SUPPLEMENTAL RADIOLOGICAL SURVEY REPORT BUILDINGS 3H/6H (FLOOR SURFACES) AND FORMER BUILDINGS 9H/10H/11H (SUBSURFACE SOILS)

Site Decommissioning Former UNC Manufacturing Facility

New Haven, Connecticut

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LIST OF ACRONYMS AND ABBREVIATIONS

α	alpha
ACM	asbestos containing material
AEC	Atomic Energy Commission
ALARA	As-Low-As-Reasonably-Achievable
bgs	below ground surface
BZ	breathing zone
Cabrera	Cabrera Services Inc.
cm^2	square centimeters
cpm	counts per minute
CT	Connecticut
CTDEEP	Connecticut Department of Energy and Environmental Protection
DAC	derived air concentration
$DCGL_W$	Derived Concentration Guideline Level for average concentrations over wide area
DGL	downhole gamma logging
DOE	Department of Energy
DQA	Data Quality Assessment
dpm	disintegrations per minute
DQCR	Daily Quality Control Report
DQOs	Data Quality Objectives
^{152}Eu	europium-152
ft	feet
FIDLER	Field Instrument for the Detection of Low-Energy Radiation
FSS	Final Status Survey
GWS	gamma walkover survey
γ	gamma
HEPA	High Efficiency Particulate Air
HEU	high-enriched uranium
IH	Industrial Hygienist
IL	investigation level
IMC	intermodal container
KAPL	Knolls Atomic Power Laboratory
kev	kiloelectron volts
lpm	liters per minute
µR/h	microroentgen per hour
MARSAME	Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manual
MBA	Material Balance Area
MDC	minimum detectable concentration
MeV	million electron volts
mrad	millirad per hour
mrem/hr	millirem per hour
mrem/yr	millirem per year
N/A	not applicable
NaI	sodium iodide
NIST	National Institute of Standards and Technology
Olin	Olin Mathieson Chemical Corporation – Winchester Western Division
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram

LIST OF ACRONYMS AND ABBREVIATIONS (Cont)

QA	Quality Assessment
QC	Quality Control
RCAs	Radiation Control Area
ROCs	Radionuclides of Concern
RPP	Radiation Protection Plan
RSP	Radiation Safety Program
RWP	radiation work permit
SNM	special nuclear material
SRSL	Site Radiation Safety Lead
SU	Survey Unit
^{99}Tc	technetium -99
^{230}Th	thorium-230
^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238
UNC	United Nuclear Corporation Naval Products
USEPA	U.S. Environmental Protection Agency
USNRC	U.S. Nuclear Regulatory Commission

EXECUTIVE SUMMARY

Cabrera Services Inc. (Cabrera) has been contracted by United Nuclear Corporation Naval Products (UNC) to perform a supplemental radiological survey of specific areas-of-interest at their former 71 Shelton Avenue facility in New Haven, Connecticut hereafter referred to as "the Site." Historic operations, including naval nuclear fuels research and production, at the Site leached uranium contamination into building surfaces and soils underlying portions of Building 3H/6H. Analytical results revealed that soils underlying these trenches contain elevated concentrations of total uranium in the form of highly enriched uranium (HEU) (i.e., uranium-234, uranium-235, and uranium-238), confirming that radioactive contamination had migrated through some of the drainage holes in the floors of the trenches.

The survey confirmed and supplemented past surveys and sampling efforts in three specific areas of interest:

- Interior H-Tract Building (3H/6H) floor, walls, and overhead surfaces
- Intact ventilation ductwork within 3H/6H and;
- Subsurface soils underneath the footprint of former Buildings 9H/10H/11H.

Building Radiological Surveys

As debris removal and housekeeping made areas accessible, radiological surveys were conducted in selected areas of the floors, walls, overhead, and ventilation system in Buildings 3H6H.

During the floor scanning survey, several metallic items containing HEU were discovered in Building 3H on the floors, often in and around piles of dirt and debris. To complete the supplemental surveys, it was necessary to perform some limited general housekeeping and waste clearing inside the building to provide access to more of the floor surfaces. Wastes consisted of asbestos-containing material (ACM) abatement materials, loose building debris, empty and partially filled drums, trash, and other larger debris. ACM abatement was performed in accordance with Connecticut Department of Public Health requirements. Wastes were loaded into intermodal containers and shipped off-site to EnergySolutions in Clive, Utah in accordance with the approved *Supplemental Radiological Survey Plan* (Cabrera, 2016a) and regulatory requirements.

Floor surveys consisted of gamma and alpha-beta scanning measurements. Follow-up investigations consisted of gamma static and alpha-beta smear measurements at biased locations. Approximately 164 gamma activity measurements on the floor exceeded the gamma investigation level (12,200 counts per minute [cpm]). There were no integrated alpha-beta floor scans or smear measurements that exceeded the Derived Concentration Guideline Levels ($DCGL_{W)}$ (<5,000 disintegrations per minute [dpm]/100 square centimeters [cm^2] [total alpha + total beta] and <1,000 dpm/100 cm^2 [removable alpha + removable beta]) above background. The presence of elevated gamma above the investigation level without significantly elevated surface alpha/beta readings is an indicator of residual subsurface radioactivity, contamination that was possibly missed during the original license decommissioning. Alternatively, the floor surfaces may have had additional paint/concrete layers applied to resolve contamination control

issues during historic facility operations, leaving radioactive contamination trapped between floor layers and undetectable using alpha/beta survey instruments.

Wall and ceiling scans consisted of alpha-beta static measurements. A total of 66 alpha-beta static measurements exceeded the $DCGL_W$. No smear measurements exceeded the $DCGL_W$. Gamma dose rates were consistent with background in all survey areas (i.e. 7-9 microroentgen per hour [uR/hr]). Most of the elevated activity above background was noted on the lower walls and on upper horizontal surfaces (i.e. steel beams, crane rails, conduit, lights, etc.). There are indications that contaminated surfaces were painted over reducing alpha/beta scan measurement sensitivity; smear measurements were collected on the outermost surface.

Pipe scale samples were collected from two pipes that were made accessible as a result of debris removal. One pipe was located in the former Chemistry laboratory. The other pipe was located in the eastern end of Building 3H. The total uranium concentrations were 122,640 picocuries per gram (pCi/g) and 246 pCi/g, respectively. The pipe scale concentration collection from the former Chemistry laboratory exceeded the volumetric criteria of 435 pCi/g. Both piping systems are radiologically impacted warranting more careful assessment and/or removal and disposal as radioactive waste.

Building 3H Ductwork System

Cabrera performed a survey of the ductwork system in Building 3H during the initial mobilization to the Site in the summer of 2016. Surveys consisted of alpha-beta integrated scans, alpha-beta static measurements, and alpha-beta smear measurements. Cabrera accessed the internal surfaces of the dilapidated Building 3H/6H ventilation system at 13 openings along the ductwork. Surveys were comprised of scans and static alpha/beta measurements and smears. All initial results were below the $DCGL_W$, however noticeably elevated above area background conditions indicating greater levels of internal radioactivity could be present in other currently inaccessible portions of the 3H/6H overhead ventilation system. Stakeholders agreed to have Cabrera carefully remove the remaining ductwork as part of radiologically impacted debris removal facilitating greater access to areas of concern in the overhead.

Former 9H/10H/11H Building Locations

Six borings were advanced within the former Building 11H Metallurgy Laboratory footprint (ML-SB-01 through ML-SB-06) and seven borings were performed within the former Building 10H Hot Waste Processing area footprint (HW-SB-07 through HW-SB-13, refer to Figure 6-1, Appendix A). Cabrera performed downhole gamma logging and scanning of intact soil cores using a Field Instrument for Detection of Low Energy Radiation sodium iodide detector to select sample intervals to be sent off-site for analysis.

Downhole gamma logging and soil core scanning results were consistent with background levels. Soil samples were selected at the interval directly below the concrete floor slab (or rubble, if the floor slab was not encountered) to determine if the soils beneath the former building foundations had residual radioactivity as a result of potential surficial contamination on the concrete. All soil samples were consistent with background uranium concentrations.

Overall Conclusions

There is extensive radioactive contamination on the floor of Building 3H. Several pieces of HEU metal were encountered during the surveys inside the building. The full extent of the contamination could not be accurately quantified in this report due to the existence of various floor coverings. Residual radioactivity was most likely historically covered by concrete pours as a method of contamination control. There is minimal radioactive contamination on the floors of Building 6H. The only contamination found was located on the floor in the eastern end of Building 6H (i.e. close to Building 3H).

There is extensive radioactive contamination on the walls and upper horizontal surfaces in Building 3H. Bare surfaces that have not been painted, such as steel supports, conduit, unpainted cinder block walls, and overhead lights, showed alpha and beta contamination in excess of the $DCGL_W$. Surfaces that were painted (i.e. cinder block walls) showed higher activity as paint was removed, indicating that the paint was used to cover historical contamination as a method of contamination control. There is minimal radioactive contamination on the walls of Building 6H. The only contamination found was located on the walls and overhead in the eastern end of Building 6H (i.e. close to Building 3H).

Future decommissioning efforts should also take into account the recommendations in *Characterization Survey Report* [Cabrera, 2015]), i.e., the known contamination inside and under the South Trench, and the potential contamination as a result of subsurface piping entering the soils on the south side of the building. Implementation of a different decommissioning approach will also require either a revision to the current *Decommissioning Plan* (UNC, 2005) or the development of a new Decommissioning Plan, which would presumably revisit site release criteria and provide new FSS protocols, as appropriate.

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1.0 INTRODUCTION

Cabrera Services Inc. (Cabrera) has been contracted by United Nuclear Corporation Naval Products (UNC) to perform a supplemental radiological survey of specific areas-of-interest at their former 71 Shelton Avenue facility in New Haven, Connecticut (CT) hereafter referred to as "the Site." Historic operations, including naval nuclear fuels research and production, at the Site leached uranium contamination into building utility trenches and soils underlying portions of Building 3H/6H. Analytical results revealed that soils underlying these trenches contain elevated concentrations of total uranium in the form of highly enriched uranium (HEU) (i.e., uranium-234 [^{234}U], uranium-235 [^{235}U], and uranium-238 [^{238}U]), confirming that radioactive contamination had migrated through some of the drainage holes in the floors of the trenches.

The purpose of this survey was to confirm and supplement past surveys and sampling efforts in three specific areas of interest:

- Interior H-Tract Building (3H/6H) wall, floor, and overhead surfaces
- Intact ventilation ductwork within 3H/6H and;
- Subsurface soils underneath the footprint of former Buildings 9H/10H/11H.

The location of the Site is displayed in Figure 1-1 (refer to Appendix A). The locations of the various buildings noted, and the accessible floor areas prior to the initial mobilization to the Site are shown in Figure 1-2 (refer to Appendix A). This work was performed in accordance with the approved *Supplemental Radiological Survey Plan* (Cabrera, 2016a).

During the floor scanning survey, several metallic radioactive items were discovered in Building 3H on the floors, often in and around piles of dirt and debris. Given the history of the Site, Cabrera suspected the debris may be uranium fuel-related and mobilized a portable gamma spectroscopy detector to the Site. Cabrera confirmed the items contained HEU. After conferring with UNC, the Department of Energy (DOE), the US Nuclear Regulatory Commission (USNRC), and other project stakeholders, it was decided that a complete survey of the floor would have to be performed to determine the extent of potential radioactive contamination on the floor. In order to complete this survey, the debris would have to be completely removed from the building and either stored or disposed off-site until the survey could be completed. The debris removal was conducted in accordance with the *Debris Removal Plan – Buildings 3H/6H* (Cabrera, 2016b).

These tasks were completed in accordance with Cabrera's *Accident Prevention Plan* (Cabrera, 2016c), *Radiation Protection Plan, Revision 1* (RPP; Cabrera 2014a), *Nuclear Material Control and Accountability Plan* (Cabrera, 2011), and *Radiation Safety Program Manual, Revision 2* (RSP) and license procedures (Cabrera, 2014b).

These survey results data may be used by UNC and Site stakeholders to augment and/or confirm historical measurements and support future site characterization, remediation, or release decisions.

1.1 DOCUMENT ORGANIZATION

This report has been organized into 13 sections and 11 appendices. The general content of each section and appendix is summarized below:

Table 1-1. Supplemental Radiological Survey Report Organization

Section	Title	Description
ES	Executive Summary	Presents a concise recapitulation of the major points of the report, including information on the project objectives, methodology, results, and conclusions.
1.0	Introduction	Presents an overview of project objectives and report purpose and organization.
2.0	Facility Background and Site Information	Presents a synopsis of the site description, history of site operations, radionuclides of concern, and previous site investigations.
3.0	Data Quality Objectives	Presents a discussion of the data quality objectives for this survey.
4.0	Pre-Survey Activities	Provides a description of the work performed before surveys began.
5.0	Debris Removal	Presents all of the activities performed to remove debris wastes from the survey area, including asbestos abatement, radiological surveys, and waste packaging and off-site shipment for disposal.
6.0	Characterization Survey Design	Discusses project derived concentration guideline levels ($DCGL_W$s), classification of survey units (SUs), and density of scans, sampling, and/or measurements in each SU.
7.0	Survey Instrumentation and Techniques	Presents procedures for soil sampling, data collection and instrumentation.
8.0	Characterization Survey Results	Summarizes characterization survey results.
9.0	Construction Quality Control	Describes the construction quality control (QC) measures implemented during field activities.
10.0	Radiation Protection	Documents the overall radiation protection measures implemented throughout the project.
11.0	Quality Assurance / Quality Control	Presents a discussion of Quality Assurance (QA) and QC procedures for field activities and analysis of on-site laboratory data quality.
12.0	Conclusions	Presents conclusions that are supported by the results of the field activities.
13.0	References	References cited in the report.

Table 1-2. Supplemental Radiollogical Survey Report Appendices

Appendix	Content	Description
A	Figures	Includes figures related to the survey performed at the Site.
B	Supplemental Radiological Survey Plan	Contains the approved plan with the means, methods, and assumptions for the characterization survey in Building 3H/6H.
C	Permits and Notifications	Includes permits that were required and notifications that were made prior to survey activities.
D	Asbestos Abatement Records	Contains the air clearance records, personal air sampling, and other records related to the asbestos abatement activities at the Site.
E	Waste Shipment Records	Contains waste manifests and other waste shipment records for the contaminated materials removed from the Site.
F	Soil Boring Logs/Downhole Gamma Logging Results	Provides soil boring logs and downhole gamma logging results documented during core drilling.
G	Analytical Results	Includes on-site and off-site analytical sampling results applicable to the survey activities at the Site.
H	Daily Quality Control Reports	Contains Daily Quality Control Reports generated during field effort.
I	Radiological Survey Data	Includes raw survey data from gamma and alpha-beta scans, and incoming/release survey results.
J	Radiological Safety and Health and Safety Records	Includes radiological safety records, including ambient air monitoring data, and health and safety documentation generated during site activities.
K	Quality Assurance/QC Records	Quality control data for instrumentation to demonstrate proper function, and calibration certificates for instrumentation to demonstrate compliance with calibration requirements

The appendices are referenced in the following sections, though not necessarily in the same order as they are presented in Table 1-2.

2.0 FACILITY BACKGROUND AND SITE INFORMATION

The former UNC Naval Facility was originally operated by Olin Mathieson Chemical Corporation – Winchester Western Division (Olin) from April 1956 to May 31, 1961 and by UNC from June 8, 1961 to April 22, 1976. Specifically, Olin operated as a contractor from 1956 to 1960, and obtained an Atomic Energy Commission (AEC) (later United States Nuclear Regulatory Commission [USNRC]) special nuclear material (SNM) license (license number SNM-368; Docket Number 07000371) in 1960 for fabrication and manufacture of reactor fuel components for the Naval Reactors Program in New Haven, CT at Building 3H/6H. On May 31, 1961, Olin transferred these assets to United Nuclear – Fuels Division. On June 8, 1961, the USNRC re-issued SNM-368 to United Nuclear – Fuels Division, which later became known as UNC. This license authorized possession and use of enriched uranium and source materials, including natural uranium, depleted uranium, and thorium for research and nuclear fuel fabrication. The radioactive material used in these operations was primarily enriched uranium and natural uranium.

In 1974, UNC announced the closing of Building 3H/6H and transferred their inventory of radioactive materials from the New Haven, CT location to the Montville, CT location. Final surveys of the New Haven facility were completed by February 1976 and the USNRC performed confirmatory surveys from March 8 to 10, 1976. On April 22, 1976, the USNRC amended the SNM-368 license to remove the New Haven facility from the license. The site was released for unrestricted use in accordance with the existing regulations and guidance.

The SNM-368 license was terminated on June 8, 1994, following the decontamination and decommissioning of the Montville site. The NRC's guidance and criteria for release for unrestricted use, at that time, was Regulatory Guide 1.86, dated June 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," dated May 3, 1973. At about the same time the SNM license was terminated, the USNRC initiated a "Terminated Sites Review Project" to ensure that formerly licensed facilities by the AEC and/or the USNRC were terminated in accordance with current USNRC criteria for release for unrestricted use. As part of the Terminated Sites Review Project, the USNRC's contractor, Oak Ridge National Laboratory, identified the retired SNM-368 license as requiring additional review because final radiological survey records were either incomplete or inadequate. USNRC Region I staff reviewed this assessment and determined further information on this site was necessary to conclude that the facility met the current criteria for release for unrestricted use.

Therefore, the USNRC and the USNRC's contractor, Oak Ridge Institute for Science and Education (ORISE), conducted an independent measurements inspection in September 1996 using the release criteria in 1981 Branch Technical Position "*Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations*", published in the Federal Register on October 23, 1981 (USNRC, 1981). The results of this inspection indicated that residual enriched uranium, in certain areas inside the building and inside a connected inactive sewer system, had exceeded the release criteria of 30 picocuries per gram (pCi/g) in soil. These contaminated areas were documented in the USNRC Inspection Report and in the ORISE "*Radiological Scoping Survey of Buildings 3H and 6H at the former UNC H-Tract Facility, New Haven, Connecticut*" (ORISE, 1997).

Based on the results of this inspection and additional information provided by UNC, the USNRC determined that more soil testing was necessary. This testing was performed by UNC on February 12, 1997. The results of the soil testing showed that a small number of local areas of soil and sediment contained enriched uranium exceeding the soil acceptance criteria established by the USNRC in 1981. These areas showed total uranium levels up to 723 pCi/g, exceeding the USNRC release criteria of 30 pCi/g. During the decontamination and decommissioning activities of 1973 to 1976 there were no published soil release criteria other than "as low as reasonably achievable" (ALARA), and meter surveys of the soil by a USNRC inspector in 1976 were found to be acceptable.

UNC developed and provided to the USNRC a characterization report that described the sampling and testing performed in 2003. A Decontamination and Decommissioning Plan was developed and submitted to the USNRC in June 2005 to remove the soil with a total uranium concentration greater than 30 pCi/g (UNC, 2005).

Limited final status surveys (FSS) operations of impacted land areas, exterior surfaces, and structures were completed by Cabrera from 2011 to 2012. These operations provided evidence that the soils beneath utility trenches underlying Building 3H/6H required additional characterization and possibly remediation of residual radioactive contamination (refer to Figure 2-1, Appendix A). Cabrera investigated the extent of contamination in soil beneath the trenches in a follow-up investigation in the fall of 2014. This survey effort did not find widespread evidence of contamination exceeding the Derived Concentration Guideline Level ($DCGL_W$) in soils beneath the Building 3H/6H. The extent of the contamination exceeding the $DCGL_W$ is most likely limited to the areas immediately around and under drainage holes that are presented in the floor of the South Trench (Cabrera, 2015).

The site is located at 71 Shelton Avenue, New Haven, CT and consists of Building 3H/6H and a connected, but inactive, sewer system that traverses an adjacent private property line. This sewer system was installed by Cabrera in 2011 and replaced the original sewer system, which contained highly enriched uranium contamination and was removed and disposed off-site. The building is constructed of concrete floors, concrete/cinder block walls and a wooden roof. A chain link fence completely surrounds the site. The south side of the building, which borders Argyle Street, is currently owned by Olin and is overgrown with vegetation. A second chain link fence surrounds the adjacent private property. This fence separates the adjacent private property and Argyle Street.

2.1 Radionuclides of Concern

Table 2-1 presents the radionuclides of concern (ROCs) for the Site. Thorium was dismissed as a radionuclide of concern through the use of process knowledge; process knowledge confirmed that the historic use of thorium on-site was far too limited to consider it an ROC (UNC, 2005).

Table 2-1. Radionuclides of Concern

ROC	Name	Half-Life	Principal Emissions
^{234}U	Uranium-234	2.45E05 years	4.72, 4.77 MeV α; 0.053 MeV λ
^{235}U	Uranium-235	7.04E08 years	4.39, 4.36 MeV α; 0.18, 0.14 MeV λ
^{238}U	Uranium-238	4.47E09 years	4.19, 4.14 MeV α; 0.049 MeV λ

MeV = million electron volt; λ = gamma; α = alpha

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3.0 DATA QUALITY OBJECTIVES

The *Supplemental Radiological Survey Plan Buildings 3H/6H (Floor Surfaces) and Former Buildings 9H/10H/11H (Subsurface Soils)* (Appendix B) was developed in consideration of the Data Quality Objective (DQO) process guidance presented in NUREG-1575, *the Multi-Agency Radiological Site Survey and Investigation Manual* (MARSSIM) (USNRC, 2000). The DQO process is meant to assure that the type, quantity, and quality of environmental data collected in decision making will be appropriate to substantiate stakeholder decisions. It provides systematic procedures for defining the criteria that the survey design should satisfy, including when and where to perform measurements, the level of decision errors for the survey, and how many measurements to perform. The DQOs for the site are to obtain data of sufficient quality and quantity to prove, within a specified degree of confidence, that residual radioactivity levels on the floor of Building 3H/6H and in soils found within the former Building 9H/10H/11H footprint are less than the release criteria.

The following sections describe inputs into the design of this supplemental survey, including:

- Detailed DQOs
- Survey planning parameters
- Instrumentation
- Measurement and sampling procedures
- Data quality assessments (DQAs)

3.1 Project Data Quality Objectives

Data Quality Objectives define the purpose of this supplemental survey, identify the data needed to satisfy the purpose, and specify the performance requirements for the quality of information to be obtained from the data. The DQO process consisted of the following steps (U.S. Environmental Protection Agency [USEPA], 2006):

3.1.1 Step 1: State the Problem

Historic operations at the Site utilized HEU, which produces alpha, beta, and gamma radiation. Subsequent to the termination of the AEC/USNRC materials license, residual radioactivity was discovered on-site in the subsurface. The presence of residual subsurface radioactivity triggered the need to perform supplemental data collection efforts in other previously released areas of the Site; areas where residual radioactivity could be present and stakeholders had expressed specific concerns about. Residual radioactivity left on-site above applicable criteria could lead to unacceptable risk for health effects to future site occupants.

3.1.2 Step 2: Identify the Decision

The objective of this step is to develop decision statements that required site data to address the problem statement above.

Principal Study Question

Does residual radioactivity remain above the release criteria for the areas of interest?

Decision Statement

1. Determine whether ROC concentrations on the floor of Building 3H/6H exceeded the site surficial release criteria used to terminate the USNRC license in 1976 (i.e., USNRC Regulatory Guide 1.86, USNRC, 1974).
2. Determine whether ROC concentrations within intact portions of the ductwork system within Building 3H exceeded the site surficial release criteria used to terminate the USNRC license in 1976 (i.e., USNRC Regulatory Guide 1.86, USNRC, 1974).
3. Determine whether soil ROC concentrations within the former Building 9H/10H/11H footprint exceeded the volumetric release criteria of 435 pCi/g established using RESRAD modeling and the State of Connecticut unrestricted release criteria of 19 millirem per year (mrem/yr) (AAA/IEM, 2008).

3.1.3 Step 3: Identify Inputs to the Decision

The objective of this section is to identify the informational inputs required to resolve the decision statement identified above. This section also describes the sources of those informational inputs, which inputs require environmental measurements, and discusses how the required inputs are obtained. The following site characteristics were determined to resolve the applicable decision statement:

3.1.3.1 Building 3H/6H Floor:

Residual radioactivity on or embedded within the immediate surface of floors within Building 3H/6H was determined as follows:

- "Indoor" 100% gamma walkover survey of readily accessible building areas using portable sodium-iodide detectors to identify any potential deposits of volumetric residual radioactivity otherwise attenuated from detection using alpha-beta surface scan survey instruments. Results are typically reported in units of counts per minute (cpm).
- General scanning of accessible as-found floor areas (minimum 10% overall) to look for indications of residual surface radioactivity above the $DCGL_W$. Results are typically reported in units of disintegrations per minute per 100 square centimeters (dpm/100cm^2).
- Collection of unbiased static measurements and smears at floor surface locations to assess residual radioactivity summary statistics within each survey unit (SU). Results are typically reported in units of dpm/100cm^2.
- Collection of static measurements and smears on floor surfaces at biased sentinel locations to follow-up on unexplained abnormally elevated readings identified from surface scan and/or gamma walkover surveys.
- Dose equivalent rate measurements (~one meter above floor) at each static measurement location to assess whole-body radiation levels within the building from any remaining

residual or naturally-occurring radioactivity present in building materials/surfaces. Results are typically reported in units of millrem per hour (mrem/hr).

Note that dose equivalent rate measurements were performed because the 1976 survey (USNRC, 1976) included beta/gamma data in units of millirad per hour (mrad/hr) for each 10 square foot area, and Cabrera intended to provide confirmatory data to compliment that data set in accessible areas.

The USNRC favored the performance of dose rate measurements with building surveys as confirmation that no large gamma radiation fields are present that may affect alpha/beta instrument backgrounds.

3.1.3.2 Building 3H Ductwork System

Residual radioactivity on intact ductwork system surfaces within Building 3H were determined as follows:

- General scanning of surfaces from all accessible ductwork openings, junction boxes, blowers, and any other remaining air moving equipment associated with the ductwork system to look for indications of residual surface radioactivity above the $DCGL_W$. Results are typically reported in units of dpm/100cm^2.
- Collection of static measurements and smears from all accessible ductwork openings, junction boxes, blowers, and any other remaining air moving equipment associated with the ductwork system at biased sentinel locations to follow-up on highest readings identified from surface scan surveys.

Note that the intact ductwork system was not used to exhaust air from within Building 3H; that system was removed previously (USNRC, 1996).

3.1.3.3 Former 9H/10H/11H Building Locations

Residual radioactivity comingled in soils in the backfilled basements associated with former Building 9H/10H/11H were determined by means of:

- Downhole gamma measurements at soil boring locations to identify depth intervals containing potential deposits of volumetric residual radioactivity surrounding the soil boring location (soil conditions permitting)
- Direct gamma scanning of soil recovered from soil bores to identify depth intervals containing potential deposits of volumetric residual radioactivity within the soil boring
- Volumetric sampling and analysis of discrete soil samples recovered from soil bores to further investigate depth intervals containing potential deposits of volumetric residual radioactivity as determined by either downhole or direct gamma measurements

3.1.4 Step 4: Define the Study Boundaries

The boundaries of the study include accessible floor surfaces within Building 3H/6H, and subsurface soils within the footprint of former Building 9H/10H/11H to a vertical extent of one

foot below the assumed basement floor within underlying soils. Because no as-builts were available for former Building 9H/10H/11H, Cabrera assumed the 15 foot depth would suffice to collect a sample beneath the basement floor slab. Cabrera advanced a hardened roller bit using air rotary methods to ensure slab penetration was achieved. Once the slab was penetrated, a continuous soil sample was collected from soils directly beneath the slab to a termination depth of 15 feet below ground surface (bgs).

3.1.5 Step 5: Develop the Decision Rules

3.1.5.1 Building 3H/6H Floor

To determine if unacceptable levels of residual surface radioactivity remain on the floor surfaces we compared survey results to criteria established by AEC/USNRC for the original 1976 license termination (derived from USNRC Regulatory Guide 1.86) as follows:

- Smear results <1,000 dpm/100 cm^2 (removable alpha + removable beta)
- Static measurement results <5,000 dpm/100cm^2 (total alpha + total beta)

The gamma scan survey and integrated alpha/beta activity scan survey were intended to locate areas of elevated activity warranting additional biased static measurements/swipe tests, as determined by the Project Certified Health Physicist.

Whole-body dose equivalent rate measurements at static measurement locations were used to assess overall external radiation hazards for personnel accessing the building; no direct criteria comparisons are planned.

3.1.5.2 Building 3H Ductwork System

To determine if unacceptable levels of residual surface radioactivity remain on the intact ductwork surfaces survey results we used the criteria established by AEC/USNRC for the original 1976 license termination (derived from USNRC Regulatory Guide 1.86) as follows:

- Smear results <1,000 dpm/100 cm^2 (removable alpha + removable beta)
- Static measurement results <5,000 dpm/100cm^2 (total alpha + total beta)

3.1.5.3 Former 9H/10H/11H Building Locations

Decisions on whether soil sample data collected substantiate stakeholder decisions were based on whether ROC concentrations within discrete soil samples are below the $DCGL_W$ of 435 pCi/g. Downhole gamma measurements at soil boring locations and direct gamma scanning of soil recovered from soil bores are intended to isolate soil samples with the highest instrument response for analysis and direct comparison to the soils $DCGL_W$.

3.1.6 Step 6: Define Acceptable Decision Errors

The hypotheses tested as part of the DQO process are the Null Hypothesis and the Alternative Hypothesis.

3.1.6.1 Null Hypothesis

Concentrations of the ROCs at the Site exceeded their respective $DCGL_W$.

3.1.6.2 Alternative Hypothesis

Concentrations of the ROCs at the Site did not exceed their respective $DCGL_W$.

Appendix D in MARSSIM (NRC, 2000) provides a discussion regarding decision errors. This discussion includes the concept that acceptable error rates must be balanced between the need to make appropriate decisions and the financial costs of achieving high degrees of certainty.

> *Errors can be made when making site remediation decisions. The use of statistical methods allows for controlling the probability of making decision errors. When designing a statistical test, acceptable error rates for incorrectly determining that a site meets or does not meet the applicable decommissioning criteria must be specified. In determining these error rates, consideration should be given to the number of sample data points that are necessary to achieve them. Lower error rates require more measurements, but result in statistical tests of greater power and higher levels of confidence in the decisions. In setting error rates, it is important to balance the consequences of making a decision error against the cost of achieving greater certainty.*

Acceptability decisions are often made based on acceptance criteria. If the mean and median concentrations of a contaminant are less than the associated acceptance criteria, for example, the results can usually be accepted. In cases where data results are not so clear, statistically based decisions are necessary. Statistical acceptability decisions, however, are always subject to error. Two possible error types are associated with such decisions.

The first type of decision error, called a Type I error, occurs when the H_o is rejected when it is actually true. A Type I error is sometimes called a "false positive." The probability of a Type I error is usually denoted by alpha (α). Consequences of Type I errors include higher potential doses to future site occupants than prescribed by the dose-based criterion.

The second type of decision error, called a Type II error, occurs when the H_o is not rejected when it is actually false. A Type II error is sometimes called a "false negative." The probability of a Type II error is usually denoted by beta (β). The power of a statistical test is defined as the probability of rejecting the null hypotheses when it is false. It is numerically equal to $1-\beta$ where β is the Type II error rate. Consequences of Type II errors include unnecessary remediation expense and project delays.

For the purposes of the characterization survey, the acceptable error rate for both Type I and Type II errors was five percent (that is [i.e.], $\alpha = \beta = 0.05$).

3.1.7 Step 7: Optimize the Design

Appendix D in MARSSIM (NRC, 2000) notes that this step is designed to produce the most resource-effective survey design that is expected to meet the DQOs, which involves reviewing

the other six steps of the DQO process. The survey plan is, in itself, an optimization of previous radiological survey designs implemented at the Site; an optimization initially focused on filling stakeholder identified data gaps for the floors in Building 3H/6H and, in the subsurface soils beneath Building 9H/10H/11H.

Optimization of this survey design included the following:

- Adding a sodium-iodide gamma walkover survey (GWS) element to the Building 3H/6H floor survey. Although normally reserved for outdoor MARSSIM surveys, this feature was added to address stakeholder concerns and determine if any larger previously unidentified deposits of elevated residual radioactivity are present that might not otherwise be detectable due to floor surface conditions-coverings.

4.0 PRE-SURVEY ACTIVITIES AND RECORDS

This section summarizes the project activities that took place before the characterization survey began. Records and documentation associated with Construction Quality Control are presented in Section 9.0.

4.1 PERMITS AND NOTIFICATIONS

Cabrera made appropriate notifications to the USNRC and to the state of Connecticut Department of Energy and Environmental Protection (CTDEEP) before beginning work on-site. The Characterization Survey site work was performed under Cabrera's USNRC radioactive materials service provider license (USNRC, 2011). Asbestos abatement notification was made to the CTDEEP at least 10 days prior to beginning work on-site. Cabrera verified the utility layout in planned sampling locations with CT Call Before You Dig a minimum of 72 hours before intrusive activities began. Copies of applicable permits and notifications are attached in Appendix C.

4.2 PRE-SURVEY ACTIVITIES

This section describes field activities that were completed prior to initiating characterization survey activities.

4.2.1 Mobilization

The initial mobilization to the site occurred on June 13, 2016 to start supplemental radiological surveys. A second mobilization to the Site occurred on February 21, 2017 to begin the debris removal. Site preparation activities required approximately two days before initiation of field activities. Mobilization and site preparation activities included:

- Personnel travel to the Site
- Review project plans with site personnel
- Conduct required site-specific training
- Set-up project offices and support facilities
- Performing initial quality control checks of field radiological instrumentation

4.2.2 Site Preparations

Areas were only considered accessible for survey if all potentially hazardous conditions in the work area were adequately evaluated and addressed, permitting safe personnel access. Previously, inaccessible areas of Building 3H/6H were made accessible to the extent practicable by clearing debris from the floor without impacting or disturbing potential asbestos containing materials (ACM). Efforts to expand access to floor surfaces were limited to debris that was easily and safely moved; any debris that was moved was added to existing debris piles. Areas occupied by items that required greater effort to move and render the floor accessible, such as cars and drummed chemicals, were initially deemed inaccessible areas. It quickly became apparent that further debris removal would be necessary to obtain access to the floors to perform complete radiological surveys as required in the approved *Supplemental Radiological Survey Plan*

(Cabrera, 2016a; see Appendix B). Section 5.0 describes the debris removal activities undertaken as part of the pre-survey activities.

As equipment was no longer needed at the project site, it was radiologically surveyed, in accordance with the *RPP* (Cabrera, 2014a), and returned to the vendor. As work was completed, safety barricades, caution tape, and other devices used to warn personnel of potential hazards were removed.

5.0 DEBRIS REMOVAL

Previous phases of work identified that the Building 3H/6H Roof was in poor overall condition with ACM-containing debris from failed roof sections strewn about the interior floor. Examples of areas where ACM was suspected and evaluated included the eastern end of Building 3H, and the room between the Decon Pit and the X-Ray Read Room (see Figure 1-2 in Appendix A).

Cabrera's asbestos abatement subcontractor, AIG, mobilized an Industrial Hygienist (IH) to collect swipe samples of dust in these areas and; to determine if asbestos abatement was required or, if the dust did not contain asbestos and could simply be broom swept, vacuumed, or cleaned without asbestos controls in place. Nine out of 10 debris flooring samples or wipes collected by the IH and analyzed at AmeriSci New York Laboratory, in New York, New York were positive for ACM. Figure 5-1 in Appendix A shows the location of the samples; complete results are provided in Appendix D.

After confirming that significant asbestos abatement would be required to continue with floor surveys, Cabrera demobilized from the Site on July 14, 2016, consulted with stakeholders, and developed the *Debris Removal Plan* (Cabrera, 2016b). The *Debris Removal Plan* (Cabrera, 2016b) described the means and methods for removal of miscellaneous debris, drums and other obstructions performed in Buildings 3H/6H. The purpose of the debris removal was to:

- Allow Cabrera to complete a characterization survey of 100% of the floor areas within the H-Tract building, known as Building 3H/6H;
- Substantially reduce the safety hazard inside the building caused by ACM in the roof debris that has fallen to the floor in Building 3H;
- Survey and release debris and other items (i.e., drums) that are not radiologically contaminated for disposal at an off-site non-radiological landfill; and
- Package, transport, and dispose of radiological wastes from the building in an off-site landfill capable of accepting radiological wastes.

5.1 REMOVAL ACTIVITIES

5.1.1 Asbestos Abatement

Areas of miscellaneous dirt and debris comingled with ACM required abatement under asbestos controls, including, but not limited to, containment with negative pressure and high-efficiency particulate air (HEPA) filtration. Only trained asbestos workers were permitted in active containment areas. ACM abatement activities were expedited in some cases by constructing the containment large enough to allow for:

1) Heavy equipment, such as a skid-steer track loader with a bucket and/or grapple, to be able to maneuver and sort through the pile and pick out debris, and

2) An empty intermodal container (IMC) to be staged in the area, lined with a double-layer bag, and be directly loaded, rather than passing the bagged ACM out of the area and loading at a different location.

After the piles of debris were removed, the floor of the containment was HEPA vacuumed to remove as much dust and dirt as possible.

As it was not possible to prevent infiltration of rainwater given the poor condition of the roof, a containment with a plastic, temporary roof was constructed in each survey area to prevent roofing material from falling down into the floor area below during abatement and subsequent floor surveys. As abatement was completed inside each area, per the approved abatement plan, and prior to moving the containment to the next work area, the IH performed air testing to confirm air concentrations met the required limits for airborne asbestos fibers. The containment walls were taken down but the temporary roof remained in place until surveys were completed. All plastic roofs were taken down at the conclusion of all survey activities.

5.1.2 Sorting of Debris Waste

The debris was sorted into three different categories:

1) Miscellaneous soil-like material/debris / trash
2) Drums
3) Large debris requiring radiological survey and evaluation against screening criteria

Separate staging areas were set up in a designated part of Building 3H.

A detailed description of the different debris waste categorized and staged is described below.

5.1.2.1 Miscellaneous Soil-Like Material and Debris/Trash

Soil-like material and small debris/trash (i.e., small items, soil-like material or items consisting of porous materials such as wood, cloth, paper, etc.) was segregated and directly loaded into double-lined IMCs as described in Section 5.1.1.

5.1.2.2 Drums

There were roughly 500 drums of known and unknown contents inside the building. Some of the drums and their contents were labeled; others were not. Many of these drums were rusted and contained holes. Several hundred of the drums appeared to be empty. The drums were brought and stored in the building after active UNC operations were completed. While it was assumed that none of these drums contained radioactive materials, there was the potential that the exterior surfaces of the drums may have been radiologically contaminated since being inside the building. Therefore, the drums were staged together in one area and the exterior surfaces of each of the drums was surveyed for radioactivity. If the drums met screening criteria (Regulatory Guide 1.86 limits for uranium [USNRC, 1974]), then the drums were moved to another area of the building and managed/removed by the Property Owner. All drums met release criteria and were released for radioactivity. If the drum was known to contain solid/and or liquid, and there were no pre-existing holes in the drum, then all efforts were made to not breach the intact drum during the decontamination effort.

If a drum could not be moved without spilling its contents due to its rusted condition, then Cabrera notified UNC. Cabrera's specialty hazardous waste subcontractor (Brightfields) was notified to manage the drums in accordance with 29 CFR 1910.120. Before Brightfield arrived, the exterior surfaces of these items were surveyed for residual surface radioactivity. All drums met screening criteria. The subcontractor then overpacked the drums and moved them to the appropriate staging area for further disposition/surveys. A total of 48 drums and 33 miscellaneous containers were managed by Brightfields. These drums are currently being staged on plastic in Building 6H. Radiological surveys are provided in Appendix I.

5.1.2.3 Large Debris Requiring Radiological Survey and Evaluation Against Screening Criteria

Debris inside the building needed to be moved in order to facilitate characterization surveys of the remainder of the building. This debris (including, but not limited to, office furniture, equipment, large containers, and structural steel) that was not otherwise mixed with ACM had been moved into the building since UNC's active operations. Any debris that could be decontaminated (i.e., consisting of non-porous materials such as metal, rubber, plastic that could be wiped clean) was segregated and staged outside the ACM containments. The exterior surfaces of these items were surveyed for residual surface radioactivity. If the debris met release criteria (Regulatory Guide 1.86 limits for uranium), then it was moved to another area of the building to be managed/removed by the Property Owner. All debris that was surveyed met screening criteria. Radiological surveys are provided in Appendix I.

5.1.3 Radioactive Material Segregation, Characterization, and Shipment

Discrete pieces of radioactive material that were found during surveys were segregated, packaged and secured. Upon their discovery, and UNC, DOE, and Knolls Atomic Power Laboratory (KAPL) were notified. All discrete items were analyzed by the on-site lab manager for uranium content and U-235 assay using the on-site gamma spectroscopy detector. Results were reviewed by the Project Health Physicist and shared with stakeholders. Once reviewed, the items were controlled as SNM, as appropriate and per the *Nuclear Material Control and Accountability Plan* (Cabrera, 2011). Shipping and receipt was coordinated between Cabrera and KAPL representatives to ensure quality and completeness of all required documentation. When a NRC Form 741, *Nuclear Materials Transaction Report*, was required to document the SNM transaction, Cabrera submitted the completed report form to the Office of Nuclear Materials Safety and Safeguards prior to shipment. Copies of NRC Form 741 and analytical reports for each piece of radioactive material are provided in Appendix E.

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6.0 CHARACTERIZATION SURVEY DESIGN

The characterization survey was designed in accordance with project DQOs (Section 3.0) and the approach outlined in MARSSIM (NRC, 2000), such that the data could be used to support decisions regarding potential future remediation efforts.

6.1 RADIOLOGICAL SURVEY OF BUILDING 3H/6H FLOOR

Surveying the floor of Building 3H/6H was completed using a combination of the following:

1. Gamma scan survey
2. Integrated alpha/beta activity scan survey
3. Smear, static, and dose rate measurements at biased locations

6.1.1 Gamma Scan Survey

Gamma scan surveys were performed over all accessible floor surfaces throughout the footprint of Building 3H/6H using a Bicron Radiation Measurement Products model G5 Field Instrument for Detection of Low Energy Radiation (FIDLER) sodium iodide (NaI) detector paired to a Ludlum model 2221 scaler/ratemeter. The survey was performed following MARSSIM (NRC, 2000) protocol by walking straight parallel lines at a speed of 0.5 meters per second over an area with the detector kept a fixed distance from the floor (i.e., a maximum of four inches above the floor). Survey passes were approximately 1 meter apart. Data from the scaler/ratemeter was automatically logged. At least 50% of all accessible floor surfaces were scanned using the FIDLER. During the scans, Cabrera physically marked areas that clearly exceeded the investigation level, set at two times background levels. The average and standard deviation of the entire dataset was calculated, and the locations of the highest activity measurements were identified. Follow-up investigations were performed using the FIDLER at areas exceeding the investigation level. Cabrera performed a one-minute static count on the area. A total of 164 locations in excess of the investigation level were identified during the gamma survey.

6.1.2 Integrated Alpha/Beta Scan Survey

Floor scans were performed with portable contamination survey instruments specifically, the Ludlum 43-37 gas flow proportional “floor monitor” detector or Ludlum Model 43-93 zinc sulfide/plastic scintillator detector. The selected detector (determined based on accessibility by the field team leader) was coupled with an appropriate scaler-ratemeter (e.g., Ludlum Models 2221, 2224, 2360, etc.) as a pre-calibrated set.

One minute long integrated alpha/beta scan measurements were performed on accessible floor surfaces throughout the footprint of Building 3H/6H. The scaler-ratemeter was set to a one minute count time. At the start of each measurement, the surveyor began the one minute count, and move the detector at a rate of approximately one detector width every two seconds. At the completion of each one-minute count, the approximate footprint covered by the integrated scan measurement was noted and the alpha and beta result recorded. Integrated alpha/beta scan measurements were performed over a minimum of 10% of all accessible floor surfaces.

The overall completeness DQO for scan surveys was 10% coverage of accessible Building 3H/6H floor surfaces; approximately 15% completeness was achieved.

6.1.3 Unbiased Measurement Locations

Unbiased (i.e. systematic) measurements were not collected during the survey. The justification for this change is provided in Section 6.6.3.

6.1.4 Biased Measurement Locations

The following measurements were collected at each biased measurement location:

1. a one-minute gamma static measurement was performed on contact with the floor
2. a smear for removable contamination was collected and counted for one minute
3. a dose rate measurement was collected at approximately one meter above the floor

Biased measurement locations were assigned based on:

1. Locations exceeding two times background (investigation level) from the gamma scan survey
2. Integrated scan results that exceeding the surface $DCGL_W$ (5,000 dpm/100cm^2)

6.1.4.1 Gamma Scan Survey Biased Measurements

One biased measurement location was assigned for each contiguous area exceeding the gamma investigation level. A one-minute gamma static measurement was performed on contact with the floor within each area, and a smear for removable contamination was collected. Summary statistics (mean, median, and standard deviation) were calculated separately for each SU, room, or area, as appropriate.

6.1.4.2 Integrated Alpha/Beta Scan Survey Biased Measurements

Biased measurement locations were also established based on integrated scan results that exceeded the 5,000 dpm/100 cm^2 surface activity $DCGL_W$. A biased measurement was assigned for each integrated scan result where the total net activity exceeds 5,000 dpm/100 cm^2. For each integrated scan assigned for bias measurement, the field team located the relative maxima from the area to ensure the most conservative measurement was obtained. If no integrated scan result exceeded 5,000 dpm/100 cm^2, biased measurement locations were selected based solely on gamma scan survey results.

6.1.5 Reference Areas and Background Correction

To the extent practicable, similar surface materials were selected from the floor of the adjacent, non-impacted property, at 91 Shelton Avenue. Integrated scan and static measurements were collected from floors within that building to establish counts to subtract for each measurement to allow calculation of net dpm/100 cm^2 using an appropriate material-specific background, total instrument efficiency, and geometric factors associated with the instrumentation.

6.2 RADIOLOGICAL SURVEY OF BUILDING 3H DUCTWORK SYSTEM

6.2.1 Integrated Alpha/Beta Scan Survey

Ductwork scans were performed with portable contamination survey instruments specifically, the Ludlum Model 43-93 zinc sulfide/plastic scintillator detector coupled with a Ludlum Model 2360 datalogger.

One-minute integrated alpha/beta scan measurements were performed on all accessible ductwork openings, junction boxes, blowers, and any other remaining air moving equipment associated with the ductwork throughout the intact sections of ductwork system. The scaler-ratemeter will be set to a one minute count time. At the start of each measurement, the surveyor began the one minute count, and moved the detector at a rate of approximately one detector width every two seconds. At the completion of each one-minute count, the approximate footprint covered by the integrated scan measurement was noted and the alpha and beta result recorded.

6.2.2 Biased Measurement Location

The following measurements were collected at each biased measurement location:

1. a one-minute alpha-beta static measurement was performed on contact with the ductwork
2. a smear for removable contamination was collected and counted for one minute

Biased sentinel measurement locations were assigned in conjunction with the highest readings identified from surface scan surveys.

6.3 ADDITIONAL SCOPING SURVEYS OF WALLS AND OVERHEAD SURFACES

Additional supplemental surveys were performed at the request of UNC after floor surveys were completed. The rationale and methods used are described in Section 6.6.1.

6.4 SUBSURFACE RADIOLOGICAL INVESTIGATION OF FORMER BUILDING 9H/10H/11H LOCATIONS

Sentinel measurements (i.e., soil borings) were performed within the footprints of formerly controlled areas of the basement of Building 9H/10H/11H. Based on review of gridded area results within the basement and identification of areas where elevated results were historically recorded, six borings were performed within the former Building 11H Metallurgy Laboratory footprint and seven borings were performed within the former Building 10H Hot Waste Processing area footprint (refer to Figure 6-1, Appendix A).

At each boring location, the boring proceeded until a maximum depth of 15 feet bgs was reached or to a depth of one foot below the assumed basement floor when underlying soils were encountered. Sample cores from boreholes were scanned for gamma activity to identify thin layers of elevated activity. A FIDLER was moved over the surface of the soils slowly, with the average count rate for each approximately one foot interval recorded.

Downhole gamma logging was performed at each borehole to provide data regarding the variation in gamma fluence with depth. A one-minute integrated measurement was performed using a Bicron Radiation Measurement Products Model G1 environmentally encapsulated one-inch by one-inch NaI detector. Measurements were collected at approximately one foot intervals, starting at the bottom of the borehole and working toward ground surface. Each borehole was sleeved with schedule-40, threaded polyvinyl chloride pipe casing prior to insertion of the probe to prevent cave-in of sidewall soils and capture of the detector at depth. Integrated count rates in units of cpm at each borehole location were recorded.

Direct soil core scanning and downhole gamma logging results were compared to collectively identify the interval containing the highest observed count rate from each boring. Generally, a single soil sample representing a one-foot interval was collected from each borehole to submit to an off-site laboratory for radioanalysis. Thirteen total samples from the 13 borings were collected. Soil samples were submitted to ALS for alpha spectroscopy isotopic analysis for ^{234}U, ^{235}U, and ^{238}U.

6.5 MEASUREMENT MINIMUM DETECTABLE CONCENTRATIONS

Nominal instrument minimum detectable concentrations for instrumentation are presented in Table 6-1.

Table 6-1. Minimum Detectable Concentrations

Instrument Model	Serial Numbers	Radiation Type	Background Count Time (Minutes)	Sample Count Time (Minutes)	Area (cm^2)	Total Efficiency	Background (cpm)	Static MDC (dpm/100 cm^2)	Scan MDC (dpm/100 cm^2)
2360/43-37	202403/ PR178371	Alpha	1	1	584	0.07	2.7	28	218
2360/43-37	202403/ PR178371	Beta	1	1	584	0.09	642.6	118	1236
2360/43-37	278586/ PR216982	Alpha	1	1	584	0.07	2.8	27	212
2360/43-37	278586/ PR216982	Beta	1	1	584	0.09	563.9	110	1158
2224-1/43-93	227246/ PR244549	Alpha	1	1	100	0.11	2.4	93	372
2224-1/43-93	227246/ PR244549	Beta	1	1	100	0.08	232.3	387	2081
2360/43-93	193638/ PR199836	Alpha	1	1	100	0.11	1.0	70	246
2360/43-93	193638/ PR199836	Beta	1	1	100	0.07	124.3	408	2156
2360/43-93	184909/ PR298426	Alpha	1	1	100	0.10	0.30	56	157
2360/43-93	184909/ PR298426	Beta	1	1	100	0.12	110.7	419	2213

Table 6-1. Minimum Detectable Concentrations

Instrument Model	Serial Numbers	Radiation Type	Background Count Time (Minutes)	Sample Count Time (Minutes)	Area (cm^2)	Total Efficiency	Background (cpm)	Static MDC (dpm/100 cm^2)	Scan MDC (dpm/100 cm^2)
2929/43-10-1	200051/ PR215948	Alpha	1	1	100	0.37	0.30	16	N/A
2929/43-10-1	200051/ PR215948	Beta	1	1	100	0.20	37.4	157	N/A

cm^2 = square centimeters
dpm – disintegrations per minute
MDC = minimum detectable concentration
N/A = not applicable

6.6 DEVIATIONS FROM SUPPLEMENTAL SURVEY DESIGN

There were several instances where Cabrera's actual survey warranted further optimization resulting in deviations from the original design in the *Supplemental Radiological Survey Plan* (Appendix B) as follows:

6.6.1 Accessibility of Floor Surfaces

The planned survey design considered that less than 100% of building floor surfaces would be available for complete radiological survey. However, when six discrete HEU metal fragments were found in Building 3H, stakeholders agreed on a temporary demobilization to facilitate planning for controlled debris removal. Cabrera demobilized from the Site on July 14, 2016.

Cabrera developed the *Debris Removal Plan* (Cabrera, 2016b), obtained stakeholder concurrence and, re-mobilized to the Site on February 21, 2017. The work plan was implemented facilitating more complete building surveys and assessment for addition HEU metal fragments. As a result of debris removal, gamma floor scan coverage increased from 50% to 90% and alpha-beta floor scan coverage increased from 10% to 74%.

6.6.2 Selection of Follow-Up Locations

In the *Supplemental Radiological Survey Plan* (Cabrera, 2016a) in Appendix B, it was stated that Cabrera would select biased locations based on gamma scan data exceeding three standard deviations above the mean cpm value. The planned approach required a more complete survey and statistical data analysis prior to selection of any follow-up locations. Due to space limitations during debris removal and ACM abatement, floor areas were surveyed in sub-sections, as they were cleared, starting in the west end of Building 6H and generally heading east. A screening investigation level of 12,200 cpm was used for the evaluation, equivalent to two times ambient gamma background radiation levels with the FIDLER. Background data for the FIDLER is provided in Appendix I.

6.6.3 Unbiased Measurement Locations

Prior to mobilization, unbiased measurement locations were assigned throughout the Building 3H/6H floor areas based on a systematic survey design (i.e., a triangular sampling grid pattern with a random starting point) (refer to Figures 4, 5, and 6 of the *Supplemental Radiological Survey Plan* [Cabrera, 2016a] in Appendix B). Soon after mobilization, it became apparent that there was extensive contamination exceeding the $DCGL_W$ on the floor inside Building 3H/6H, and remediation would be required to address these areas. Continuing to utilize a characterization survey design based on a MARSSIM approach was no longer necessary, and unbiased measurements were not collected.

6.6.4 Alpha-Beta Static Measurements

The *Supplemental Radiological Survey Plan* (Cabrera, 2016a) in Appendix B required static alpha-beta measurements at biased locations that were identified during gamma and alpha-beta floor scans. The static measurements were not performed; rather, a gamma static measurement

and smear measurement were performed. The reason that the static measurements were not performed were two-fold:

1) The areas were often so widespread it was difficult for the technicians to isolate one 100 cm^2 area to collect a static measurement as a maximum; and

2) The gamma readings at particular locations were usually elevated, but due to a variety of factors (i.e., floor coverings, multiple layers of concrete floors, pitting or holes in the floor), alpha-beta static results at the same location were still a fraction of the $DCGL_W$. This is supported by the data in Section 8.1.1, where 167 gamma measurements exceeded the investigation level, but no alpha-beta scan measurements exceeded the $DCGL_W$. Smear measurements were still collected to ensure that removable activity was not being tracked around or outside the building by survey or asbestos abatement personnel.

6.6.5 Additional Wall/Ceiling Surveys

Upon completion of the flooring surveys and initial discussions of the results with project stakeholders, it was decided that additional radiological surveys would also be performed on the walls, upper surfaces, and ceilings inside Building 3H/6H. The purpose of these surveys was to determine the potential extent of contamination in these areas. Survey means and methods were consistent with those in Section 3.0 of the approved *Supplemental Radiological Survey Plan* (Cabrera, 2016a; see Appendix B). Scoping surveys were biased towards areas of known or suspected radiological contamination. For this reason, a greater percentage of scans/measurements were performed inside Building 3H (approximately 25% scans of walls and ceilings) as compared to Building 6H (approximately 10% scans of walls and ceilings). Cabrera performed alpha-beta and gamma scans along the different surfaces. Areas with elevated activity were flagged for further investigation (i.e. biased measurements). Alpha-beta static biased measurements were performed rather than gamma static measurements because it was determined that contamination was more likely to be surficial rather than embedded in the wall or equipment at depth. Static measurements were taken on horizontal surfaces that were likely to be impacted by settling particles derived during the fuel making process. Surveys also included other equipment and/or miscellaneous materials inside the building that were not a part of the floor scan surveys, such as lights hanging from the ceiling, pipe penetrations in walls and floor. Samples were collected from pipe scale in two separate pipes; one inside the former Chemistry Lab, and one in the eastern end of Building 3H. The samples were analyzed at ALS for isotopic uranium via alpha spectroscopy. Several In Situ Object Counting System gamma spectroscopy measurements were also collected inside the building. The purpose of these measurements was to quantify uranium on or behind surfaces where subsurface contamination was suspected.

7.0 MATERIAL HANDLING AND TRANSPORT

The contaminated soils and debris generated during the debris removal at the Site was disposed as radioactive waste under the United States Department of Energy's existing disposal contract with EnergySolutions in Clive, Utah. Cabrera subcontracted Greenfield Logistics, LLC to coordinate the waste transportation from the Site to EnergySolutions.

7.1 WASTE CHARACTERIZATION

Prior to shipping, the debris waste streams were characterized as described in the *Debris Removal Plan* (Cabrera, 2016b) confirming waste met EnergySolutions's waste acceptance criteria. The waste was consistent with the profile established for ACM wastes previously shipped from the Site to EnergySolutions in 2014; therefore, off-site waste characterization sample analysis via the Toxicity Characteristic Leaching Procedure (USEPA Method SW846) was not required.

In order to remain compliant with Cabrera's NRC Broad Scope License and the project *Nuclear Material Control and Accountability Plan* (Cabrera, 2011), Cabrera calculated the amount of SNM, specifically the grams of ^{235}U, in the filled IMCs using gamma spectroscopy analysis results from waste characterization samples. At least eight samples from each IMC were analyzed, and the average uranium activity and enrichment of the samples was applied to all of the material in the IMC. Activities in each IMC were added to the Material Balance Area (MBA) General Inventory Ledger. IMCs with a concentrated uranium total of less than 0.5 grams were tracked on the MBA but did not require a NRC 741 form for disposition. The waste characterization sample results, MBA ledger, and 741 forms are presented in Appendix E.

In total 374,000 pounds (187 tons) of building debris, ACM abatement related wastes, and associated investigation derived wastes were generated during field activities. Based on material accountability measurements, the waste generated contained a total of 81 grams ^{235}U.

7.2 WASTE TRANSPORTATION

Radiological wastes were prepared for shipment and transported to EnergySolutions per 49 CFR 173 requirements, as follows:

- Wastes were carefully loaded into 25 cubic yard IMCs (strong-tight IP-1 package); a total of 17 IMCs were shipped from the Site to EnergySolutions.
- IMCs were surveyed for external radiation and removable contamination and placarded, if required. Records are presented in Appendix E.
- A waste bill of lading and a waste manifest were generated by Cabrera for transport via rail to EnergySolutions. Records are presented in Appendix E.

Waste shipping campaigns were conducted in June, 2017 (10 IMCs) and August, 2017 (7 IMCs). EnergySolutions confirmed receipt, complete unloading, and burial of each IMC's contents. EnergySolutions personnel performed necessary IMC decontamination and radiological surveys

prior release from their license control. The EnergySolutions SNM Certifications, and Certificates of Disposal are included in Appendix E.

7.3 DEMOBILIZATION

Cabrera conducted its initial demobilization from the Site on July 14, 2016 after the completion of survey activities in accessible areas of Building 3H/6H. After the debris removal and subsequent radiological surveys on the floors and upper walls, Cabrera conducted the final demobilization from the Site on August 30, 2017. All potentially radiologically impacted tools and equipment used by Cabrera and subcontractors were subject to survey prior to unconditional release in accordance with Cabrera NRC License Procedure *OP-004 Unconditional Release of Materials from Radiological Control Area, Rev. 2.* Copies of radiological surveys are provided in Appendix I.

8.0 CHARACTERIZATION SURVEY RESULTS

8.1 BUILDING 3H/6H FLOORS AND WALLS

Gamma activity scans, biased alpha/beta scan and smear measurements were performed on the floors, walls, ceilings, and other building components inside Building 3H/6H as follows:

8.1.1 Building 3H/6H Floors

Gamma Scans and Biased Measurements

At least 90% of accessible floor areas were scanned during the survey. Gamma activity scans were performed using a FIDLER. Data from the scaler/ratemeter were automatically logged. The locations of the highest activity measurement were identified using an investigation level of 12,200 cpm, which was set to equal two times the background levels, which was approximately 6,100 cpm. Gamma scan data is displayed in Figures 8-1 through 8-3. The raw scan data is presented in Appendix I.

Numerous floor locations in Building 3H (i.e. the eastern part of Building 3H/6H) displayed elevated gamma activity greater than the investigation level requiring a total of 164 additional biased static gamma and alpha-beta smear measurements. Biased measurement locations and data are visually presented in Figure 8-4 and summarized in Table 8-1.

Table 8-1. Building 3H/6H Biased Measurement Data Summary

Statistic	Gamma Static Measurements	Smear Measurements		
	cpm	a (dpm/100cm^2)	b (dpm/100cm^2)	a plus b (dpm/100cm^2)
# of Measurements	164			
Mean	29,014	10.7	37.2	47.9
Median	22,615	8.2	34.8	41.6
Maximum	134,326	57.1	203.8	228.8
Minimum	1,580	0.0	-188.9	-183.5
Standard Deviation	19,244	11.3	52.0	56.7
IL/DCGL$_W$	12,209	N/A	N/A	1,000

Notes:
cpm = counts per minute
dpm/100 cm^2 = disintegrations per minute per 100 square centimeters
a – alpha activity
b – beta activity
a + b – alpha plus beta activity
N/A – not applicable
IL/DCGL$_W$ – Investigation Level or Derived Concentration Guideline Level, as applicable. The investigation level for gamma static measurements was calculated as 12,209 cpm. The DCGLW for alpha plus beta activity is 1,000 dpm/100cm^2.

Integrated Alpha-Beta Floor Scan Measurements

One-minute integrated alpha/beta scan measurements were performed on approximately 74% of accessible floor surfaces throughout the footprint of Building 3H/6H. Zero (0) measurements exceeded the $DCGL_W$. The summary of these results are presented in Table 8-2. These results are visually displayed in Figures 8-5 through 8-7. The raw scan data is presented in Appendix I.

Table 8-2. Building 3H/6H Alpha-Beta Floor Scan Data Summary

Statistic	Scan Measurements		
	a ($dpm/100cm^2$)	b ($dpm/100cm^2$)	a plus b ($dpm/100cm^2$)
# of Measurements	3,369		
Mean	-18.8	462.2	443.4
Median	-23.3	444.6	419.5
Maximum	350.2	4096.8	4154.6
Minimum	-70.0	-1803.1	-1857.6
Standard Deviation	37.8	468.6	491.2
IL/$DCGL_W$	N/A	N/A	5,000

Notes:
cpm = counts per minute
$dpm/100\ cm^2$ = disintegrations per minute per 100 square centimeters
a – alpha activity
b – beta activity
a + b – alpha plus beta activity
All results in table are net values that have been corrected for background radioactivity using material-specific background measurements collected in non-impacted areas.
IL/$DCGL_W$ – Investigation Level or Derived Concentration Guideline Level, as applicable. The $DCGL_W$ for total alpha plus beta activity is 5,000 $dpm/100cm^2$

It was noted by field personnel that there were many areas of elevated gamma activity above the 2 times background gamma investigation level (IL) with corresponding alpha-beta surface scan measurements well below the $DCGL_W$. The presence of elevated gamma above the investigation level without significantly elevated surface alpha/beta readings is an indicator of residual subsurface radioactivity, contamination that was possibly missed during the original license decommissioning. Alternatively, the floor surfaces may have had additional paint/concrete layers applied to resolve contamination control issues during historic facility operations leaving radioactive contamination trapped between floor layers and undetectable using alpha/beta survey instruments. Several of the identified gamma "hot spots" in Building 3H appear to have had sections of the floor replaced or covered with additional floor layers. Additional investigation, with volumetric soils/concrete sampling should be considered to more fully assess contamination potential within the concrete and/or in the underlying soils.

8.1.2 Building 3H/6H Walls and Ceiling

At least 25% of accessible wall and ceiling areas in Building 3H and 10% of accessible wall and ceiling areas in Building 6H were scanned for alpha-beta and gamma activity during the survey. One minute static alpha-beta measurements were performed throughout the building at locations where elevated activity was noted during scans, and the data from the scaler/ratemeter were automatically logged or recorded by hand. The average and standard deviation of the entire dataset was calculated, and the locations of the highest activity measurement were identified. A total of 66 static alpha-beta measurements exceeded the $DCGL_W$.

Numerous wall and upper horizontal surfaces in both buildings appeared elevated above expected background including, but not limited to, the following surfaces:

- Steel beams;
- Steel rail beneath windows along northern wall of building;
- Lights
- Overhead conduit near ceiling

Alpha-beta static surface measurement results were highest in the Building 3H (i.e. the eastern part of Building 3H/6H) with distributed results well exceeding the $DCGL_W$. Measurement results are summarized and presented in Table 8-3; graphically displayed in Figures 8-8 through 8-10 with; raw data included in Appendix I.

Table 8-3. Building 3H/6H Alpha-Beta Wall Static Measurement Data Summary

Statistic	Static Measurements		
	a (dpm/100cm^2)	b (dpm/100cm^2)	a plus b (dpm/100cm^2)
# of Measurements	757		
Mean	1217.5	770.4	1987.9
Median	102.7	567.9	865.0
Maximum	39400.0	5996.2	43185.7
Minimum	-100.0	-1767.9	-1787.9
Standard Deviation	3418.1	1069.9	3896.8
IL/$DCGL_W$	N/A	N/A	5,000

Notes:
dpm/100 cm^2 = disintegrations per minute per 100 square centimeters
a – alpha activity
b – beta activity
a + b – alpha plus beta activity
All results in table are net values that have been corrected for background radioactivity using material-specific background measurements collected in non-impacted areas.

Twelve smear measurements were collected at different wall and overhead locations displaying elevated static measurements. These descriptions and results are provided in Table 8-4. The results did not exceed the $DCGL_W$, but were elevated above background levels.

Table 8-4. Building 3H/6H Alpha-Beta Wall Smear Measurement Data Summary

Location	a Result (dpm/100cm^2)	b Result (dpm/100cm^2)	a plus b Result (dpm/100cm^2)
West 3H south overhead	29.9	159	189
West 3H south overhead conduit	130.5	283	414
West 3H south upper wall Column 36	13.6	179	193
West 3H north OH Column 34	2.7	139	142
West 3H north OH Column 37	0.0	65	65
Central 3H south wall overhead	2.7	20	23
Central 3H south overhead beam	0.0	104	104
East 3H south OH light Column 42	2.7	-5	-2
East 3H south OH beam Column 44	21.8	259	280
East 3H north OH Column 48 mezzanine	13.6	45	58
East 3H north Column 44 beam	10.9	80	90
West 3H south X-ray rr OH	16.3	264	280

Notes:
dpm/100 cm^2 = disintegrations per minute per 100 square centimeters
a – alpha activity
b – beta activity
a + b – alpha plus beta activity
All results in table are net values that have been corrected for background radioactivity using background measurements collected during initial instrument setup.

On the western wall of the eastern-most section of Building 3H, and on the western wall of the western-most section Building 3H (i.e. X-Ray Read Room), there is evidence of wall paint covering contamination on walls and cross beams in the overhead. Cabrera performed three initial static alpha-beta measurements on the painted surfaces with, all results less than the $DCGL_W$, and minimal alpha response. Cabrera then carefully removed paint from each surface and repeated each measurement. In all three locations, the re-check results exceeded the $DCGL_W$ with much greater alpha response. It is possible that some wall areas were specifically painted as a fixative method of contamination control during historic operations.

In situ gamma spectroscopy measurements were performed inside the building in several areas suspected of containing uranium contamination that may not have been accessible to surficial measurements. These measurements were performed in the 3H vault, west-facing wall in the

western portion of 3H, the east-facing wall in the central portion of 3H, the 6H Chemistry Laboratory pipe, and the eastern portion of 3H along the north wall. Four of five measurements confirmed the presence of ^{235}U in varying concentrations. The measurements were qualitative in nature, due to source modeling uncertainties and field-of-view limitations. Spectroscopy reports are presented as Appendix G.

8.1.3 Building 3H/6H Components

After removal of flooring debris in Building 3H/6H, two pipes were accessible for further investigation. The pipes are displayed in Figure 1-3. One of the pipes was in the eastern-most section of Building 3H against the western wall. It ran approximately 30 feet horizontally about 6 inches above the floor slab before entering a hole in the floor slab down into the South Trench, where it eventually exited the building through the south wall of the South Trench. Further attempts to follow the pipe outside the building were not possible due to the plant overgrowth, and suspected pipe depth (5-6 feet bgs). Exterior gamma readings using the FIDLER on the outside of the pipe did not indicated elevated activity above 2 times background levels. Pipe scale was collected from the open end of the pipe and sent to the off-site laboratory for isotopic uranium analysis. Volumetric sample results did not exceed the 435 pCi/g criteria established for Site soils (Cabrera, 2012) and are presented in Table 8-5.

The other piping was located in the former Chemistry Laboratory. Several pipes intersected in this one room: one pipe ran down the southern wall from a penetration in the ceiling, another pipe ran horizontally along the southern wall approximately 1.5 feet above the floor through the western wall, and these pipes combined into one pipe, which entered a penetration through the floor slab down into the South Trench, where it eventually exited the building through the south wall of the South Trench. Further attempts to follow the pipe outside the building were not possible due to the plant overgrowth, and suspected pipe depth (5-6 feet bgs). FIDLER measurements indicated elevated activity and potential internal contamination with results ranging from 25,000 – 175,000 cpm. Pipe scale was collected sent to the off-site laboratory for isotopic uranium analysis with results also exceeding the 435 pCi/g criteria (Table 8-5). Note also that free-flowing mercury was observed coming from the pipe during evaluation. Loose mercury was controlled in a rubber glove that was tied off and placed back into the pipe to mitigate additional leaking. Other potentially mercury-contaminated gloves worn by Cabrera personnel were placed in a nearby container and left in the room for future disposition by UNC.

Table 8-5. Uranium Concentrations in Scale Collected from Piping in Building 3H/6H

Location	Sample Designation	Sample Collection Date	^{234}U (pCi/g)		^{235}U (pCi/g)		^{238}U (pCi/g)		Total U (pCi/g)	U Enrichment (%)
			Result	Flag	Result	Flag	Result	Flag		
Building 3H Pipe	UNC-3H-002	8/30/17	233	M3	11	M3	2.6	M3	246.6	39.6
Chemistry Lab Piping	UNC-6H-001	8/30/17	117,000	M3	3,960	M3	1,680	M3	122,640	26.8

pCi/g = picocuries per gram
M3 = The requested minimum detectable concentration (MDC) was not met, but the reported activity is greater than the reported MDC.
^{234}U = uranium-234
^{235}U = uranium-235
^{238}U = uranium-238
Total U = total uranium, or the sum of the three individual uranium isotope concentration

8.2 BUILDING 3H DUCTWORK SYSTEM

Cabrera performed a survey of the ductwork system in Building 3H during the initial mobilization to the Site in the summer of 2016. Surveys consisted of alpha-beta integrated scans, alpha-beta static measurements, and alpha-beta smear measurements. Cabrera accessed the internal surfaces of the ductwork at the various openings along the ductwork. A total of 13 openings were investigated based on accessibility to the floor below. A summary of the survey data is presented in Table 8-6.

Table 8-6. Summary Statistics of Building 3H Ductwork Surveys

Statistic	Integrated Scans		Static Measurements		Smear Measurements	
	a (dpm/100cm^2)	b (dpm/100cm^2)	a (dpm/100cm^2)	b (dpm/100cm^2)	a (dpm/100cm^2)	b (dpm/100cm^2)
Mean	1,717	404.0	873.8	432.1	32.4	19.3
Median	1,152	296.4	513.2	390.4	25.0	11.1
Maximum	6,485	1,398	3,740	1,477	79.0	122.4
Minimum	170.7	-105.9	19.7	-67.9	2.3	-44.5
Standard Deviation	1,728	490.2	1,097	402.7	24.9	47.7

One integrated scan measurement exceeded the $DCGL_W$ of 5,000 dpm/100 cm^2. A static measurement was performed at the highest activity location covered by the integrated scan measurement, and the result was 3,740 dpm/100 cm^2. The smear measurement at this location was 65 dpm/100 cm^2. All other initial results were below the $DCGL_W$ but, noticeably elevated above area background conditions indicating greater levels of internal radioactivity could be present in other currently inaccessible portions of the 3H/6H overhead ventilation system. Stakeholders agreed to have Cabrera carefully remove the remaining ductwork as part of radiologically impacted debris removal facilitating greater access to areas of concern in the overhead.

8.3 SUBSURFACE SOILS BENEATH FORMER BUILDINGS 9H/10H/11H

Six borings were advanced within the former Building 11H Metallurgy Laboratory footprint (ML-SB-01 through ML-SB-06) and seven borings were performed within the former Building 10H Hot Waste Processing area footprint (HW-SB-07 through HW-SB-13, refer to Figure 6-1, Appendix A). Cabrera performed downhole gamma logging (DGL) and soil core scanning to select sample intervals to be sent off-site for analysis.

8.3.1 Downhole Gamma Logging Results

After core drilling was concluded at each sample location, Cabrera performed DGL to the bottom of each sample hole, up to 15 feet. DGL results for each depth were evaluated using Z-

scores (i.e., number of standard deviations from the mean). Background radiation is assumed to be normally distributed, so higher Z-score values identify data less likely to be part of background. The Multi-Agency Laboratory Analytical Protocols Manual (USEPA, NRC, U.S. DOE, 2004) describes Z-scores and recommends using a Z-score of 3.0 to identify excursions from a normal distribution. A detailed summary of the DGL results are presented in Table 8-7.

None of the z-score measurements exceeded 3.0. The highest z-score result of 2.72 was noted at a depth of 7 feet bgs at boring location ML-SB-06.

Table 8-7. Downhole Gamma Logging Results

Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score	Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score
ML-SB-01	1	2124	0.18	**ML-SB-02**	1	2679	1.49
	2	2309	-1.48		2	2586	-0.27
	3	2458	-0.02		3	1894	-1.56
	4	1844	-0.94		4	1539	-1.42
	5	1573	-1.17		5	1866	-0.69
	6	1481	-1.11		6	1760	-0.68
	7	2726	0.97		7	2180	-0.17
	8	3000	1.86		8	2143	-0.07
	9	2737	0.53		9	2374	-0.30
	10	2424	-0.63		10	2270	-0.91
	11	2242	-1.50		11	2320	-1.25
	12	2300	-1.88		12	2867	0.36
	13	2586	0.31		13	2460	-0.82
	14	2655	0.89		14	2681	1.16
	15	2717	0.49		15	2740	0.66
ML-SB-03	**1**	2576	1.25	**ML-SB-04**	**1**	2159	0.27
	2	2221	-1.86		**2**	2861	0.92
	3	2230	-0.65		3	2440	-0.07
	4	3467	1.64		4	2014	-0.67
	5	2726	0.71		5	1580	-1.16
	6	2531	0.53		6	1682	-0.80
	7	2205	-0.11		7	2496	0.49
	8	1661	-1.16		8	2960	1.77
	9	2571	0.15		9	2657	0.35
	10	2523	-0.45		10	2605	-0.31
	11	2655	-0.15		11	2698	-0.01
	12	2395	-1.50		12	2673	-0.41
	13	2542	-0.08		13	(1)	(1)
	14	(1)	(1)		14	(1)	(1)
	15	(1)	(1)		15	(1)	(1)
ML-SB-05	**1**	1562	-1.14	**ML-SB-06**	**1**	2371	0.76
	2	2332	-1.38		**2**	2786	0.60

Table 8-7. Downhole Gamma Logging Results

Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score	Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score
	3	1617	-2.32		3	2721	0.70
	4	1653	-1.24		4	3585	1.82
	5	1672	-1.01		5	3425	1.85
	6	1826	-0.57		6	3617	2.23
	7	2184	-0.16		7	3568	2.72
	8	1891	-0.64		8	2714	1.21
	9	1977	-1.21		9	1849	-1.50
	10	2510	-0.48		10	1823	-1.71
	11	2365	-1.10		11	(1)	(1)
	12	2683	-0.37		12	(1)	(1)
	13	2724	1.55		13	(1)	(1)
	14	2614	0.47		14	(1)	(1)
	15	2496	-1.15		15	(1)	(1)
HW-SB-07	**1**	1551	-1.16	**HW-SB-08**	**1**	1621	-1.00
	2	2553	-0.42		**2**	2746	0.42
	3	2621	0.42		3	2778	0.85
	4	2657	0.35		4	2825	0.62
	5	2910	1.01		5	2692	0.65
	6	3194	1.57		6	1975	-0.34
	7	2365	0.22		7	2128	-0.27
	8	1954	-0.50		8	2008	-0.38
	9	2650	0.33		9	2717	0.48
	10	2915	0.25		10	4022	2.24
	11	2697	-0.02		11	3123	1.38
	12	2817	0.16		12	3043	1.05
	13	2534	-0.15		13	2690	1.24
	14	2675	1.10		14	2602	0.35
	15	(1)	(1)		15	(1)	(1)
HW-SB-09	**1**	1692	-0.83	**HW-SB-10**	**1**	2281	0.55
	2	2722	0.32		**2**	2785	0.59
	3	2452	-0.04		3	2903	1.19
	4	2219	-0.34		4	2801	0.58

Table 8-7. Downhole Gamma Logging Results

Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score	Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score
	5	1905	-0.63		5	2991	1.14
	6	1842	-0.55		6	2537	0.54
	7	1969	-0.60		7	1940	-0.66
	8	2009	-0.38		8	1768	-0.92
	9	3333	1.89		9	2878	0.85
	10	3370	1.07		10	3340	1.01
	11	3163	1.51		11	2880	0.58
	12	2741	-0.14		12	2836	0.24
	13	2618	0.60		13	2557	0.05
	14	2460	-1.10		14	2514	-0.55
	15	(1)	(1)		15	(1)	(1)
HW-SB-11	**1**	1751	-0.69	**HW-SB-12**	**1**	1654	-0.92
	2	2922	1.19		**2**	2805	0.68
	3	2525	0.16		3	2691	0.61
	4	2392	-0.07		4	2474	0.06
	5	2518	0.37		5	2018	-0.44
	6	2392	0.31		6	1653	-0.84
	7	1947	-0.65		7	2060	-0.41
	8	2174	0.00		8	2223	0.11
	9	2133	-0.85		9	1892	-1.40
	10	2875	0.18		10	2722	-0.10
	11	2474	-0.75		11	2875	0.57
	12	2851	0.29		12	3241	1.83
	13	2311	-2.15		13	2489	-0.56
	14	2442	-1.28		14	2605	0.38
	15	(1)	(1)		15	(1)	(1)
HW-SB-13	**1**	2579	1.25				
	2	2806	0.68				
	3	2733	0.73				
	4	2191	-0.39				
	5	1897	-0.64				
	6	2007	-0.29				

Table 8-7. Downhole Gamma Logging Results

Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score	Sample Location	Depth bgs (ft)	Downhole Gamma Logging Counts (cpm)	Z-Score
	7	1607	-1.36				
	8	1782	-0.89				
	9	2805	0.68				
	10	2687	-0.16				
	11	2931	0.75				
	12	2868	0.36				
	13	2552	0.01				
	14	2428	-1.42				
	15	(1)	(1)				

Notes:
Ft = feet
bgs = below ground surface
N/A = not applicable
(1) Sample not collected due to cave in / refusal.
(2) Samples were collected of the interval depths i**n bold**

8.3.2 Soil Core Scanning

Soil cores were extracted from each borehole in 5 ft sections. The acetate sleeves were carefully cut open, and the soil cores were scanned using a FIDLER. General area background levels during core scanning were approximately 4,400 cpm. Gross count rates and a description of soil characteristics were documented for each section on soil core scanning sheets, which are provided in Appendix F.

The concrete slab was clearly encountered in 3 of the 6 locations (ML-SB-01, ML-SB-03, and ML-SB-04) around the former Building 11H Metallurgy Laboratory footprint at a depth of 8-9 ft bgs. Concrete rubble was often found below the slab at these locations; for example, at location ML-SB-01 concrete rubble extended to a depth of 16 ft bgs. Concrete rubble was encountered at the other three locations (ML-SB-02, ML-SB-05, and ML-SB-06) at an initial depths ranging from 2 ft to 8 ft. Soil core scanning results were consistent with normal background. Therefore, soils from the 1-foot interval directly beneath either the concrete foundation or rubble were collected and sent to the off-site laboratory (ALS) for isotopic uranium analysis.

The concrete slab was clearly encountered in 6 of the 7 locations (all but HW-SB-12) around the former Building 10H Hot Waste Processing area footprint at a depth of 8-9 ft bgs. Concrete rubble was often found above and below the slab at these locations; it was encountered at most locations as shallow as three ft bgs, and continued to depth of 9-12 ft bgs. Concrete rubble was encountered at location HW-SB-12 from 3-10 ft bgs. Concrete rubble was not encountered at location HW-SB-13. Soil core scanning results were consistent with normal background. Therefore, soils from the 1-foot interval directly beneath either the concrete foundation or rubble were collected and sent to the off-site laboratory (ALS) for isotopic uranium analysis.

8.3.3 Sample Analysis

All samples collected from soil borings advanced within the former Metallurgy Laboratory footprint and the former Hot Waste Processing area footprint were sent to ALS for alpha spectroscopy analysis for uranium-234, uranium-235, and uranium-238. Sample results are presented in Table 8-8.

No sample results exceeded the 1% of the $DCGL_W$ of 435 pCi/g total uranium (Cabrera, 2012). The maximum result was 3.25 pCi/g total uranium.

Table 8-8. Uranium Concentrations in Soils Beneath Former Building 9H/10H/11H Foundations

Location	Sample Designation	Sample Depth (ft bgs)	Sample Collection Date	^{234}U (pCi/g)		^{235}U (pCi/g)		^{238}U (pCi/g)		Total U (pCi/g)
				Result	Flag	Result	Flag	Result	Flag	
ML-SB-01	ML-SB-01-S-P-17	16-17	7/11/16	1.08		0.07		0.40		1.55
ML-SB-02	ML-SB-02-S-P-14	13-14	7/11/16	0.50		0.02	U	0.41		0.93
ML-SB-03	ML-SB-03-S-P-12	11-12	7/11/16	0.68		0.03	U	0.36		1.07
ML-SB-04	ML-SB-04-S-P-9	8-9	7/11/16	0.53		0.02	LT	0.48		1.03
ML-SB-05	ML-SB-05-S-P-9	8-9	7/11/16	0.30		0.04	LT	0.34		0.68
ML-SB-06	ML-SB-06-S-P-11	10-11	7/11/16	0.36		0.04	LT	0.33		0.73
HW-SB-07	HW-SB-07-S-P-10	9-10	7/12/16	1.04		0.03	LT	0.67		1.74
HW-SB-08	HW-SB-08-S-P-10	9-10	7/12/16	0.61		0.03	U	0.37		1.01
HW-SB-09	HW-SB-09-S-P-10	9-10	7/12/16	0.56		0.02	LT	0.4		0.98
HW-SB-10	HW-SB-10-S-P-10	9-10	7/12/16	0.66		0.05		0.45		1.16
HW-SB-11	HW-SB-11-S-P-10	9-10	7/12/16	0.77		0.01	U	0.33		1.12
HW-SB-12	HW-SB-12-S-P-12	11-12	7/12/16	2.64		0.12		0.49		3.25
HW-SB-13	HW-SB-13-S-P-11	10-11	7/12/16	2.22		0.10		0.42		2.74

pCi/g = picocuries per gram
U = Result is less than sample-specific minimum detectable concentration (MDC)
LT = Result is less than requested MDC, greater than sample-specific MDC
N/A= not applicable
ft = feet
bgs = below ground surface
^{234}U = uranium-234
^{235}U = uranium-235
^{238}U = uranium-238
Total U = total uranium, or the sum of the three individual uranium isotope concentrations

9.0 CONSTRUCTION QUALITY CONTROL

The purpose of the Construction Quality Control on this project was to provide for the necessary oversight of the different phases of work, define project communication, documentation, and recordkeeping procedures and to establish quality control (QC) procedures, including the necessary supervision and tests, to ensure that the work met applicable requirements. The site QC Manager ensured that the activities conducted at Site complied with the *Supplemental Radiological Survey Plan* (Appendix B), other applicable Cabrera project plans, licenses, and programs, and other federal, state, and local requirements.

9.1 DAILY QUALITY CONTROL REPORTS

Daily QC reports (DQCRs) were prepared every day by the Contractor Quality Control Systems Manager during field work and sent electronically to the Project Manager, UNC personnel, and other stakeholders. All significant events that occurred daily during the Characterization Survey were documented and included in the report. Significant project events, including daily progress, site visitors' contact information, and decisions regarding field activities, were noted daily and were used in preparing the DQCRs at the conclusion of the work day. The DQCRs generated during field work are attached in Appendix H.

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10.0 RADIATION PROTECTION

Cabrera implemented radiation protection measures as outlined in the RPP (Cabrera, 2014a) and supported by Cabrera's RSP (Cabrera, 2014b). Cabrera operating procedures that are referenced within the RPP (Cabrera, 2014a) and this report are radiological procedures from the RSP. The purpose of the RSP and RPP were to protect remediation worker health and safety during remediation activities and minimize impact on the environment and the general public. The Site Radiation Safety Lead (SRSL) for the remediation efforts ensured that contamination control activities were effective, samples and areas were not cross-contaminated, that occupational doses were maintained ALARA, workers and the environment were protected and that activities complied with requirements in the RPP.

10.1 RADIATION WORK PERMITS AND POSTINGS

Radiation work permits (RWPs) were issued, as specified in the RPP (Cabrera, 2014a), to provide work controls within Radiation Control Areas (RCAs) by specifying radiation dose levels (direct, contamination, and airborne levels), personal protective equipment, training, dosimetry and special work tools or requirements. Those controls, along with management monitoring of work practices and doses, assured that remediation personnel worked safely in areas having elevated levels of ionizing radiation or contamination. Copies of RWPs are included in Appendix J.

RCAs were marked using rad rope and posted in accordance with the *RPP* (Cabrera, 2014a). All temporary radiological controls and postings were removed prior to demobilization.

10.2 RADIATION DETECTION INSTRUMENTATION

Instrumentation was used during the project to detect and measure alpha, beta and gamma ionizing radiation to support characterization activities. Equipment was calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy and precision of the equipment/instruments are maintained. Survey and counting instruments were source-checked daily and instrument performance used to count wipe samples was tracked on control charts. Daily source counts were handled in accordance with the RPP (Cabrera, 2014a) and RSP (Cabrera, 2014) procedures. Calibration certificates and daily QC calibration checks of all instrumentation and National Institute of Standards and Technology (NIST) traceable radiological sources used during this project are presented in Appendix K.

Three categories of radiation detection instrumentation were used on the project – direct radiation measurement equipment, contamination measuring equipment, and airborne measurement equipment. The equipment probes listed below was calibrated with a variety of meters to provide different characteristics and monitoring capabilities. Some equipment was used for multiple purposes. Direct radiation and contamination measurement instruments used on the project included:

- Ludlum FIDLER NaI Gamma Scintillation probes capable of detecting X- and gamma radiations
- Model G1 1" X 1" NaI probe capable of detecting gamma radiations
- Ludlum 2929 smear counters equipped with 43-10-1 alpha-beta scintillation detectors capable of detecting alpha and beta levels on contamination smears

Airborne radioactivity measurement instrumentation used on the project included:

- SKC breathing zone (BZ) lapel air samplers [0 – 5 liters per minute (lpm)] to collect airborne radioactive particulate contaminants in a worker's BZ
- LV-1 low volume air samplers (0 – 100 lpm) to collect airborne radioactive particulate contaminants and for work zone sampling
- Ludlum 2929 counter with 43-10-1 alpha-beta scintillation detector capable of detecting alpha and beta levels collected on airborne radioactivity filters

Instrumentation for personnel and equipment frisking and wipe counting included:

- Ludlum Model 3 Ratemeter coupled with a Ludlum Model 44-9 pancake Geiger Mueller detector
- Ludlum Model 2360 coupled with 43-93 scintillation probe
- Ludlum 2929 counter with 43-10-1 alpha-beta scintillation detector.

Radiation surveys and monitoring were performed to evaluate removable contamination (i.e., smears) and fixed radioactivity (i.e., direct measurements) as applicable. The surveys and monitoring consisted of direct measurements for total radioactivity and wipe surveys for removable contamination in accordance with the RPP (Cabrera, 2014a).

10.3 RADIATION SURVEYS AND MONITORING

Radiation surveys were performed on equipment and personnel prior to leaving RCAs. Acceptable surface contamination levels used during characterization activities are presented in the RPP (Cabrera, 2014a).

Routine radiation surveys evaluated on-site laboratory floors and desks, office floors and desktops, break area floor and tabletops, and other work spaces used by personnel to ensure that contamination controls were adequate.

Radiation surveys were approved by the SRSL after completion and were stored in the on-site project files.

10.4 PERSONAL AND PERIMETER AIR MONITORING

Work activities related to the handling of waste materials and debris by personnel or equipment traffic over contaminated surfaces presented the greatest potential for generation of radiological airborne hazards. Therefore, ambient air monitoring was conducted during the survey to assess the potential for off-site effluent airborne concentrations of gross alpha activity. Low volume air samplers and BZ air samplers were used to evaluate effluent, work area, and personal activity levels.

The action level concentrations were set to 20% of the values published in Columns I & II of Table 2 of 10 Code of Federal Regulations (CFR) 20 Appendix B per the RPP (Cabrera, 2014a). The raw Appendix B values are equivalent to the radionuclide concentrations which if inhaled or ingested continuously over the course of a year would produce a total effective dose equivalent of 50 mrem/yr. The reduction to 20% of these values allows consistency with the USEPA's 10 mrem/yr standard for effluent releases published in 40 CFR Part 61, Sections 92 and 102 (USEPA, 1999).

All air sampling results were below 20% of the Chapter 10 United States Code of Federal Regulations Subpart 20 Appendix B occupational limits (USNRC, 2006), which are included in the table below. Specific air sampling results and calculations are presented in Appendix J.

Table 10-1. UNC Site Contaminant Air Effluent and Occupational Derived Air Concentration (DAC) Values

ROC	Air Effluent Values (µCi/ml)[1]	Occupational Values (DAC) (µCi/ml)
^{234}U	1.0E-14 (Class Y)	2.00E-11
^{235}U	1.25E-14 (Class Y)	2.00E-11
^{238}U	1.25E-14 (Class Y)	2.00E-11

Notes: 1) µCi/ml = microcuries per milliliter. Air effluent limits set at 20% of the values published in Columns I & II of Table 2 of 10 Code of Federal Regulations 20 Appendix B per the RPP (Cabrera, 2014a).

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11.0 QUALITY ASSURANCE/QUALITY CONTROL

The purpose of the Quality Assurance (QA)/QC program was to produce analytical measurement data of known quality that satisfied the project DQOs. Overall QA/QC for the Characterization Survey portion of the decommissioning process at the Site was achieved through a combination of the following:

- Project management oversight and direction
- Adherence to approved plans and procedures
- Audits/surveillances of operations
- Qualifications and training of staff
- Use of appropriate instrumentation calibrated in accordance with industry standards using NIST-traceable radioactive sources and routinely tested to assure proper function
- Data review and evaluation for adequacy in type, quality, and quantity to satisfy requirements for each SU
- Independent review of calculations and results for accuracy
- Verification of sample analysis results received from off-site laboratory

11.1 ONSITE INSTRUMENTATION

On site instrumentation included alpha/beta smear-sample counters and field survey instruments. These instruments were selected and operated to meet the minimum requirements established in Cabrera operating procedures. All instrumentation was calibrated in accordance with standard operating procedures or manufacturer’s recommendations, using NIST-traceable radioactive sources. Calibration and maintenance records are maintained for each instrument used to perform characterization measurements and analyses. Calibration certificates for all instruments are presented in Appendix K.

11.1.1 Alpha/Beta Sample Counters

Smears for removable alpha activity on exterior solid surfaces were analyzed with a Ludlum model 43-10-1 zinc sulfide scintillation detector paired with a Ludlum model 2929 dual-channel scaler, an instrument capable of simultaneous analysis of alpha and beta radioactivity on media such as smears. This instrument was calibrated with NIST-traceable thorium-230 (^{230}Th) alpha and technetium-99 (^{99}Tc) beta sources.

11.1.2 Quality Assurance/Quality Control

Quality control criteria established for instrumentation and daily performance checks were conducted prior to using instrumentation on a daily basis. QC criteria included establishing a mean source count rate using a radioactive source in a reproducible geometry, standard deviation and multiples of the standard deviation (two and three times the standard deviation of the mean) to define control limits. QC performance checks included analysis of the check source in the same counting geometry and comparison of the result with the QC criteria. Typically, the daily

performance QC checks should fall within the mean plus two standard deviations which demonstrate acceptable performance. Whenever a daily performance check fell outside the mean plus two standard deviations but within the mean plus three standard deviations the result would be flagged as “questionable.” Measurements following a questionable QC measurement were reviewed to ensure a trend adverse to performance did not occur. Daily performance checks that fall outside the mean plus three standard deviations resulted in an instrument being removed from service. All daily performance checks fell within criteria. In instances where adverse instrument performance was noted during normal use, steps were taken to restore the instrument to full working condition prior to returning it to service (e.g., mylar window replacement, battery replacement, recalibration, etc.) Complete QC instrument records are presented in Appendix K.

11.1.3 Field Instrumentation

Field instrumentation used for the characterization survey included a Bicron model G5 FIDLER detector for soil core scanning, , Ludlum model 43-93 scintillation detector paired with a model 2224-1 or model 2360 dual-channel scaler/ratemeter for alpha/beta activity scans and static measurements, and a Bicron G1 1x1 NaI for downhole gamma logging.

Floor surveys were conducted using an Ludlum 43-37 large are gas proportional alpha/beta detector coupled with a Ludlum 2360 dual-channel scaler/ratemeter.

FIDLER detectors and Bicron MicroRem survey meters were calibrated to ^{137}Cs and response checked using a ^{137}Cs source. Alpha/beta radioactivity detectors were calibrated using NIST-traceable ^{230}Th and ^{99}Tc sources. Daily performance check (QC) criteria were established and performed in a manner similar to that for the alpha/beta smear sample counter. Complete QC instrument results are presented in Appendix K.

Field instrumentation was operated in accordance with the criteria established in Section 6.0, including scan speed for surface activity scanning instrumentation and measurement times for direct surface activity measurements.

11.1.4 Onsite Laboratory Sample Analysis

Samples were counted onsite at the on-site lab using a Canberra Broad Energy Germanium high-purity germanium detector utilizing its integrated lead collimator to reduce noise from background radioactivity. Utilizing the low background collimator gave the allowed samples to be counted in an acceptably low onsite background environment. A europium-152 (^{152}Eu) gamma calibration source was utilized for initial instrument set-up and routines QC measurements every day that the gamma spectroscopy system was in use on-site. Three separate QC parameters for three different photon energy ranges (i.e., nine total parameters) were used each day in operation to ensure the unit was functioning within design parameters. These parameters are as follows:

- Photopeak energy for low, medium, and high-energy photons (121.7 kiloelectron volts [k ev], 964 kev and 1407.92 kev)
- Full-width half-maximum for low, medium, and high-energy photons

- Decay corrected activity for low, medium, and high-energy photons

Quality control criteria included establishing a benchmark, target value for each of the nine parameters above using the ^{152}Eu source in a reproducible geometry, and performing ten initial measurements of the source. These ten measurements were used to establish a standard deviation and multiples of the standard deviation (two and three times the standard deviation of the mean) to define control limits. Quality control performance checks included analysis of the check source in the same counting geometry and comparison of the result with the QC criteria. Typically, the daily performance QC checks fell within the mean plus two standard deviations which demonstrated acceptable performance. Whenever a daily performance QC check fell outside the mean plus two standard deviations but within the mean plus three standard deviations the result was flagged as “questionable.” Measurements following a questionable daily performance check were reviewed to assure a trend adverse to performance was not occurring.

Daily performance QC checks were not outside of two and/or three standard deviations of the established target values during field activities where repeating the QC measurement did not correct the instrument response in compliance with Cabrera’s OP-429, *Gamma Spectroscopy Operations*, *Rev 5*. Complete gamma spectroscopy QC results are presented in Appendix K.

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12.0 CONCLUSIONS

The purpose of this survey was to confirm and supplement past surveys and sampling efforts in three specific areas of interest:

- Interior H-Tract Building (3H/6H) wall, floor, and overhead surfaces
- Intact ventilation ductwork within 3H/6H and;
- Subsurface soils underneath the footprint of former Buildings 9H/10H/11H.

During Cabrera's survey activities, a portion of upper walls and ceilings in Building 3H/6H were added to the scope of the survey. These survey results data were used by UNC and Site stakeholders to augment and/or confirm historical measurements and support future site characterization, remediation, or release decisions.

12.1 CHARACTERIZATION SURVEY RESULTS

Supplemental characterization surveys have been completed in accordance with the requirements specified in the *Supplemental Radiological Survey Plan* (Appendix B). The results were then used to verify the DQOs were achieved for each survey area. Results are described in the following sections.

12.1.1 Building 3H/6H Floor

During the floor scanning survey, several metallic items containing HEU were discovered in Building 3H on the floors, often in and around piles of dirt and debris. To complete the supplemental surveys, it was necessary to perform some limited general housekeeping and waste clearing inside the building to provide access to more of the floor surfaces. Wastes consisted of ACM abatement materials, loose building debris, empty and partially filled drums, trash, and other larger debris. ACM abatement was performed in accordance with Connecticut Department of Public Health requirements. Wastes were carefully loaded into IMCs and shipped off-site to EnergySolutions in Clive, Utah.

Floor surveys consisted of gamma and alpha-beta scanning measurements. Follow-up investigations consisted of gamma static and alpha-beta smear measurements at biased locations. Approximately 164 gamma activity measurements on the floor exceeded the gamma investigation level (12,200 cpm). There were no integrated alpha-beta floor scans or smear measurements that exceeded the $DCGL_W$ (<5,000 dpm/100cm^2 [total alpha + total beta] and <1,000 dpm/100 cm^2 [removable alpha + removable beta]) above background. The presence of elevated gamma above the investigation level without significantly elevated surface alpha/beta readings is an indicator of residual subsurface radioactivity, contamination that was possibly missed during the original license decommissioning. Alternatively, the floor surfaces may have had additional paint/concrete layers applied to resolve contamination control issues during historic facility operations leaving radioactive contamination trapped between floor layers and undetectable using alpha/beta survey instruments.

12.1.2 Building 3H/6H Walls and Ceiling

Wall and ceiling scans consisted of alpha-beta static measurements. A total of 66 alpha-beta static measurements exceeded the $DCGL_W$. No smear measurements exceeded the $DCGL_W$. Gamma dose rates were consistent with background in all survey areas (i.e. 7-9 uR/hr). Most of the elevated activity above background was noted on the lower walls and on upper horizontal surfaces (i.e. steel beams, crane rails, conduit, lights, etc.). There are indications that contaminated surfaces were painted over reducing alpha/beta scan measurement sensitivity; smear measurements were collected on the outermost surface.

Pipe scale samples were collected from two pipes that were made accessible as a result of debris removal. One pipe was located in the former Chemistry laboratory. The other pipe was located in the eastern end of Building 3H. The total U concentrations were 122,640 pCi/g and 246 pCi/g, respectively. The pipe scale concentration collection from the former Chemistry laboratory exceeded the volumetric criteria of 435 pCi/g. Both piping systems are radiologically impacted warranting more careful assessment and/or removal and disposal as radioactive waste. A total of 66 integrated alpha-beta wall scans exceeded the $DCGL_W$ (<5,000 dpm/100cm^2 [total alpha + total beta]).

12.1.3 Building 3H Ductwork System

Cabrera performed a survey of the ductwork system in Building 3H during the initial mobilization to the Site in the summer of 2016. Surveys consisted of alpha-beta integrated scans, alpha-beta static measurements, and alpha-beta smear measurements. Cabrera accessed the internal surfaces of the dilapidated Building 3H/6H ventilation system at 13 openings along the ductwork. Surveys were comprised of scans and static alpha/beta measurements and smears. All initial results were below the $DCGL_W$ but, noticeably elevated above area background conditions indicating greater levels of internal radioactivity could be present in other currently inaccessible portions of the 3H/6H overhead ventilation system. Stakeholders agreed to have Cabrera carefully remove the remaining ductwork as part of radiologically impacted debris removal facilitating greater access to areas of concern in the overhead.

12.1.4 Former 9H/10H/11H Building Locations

Six borings were advanced within the former Building 11H Metallurgy Laboratory footprint (ML-SB-01 through ML-SB-06) and seven borings were performed within the former Building 10H Hot Waste Processing area footprint (HW-SB-07 through HW-SB-13, refer to Figure 6-1, Appendix A). Cabrera performed DGL and scanning of intact soil cores using a FIDLER NaI detector to select sample intervals to be sent off-site for analysis.

The DGL and soil core scanning results were consistent with background levels. Soil samples were selected at the interval directly below the concrete floor slab (or rubble, if the floor slab was not encountered) to determine if the soils beneath the former building foundations had residual radioactivity as a result of potential surficial contamination on the concrete. All soil samples were consistent with background uranium concentrations.

12.2 CONCLUSIONS

There is extensive radioactive contamination on the floor of Building 3H. Several pieces of radioactive metal containing HEU were encountered during the surveys inside the building. The full extent of the contamination could not be accurately quantified in this report due to the existence of various floor coverings. Residual radioactivity was most likely historically covered by concrete pours as a method of contamination control.

There is minimal radioactive contamination on the floors of Building 6H.

There is extensive radioactive contamination on the walls and upper horizontal surfaces in Building 3H. Bare surfaces that have not been painted, such as steel supports, conduit, unpainted cinder block walls, and overhead lights, showed alpha and beta contamination in excess of the $DCGL_W$. Surfaces that were painted (i.e. cinder block walls) showed higher activity as paint was removed, indicating that the paint was used to cover historical contamination as a method of contamination control.

There is minimal radioactive contamination on the walls of Building 6H. The only contamination found was located on the walls and overhead surfaces in the eastern end of Building 6H (i.e. close to Building 3H).

Pipe scale samples collected from two pipes (one in Building 6H, one in Building 3H) that entered the South Trench and eventually the soils south of the building contained ^{235}U contamination. Further investigation should be conducted of other piping inside the buildings.

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APPENDIX A

Figures

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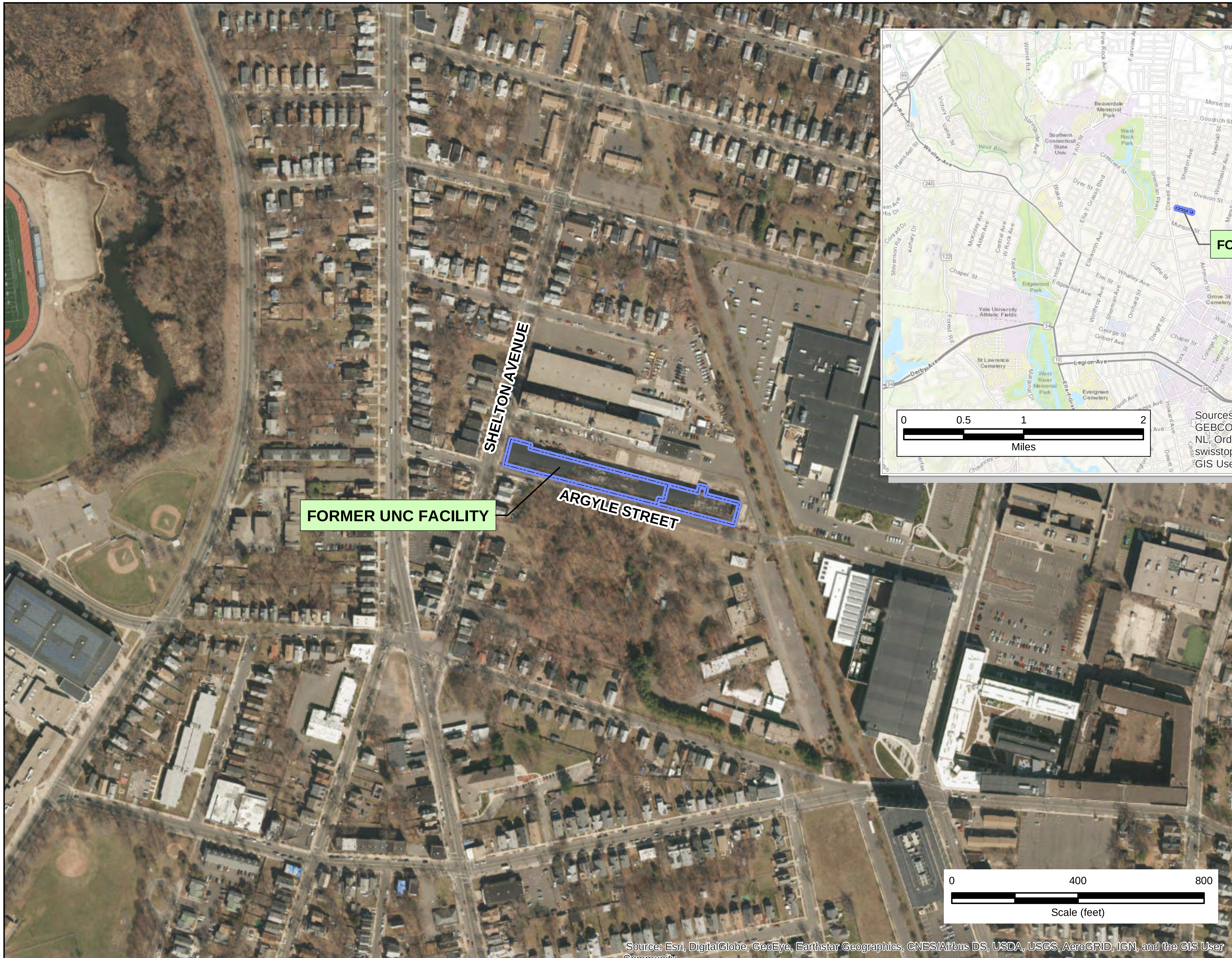


Legend

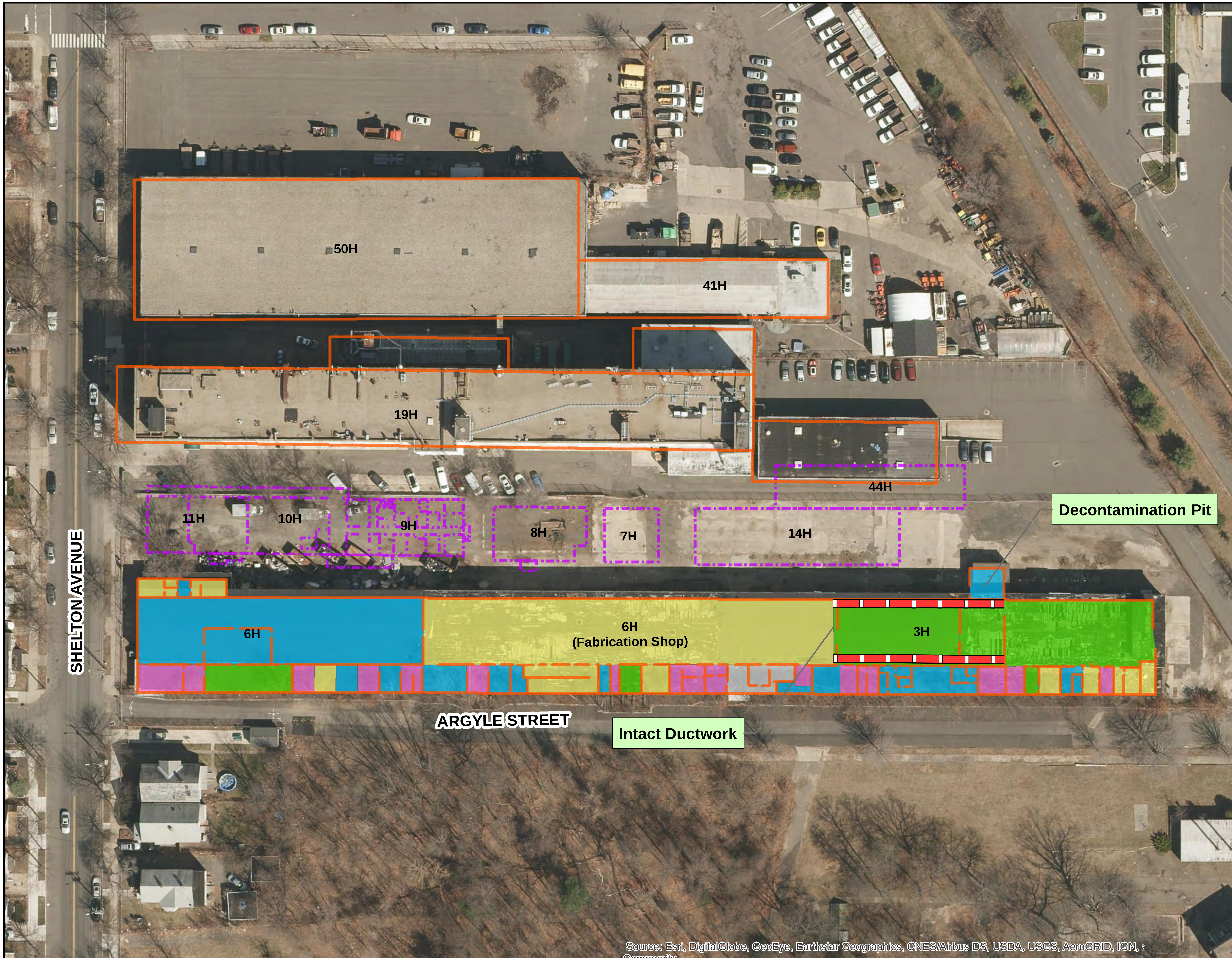
Former UNC Facility

SITE LOCATION

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 1-1

CABRERA SERVICES
CHALLENGE ACCEPTED



Legend

Intact Ductwork

Buildings

Existing Building

Demolished Building

Accessible Area

Percent

0 to 25%

>25 to 50%

>50 to 75%

>75 to 100%

Unknown

0 80 160

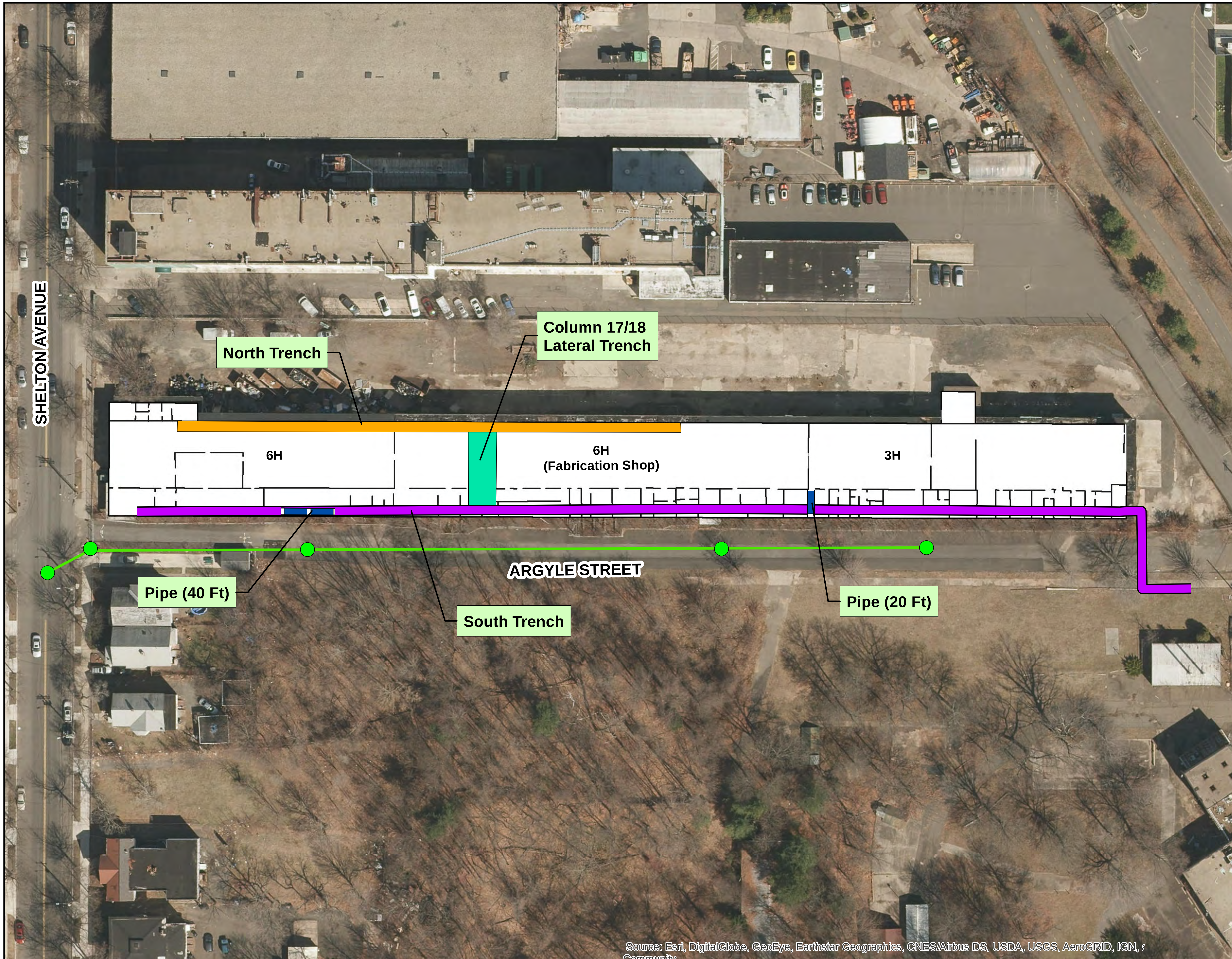
Scale (feet)

BUILDING 3H/ 6H
ACESSIBLE AREA

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 1-2

CABRERA SERVICES
CHALLENGE ACCEPTED



Legend

- Pipes Included in Survey
- North Trench
- South Trench
- Column 17/18 Lateral Trench
- Sewer Line
- Sewer Manhole
- Columns
- Building

0 80 160
Scale (feet)

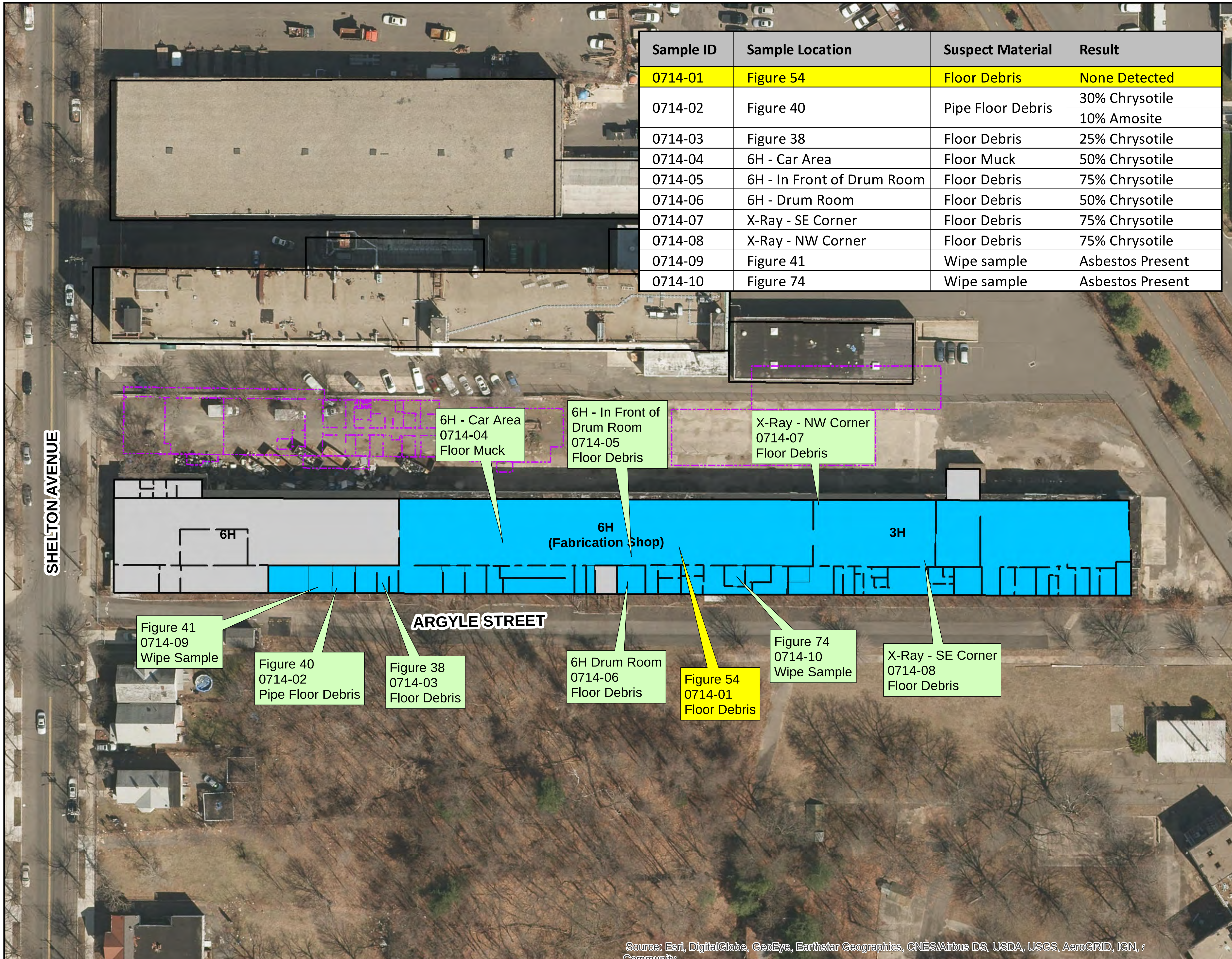
BUILDING 3H/ 6H
UTILITY TRENCHES

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 1-3

CABRERA SERVICES
CHALLENGE ACCEPTED

Sample ID	Sample Location	Suspect Material	Result
0714-01	Figure 54	Floor Debris	None Detected
0714-02	Figure 40	Pipe Floor Debris	30% Chrysotile 10% Amosite
0714-03	Figure 38	Floor Debris	25% Chrysotile
0714-04	6H - Car Area	Floor Muck	50% Chrysotile
0714-05	6H - In Front of Drum Room	Floor Debris	75% Chrysotile
0714-06	6H - Drum Room	Floor Debris	50% Chrysotile
0714-07	X-Ray - SE Corner	Floor Debris	75% Chrysotile
0714-08	X-Ray - NW Corner	Floor Debris	75% Chrysotile
0714-09	Figure 41	Wipe sample	Asbestos Present
0714-10	Figure 74	Wipe sample	Asbestos Present



Legend

ACM Abatement

- ACM Abatement Required
- ACM Abatement Not Required
- Existing Building
- Demolished Building

0 80 160

Scale (feet)

BUILDING 3H/ 6H
ACM ABATEMENT

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 5-1

CABRERA SERVICES
CHALLENGE ACCEPTED

Legend

- Soil Boring Location
- Existing Building
- Demolished Building

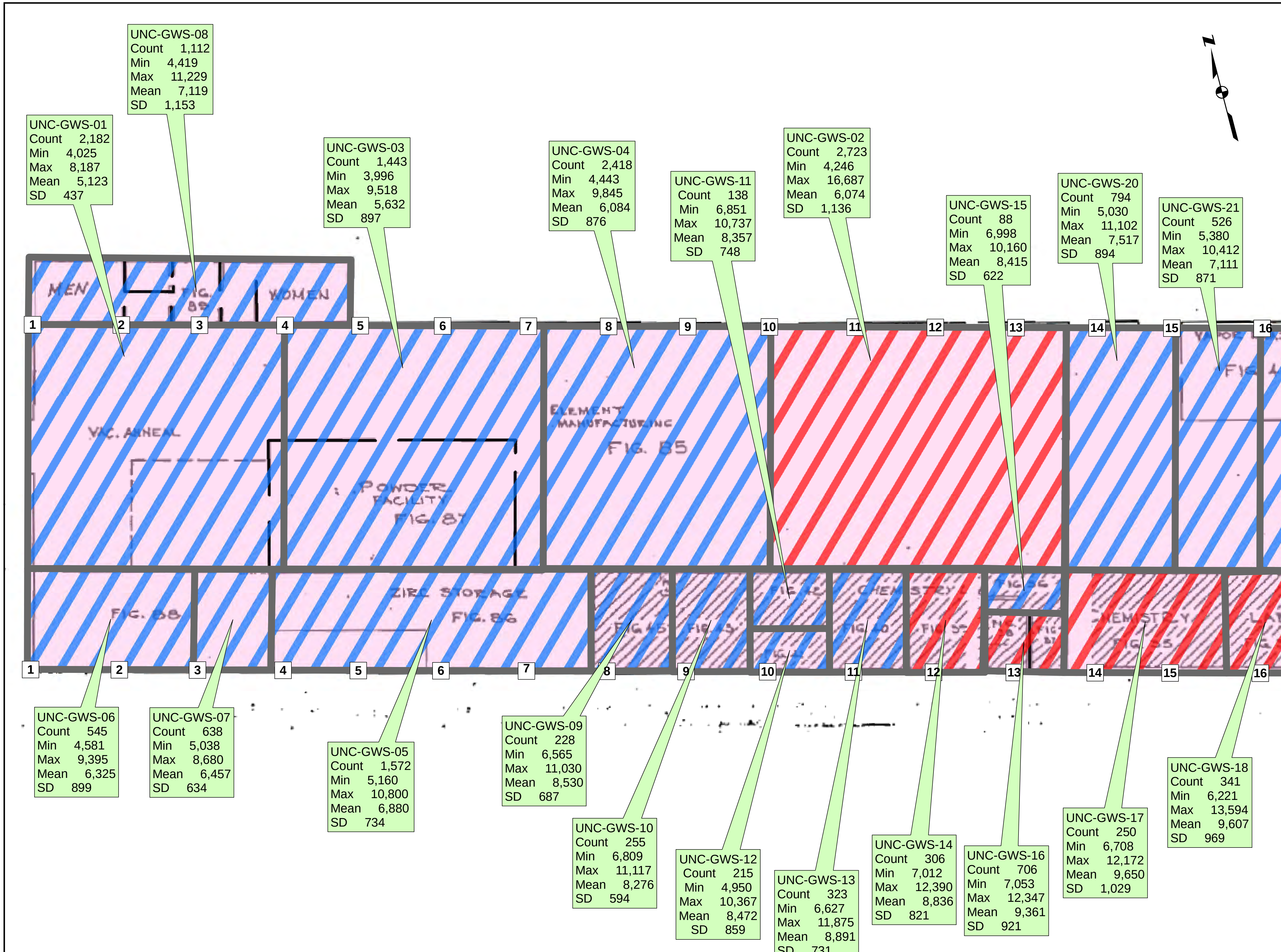
0 20 40
Scale (feet)

BUILDING 9H/ 10H/ 11H
SOIL BORING LOCATIONS

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 6-1

CABRERA SERVICES
CHALLENGE ACCEPTED



BUILDING 6H WEST

Legend

Area of Elevated Gamma Activity

GWS Scan Area Results

(Max cpm)

< 11,999.9

> 12,000 (IL)

Building 3H

Building 6H

Building Columns

Note: Survey performed with Ludlum 2360/ FIDLER. Survey results are in counts per minute (cpm).

0 20 40

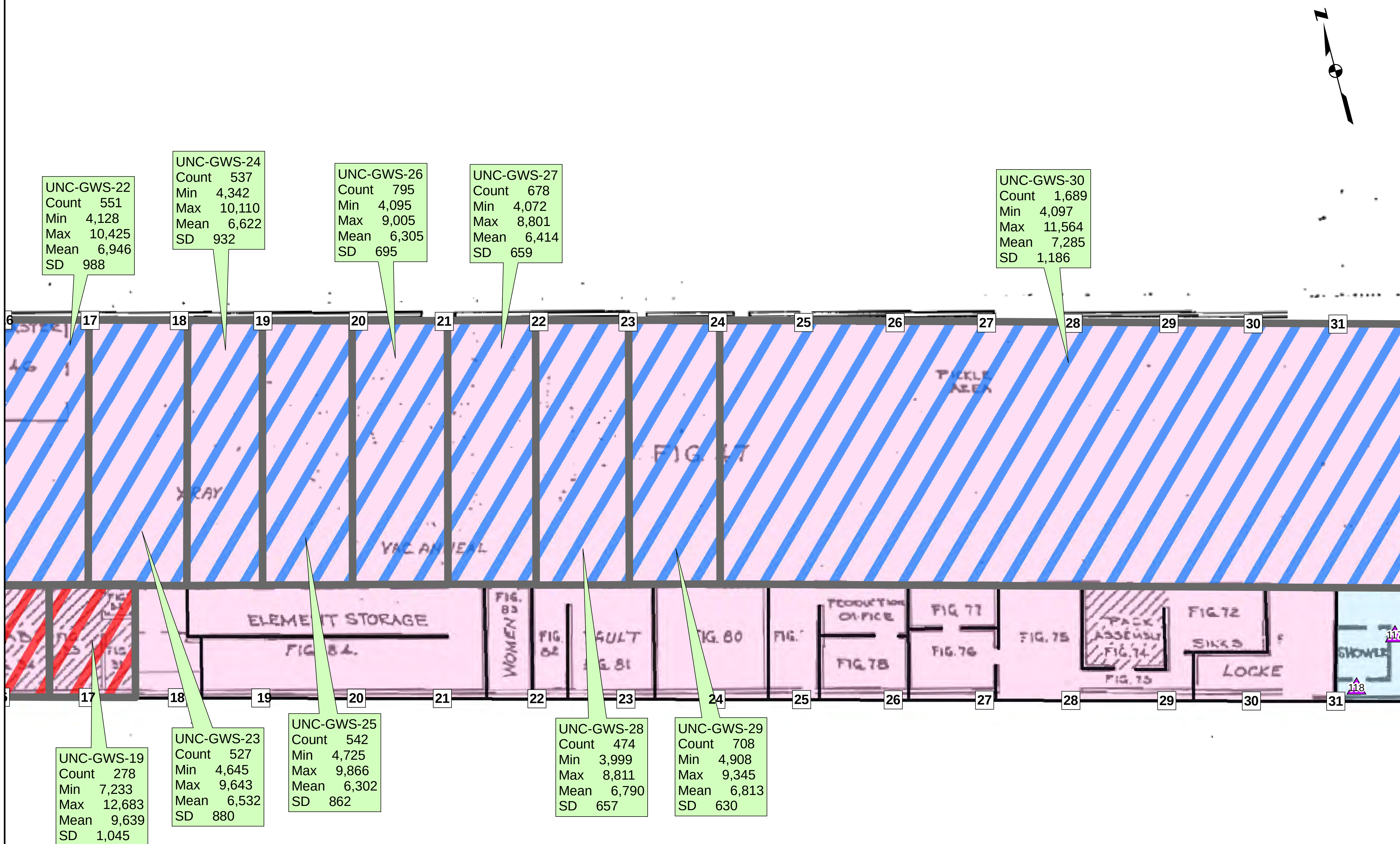
Scale (feet)

GAMMA WALKOVER SURVEY SCAN AREA RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-1

CABRERA SERVICES CHALLENGE ACCEPTED



Legend

Area of Elevated Gamma Activity

GWS Scan Area Results

(Max cpm)

< 11,999.9

> 12,000 (IL)

Building 3H

Building 6H

Building Columns

Note: Survey performed with Ludlum 2360/ FIDLER. Survey results are in counts per minute (cpm).

0 20 40

Scale (feet)

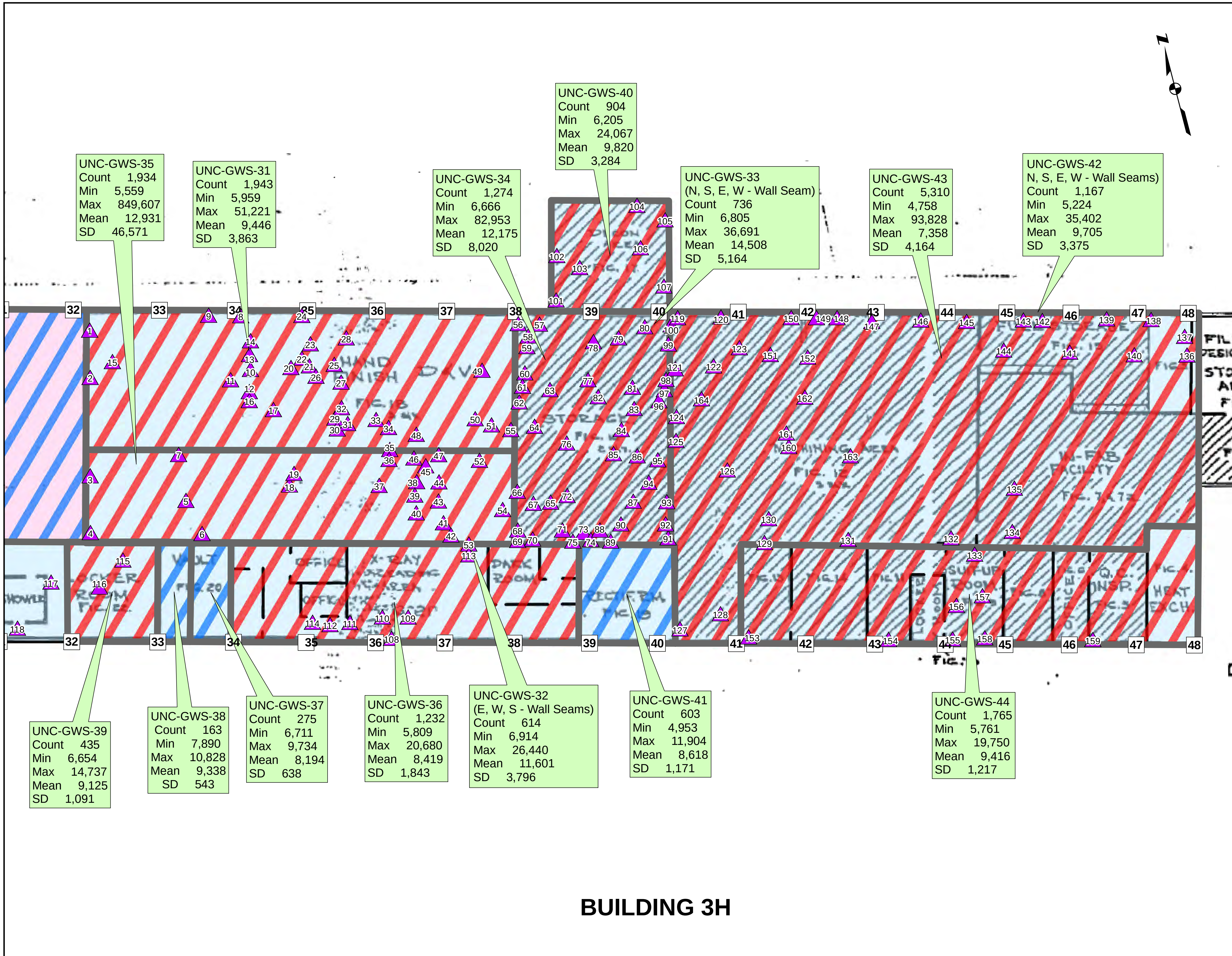
GAMMA WALKOVER SURVEY SCAN AREA RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-2

CABRERA SERVICES
CHALLENGE ACCEPTED

BUILDING 6H CENTER



Legend

▲ Area of Elevated Gamma Activity

GWS Scan Area Results

(Max cpm)

- < 11,999.9
- > 12,000 (IL)
- Building 3H
- Building 6H
- Building Columns

Note: Survey performed with Ludlum 2360/ FIDLER. Survey results are in counts per minute (cpm).

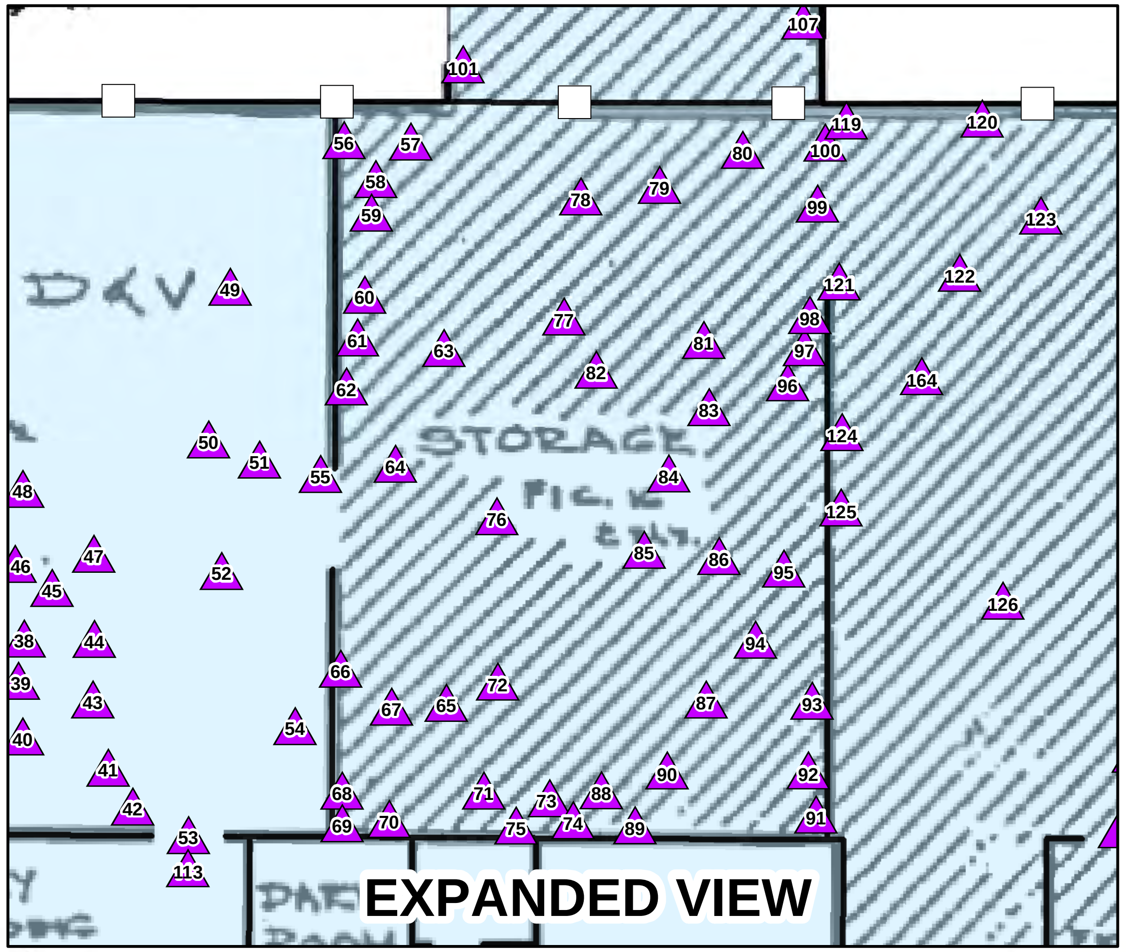
0 20 40
Scale (feet)

GAMMA WALKOVER SURVEY SCAN AREA RESULTS

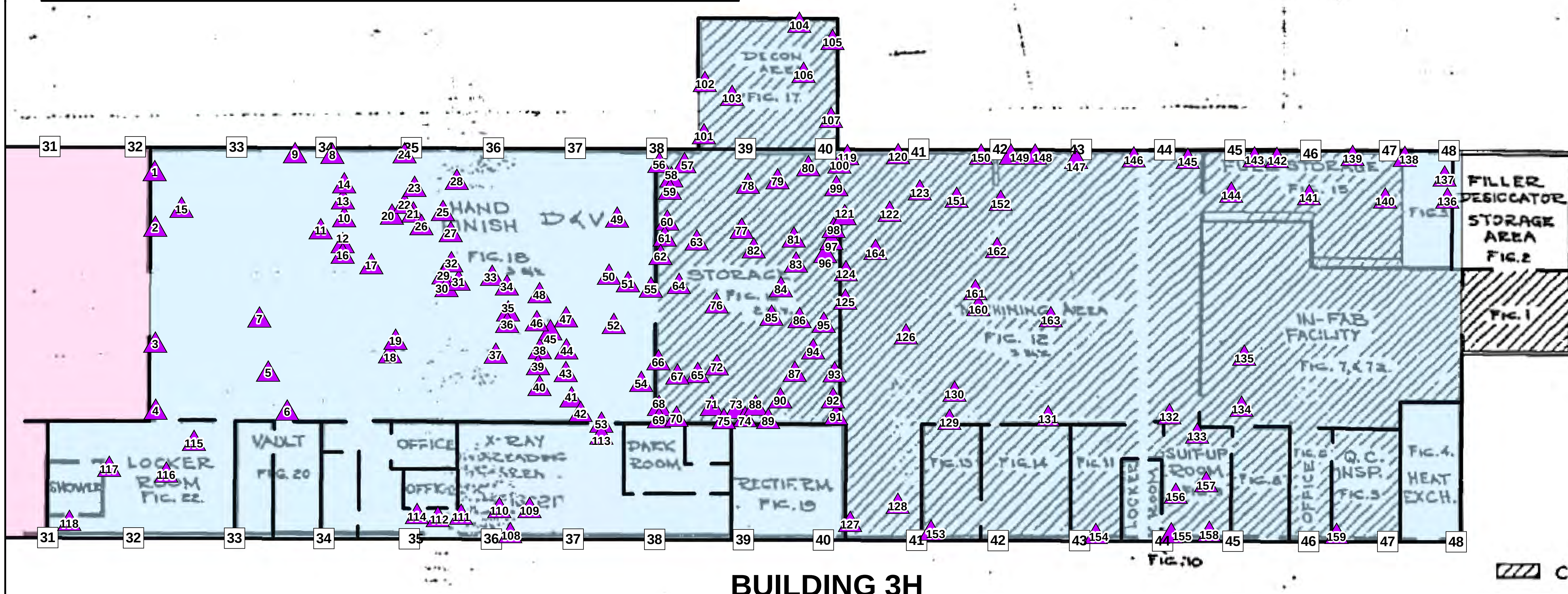
FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-3

CABRERA SERVICES
CHALLENGE ACCEPTED



Location ID	Direct Gamma Static Measurement (cpm)	Location ID	Direct Gamma Static Measurement (cpm)	Location ID	Direct Gamma Static Measurement (cpm)	Location ID	Direct Gamma Static Measurement (cpm)
1	22,450	42	18,104	83	15,545	124	18,219
2	12,826	43	55,507	84	15,500	125	51,305
3	26,204	44	134,326	85	84,735	126	28,685
4	50,397	45	45,019	86	29,874	127	18,158
5	10,168	46	27,420	87	18,000	128	13,241
6	37,620	47	32,343	88	20,540	129	24,455
7	27,769	48	21,457	89	25,001	130	81,598
8	37,771	49	12,681	90	20,000	131	11,653
9	30,372	50	18,417	91	25,747	132	12,914
10	63,744	51	15,361	92	31,569	133	18,243
11	29,507	52	16,425	93	31,829	134	11,914
12	39,965	53	45,405	94	25,151	135	12,417
13	65,104	54	14,466	95	74,071	136	20,812
14	14,849	55	23,441	96	40,000	137	16,247
15	28,002	56	25,416	97	19,241	138	14,941
16	50,608	57	18,399	98	24,000	139	24,987
17	54,370	58	15,000	99	20,257	140	12,224
18	46,203	59	16,000	100	27,050	141	16,628
19	27,151	60	1,580	101	16,354	142	36,257
20	74,218	61	28,792	102	14,000	143	28,914
21	60,581	62	20,254	103	15,333	144	11,122
22	43,783	63	12,000	104	21,640	145	23,909
23	68,335	64	18,000	105	16,000	146	16,372
24	31,712	65	40,078	106	16,147	147	23,192
25	13,777	66	24,529	107	32,133	148	18,177
26	20,001	67	18,400	108	53,507	149	16,991
27	13,647	68	19,452	109	14,685	150	35,016
28	17,722	69	22,779	110	17,577	151	39,129
29	52,416	70	35,486	111	24,356	152	68,214
30	38,747	71	14,000	112	16,971	153	11,447
31	65,098	72	25,127	113	27,412	154	13,214
32	23,430	73	50,277	114	21,909	155	20,234
33	19,870	74	92,749	115	19,417	156	27,439
34	16,701	75	26,000	116	36,520	157	13,149
35	38,476	76	18,000	117	23,575	158	18,176
36	46,015	77	16,000	118	14,179	159	13,449
37	37,795	78	32,000	119	19,063	160	18,336
38	38,330	79	18,000	120	21,107	161	17,183
39	98,364	80	54,847	121	25,017	162	17,133
40	21,455	81	55,859	122	18,378	163	18,192
41	15,462	82	17,177	123	36,277	164	27,113



Legend

- ▲ Area of Elevated Gamma Activity
- Building 3H
- Building 6H
- □ Building Columns

Note: Survey performed with Ludlum 2360/ FIDLER. Survey results are 1-min direct static counts in counts per minute (cpm).

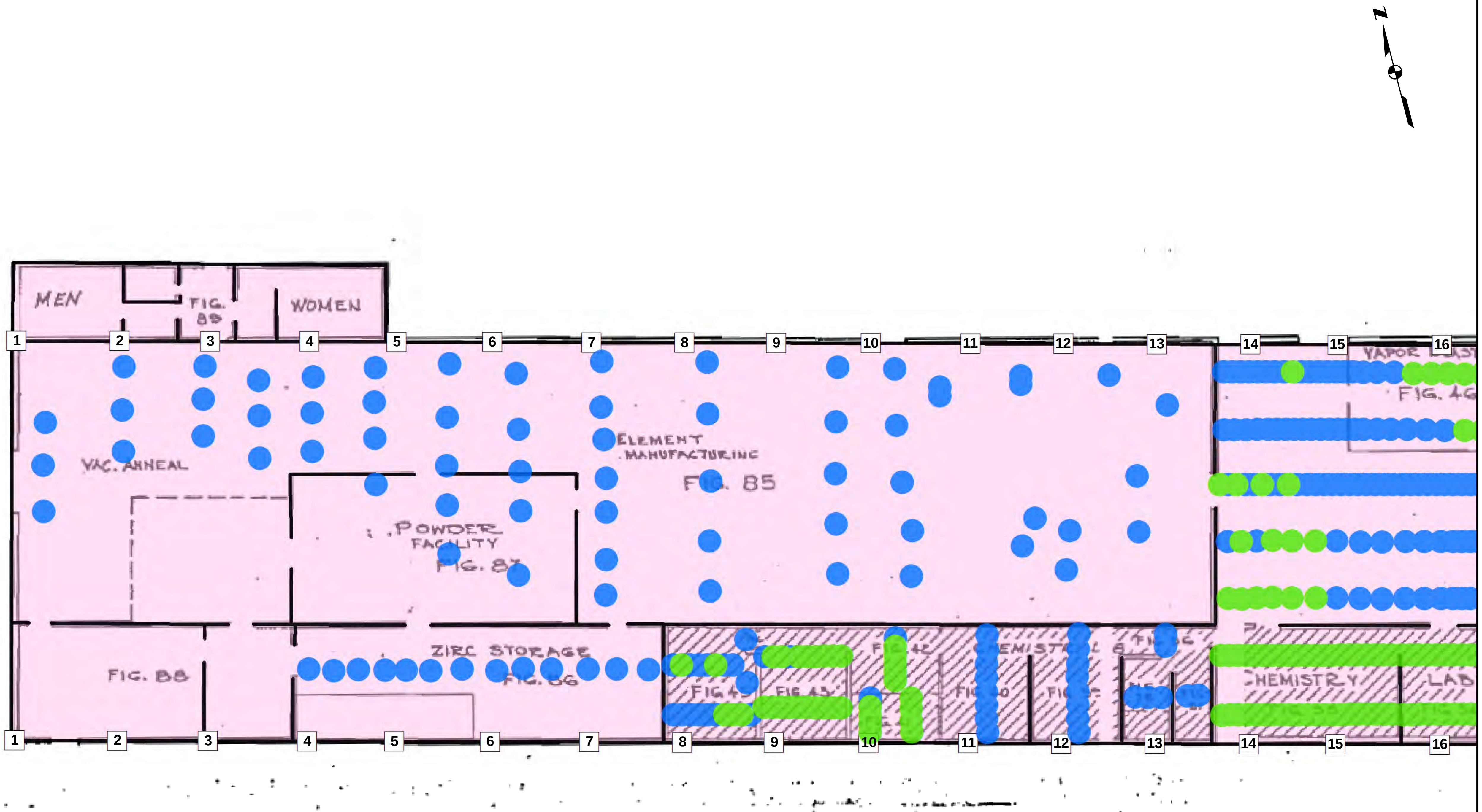
0 20 40
Scale (feet)

LOCATIONS OF ELEVATED GAMMA ACTIVITY

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-4

CABRERA SERVICES
CHALLENGE ACCEPTED



BUILDING 6H WEST

Legend

Area of Elevated Gamma Activity

Floor Scan Results

(Alpha + Beta dpm/100 cm2)

- < 99.9
- 100 - 2,499.9
- 2,500 - 4,999.9
- > 5,000
- Building 3H
- Building 6H
- Building Columns

Note: Survey performed with Ludlum 2360/ 43-37. All measurements are 1-min integrated scans. Survey results represent the centroid of the area scanned during the 1-min interval.

0 20 40

Scale (feet)

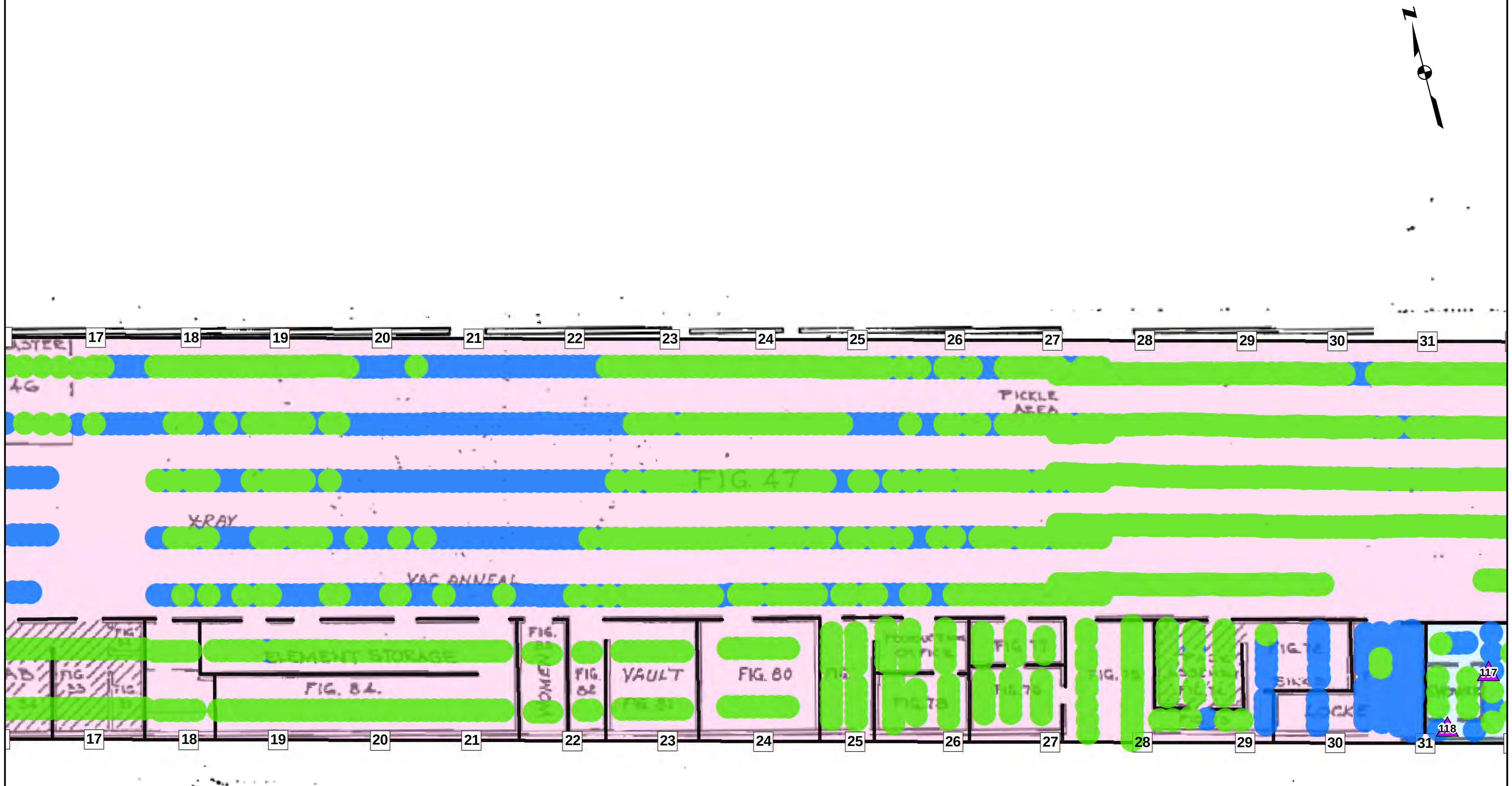
ALPHA-BETA FLOOR SCAN SURVEY RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-5

CABRERA SERVICES

CHALLENGE ACCEPTED



BUILDING 6H CENTER

Legend

Area of Elevated Gamma Activity

Floor Scan Results

(Alpha + Beta dpm/100 cm2)

< 99.9

100 - 2,499.9

2,500 - 4,999.9

> 5,000

Building 3H

Building 6H

Building Columns

Note: Survey performed with Ludlum 2360/ 43-37. All measurements are 1-min integrated scans. Survey results represent the centroid of the area scanned during the 1-min interval.

0 20 40

Scale (feet)

ALPHA-BETA FLOOR SCAN SURVEY RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-6

CABRERA SERVICES
CHALLENGE ACCEPTED

BUILDING 3H

Legend

Area of Elevated Gamma Activity

Floor Scan Results

(Alpha + Beta dpm/100 cm2)

- < 99.9
- 100 - 2,499.9
- 2,500 - 4,999.9
- > 5,000
- Building 3H
- Building 6H
- Building Columns

Note: Survey performed with Ludlum 2360/ 43-37. All measurements are 1-min integrated scans. Survey results represent the centroid of the area scanned during the 1-min interval.

0 20 40

Scale (feet)

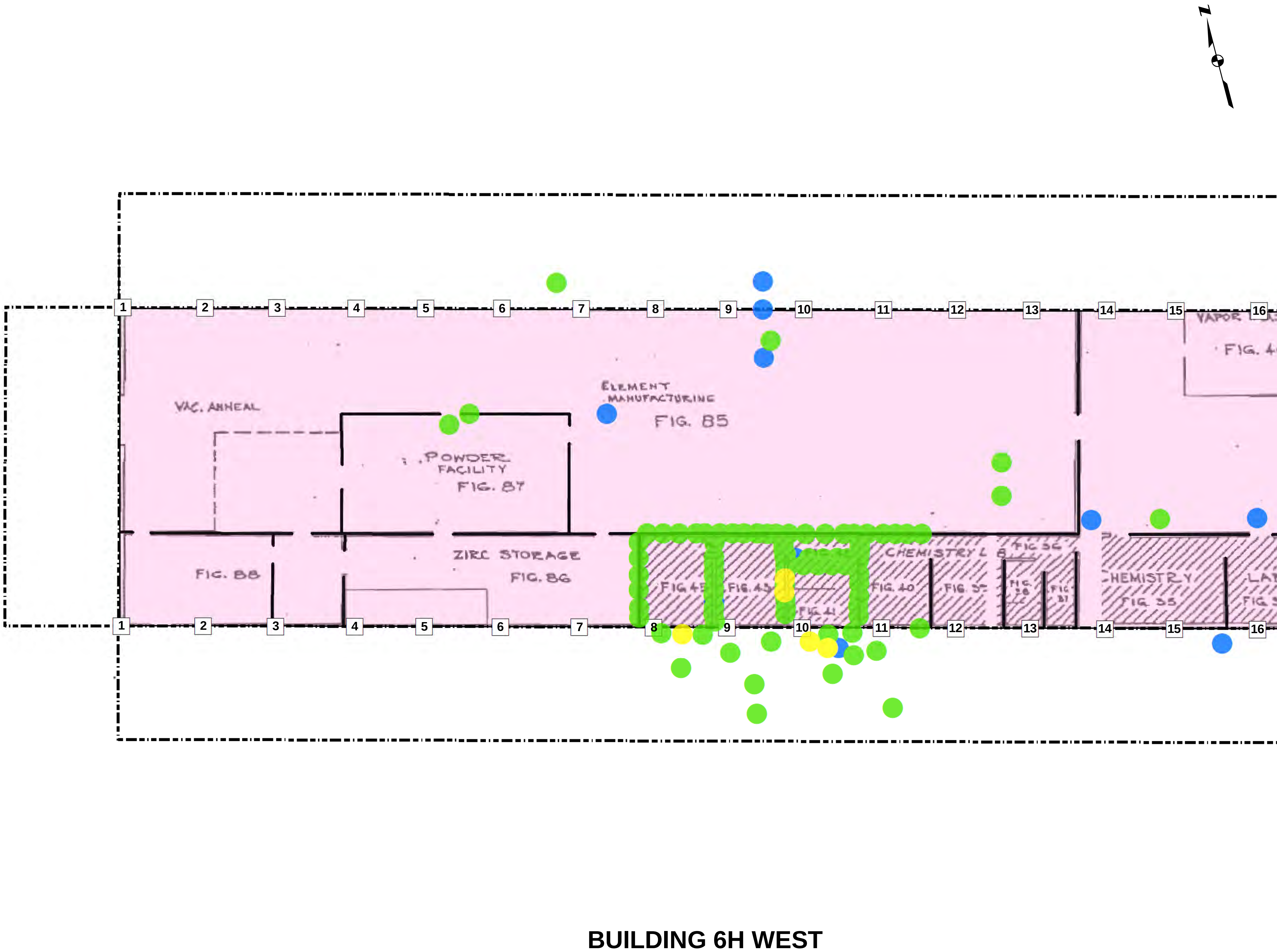
ALPHA-BETA FLOOR SCAN SURVEY RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-7

CABRERA SERVICES

CHALLENGE ACCEPTED



Legend

Wall/ Ceiling Scan Results

(Alpha + Beta dpm/100 cm2)

- < 99.9
- 100 - 2,499.9
- 2,500 - 4,999.9
- > 5,000
- Building 3H
- Building 6H
- Wall (Fold-out)
- Building Columns

Note: Survey performed with Ludlum 2360/ 43-37 and Ludlum 2360/ 43-93. All measurements are 1-min integrated scans.

0 20 40

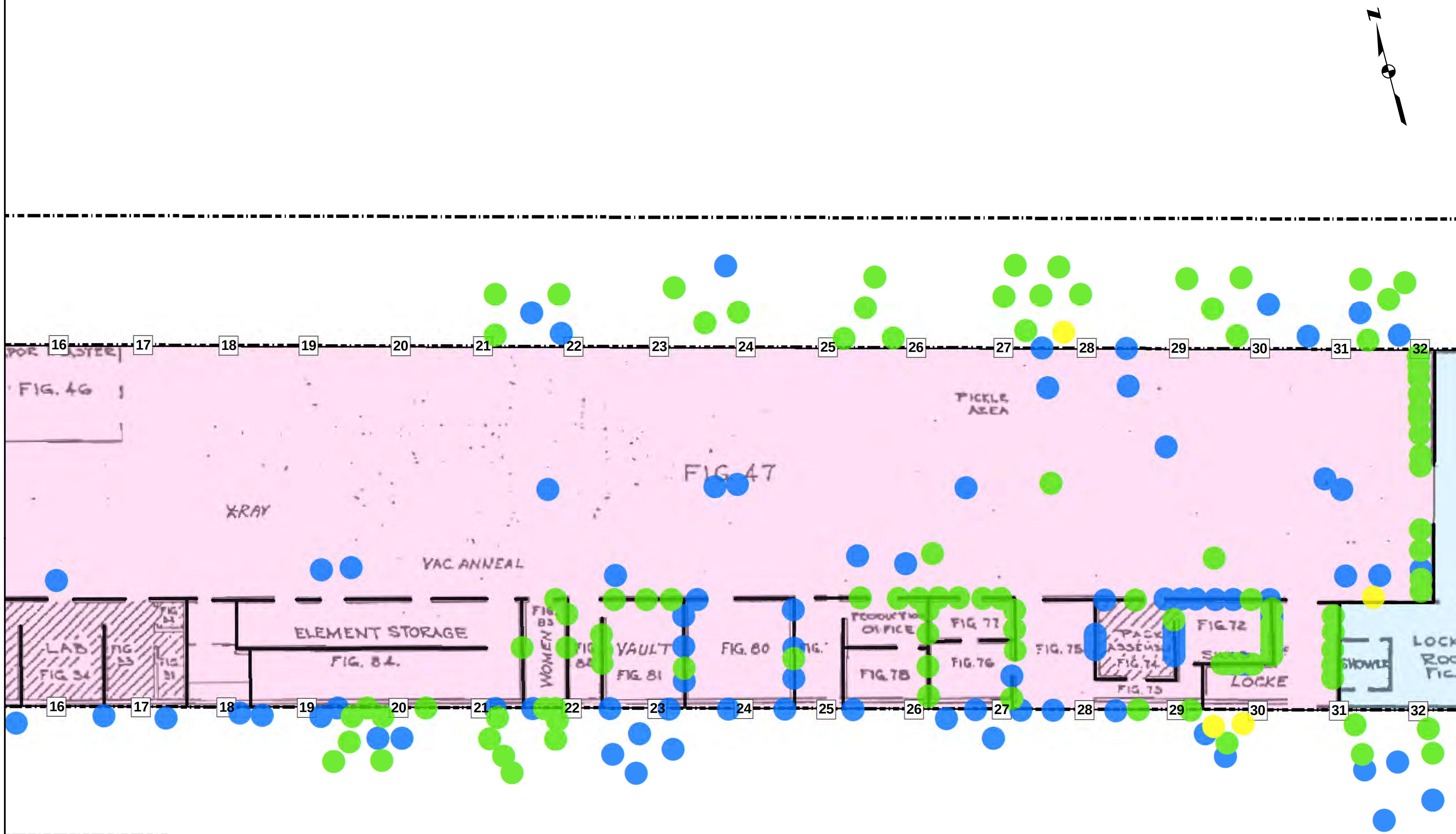
Scale (feet)

ALPHA-BETA WALL/ CEILING SCAN SURVEY RESULTS

FORMER UNC FACILITY
NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-8

CABRERA SERVICES
CHALLENGE ACCEPTED



BUILDING 6H CENTER

Legend

Wall/ Ceiling Scan Results

(Alpha + Beta dpm/100 cm2)

- < 99.9
- 100 - 2,499.9
- 2,500 - 4,999.9
- > 5,000
- Building 3H
- Building 6H
- Wall (Fold-out)
- Building Columns

Note: Survey performed with Ludlum 2360/ 43-37 and Ludlum 2360/ 43-93. All measurements are 1-min integrated scans.

0 20 40

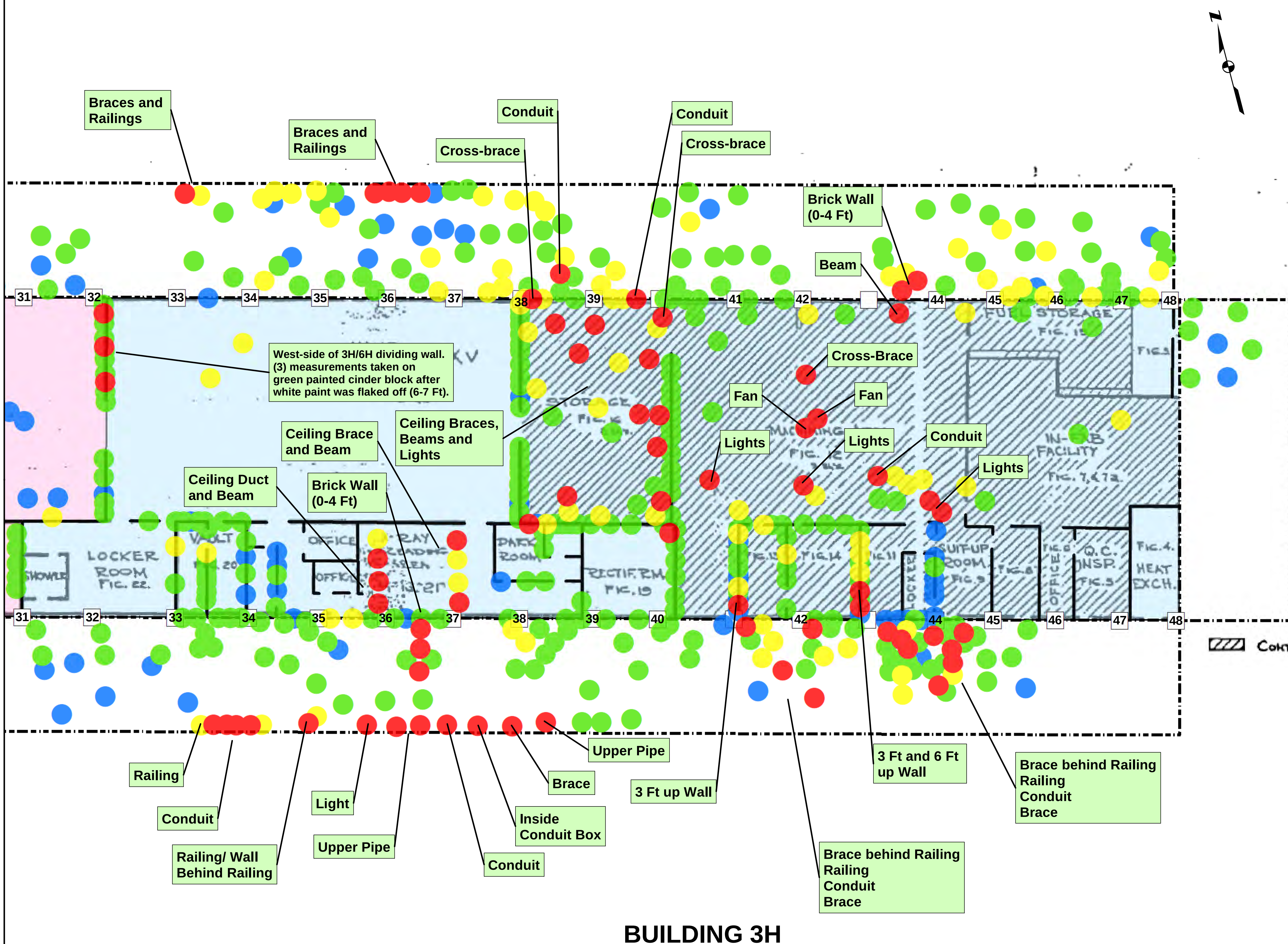
Scale (feet)

ALPHA-BETA WALL/ CEILING SCAN SURVEY RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-9

CABRERA SERVICES
CHALLENGE ACCEPTED



Legend

Wall/ Ceiling Scan Results

(Alpha + Beta dpm/100 cm2)

- < 99.9
- 100 - 2,499.9
- 2,500 - 4,999.9
- > 5,000
- Building 3H
- Building 6H
- Wall (Fold-out)
- Building Columns

Note: Survey performed with Ludlum 2360/ 43-37 and Ludlum 2360/ 43-93. All measurements are 1-min integrated scans.

0 20 40

Scale (feet)

ALPHA-BETA WALL/ CEILING SCAN SURVEY RESULTS

FORMER UNC FACILITY NEW HAVEN, CONNECTICUT

10/2017	PROJECT No. 10-1007.00	FIGURE 8-10

CABRERA SERVICES

CHALLENGE ACCEPTED

APPENDIX B

Supplemental Radiological Survey Plan

(provided electronically on CD)

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APPENDIX C

Permits and Notifications

(provided electronically on CD)

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APPENDIX D

Asbestos Abatement Records

(provided electronically on CD)

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APPENDIX E

Waste Shipment Records

(provided electronically on CD)

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APPENDIX F

Soil Boring Logs

(provided electronically on CD)

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APPENDIX G

Analytical Laboratory Results

(provided electronically on CD)

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APPENDIX H

Daily Quality Control Reports

(provided electronically on CD)

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APPENDIX I

Radiological Survey Data

(provided electronically on CD)

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APPENDIX J

Radiological Safety/Health and Safety Records

(provided electronically on CD)

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APPENDIX K

QA/QC Records

(provided electronically on CD)

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