Enclosure

OAK RIDGE ASSOCIATED UNIVERSITIES:

SITE STATUS REPORT FOR THE FORMER SESSIONS CLOCK COMPANY-2 AT 164 CENTRAL STREET, REAR, BRISTOL, CONNECTICUT

FEBRUARY 2, 2018

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that Oak Ridge Associated Universities (ORAU) perform radiological surveys of the property at 164 Central Street, rear, in Bristol, Connecticut. This property contains structures that were once part of the former Sessions Clock Company that used radium paint in the manufacturing of clocks and watches in the early 1900s. The objective of these surveys was to locate possible discrete sources of radium-226, if any, that would be associated with former Sessions Clock Company operations.

ORAU performed radiological surveys during a February 7, 2017 initial site visit. Surveys were performed in the former clock company structure and over the property's open land area. The survey did not identify elevated activity on accessible structure surfaces, but relatively high levels of radium-226 contamination were identified along the bank of the Pequabuck River, south of the building structure. To gain a better understanding of the impacts to site soil, the Pequabuck River, and the local environment, a more extensive scoping survey was conducted on April 25–26, 2017. Several soil, sediment, and water samples were collected in the study area. Elevated radium-226 concentrations were identified in soils down to approximately 1 meter (the maximum sample depth obtained) and in adjacent river sediment. Based on these results, it is recommended that the NRC maintain oversight by working with the site owner to control and mitigate exposure to sources of radium-226 at the former Sessions Clock Company property.

SITE STATUS REPORT

Property:	Sessions Clock Company-2 164 Central Street, Rear Bristol, Connecticut 06010
Docket Number:	3039005
Current Property Name(s):	Bristol Instrument Gears
Current Property Owner(s):	James F. Carros
Inspection Dates:	February 7 and April 25–26, 2017
Inspector(s):	Laurie Kauffman, Mark Roberts, and Katherine Warner/U.S. Nuclear Regulatory Commission (NRC); supported by Kaitlin Engel 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 NRC is evaluating properties where a review of historical information identified possible Ra-226 use. The property at 164 Central Street, rear, in Bristol, Connecticut, was identified as part of the former Sessions Clock Company that operated from the early 1900s to the 1940s (ORNL 2015). The objectives of the initial site visit and subsequent scoping survey were to determine if discrete sources of Ra-226 and/or distributed Ra-226 contamination are present, to identify the areas of highest contamination, and to determine if there are any health and safety concerns to current or plausible future occupants.

During the initial site visit on February 7, 2017, survey data indicated radium contamination in soil in a general area to the south of the building near the Pequabuck River. Consequently, a scoping survey was conducted on April 25-26, 2017 to further investigate the contaminated soil. Data collected during the February 7, 2017 site visit and April 25–26, 2017 scoping survey—which includes alpha-plus-beta measurements, gamma radiation scans, exposure rate measurements, and sample collection—will be used to plan future actions that may be needed to reduce Ra-226 exposure to current or future site occupants to levels that do not produce a radiological dose above 25 mrem/yr, per 10 Code of Federal Regulations (CFR) Part 20, Standards for Protection Against Radiation, Section 20.1402. It may be noted that destructive testing is not generally performed as described within NRC's procedures in Temporary Instruction 2800/043 *Inspection of Facilities Potentially Contaminated with Discrete Radium-226 Sources* (NRC 2017) (Agencywide Documents Access and Management System [ADAMS] Accession No. ML16330A678). However, water, soil, and sediment sample collection was necessary in this instance to assess the impacts to the local environment.

2.0 PROPERTY DESCRIPTION AND INITIAL SITE VISIT CONSIDERATIONS

2.1 Property Description and History

The site summary included in the "*Historical Non-Military Radium Sites Research Effort Addendum"* report (ORNL 2015) provides known site details about the type, form, history, potential locations and other information related to discrete sources of Ra-226 used at the site. The Sessions Clock Company, a former clock manufacturing facility, is located on either side of the Pequabuck River. The main property is located to the south of the river at 61 East Main Street in Bristol, Connecticut, with an additional building located to the north of the river at 164 Central Street, rear. In 1960, the 164 Central Street, rear building, shown in Figure 1, was sold to the Bristol Instrument Gears Company. The scope of this report is limited to the Bristol Instrument Gears building and surrounding land area.

The brick building contains two levels and a crawl space. The building is approximately 1,100 square meters in area and contains the original wood flooring throughout most of the facility. The floor space on the two levels inside the building is mainly occupied by equipment. The surrounding land area is approximately 1.4 hectares and extends south to the Pequabuck River. An asphalt driveway surrounds the building, and the ground leading to the river is mostly grassy (some gravel). A warehouse used for storage is located to the southeast of the Bristol Instrument Gears building. The eastern portion of the land area is used for storage.

The 1999 Agency for Toxic Substances and Disease Registry (ATSDR) Public Health Assessment reported one location on the first floor of the Bristol Instrument Gears building that had radiation levels at the U.S. Environmental Protection Agency dose limit of 15 mrem/yr. Elevated radiation levels were not identified on the first floor during the 2017 initial site visit.

Figure 1. Location of Bristol Instrument Gears at 164 Central Street on Former Sessions Clock Company Property (Google Earth 2017)

2.2 Initial Site Visit and Scoping Survey Considerations

Prior to commencing initial site visit surveys on February 7, 2017, the general layout of the land area and building was examined for consistency with historical information and to identify impediments to conducting the survey and/or health and safety considerations. The two-story building is the original facility. The structural integrity is sound except for a set of stairs located on the southern side of the building, which may be unsteady. Much of the floor space contains machining equipment and business related items that limited access to surfaces. The terrain surrounding the building limited survey access to portions of the property. The inspection team was unable to fully investigate the area near the river as access was limited at the time due to the slope of the land, heavy leaf coverage, and rainy/icy weather conditions.

Prior to commencing scoping survey activities on April 25–26, 2017, the previously identified area with contaminated soil north of the Pequabuck River was examined to identify any impediments to conducting the survey and/or health and safety considerations. Other than a delay due to rain on the morning of April 26, no impediments and/or health and safety concerns pertaining to performing the survey were identified.

3.0 SITE OBSERVATIONS AND FINDING

3.1 Summary of Activities

The inspection team conducted an initial site visit of the 164 Central Street, rear, property on February 7, 2017, followed by a scoping survey of contaminated outdoor areas on April 25–26, 2017. The following individuals were present during at least one of the pre-inspection team meetings: Laurie Kauffman, Mark Roberts and Katherine Warner (NRC); Kaitlin Engel and Stephen Pittman (ORAU); James Carros (owner); and Gary MaCahill and Maxine McCarthy (Connecticut Department of Energy and Environmental Protection [CT DEEP]). Participants discussed the inspection team's intention to perform general area surveys of the 164 Central Street, rear, property and collect soil, sediment, and water samples, as needed. The inspection teams were granted access to all portions of the property.

Table 1 and Table 2 present the specific instruments used during the initial site visit and scoping survey, respectively. Radiological surveys performed by the inspection teams consisted of gamma radiation scans using a Ludlum model 44-10 2-inch by 2-inch (2×2) sodium iodide detector connected to a Ludlum model 2221 ratemeter/scaler, alpha-plus-beta radiation direct (surface) measurements using a Ludlum model 44-142 plastic scintillator connected to a Ludlum model 2221 ratemeter/scaler, and radiation exposure rate measurements using a Ludlum model 192 sodium iodide based microRoentgen (μR) ratemeter[1]. The 2×2 sodium iodide detector gamma radiation measurements were obtained near the target surface, and the exposure rates were obtained at approximately 3 feet (1 meter) above the surface and on contact at select locations. As a rule-of-thumb, the 2×2 sodium iodide detector can respond to

[1] NOTE: 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).

gamma-emitting radionuclides located in the top 15 to 30 centimeters (approximately 6 inches to 12 inches) of soil—there is no rule-of-thumb for structural surfaces.

Global positioning system equipment was used for real-time gamma measurements and position data capture during the scoping survey. Also during the scoping survey, gamma radiation scans of the boreholes were performed with the 2×2 sodium iodide detector and a Ludlum model 44-159-1 cesium iodide detector connected to a Ludlum model 2221 ratemeter/scaler. The smaller cesium iodide detector was available in case borehole widths precluded access by the larger 2×2 sodium iodide detector. Gamma radiation measurements in the river were performed by placing the same 2×2 sodium iodide detector in a capped PVC tube. The tube prevented river water from damaging detector electronics, while allowing the wading surveyor to collect gamma radiation data along the riverbed. Although the surrounding water reduced the detector's response (i.e., "clicks" per minute), the surveyor was still able to hear significant response changes and identified potential Ra-226-contaminated sediment at two locations.

Table 1. Survey Instruments Used During the Site Visit

Radiation Type (units)	Detector Type	Detector (Number)	Ratemeter (Number)
Alpha plus beta (cpm)	Plastic Scintillator	44-142 (920) Calibrated 11/23/16 44-142 (1031) Calibrated 01/26/17	2221 (1143) Calibrated 01/26/17 2221 (590) Calibrated 01/26/17
Gross gamma (cpm)	Sodium Iodide	44-10 (664) Calibrated 01/26/17 44-10 (908) Calibrated 11/01/16	2221 (1143) Calibrated 01/26/17 2221 (590) Calibrated 01/26/17
Gross gamma (µR/h)	Exposure Rate Meter	192 (1127) Calibrated 06/03/16 192 (1129) Calibrated 06/03/16	N/A
Gamma Spectrum Analyzer (SAM-940)	Lanthanum Bromide	940 (864)[a]	N/A

N/A = not applicable; ratemeter is not required
Number = equipment tracking number
cpm = counts per minute
µR/h = microRoentgen per hour
[a]Device performs automatic calibration upon startup and is source checked before use (available but not used given samples were collected)

Table 2. Survey Instruments Used During the Scoping Survey			
Radiation Type (units)	**Detector Type**	**Detector Model (Number)**	**Ratemeter Model (Number)**
Gross gamma (cpm)	Sodium Iodide	44-10 (664) Calibrated 01/26/17 44-10 (908) Calibrated 03/09/17	2221 (1143) Calibrated 01/26/17 2221 (590) Calibrated 01/26/17
Gross gamma (cpm)	Cesium Iodide	44-159-1 (921) Calibrated 04/21/17	2221 (590) Calibrated 01/26/17

Number = equipment tracking number
cpm = counts per minute

Summary of Initial Site Visit Activities – February 7, 2017:

At the completion of the 9:45 a.m. meeting with the site owner, the site visit began outside due to the potential for rain later that day. Gamma radiation scans identified general area contamination to the south of the building near the river that was further investigated. The total area of elevated radiation was unable to be determined due to terrain, but the western edge is located approximately halfway down the length of the building and 21 meters (approximately 69 feet) away from the building. The elevated area extends 12 meters east, (39 feet) parallel to the building, but the width towards the river is unknown, see Figure B-4. The radiation levels identified in the area are as follows:

- 11,000 to 270,000 counts per minute (cpm) on the surface using the 2×2 sodium iodide detector
- 92,000 to 630,000 cpm post-sample count (i.e., in the sample hole) using the 2×2 sodium iodide detector
- 70 to 430 µR/h on contact using the model 192 exposure meter
- 35 µR/h at 1 meter (3.3 feet) above the surface using the model 192 exposure meter (A 90 µR/h reading was directly over the excavated area.)

Three soil samples were collected in the elevated area: two soil samples were collected from the surface soil, 0 to 15 centimeters (approximately 0 to 6 inches) deep; and one soil sample was collected of the subsurface soil, 15 to 30 centimeters (approximately 6 to 12 inches) deep. The subsurface soil sample was collected based on the significant increase of the 2×2 sodium iodide detector response after the surface sample was collected (response increased ~80 percent).

The inspection team noted no other elevated detector response across the remainder of the accessible land area and then went indoors to complete structural surfaces. General area surveys of the first and second floors were performed. Approximately half of the floor space was inaccessible due to material storage. These investigations did not identify any detector responses distinguishable from background. Previous surveys (DEEP 1998) identified exposure measurements up to 15 µR/h on contact on the exterior wall in the first-floor men's

restroom. The current survey also noticed an increase in the first-floor men's restroom, but it is likely due to the red brick wall and the concrete floor (i.e., naturally occurring radioactive material [NORM]). This was a consistent result throughout the first floor, second floor, and outdoor surveys—i.e., increased gamma radiation levels near red brick and concrete.

Summary of Scoping Survey Activities – April 25, 2017:

The team arrived onsite at 10:00 a.m., as requested by the property owner. After a brief meeting with the owner, gamma radiation scans were performed over the contaminated zone located to the south of the Bristol Instrument Gears building and along the north bank of the Pequabuck River. ORAU proceeded to implement the approved scoping survey plan (ORISE 2017b). Scans started at the gravel driveway and continued to the bank of the river, covering an approximate 770 square meters. Scan coverage was approximately 80 percent of the 770 square meter area—access was limited in some areas by trees and fallen branches. The team placed flags in the ground to delineate the areas with elevated levels of radiation.

While ORAU was surveying the land, the NRC and CT DEEP team members investigated the warehouse located on the southeast portion of the property and determined not to pursue surveys inside the structure due to its deterioration. The site owner indicated that the former Sessions Clock Company used the warehouse for wood storage.

The team selected three areas with elevated levels of radiation within the contaminated zone for soil sampling (using a T-bar hand auger) with the goal of collecting three samples per location ranging in depth from 0 to 0.3 meters, 0.3 to 0.6 meters, and 0.6 to 1 meter. However, only eight soil samples were collected because refusal was reached at one location after the second sample interval. After each sample was collected, the 2×2 sodium iodide detector was placed at the bottom of the borehole and gamma count rates were recorded. After the final sample was collected at each location, the cesium iodide detector was placed in the borehole and gamma count rates were collected every 8 centimeters.

An area upstream of the site was selected for collecting background soil samples. The area was scanned with a 2×2 sodium iodide detector to confirm the absence of elevated gamma radiation levels. Two soil samples were collected at one location from the 0 to 0.3 meter and 0.3 to 0.6 meter depth intervals. After each sample was collected, the 2×2 sodium iodide detector was placed in the borehole and gamma count rates were recorded. After the final sample was collected, the cesium iodide detector was placed in the borehole and gamma count rates were collected every 8 centimeters. The team departed the site at 4:40 p.m.

Summary of Scoping Survey Activities – April 26, 2017:

The team arrived at the site at 11:10 a.m. after a rain event had subsided. Two additional locations upstream of the site were selected for background soil samples. The areas were scanned with a 2×2 sodium iodide detector to confirm the absence of elevated gamma radiation levels. A total of four soil samples were collected at two locations. At each location, a sample was collected from the 0 to 0.3 meter and 0.3 to 0.6 meter depth intervals. After each sample was collected, the 2×2 sodium iodide detector was placed in the borehole and gamma count rates were recorded. After the final sample was collected at each location, the cesium iodide detector was placed in the borehole and gamma count rates were collected every 8 centimeters.

The team returned to the contaminated zone and collected additional soil samples from a single location within the contaminated zone but closer to the river than the previous three. The decision to collect samples at this location was made by the NRC due to the combination of elevated gamma radiation and proximity to the river. Three soil samples were collected at this location until refusal was reached at 0.8 m. After each sample was collected, the 2×2 sodium iodide detector was placed in the borehole and gamma count rates were recorded. After the final sample was collected, the cesium iodide detector was placed in the borehole and gamma count rates were collected every 8 centimeters.

Gamma radiation scans were then performed in the river with the PVC-encased 2×2 sodium iodide detector, starting upstream of the contaminated zone and continuing downstream to a location adjacent to the warehouse, covering a length of approximately 40 meters. Heavy river water flow conditions limited the survey extent to approximately 1 meter from the north bank. Two riverbed locations adjacent to the contaminated zone produced elevated radiation levels and were selected for sediment and surface water sampling. One location downstream, near the warehouse and in a potential deposition area, was selected for sediment and surface water sampling. Surface water samples were collected prior to sediment samples at each location.

Two locations upstream of the site were selected for background sediment and surface water sampling. The areas were scanned with the PVC-encased 2×2 sodium iodide detector confirm the absence of elevated gamma radiation levels. Surface water samples were collected prior to sediment samples at each location.

Finally, all boreholes were filled in with clean soil (purchased at a local store) prior to the team's departure. The NRC team members met with the site owner to discuss the results of the scoping survey. The team departed the site at 5:30 p.m.

3.2 Summary of Results

Appendix A presents photos from both the initial site visit and scoping survey. Figures A-1 through A-14 are from the initial site visit, and Figures A-15 through A-22 are from the scoping survey. All survey results for the initial site visit and scoping survey can be found in Appendix B. Figures B-1 through B-3 are from the initial site visit, and Figure B-4 is from the scoping survey. Table B-1 is from the initial site visit, and Tables B-2 through B-5 are from the scoping survey. Table B-6 presents a comparison of Radiological and Environmental Analytical Laboratory (REAL) and TestAmerica analytical laboratory results from the scoping survey. Appendix C presents excerpts from analytical data packages and shows reported Ra-226 results for all soil, sediment, and water samples.

Initial Site Visit – February 7, 2017:

Surveys, using the 2×2 sodium iodide detector and an exposure rate meter, were performed of approximately 50 percent of the inside floor surfaces of the building. The remaining floor areas were not accessible due to the presence of equipment and stored materials.

Surveys of outdoor areas covered an estimated 20 percent of the outdoor areas, noting that most of the outdoor areas were covered by asphalt, equipment (warehouse, logs, etc.), or have steep terrain. Over the contaminated zone near the north bank of the Pequabuck River, 2×2 sodium iodide detector responses reached a maximum of 270,000 cpm, and exposure rates

reached a maximum of 90 µR/h at 1 meter and up to 430 µR/h on contact with the soil (over areas with borehole sampling).

Three soil samples were collected from the contaminated zone and were analyzed at the REAL in Oak Ridge, Tennessee. All three samples (S0003, S0004, and S0005) contain elevated concentrations of Ra-226, as shown in Table B-1, with a maximum Ra-226 concentration of 228 pCi/g in sample S0005. The radiation levels in the sample hole continued to rise, reaching 630,000 cpm below the 15-30-centimeter interval from S0005, but the inspection team could not sample deeper than 30 centimeters at the time. Elevated gamma radiation levels and Ra-226 concentrations along the north bank of the Pequabuck River resulted in the decision to perform a follow-up scoping survey to determine the distribution and magnitude of Ra-226 contamination in the area.

The 2×2 sodium iodide detector background responses ranged from about 4,000 to 14,000 cpm inside the building and 7,000 to 14,000 cpm in the general outdoor area—relatively high results were recorded near brick walls (NORM). Exposure rates also similarly varied depending on proximity to NORM, ranging from 3 to 13 µR/h inside the building and 6 to 10 µR/h in the general outdoor area.

Scoping Survey – April 25-26, 2017:

Appendix B Tables B-2 through B-4 summarize sample and measurement data collected during the scoping survey. These tables list the coordinate of each sample location, the sample identification number, the depth interval of each sample (if applicable), and the *in situ* and *ex situ* gamma measurement reading using the 2×2 sodium iodide detector. The *in situ* value represents the 2×2 sodium iodide detector reading as collected in the field at the sample location. The *ex situ* value represents the 2×2 sodium iodide detector reading from only the containerized sample well away from the contaminated zone. The latter measurement was collected to help determine which samples were most likely to contain elevated concentrations of Ra-226. The *in situ* cesium iodide detector measurement data are not presented in Appendix B tables because the 2×2 sodium iodide detector was able to reach the deepest sample intervals; the cesium iodide detector and the 2×2 sodium iodide detector results are somewhat redundant, and the tabulated 2×2 sodium iodide detector *in situ* and *ex situ* results are directly comparable.

Contaminated Zone Soils. Surface soil radiation scans delineated a 20 meter by 8 meter area with elevated levels of radiation along the north bank of the Pequabuck River. Gamma radiation levels in the contaminated zone ranged from approximately 9,000 to 115,000 cpm (during scanning) and up to 300,000 cpm from static counts, compared to a background of approximately 8,000 cpm. Global position system data were collected along with the co-located sodium iodide response during surveys; however, poor satellite reception due to overhead obstructions resulted in significant positional uncertainty. As a result, gamma survey data could not be accurately mapped. However, Table B-5 presents summary statistics of the captured scan data over contaminated zone soils.

Table B-2 presents soil sample and associated gamma count rate measurements for samples collected within the contaminated zone. As with scan data, overhead obstructions precluded the collection of accurate positional data, so the soil sample locations illustrated in Figure B-4 are approximated based on field notes and physical measurements. A total of 11 soil samples

(S0007-S0014 and S0021-23) at four different locations were collected, reaching a maximum depth of 1 meter. Down-hole gamma radiation count rate measurements reached a maximum at the bottom of the borehole closest to the river (Sample S0023), with an *in situ* value of 725,000 cpm and an *ex situ* value of 39,000 cpm. Table B-2 results suggest that the maximum depth of contamination was not encountered in any of the four boreholes, and the relative responses increased in the final interval of two boreholes. Maximum concentrations were reached in the borehole that includes samples S0021-23. REAL analyzed sample S0023 and reported a concentration of 680 pCi/g from the 0.7-0.8-meter interval. TestAmerica analyzed an aliquot of this sample and reported only 350 pCi/g—differences are not unexpected for samples that may contain discrete pieces of contamination, which may be the case here. The maximum concentration reported by TestAmerica is 455 pCi/g, from sample S0021 from the 0.0-0.4-meter interval of the same borehole.

Pequabuck River. Gamma radiation levels in the river ranged from approximately 1,800 cpm to 58,000 cpm. Gamma radiation levels decreased farther away from the bank; therefore, surveys were not performed in the middle of the river (access was also limited due to high water flow conditions). Table B-5 presents summary statistics of scan data over river sediments. Note that many more measurements were taken in the river compared to over land. This is because relatively high water levels caused surveyors to walk slowly and methodically, resulting in more time and thus more recorded measurements.

Table B-3 presents results for the six samples that were collected from the river—including three sediment samples (S0024-S0026) and three water samples (W0001-W0003) from two locations adjacent to the contaminated zone, and one downstream location. These locations are illustrated in Figure B-4. The maximum sediment concentration is 11 pCi/g. The other sediment sample collected adjacent to (S0025) and downstream of (S0026) the contaminated zone also appear to contain elevated Ra-226 concentrations. Radium-226 was not detected in any water sample.

Background Soil and Water Samples. As shown in Table B-4, a total of ten samples were collected from an up-river location for background concentration determination including six soils samples (S0015-S0020), two sediment samples (S0027-S0028), and two water samples (W004-W0005). Gamma radiation scans of the surface soil for these areas ranged from 7,000 to 8,000 cpm. Two soil samples were collected per location, at the 0.0-0.3-meter and 0.3-0.6-meter intervals. It is noted that *in situ* gamma radiation levels increased with depth in background area boreholes due to geometry effects (i.e., the “source” surrounds the detector as it is lowered into the hole). Two water and two sediment samples were also collected for comparison to those collected adjacent and downstream of the contaminated zone. Based on these results, background surface soil concentrations on the order of 1-1.5 pCi/g are expected in surface soils and sediments, and 1.5-2 pCi/g in subsurface soils. Radium-226 was not detected in water samples.

Comparison of Analytical Datasets. Only a subset of samples from the scoping survey was analyzed by REAL. However, all scoping survey samples were analyzed by TestAmerica, including those already analyzed by REAL. Table B-6 presents side-by-side results from samples analyzed by both laboratories. While both laboratories used gamma spectrometry to analyze the Ra-226 concentration, REAL allowed for progeny ingrowth and reported Ra-226 via a proxy (lead-214), while TestAmerica did not allow for ingrowth and did not use a proxy. Additionally, TestAmerica analyzed an aliquot of the sample, whereas REAL analyzed the entire

sample. It is possible that discrete particles containing high concentrations of Ra-226 were not included in the TestAmerica aliquot, thus the lower reported concentration in sample S0023. Given the differences in analytical protocols, and given different sample volumes were analyzed by each lab, the range of results in some samples (e.g., S0023) is not unexpected. The conclusion, however, does not change whether considering REAL, TestAmerica, or combined results: discrete sources of Ra-226 are present in site soils at concentrations in the hundreds of pCi/g.

3.3 Summary of Dose Assessment Results

To date, a site-specific dose assessment has not been performed for the Bristol Instrument Gears property located on a portion of the former Sessions Clock Company site. During the scoping survey, Ra-226 concentrations on the order of hundreds of pCi/g were measured in the sub-surface soil along the north bank of the Pequabuck River, and up to 11 pCi/g of Ra-226 was measured in small pockets of river sediment. The total contaminated zone covers an estimated 20-meter by 8-meter area, and the depth of contamination likely extends below the 1-meter sample depth achieved during the scoping survey. It is the NRC's understanding that, in general, this contaminated area is not regularly occupied for appreciable lengths of time due to its proximity to the river, rough terrain, and the steep slope leading to the river. Because the criterion for implementing controls in NRC's Temporary Instruction 2800/043 will not be exceeded, based on the survey results and current use of the area, the NRC staff concludes there are no immediate health and safety concerns at this site, provided that the identified contaminated soil is not disturbed and the occupancy of the area remains minimal. Additionally, NRC staff did not detect Ra-226 within the water of the Pequabuck River.

However, it is possible, but unlikely, that at some point in the future, contaminated soils could be re-purposed or a small habitable structure could be placed on the area. Those possible future circumstances could reasonably result in a radiological dose above the 25-mrem/yr limit for unrestricted release (for current or future receptors). Sediment and surface water results add the complicating factor that contaminated soils are within the river.

Finally, it is noted that the "*Dose Assessment Technical Basis Document for Potential Exposures to Discrete Sources of Radium-226 and Associated Contamination"* (ORISE 2017b) describes a "not-to-exceed" Ra-226 concentration that corresponds to 25 mrem/yr from exposure to a small area of elevated activity. Eight individual samples produced Ra-226 concentrations above the "not-to-exceed" concentration of 42 pCi/g, with a maximum reported value of 680 pCi/g.

4.0 OBSERVATIONS AND RECOMMENDATIONS

Based on the data collected, the Bristol Instrument Gears site of the former Sessions Clock Company property contains discrete sources of Ra-226 (spread over a large area) on the Pequabuck River riverbank and in river sediments. This conclusion is based on the following observations:

- General area surveys of the first and second floors were performed. Approximately half of the floor space was inaccessible due to material storage. However, these investigations did not identify any detector responses distinguishable from background indoors.

- Ra-226 was positively identified on the order of hundreds of pCi/g in a soil sample collected at 1-meter depth along the north riverbank, and elevated gamma radiation was measured over a 20-meter by 8-meter area. The total depth of contamination was not reached using hand tools, which could only extend 1 meter below the ground surface—i.e., the depth of Ra-226 contamination is unknown.

- Ra-226 was positively identified in Pequabuck River sediments near the contaminated zone (at 11 pCi/g), though surface water results show no significant impact during the sampling window.

- Eight soil sample results exceed the "not-to-exceed" concentration of 42 pCi/g that corresponds to 25 mrem/yr from exposure to a small area of elevated activity.

- While current occupancy is limited and the 100-mrem/yr limit for controls is unlikely to be exceeded, it is conceivable that future activities could lead to a radiological dose above 25 mrem/yr.

Based on the above observations, it is recommended that the NRC maintain oversight by working with the owners to control and mitigate the potential for exposure to Ra-226 contamination at the Bristol Instrument Gears portion of the former Sessions Clock Company property.

5.0 REFERENCES

ATSDR 1999. Public Health Implications of Radiation Contamination at Former Clock Factories Located in Bristol (Hartford County), New Haven, (New Haven County), Thomaston (Litchfield County), and Waterbury (New Haven County), Connecticut, prepared by the Connecticut Department of Public Health under Cooperative Agreement with The Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. January 29. (Agencywide Documents Access and Management System [ADAMS] Accession No. ML17038A052).

DEEP 1998. Data on Former Watch Manufacturers in Connecticut – Noted from the Connecticut Department of Energy and Environmental Protection (formerly Department of Environmental Protection [DEP]). (ADAMS Accession No. ML17038A170).

NRC 2017. *Inspection of Facilities Potentially Contaminated with Discrete Radium-226 Sources*, Temporary Instruction 2800/043, Revision 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, Washington, D.C., October. (ADAMS Accession No. ML16330A678).

ORISE 2017a. *Scoping Survey Plan for Soils at the Former Sessions Clock Company (Building #9) In Bristol, Connecticut*, DCN 5289-PL-03-0, Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee, March 24.

ORISE 2017b. *Dose Assessment Technical Basis Document for Potential Exposures to Discrete Sources of Radium-226 and Associated Contamination*, DCN 5289-TR-01-2, Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee, May 30. (ADAMS Accession No. ML17152A204).

ORNL 2015. *Historical Non-Military Radium Sites Research Effort Addendum*, "Sessions Clock Company: Site Summary," pp. 119-127, Oak Ridge National Laboratory, Oak Ridge, Tennessee, November 24. (ADAMS Accession No. ML16291A488).

APPENDIX A
PHOTOS FROM THE SESSIONS CLOCK COMPANY SITE VISIT AND SCOPING SURVEY

A-1. West Side of Bristol Gears

A-2. East and North Sides of Bristol Gears

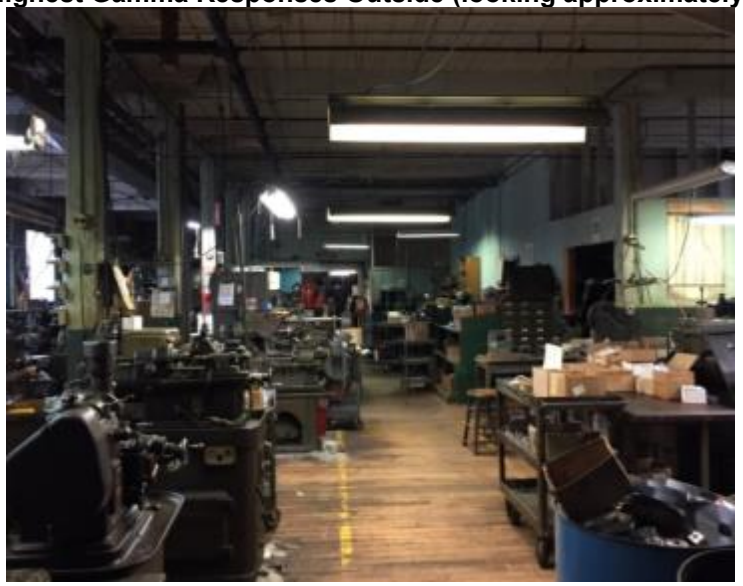
A-3. Warehouse Southeast of Bristol Gears

A-4. Looking South Towards the Pequabuck River

A-5. Highest Gamma Responses Outside (looking approximately west)

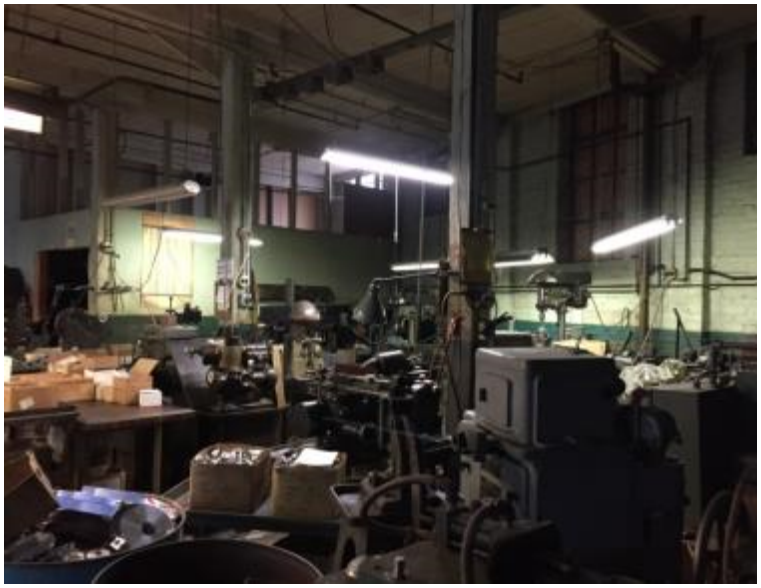
A-6. Highest Gamma Responses Outside (looking approximately east)

A-7. Access Limitations First Floor



A-8. Manufacturing Area First Floor

A-9. Manufacturing Area First Floor



A-10. Access Limitations First Floor

A-11. Office Area Second Floor

A-12. Packaging Area Second Floor

A-13. Access Limitations Second Floor

A-14. Access Limitations Second Floor

A-15. Contaminated Zone (looking approximately southeast)

A-16. Contaminated Zone (looking approximately west)

A-17. Soil Sample Location 5289S0023 (within contaminated zone)

A-18. River Location with the Highest Gamma Radiation Levels

A-19. Downstream Sediment and Water Sampling Location

A-20. Upstream Sediment and Water Sampling Location

A-21. Background Soil Sample Location (looking approximatly east)

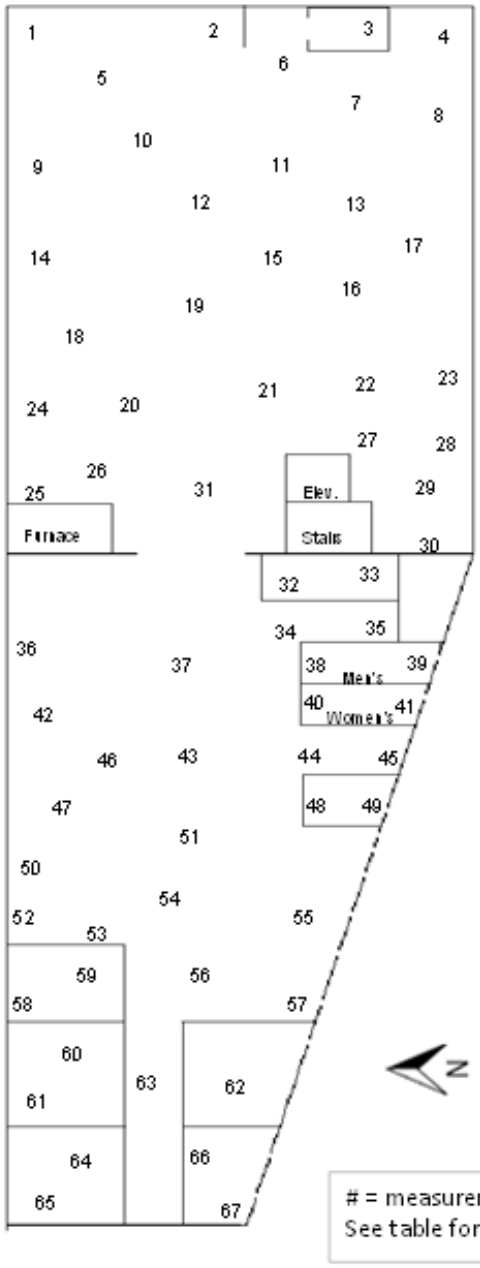
A-22. River Survey using 2×2 Nal in PVC Tube

APPENDIX B
SUMMARY OF SURVEY RESULTS FROM THE SESSIONS CLOCK COMPANY SITE VISIT AND SCOPING SURVEY

Site: Sessions Clock Company	Area: Bristol Instrument Gears, 1st Floor	Date(s): 02/07/2017	Time: 12:40-13:50
Surveyor(s): KME		Purpose: Site Visit	

Radiation Type	Instrument	Detector	Background
Gamma	2221: No.590	44-10: No.908	5.5 - 14 kcpm[a]
Gamma	192: No.1127	NA	5 - 13 µR/h[a]

[a]Background varied depending on naturally occurring radioactive material in the area (i.e., red brick).



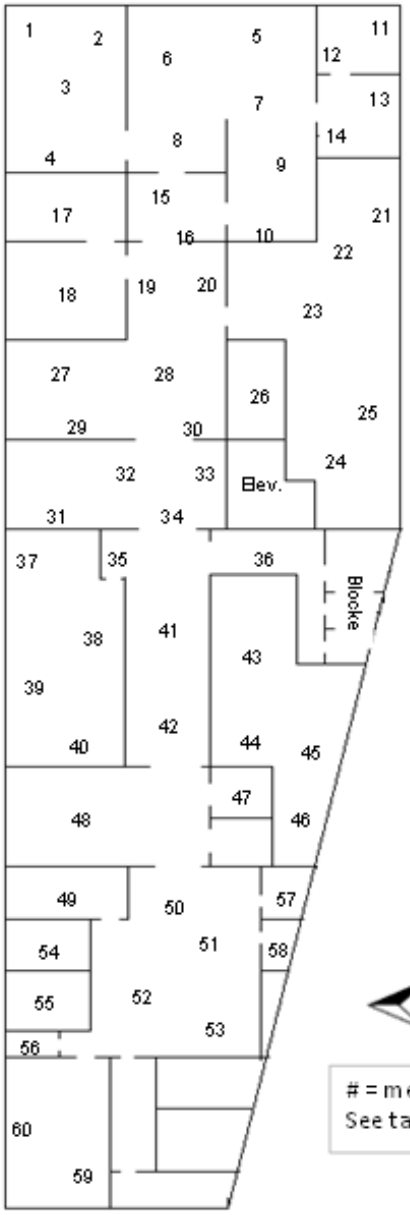
Location	cpm	µR/h	Location	cpm	µR/h
1	12,000	10	35	9,000	8
2	10,000	8	36	11,000	8
3	10,000	8	37	6,500	7
4	11,000	10	38	9,000	8
5	8,000	7	39	14,000	13
6	10,000	7	40	9,500	8
7	9,000	7	41	10,000	11
8	9,000	10	42	8,000	6
9	9,000	7	43	6,000	6
10	7,000	7	44	8,000	8
11	8,000	6	45	12,000	8
12	7,000	6	46	5,500	5
13	7,500	6	47	7,000	6
14	9,000	8	48	7,000	6
15	6,000	6	49	10,000	9
16	7,000	5	50	7,000	5
17	8,000	6	51	6,000	5
18	8,000	5	52	9,000	8
19	6,500	5	53	6,000	5
20	7,500	5	54	6,000	5
21	6,500	6	55	8,000	7
22	9,000	7	56	7,000	6
23	10,000	7	57	9,000	7
24	8,000	6	58	11,000	10
25	9,000	7	59	8,000	7
26	7,000	6	60	7,000	6
27	7,000	8	61	8,000	8
28	8,000	8	62	7,800	7
29	9,000	8	63	7,000	6
30	12,000	10	64	8,000	7
31	8,000	7	65	9,500	8
32	8,000	6	66	10,000	9
33	12,000	10	67	13,000	11
34	6,500	6			

Figure B-1. Initial Site Visit, First Floor Survey Results

Site: Sessions Clock Company	Area: Bristol Instrument Gears, 2nd Floor	Date(s): 02/07/2017	Time: 12:40 - 14:10
Surveyor(s): KME/STP		Purpose: Site Visit	

Radiation Type	Instrument	Detector	Background
Gamma	2221: No.590, No.1143	44-10: No.908, No.664	4 - 11.5 kcpm[a]
Exposure Rate (gamma)	192: No.1127, 1129	NA	3 - 9 µR/h[a]

[a]Background varied depending on naturally occurring radioactive material in the area (i.e., red brick).



= measurements location number
See table for measurements results

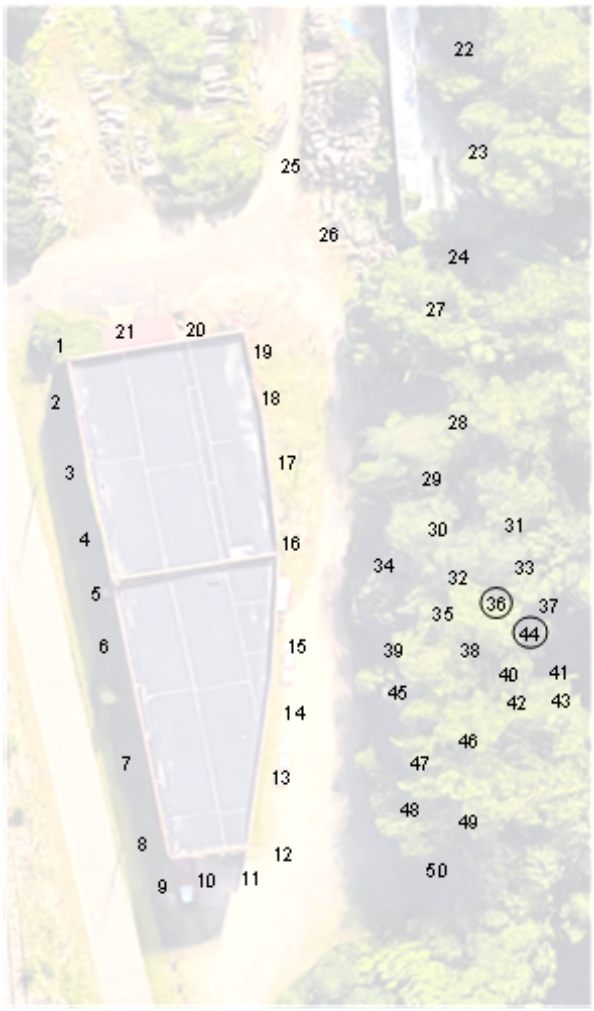
Location	cpm	µR/h	Location	cpm	µR/h
1	10,000	9	31	10,500	8
2	9,000	9	32	5,000	5
3	6,500	5	33	5,500	5
4	6,000	5	34	7,500	5
5	7,000	5	35	8,500	7
6	6,000	5	36	9,000	6
7	6,000	5	37	11,500	8
8	6,000	5	38	6,000	5
9	6,000	5	39	8,500	7
10	5,000	5	40	5,000	4
11	10,000	9	41	7,400	5
12	7,000	5	42	5,000	4
13	10,000	9	43	6,000	5
14	7,000	5	44	5,000	4
15	5,000	4	45	7,200	6
16	4,500	4	46	5,500	3
17	6,000	5	47	4,000	4
18	5,500	5	48	6,000	5
19	5,000	4	49	5,000	5
20	5,000	3	50	4,500	5
21	7,500	6	51	5,500	4
22	4,500	6	52	4,500	5
23	6,000	4.5	53	6,000	5
24	5,500	3.5	54	6,000	6
25	7,000	6	55	7,500	7
26	4,500	5	56	6,500	5
27	8,000	6	57	8,000	5
28	5,000	4	58	9,000	7
29	7,000	5	59	9,500	8
30	6,000	4	60	11,000	8

Figure B-2. Initial Site Visit, Second Floor Survey Results

Site: Sessions Clock Company	Area: Bristol Instrument Gears, Land Area	Date(s): 02/07/2017	Time: 10:30-12:00
Surveyor(s): KME/STP		Purpose: Site Visit	

Radiation Type	Instrument	Detector	Background
Gamma	2221: No.590, 1143	44-10: No.908, 664	7.5 - 13 kcpm[a]
Gamma	192: No.1127, 1129	NA	7 - 10 µR/h[a]

[a]Background varied depending on naturally occurring radioactive material in the area (i.e., red brick).



N

○ = sample location
= measurement location number
See table for measurement

Location	cpm	µR/h	Location	cpm	µR/h
1	8,500	7	37	110,000	--
2	10,000	10	38	14,000	--
3	10,200	11	39	9,000	8
4	10,500	9.5	40	11,000	--
5	14,000	13	41	70,000	--
6	9,500	9	42	8,000	--
7	11,000	7.5	43	10,000	--
8	11,800	10	44	270,000	90
9	9,000	7	45	7,500	7
10	11,000	10	46	8,000	7
11	9,000	7	47	7,500	7
12	8,500	6	48	7,500	6
13	10,600	9	49	8,000	7
14	9,000	10	50	7,000	6
15	11,300	9			
16	10,000	9			
17	13,600	10			
18	12,500	10			
19	11,500	9.5			
20	12,000	10			
21	7,000	6			
22	7,500	6			
23	8,000	7			
24	8,000	7			
25	7,000	6			
26	8,500	6			
27	7,500	6			
28	8,000	8			
29	9,000	7			
30	11,000	--			
31	20,000	--			
32	10,000	--			
33	36,000	--			
34	9,000	8			
35	50,000	35			
36	78,000	35			

Figure B-3. Initial Site Visit, Land Area

Figure B-4. Scoping Survey, Approximate Sample Locations

Table B-1. Initial Site Visit, Sessions Clock Company Bristol Instrument Gears, Land Area Sample Results									
Location No.	Sample No.	Depth	Gamma				Concentration		
			Contact			1 m	Ra-226		
			cpm		μR/h	μR/h	pCi/g		
		cm	pre-sample	post-sample			Conc.	TPU [a]	MDC [b]
36	S0003	0-15	78,000	92,000	70	35	4.71	0.31	0.16
44	S0004	0-15	270,000	490,000	430	90	41.6	2.1	0.2
	S0005	15-30	490,000	630,000	N/A	N/A	228	12	1

[a] Uncertainties are based on total propagated uncertainties at the 95 percent confidence level.

[b] MDC = minimum detectable concentration

Table B-2. Scoping Survey, Sessions Clock Company Bristol Instrument Gears, Contaminated Zone Soil Samples						
Coordinates (m)		Sample ID	Depth (m)	2×2 (kcpm)		Ra-226 Concentration (pCi/g)
Northing	Easting			in situ	ex situ[b]	
245712	292752	--	Surface	246	--	--
		S0007	0-0.3	561	12.5	42.8
		S0008	0.3-0.6	430	32	419
		S0009	0.6-1	425	20	165
245708	292747	--	Surface	32	--	--
		S0010	0-0.3	71	12	28.5
		S0011[a]	0.3-0.4	76	12	21.6
245719	292761	--	Surface	40	--	--
		S0012	0-0.3	164	11	2.16
		S0013	0.3-0.6	406	18	89.7
		S0014	0.6-0.7	426	18	136
245717	292757	--	Surface	200	--	--
		S0021	0-0.4	720	32	455
		S0022	0.4-0.7	700	25	294
		S0023	0.7-0.8	725	39	353

-- Not applicable

[a]Sample hit refusal at 0.4m.

[b]Background for ex situ measurements was 10-12 kcpm.

Table B-3. Scoping Survey, Sessions Clock Company Bristol Instrument Gears, Pequabuck River Water and Sediment Samples						
Coordinates (m)		Sample ID	Depth (m)	2×2 (kcpm)		Ra-226 Conc.[b]
Northing	Easting			in situ	ex situ[a]	
Adjacent to Contaminated Zone						
245711	292758	S0024	--	50	12.8	11.0 pCi/g
		W0001	--	--	10.8	0.840U pCi/L
245706	292760	S0025	--	33	12.2	1.89 pCi/g
		W0002	--	--	10.7	0.261U pCi/L
Downstream of Contaminated Zone						
245708	292780	S0026	--	5.3	12	3.21 pCi/g
		W0003	--	--	10	-0.0503U pCi/L

-- Not applicable

[a]Background for ex situ measurements was 10-12 kcpm.

[b]pCi/g applies to sediment samples (e.g., S0024); pCi/L applies to water samples (e.g., W0001)

U = Undetected; J = Estimated (not used here)

Table B-4. Scoping Survey, Sessions Clock Company Bristol Instrument Gears, Background Soil Samples						
Coordinates (m)		Sample ID	Depth (m)	2×2 (kcpm)		Ra-226 Concentration (pCi/g)
Northing	Easting			in situ	ex situ[a]	
Soil Samples						
245709	292616	--	Surface	7.5	--	--
		S0015	0-0.3	15	12	1.57
		S0016	0.3-0.6	12.4	11	2.03
245714	292569	--	Surface	7	--	--
		S0017	0-0.3	12	11	1.36
		S0018	0.3-0.6	21	12.5	2.37
245715	29255	--	Surface	8	--	--
		S0019	0-0.3	14	11	0.97J
		S0020	0.3-0.5	17	13.5	1.53
Sediment (S) and Water (W) Samples						
245701	292622	S0027	--	5	11.3	0.894J
		W0004	--	--	10.2	0.162U
245704	292604	S0028	--	5	11.6	0.939J
		W0005	--	--	10.5	-0.0509U

-- Not applicable

[a]Background for ex situ measurements was 10-12 kcpm.

U = Undetected; J = Estimated (not used here)

Table B-5. Scoping Survey, Sessions Clock Company Bristol Instrument Gears, Gamma Scan Data Summary Statistics						
Number of Measurements	Units	Minimum	Maximum	Mean	Median	St. Deviation
Contaminated Zone Soils						
778	cpm	7,869	114,592	20,360	10,894	20,346
Pequabuck River Sediments						
2,818	cpm	1,840	57,563	11,435	6,177	11,516

Table B-6. Scoping Survey Sessions, Clock Company Bristol Instrument Gears, Soil Sample Results Comparison		
Sample ID	Ra-226 Conc. (pCi/G)	
	ORAU Result	Test American Result
S0023	680	353
S0024	11.17	11.0
S0026	0.648	3.21
S0028	0.409	0.939J
W0001	3.8U	0.84U
W0003	-7.9U	-0.0503U

U = undetected; J = estimated

APPENDIX C
RAW ANALYTICAL RESULTS

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
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Gamma Spectrometry Summary Sheet

ORAU
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Report Date: March 21, 2017

Project # : 201211310 **COC # :** 1702-009

Project Name: NRC Radium Sites

Batch Number: GS0458 **Analyst:** smithw

Client Sample ID: 5289S0003

Lab Sample ID: 11310S0002 **Smp Qty.:** 157.19 **Units:** grams **Geometry:** 250LM

Detector ID: DET10 **Live Time(s):** 7,200 **SOP (Rev. #):** CP1 (21)

Count Date: 3/16/2017 **Receipt Date:** 2/10/2017 **Collection Date:** 2/7/2017

SDG: 201211310-9

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	0.45	0.17	0.34	pCi/g	910.78		N/A	N/A
Bi-212	727.33	0.88	0.44	0.91	pCi/g	728.08	U	N/A	N/A
Bi-214	609.32	4.14	0.35	0.17	pCi/g	609.06		N/A	N/A
K-40	1460.82	9.1	1.3	1.9	pCi/g	1459.78		N/A	N/A
Pa-234	1001.03	-1.4	5.5	12.9	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	0.495	0.086	0.160	pCi/g	238.66		N/A	N/A
Ra-226 by Pb-214	351.93	4.71	0.31	0.16	pCi/g	351.88		N/A	N/A
Ra-226	186.21	5.43	0.90	1.62	pCi/g	186.17		N/A	N/A
Th-230	67.67	4	13	33	pCi/g		U	N/A	N/A
U-238 by Th-234	63.29	2.0	1.6	4.0	pCi/g		U	N/A	N/A
U-235	143.76	0.22	0.17	0.40	pCi/g	144.10	U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-1. REAL Results for Soil Sample 5289S0003

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Gamma Spectrometry Summary Sheet

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Report Date: March 21, 2017

Project # : 201211310 **COC # :** 1702-009
Project Name: NRC Radium Sites
Batch Number: GS0458 **Analyst:** smithw
Client Sample ID: 5289S0004
Lab Sample ID: 11310S0003 **Smp Qty.:** 661.18 **Units:** grams **Geometry:** LM
Detector ID: DET09 **Live Time(s):** 3,600 **SOP (Rev. #):** CP1 (21)
Count Date: 3/16/2017 **Receipt Date:** 2/10/2017 **Collection Date:** 2/7/2017
SDG: 201211310-9

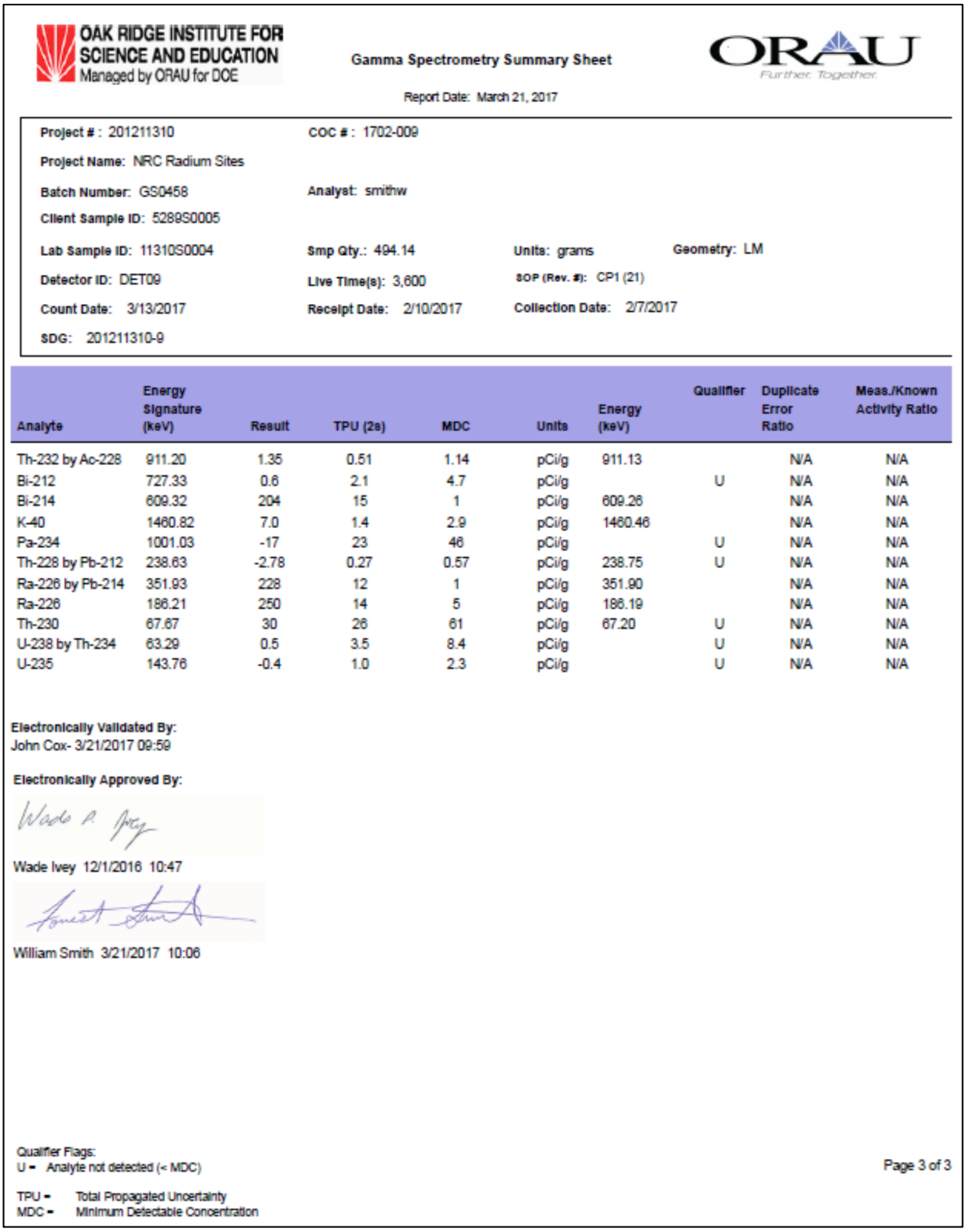
Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	0.70	0.19	0.39	pCi/g	910.55		N/A	N/A
Bi-212	727.33	1.04	0.55	1.23	pCi/g	727.14	U	N/A	N/A
Bi-214	609.32	37.2	2.7	0.2	pCi/g	609.21		N/A	N/A
K-40	1460.82	7.65	0.93	1.28	pCi/g	1460.67		N/A	N/A
Pa-234	1001.03	6.7	8.6	18.6	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	-0.026	0.090	0.215	pCi/g	238.62	U	N/A	N/A
Ra-226 by Pb-214	351.93	41.6	2.1	0.2	pCi/g	351.87		N/A	N/A
Ra-226	186.21	44.8	2.7	2.0	pCi/g	186.17		N/A	N/A
Th-230	67.67	11.9	9.3	21.3	pCi/g	67.29	U	N/A	N/A
U-238 by Th-234	63.29	1.3	1.4	3.5	pCi/g		U	N/A	N/A
U-235	143.76	-0.16	0.41	0.94	pCi/g		U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

Page 2 of 3

Figure C-2. REAL Results for Soil Sample 5289S0004



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Gamma Spectrometry Summary Sheet

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Report Date: March 21, 2017

Project # : 201211310 **COC # :** 1702-009
Project Name: NRC Radium Sites
Batch Number: GS0458 **Analyst:** smithw
Client Sample ID: 5289S0005
Lab Sample ID: 11310S0004 **Smp Qty.:** 494.14 **Units:** grams **Geometry:** LM
Detector ID: DET09 **Live Time(s):** 3,600 **SOP (Rev. #):** CP1 (21)
Count Date: 3/13/2017 **Receipt Date:** 2/10/2017 **Collection Date:** 2/7/2017
SDG: 201211310-9

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	1.35	0.51	1.14	pCi/g	911.13		N/A	N/A
Bi-212	727.33	0.6	2.1	4.7	pCi/g		U	N/A	N/A
Bi-214	609.32	204	15	1	pCi/g	609.26		N/A	N/A
K-40	1460.82	7.0	1.4	2.9	pCi/g	1460.46		N/A	N/A
Pa-234	1001.03	-17	23	46	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	-2.78	0.27	0.57	pCi/g	238.75	U	N/A	N/A
Ra-226 by Pb-214	351.93	228	12	1	pCi/g	351.90		N/A	N/A
Ra-226	186.21	250	14	5	pCi/g	186.19		N/A	N/A
Th-230	67.67	30	26	61	pCi/g	67.20	U	N/A	N/A
U-238 by Th-234	63.29	0.5	3.5	8.4	pCi/g		U	N/A	N/A
U-235	143.76	-0.4	1.0	2.3	pCi/g		U	N/A	N/A

Electronically Validated By:
John Cox- 3/21/2017 09:59

Electronically Approved By:

Wade Ivey 12/1/2016 10:47

William Smith 3/21/2017 10:06

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-3. REAL Results for Soil Sample 5289S0005

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Gamma Spectrometry Summary Sheet

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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0518 **Analyst:** smithw
Client Sample ID: 5289S0023
Lab Sample ID: 11310S0021 **Smp Qty.:** 345.70 **Units:** grams **Geometry:** 250LM
Detector ID: DET10 **Live Time(s):** 7,200 **SOP (Rev. #):** CP1 (21)
Count Date: 5/30/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	-0.2	1.0	2.2	pCi/g		U	N/A	N/A
Bi-212	727.33	-3.1	3.3	6.8	pCi/g		U	N/A	N/A
Bi-214	609.32	607	41	1	pCi/g	609.41		N/A	N/A
K-40	1460.82	2.3	1.8	4.2	pCi/g	1460.89	U	N/A	N/A
Pa-234	1001.03	-6	30	63	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	-10.39	0.66	0.85	pCi/g	239.01	U	N/A	N/A
Ra-226 by Pb-214	351.93	680	35	1	pCi/g	352.10		N/A	N/A
Ra-226	186.21	687	38	9	pCi/g	186.42		N/A	N/A
Th-230	67.67	14	73	179	pCi/g		U	N/A	N/A
U-238 by Th-234	63.29	-6.8	8.4	20.2	pCi/g		U	N/A	N/A
U-235	143.76	-0.9	1.7	3.8	pCi/g		U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-4. REAL Results for Soil Sample 5289S0023

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Gamma Spectrometry Summary Sheet

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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0518 **Analyst:** smithw
Client Sample ID: 5289S0024
Lab Sample ID: 11310S0022 **Smp Qty.:** 539.19 **Units:** grams **Geometry:** 250FM
Detector ID: DET09 **Live Time(s):** 7,200 **SOP (Rev. #):** CP1 (21)
Count Date: 5/30/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	1.38	0.16	0.18	pCi/g	910.91		N/A	N/A
Bi-212	727.33	1.23	0.31	0.56	pCi/g	726.98		N/A	N/A
Bi-214	609.32	9.62	0.85	0.09	pCi/g	609.12		N/A	N/A
K-40	1460.82	7.26	0.69	0.54	pCi/g	1460.41		N/A	N/A
Pa-234	1001.03	-0.4	3.8	7.9	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	0.990	0.077	0.095	pCi/g	238.56		N/A	N/A
Ra-226 by Pb-214	351.93	11.17	0.61	0.10	pCi/g	351.82		N/A	N/A
Ra-226	186.21	14.83	0.98	0.90	pCi/g	186.15		N/A	N/A
Th-230	67.67	-1.6	5.1	12.5	pCi/g		U	N/A	N/A
U-238 by Th-234	63.29	0.99	0.44	0.89	pCi/g	63.37		N/A	N/A
U-235	143.76	0.03	0.18	0.41	pCi/g		U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-5. REAL Results for Soil Sample 5289S0024

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Gamma Spectrometry Summary Sheet

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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001

Project Name: NRC Radium Sites

Batch Number: GS0518 **Analyst:** smithw

Client Sample ID: 5289S0026

Lab Sample ID: 11310S0024 **Smp Qty.:** 766.90 **Units:** grams **Geometry:** LM

Detector ID: DET08 **Live Time(s):** 3,600 **SOP (Rev. #):** CP1 (21)

Count Date: 5/30/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017

SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	0.735	0.099	0.104	pCi/g	911.10		N/A	N/A
Bi-212	727.33	0.65	0.19	0.34	pCi/g	727.69		N/A	N/A
Bi-214	609.32	0.564	0.058	0.045	pCi/g	609.19		N/A	N/A
K-40	1460.82	10.04	0.86	0.44	pCi/g	1460.86		N/A	N/A
Pa-234	1001.03	1.0	2.1	4.5	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	0.583	0.049	0.054	pCi/g	238.48		N/A	N/A
Ra-226 by Pb-214	351.93	0.648	0.055	0.046	pCi/g	351.82		N/A	N/A
Ra-226	186.21	1.10	0.24	0.46	pCi/g	185.90		N/A	N/A
Th-230	67.67	0.1	2.9	7.3	pCi/g		U	N/A	N/A
U-238 by Th-234	63.29	0.65	0.28	0.54	pCi/g	63.38		N/A	N/A
U-235	143.76	0.064	0.081	0.193	pCi/g		U	N/A	N/A

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

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TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

Figure C-6. REAL Results for Soil Sample 5289S0026

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Gamma Spectrometry Summary Sheet

ORAU
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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0518 **Analyst:** smithw
Client Sample ID: 5289S0028
Lab Sample ID: 11310S0026 **Smp Qty.:** 1,110.80 **Units:** grams **Geometry:** FM
Detector ID: DET07 **Live Time(s):** 3,600 **SOP (Rev. #):** CP1 (21)
Count Date: 5/30/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	0.436	0.080	0.101	pCi/g	911.18		N/A	N/A
Bi-212	727.33	0.47	0.18	0.34	pCi/g	727.22		N/A	N/A
Bi-214	609.32	0.323	0.043	0.040	pCi/g	609.17		N/A	N/A
K-40	1460.82	8.88	0.84	0.33	pCi/g	1460.33		N/A	N/A
Pa-234	1001.03	1.7	1.9	4.5	pCi/g		U	N/A	N/A
Th-228 by Pb-212	238.63	0.375	0.022	0.045	pCi/g	238.64		N/A	N/A
Ra-226 by Pb-214	351.93	0.409	0.045	0.047	pCi/g	351.86		N/A	N/A
Ra-226	186.21	0.63	0.19	0.38	pCi/g	186.15		N/A	N/A
Th-230	67.67	1.0	2.5	6.3	pCi/g		U	N/A	N/A
U-238 by Th-234	63.29	0.32	0.22	0.47	pCi/g	63.28	U	N/A	N/A
U-235	143.76	0.006	0.075	0.176	pCi/g		U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-7. REAL Results for Soil Sample 5289S0028

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Gamma Spectrometry Summary Sheet

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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0508 **Analyst:** smithw
Client Sample ID: 5289W0001
Lab Sample ID: 11310W0001 **Smp Qty.:** 1.00 **Units:** liters **Geometry:** 1LW
Detector ID: DET07 **Live Time(s):** 180,000 **SOP (Rev. #):** CP1 (21)
Count Date: 5/28/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	13.0	5.5	12.6	pCi/L			N/A	N/A
Bi-212	727.33	21	20	44	pCi/L		U	N/A	N/A
Bi-214	609.32	-1.1	4.7	11.2	pCi/L	609.22	U	N/A	N/A
K-40	1460.82	-6	39	94	pCi/L	1460.11	U	N/A	N/A
Pa-234	1001.03	270	120	270	pCi/L	1000.88	U	N/A	N/A
Th-228 by Pb-212	238.63	1.7	3.3	7.9	pCi/L	238.49	U	N/A	N/A
Ra-226 by Pb-214	351.93	3.8	2.9	6.4	pCi/L		U	N/A	N/A
Ra-226	186.21	13	36	86	pCi/L	185.61	U	N/A	N/A
Th-230	67.67	100	120	270	pCi/L	66.64	U	N/A	N/A
U-238 by Th-234	63.29	6	32	76	pCi/L	63.33	U	N/A	N/A
U-235	143.76	10.0	3.8	8.6	pCi/L	143.66		N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-8. REAL Results for Water Sample 5289W0001

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Gamma Spectrometry Summary Sheet

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Report Date: May 31, 2017

Project #: 201211310 **COC #:** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0508 **Analyst:** smithw
Client Sample ID: 5289W0003
Lab Sample ID: 11310W0003 **Smp Qty.:** 1.00 **Units:** liters **Geometry:** 1LW
Detector ID: DET08 **Live Time(s):** 180,000 **SOP (Rev. #):** CP1 (21)
Count Date: 5/28/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	12.3	4.6	9.9	pCi/L			N/A	N/A
Bi-212	727.33	9	15	32	pCi/L		U	N/A	N/A
Bi-214	609.32	1.0	4.1	9.7	pCi/L	609.16	U	N/A	N/A
K-40	1460.82	-13	35	85	pCi/L	1460.79	U	N/A	N/A
Pa-234	1001.03	-130	140	280	pCi/L		U	N/A	N/A
Th-228 by Pb-212	238.63	1.8	2.9	7.0	pCi/L	238.48	U	N/A	N/A
Ra-226 by Pb-214	351.93	-7.9	2.3	4.9	pCi/L		U	N/A	N/A
Ra-226	186.21	-10	29	70	pCi/L	185.47	U	N/A	N/A
Th-230	67.67	-290	120	340	pCi/L		U	N/A	N/A
U-238 by Th-234	63.29	16	26	62	pCi/L	63.26	U	N/A	N/A
U-235	143.76	-12.1	5.4	11.9	pCi/L		U	N/A	N/A

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-9. REAL Results for Water Sample 5289W0003

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Gamma Spectrometry Summary Sheet

ORAU
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Report Date: May 31, 2017

Project # : 201211310 **COC # :** 1705-001
Project Name: NRC Radium Sites
Batch Number: GS0508 **Analyst:** smithw
Client Sample ID: 5289W0005
Lab Sample ID: 11310W0005 **Smp Qty.:** 1.00 **Units:** liters **Geometry:** 1LW
Detector ID: DET09 **Live Time(s):** 180,000 **SOP (Rev. #):** CP1 (21)
Count Date: 5/28/2017 **Receipt Date:** 5/1/2017 **Collection Date:** 4/26/2017
SDG: 201211310-13

Analyte	Energy Signature (keV)	Result	TPU (2s)	MDC	Units	Energy (keV)	Qualifier	Duplicate Error Ratio	Meas./Known Activity Ratio
Th-232 by Ac-228	911.20	4.7	6.8	16.1	pCi/L	910.80	U	N/A	N/A
Bi-212	727.33	17	14	33	pCi/L		U	N/A	N/A
Bi-214	609.32	0.2	4.2	10.0	pCi/L	609.02	U	N/A	N/A
K-40	1460.82	4	33	80	pCi/L	1460.28	U	N/A	N/A
Pa-234	1001.03	100	140	310	pCi/L		U	N/A	N/A
Th-228 by Pb-212	238.63	-1.6	2.0	4.7	pCi/L	238.35	U	N/A	N/A
Ra-226 by Pb-214	351.93	-1.4	4.2	10.1	pCi/L	351.72	U	N/A	N/A
Ra-226	186.21	30	33	78	pCi/L	185.68	U	N/A	N/A
Th-230	67.67	-210	140	370	pCi/L		U	N/A	N/A
U-238 by Th-234	63.29	12	30	71	pCi/L	63.20	U	N/A	N/A
U-235	143.76	-3.1	5.6	12.9	pCi/L		U	N/A	N/A

Electronically Validated By:
John Cox- 5/31/2017 08:32

Electronically Approved By:

Wade Ivey 5/31/2017 11:51

William Smith 5/31/2017 09:04

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

TPU = Total Propagated Uncertainty
MDC = Minimum Detectable Concentration

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Figure C-10. REAL Results for Water Sample 5289W0005

Sample Results Summary

TestAmerica Inc TARL

Ordered by Method, Batch No., Client Sample ID.

Date: 30-Sep-17

Report No. : 71799 **SDG No:** 54118

Batch	Client Id / Work Order	Parameter	Result +- CSU (2 s)	Qual	Units	Tracer Yield	MDL	CRDL	RER2
7269015	RL-GAM-001								
	5289S0003								
	NACF41AA	RA-226	4.65E+00 +- 1.2E+00		pCi/g		1.25E+00	1.00E+00	
	5289S0004								
	NACF51AA	RA-226	5.30E+01 +- 9.3E+00		pCi/g		2.54E+00	1.00E+00	
	5289S0005								
	NACF71AA	RA-226	4.52E+01 +- 8.5E+00		pCi/g		4.55E+00	1.00E+00	

No. of Results: 3

TestAmerica Inc RER2 - Replicate Error Ratio = (S-D)/[sqrt(sq(TPUs)+sq(TPUd))] as defined by ICPT BOA.

rptTALRchSaSum mary2 V5.8.5 A2002

Figure C-11. TestAmerica Results for Soil Samples 5289S0003 – 5289S0005

Sample Results Summary

TestAmerica Inc TARL

Ordered by Method, Batch No., Client Sample ID.

Date: 30-Sep-17

Report No. : 71800 **SDG No:** 54119

Batch	Client Id / Work Order	Parameter	Result +- CSU (2 s)	Qual	Units	Tracer Yield	MDL	CRDL	RER2
7269016	RL-GAM-001								
	5289S0007								
	NACF81AE	RA-226	4.28E+01 +- 7.5E+00		pCi/g		1.70E+00	1.00E+00	
	5289S0007 DUP								
	NACF81AF	RA-226	4.35E+01 +- 7.6E+00		pCi/g		1.79E+00	1.00E+00	0.1
	5289S0008								
	NACF91AD	RA-226	4.19E+02 +- 7.1E+01		pCi/g		6.00E+00	1.00E+00	
	5289S0009								
	NACGA1AD	RA-226	1.65E+02 +- 2.8E+01		pCi/g		3.48E+00	1.00E+00	
	5289S0010								
	NACGC1AD	RA-226	2.85E+01 +- 5.1E+00		pCi/g		1.57E+00	1.00E+00	
	5289S0011								
	NACGD1AD	RA-226	2.16E+01 +- 3.8E+00		pCi/g		1.17E+00	1.00E+00	
	5289S0012								
	NACGE1AD	RA-226	2.16E+00 +- 5.3E-01		pCi/g		5.78E-01	1.00E+00	
	5289S0013								
	NACGF1AD	RA-226	8.97E+01 +- 1.6E+01		pCi/g		2.34E+00	1.00E+00	
	5289S0014								
	NACGG1AD	RA-226	1.36E+02 +- 2.3E+01		pCi/g		2.61E+00	1.00E+00	
	5289S0015								
	NACGH1AD	RA-226	1.57E+00 +- 4.5E-01		pCi/g		5.67E-01	1.00E+00	
	5289S0016								
	NACGJ1AD	RA-226	2.03E+00 +- 5.0E-01		pCi/g		5.57E-01	1.00E+00	

No. of Results: 11

TestAmerica Inc RER2 - Replicate Error Ratio = (S-D)/[sqrt(sq(TPUs)+sq(TPUd))] as defined by ICPT BOA.

rptTALRchSaSum mary2 V5.8.5 A2002

Figure C-12. TestAmerica Results for Soil Samples 5289S0007 – 5289S0016

Sample Results Summary **Date:** 30-Sep-17

TestAmerica Inc TARL

Ordered by Method, Batch No., Client Sample ID.

Report No. : 71796 **SDG No:** 54117

Batch	Client Id / Work Order	Parameter	Result +- CSU (2 s)	Qual	Units	Tracer Yield	MDL	CRDL	RER2
7269015 RL-GAM-001									
	5289S0017								
	NACFF1AD	RA-226	1.36E+00 +- 4.0E-01		pCi/g		5.10E-01	1.00E+00	
	5289S0018								
	NACFG1AC	RA-226	2.37E+00 +- 5.3E-01		pCi/g		5.10E-01	1.00E+00	
	5289S0019								
	NACFH1AC	RA-226	9.70E-01 +- 3.9E-01	J	pCi/g		5.79E-01	1.00E+00	
	5289S0020								
	NACFJ1AC	RA-226	1.53E+00 +- 4.5E-01		pCi/g		5.84E-01	1.00E+00	
	5289S0021								
	NACFK1AC	RA-226	4.55E+02 +- 7.7E+01		pCi/g		5.00E+00	1.00E+00	
	5289S0022								
	NACFL1AC	RA-226	2.94E+02 +- 5.0E+01		pCi/g		5.21E+00	1.00E+00	
	5289S0023								
	NACFM1AC	RA-226	3.53E+02 +- 6.1E+01		pCi/g		1.19E+01	1.00E+00	
	5289S0024								
	NACFN1AC	RA-226	1.10E+01 +- 2.2E+00		pCi/g		1.78E+00	1.00E+00	
	5289S0025								
	NACFP1AC	RA-226	1.89E+00 +- 5.0E-01		pCi/g		5.66E-01	1.00E+00	
	5289S0026								
	NACFQ1AC	RA-226	3.21E+00 +- 7.4E-01		pCi/g		7.27E-01	1.00E+00	
	5289S0027								
	NACFR1AC	RA-226	8.94E-01 +- 3.1E-01	J	pCi/g		4.44E-01	1.00E+00	
	5289S0028								
	NACFT1AC	RA-226	9.39E-01 +- 3.3E-01	J	pCi/g		4.67E-01	1.00E+00	
7261021 RL-RA-002									
	5289W0001								
	NACFV1AA	TOTAL ALPHA RA	8.40E-01 +- 6.8E-01	U	pCi/L	67%	8.81E-01	5.00E+00	
	5289W0001 DUP								
	NACFV1AE	TOTAL ALPHA RA	7.75E-01 +- 6.5E-01	U	pCi/L	74%	8.78E-01	5.00E+00	0.1
	5289W0002								
	NACFW2AA	TOTAL ALPHA RA	2.61E-01 +- 3.5E-01	U	pCi/L	50%	5.86E-01	5.00E+00	
	5289W0003								
	NACFX1AA	TOTAL ALPHA RA	-5.03E-02 +- 4.0E-01	U	pCi/L	62%	9.18E-01	5.00E+00	
	5289W0004								
	NACF02AA	TOTAL ALPHA RA	1.62E-01 +- 3.1E-01	U	pCi/L	49%	5.29E-01	5.00E+00	
	5289W0005								
	NACF12AA	TOTAL ALPHA RA	-5.09E-02 +- 2.8E-01	U	pCi/L	48%	5.47E-01	5.00E+00	

No. of Results: 18

TestAmerica Inc

rptTALRchSaSummary2 V5.8.5 A2002

RER2 - Replicate Error Ratio = (S-D)/[sqrt(sq(TPUs)+sq(TPUd))] as defined by ICPT BOA.

J Qual - No U or < qualifier has been assigned and the result is below the Reporting Limit, RL (CRDL) or Report Value is Estimated.

U Qual - Analyzed for but not detected above limiting criteria, Mdc/Mda/Mdl, Total Uncert, RDL or not identified by gamma scan software.

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Figure C-13. TestAmerica Results for Soil Samples 5289S0017 – 5289S0028 and Water Samples 5289W0001 – 5289W0005