ORAU
Further. Together.

September 14, 2018

Mr. Christopher Grossman
Nuclear Material Safety and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Materials Decommissioning Branch
U.S. Nuclear Regulatory Commission
11545 Rockville Pike, MS T8-F05
Rockville, MD 20852

SUBJECT: CONFIRMATION SURVEY REPORT FOR THE FORMER BENRUS CLOCK COMPANY AT 145 CHERRY AVENUE, IN WATERBURY, CONNECTICUT
CONTRACT NO. NRC-HQ-50-17-A-0001; DCN 5307-SR-22-1

Dear Mr. Misenhimer:

Oak Ridge Associated Universities (ORAU) is pleased to provide the attached confirmation survey report for the confirmatory survey of the former Benrus Clock Company property at 145 Cherry Avenue in Waterbury, Connecticut, on January 9, 2018. This report follows the outline given in the Temporary Instruction 2800/043, Appendix C.

Please feel free to contact me at 865.574.0685 or Erika Bailey at 865.576.6659 if you have any questions.

Sincerely,

David A. King, CHP, PMP
Sr. Health Physicist/Project Manager
ORAU

DAK:lw

Attachment

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Quality Review	YB

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Enclosure

OAK RIDGE ASSOCIATED UNIVERSITIES:

CONFIRMATION SURVEY REPORT FOR THE FORMER BENRUS CLOCK COMPANY AT 145 CHERRY AVENUE, WATERBURY, CONNECTICUT

SEPTEMBER 14, 2018

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EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that Oak Ridge Associated Universities (ORAU) perform a confirmatory radiation survey of the property at 145 Cherry Avenue in Waterbury, Connecticut. This property was identified as the former Benrus Clock Company, which used luminous radium paint in the manufacturing of clocks and/or watches into the mid-1940s. The objective of this survey was to confirm that Ra-226 contamination has been remediated to levels that will produce a dose below the criterion (25 mrem/yr) necessary for unrestricted use of this property.

ORAU performed the confirmatory radiation survey in the seven-story main building of the complex on January 9, 2018. Survey activities included judgmental surveys for gamma and alpha-plus-beta radiation of the fourth through seventh floors, though efforts were primarily focused on the seventh floor, where historical contamination was most prominent. Most of the contaminated material identified during historical surveys and NRC's November 2016 initial site visit has been physically removed. Some small areas of elevated activity remain, though ORAU estimates that the corresponding average dose to a residential receptor will be less than 25 mrem/yr. Side-by-side measurements were also collected with the remediation contractor, and ORAU has concluded that the contractor's methods are conservative, tending to overestimate actual conditions. Based on these results, ORAU supports the conclusion that facility remediation efforts are sufficient to satisfy the 25 mrem/yr dose limit.

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SITE STATUS REPORT

Property:	Former Benrus Clock Company 145 Cherry Avenue Waterbury, CT 06702
Docket Number:	03038943
Current Property Name(s):	Cherry Avenue Partners, LP
Current Property Owner(s):	Cherry Avenue Partners, LP
Inspection Dates:	January 9, 2018
Inspector(s):	Mark Roberts and John Nicholson/ U.S. Nuclear Regulatory Commission (NRC), supported by Nick Altic and Stephen Pittman/ Oak Ridge Associated Universities (ORAU)

1.0 INTRODUCTION

The Energy Policy Act of 2005 amended section 11e. (3) of the Atomic Energy Act of 1954 to place discrete sources of radium-226 (Ra-226) under NRC regulatory authority as byproduct material. The property at 145 Cherry Avenue in Waterbury, Connecticut, was identified as the former Benrus Clock Company, a manufacturing facility that operated from the 1920s to the mid-1940s (ORNL 2015). The company was known to produce watches with radium-luminous dials, and the presence of residual Ra-226 was verified in the West Valley Nuclear Services Company Inc. report (DEEP 1998), the Agency for Toxic Substances and Disease Registry (ATSDR) report (ATSDR 1999), the Scientech report (Scientech 2003), and the Site Status Report (ORISE 2017b). During the most recent survey in support of NRC's Radium Program, ORAU identified multiple contaminated surfaces on numerous building levels/floors, including several small, isolated areas of elevated activity and a few areas with relatively wide-spread contamination. Dose calculations estimated that doses could be in excess of the 25 mrem/yr dose limit for unrestricted use, as described in 10 CFR Part 20, Section 20.1402.

On September 21, 2017, the property was transferred from Bender Plumbing to Cherry Avenue Partners, LP, and a condition of transfer was that the property must be remediated to levels that would satisfy the unrestricted release criteria in Section 20.1402. The NRC, therefore, requested that ORAU return to the former clock company property to ensure, if supported by the results, that the remediation contractor (Decontamination Decommissioning & Environmental Services, LLC [DDES]) has remediated the facility to levels that satisfy the 25 mrem/yr dose limit.

2.0 PROPERTY DESCRIPTION AND INITIAL SITE VISIT CONSIDERATIONS

2.1 Property Description and History

The former Benrus Clock Company property is pictured in Figure 1. The main building, located at 145 Cherry Avenue in Waterbury, Connecticut, is a seven-story structure with a combination of brick and poured concrete walls, wood floors (possibly original), and concrete columns at regular intervals within the interior, as illustrated in the Figure 2 general floorplan. The first story was most recently used for operation of the Bender Plumbing Company. All other floors were used to store equipment and supplies, though materials were removed prior to property transfer and remediation.

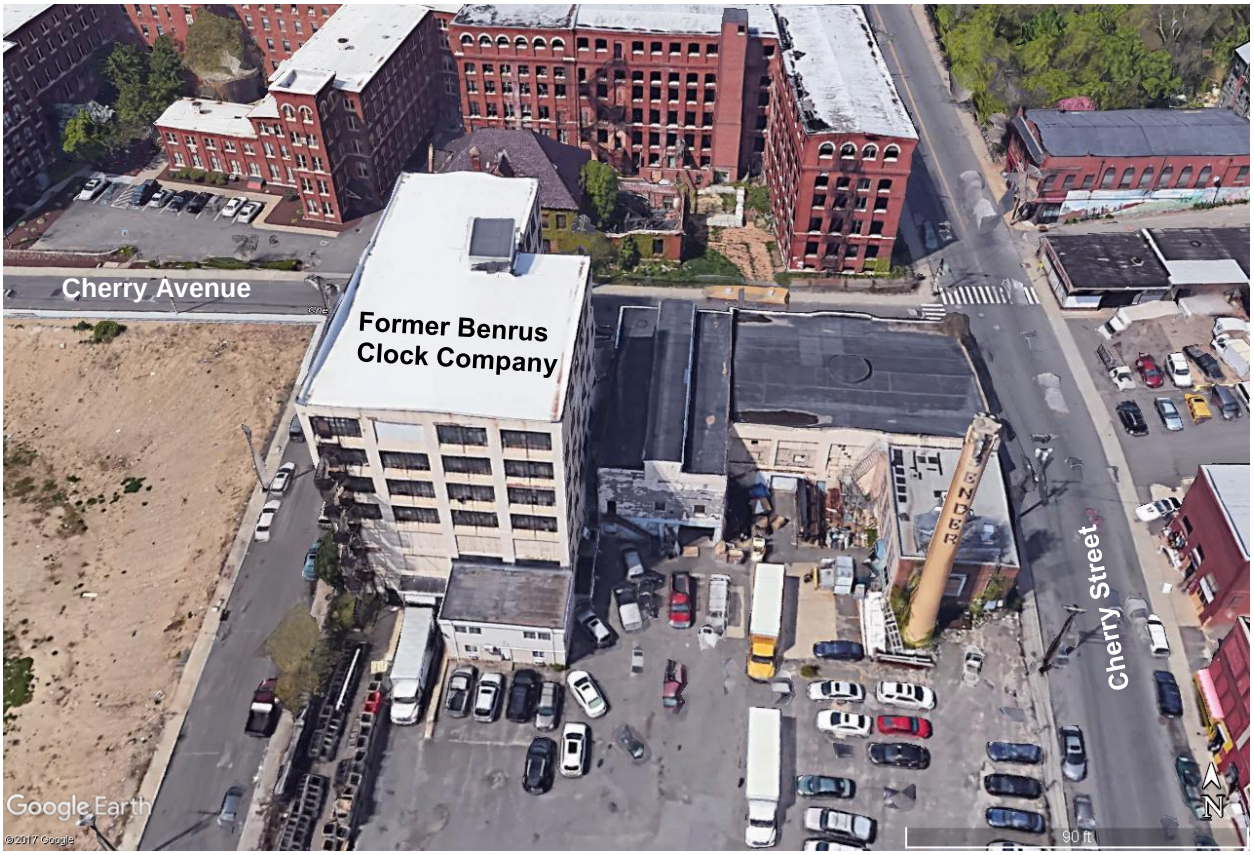

Figure 1. Former Benrus Clock Company Facility (Google Earth)

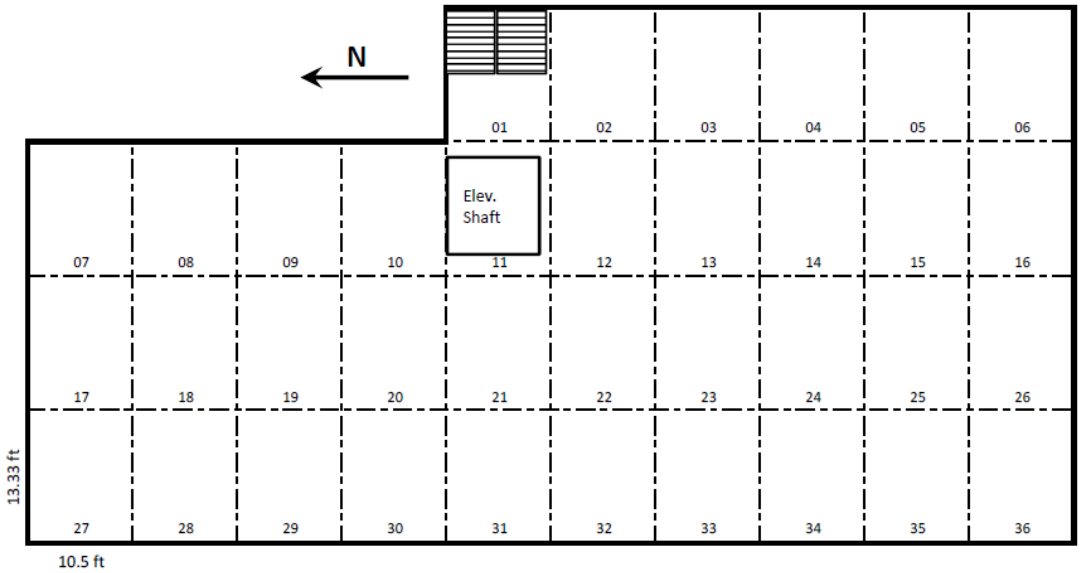

Figure 2. Benrus Structure General Floor Plan

Historical surveys (DEEP 1998, ATSDR 1999, and Scientech 2003) identified Ra-226 contamination on the fourth, fifth, and seventh stories. The *Historical Non-Military Radium Sites Research Effort Addendum* report (ORNL 2015) includes additional details about the type, form, history, potential locations, and other information related to discrete sources of Ra-226 used at the site. The November 2016 site visit by NRC/ORAU verified historical survey results and determined that Ra-226 is present at levels that could produce a radiological dose above 25 mrem/yr to a plausible facility occupant (ORISE 2017b). Identified contamination was most prominent on the seventh floor; though at least one small area of elevated activity was also found on each of the lower floors. As during historical surveys and the site visit, much of the building's floor and wall space was inaccessible due to a large volume of stored materials. Therefore, the full extent of contamination was unknown. Outdoor areas and the adjoining warehouse structures were also investigated during the November 2016 site visit, though no known link to radium-related activities in these structures existed, and elevated radiation levels were not detected.

In 2017, Bender Plumbing vacated the main building, allowing full access to areas previously obstructed by stored materials. The building was remediated (thus the need for this confirmation survey), and much of the wood flooring, brick wall surfaces, etc., exhibiting elevated levels of radiation were physically removed.

2.2 Confirmation Survey Considerations

Prior to commencing survey activities, the general building layout was examined to identify impediments to conducting the survey and/or health and safety considerations. It was observed that vast sections of entire flooring were removed along the north and east walls of some levels during the remediation process, allowing a direct line of sight to higher and lower levels in the building. These areas were cordoned off with wooden barricades. Some levels also had wooden joists installed to support upper levels. Generally throughout, patches of flooring overlay had been removed, exposing subflooring, which presented a moderate tripping hazard.

The northeastern corner of the seventh floor, where all three layers of flooring was cut away, as pictured in Figure 3 and Figure 4, shows post-remedial conditions where localized contamination was encountered. Most of the north wall was inaccessible because surveyors could not cross the safety barrier.

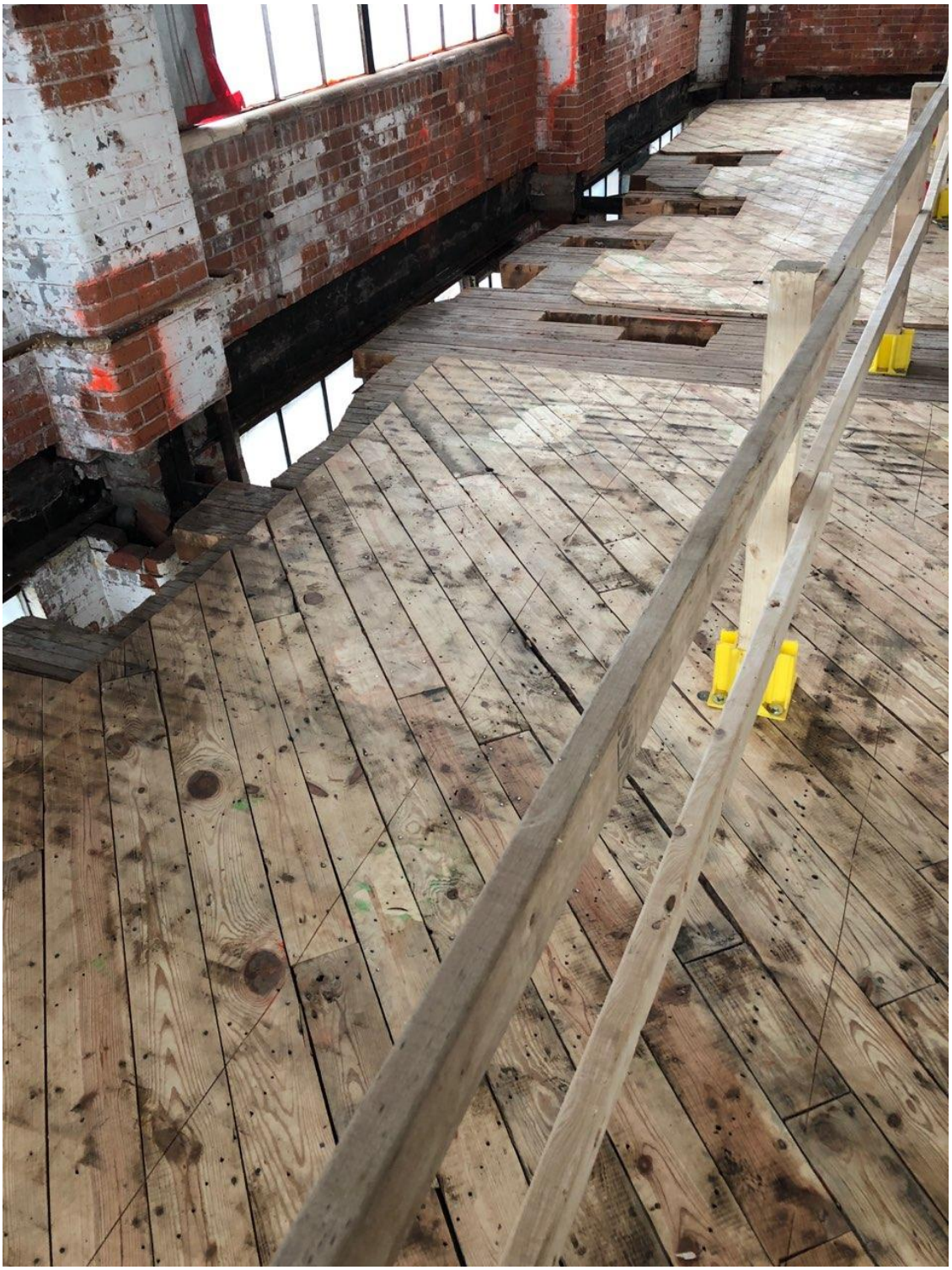

Figure 3. Extensive Remediation on the Seventh Floor of the Benrus Structure

Figure 4. Small Area Surface Remediation within the Benrus Structure

3.0 SITE OBSERVATIONS AND FINDINGS

3.1 Summary of Activities

The inspection team conducted a survey at the 145 Cherry Avenue property on January 9, 2018. A pre-inspection meeting was held with Mark Roberts and John Nicholson (NRC); Matt Norton and Chris Kovalovsky (DDES); and Nick Altic and Stephen Pittman (ORAU). Participants discussed the areas that had been remediated and the inspection team's intention to re-visit the locations identified as potentially contaminated with radium during the 2016 survey and to perform general area scans in other portions of the property.

Radiological surveys performed by the inspection team consisted of gamma radiation scans using Ludlum model 44-10 2-inch by 2-inch (2×2) sodium iodide detectors connected to Ludlum model 2221 ratemeter/scalers, alpha-plus-beta radiation direct measurements using a Ludlum model 44-142 plastic scintillator connected to a Ludlum model 2221 ratemeter/scaler, and radiation exposure rate measurement using a Ludlum model 192 sodium iodide-based µR ratemeter[1]. Table 1 presents the specific instruments used during the site visit. Smear samples were also collected at select locations to quantify removable surface activity levels.

[1]Roentgen is a unit of exposure (energy absorbed in air), whereas a rem is a unit of dose delivered to a person (resulting from the radiation energy absorbed in that person). While Roentgen and rem are related, these are different units. Because they are similar for gamma ray energies from Ra-226, NRC makes the simplifying assumption in this case that these units are equivalent (1 Roentgen = 1 rem).

Table 1. Benrus Clock Company Survey Instruments			
Radiation Type (units)	**Detector Type**	**Detector Model (Number)**	**Ratemeter (Number)**
Alpha-plus-beta (cpm)	Plastic Scintillator	44-142 (689) Calibrated 09/22/2017	2221 (1139) Calibrated 10/10/2017
Gross gamma (cpm)	Sodium Iodide	44-10 (1152) Calibrated 11/03/2017 44-10 (1151) Calibrated 11/03/2017	2221 (1139) Calibrated 10/10/2017 2221 (1140) Calibrated 11/03/2017
Gross gamma (µR/h)	Exposure Meter	192 (1127) Calibrated 06/02/2017	N/A

N/A = not applicable
Number = ORAU equipment barcode
cpm = counts per minute
µR/h = microRoentgen per hour

A high-density survey (approximately 100 percent scan coverage) was conducted on the accessible portions of the seventh floor where the greatest amount of contamination had previously been identified. Areas that exhibited elevated radioactivity were bound using a 5-point method to determine the extent of contamination; surface activity was measured with a plastic scintillator; and smears were collected to assess removable contamination by laboratory analysis. Data were recorded on field forms with locations noted on areal maps. During the seventh-floor survey, a team from the Connecticut Department of Energy and Environmental Protection (CT DEEP), led by Michael Firsick, arrived, performed gamma radiation measurements, and collected smears. Where sections of the floor had been removed (see Figure 3), detectors were affixed to extendable poles to survey materials up to approximately six feet beyond the barricades.

Twenty (20) side-by-side measurements were also collected (using DDES and ORAU instruments) on the sixth and seventh floors. Side-by-side measurement locations were selected by the NRC, with preference given to areas that had elevated surface activity. Lower density scans (approximately 50 to 75 percent) were performed on floors four, five, and six, as time permitted. Material-specific background measurements were also collected before the end of the day. The sun was setting by the time the fourth floor survey was complete, and electric lighting was only available on lower floors. After concurrence with NRC, survey activities were terminated, and the team departed the site at approximately 5:15 p.m.

3.2 Summary of Results

This discussion is organized into three sections. The first covers results collected during the judgmental confirmation survey of the top four floors (primarily the seventh floor). The second discusses the results associated with side-by-side measurements. The third includes DDES measurements collected from pre-and post-remediated small areas of elevated activity after ORAU left the facility.

Confirmation Survey Results. Appendix A, Table A.1 presents alpha-plus-beta total and removable surface activity results in units of disintegrations per minute per 100 cm^2 (dpm/100 cm^2), and associated gross gamma radiation levels in cpm and µR/h, where available. Figures A-1 and A-2 present discrete measurement locations on the seventh and fourth floors, respectively, overlaid onto facility floorplans. Note that drawings are not to scale, and depictions of facility features are based on the observations of surveyors during the investigation. Table 2 summarizes confirmation survey data by floor, listing the number of measurements by floor and type; plus mean, minimum, and maximum results.

Continuous gamma walkover scans were performed on the fourth, fifth, sixth, and seventh floors. Gross gamma radiation levels ranged from 5,000 to 52,000 cpm for all floors. The maximum gamma level observed was located on the fourth floor. Exposure rate measurements were only performed over portions of the seventh floor due to access and time limitations. The exposure rate measurements ranged from 7 to 17 µR/h at 1 meter and from 6 to 60 µR/h on contact. In general, the higher levels at 1 meter were associated with naturally occurring radioactive materials in exterior brick walls. A conservative background exposure rate of 6 µR/h is assumed for the site. It is noted that ORAU surveyors identified a few small areas of elevated activity during the gamma scan that DDES did not identify using alpha-only measurements with a floor monitor. This suggests that gamma measurements are more effective than alpha measurements when locating discrete sources of Ra-226 and supports the assumption that layers of dust or other materials can limit alpha-only measurement efficiencies.

Total and removable alpha-plus-beta radiation measurements were collected on the fourth and seventh floors. Locations were judgmentally selected based on the results of the gamma walkover survey. Alpha-plus-beta total activity measurements ranged from background (i.e., 0) to 1,300 dpm/100 cm^2 (same max value occurred on fourth and seventh floors). The total removable activity ranged from background to 46 dpm/100 cm^2, noting that the removable fraction from small areas of elevated activity is almost always below 10 percent of the total (fixed plus removable) surface activity value. Two discrete locations on the fourth floor and two discrete locations on the seventh floor exceeded the residential 630 dpm/100 cm^2 large-area limit for total surface activity, as presented in the Dose Assessment Technical Basis Document (ORISE 2017a). Total removable activity at these locations was less than 1 percent of the limit (i.e., less than 6.3 dpm/100 cm^2), and all four areas were less than 0.1 m^2 in size.

Smears were submitted for gross alpha and gross beta analysis at a radio-analytical laboratory. ORAU field measurements of total alpha-plus-beta static measurements in cpm were converted to total surface activity units of dpm/100 cm^2 using the equation below:

$$dpm/100\ cm^2 = \frac{C - B}{\varepsilon_{tot} \times G}$$

Where:

C = measured count rate (cpm)
B = background count rate (cpm)
G = geometry factor (unitless) = $\frac{Physical\ Detector\ Area\ (cm^2)}{100\ cm^2}$ = 1.0

ε_{tot} = total weighted efficiency (unitless) = 1.6

Due to the number of emissions from Ra-226 and its associated progeny, multiple radiation types and energies are emitted from contaminated surfaces. Therefore, a total weighted efficiency for Ra-226 and its associated progeny was calculated by:

$$\varepsilon_{tot} = \sum_{n} F_n \times \varepsilon_{i,n} \times \varepsilon_{s,n}$$

Where:

F_n = fractional abundance of nth emission

$\varepsilon_{i,n}$ = instrument efficiency for n^{th} emission

$\varepsilon_{s,n}$ = surface efficiency (0.25 for low-energy beta particles, 0.5 for high-energy beta particles) for n^{th} emission

Table 2. Summary of Field Measurement Results

Parameter	No. of Discrete Measurements[a]	Mean	Minimum	Maximum
4th Floor				
NaI (kcpm)	111	11	6.5	52
Exposure, 1 meter (µR/hr)	--	--	--	--
Exposure, Contact (µR/hr)	--	--	--	--
Removable (dpm/100 cm²)	5	0.64	0.15	1.4
Total (dpm/100 cm²)	5	440	3	1,300
5th Floor				
NaI (kcpm)	13	10	7.7	14
Exposure, 1 meter (µR/hr)	--	--	--	--
Exposure, Contact (µR/hr)	--	--	--	--
Removable (dpm/100 cm²)	--	--	--	--
Total (dpm/100 cm²)	--	--	--	--
6th Floor				
NaI (kcpm)	112	10	6.5	19
Exposure, 1 meter (µR/hr)	--	--	--	--
Exposure, Contact (µR/hr)	--	--	--	--
Removable (dpm/100 cm²)	--	--	--	--
Total (dpm/100 cm²)	--	--	--	--

Table 2. Summary of Field Measurement Results				
Parameter	**No. of Discrete Measurements[a]**	**Mean**	**Minimum**	**Maximum**
7th Floor				
NaI (kcpm)	124	11	5	42
Exposure, 1 meter (µR/hr)	41	11	7	17
Exposure, Contact (µR/hr)	42	13	6	60
Removable (dpm/100 cm²)	40	5.9	0.49	46
Total (dpm/100 cm²)	40	160	-23	1,300

[a]Gamma ranges (cpm) using 2×2 NaI also collected.

Side-by-Side Field Measurements. ORAU was directed by NRC to collect side-by-side measurements at 20 small areas of elevated activity. Both ORAU and DDES performed static measurement at each location, ORAU using the Ludlum model 44-142 for alpha-plus-beta measurements, and DDES using the Ludlum model 43-93 for separate alpha and beta measurements. The objective was to determine if DDES results were consistent with ORAU results, or whether adjustments would be required to ensure final status data accurately or conservatively represent site conditions.

ORAU recorded DDES's raw (cpm) alpha measurement results in the field and, prior to receiving DDES's converted (to dpm/100 cm^2) values, used calibration data provided by DDES and the weighted efficiency methods described earlier in this section. ORAU calculated an alpha-only weighted efficiency of 0.5 for the DDES instrumentation. DDES later provided their total efficiency of 0.104. Figure 5 presents DDES's total surface activity results based on the weighted total efficiency calculated by ORAU (left) and the un-weighted efficiency total used by DDES (right). These charts demonstrate that DDES is using a conservative efficiency that tends to overestimate surface concentration levels. Side-by-side measurement results are presented in Appendix A, Table A.2.

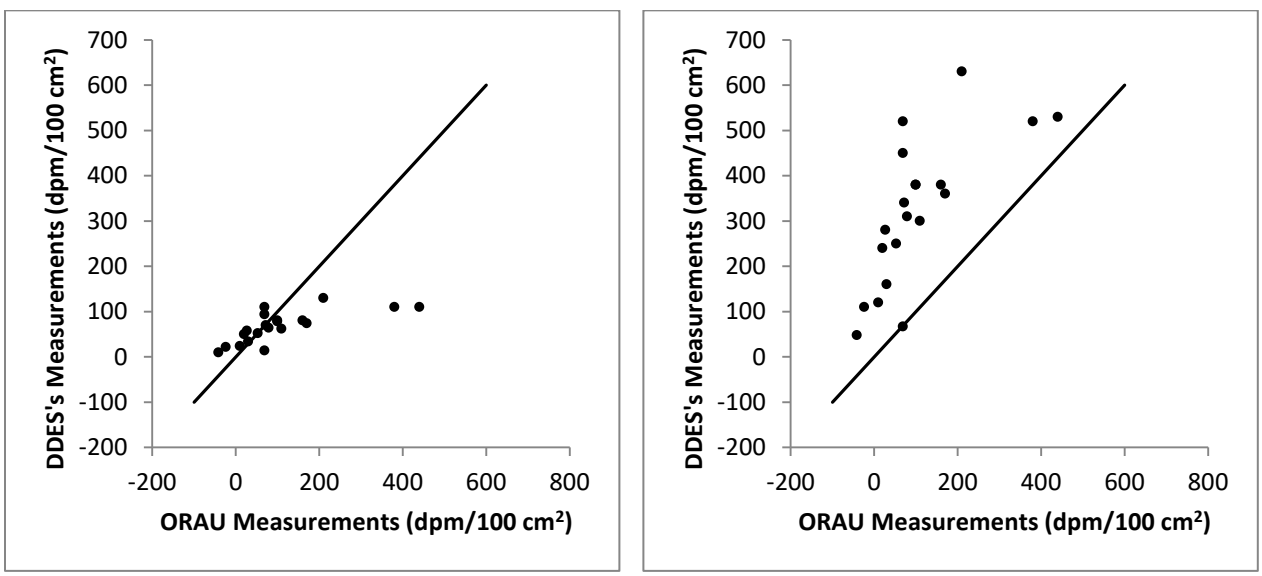

Figure 5. Ra-226 Total Surface Activity Comparison using ORAU's Weighted Alpha Efficiency (left) and DDES's Weighted Alpha Efficiency (right).

ORAU recorded DDES's raw (cpm) beta measurement results in the field and, prior to receiving DDES's converted (to dpm/100 cm^2) values, used calibration data provided by DDES and the weighted efficiency methods described earlier in this section. ORAU calculated a beta-only weighted efficiency of 0.7 for the DDES instrumentation. DDES later provided their total efficiency of 0.1505. Figure 6 presents DDES's total surface activity results based on the weighted total efficiency calculated by ORAU (left) and the un-weighted total efficiency used by DDES (right). These charts demonstrate that DDES is using a conservative efficiency that tends to overestimate surface concentration levels. Side-by-side measurement results are presented in Appendix A, Table A-2.

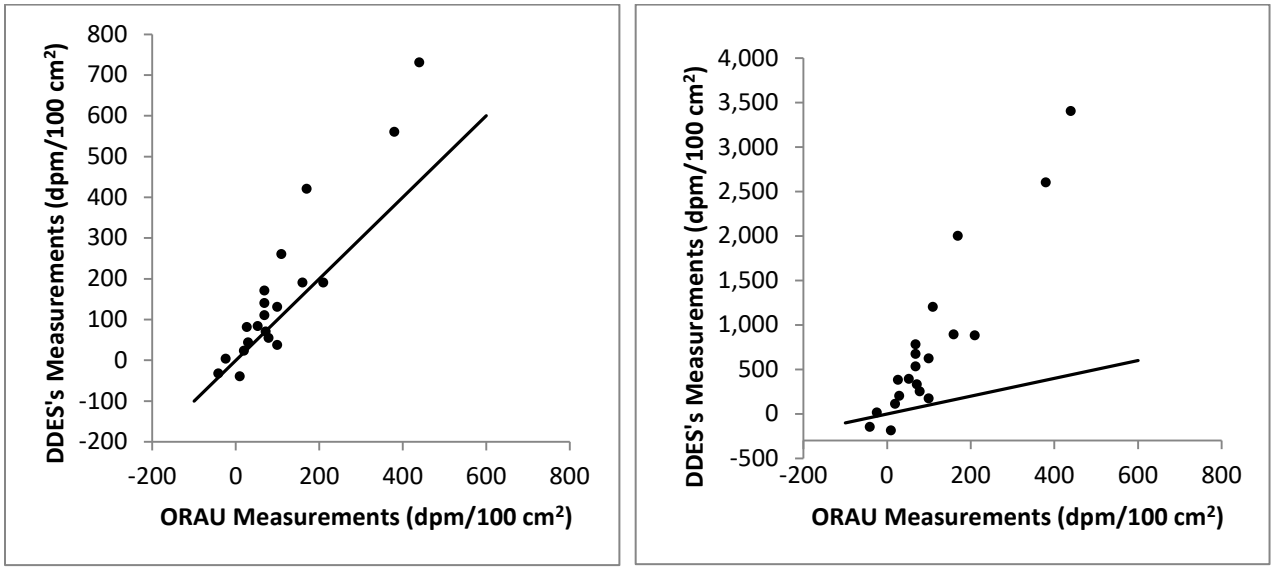

Figure 6. Ra-226 Total Surface Activity Comparison using ORAU's Weighted Beta Total Efficiency (left) and DDES's Un-weighted Beta Total Efficiency (right).

Post Survey Remediation. After ORAU left the Benrus site, NRC was informed that DDES remediated eight small areas of elevated activity on the fourth floor (two locations) and seventh floor (six locations). Using ORAU calculated efficiencies (which are less conservative), surface activities reached up to 140 dpm/100 cm^2 alpha prior to remediation and only 54 dpm/100 cm^2 post-remediation.

Though DDES focused on alpha radiation throughout the final status survey process, they also provided beta measurement data for the pre- and post-remediation dataset. ORAU estimated a weighted efficiency of 0.7 for the DDES beta measurement (as previously described). However, DDES used a conservative efficiency of 0.1505 that again tends to overestimate surface concentration levels. It is ORAU's opinion that individual locations that exceed the 630 dpm/100 cm^2 limit, according to the DDES beta measurement, are actually below the limit when applying a more realistic weighted efficiency. ORAU's alpha-plus-beta and DDES's alpha-only data support this conclusion. However, it is noted that the beta measurement appears to be more effective at identifying Ra-226 contamination. ORAU had already demonstrated that gamma measurements were more reliable than alpha at locating Ra-226 contamination. These results strongly suggest that beta or alpha-plus-beta measurements are preferred over alpha. DDES's pre- and post-remediation data are presented in Appendix A, Table A-3.

3.3 Summary of Dose Assessment Results

The Dose Assessment Technical Basis Document (ORISE 2017a) presents default concentration-based screening levels based on guidance in NUREG-1757 (NRC 2006) using the Decontamination and Decommissioning (DandD) code Version 2.4 (NRC 2001). The Dose Assessment Technical Basis Document (ORISE 2017a) also presents methods for developing site-specific screening levels and dose estimates, assuming a default conceptual model may not apply at a given site. The most conservative member of the critical group at the Benrus structure is a future residential building occupant, who is conservatively assumed to spend up to 5,770 hours in the building. Potential exposure pathways include external gamma, inhalation, and secondary ingestion. ORAU identified two areas with measurements in excess of the large-area limit of 630 dpm/100 cm^2. These areas are the focus of this dose assessment.

On the fourth floor, two total activity measurements (770 and 1,300 dpm/100 cm^2) exceeded the screening level of 630 dpm/100 cm^2. However, both contamination locations are highly localized and below the screening value of 63,000 dpm/100 cm^2, associated with a surface area of 0.1 m^2 or less. The average measurement in the area (see Figure A-2) is 440 dpm/100 cm^2, which is below the screening value for an unlimited area. Because 630 dpm/100 cm^2 corresponds to a dose of 25 mrem/yr, the average measured activity, assuming an unlimited source area, corresponds to a dose of less than 18 mrem/yr. This dose estimate is conservative given removable fractions are less than 10 percent assumed by Dose Assessment Technical Basis Document (ORISE 2017a) calculations.

On the seventh floor, two total activity measurements (1,300 dpm/100 cm^2 at Location 1 in Figure A-1 and 760 dpm/100 cm^2 at Location 2 in Figure A-1) exceeded the screening level of 630 dpm/100 cm^2. This highly localized contamination is again well below the discrete point screening level of 63,000 dpm/100 cm^2. Measurements in Figure A-1 grids 35 and 36 were average, noting that Location 1 falls close to the center, producing an average value of 280 dpm/100 cm^2. Because 630 dpm/100 cm^2 corresponds to a dose of 25 mrem/yr, the average measured activity, assuming an unlimited source area, corresponds to a dose of less than 11 mrem/yr. Measurements in Figure A-1 grids 30 and 31 were average, noting that Location 2 can be associated with either, producing an average value 200 dpm/100 cm^2. Because 630 dpm/100 cm^2 corresponds to a dose of 25 mrem/yr, the average measured activity, assuming an unlimited source area, corresponds to a dose of less than 8.0 mrem/yr. These dose estimates are again conservative given removable fractions are less than 10 percent assumed by the Dose Assessment Technical Basis Document (ORISE 2017a) calculations.

4.0 FINAL STATUS SURVEY REPORT REVIEW

As part of the confirmatory survey, ORAU reviewed the technical content of the DDES's final status survey report (FSSR). The review was intended to identify technical deficiencies that would preclude the site from accurate decision making. ORAU made the following observations:

1. Table 8-1 in the FSSR provides typical total efficiencies for instrumentation used for scanning and total surface activity measurements. Total efficiencies are based on thorium-230, which is conservative, as Th-230 emits a relatively low-energy alpha. DDES elected not to take credit for the multiple alpha emissions from the Ra-226 decay chain (i.e., every alpha particle detected is attributed directly to Ra-226). ORAU determined the weighted efficiency for the site's instrumentation to be approximately 0.5,

assuming secular equilibrium with Ra-226 progeny. This weighted efficiency is approximately a factor of five greater than that presented in FSSR Table 8-1. Thus, resulting Ra-226 total surface activities presented in the FSSR are conservative (i.e., tend to overestimate surface concentrations).

2. The remediation contractor performed alpha only surface scans using either model 43-93 hand-held detectors or model 43-37 large-area floor monitors. FSSR Section 8.3.2 provides the contractor's methodology for determining the scan minimum detectable concentration (MDC), which is based on guidance outlined in Section 6 of the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000) and NUREG-1507 (NRC 1998). The instrumentation used by the contractor can detect both alpha and beta radiation simultaneously. Based on the information presented in the FSSR, it is unclear whether the contractor performed alpha-only surface scans or set the instrumentation to detect alpha-plus-beta. The scan MDC calculations presented in Appendix B indicate that alpha-only scans were performed. Due to the relatively low background of alpha detectors, a probability of detecting a single count from scanning a surface with a given contamination level is determined *in lieu* of a traditional scan MDC (i.e., for beta radiation). ORAU evaluated the probability of detecting a hypothetical hot-spot with concentration equal to: 1) the contractor's stated MDC, 2) the derived concentration guideline level (DCGL) stated in the ORAU Dose TBD (630 dpm/100cm^2), and 3) the contractor's DCGL (819 dpm/100 cm^2, FSSR Section 3.0). Table 3 presents the probability of detection for the three previously mentioned scenarios. Due to the higher background of the model 43-37 floor monitor, the probability of getting two or more counts during the observation window was calculated as opposed to the probability of getting one count for the hand-held model 43-93 detector.

Table 3. Probability of Detection for Alpha Scans[a]

Contamination Scenario	P(n>1) for Hand-Held Detector		P(n>2) for Floor Monitor	
	Using Site's Efficiency	Using Weighted Efficiency	Using Site's Efficiency	Using Weighted Efficiency
DDES's Stated Scan MDC	0.46	0.95	0.05	0.24
DCGL from Dose TBD	0.89	1.00	0.49	0.99
DDES's DCGL	0.94	1.00	0.62	1.00

[a]Detection probabilities were calculated using scan MDC inputs from Appendix B of the FSSR

The data presented in Table 3 above provides reasonable confidence that the contractor should have been able to identify contamination at levels equal to the ORAU and site-determined DCGL, given that the weighted efficiency is more representative of field conditions. This assessment is from *a priori* planning aspect and, thus, does not consider actual field conditions.

3. As previously discussed in item 2 above, it is assumed that the contractor performed alpha surface scans. ORAU recommends that the contractor incorporate gamma surface scans as a best practice, using a scintillation-based detector, such as a 2x2 sodium iodide, into future survey designs. This recommendation is based on ORAU's

previous experience at Ra-226 sites, and noting that ORAU surveyors identified some small areas of elevated activity using the 2x2 sodium iodide detector that DDES surveyors missed using the model 43-37 floor monitor. A sodium iodide gamma detector has a much greater detection sensitivity, relative to the alpha detector, for detecting discrete spots of Ra-226, especially if there is a barrier—such as dirt—between the source and detector.

4. Section 3.2 of the FSSR states that non-impacted material-specific backgrounds were established. Based on ORAU's on-site activities, it is known that material-specific backgrounds were applied to total surface activity calculations. However, the FSSR does not reference the material-specific background values. These values should be provided in the report so that a third party can independently calculate the reported total surface activity values.

5. Per FSSR Section 10.6.5.2, static measurements collected from Class 3 survey units were collected based on professional judgment. As recommended by MARSSIM FSS, measurements in a Class 3 survey unit should be collected randomly. However, the site does not have an elevated measurement comparison criterion; therefore, decisions related to a survey unit passing are not based on the mean/median concentration. Given that scan sensitivities appear to be adequate (see Table 3), actual scan coverage was around 50 percent per the FSSR, ORAU considers it unnecessary to collect additional random measurements. Furthermore, random measurements provide minimal confidence of detecting small areas of elevated activity.

6. ORAU notes that the FSSR only qualitatively addresses potential contamination on the ceiling and elevated surfaces. However unlikely contamination may be, some former clock companies did use powdered products that resulted in airborne releases (Clark 1997). Therefore, the potential for contamination on overhead surfaces should be more thoroughly addressed by the FSSR. The FSSR does reference an historical site assessment and characterization survey, presumably containing relevant information, though specific references were not provided.

5.0 OBSERVATIONS AND RECOMMENDATIONS

Based on the confirmation data collected during the January 2018 survey, and considering DDES's FSSR, ORAU concludes that DDES results conservatively represent site conditions. Additionally, residual Ra-226 concentrations likely would not produce a radiological dose above 25 mrem/yr, even when considering conservative residential exposure scenarios. This conclusion is based on the following observations:

- Identified Ra-226 contamination is limited to small, isolated areas of elevated activity (generally less than 0.1 m^2), thus the 63,000 dpm/100 cm^2 limit is applicable—no measured value approaches this limit.

- Average doses calculated for areas with the highest measured Ra-226 concentrations are below the 25 mrem/yr limit, with a maximum of 18 mrem/yr.

- DDES uses conservative detector efficiencies that tend to overestimate actual Ra-226 concentrations.

- Dose estimates show that a residential building occupant would receive an estimated dose less than the 25 mrem/yr unrestricted use limit in 10 CFR 20.1402, even if spending up to 5,770 hours/yr in a room containing the maximum observed area of elevated activity in a survey unit. These results are consistent with the dose assessment conclusions presented in ATSDR 1999.

Based on these observations, it is recommended that the NRC not pursue additional actions at the Benrus facility. NRC should, however, note that DDES used alpha-only measurements to locate and quantify Ra-226 contaminations. ORAU believes that the measurement of either gamma or beta radiation is superior to measurement of alpha radiation.

6.0 REFERENCES

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APPENDIX A
Confirmatory Survey Data of the Benrus Structure

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Table A-1. Confirmatory Surface Activity Measurements								
Floor	Location ID	Removable		Alpha-plus-Beta		Gamma	Exposure Rate (µR/hr)	
		Smear ID	Alpha-plus-Beta (dpm/100 cm^2)	Gross cpm	Total Activity (dpm/100 cm^2)	Gross kcpm[a]	1 meter	On Contact
4th	1	5307R0087	0.59	1,548	770	41	NC	NC
	2	5307R0088	0.67	2,340	1,300	52	NC	NC
	3	5307R0089	0.15	397	48	11	NC	NC
	4	5307R0090	0.41	434	71	11.5	NC	NC
	5	5307R0091	1.4	324	3	10	NC	NC
	Mean		**0.64**	**--**	**440**	**--**	**--**	**--**
7th	1	5307R0047	8.9	2,324	1,300	50	13	60
	2	5307R0048	4.9	1,533	760	20	8	8
	3	5307R0049	1.7	1,116	500	20	8	22
	4	5307R0050	5.9	540	140	24	12	11
	5	5307R0051	5.6	496	110	12	11	10
	6	5307R0052	23	338	11	18	12	13
	7	5307R0053	3.1	850	330	19	13	20
	8	5307R0054	6.6	351	19	9	12	9
	9	5307R0055	1.5	295	-16	20	14	9
	10	5307R0056	46	826	320	10.5	11	9
	11	5307R0057	9.5	778	290	17	13	16
	12	5307R0058	3.8	888	360	18.5	12	20
	13	5307R0059	10	455	84	13	12	11
	14	5307R0060	10	548	140	14.1	10	11
	15	5307R0061	5.2	460	88	11.1	10	12
	16	5307R0062	3.8	774	280	13.4	11	14
	17	5307R0063	2.4	450	81	11.3	9	10
	18	5307R0064	8.5	490	110	11	9.5	9
	19	5307R0065	3.7	483	100	5 - 13	NC	NC
	20	5307R0066	2.3	549	140	5 - 15	NC	NC

Table A-1. Confirmatory Surface Activity Measurements								
Floor	Location ID	Removable		Alpha-plus-Beta		Gamma	Exposure Rate (µR/hr)	
		Smear ID	Alpha-plus-Beta (dpm/100 cm^2)	Gross cpm	Total Activity (dpm/100 cm^2)	Gross kcpm[a]	1 meter	On Contact
	21	5307R0067	2.2	466	91	5 - 15	11	12
	22	5307R0068	12	377	36	5 - 15	8	17
	23	5307R0069	8.5	420	63	5 - 15	8	8
	24	5307R0070	5.5	456	85	5 - 15	9	9
	25	5307R0071	6.9	392	45	5 - 15	8	7
	26	5307R0072	1.4	892	360	15 - 25	16	20
	27	5307R0073	1	483	100	15 - 25	10	10
	28	5307R0074	0.98	706	240	15 - 25	17	22
	29	5307R0075	7.5	634	200	15 - 25	10	9
	30	5307R0076	0.52	466	91	15 - 25	11	14
	31	5307R0077	2.9	283	-23	7 - 13	NC	NC
	32	5307R0078	1.2	316	-3	7 - 13	NC	NC
	33	5307R0079	0.49	314	-4	7 - 13	NC	NC
	34	5307R0080	1.7	310	-6	7 - 13	NC	NC
	35	5307R0081	2.1	289	-19	7 - 13	NC	NC
	36	5307R0082	4.1	341	13	6 - 9	NC	NC
	37	5307R0083	2	305	-9	5 - 7	NC	NC
	38	5307R0084	1.9	346	16	5 - 13	NC	NC
	39	5307R0085	3	503	110	9.8	NC	NC
	40	5307R0086	2.2	325	3	7.2	NC	NC
	Mean		**5.9**	**--**	**160**	**--**	**--**	**--**

[a]Range used if no direct measurement was taken for location
NC = Not Collected

Table A-2. ORAU and DDES's Surface Activity Measurements								
Survey Area	ORAU Location ID	Licensee Location ID	Surface Material	ORAU (dpm/100 cm^2)	DDES's Measurements (dpm/100 cm^2)			
				Alpha + Beta	Alpha (50% Eff)	Alpha (10% Eff)	Beta (70% Eff)	Beta (15% Eff)
6th Floor	1	9	Wood	160	80	380	190	890
	2	10	Wood	79	64	310	54	250
	3	11	Wood	100	78	380	37	170
	4	21	Wood	10	24	120	-40	-190
	5	3	Wood	-24	22	110	3	13
	6	6	Wood	30	34	160	43	200
	7	5	Wood	-41	10	48	-33	-150
7th Floor	1	18	Wood	27	58	280	81	380
	2	32	Wood	100	80	380	130	620
	3	18	Brick	69	14	67	140	670
	4	16	Wood	72	70	340	70	330
	5	13	Wood	20	50	240	23	110
	6	4	Wood	53	52	250	83	390
	7	17	Wood	69	94	450	170	780
	8	4	Wood	210	130	630	190	880
	9	19	Wood	170	74	360	420	2,000
	10	21	Wood	440	110	530	730	3,400
	11	3	Wood	380	110	520	560	2,600
	12	5	Wood	69	110	520	110	530
	13	21	Wood	110	62	300	260	1,200

Table A-3. Post-Survey Remediation								
DDES Location	Pre-Remediation Activity				Post-Remediation Activity			
	Gross Alpha (cpm)	Gross Beta (cpm)	Alpha[a] (dpm/100 cm^2)	Beta[a] (dpm/100 cm^2)	Gross Alpha (cpm)	Gross Beta (cpm)	Alpha[a] (dpm/100 cm^2)	Beta[a] (dpm/100 cm^2)
4A	7	843	8	870	30	549	54	450
4B	14	1,499	22	1,800	24	663	42	620
7A	71	979	140	1,100	30	680	54	640
7B	37	777	68	780	15	643	24	590
7C	43	490	80	370	6	390	6	230
7D	49	765	92	760	10	362	14	190
7E	48	410	90	260	6	222	6	-13
7F	27	905	48	960	14	694	22	660

[a]Calculated using the ORAU calculated efficiencies for alpha (50 percent) and for beta (70 percent).

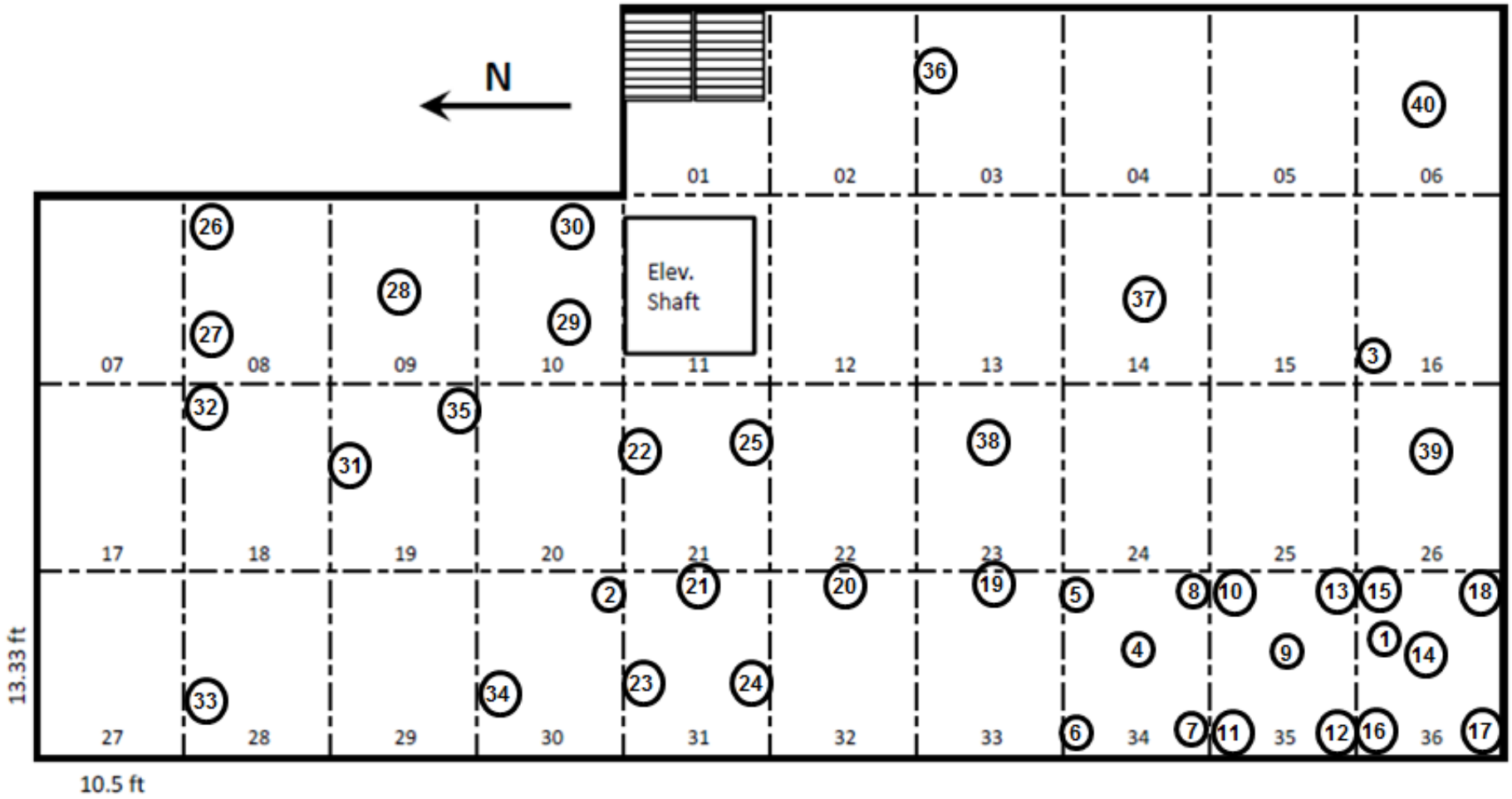

Figure A-1. Seventh Floor Discrete Measurement Confirmatory Survey Map

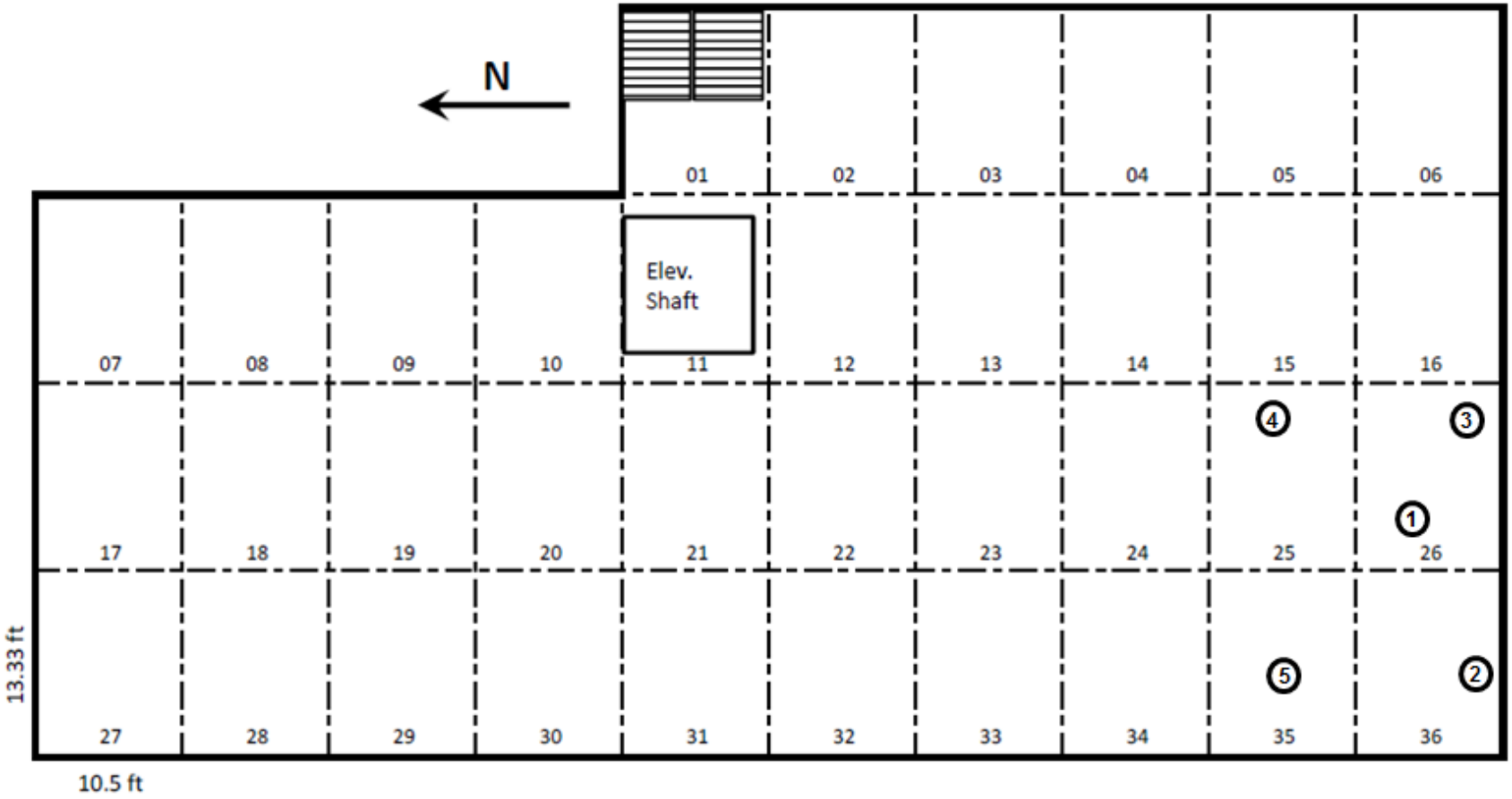

Figure A-2. Fourth Floor Discrete Measurement Confirmatory Survey Map