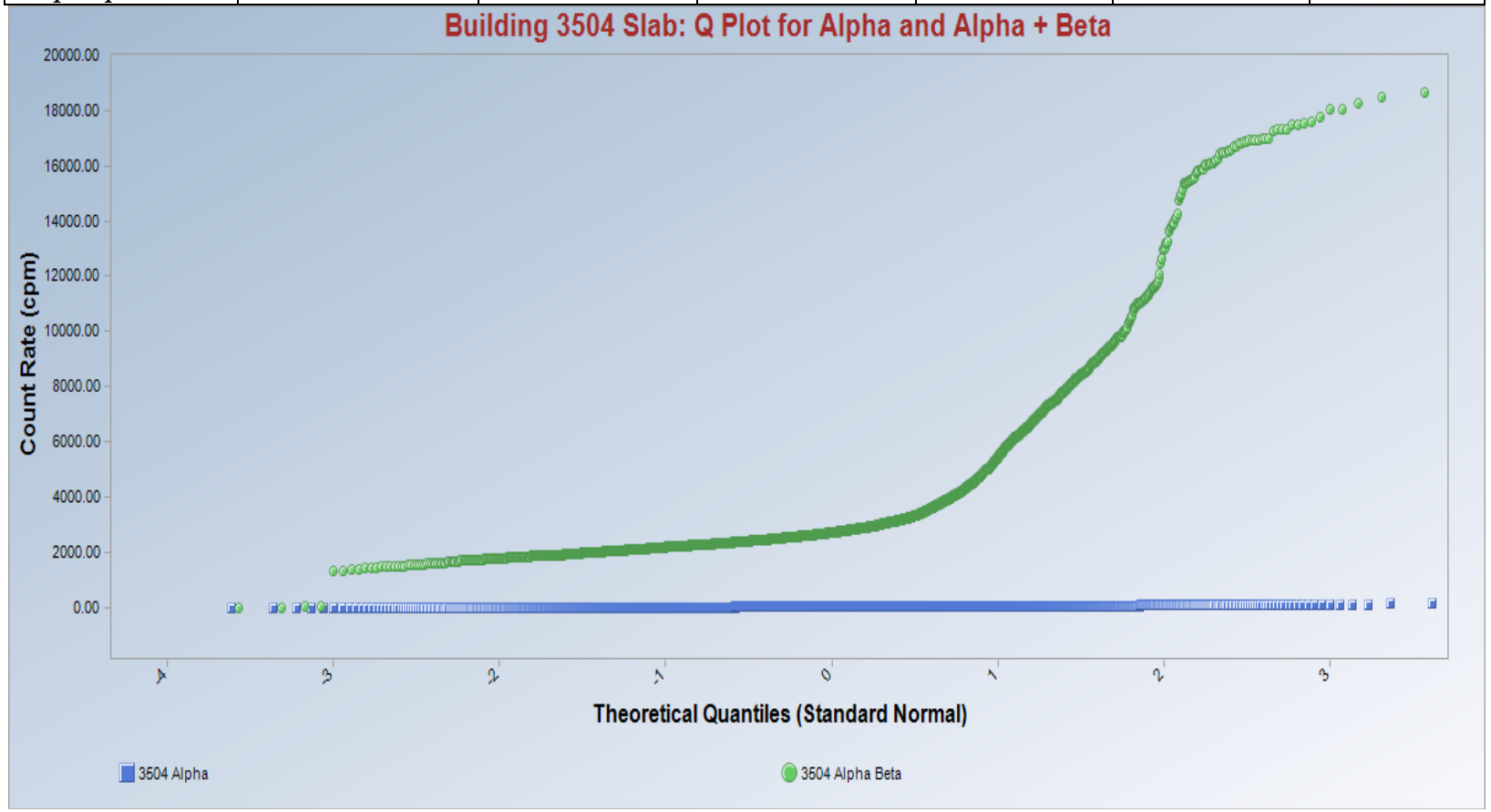

Fig. A-22. Alpha and Alpha Plus Beta Scan Q-Plot for the Building 3504 Slab

Building 3504 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	1,243	14,567	84,130	23,974	22,501	6,851

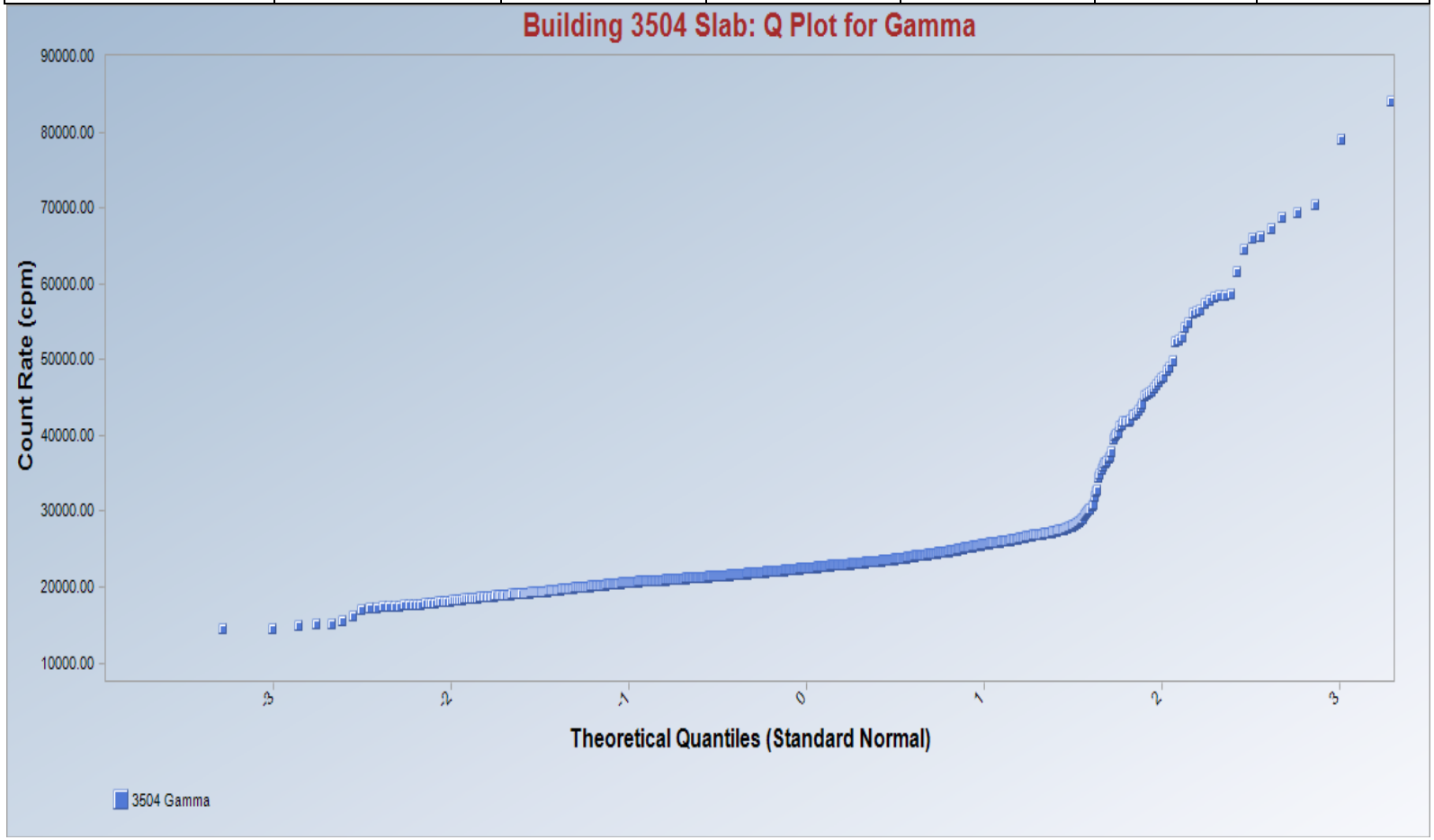

Fig. A-23. Gamma Scan Q-Plot for the Building 3504 Slab

3504

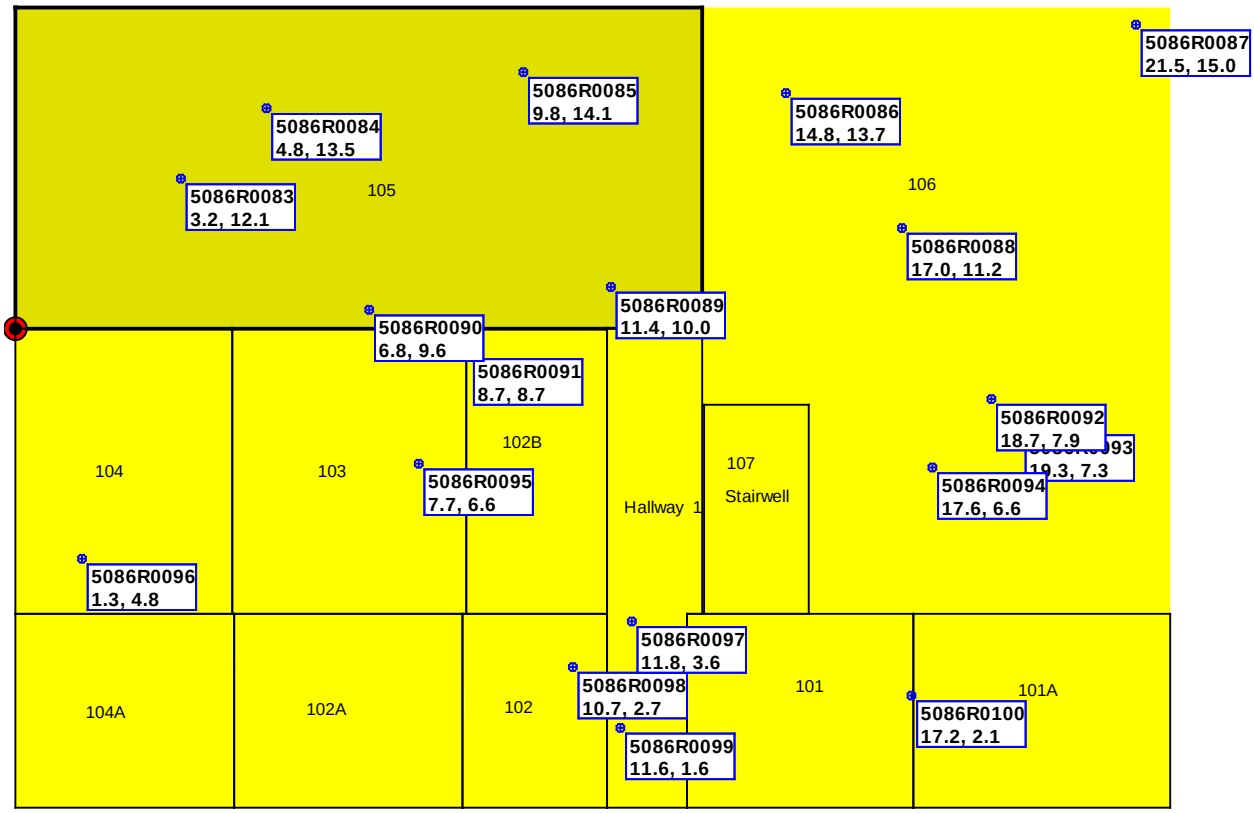

Fig. A-24. Sampling and Direct Measurement Locations for the Building 3504 Slab

Table A-7. Radionuclide Activities for the Southeast Laboratory Complex Building 3504 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
5086R0083	8	41	537	640	1	2
5086R0084	16	110	755	1,300	1	1
5086R0085	3	0	788	1,400	0	0
5086R0086	7	33	652	980	0	2
5086R0087	3	0	655	990	0	0
5086R0088	14	90	580	770	0	3
5086R0089	13	81	753	1,300	0	2
5086R0090	11	65	594	810	0	0
5086R0091	9	49	598	820	1	2
5086R0092	3	0	473	450	0	0
5086R0093	4	8	595	810	0	3
5086R0094	7	33	591	800	0	5
5086R0095	9	49	594	810	4	0
5086R0096	9	49	809	1,400	0	0
5086R0097	3	0	643	950	1	0
5086R0098	11	65	1,049	2,100	1	0
5086R0099	9	49	1,221	2,700	0	1
5086R0100	8	41	580	770	0	4
5086R0130	12	73	4,428	12,000	0	4

BUILDING 3508 SLAB

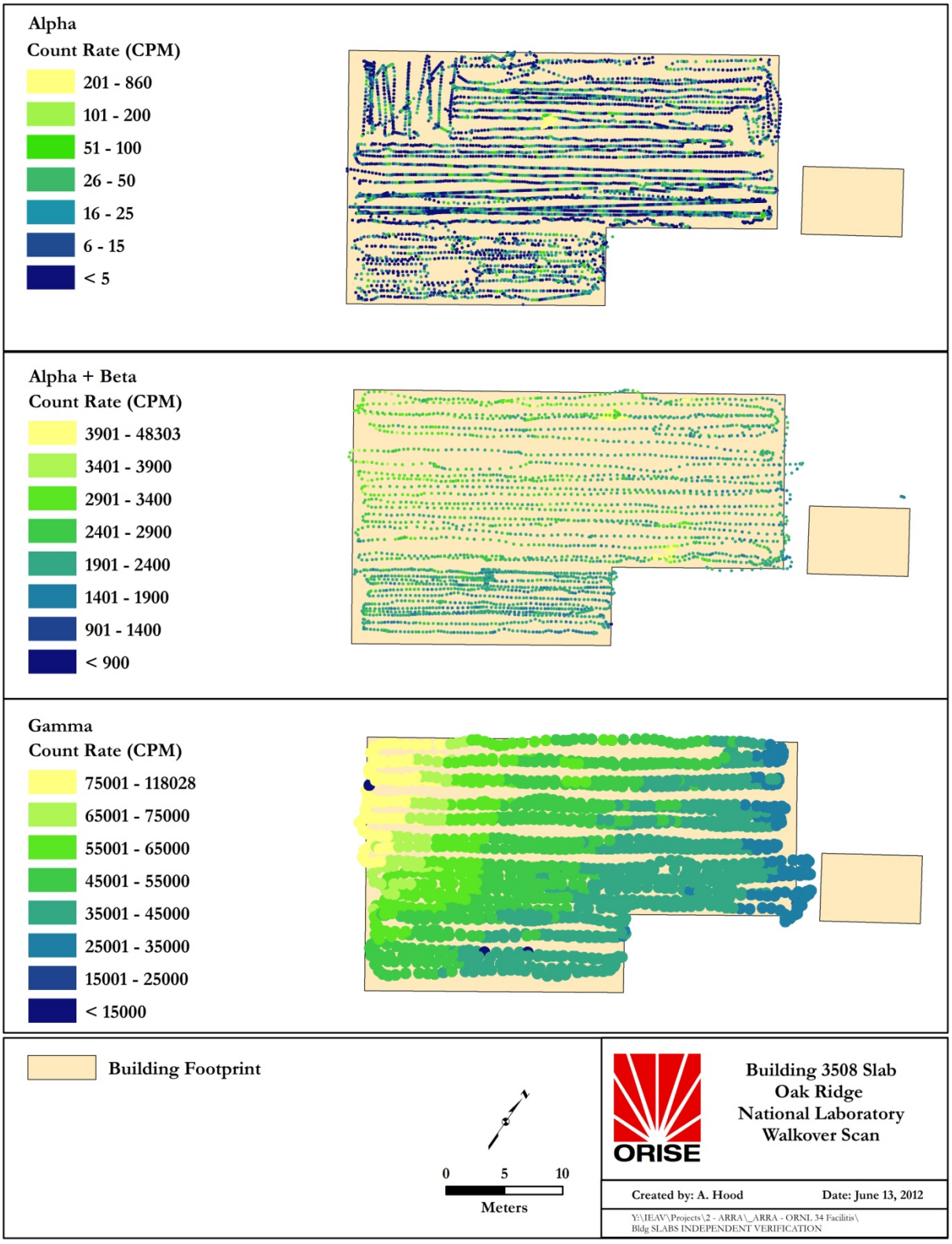

Fig. A-25. Surface Radiation Scans for the Building 3508 Slab

Building 3508 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	16,206	0	860	17	9	44
Alpha-plus-Beta	3,155	0	48,303	3,280	2,279	5,762

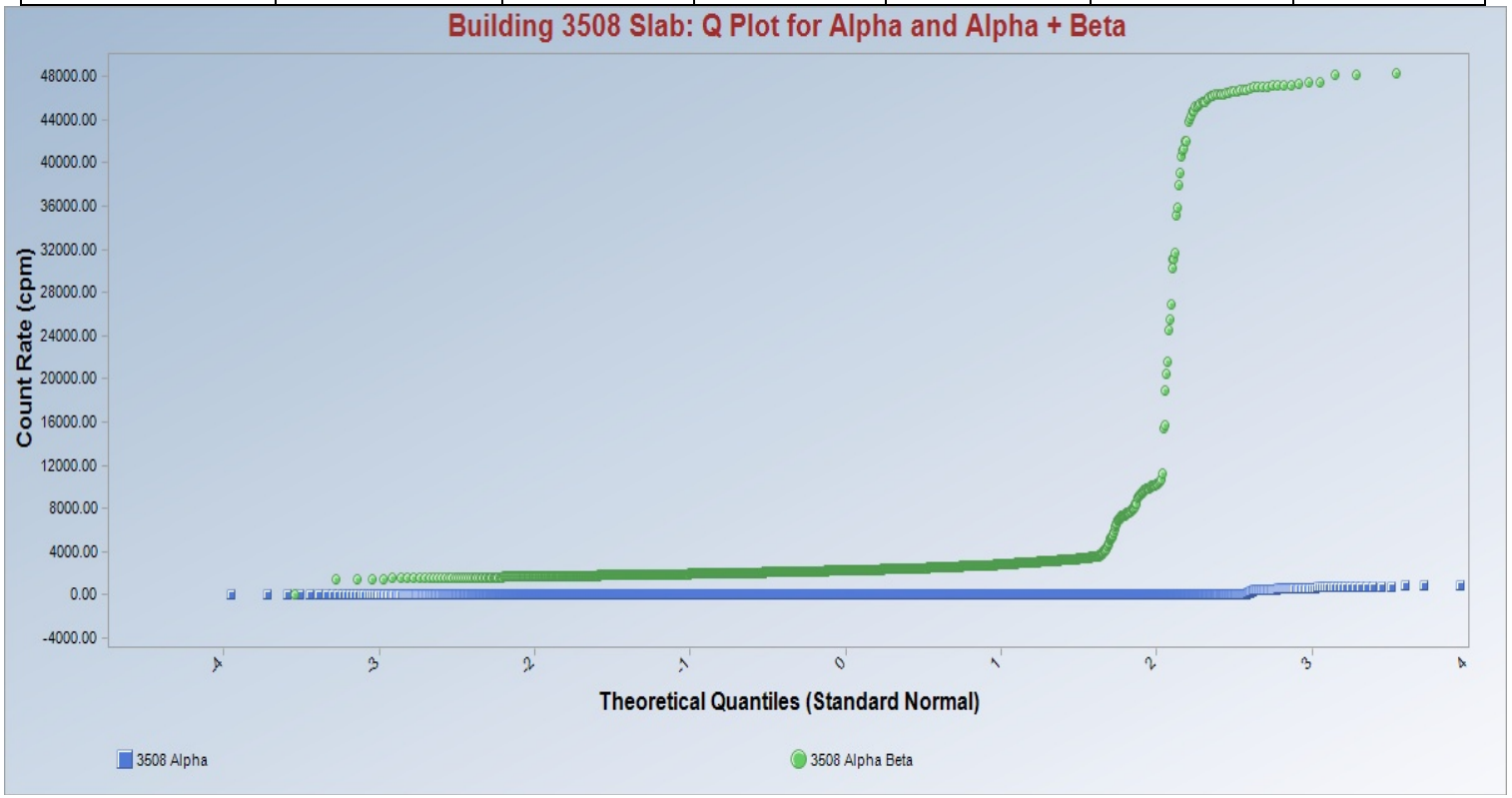

Fig. A-26. Alpha and Alpha Plus Beta Scan Q-Plot for the Building 3508 Slab

Building 3508 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	1,339	17,447	118,028	48,641	45,195	14,708

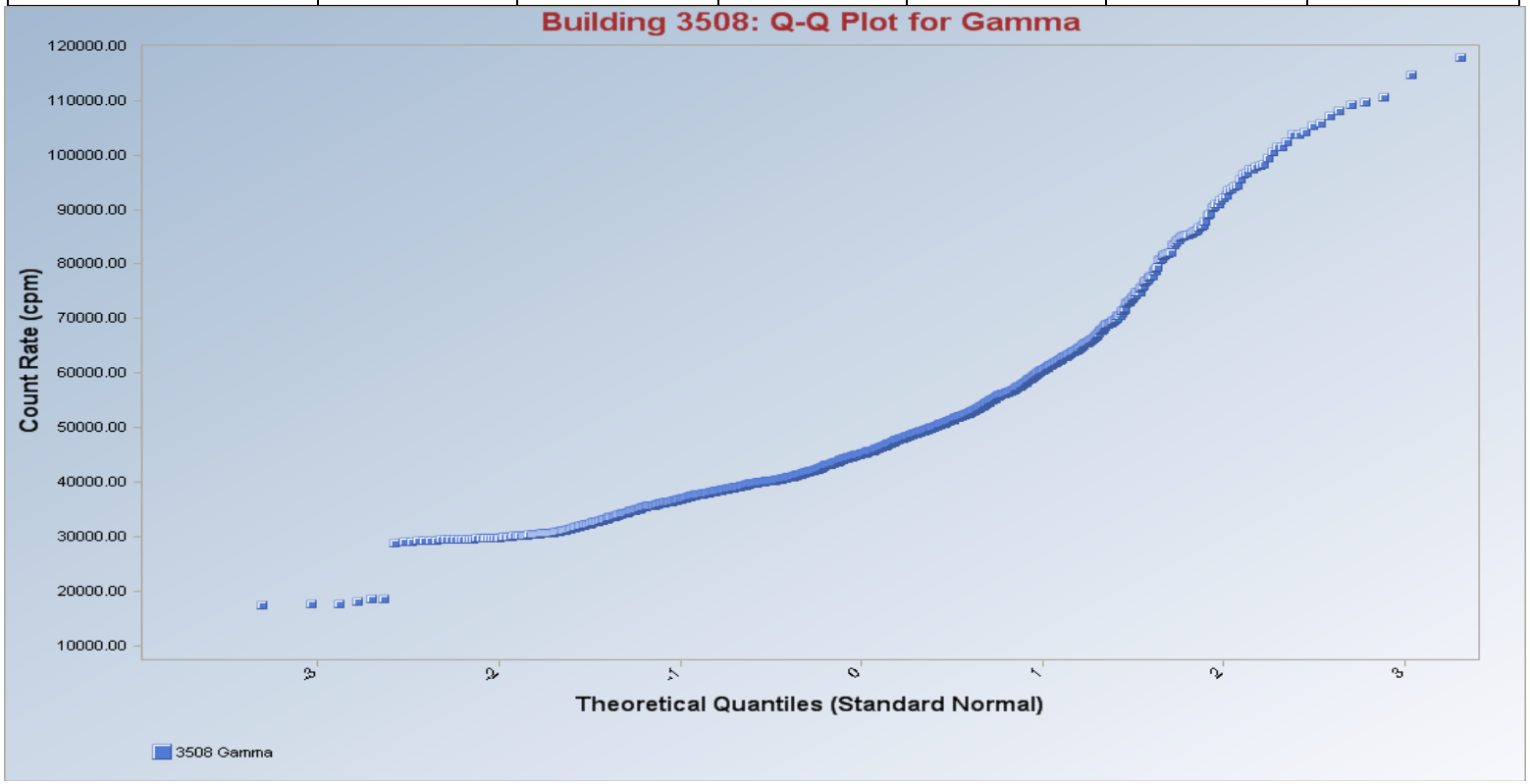

Fig. A-27. Gamma Scan Q-Plot for the Building 3508 Slab

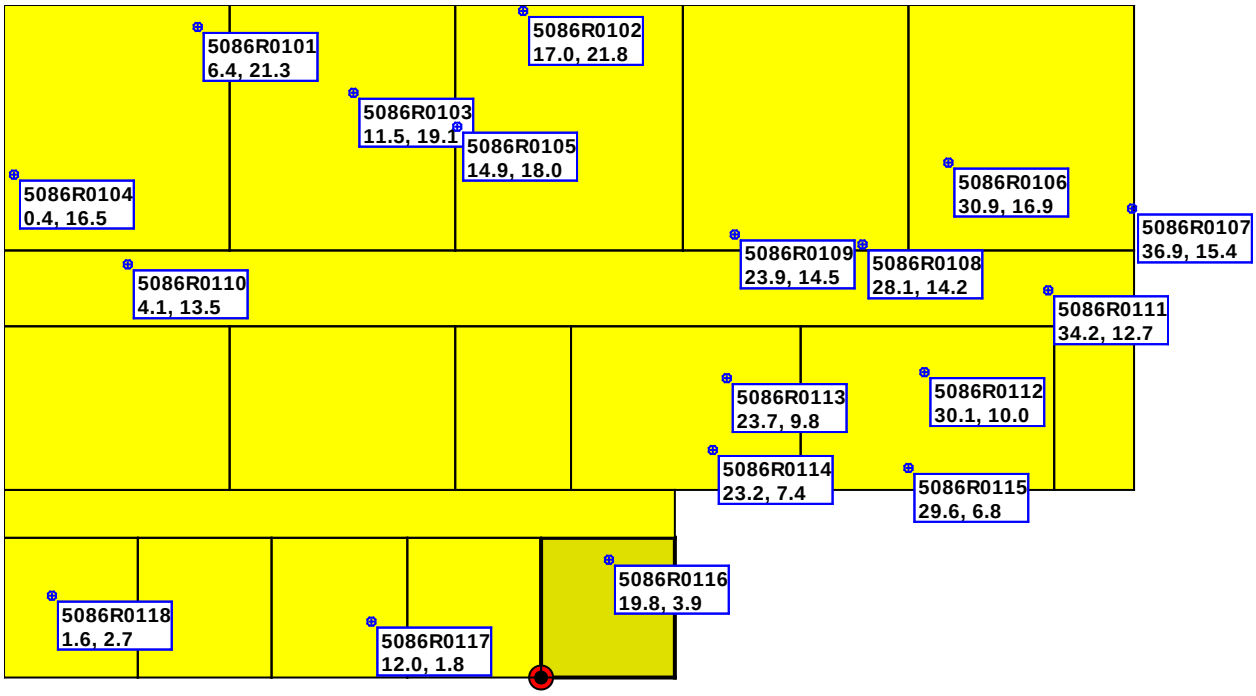

Fig. A-28. Sampling and Direct Measurement Locations for the Building 3508 Slab

Table A-8. Radionuclide Activities for the Southeast Laboratory Complex Building 3508 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3508 Slab						
5086R0101	6	24	663	1,000	na	na
5086R0102	8	41	582	770	na	na
5086R0103	6	24	610	860	1	2
5086R0104	5	16	706	1,100	na	na
5086R0105	14	90	809	1,400	0	4
5086R0106	3	0	526	610	na	na
5086R0107	5	16	550	680	na	na
5086R0108	5	16	505	550	na	na
5086R0109	2	-8	490	500	na	na
5086R0110	7	33	680	1,100	4	3
5086R0111	5	16	557	700	4	3
5086R0112	10	57	525	610	0	0
5086R0113	5	16	554	690	1	4
5086R0114	1	-16	602	830	0	1
5086R0115	7	33	517	580	1	3
5086R0116	9	49	549	680	1	2
5086R0117	15	98	603	830	1	2
5086R0118	7	33	611	860	0	7
5086R0131	62	480	33,113	96,000	0	0
5086R0132	3,980	32,000	3,490	9,300	27	7

BUILDING 3541 SLAB

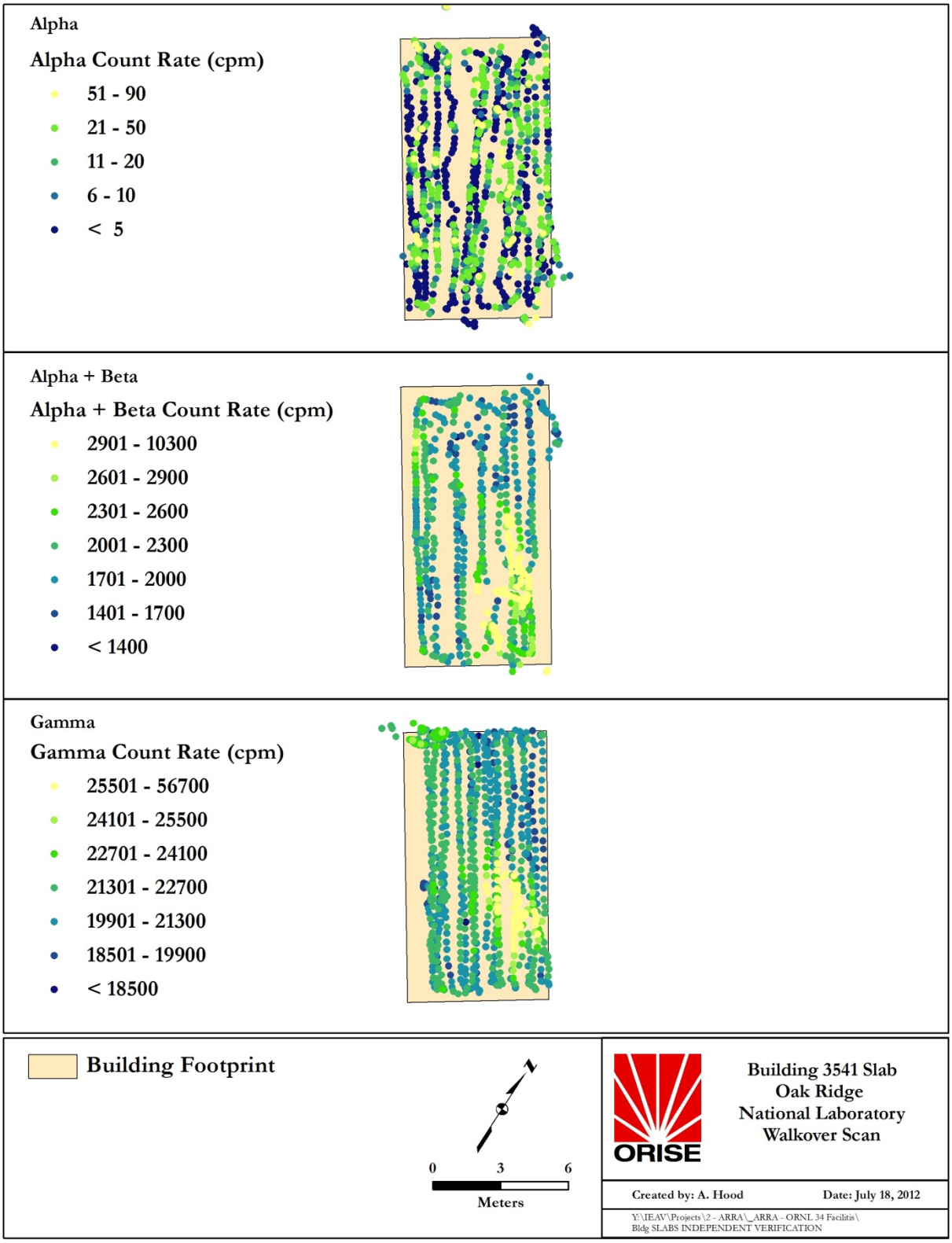

Fig. A-29. Surface Radiation Scans for the Building 3541 Slab

Building 3541 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Alpha	991	0	90	15.27	9	16.7
Alpha-plus-Beta	716	0	10,230	2,639	2,036	1,682

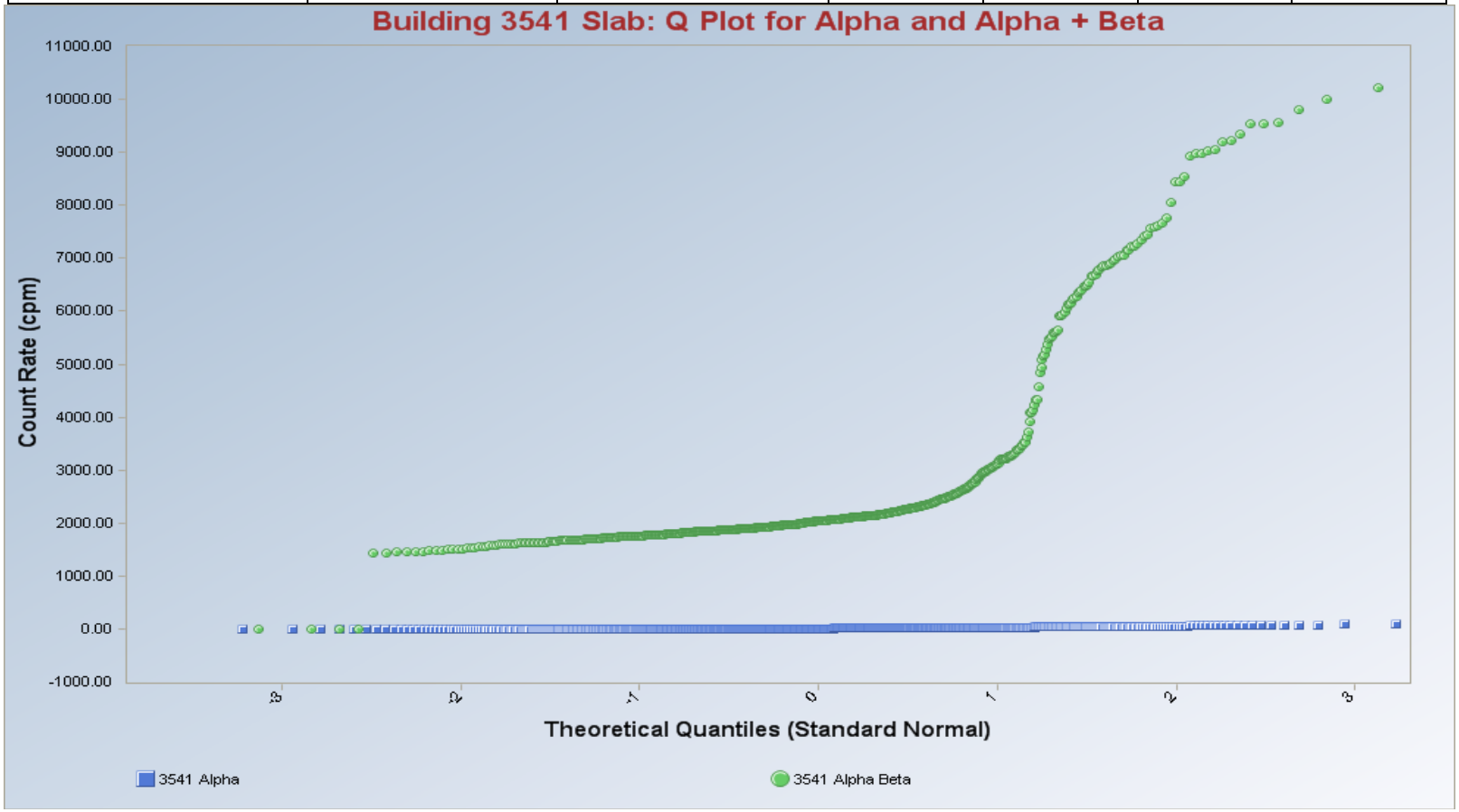

Fig. A-30. Alpha and Alpha-plus-Beta Scan Q-Plot for the Building 3541 Slab

Building 3541 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Minimum**	**Maximum**	**Mean**	**Median**	**SD**
Gamma	1,047	2,154	56,669	23,284	21,461	7,083

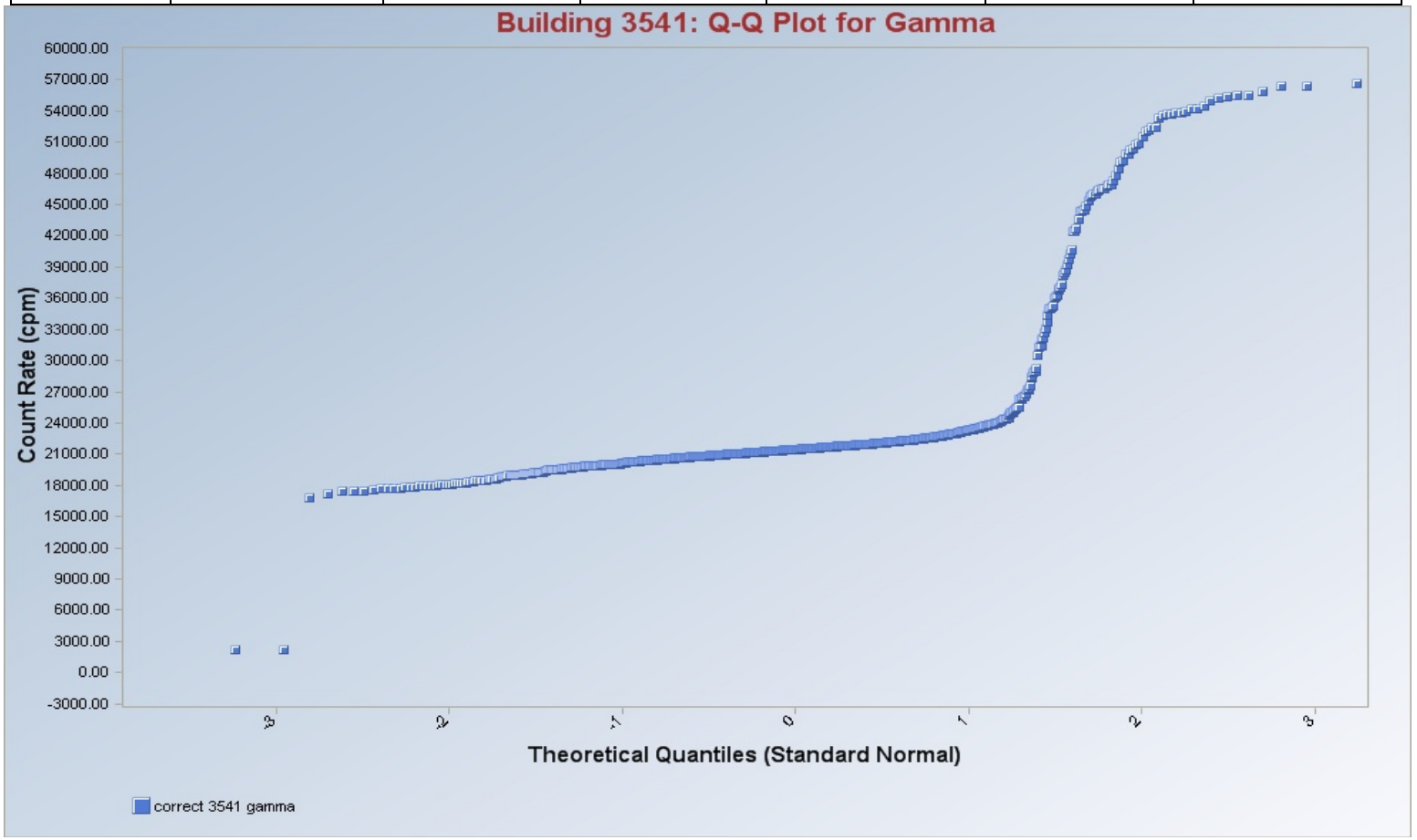

Fig. A-31. Gamma Scan Q-Plot for the Building 3541 Slab

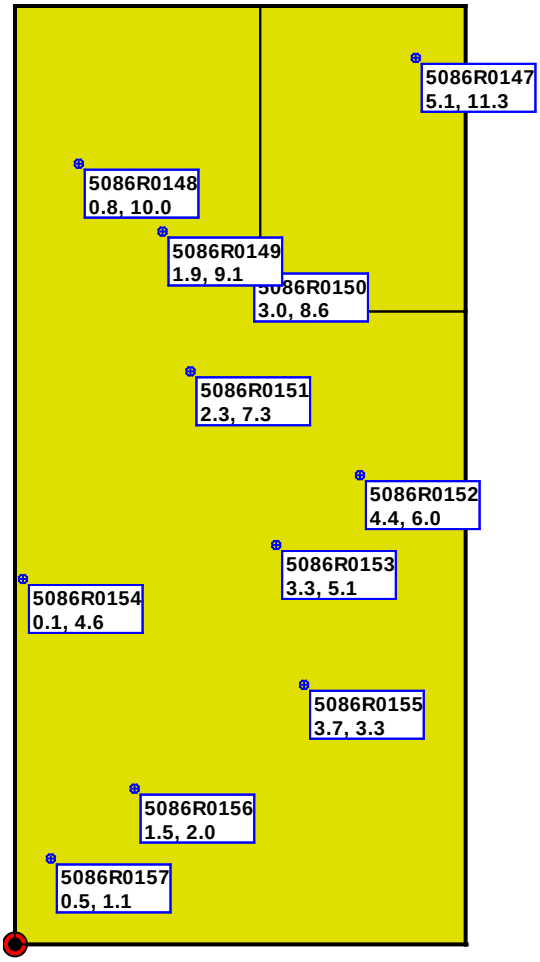

Fig. A-32. Sampling and Direct Measurement Locations for the Building 3541 Slab

Table A-9. Radionuclide Activities for the Southeast Laboratory Complex Building 3541 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3541 Slab						
5086R0147	3	0	508	560	0	3
5086R0148	4	8	486	490	0	1
5086R0149	3	0	447	380	1	0
5086R0150	3	0	559	710	1	6
5086R0151	3	0	514	570	1	4
5086R0152	4	8	564	720	0	0
5086R0153	3	0	528	610	1	3
5086R0154	2	-8	465	430	0	3
5086R0155	4	8	504	540	3	0
5086R0156	3	0	505	550	1	0
5086R0157	6	24	530	620	0	0

BUILDING 3543 SLAB

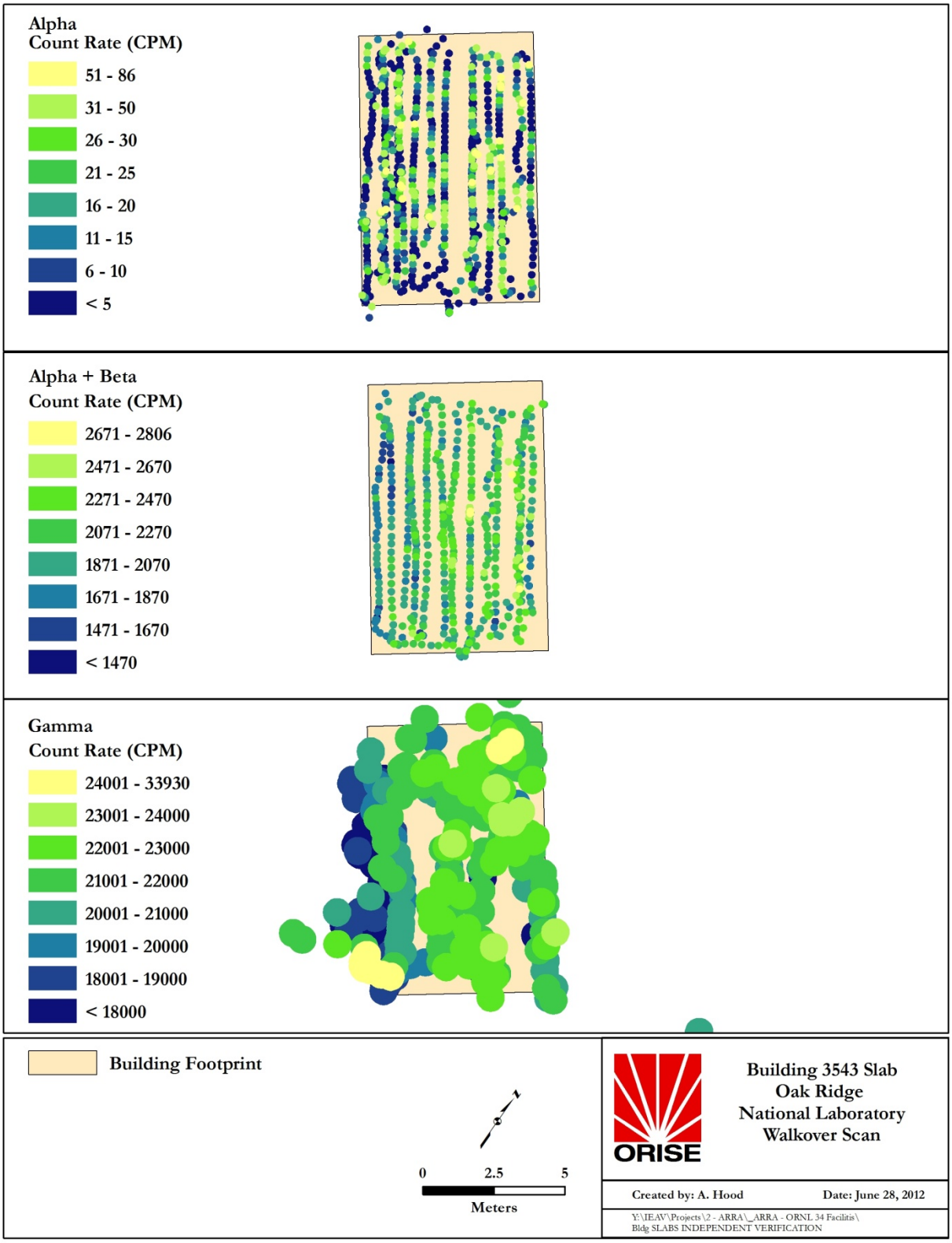

Fig. A-33. Surface Radiation Scans for the Building 3543 Slab

Building 3543 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	703	0	86	16	11	16
Alpha-plus-Beta	573	160	2,806	2,072	2,079	239

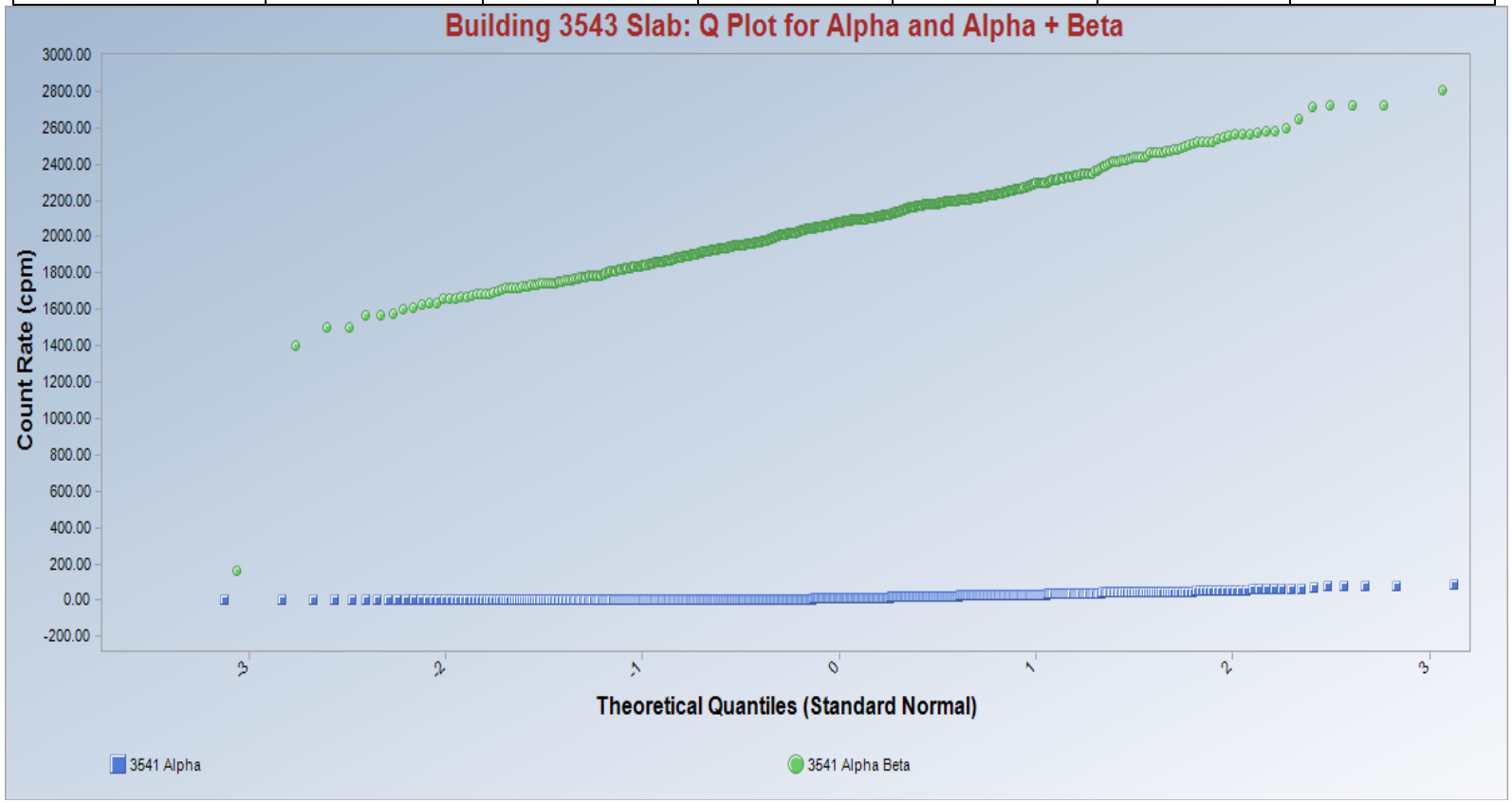

Fig. A-34. Alpha and Alpha Plus Beta Scan Q-Plot for the Building 3543 Slab

Building 3543 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	256	16518	33,930	21,732	21,533	3,676

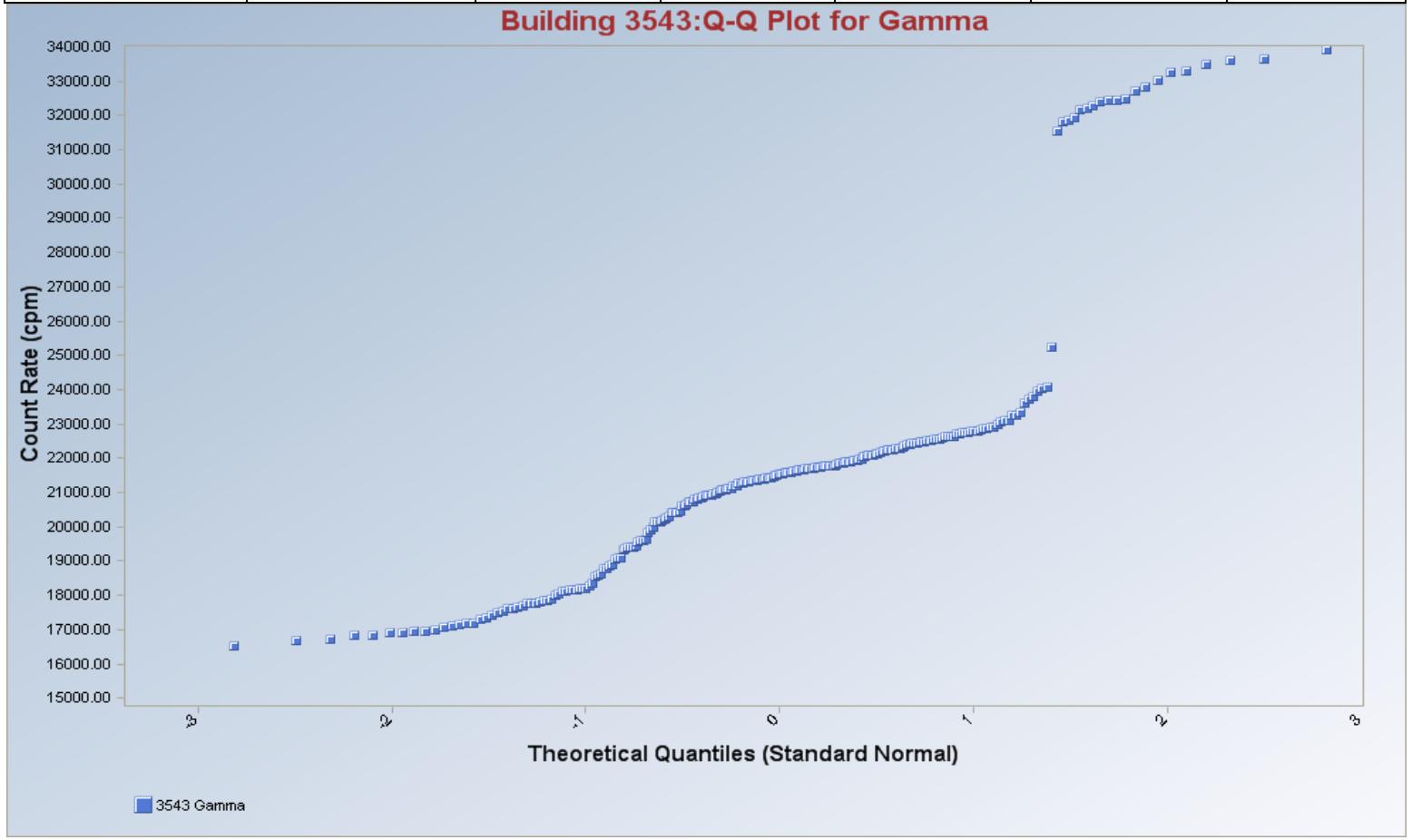

Fig. A-35. Gamma Scan Q-Plot for the Building 3543 Slab

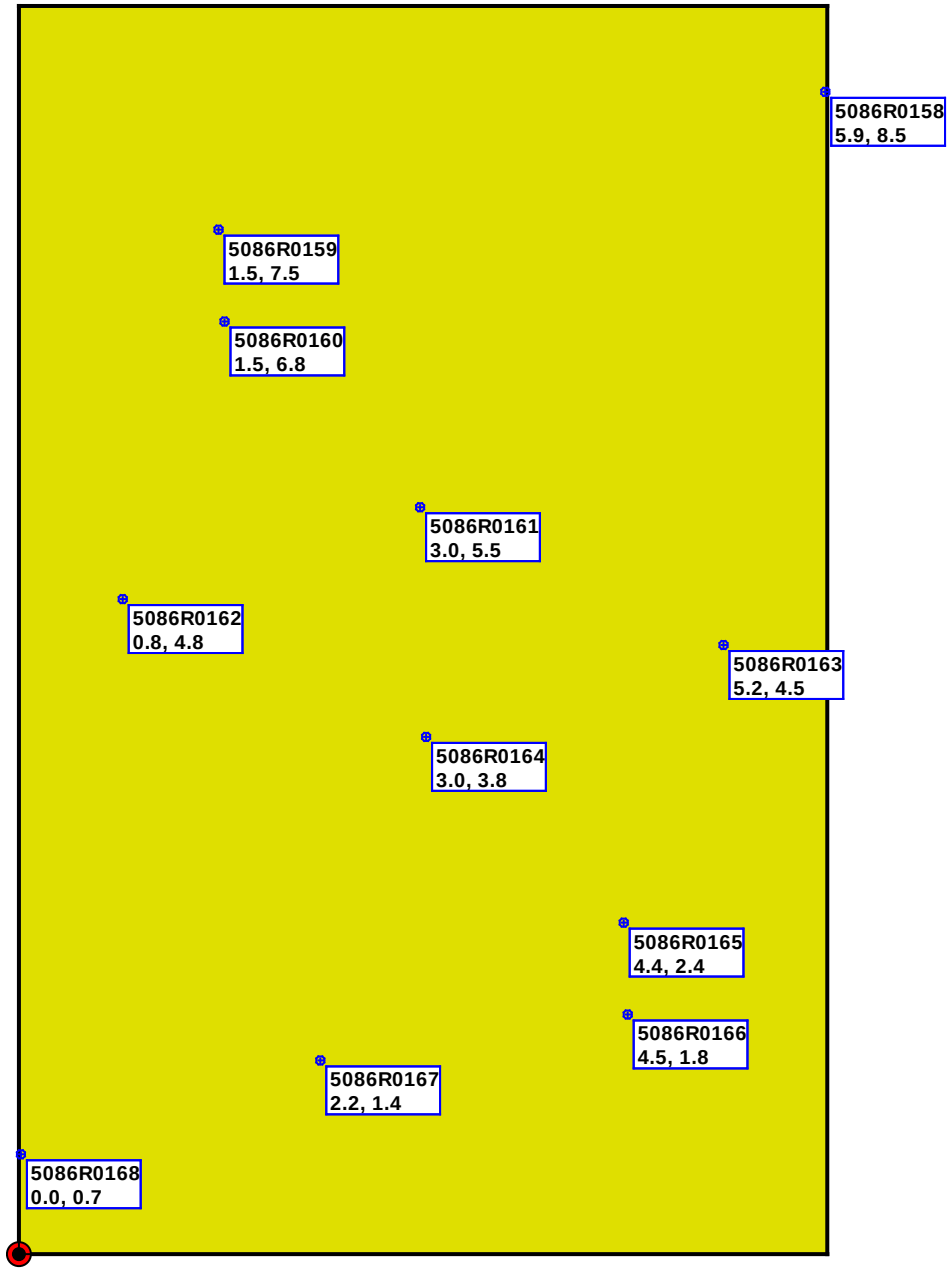

Fig. A-36. Sampling and Direct Measurement Locations for the Building 3543 Slab

Table A-10. Radionuclide Activities for the Southeast Laboratory Complex Building 3543 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3543 Slab						
5086R0158	15	98	516	580	0	5
5086R0159	38	280	543	660	0	4
5086R0160	31	230	582	770	0	0
5086R0161	17	110	442	360	0	3
5086R0162	22	150	494	510	1	2
5086R0163	18	120	552	680	1	1
5086R0164	5	16	631	920	0	0
5086R0165	27	200	575	750	1	3
5086R0166	68	530	797	1,400	0	1
5086R0167	79	620	792	1,400	1	0
5086R0168	9	49	517	580	0	0

BUILDING 3592 SLAB

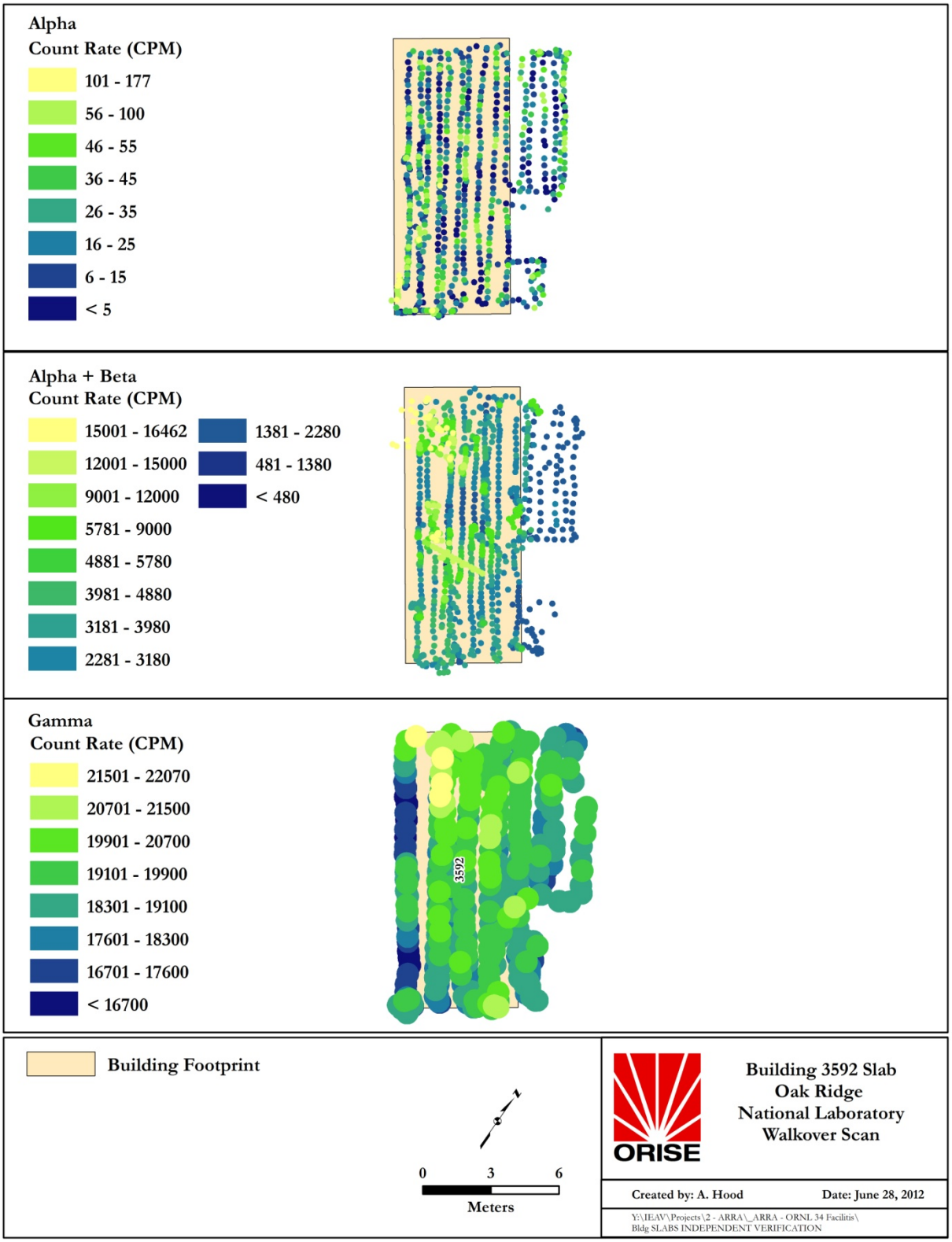

Fig. A-37. Surface Radiation Scans for the Building 3592 Slab

Building 3592 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	777	0	177	28	23	25
Alpha-plus-Beta	1,418	0	16,462	5,759	4,296	3,785

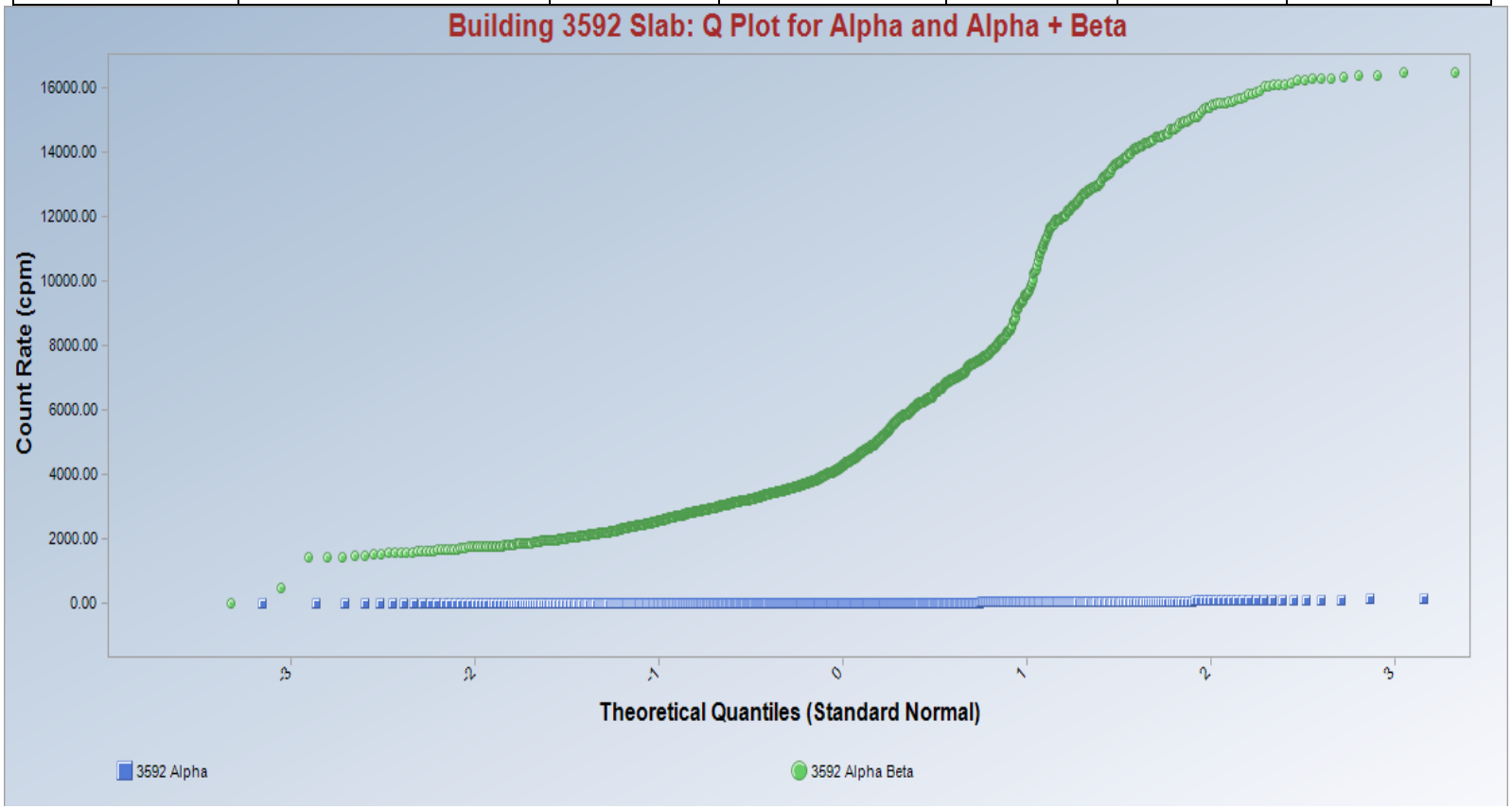

Fig. A-38. Alpha and Alpha-plus-Beta Scan Q-Plot for the Building 3592 Slab

Building 3592 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	335	16,009	22,070	18,985	19,012	1,016

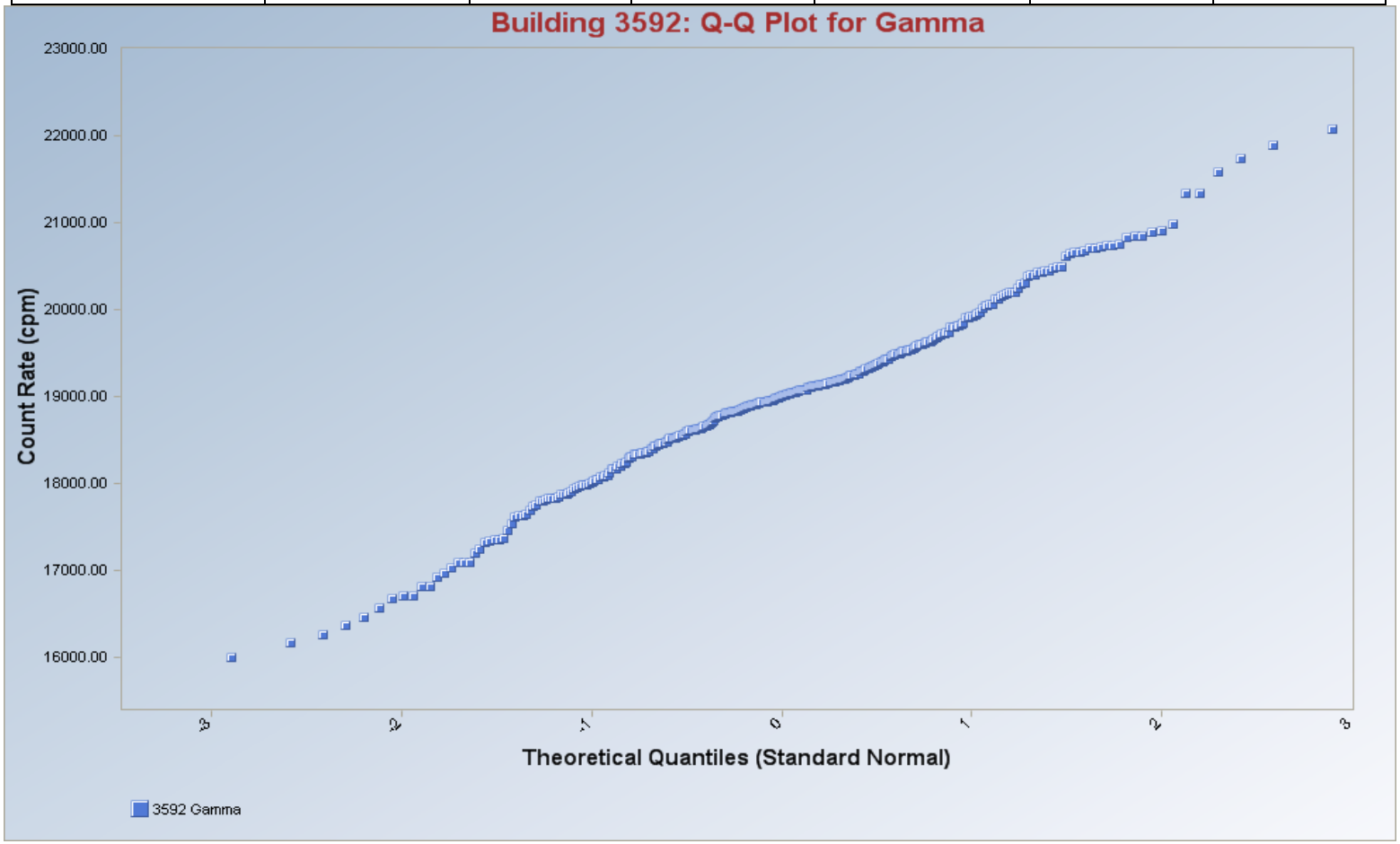

Fig. A-39. Gamma Scan Q-Plot for the Building 3592 Slab

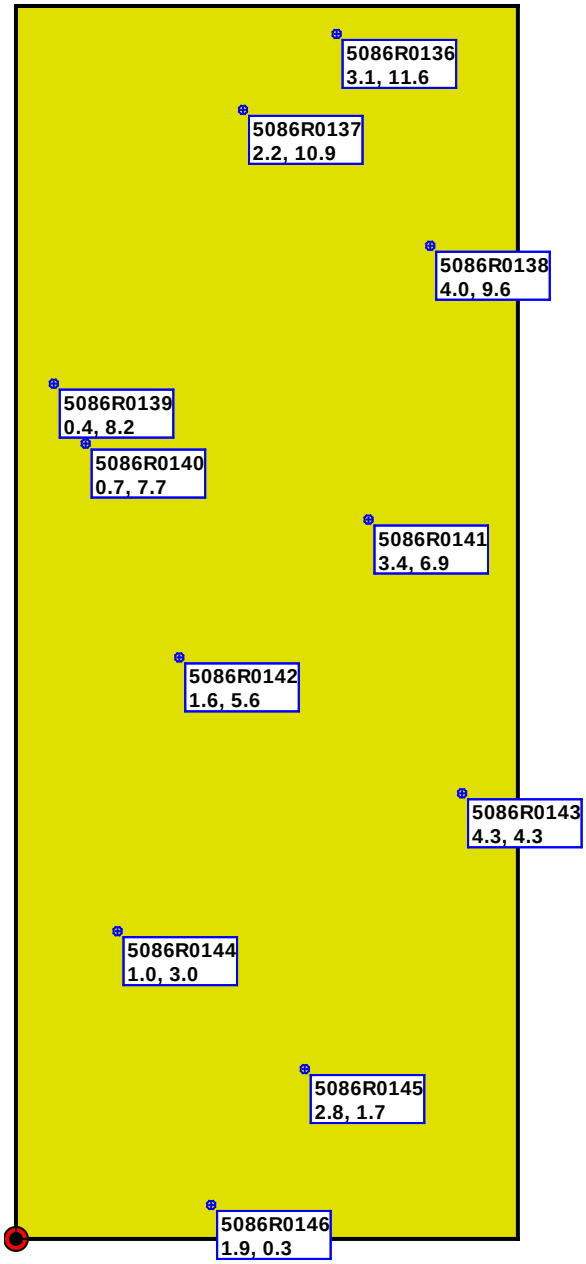

Fig. A-40. Sampling and Direct Measurement Locations for the Building 3592 Slab

Table A-11. Radionuclide Activities for the Southeast Laboratory Complex Building 3592 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3592 Slab						
5086R0136	15	98	571	740	0	1
5086R0137	13	81	1,023	2,100	0	0
5086R0138	6	24	657	1,000	0	0
5086R0139	11	65	916	1,800	0	5
5086R0140	13	81	599	820	0	0
5086R0141	9	49	663	1,000	1	1
5086R0142	7	33	1,347	3,000	1	3
5086R0143	8	41	766	1,300	0	1
5086R0144	5	16	1,714	4,100	0	2
5086R0145	13	81	1,187	2,600	1	1
5086R0146	2	-8	1,014	2,000	0	1
5086R0169	16	110	3,861	10,000	1	6

BUILDING 3605 SLAB

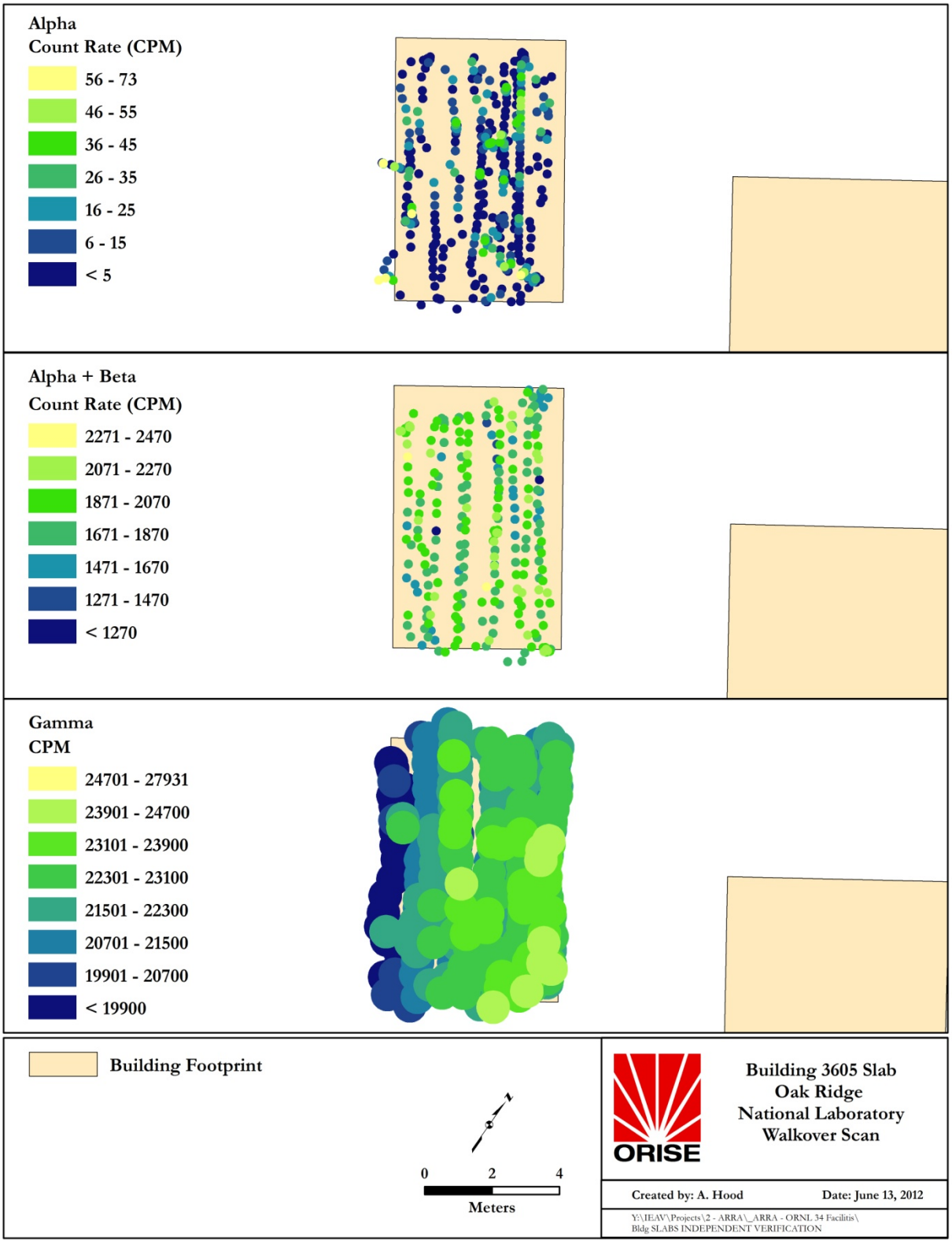

Fig. A-41. Surface Radiation Scans for the Building 3605 Slab

Building 3605 Slab Alpha and Alpha-plus-Beta Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Alpha	393	0	73	11	5	14
Alpha-plus-Beta	278	0	2,474	1,853	1,874	271

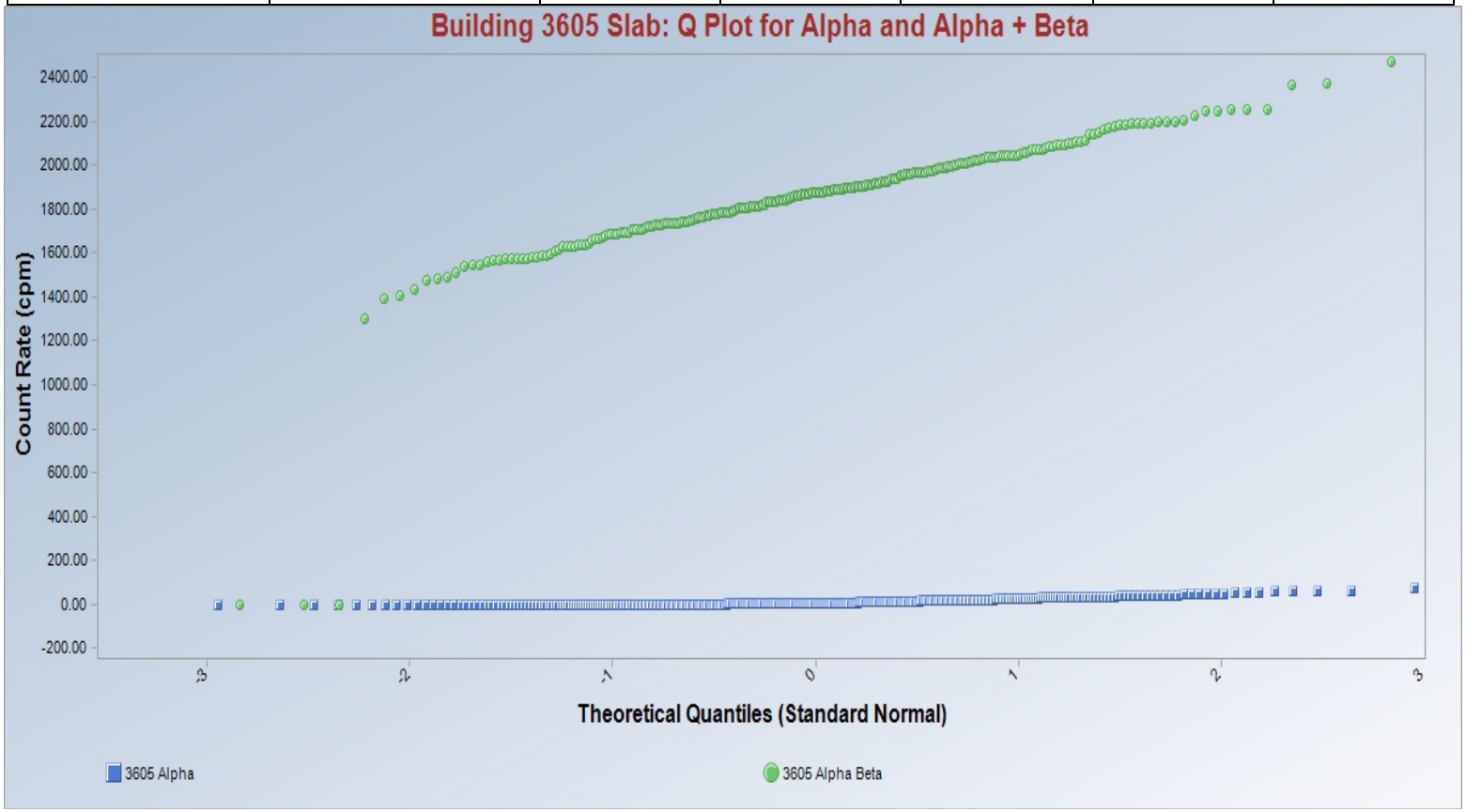

Fig. A-42. Alpha and Alpha-plus-Beta Scan Q-Plot for the Building 3605 Slab

Building 3605 Slab Gamma Q Plot Summary Statistics for Raw Full Dataset						
Variable	**NumObs**	**Min**	**Max**	**Mean**	**Median**	**SD**
Gamma	311	18,265	27,931	22,157	22,215	1,425

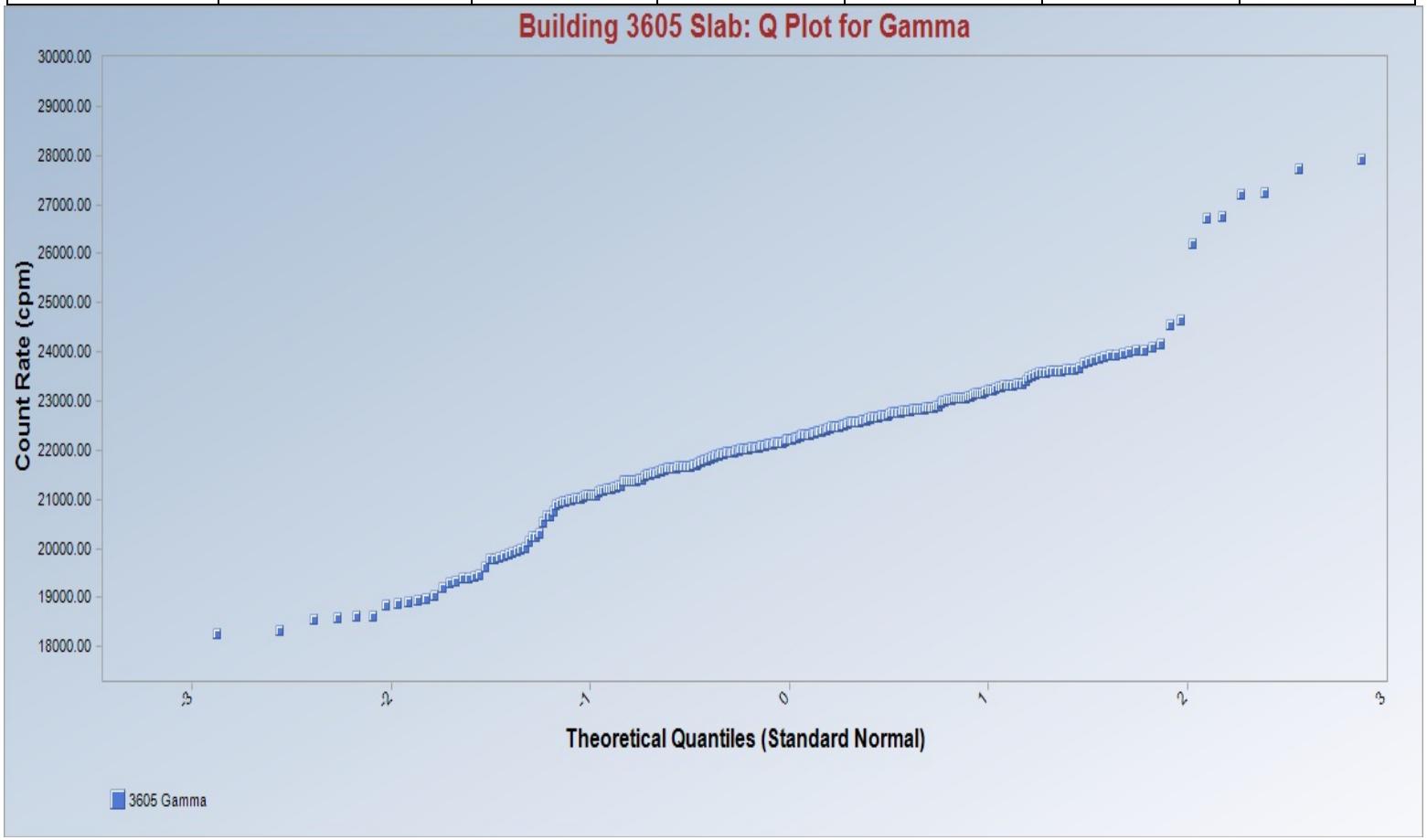

Fig. A-43. Gamma Scan Q-Plot for the Building 3605 Slab

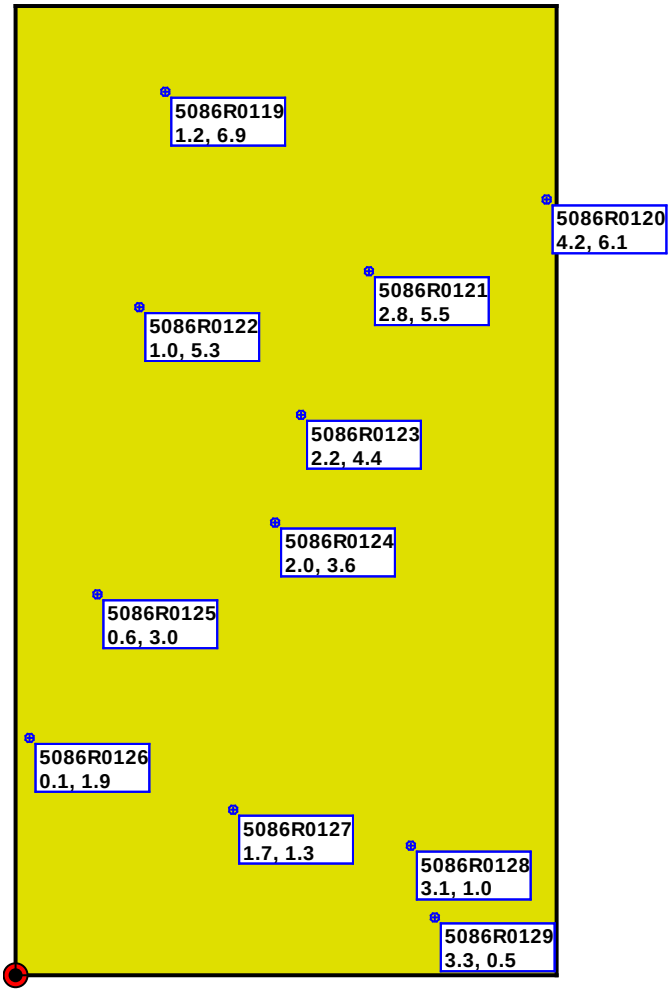

Fig. A-44. Sampling and Direct Measurement Locations for the Building 3605 Slab

Table A-12. Radionuclide Activities for the Southeast Laboratory Complex Building 3605 Slab Oak Ridge National Laboratory Oak Ridge, Tennessee						
Measurement Location/ Sample ID	Total Activity				Removable Activity	
	Alpha		Alpha-plus-Beta		Gross Alpha & Beta	
	Gross cpm	Activity (dpm/100cm²)	Gross cpm	Activity (dpm/100cm²)	Alpha Activity (dpm/100cm²)	Beta Activity (dpm/100cm²)
3605 Slab						
5086R0119	10	57	493	510	0	0
5086R0120	7	33	527	610	0	2
5086R0121	7	33	548	670	0	1
5086R0122	7	33	499	530	1	4
5086R0123	9	49	517	580	0	1
5086R0124	7	33	532	630	0	0
5086R0125	2	-8	488	500	1	3
5086R0126	8	41	507	550	0	2
5086R0127	9	49	577	760	0	3
5086R0128	6	24	565	720	0	1
5086R0129	5	16	531	620	0	1

APPENDIX B
MAJOR INSTRUMENTATION

B.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

B.1.1 ALPHA-PLUS-BETA

Ludlum Floor Monitor Model 239-1
combined with
Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-37, Physical Area: 550 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

B.1.2 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm x 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Ludlum Ratemeter-Scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)

B.2 DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

B.2.1 ALPHA AND BETA

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

B.3 LABORATORY ANALYTICAL INSTRUMENTATION

Low background alpha/beta counting system
Canberra/Tennelec LB5100W Eclipse Software
(Canberra, Inc., Meriden, CT)

APPENDIX C
SURVEY AND ANALYTICAL PROCEDURES

C.1 PROJECT HEALTH AND SAFETY

Survey activities were conducted in accordance with the ORAU/ORISE overall health and safety program (HASP) and radiological protection program manuals. Pre-survey activities included an overview of potential health and safety issues. Potential health and safety issues that were identified were appropriately addressed by the ORAU/ORISE HASP, site-specific Integrated Safety Management (ISM) pre-job hazard checklist, and an activity hazard analysis (AHA) prior to beginning site work.

C.2 QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following ORAU and ORISE documents:

- Survey Procedures Manual (ORISE 2012a)
- Laboratory Procedures Manual (ORISE 2012b)
- Quality Program Manual (ORAU 2012)

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements*, Department of Energy Order 414.1C, *Quality Assurance*, and the U.S. Nuclear Regulatory Commission, *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 (MAPEP), National Institute for Standards and Technology (NIST) Radiochemistry Intercomparison Program (NRIP), and Intercomparison Testing Program (ITP) Laboratory Quality Assurance Programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

C.3 CALIBRATION

Detectors used for assessing surface activity were calibrated in accordance with ISO-7503[1] recommendations. Total alpha and beta efficiencies (ε_{total}) were determined for each instrument/detector combination and consisted of the product of the 2π instrument efficiency (ε_i) and surface efficiency (ε_s): $\varepsilon_{total} = \varepsilon_i \times \varepsilon_s$. Beta total efficiencies were determined based on a beta energy multi-point calibration, development of instrument efficiency to beta energy calibration curves, and the calculation of the weighted efficiency representing the Th-232 decay series. Included in the weighted efficiency was an empirically determined correction for disequilibrium in the decay series that results from Rn-220 loss. A 3.8 mg/cm^2 density thickness mylar window was used on the beta detectors to block detector response contributions from alpha radiation.

Th-230 was selected as the alpha calibration source. The 2π alpha instrument efficiency (ε_i) factor was 0.39 for the gas proportional detector. C-14, Tc-99, Tl-204, and Sr/Y-90 were selected as the beta calibration sources to represent the energy distribution of the detectable beta-emitters in the Th-232 decay series. The 2π interpolated ε_i factors for the detectable beta-emitters ranged from 0.34 to 0.56 for the gas proportional detector. ISO-7503 recommends an ε_s of 0.25 for alpha emitters and beta emitters with a maximum energy of less than 0.4 MeV, and an ε_s of 0.5 for maximum beta energies greater than 0.4 MeV. The thorium series alpha efficiency is 0.10. The total weighted beta efficiency for the beta detectors ranged from 0.08 to 0.28.

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

C.4 SURVEY PROCEDURES

C.4.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface, the distance between the detector and the surface was maintained at a minimum—nominally about 1 cm or as close to the surface as possible. A NaI scintillation detector was used to scan for elevated

[1]International Standard. ISO 7503-1, Evaluation of Surface Contamination - Part 1: Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters. August 1, 1988.

gamma radiation throughout the slab. The scan minimum detectable concentrations (MDCs) for the NaI scintillation detector for the contaminants of concern for a concrete surface were obtained directly from NUREG-1507[2], when available, or estimated using the calculation approach described in NUREG-1507. A typical NaI 2-in × 2-in detector MDC is 6.4 pCi/g for cesium-137. Audible increases in the activity rate are investigated by ORAU. It is standard procedure for ORAU staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

C.4.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of total alpha and total beta surface activity levels were performed using hand-held scintillation detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the count rate by the total static efficiency ($\varepsilon_i \times \varepsilon_s$) and correcting for the physical area of the detector.

The *a priori* MDC for surface activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{Tx\varepsilon_{Tot}xG}$$

Where:

B	=	background (total counts) in time interval, T
T	=	count time (min) used for field instruments
ε_{Tot}	=	total efficiency = ε_i x ε_s
ε_i	=	instrument efficiency
ε_s	=	source efficiency
G	=	geometry (physical detector area cm^2/100)

The *a priori* alpha static MDC was approximately 76 dpm/100 cm^2 using the total efficiency of 0.10 and an instrument background of 2 cpm. The physical surface area assessed by the scintillation detector used was 100 cm^2. The *a priori* beta static MDC was approximately 280 dpm/100 cm^2 using the total efficiency of 0.27 and the nominal instrument background of 400 cpm. The physical surface area assessed by the detector used was 126 cm^2.

[2]NUREG-1507. *Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*. U.S. Nuclear Regulatory Commission. Washington, DC; June 1998.

C.4.3 REMOVABLE ACTIVITY MEASUREMENTS

Smear samples for removable gross alpha and gross beta contamination were obtained from each measurement location. Removable activity samples were collected using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

C.5 RADIOLOGICAL ANALYSIS

C.5.1 GROSS ALPHA/BETA

Smears were counted on a low-background gas proportional system for gross alpha and beta activity. The MDCs of the procedure were 12.5 dpm/100 cm^2 and 12.8 dpm/100 cm^2 for a 2-minute count time for gross alpha and gross beta, respectively.

C.5.2 DETECTION LIMITS

Detection limits, referred to as MDC, were based on 3 plus 4.65 times the standard deviation of the background (BKG) count [$3 + (4.65\ (BKG)^{1/2})$]. 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.