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January 8, 2021

Ms. Orysia Masnyk Bailey
U.S. Nuclear Regulatory Commission
Division of Nuclear Materials Safety
Decommissioning Branch
2100 Renaissance Boulevard
Suite 100
King of Prussia, PA 19406

**SUBJECT:** **CONTRACT NO. DE-SC0014664**
**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE FORMER UNC NAVAL PRODUCTS FACILITY NEW HAVEN, CONNECTICUT**
**DOCKET NO. 07000371; RFTA NO. 19-006;**
**DCN: 5340-SR-01-0**

Dear Ms. Bailey:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed final report detailing the confirmatory survey activities for the 3H/6H Tract building excavation and associated areas at the United Nuclear Corporation (UNC) Naval Products facility in New Haven, Connecticut. The U.S. Nuclear Regulatory Commission's (NRC's) comments on the draft report were addressed in this final version.

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

Sincerely,

Nick A. Altic, CHP
Health Physicist/Project Manager
ORISE

NAA:jlc

Attachment

Electronic distribution: K. Conway, NRC E. Bailey, ORISE D. Hagemeyer, ORISE
Z. Cruz Perez, NRC File/5340

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# INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE FORMER UNC NAVAL PRODUCTS FACILITY NEW HAVEN, CONNECTICUT

**Prepared by:**
**E. N. Bailey**

**FINAL REPORT**

**Prepared for the:**
**U.S. Nuclear Regulatory Commission**

**January 2021**



This document was prepared for the U.S. Nuclear Regulatory Commission by the Oak Ridge Institute for Science and Education (ORISE) through interagency agreement number 31310018N0014 with the U.S. Department of Energy (DOE). ORISE is managed by Oak Ridge Associated Universities under DOE contract number DE-SC0014664.

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE FORMER UNC NAVAL PRODUCTS FACILITY NEW HAVEN, CONNECTICUT**

| | | | |
|---|---|---|---|
| Prepared by: | E. N. Bailey, Survey and Technical Projects Group Manager<br>ORISE | Date: | 1/8/2021 |
| Prepared by: | N. A. Altic, CHP, Health Physicist/Project Manager<br>ORISE | Date: | 1/8/2021 |
| Reviewed by: | P. H. Benton, Quality Manager<br>ORISE | Date: | 1/8/2021 |
| Reviewed by: | W. F. Smith, Senior Chemist<br>ORISE | Date: | 1/8/2021 |
| Reviewed and approved for release by: | D. A. Hagemeyer, Program Director<br>ORISE | Date: | 1/8/2021 |

**FINAL REPORT**

**JANUARY 2021**

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## ABBREVIATIONS AND ACRONYMS LIST

| | |
|---|---|
| AA | alternative action |
| CB | catch basin |
| CFR | Code of Federal Regulations |
| cm | centimeter(s) |
| cpm | counts per minute |
| CU | confirmatory unit |
| DCGL | derived concentration guideline level |
| $DCGL_{U-tot}$ | total uranium derived concentration guideline level |
| DQO | data quality objective |
| EPA | U.S. Environmental Protection Agency |
| EU | enriched uranium |
| FSS | final status survey |
| GE | General Electric Company |
| GPS | global positioning system |
| m | meter(s) |
| MDC | minimum detectable concentration |
| mrem/yr | millirem per year |
| NaI[Tl] | thallium-doped sodium iodide |
| NRC | U.S. Nuclear Regulatory Commission |
| ORAU | Oak Ridge Associated Universities |
| ORISE | Oak Ridge Institute for Science and Education |
| pCi/g | picocurie per gram |
| PSQs | principal study questions |
| Q | quantile |
| REAL | Radiological and Environmental Analytical Laboratory |
| ROCs | radionuclides of concern |
| RSS | ranked set sampling |
| SNM | special nuclear material |
| SU | survey unit |
| TEDE | total effective dose equivalent |
| UNC | United Nuclear Corporation |
| VSP | Visual Sample Plan |

# INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE FORMER UNC NAVAL PRODUCTS FACILITY, NEW HAVEN, CONNECTICUT

## EXECUTIVE SUMMARY

The United Nuclear Corporation (UNC) holds a special nuclear material (SNM) license, SNM-368, managed by the U.S. Nuclear Regulatory Commission (NRC). The SNM license authorized the possession and use of highly-enriched uranium and later source material, including natural uranium, depleted uranium, and thorium for research and nuclear fuel fabrication. The UNC site is located in New Haven, Connecticut. UNC operated the facility from 1961 to 1976. Buildings 3H and 6H were part of a larger nuclear fuel complex, referred to as the H-Tract (Arcadis 2019).

In 1974, UNC announced the closing of the H-Tract facility and transferred their equipment and inventory of radioactive materials from the New Haven location to the Montville, Connecticut location. Final surveys of the New Haven facility were completed in February 1976, and NRC subsequently released the site for unrestricted use in accordance with the existing release criteria at the time. License SNM-368 was amended in 1976 to remove the New Haven facility from the license. NRC's guidance and criteria for release for unrestricted use, at that time, was Regulatory Guide 1.86 (NRC 1974) and *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material* (NRC 1973).

From 1989 to 1990, NRC initiated a Terminated Sites Review Project to ensure that formerly licensed facilities were terminated in accordance with current NRC criteria for release for unrestricted use. As part of this program, license SNM-368 was identified as a site that required additional review since final radiological survey records were either incomplete or inadequate. A radiological survey was conducted in 1996 using the release criteria in the 1981 Branch Technical Position *Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations* (NRC 1981). Results of the survey indicated that residual enriched uranium (EU) exceeded the release criteria of 30 picocuries per gram (pCi/g) established in 46 CFR 52061 (NRC 1981) in several areas of the site.

In 1997, the site was acquired by General Electric Company. A final site cleanup plan was submitted in 2019 (Arcadis 2019). NRC requested that Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities at the former UNC Naval Facility with a focus on excavated areas under the former 3H/6H building and Argyle Street. ORISE performed

confirmatory activities during the period of October 6–8, 2020. Confirmatory survey activities included gamma walkover scanning of the entire site, gamma direct measurements, soil sampling, and gamma scanning of catch basins and accessible piping. A total of 32 soil samples were collected across all confirmatory units: 27 random samples and 5 judgmental samples. All confirmatory samples had uranium concentrations less than the applicable release criterion ($DCGL_{U\text{-}tot}$).

# 1. INTRODUCTION

The Atomic Energy Commission (later the U.S. Nuclear Regulatory Commission [NRC]) issued a special nuclear material (SNM) license, SNM-368, to Olin Mathieson Chemical Corporation—Winchester Western Division in 1960 for fabrication and manufacturing of reactor fuel components for the Naval Reactors Program in New Haven, Connecticut. In 1961, Olin transferred the facility and license to United Nuclear—Fuels Division, which became United Nuclear Corporation (UNC). The SNM license authorized possession and use of highly-enriched uranium and later source material, including natural uranium, depleted uranium, and thorium for research and nuclear fuel fabrication. UNC operated the facility from 1961 to 1976. Buildings 3H and 6H were part of a larger nuclear fuel complex, referred to as the H-Tract (Arcadis 2019).

In 1974, UNC announced the closing of the H-Tract facility and transferred their equipment and inventory of radioactive materials from the New Haven location to the Montville, Connecticut location. Final surveys of the New Haven facility were completed in February 1976, and NRC subsequently released the site for unrestricted use in accordance with the existing release criteria at the time. License SNM-368 was amended in 1976 to remove the New Haven facility from the license. NRC's guidance and criteria for release for unrestricted use, at that time, was Regulatory Guide 1.86 (NRC 1974) and *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material* (NRC 1973).

From 1989 to 1990, NRC initiated a Terminated Sites Review Project to ensure that formerly licensed facilities were terminated in accordance with current NRC criteria for release for unrestricted use. As part of this program, License No. SNM-368 was identified as a site that required additional review since final radiological survey records were either incomplete or inadequate. A radiological survey of the subsurface soils was conducted in 1996 using the release criteria in the 1981 Branch Technical Position *Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations* (NRC 1981). Results of the survey indicated that residual enriched uranium (EU), in certain subsurface/subfloor soil samples collected from inside the building and connected inactive sewer system, exceeded the release criteria of 30 picocuries per gram (pCi/g) established in 46 CFR 52061 (NRC 1981). These contaminated areas were documented in an NRC inspection report (NRC 1996) and in *Radiological Scoping Survey of Buildings 3H and 6H at the Former UNC H-Tract Facility, New Haven, Connecticut* (ORISE 1997).

In 1997, the site was acquired by General Electric Company (GE). A characterization report was completed in 2003 followed by a decontamination and decommissioning plan in 2005. A final status survey (FSS) plan was developed and submitted to NRC in 2006 to describe the surveys performed to confirm the removal of soil with total uranium concentrations greater than 30 pCi/g (Cabrera 2018). In 2013, NRC accepted an addendum to the decommissioning plan to use dose-based release criteria (derived concentration guideline levels [DCGLs]) that meet the state of Connecticut's dose standard (19 millirem per year [mrem/yr]). Subsequent investigations of the soil under the 3H/6H building did not find widespread contamination. It was determined that contamination most likely was present under drainage holes in the south trench and in a utility trench that runs the length of the building. A survey of the floor surfaces, portions of the walls, and other interior building surfaces (e.g., lamps, crossbeams) was conducted and reported in 2018 (Arcadis 2019).

Based on the history and characterization studies, it was decided to raze the 3H/6H tract building and remove the debris and a portion of the underlying soil. A cleanup plan was submitted in 2019 for the work (Arcadis 2019). NRC has requested that Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities at the former UNC Naval Facility with a focus on excavated areas under the former 3H/6H building and Argyle Street. NRC will use the confirmatory survey data for their decision making.

## 2. SITE DESCRIPTION

The UNC H-Tract site is located at 71 Shelton Avenue in New Haven, Connecticut, and consists of a contiguous building (3H/6H) connected to an inactive sewer system that traverses an adjacent private property line. The building is adjacent to Argyle Street to the south. Figure 2.1 provides an aerial view of the site. The approximate total footprint of the 3H/6H building is 5,000 square meters ($m^2$). Figure A.1 in Appendix A provides key features of the former 3H/6H building, including the South Trench, the sewer line, and manhole locations (Arcadis 2019). The UNC Naval Site was composed of several other buildings, which were demolished prior to 1990. Three of these buildings are identified as Building 9H, 10H, and 11H—and are also depicted in Figure A.1. Radiological operations were conducted in the basements of these buildings. However, historical information related to these operations was not identified in site decommissioning documents.

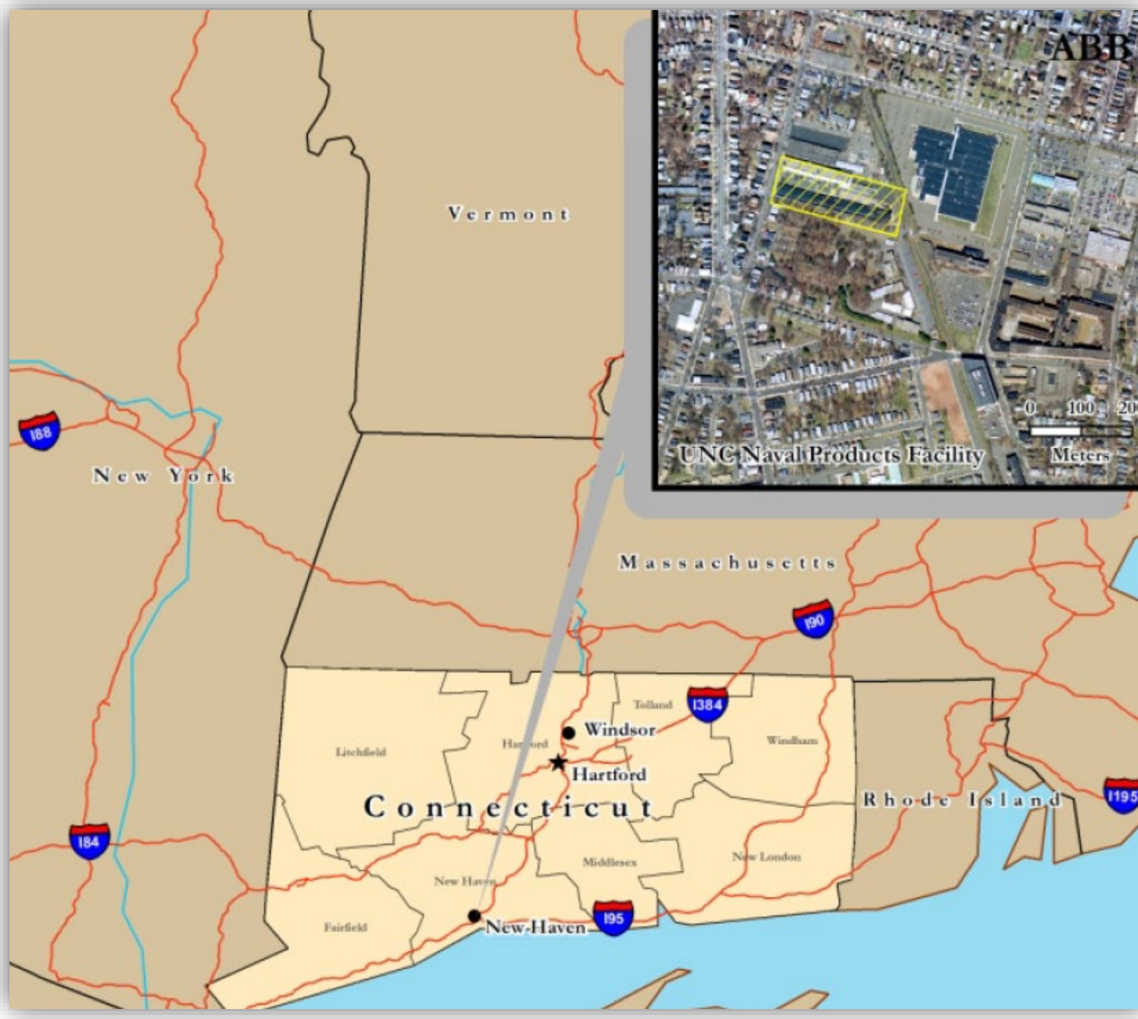


**Figure 2.1. Aerial View of UNC Naval Products Facility**

Deconstruction of Buildings 3H/6H occurred prior to the ORISE confirmatory survey and involved the complete removal of the above-grade portion of buildings and partial removal of the at-grade and subslab features. The at-grade and subslab portions include slabs, trenches to full depth, interior and perimeter foundation walls to a depth of approximately 0.3 m below slab bottom, and approximately 0.3 m of soil from underneath the finished slabs and trenches. Above-grade portions of Buildings 9H/10H/11H were demolished, prior to the decommissioning efforts of Buildings 3H/6H, and the basement portions were backfilled.

# 3. DATA QUALITY OBJECTIVES

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

1. State the problem.
2. Identify the decision.
3. Identify inputs to the decision.
4. Define the study boundaries.
5. Develop a decision rule.
6. Specify limits on decision errors.
7. Optimize the design for obtaining data.

## 3.1 STATE THE PROBLEM

The first step in the DQO process defines the problem that necessitates the study, identifies the planning team, and examines the project budget and schedule. A FSS was performed at the site to demonstrate that residual contamination levels do not result in a dose that exceeds NRC decommissioning criteria. NRC staff will review the FSS data submittal to evaluate the adequacy and accuracy of the FSS survey relative to the decommissioning approved end-point criteria. To support this effort, NRC requested that ORISE perform confirmatory surveys to generate independent radiological data to assist them in evaluating FSS results for the former UNC Naval site. Therefore, the problem statement was as follows:

> Confirmatory surveys are necessary to generate independent radiological data to assist NRC with their assessment and determination of the adequacy of FSS results used for demonstrating compliance with the release criteria.

## 3.2 IDENTIFY THE DECISION/OBJECTIVE

The second step in the DQO process identified the principal study questions (PSQs) and alternative actions (AAs), developed a decision statement, and organized multiple decisions, as appropriate. This was done by specifying AAs that could result from a "yes" response to the PSQs and combining the PSQs and AAs into a decision statement. Given that the problem statement introduced in Section 3.1 is fairly broad, multiple PSQs arise. PSQs, AAs, and combined decision statements are presented in Table 3.1.

| Table 3.1. Confirmatory Survey Decision Process | |
|---|---|
| **Principal Study Questions** | **Alternative Actions** |
| **PSQ1:** Are residual radioactivity concentrations within the former UNC Naval site below applicable limits? | **Yes:**<br>Compile confirmatory data and report results to NRC for their decision making. Provide independent interpretation that confirmatory field surveys did not identify anomalous areas of residual radioactivity and quantitative field and laboratory data satisfied NRC-approved decommissioning criteria.<br><br>**No:**<br>Compile confirmatory data and report results to NRC for their decision making. Provide independent interpretation of confirmatory survey results identifying any anomalous field or laboratory data. |
| **PSQ2:** Do the confirmatory results support the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) classification of the FSS survey units (SUs)? | **Yes:**<br>Confirmatory results support the classification of the FSS SUs. Compile confirmatory survey data and present results to NRC for their decision making.<br><br>**No:**<br>Confirmatory results do not support the classification of the FSS SUs. Summarize the discrepancies and provide technical comments to NRC for their decision making. |
| **Decision Statements** | |
| Determine if radionuclide concentrations in confirmatory survey samples exceed the applicable limits.<br>Determine if confirmatory survey results support the site's MARSSIM classification of the FSS SUs. | |

## 3.3 IDENTIFY INPUTS TO THE DECISION/OBJECTIVE

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

- Site specific DCGLs, further discussed in subsection 3.3.1
- ORISE confirmatory surface scans
- ORISE volumetric sample analytical results

### 3.3.1 Radionuclides of Concern and Contaminants of Concern

The primary radionuclides of concern (ROCs) for the UNC facility are those associated with EU (i.e., uranium-234, uranium-235, and uranium-238). UNC has developed site-specific DCGLs that correspond to a residual radioactive contamination level, which could result in a total effective dose equivalent (TEDE) of 19 mrem/yr. A TEDE of 19 mrem/yr corresponds to the state of Connecticut's dose criterion (AAA 2008). Rather than demonstrating compliance with the DCGL for the individual isotopes of uranium, NRC approved the use of a total uranium DCGL ($DCGL_{U\text{-}tot}$). The $DCGL_{U\text{-}tot}$ was calculated assuming a U-235 assay of 93% (by U-235 mass), resulting in a value of 435 pCi/g total uranium.

Per Section 6.5 of the site's cleanup plan, all soil sample concentrations will be directly compared to $DCGL_{U\text{-}tot}$ and any exceedances will be cause for additional remediation (Arcadis 2019). As such, the total uranium DCGL was treated as a not-to-exceed value, i.e., an elevated measurement comparison will not be performed.

## 3.4 DEFINE THE STUDY BOUNDARIES

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

Areas of the New Haven site that were targeted for confirmatory survey activities were the Building 3H/6H Tract excavation (prior to backfill), Argyle Street sewer, laydown area, storm water system, former Building 9H/10H/11H footprint, and the haul road.

NRC staff prioritized areas below the former 3H/6H Tract building, prior to backfill and the storm water system. ORISE focused on these priority areas first and then investigated other areas with the greatest potential for residual contamination, as directed by NRC. A portion of the storm water system was removed by the site prior to the confirmatory survey. Storm water piping investigated by ORISE was selected by visual identification of available access points during a walkdown with NRC staff prior to conducting confirmatory survey activities—with the exception of piping containing visible asbestos material. Additionally, the storm water piping was caved in at many of the identified access location (most locations had less than 1 m of piping available for the survey). Individual survey units (SUs) were combined into larger confirmatory units (CUs) for confirmatory survey purposes: CU1 is the Building 3H footprint, CU2 is the Building 6H center footprint, CU3 is the Building 6H west footprint, and CU4 is the balance of the site. Figure A.2 in Appendix A depicts the CU boundaries. Storm water piping was investigated as part of the CU in which it was located.

## 3.5 Develop a Decision Rule

The fifth step in the DQO process specified appropriate population parameters (e.g., mean, median), evaluated action levels relative to the appropriate detection limits, and developed an "if…then…" decision rule statement. Multiple PSQs were introduced in Table 3.1; therefore, multiple decision rules arose. The first PSQ relates to whether the residual radioactivity concentrations are below applicable limits with the second PSQ confirming the appropriateness of the SU classification. Decision rules for each PSQ are discussed below.

### 3.5.1 PSQ1: Confirmatory Sample Concentrations

Confirmatory survey samples were collected to determine if residual radioactivity concentrations were below applicable limits to support NRC staffs' determination that the FSS results are appropriate for the intended use. The general confirmatory survey approach to support this determination focused on collecting systematic data from specific survey areas and covering the majority of the site with qualitative investigations (i.e., surface scans). Two types of confirmatory samples were collected as part of this study: judgmental and random. Judgmental samples were collected based on on-site investigations, such as gamma walkover surveys, to evaluate discrete locations of potential contamination. Random samples were collected from CUs 1, 2, and 3 to provide NRC with an unbiased estimate of the mean radionuclide concentration. Because the ORISE field crew had access to the majority of the site and the surface scans were sufficient to identify residual radioactivity above the DCGL, surface scans served the basis for concluding residual radioactivity in CU4 was less than the allowable limit. The investigation level for the surface scans was an instrument response distinguishable from background.

The decision rule addressing PSQ1 was stated as:

> If each individual confirmatory survey sample result is below the applicable limit ($DCGL_{U\text{-}tot}$), then conclude that the confirmatory survey results satisfy the NRC-approved decommissioning criteria; otherwise, perform further evaluation(s) and provide technical comments/recommendations to NRC for their evaluation and decision making.

### 3.5.2 PSQ2: Survey Unit Classification

The intent of assessing the classification of the survey areas as part of the confirmatory survey process based on the requirements outlined in the site's cleanup plan (Arcadis 2019), would primarily relate to Class 2 and Class 3 survey areas as well as non-impacted areas because a Class 1 SU will not receive a higher classification. However, this confirmatory action was not necessary as the final status survey plan deemed the entire site as impacted and all survey units were classified as Class 1 SUs (Arcadis 2020).

## 3.6 SPECIFY LIMITS ON DECISION ERRORS

The sixth step in the DQO process examined the consequences of making an incorrect decision and establishes bounds of decision errors. Decision errors are controlled during the survey design, on-site field investigations, and during the data assessment. For this confirmatory survey effort, there were two orders of control.

The first order of control was to limit the uncertainty of the estimated CU mean ROC concentration. Conservative planning inputs for estimating the mean at the 95% confidence level within 87 pCi/g (20% of the $DCGL_{U\text{-}tot}$) above/below the true mean served the basis for sample size determination.

The second order of control was to minimize the minimum detectable concentrations (MDCs) of field instrumentation and laboratory analytical equipment. Scan MDCs for field instrumentation were below the $DCGL_{U\text{-}tot}$ based on survey procedures described in Section 4. Table 3.2 provides nominal total uranium scan MDCs based on the calculation methodology described in

NUREG-1507 (NRC 1998). Any anomalies above background identified while performing the surveys or subsequent data assessments were investigated thoroughly and discussed with NRC staff.

| Table 3.2. Total Uranium Scan MDC for 2-inch by 2-inch NaI Detector[a] | | |
|---|---|---|
| **U-235 Assay** | **Weighted Detector Response (cpm/-uR/h)** | **Scan MDC (pCi/g)** |
| 3% | 4,328 | 140 |
| 20% | 5,027 | 160 |
| 50% | 5,106 | 200 |
| 75% | 5,129 | 230 |
| 93% | 5,141 | 250 |

[a] Based on scan MDC calculation methodology outlined in NRC 1998. Assumes 0.25 $m^2$ source size, d' = 2.32, a detector background of 10,000 cpm, and a 1-second observation interval.
NaI = sodium iodide
cpm = counts per minute
uR = microrem
h = hour

### 3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA

The seventh step in the DQO process was used to review DQO outputs, develop data collection design alternatives, formulate mathematical expressions for each design, select the sample size to satisfy DQOs, decide on the most resource-effective design of agreed alternatives, and document requisite details. Specific survey procedures are presented in Section 4.

## 4. PROCEDURES

The ORISE survey team performed visual inspections, measurements, and sampling activities requested by NRC staff during the period of October 6–8, 2020. Survey activities were conducted in accordance with the project-specific confirmatory survey plan, the *Oak Ridge Associated Universities (ORAU) Radiological and Environmental Survey Procedures Manual,* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORISE 2020, ORAU 2016, ORAU 2019). Appendices C and D provide additional information regarding survey instrumentation and related processes discussed within this section.

### 4.1 REFERENCE SYSTEM

ORISE referenced confirmatory measurement/sampling locations to global positioning system (GPS) coordinates using the NAD 1983 (CORS96) State Plane Connecticut FIPS 0600 (meters). Measurement and sampling locations were documented on detailed survey maps. Specific areas were also digitally photographed.

### 4.2 SURFACE SCANS

For land areas, Ludlum model 44-10 2-inch by 2-inch thallium-doped sodium iodide (NaI[Tl]), hereafter referred to as NaI, detectors were used to evaluate direct gamma radiation levels. Accessible areas of the site were scanned with medium- to high-density coverage. All detectors were coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Ratemeter-scalers also were coupled to hand-held GPS data-loggers to electronically record detector response concurrently with geospatial coordinates. Locations of elevated response that were audibly distinguishable from localized background levels, suggesting the presence of residual contamination, were marked for further investigation via volumetric sampling.

For piping, a Ludlum model 44-157 2-inch by 2-inch NaI Scintillation Detector Model 44-157, was used to evaluate direct gamma radiation levels on interior surfaces. The detector was coupled to a Ludlum Model 2221 ratemeter-scaler with audible indicators.

### 4.3 MEASUREMENT/SAMPLING LOCATIONS

For land areas, soil samples were collected from both randomly- and judgmentally-selected locations. The data sets generated for CUs 1, 2, and 3 were for the purpose of estimating the mean. Visual Sample Plan (VSP), version 7, was used to assess the sample size required for decision making and to randomly place locations throughout the CUs. The sample size determination is discussed in the following subsection. The total number of judgmental measurements was based upon findings during gamma surface scans or NRC direction.

For piping, 1-minute, static NaI gamma counts were recorded in 1-foot segments for the accessible length of the pipe. Soil/debris was collected if present.

### 4.3.1 Ranked Set Sampling

A ranked-set-sampling (RSS) process, following U.S. Environmental Protection Agency (EPA) guidance, was used to select a sample set for an unbiased estimate of the mean (EPA 2002) in CUs 1, 2, and 3. RSS provides a methodology to determine the necessary number of soil samples to estimate the mean concentration of a population. However, it does not require the assumption of a normal distribution. The process combines random sampling with the use of a field screening method capable of distinguishing the relative magnitude of a parameter of interest in a population in combination with professional judgment to select sampling locations. For this effort, 1-minute, static NaI gamma counts collected at each of the randomly-selected locations provided the measurable field screening method that correlated with the relative concentrations of the gamma-emitting ROCs. The professional-judgmental component was the ability to assess the magnitude of gamma radiation levels (count rates) between randomly-selected locations. The count rate data obtained from the group of random gamma measurement locations then was used to select specific locations for collecting the confirmatory soil samples.

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

- **Set 1:** The lowest gamma count value of three locations within Set 1 is sampled.
- **Set 2:** The middle gamma count value of three locations within Set 2 is sampled.
- **Set 3:** The highest gamma count value of three locations within Set 3 is sampled.

The number of repetitive cycles was dependent on the total number of soil samples ($n$) required and is a function of $n$ and $m$—simply defined as $n = m \times r$. VSP was used to calculate the number of required samples. Inputs to this calculation were the desired confidence level of the estimated mean, allowable uncertainty of the estimated mean, and expected variability. Based on the planning inputs specified in Section 3.6, nine samples (i.e., $n$ = 9) were collected. Therefore, with nine required soil samples, the number of repetitive cycles was 3 ($r = n/m = 9/3 = 3$). The total number of assessment locations per CU was defined as $m^2 \times r$ (where $r = 3$ in this case), which was $3^2 \times 3 = 27$.

### 4.4 SOIL SAMPLING

Soil samples were collected from both randomly- and judgmentally-selected locations as discussed in Section 4.3. Two locations were identified during surface scans with elevated direct gamma radiation levels distinguishable from background and samples were collected.

Prior to soil sampling, a 1-minute, static gamma radiation measurement was performed and then the surface soil sample was collected from a depth of 0 to 15 centimeters (cm) followed by a static gamma radiation measurement at the 15-cm depth. A subsurface sample was collected at one judgmentally-selected location following the collection of the surface sample because of a notable increase in the gamma count rate.

Soil samples were collected using clean hand trowels. All sampling equipment was rinsed in the field after the collection of each sample to prevent cross-contamination. Table 4.1 provides a summary of the soil samples collected.

**Table 4.1. Summary of Volumetric Samples Collected**

| Sample Collection Type | Depth/Type | No. Collected |
|---|---|---|
| RSS | Surface-Soil | 9 |
| | Surface-Soil | 9 |
| | Surface-Soil | 9 |
| Judgmental | Surface-Soil | 2 |
| | Subsurface-soil (15-30 cm) | 1 |
| | Soil/Sediment in pipes | 2 |
| **Total** | | 32 |

### 4.5 MISCELLANEOUS SAMPLES

Two samples, consisting of soil/sediment and vegetation debris, were collected from within a pipe connected to Catch Basin-22 (CB-22) (sample 5340S0028) and what the site called the "East Pipe" (sample 5340S0029). The pipe samples were collected with clean scooping tools attached to an extension pole.

# 5. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were transferred to the ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2020a). Soil samples were homogenized and analyzed by gamma spectrometry for gamma-emitting radionuclides. Analytical results were reported in units of pCi/g. The site's cleanup plan states that the total uranium concentration in each FSS sample will be calculated by inferring the U-234 concentration based on the U-235 assay (Arcadis 2019). Total uranium concentration was calculated in the same manner for the confirmatory soil samples. NRC staff did not direct ORISE to perform isotopic uranium analysis via alpha-spec, nor did ORISE recommend isotopic-specific analysis—based on review of the gamma spec data. Total uranium concentration is calculated by:

$$C_{U,tot} = C_{U-238} + C_{U-235}\left(1 + R_{234/235}\right)$$

Where:

$C_{U,tot}$ = total uranium sample concentration,
$C_{U\text{-}238}$ = U-238 sample concentration,
$C_{U\text{-}235}$ = U-235 sample concentration, and
$R_{234/235}$ = Activity ratio of U-234 to U-235 for a U-235 assay of 93%=27.

Random soil sample and gamma walkover results were graphed in quantile (Q) plots for assessment, and are discussed further in Section 6. The Q-plot is a graphical tool for assessing the distribution of a dataset. The Y-axis represents the ROC concentrations in units of pCi/g for sample data and cpm for scan data. The X-axis represents the data quantiles about the mean value. Values less than the mean are represented in the negative quantiles; the values greater than the mean are represented in the positive quantiles. A normal distribution that is not skewed by outliers (i.e., a background population) will appear as a straight line, with the slope of the line subject to the degree of variability among the data population. More than one distribution, such as background plus contamination or other outliers, will appear as a step function.

# 6. FINDINGS AND RESULTS

The results of the confirmatory survey are discussed in the following subsections.

## 6.1 SURFACE SCANS

Figures A.3 through A.6 in Appendix A present the gamma walkover data for each CU. Overall, the gamma responses ranged from approximately 3,600 counts per minute (cpm) to 15,500 cpm. Table 6.1 provides the summary statistics for the gamma walkover survey. Figure 6.1 presents Q-plots for gamma walkover survey data in each CU. The shape of the Q-plots in Figure 6.1 are consistent with multiple background conditions—notably, CU2 and CU3—rather than the presence of contamination.

Two areas had elevated gamma radiation levels slightly distinguishable from background in CU2; see Figure A.4 (red locations). Both locations were localized (less than 1 $m^2$) and had slightly-elevated gamma radiation levels compared to surrounding gamma radiation levels. The locations were marked for judgmental sampling.

**Table 6.1. Gamma Walkover Summary Statistics**

| Area | Statistic (cpm) | | | | |
|---|---|---|---|---|---|
| | Min | Max | Median | Mean | SD |
| CU1 | 4,982 | 10,500 | 7,590 | 7,605 | 662 |
| CU2 | 4,260 | 15,546 | 6,773 | 6,844 | 1,314 |
| CU3 | 4,148 | 12,060 | 8,444 | 8,210 | 1,446 |
| CU3 (Slab) | 3,987 | 7,535 | 5,039 | 5,111 | 514 |
| CU4 | 3,654 | 9,946 | 6,423 | 6,529 | 964 |

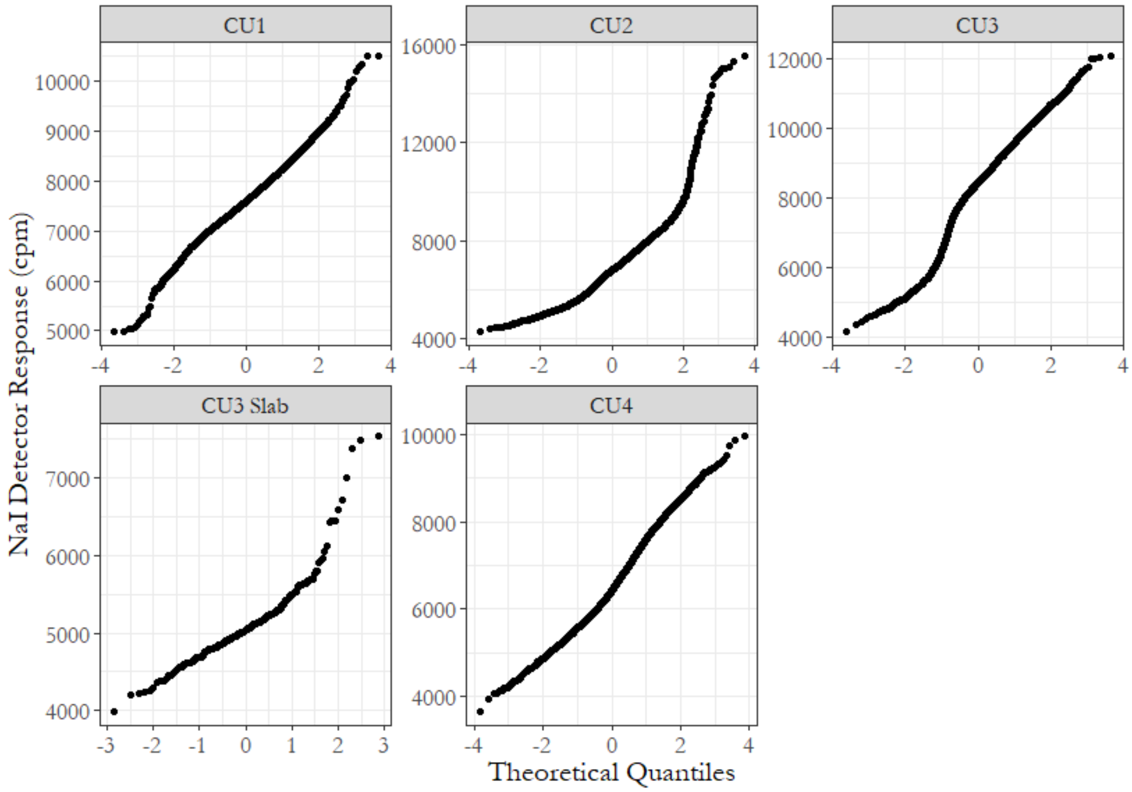


**Figure 6.1. Q-plots for Confirmatory Gamma Walkover Surveys**

ORISE staff collected measurements in all piping that was visibly identified during walk-downs with the exception of piping containing visible asbestos material present. As previously mentioned most piping had caved in preventing survey and, therefore, measurements were collected just inside the pipe opening. However, 1-minute static measurements were recorded at 0.3 m (1 foot) increments at numerous locations within 2 pipes. Table 6.2 presents the single measurement or scan ranges for all piping assessed.

| Table 6.2. Summary of Piping Assessed, Scan Ranges | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Piping** | **Scan Range (cpm)[a]** | | | **Piping** | **Scan Range (cpm)[a]** | | |
| CB-20 | 10,871 | to | NA | C-38[e] | 10,235 | to | NA |
| CB-20[b] | 16,344 | to | NA | East pipe | 13,200 | to | 16,200 |
| CB-22 | 15,300 | to | 19,200 | Water pipe in concrete trench between columns 14 and 15 | 6,329 | to | NA |
| CB-22/CB-23[c] | 12,000 | to | 16,000 | Water pipe in concrete trench in line with column 6 | 4,300 | to | NA |
| CB-26[d] | 9,106 | to | NA | C45 Manway | 12,000 | to | 14,000 |

[a]Ludlum Detector Model 44-157 used. If a range is not provided, the pipe was caved in and only a 1-min static gamma measurement was collected at the pipe opening.
[b]Measurement was collected in a remaining pipe heading west from the CB-20 excavation.
[c]Scan range for a pipe that connected CB-22 to CB-23. Only 9 feet of piping was accessible.
[d]CB-26 was removed; the measurement was collected in a remaining pipe heading east from the CB-26 excavation.
[e]Column-38 storm water piping.

Raw detector responses, in units of cpm, were plotted to examine the NaI gamma response profile of the CB-22 and the "East Pipe." These plots are presented in Figure 6.2. The profile for CB-22 indicates about a 1,600 cpm increase in the NaI detector response approximately 2 m inside the pipe. The exact cause of the increase is not known, a sample of available material was collected from this pipe.

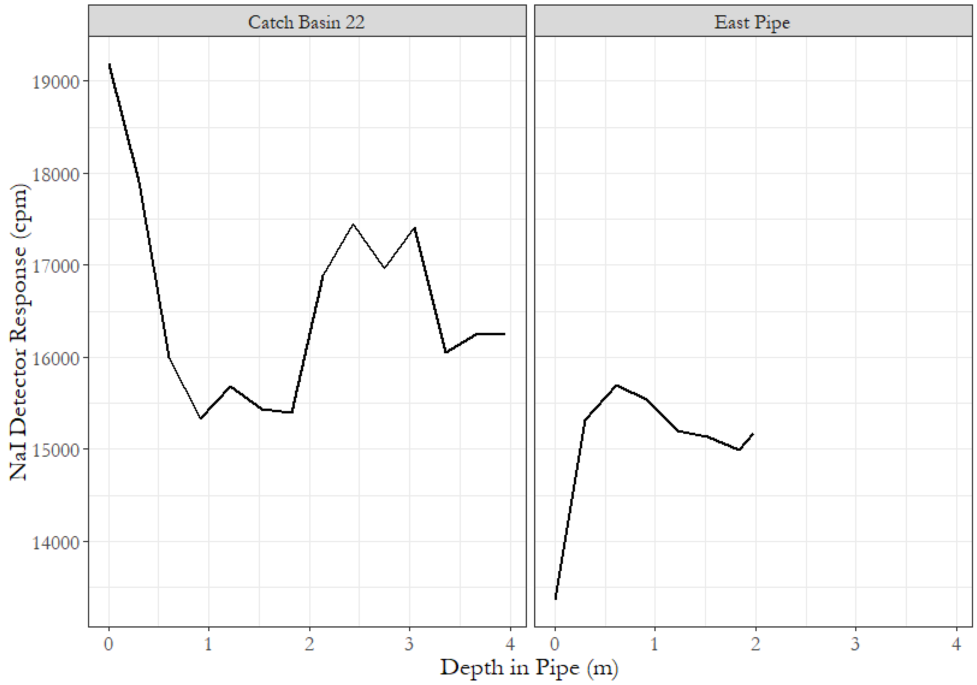


**Figure 6.2. Piping NaI Gamma Response Depth Profile**

## 6.2 Radionuclide Concentrations in Soil and Miscellaneous Samples

Figures A.7 through A.9 in Appendix A provide a graphical representation of all RSS locations where 1-minute, static gamma measurements were collected along with the resulting detector response used for the field ranking. Figures A.10 through A.12 display the locations for the soil samples collected. Ranked set sampling locations and sample coordinates, the soil sample pre- and post-sample static gamma counts, and uranium concentrations are presented in Tables B.1, B.2, and B.3 in Appendix B. The total uranium concentrations for all random soil samples are presented in Table B.4. The sample coordinates, the soil sample pre- and post-sample static gamma counts, and uranium concentrations for judgmental samples are presented in Table B.5.

Table 6.3 provides the summary statistics for the uranium concentrations in the randomly-selected soil samples.

| Table 6.3. Summary Statistics for Radionuclide Concentrations in Random Soil Samples | | | | | |
|---|---|---|---|---|---|
| ROC | Statistic (pCi/g) | | | | |
| | Min | Max | Median | Mean | SD |
| *CU1 (Bldg. 3H Footprint)* | | | | | |
| U-235 | 0.029 | 0.24 | 0.098 | 0.11 | 0.03 |
| U-238 | 0.29 | 0.91 | 0.67 | 0.65 | 0.07 |
| Total U | 1.62 | 7.63 | 3.48 | 3.72 | 0.77 |
| *CU2 (Bldg. 6H Center Footprint)* | | | | | |
| U-235 | 0.00 | 0.148 | 0.07 | 0.06 | 0.05 |
| U-238 | 0.12 | 1.03 | 0.62 | 0.66 | 0.31 |
| Total U | 0.4 | 4.49 | 2.88 | 2.39 | 1.52 |
| *CU3 (Bldg. 6H West Footprint)* | | | | | |
| U-235 | -0.026 | 0.14 | 0.029 | 0.03 | 0.01 |
| U-238 | -0.02 | 1.28 | 0.36 | 0.56 | 0.17 |
| Total U | -0.14 | 4.28 | 0.79 | 1.48 | 0.24 |

The two locations identified in CU2 during gamma walkover surveys with slightly elevated radiation levels were sampled. At the first location, two samples were collected. Following the collection of the surface soil sample 5340S0030, the gamma radiation levels increased notably. A second sample 5340S0031 was collected of the 15 to 30 cm depth and the gamma radiation levels increased again. NRC staff requested additional excavation at this location to further investigate the increasing radiation levels. Three excavator buckets of soil were removed and spread out in thin layers. ORISE performed gamma scans following the removal of each bucket. After the removal of the third bucket, the radiation levels decreased. No additional samples were collected at this location.

At the second location, judgmental sample 5340S0032 was collected in the side wall of an excavation and above a pipe adjacent to CB-22.

All random and judgmental samples collected had concentrations that were less than the NRC approved total uranium $DCGL_{U\text{-}tot}$. The random soil sample data sets in CUs 1, 2, and 3 provide NRC with an unbiased estimate of the residual mean ROC concentration. One error occurred during the field ranking process, precluding assessment of data from CU2 using traditional RSS methods (see Table B.2). However, the RSS approach is as efficient as simple random sampling, regardless of the accuracy in the field ranking (Presnell 1999). As a result, there was a slight increase in the uncertainty of the estimated mean for CU2, relative to what was planned, although the uncertainty is not greater than that resulting from the collection of nine random samples. Because there were no uranium concentrations identified near or greater than the $DCGL_{U\text{-}tot}$ in the sample set for CU2, the increased uncertainty does not limit confirmatory survey decisions.

Figure 6.3 provides a Q-plot of uranium concentrations for the ORISE confirmatory data sets. Review of Figure 6.3 indicates that shape of the Q-plot indicates an approximately normal distribution. Data near the analytical MDC are represented by the relatively flat portion of the curve present at the lower quantiles. The shape of the Q-plots are consistent with background conditions.

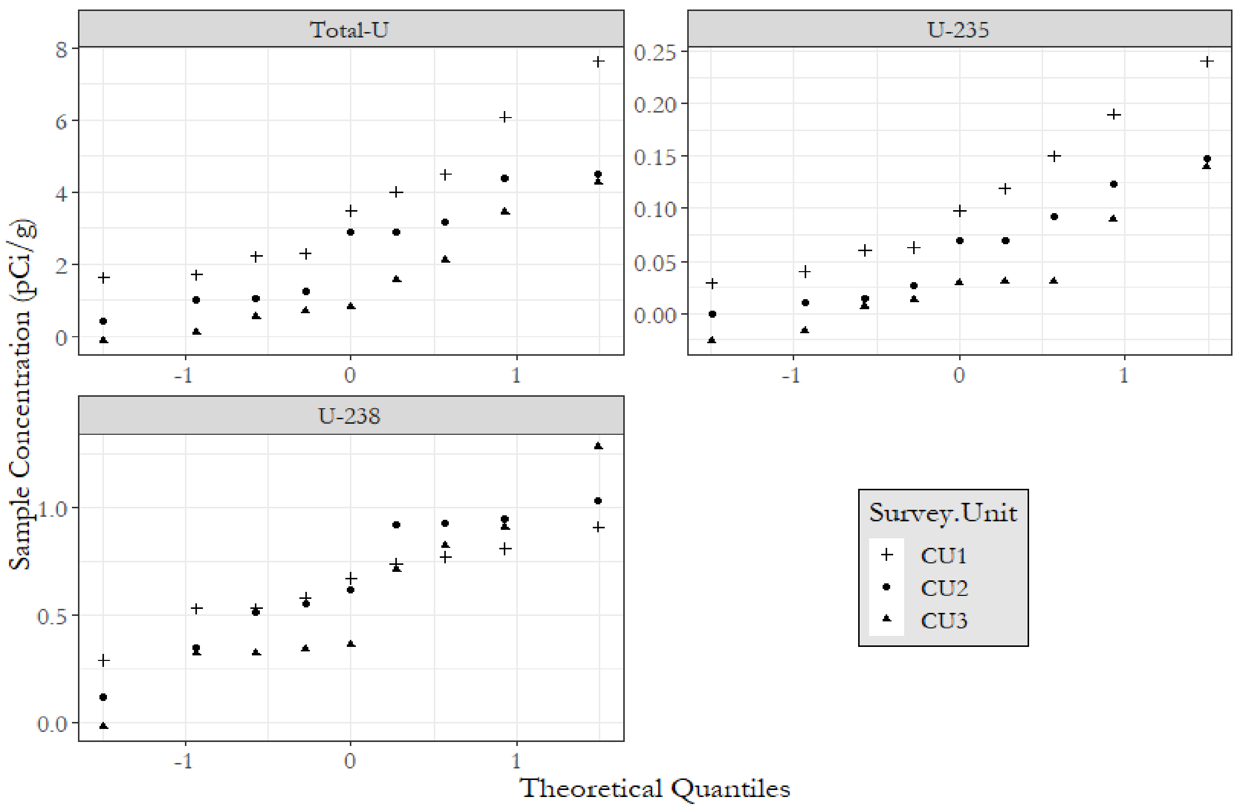


**Figure 6.3. Q-plots for ORISE Confirmatory Survey Soil Sample Uranium Concentrations**

## 7. SUMMARY AND CONCLUSIONS

During the period of October 6–8, 2020, ORISE performed independent confirmatory survey activities of surface soils and remaining piping associated with the UNC Naval Products site. The confirmatory survey activities consisted of gamma walkover surface scans of the entire site, gamma direct measurements, and surface and subsurface (one location) soil sampling.

Gamma scans identified two areas of elevated radiation distinguishable from background. These two locations had slightly-elevated gamma radiation levels compared to surrounding gamma radiation levels. Thirty-two total soil samples were collected. Twenty-seven sample locations were randomly selected, with 9 surface samples collected within each of the CUs 1, 2, and 3. The two identified areas with slightly elevated gamma radiation levels in CU2 were judgmentally selected for sampling: three samples were collected from the two locations. Additionally, two judgmental samples were collected from piping: one from CB-22 piping and one from the "East Pipe." All random and judgmental samples collected had concentrations that were less than the NRC approved total uranium $DCGL_{U\text{-}tot}$.

Based on the results of the collected confirmatory survey data, ORISE did not identify instances of residual activity that exceeded the DCGL for total uranium. Additionally, the confirmatory survey data assessment confirmed that project DQOs were met.

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# APPENDIX A:
# FIGURES

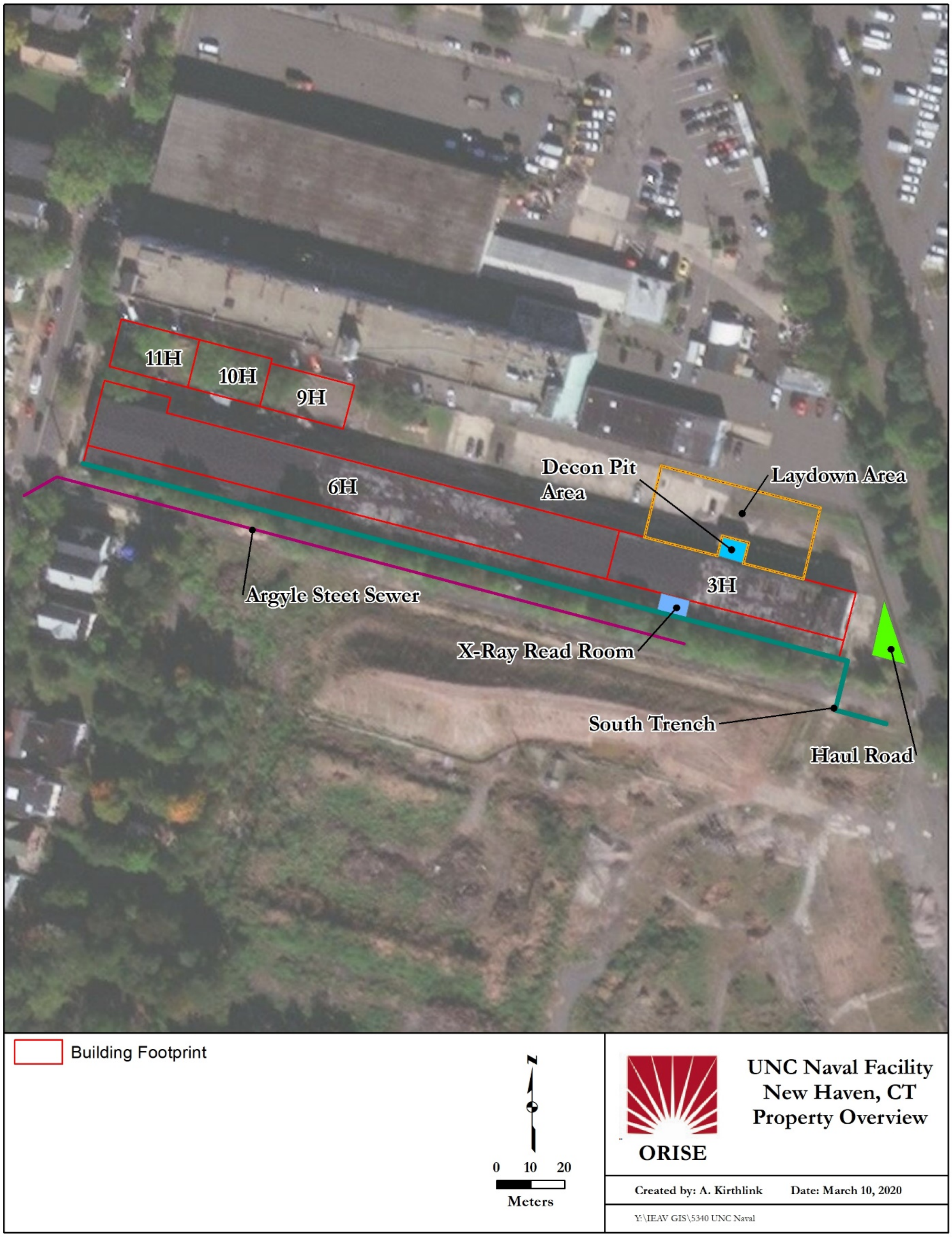


**Figure A.1. UNC Naval Site Layout**


**Figure A.2. Confirmatory Unit (CU) Boundaries**

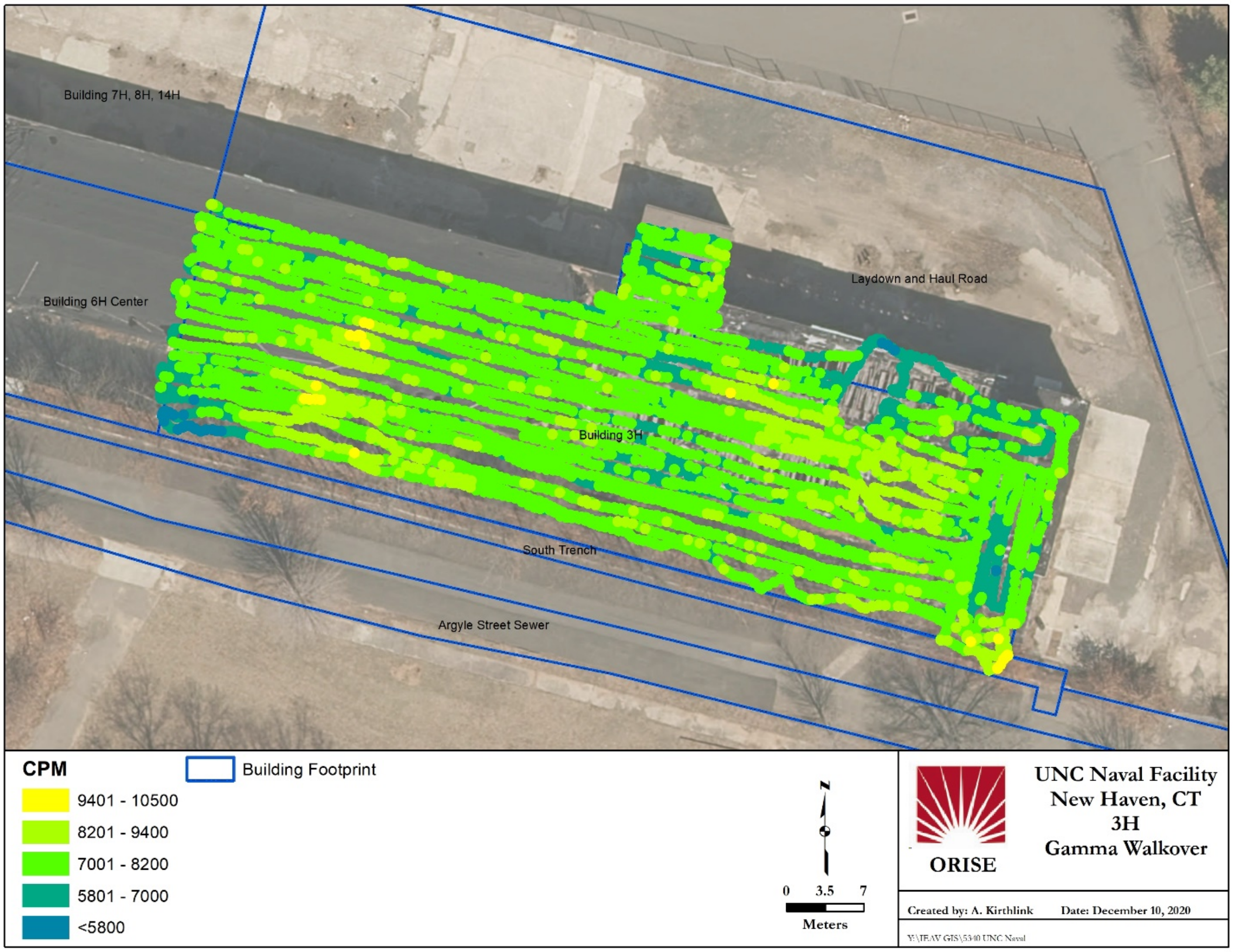


**Figure A.3. Gamma Walkover Data for CU1, Building 3H Footprint**

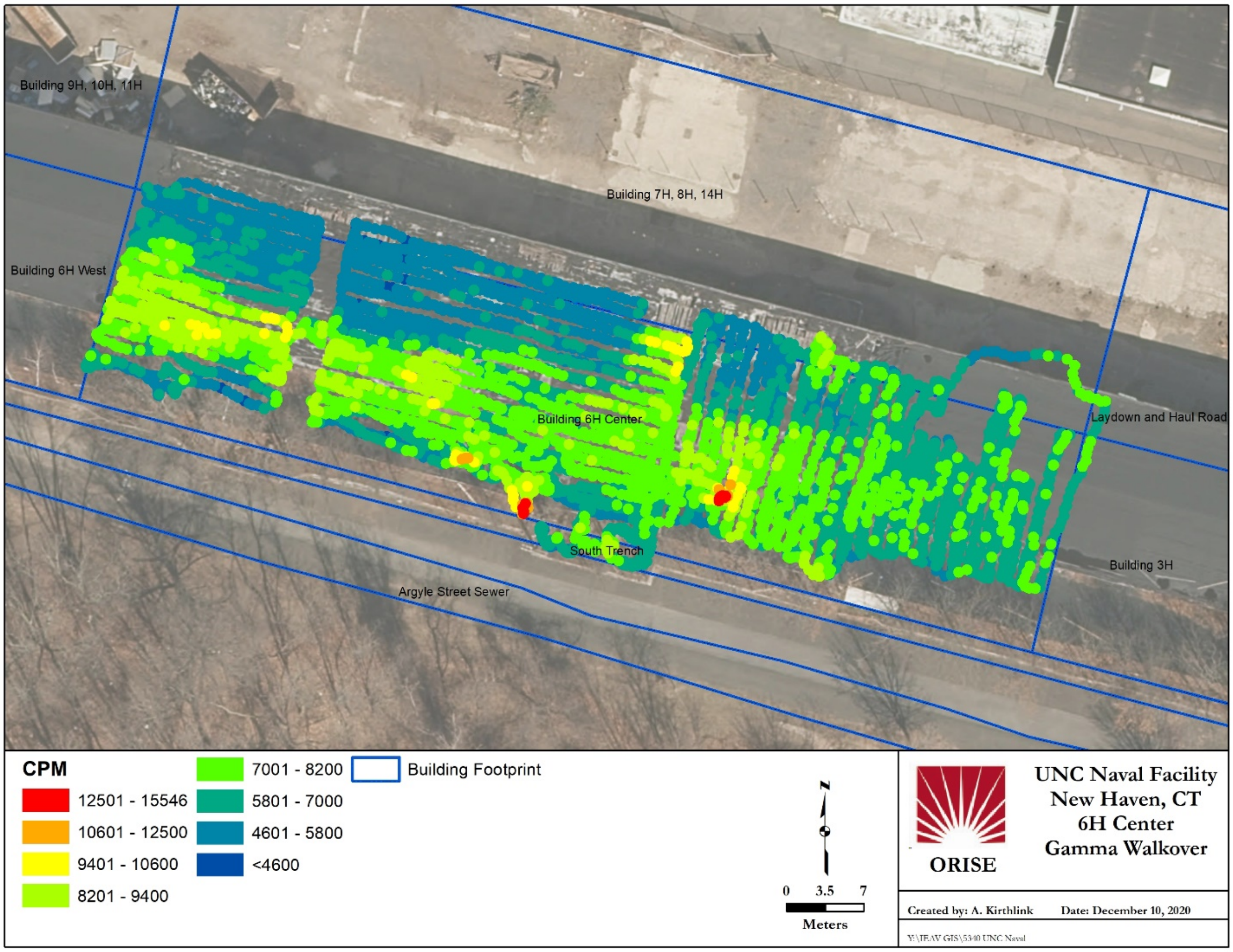


**Figure A.4. Gamma Walkover Data for CU2, Building 6H Center Footprint**

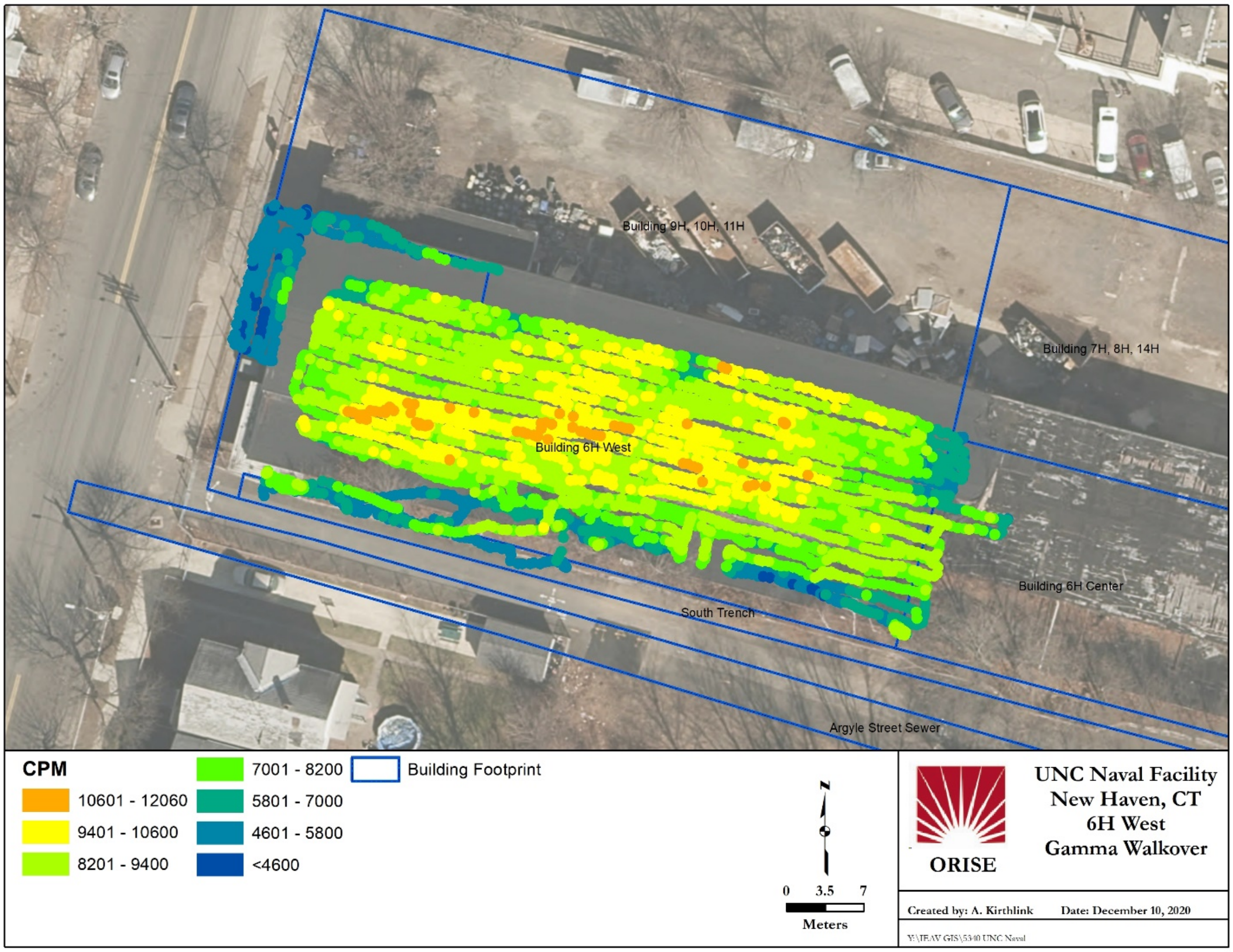


**Figure A.5. Gamma Walkover Data for CU3, Building 6H West Footprint**

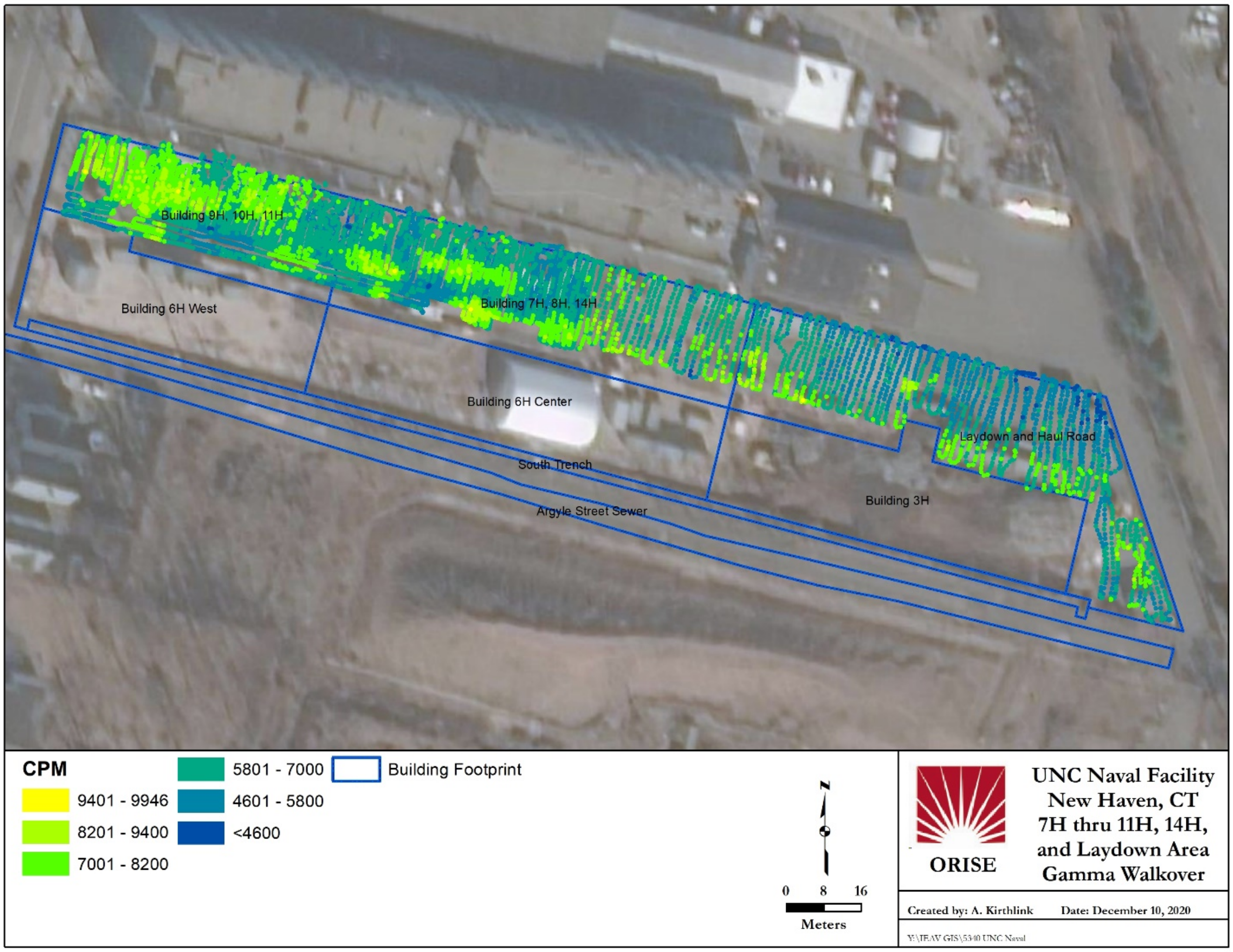


**Figure A.6. Gamma Walkover Data for CU4, Balance of the Site**

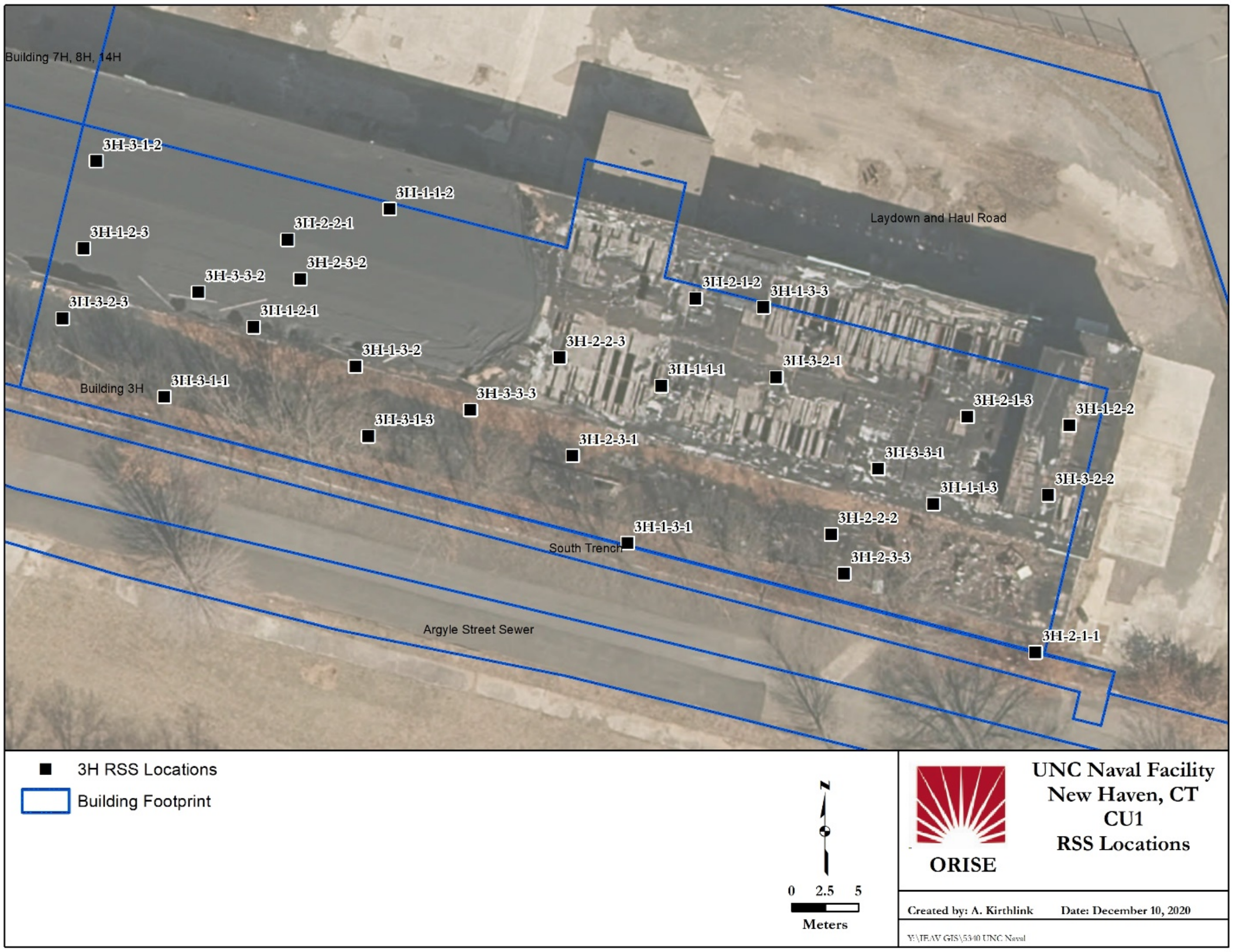


**Figure A.7. RSS Locations for CU1, Building 3H Footprint**

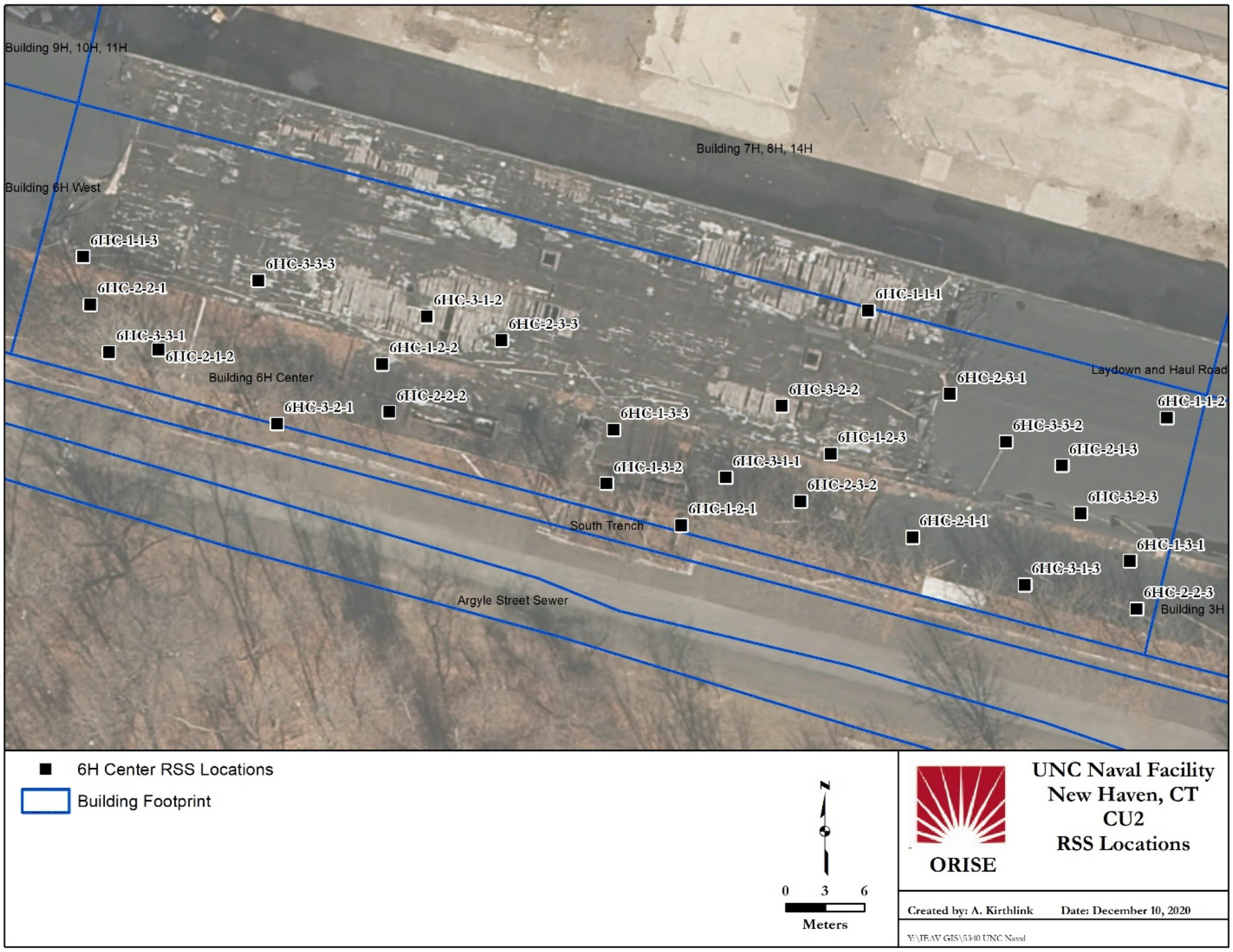


**Figure A.8. RSS Locations for CU2, Building 6H Center Footprint**

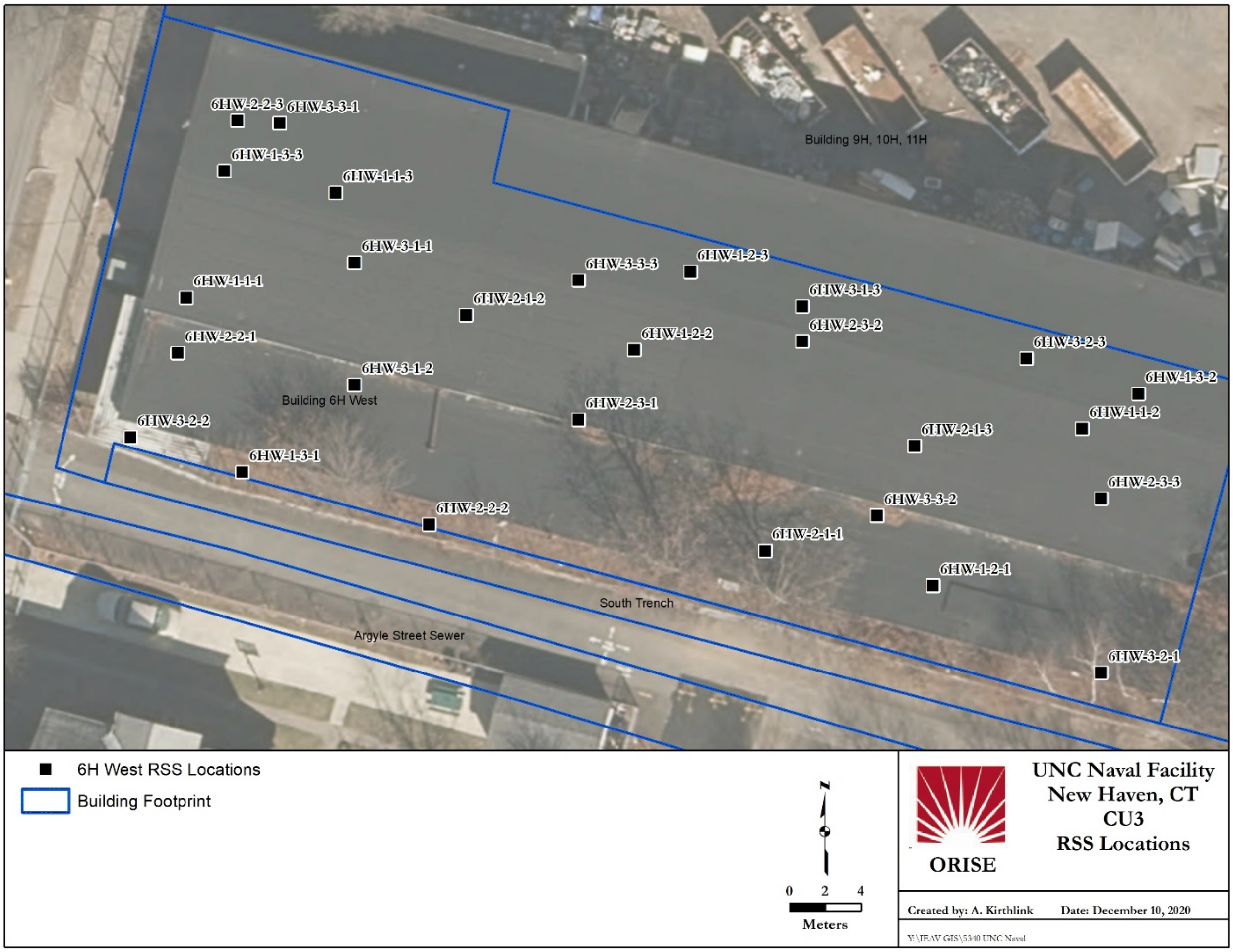


**Figure A.9. RSS Locations for CU3, Building 6H West Footprint**

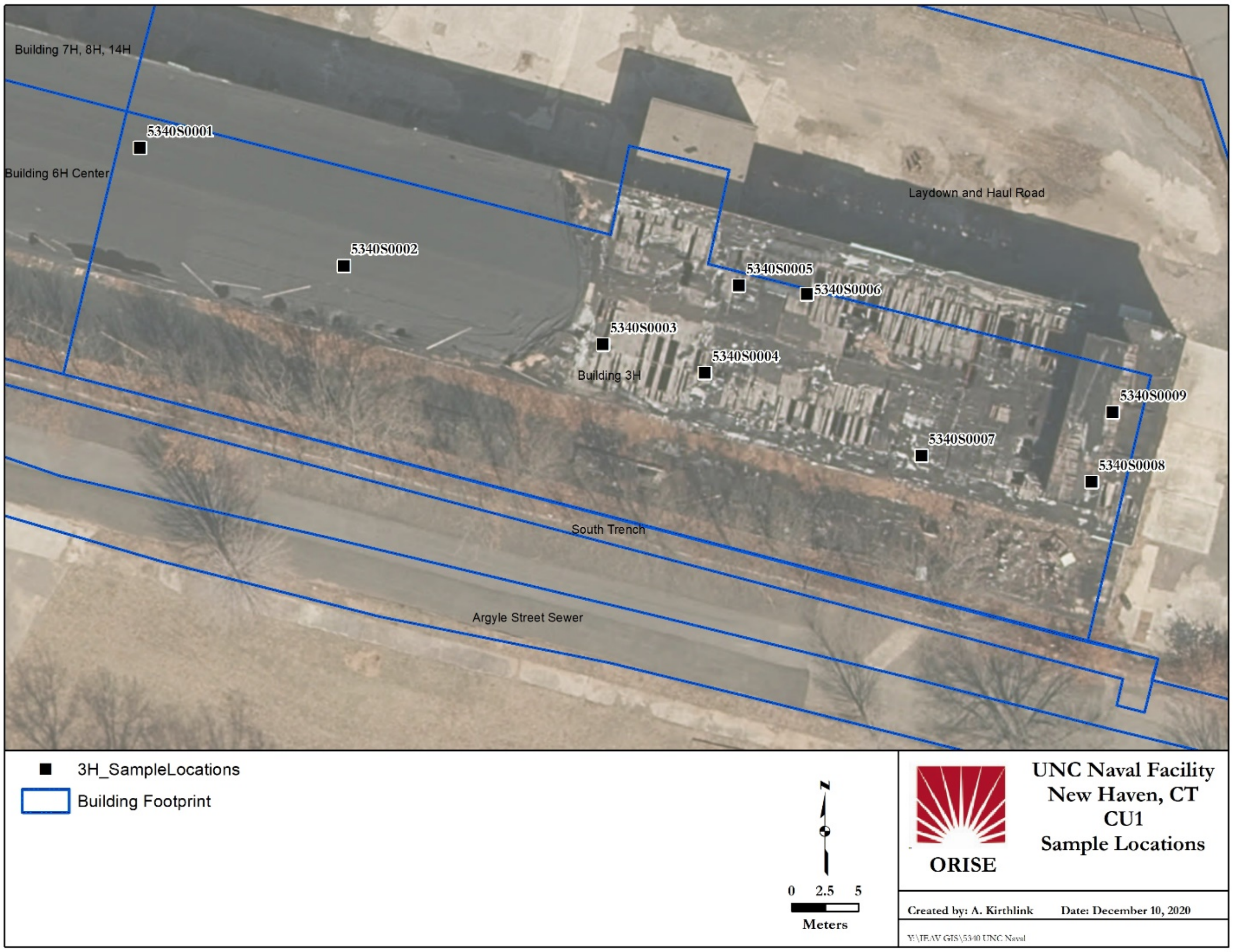


**Figure A.10. Soil Sample Locations for CU1, Building 3H Footprint**

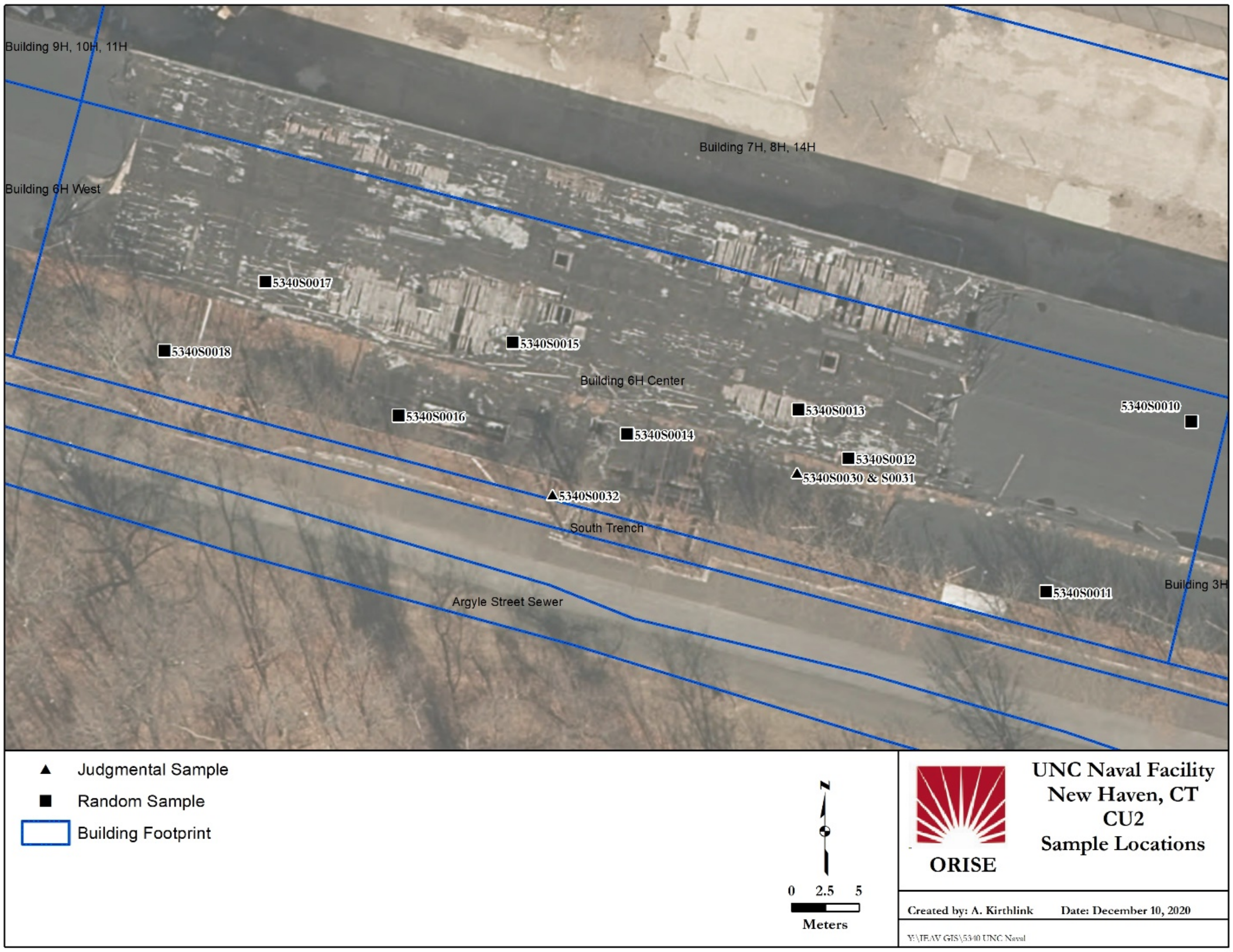


**Figure A.11. Soil Sample Locations for CU2, Building 6H Center Footprint**

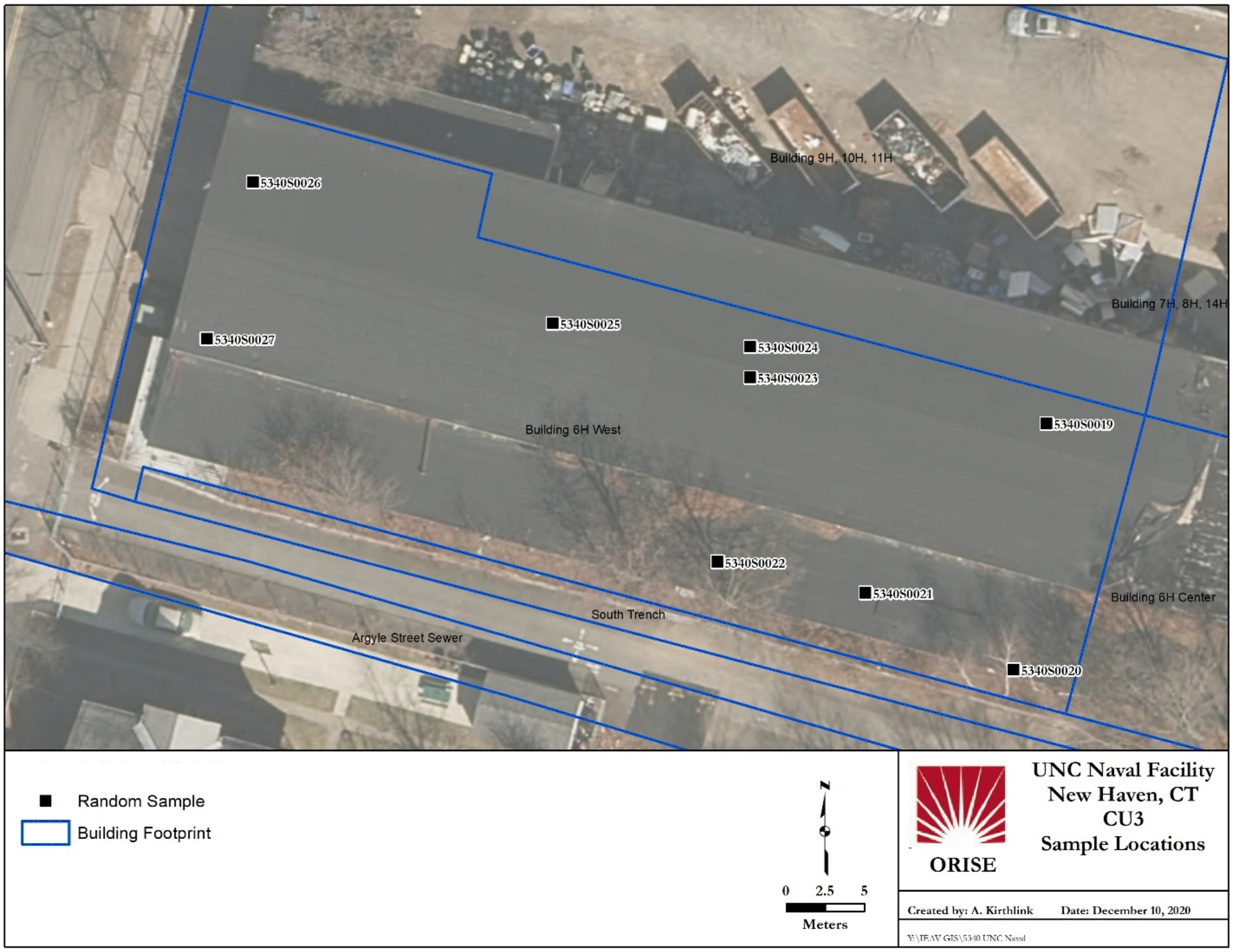


**Figure A.12. Soil Sample Locations for CU3, Building 6H West Footprint**

**APPENDIX B:**
**TABLES**

| Table B.1. CU1 (Building 3H Footprint) RSS Field Ranking and Sample Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **RSS ID** | **Easting (m)** | **Northing (m)** | **Field Ranking, Pre-sample (cpm)** | **Rank** | **Sample ID** | **Post-sample (cpm)** | **U-235 (pCi/g)** | **U-238 (pCi/g)** | **Total Uranium (pCi/g)** |
| 1-1-1 | 289600 | 206911 | 7,115 | **L** | 5340S0004 | 7,747 | 0.098 | 0.74 | 3.5 |
| 1-1-2 | 289579 | 206924 | 7,602 | L | | | | | |
| 1-1-3 | 289620 | 206902 | 10,000 | L | | | | | |
| 1-2-1 | 289569 | 206915 | 7,895 | M | | | | | |
| 1-2-2 | 289630 | 206908 | 7,525 | **M** | 5340S0009 | 8,285 | 0.19 | 0.77 | 6.1 |
| 1-2-3 | 289556 | 206921 | 7,145 | M | | | | | |
| 1-3-1 | 289597 | 206899 | 7,130 | H | | | | | |
| 1-3-2 | 289577 | 206912 | 6,848 | H | | | | | |
| 1-3-3 | 289607 | 206917 | 7,350 | **H** | 5340S0006 | 8,626 | 0.24 | 0.91 | 7.63 |
| 2-1-1 | 289628 | 206891 | 8,782 | L | | | | | |
| 2-1-2 | 289602 | 206917 | 6,880 | **L** | 5340S0005 | 7,413 | 0.029 | 0.81 | 1.62 |
| 2-1-3 | 289623 | 206908 | 8,446 | L | | | | | |
| 2-2-1 | 289572 | 206922 | 7,631 | M | | | | | |
| 2-2-2 | 289612 | 206900 | 8,285 | M | | | | | |
| 2-2-3 | 289592 | 206913 | 8,028 | **M** | 5340S0003 | 9,393 | 0.063 | 0.53 | 2.3 |
| 2-3-1 | 289593 | 206905 | 7,086 | H | | | | | |
| 2-3-2 | 289572 | 206919 | 8,340 | **H** | 5340S0002 | 8,702 | 0.04 | 0.58 | 1.7 |
| 2-3-3 | 289613 | 206897 | 8,161 | H | | | | | |
| 3-1-1 | 289562 | 206910 | 7,812 | L | | | | | |
| 3-1-2 | 289557 | 206928 | 7,269 | **L** | 5340S0001 | 8,973 | 0.119 | 0.67 | 4.00 |
| 3-1-3 | 289578 | 206907 | 7,715 | L | | | | | |
| 3-2-1 | 289608 | 206911 | 8,465 | M | | | | | |
| 3-2-2 | 289629 | 206902 | 7,095 | **M** | 5340S0008 | 7,735 | 0.06 | 0.53 | 2.2 |
| 3-2-3 | 289555 | 206916 | 6,952 | M | | | | | |
| 3-3-1 | 289616 | 206904 | 9,012 | **H** | 5340S0007 | 9,401 | 0.15 | 0.29 | 4.5 |
| 3-3-2 | 289565 | 206918 | 7,172 | H | | | | | |
| 3-3-3 | 289585 | 206909 | 7,298 | H | | | | | |

| Table B.2. CU2 (Building 6H Center Footprint) RSS Field Ranking and Sample Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| RSS ID | Easting (m) | Northing (m) | Field Ranking, Pre-sample (cpm) | Rank | Sample ID | Post-sample (cpm) | U-235 (pCi/g) | U-238 (pCi/g) | Total Uranium (pCi/g) |
| 1-1-1 | 289531 | 206937 | 7,394 | L | | | | | |
| 1-1-2 | 289553 | 206929 | 7,265 | **L** | 5340S0010 | 7,684 | 0 | 1.03 | 1.03 |
| 1-1-3 | 289471 | 206941 | 8,982 | L | | | | | |
| 1-2-1 | 289516 | 206920 | 5,701 | M | | | | | |
| 1-2-2 | 289494 | 206933 | 8,194 | M | | | | | |
| 1-2-3 | 289528 | 206926 | 7,490 | **M** | 5340S0012 | 8,385 | 0.124 | 0.93 | 4.40 |
| 1-3-1 | 289550 | 206918 | 7,041 | H | | | | | |
| 1-3-2 | 289511 | 206924 | 6,242 | H | | | | | |
| 1-3-3 | 289511 | 206928 | 8,240 | **H** | 5340S0014 | 9,435 | 0.026 | 0.51 | 1.24 |
| 2-1-1 | 289534 | 206920 | 5,721 | L | | | | | |
| 2-1-2 | 289477 | 206934 | 5,442 | **L** | 5340S0018 | 4,995 | 0.093 | 0.55 | 3.2 |
| 2-1-3 | 289545 | 206925 | 6,933 | L | | | | | |
| 2-2-1 | 289471 | 206937 | 9,419 | M | | | | | |
| 2-2-2 | 289494 | 206929 | 7,672 | **M** | 5340S0016 | 8,714 | 0.014 | 0.62 | 1.01 |
| 2-2-3[a] | 289551 | 206914 | 7,695 | M | | | | | |
| 2-3-1 | 289537 | 206930 | 7,126 | H | | | | | |
| 2-3-2 | 289525 | 206922 | 7,437 | H | | | | | |
| 2-3-3 | 289503 | 206935 | 7,523 | **H** | 5340S0015 | 8,222 | 0.01 | 0.12 | 0.4 |
| 3-1-1 | 289520 | 206924 | 7,479 | L | | | | | |
| 3-1-2 | 289497 | 206936 | 9,216 | L | | | | | |
| 3-1-3 | 289542 | 206916 | 5,144 | **L** | 5340S0011 | 5,304 | 0.148 | 0.35 | 4.49 |
| 3-2-1 | 289486 | 206928 | 9,075 | M | | | | | |
| 3-2-2 | 289524 | 206930 | 8,694 | **M** | 5340S0013 | 10,988 | 0.07 | 0.92 | 2.9 |
| 3-2-3 | 289547 | 206921 | 7,025 | M | | | | | |
| 3-3-1 | 289473 | 206934 | 6,669 | H | | | | | |
| 3-3-2 | 289541 | 206927 | 6,551 | H | | | | | |
| 3-3-3 | 289484 | 206939 | 9,206 | **H** | 5340S0017 | 10,472 | 0.07 | 0.95 | 2.91 |

[a]Field ranking error. RSS ID 2-2-3 should have been sampled instead of RSS ID 2-2-2. See section 6.2 for details.

| Table B.3. CU3 (Building 6H West Footprint) RSS Field Ranking Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **RSS ID** | **Easting (m)** | **Northing (m)** | **Field Ranking, Pre-sample (cpm)** | **Rank** | **Sample ID** | **Post-sample (cpm)** | **U-235 (pCi/g)** | **U-238 (pCi/g)** | **Total Uranium (pCi/g)** |
| 1-1-1 | 289411 | 206957 | 7,979 | **L** | 5340S0027 | 9,497 | -0.017 | 0.34 | -0.14 |
| 1-1-2 | 289461 | 206950 | 8,733 | L | | | | | |
| 1-1-3 | 289419 | 206963 | 8,611 | L | | | | | |
| 1-2-1 | 289453 | 206941 | 8,633 | **M** | 5340S0021 | 10,255 | 0.03 | 0.71 | 1.6 |
| 1-2-2 | 289436 | 206954 | 10,082 | M | | | | | |
| 1-2-3 | 289439 | 206959 | 8,491 | M | | | | | |
| 1-3-1 | 289414 | 206948 | 5,257 | H | | | | | |
| 1-3-2 | 289464 | 206952 | 8,419 | **H** | 5340S0019 | 10,131 | 0.14 | 0.36 | 4.3 |
| 1-3-3 | 289413 | 206965 | 7,063 | H | | | | | |
| 2-1-1 | 289443 | 206943 | 7,197 | **L** | 5340S0022 | 9,028 | 0.007 | 0.32 | 0.5 |
| 2-1-2 | 289426 | 206956 | 8,857 | L | | | | | |
| 2-1-3 | 289452 | 206949 | 9,585 | L | | | | | |
| 2-2-1 | 289410 | 206954 | 9,045 | M | | | | | |
| 2-2-2 | 289424 | 206945 | 5,183 | M | | | | | |
| 2-2-3 | 289414 | 206967 | 7,276 | **M** | 5340S0026 | 8,803 | 0.013 | 0.32 | 0.68 |
| 2-3-1 | 289433 | 206951 | 8,703 | H | | | | | |
| 2-3-2 | 289445 | 206955 | 8,762 | **H** | 5340S0023 | 11,477 | 0.09 | 0.91 | 3.4 |
| 2-3-3 | 289462 | 206946 | 8,572 | H | | | | | |
| 3-1-1 | 289420 | 206959 | 10,631 | L | | | | | |
| 3-1-2 | 289420 | 206952 | 9,397 | L | | | | | |
| 3-1-3 | 289445 | 206957 | 8,092 | **L** | 5340S0024 | 9,990 | -0.026 | 0.82 | 0.09 |
| 3-2-1 | 289462 | 206936 | 5,993 | **M** | 5340S0020 | 6,789 | 0.029 | -0.02 | 0.79 |
| 3-2-2 | 289407 | 206950 | 5,085 | M | | | | | |
| 3-2-3 | 289458 | 206954 | 9,968 | M | | | | | |
| 3-3-1 | 289416 | 206967 | 7,049 | H | | | | | |
| 3-3-2 | 289449 | 206945 | 8,172 | H | | | | | |
| 3-3-3 | 289433 | 206958 | 9,591 | **H** | 5340S0025 | 12,730 | 0.03 | 1.28 | 2.1 |

| Table B.4. Radionuclide Concentrations in Random Soil Samples | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample ID | Area | ROC (pCi/g) | | | | | | | | | |
| | | U-235 | | | U-238 | | | Total Uranium | | | |
| | | Conc. | | TPU[a] | Conc. | | TPU | Conc. | | TPU | |
| 5340S0001 | CU1 | 0.119 | ± | 0.098 | 0.67 | ± | 0.37 | 4.0 | ± | 2.7 | |
| 5340S0002 | CU1 | 0.04 | ± | 0.12 | 0.58 | ± | 0.38 | 1.7 | ± | 3.3 | |
| 5340S0003 | CU1 | 0.063 | ± | 0.096 | 0.53 | ± | 0.74 | 2.3 | ± | 2.7 | |
| 5340S0004 | CU1 | 0.098 | ± | 0.081 | 0.74 | ± | 0.35 | 3.5 | ± | 2.2 | |
| 5340S0005 | CU1 | 0.029 | ± | 0.094 | 0.81 | ± | 0.32 | 1.6 | ± | 2.6 | |
| 5340S0006 | CU1 | 0.240 | ± | 0.095 | 0.91 | ± | 0.51 | 7.6 | ± | 2.6 | |
| 5340S0007 | CU1 | 0.15 | ± | 0.12 | 0.29 | ± | 0.79 | 4.5 | ± | 3.3 | |
| 5340S0008 | CU1 | 0.060 | ± | 0.075 | 0.53 | ± | 0.32 | 2.2 | ± | 2.1 | |
| 5340S0009 | CU1 | 0.19 | ± | 0.11 | 0.77 | ± | 0.38 | 6.1 | ± | 3.0 | |
| 5340S0010 | CU2 | 0.00 | ± | 0.13 | 1.03 | ± | 0.48 | 1.0 | ± | 3.5 | |
| 5340S0011 | CU2 | 0.148 | ± | 0.077 | 0.35 | ± | 0.51 | 4.5 | ± | 2.1 | |
| 5340S0012 | CU2 | 0.124 | ± | 0.090 | 0.93 | ± | 0.41 | 4.4 | ± | 2.5 | |
| 5340S0013 | CU2 | 0.07 | ± | 0.10 | 0.92 | ± | 0.42 | 2.9 | ± | 2.7 | |
| 5340S0014 | CU2 | 0.026 | ± | 0.081 | 0.51 | ± | 0.33 | 1.2 | ± | 2.2 | |
| 5340S0015 | CU2 | 0.01 | ± | 0.10 | 0.12 | ± | 0.60 | 0.4 | ± | 2.8 | |
| 5340S0016 | CU2 | 0.014 | ± | 0.078 | 0.62 | ± | 0.33 | 1.0 | ± | 2.1 | |
| 5340S0017 | CU2 | 0.07 | ± | 0.11 | 0.95 | ± | 0.46 | 2.9 | ± | 3.0 | |
| 5340S0018 | CU2 | 0.093 | ± | 0.080 | 0.55 | ± | 0.43 | 3.2 | ± | 2.2 | |
| 5340S0019 | CU3 | 0.14 | ± | 0.11 | 0.36 | ± | 0.83 | 4.3 | ± | 3.1 | |
| 5340S0020 | CU3 | 0.029 | ± | 0.064 | -0.02 | ± | 0.36 | 0.8 | ± | 1.8 | |
| 5340S0021 | CU3 | 0.03 | ± | 0.11 | 0.71 | ± | 0.29 | 1.6 | ± | 3.0 | |
| 5340S0022 | CU3 | 0.007 | ± | 0.084 | 0.32 | ± | 0.58 | 0.5 | ± | 2.3 | |
| 5340S0023 | CU3 | 0.09 | ± | 0.11 | 0.91 | ± | 0.51 | 3.4 | ± | 3.0 | |
| 5340S0024 | CU3 | -0.026 | ± | 0.084 | 0.82 | ± | 0.43 | 0.1 | ± | 2.3 | |
| 5340S0025 | CU3 | 0.03 | ± | 0.11 | 1.28 | ± | 0.83 | 2.1 | ± | 3.1 | |
| 5340S0026 | CU3 | 0.013 | ± | 0.064 | 0.32 | ± | 0.31 | 0.7 | ± | 1.8 | |
| 5340S0027 | CU3 | -0.017 | ± | 0.063 | 0.34 | ± | 0.35 | -0.1 | ± | 1.7 | |

[a]Uncertainties represent total propagated uncertainties, reported at the 95 % confidence level
ROC = radionuclide of concern

| Table B.5. Radionuclide Concentrations in Judgmental Soil Samples | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample ID | Area | Pre-sample (cpm) | Post-sample (cpm) | ROC (pCi/g) | | | | | | | | | |
| | | | | U-235 | | | U-238 | | | Total Uranium | | | |
| | | | | Conc. | | TPU[a] | Conc. | | TPU | Conc. | | TPU | |
| 5340S0028[b] | CU4 | -- | -- | 0.24 | ± | 0.58 | -2.1 | ± | 2.7 | 4.6 | ± | 15.9 | |
| 5340S0029[c] | CU4 | -- | -- | 3.31 | ± | 0.33 | 0.97 | ± | 0.46 | 93.7 | ± | 8.9 | |
| 5340S0030[d] | CU2 | 13,785 | 22,093 | 0.27 | ± | 0.12 | 2.0 | ± | 1.0 | 9.7 | ± | 3.3 | |
| 5340S0031[e] | CU2 | 22,093 | 31,258 | 0.15 | ± | 0.15 | 3.43 | ± | 0.86 | 7.6 | ± | 4.1 | |
| 5340S0032[f] | CU2 | 11,859 | 13,755 | 0.16 | ± | 0.13 | 0.40 | ± | 0.42 | 4.8 | ± | 3.5 | |

[a]Uncertainties represent total propagated uncertainties, reported at the 95 % confidence level
[b]Sample 5340S0028 consisted of vegetation debris collected from pipe connected to Catch Basin-22
[c]Sample 5340S0029 consisted of sediment/debris collected from the 'East Pipe'
[d]Sample coordinates 289523.3 E, 206925.4 N in meters
[e]Sample 5340S0031 was collected at the sample location as sample 5340S0030 at the 15-30 cm depth
[f]Sample coordinates 289505.8 E, 206922.5 N in meters.
ROC = radionuclide of concern

# APPENDIX C: MAJOR INSTRUMENTATION

# C.1. SCANNING AND MEASUREMENT INSTRUMENT/ DETECTOR COMBINATIONS

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

## C.1.1 GAMMA

Ludlum NaI[Tl] Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
Coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
Coupled to: Trimble Geo 7X
(Trimble Navigation Limited, Sunnyvale, CA)

Ludlum NaI Scintillation Detector Model 44-157, Crystal: 5.1 cm × 5.1 cm
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

# C.2. LABORATORY ANALYTICAL INSTRUMENTATION

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

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-45-76-CW-S
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-30P4
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. CDG-SV-76/GEM-MX5970-S
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

**APPENDIX D: SURVEY AND ANALYTICAL PROCEDURES**

## D.1. PROJECT HEALTH AND SAFETY

The Oak Ridge Institute of Science and Education (ORISE) performed all survey activities in accordance with the *Oak Ridge Associated Universities (ORAU) Radiation Protection Manual*, the *ORAU Radiological and Environmental Survey Procedures Manual,* and the *ORAU Health and Safety Manual* (ORAU 2020b, ORAU 2016a, and ORAU 2020c). Prior to on-site activities, a Work-Specific Hazard Checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORISE have identified a hazard not covered in ORAU 2016a or the project's Work-Specific Hazard Checklist for the planned survey and sampling procedures, work would not have been initiated or continued until the hazard was addressed by an appropriate job hazard analysis and hazard controls.

## D.2. CALIBRATION AND QUALITY ASSURANCE

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

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

- ORAU Radiological and Environmental Survey Procedures Manual (ORAU 2016a)
- ORAU Environmental Services and Radiation Training Quality Program Manual (ORAU 2019)
- ORAU Radiological and Environmental Analytical Laboratory Procedures Manual (ORAU 2020a)

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

Quality control procedures include

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed-Analyte Performance Evaluation Program and Intercomparison Testing Program laboratory quality assurance programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

## D.3. SURVEY PROCEDURES

### D.3.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing NaI detectors slowly over the surface. The distance between the detector and surface was maintained at a minimum. The thallium-doped sodium iodide (NaI[Tl]) scintillation detectors were used solely as a qualitative means to identify elevated radiation levels in excess of background in surface soil. Identification of elevated radiation levels that could exceed the localized background were determined based on an increase in the audible signal from the indicating instrument or were identified after post-processing the scan data while the team was still at the site. A NaI pipe detector was used to evaluate direct gamma radiation levels on the interior of piping remaining at the site. All detectors were coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators.

### D.3.2 SOIL SAMPLING

Surface soil samples (approximately 0.5 kilogram each) were collected by ORISE personnel using a clean garden trowel to transfer soil into a new sample container. Soil or other debris was collected from piping if present or accessible to sample. All containers were labeled and security sealed in accordance with ORISE procedures and shipped under chain-of-custody to the ORISE laboratory for analysis.

# D.4. RADIOLOGICAL ANALYSIS

## D.4.1 Gamma Spectroscopy

Samples were analyzed as received or homogenized, as necessary, and a dry portion sealed in a size-appropriate Marinelli beaker or container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined, and the samples were counted using intrinsic, high-purity, germanium detectors coupled to a pulse-height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the radionuclides of concern (ROCs) were reviewed for consistency of activity. Spectra also were reviewed for other identifiable TAPs. TAPs used for determining the activities of the radionuclides and the typical associated minimum detectable concentrations (MDCs) for a 1-hour count time are presented in Table D.1.

**Table D.1. Typical MDCs and TAPs for ROCs**

| Radionuclide[a] | TAP (MeV)[b] | MDC (pCi/g)[c] |
|---|---|---|
| U-235 | 0.186 | 0.05 |
| U-238 | 0.063 | 0.75 |

[a]Spectra also were reviewed for other identifiable TAPs.
[b]MeV = mega electron volt
[c]picocurie per gram

## D.4.2 Detection Limits

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