University of Missouri
Pickard Hall
Site Characterization Plan
Revision 0

US Nuclear Regulatory Commission
Radioactive Material License 24-00513-32

March 26, 2015

Prepared by:

CHASE Environmental Group INC.

Chase Environmental Group, Inc.
109 Flint Road
Oak Ridge, TN 37830
865-481-8801

University of Missouri
Pickard Hall
Site Characterization Plan

Pickard Hall
405 S. Ninth Street
Columbia, MO 65211-1420

US Nuclear Regulatory Commission
Radioactive Material License 24-00513-32

Revision 0
March 26, 2015

Prepared:	Dave Culp	Chase Project Manager	Date: 3-26-15
Technical Review:	Patrick McDermott	Certified Health Physicist	Date: 3-26-15
Approved:	Jack Crawford	Radiation Safety Officer	Date: 3-30-15
Approved:	Todd Houts	Environmental Health and Safety Director	Date: 3-30-15

Document Control # 15007-01

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

ACM	Asbestos-Containing Material
ALARA	As Low As Reasonably Achievable
CFR	Code of Federal Regulations
COC	Chain of Custody
CRSO	Chase Corporate Radiation Safety Officer
DAC	Derived Air Concentration
DAW	Dry Active Waste
DCGL	Derived Concentration Guideline Level
DOT	US Department of Transportation
DP	Decommissioning Plan

DRS	Director of Radiological Services
DQA	Data Quality Assessment
DQO	Data Quality Objective
DSV	Default Screening Value
EF	Emanation Factor
EHS	Environmental Health and Safety
FSM	Field Services Manager
FSSR	Final Status Survey Report
GPS	Global Positioning System
G-M	Geiger-Mueller
HEPA	High Efficiency Particulate Air
HVAC	Heating , Ventilation, Air Conditioning
IL	Investigation Level
IRT	Infrared Thermography
LAW	Large Area Wipe
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MU	University of Missouri
NRC	U.S. Nuclear Regulatory Commission
NIST	National Institute of Standards and Technology
PM	Project Manager
PPE	Personal Protective Equipment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QM	Quality Manager
RCS	Radiation Control Supervisor
RCT	Radiation Control Technician
RPP	Radiation Protection Program
RSM	Radiation Safety Manual
RSO	Radiation Safety Officer
RW	Radiation Worker
RWP	Radiation Work Permit
SCP	Site Characterization Plan
SCR	Site Characterization Report
SPR	Surface Penetrating Radar
TEDE	Total Effective Dose Equivalent
THH	Trabue, Hansen, & Hinshaw, Inc.
TLD	Thermoluminescent Dosimeter
USDA	US Department of Agriculture

1.0 EXECUTIVE SUMMARY

The University of Missouri (MU) identified residual radioactivity from historical operations in the basement of Pickard Hall located at 405 S. Ninth Street, Columbia, MO 65211-1420. Built in 1892 as the Chemistry Building, Pickard was subsequently used as the Museum of Art and Archaeology, and housed the Department of Art History and Archaeology. The building has a footprint of 8,400 square feet with approximately 24,600 gross square feet of floor area over three elevations (not including the attic). The building is located within the Francis Quadrangle, which is listed on the National Register of Historic Places. See Appendix A for a satellite photo.

In the early 1900's, the basement of Pickard Hall was used for separation of radium-226 from uranium ores and research with thorium-232 daughters (specifically Ra-228 as a potential substitute for Ra-226). Additionally, the purified materials may have been used in other areas of the building. These radioactive materials had historically been regulated by the State of Missouri, but became licensed by the US Nuclear Regulatory Commission (NRC) in 2009 under the broad scope license 24-00513-32 due to implementation of the NRC's expanded definition of byproduct material in 2007. As a result of these historical operations, Pickard Hall is impacted by legacy radioactive materials on building structures and in soils around (and potentially under) the building.

Chase Environmental Group, Inc. (Chase) conducted an initial radiological assessment in several phases from 2009 to 2011 while the building was being utilized as a museum. The scope of the radiological assessment was limited to activities that would not disturb ongoing museum operations; this precluded movement of interior furnishings, disturbing interior finishes, or causing vibration. The assessment results indicate that the nuclides of concern are U-238, Th-232 and their progeny (particularly Ra-226) and that residual radioactivity is present in or on contaminated building structures, building systems, and soils. In 2013 and 2014, MU moved building occupants and a majority of the museum pieces and furnishings; this allows for a more comprehensive characterization of the building and surrounding soils.

MU has procured Chase to assist MU in the development and implementation of this Site Characterization Plan (SCP) to fully characterize the site and collect the information necessary to develop a Decommissioning Plan (DP). The goal of decommissioning is to accomplish unrestricted release of the building and grounds. This plan was developed using the guidance provided in NUREG 1757, "Consolidated NMSS Decommissioning Guidance"; and NUREG 1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM). It provides the approach, methods, and techniques for the radiological characterization of impacted areas of the facility. Characterization activities will

be conducted under the provisions of the MU broad scope radioactive materials license number 24-00513-32. On-site characterization activities are expected to occur several months after NRC approval of this Plan and are expected to take up to six months to complete. After characterization, MU will submit a DP that addresses remediation and decommissioning the site for unrestricted use.

2.0 FACILITY OPERATING HISTORY

Originally called the Chemistry Building, over the years Pickard Hall has been referred to as the Chemical Laboratory, Old Chemistry Building, School of Commerce, and the Art History and Archaeology Building. The name was eventually changed to Pickard Hall, to honor Professor John Pickard, the first chair of the Department of Art History and Archaeology.

2.1 History of the Chemistry Department

Upon completion of construction in 1892, the building housed the chemistry department. As the chemistry department, which grew to include organic, agricultural, general, analytical, technical, industrial and physical chemistry began to outgrow the facilities, professors met in 1911 to examine their relocation options. It was decided that general laboratories and other offices would share the top floor of the new Schweitzer Hall, originally constructed for agricultural chemistry. A third home for the chemistry department, Schlundt Hall, was completed in 1923, but it was still not large enough to house the entire department. By 1951, general, analytical, technical, industrial, and physical chemistry had moved to other buildings, leaving only organic chemistry in the old building (Pickard Hall). By 1969, plans were approved for a new chemistry building that opened in November of 1972, consolidating the Chemistry Department to one building for the first time since 1912. Subsequently, Pickard Hall housed the Art and Archeology Museum from 1976 until 2013. Currently the building is unoccupied, but several artifacts and furnishings remain that are challenging to move.

2.2 History of Radium Processing

Professor Herman Schlundt had the greatest impact on the contamination of Pickard Hall. Schlundt began his career at MU in 1901. By 1911, he became the chairman of the chemistry faculty. In 1913, he was introduced to radium refining when he spent time at the U.S. Bureau of Mines in Denver Colorado. There he learned the method of converting ore into “tiny crystals of radium bromide salts.” The process was described as laborious, messy, and dangerous. From 1913 through the mid 1930’s Schlundt focused his research on radium. Schlundt began his extensive research of radium in water sources on one of the deep wells at the University and soon expanded to various water sources across the country.

In 1914 Schlundt returned to the university, but did not end his refining research. He partnered with fellow researcher, Howard H. Barker and the two found new ways to make the refining process more efficient and cost effective.

2.2.1 Economic Factors Driving Radium Production

The scarcity of radium contributed to its value, which at the time was higher than gold or diamonds. In fact, "according to the New International Yearbook: A Compendium of the World's Progress, published in 1921, radium sold for $115 to $120 per milligram that year, gold cost about $21 per troy ounce- roughly 1.09 ounces- that year, according to the National Mining Association. A milligram of gold would have been worth just 0.0007 cents" (Gibbons, 2013).

2.2.2 Business Arrangements with Commercial Entities

In addition to his responsibilities to the university, Schlundt was contracted as a consultant for the Welsbach Company due to his well-known refining expertise. The company made mantels for gas lanterns and utilized a method of extracting thorium that produced large amount of radioactive waste. They needed Schlundt to turn the waste into a source of new profit by extracting radium-228. A letter from Schlundt claims that his graduate students had refined more than 3,600 milligrams of radium-228 in a 12 year period. "These 3,600 milligrams had a market price of between $216,000 and $360,000 at the time, according to prices Schlundt quoted in his letters" (Gibbons, 2013). Not only did the Welsbach Company reimburse Schlundt, but the company also made large contributions to the department. The exact total value of these contributions is unclear, perhaps because the donations were a benefit of Schlundt's use of university space and materials for commercial use, which was strictly forbidden by the university's policies (Gibbons, 2013). However, Schlundt did make it clear in a letter to the university president that the primary source of the department's equipment and materials was provided by "private individuals or firms" (Gibbons, 2013).

2.2.3 Radium Production Processes

Schlundt appealed to individuals and companies to donate ores containing radium, ultimately receiving over 4 tons. The concentration of radium within the ore was such that the refining techniques only yielded a couple hundred milligrams per ton of raw ore. The small amount of radium produced per ton of ore also meant there was a large amount of waste, a majority of which was returned to the donors.

Radium is extracted from uranium ore by crushing it and then dissolving it in sulfuric acid. The resulting precipitate contains radium salts, barium salts, and other compounds. This precipitate is treated with chemicals to produce a solution of radium bromide. Radium is produced by crystallization and filtration of the radium bromide solution (Radium, 2009).

2.2.4 Description of Radium Processing Equipment/Operation

A laboratory was established in the basement to test radium separation techniques. Commercial production was not an objective. Differing sources of carnotite ore were received. Ore was crushed and then digested in an acid. At about the time that the major part of the research was complete in the fall of 1922, radium prices drastically declined due to the discovery of very rich deposits of uranium ore in the Belgian Congo (15-20 times that of American deposits).

The separation equipment was installed in what is now rooms 12, 12A, 13, 13A, and 15. The layout of the equipment is presented in Figure 2-1.

Many compromises were made regarding equipment. Equipment designed for different functions or operational scale was adapted for use in the radium separation process. All of the equipment requiring power was driven from one line shaft powered by a five horsepower motor. Preliminary preparation of ores includes grinding to pass 20 mesh before chemical treatment, the manner of which greatly affects the radium extraction efficacy. Grinding and crushing consisted of one small Braun jaw crusher and one Braun disc pulverizer. This equipment was serviceable, but not well suited for this scale of operation. The existing Chemistry Department air compressor was utilized to power a small vacuum pump and receiver tank. Utilities used in the operation included tap water, distilled water, gas, steam, air, and vacuum.

<u>Acid Treatment Equipment</u>

Two round-bottom stoneware leaching pots (24-gallon and 37-gallon) were used as boiling pots for treatment of ores with acid. Pots were housed in boxes mounted on an elevated platform and packed in hay to hold them in position. The pots were serviced by water, air, and steam. Charges of ore up to 100 pounds could be treated in the larger pot.

Acid solutions from the pots were filtered with two nearby stoneware suction filters at a lower elevation to accommodate direct siphoning into the filters. The larger filter had 45-gallon upper and lower chambers, and the smaller filter had an 11-gallon upper chamber and 22-gallon lower chamber. The filter media consisted of filter cloth and sand. Live steam was passed into the mixture of ore and acid, then cooled by running cold water.

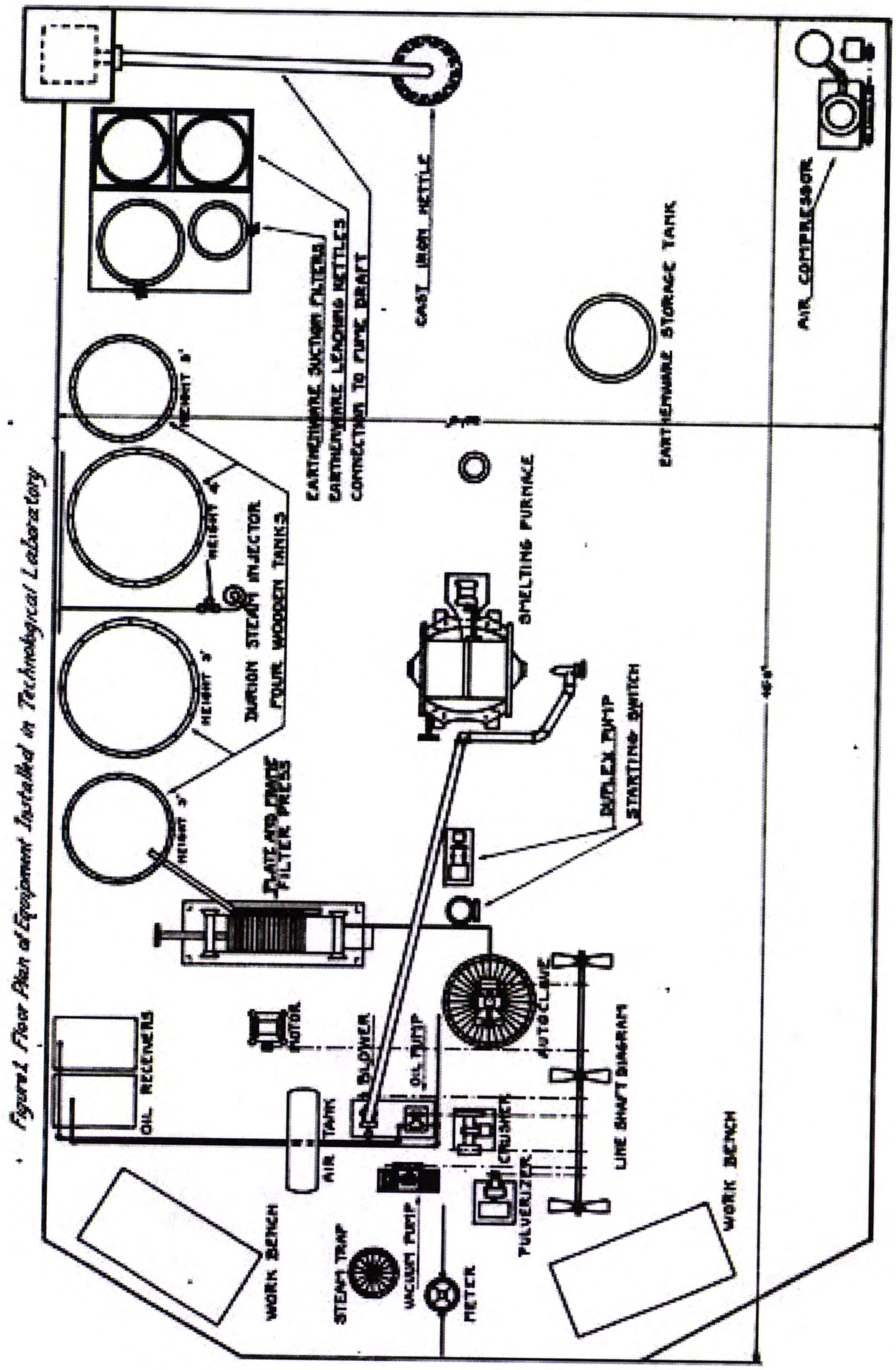


Figure 2-1: Radium Separation Equipment Layout

The leaching pots and suction filter layout is depicted in Figure 2-2. The photo is taken looking northeast. The exhaust flue is apparent in the corner of the room. Note that the basement walls were bare brick at the time and were subsequently covered in plaster, likely during the 1940 renovation. Also, the floor appears to be concrete, in spite of the original specification that floors were not to be installed in the basement. The load of the platform legs on the floor reinforces that the floors are concrete. The timing of the concrete installation cannot be determined from the historical records available, but could have been part of the radium separation lab construction. The fact that surface contamination exists on the current concrete floor supports the conclusion that the concrete floors were installed in this area prior to operations using radium. This is important for assessing the potential for residual radioactivity under the slab.

PLATE No. 1. LEACHING POTS, BOXED, AND SUCTION FILTERS.

Figure 2-2: Stoneware Leaching Pot and Suction Filter Arrangement

The acidic solutions were precipitated in elevated 110-gallon conical stoneware pots. A large cast iron kettle served for cooking ore with concentrated sulfuric acid and sodium bi-sulfate.

Alkali Treatment Equipment

Most of the processes using alkali leaches on the ore were conducted under pressure using an autoclave. The autoclave was a 50-gallon seamless steam-jacketed cast iron kettle with a bolted lid equipped with a stirrer attached to a driving mechanism. The autoclave was capable of being operated pressurized or under vacuum. In addition to the jacket, steam could be supplied directly into the top or bottom of the autoclave. The bottom of the autoclave was piped directly to a plate and frame filter press with eighteen 18" x 18" square plates. This allowed the autoclave to charge the press. The press was equipped for backwashing and air drying. A small steam pump was connected into the press supply line to force wash water through the press when charged. The press was mounted on an elevated platform to allow gravity feed of discharges into a series of four wooden tanks with capacities of 204 gallons (2), 316 gallons, and 444 gallons. The tanks were elevated about one foot as shown in Figure 2-2 and slightly tilted to accommodate complete draining. Steam, air, and water were available to all tanks. A one-inch iron steam injector was installed to transfer solutions between the tanks.

The layout of the autoclave and filter press is presented in Figure 2-3. Note that the photo is looking northwest and the window in the current mechanical room 13 is shown at the left side of the photo. The location of the cast iron support column aids in determining the exact location of the equipment relative to the current room configuration. It is evident in the photo that the first floor joists and beams were not covered at the time, providing useful information for assessing the potential for contamination of building structural members. Again, it is evident that concrete floors were installed prior to radium separation operations.

A smelting furnace heated with an oil blast burner was used for roasting ores. See Figure 2-4. The furnace was equipped with rotating and tilting mechanisms and was designed to operate at a much higher temperature than was needed for the experiments, so it was difficult to maintain temperatures low enough. The air blast was so strong that the ore was continually blown out the back end of the furnace.

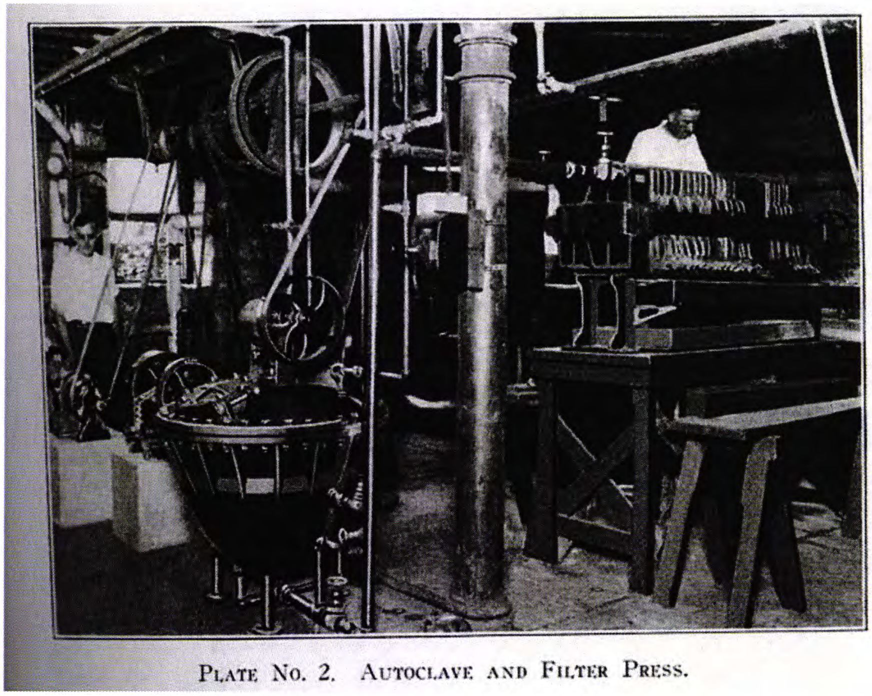


Figure 2-3: Autoclave and Filter Press Arrangement

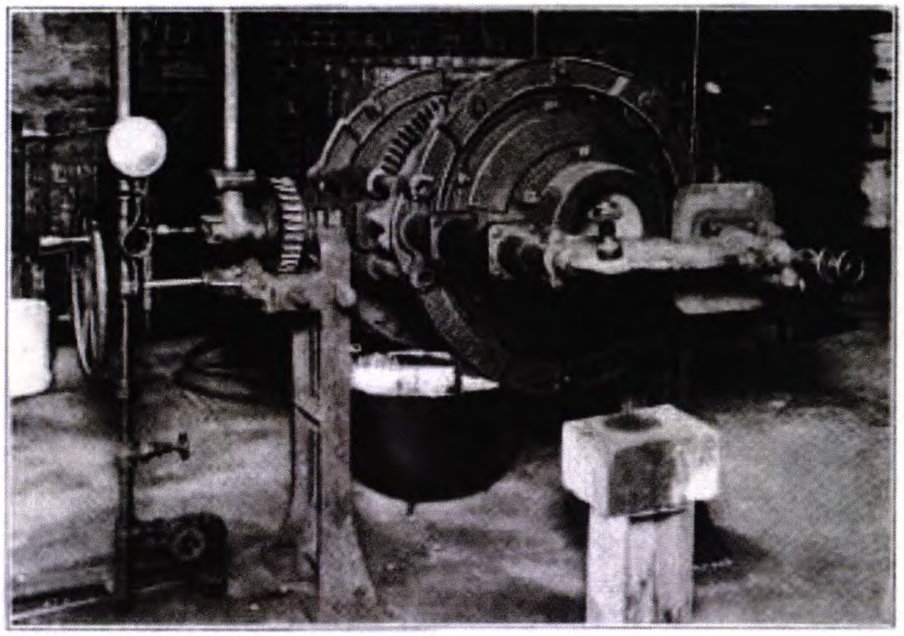


Figure 2-4: Smelting Furnace Looking Northeast

Crystallizing Equipment

One of the smaller rooms in the basement was used for crystallization. There is considerable uncertainty regarding which room was used, but it is suspected that it was room 27. Evaporation of plant liquors with radium and barium chlorides and the earlier fractionations were conducted in a series of glass enameled evaporators consisting of two 10-gallon steel pots and three 10-gallon cast iron pans loaned by the Welsbach Company as shown in Figure 2-5.

PLATE NO. 4. STEEL AND CAST IRON, GLASS ENAMEL EVAPORATORS.

Figure 2-5: Evaporators

As the radium concentrations increased during the crystallization process, large porcelain evaporating dishes graduating to smaller sizes were used. After conversion into bromides, porcelain dishes were used for a time, but fused silica ware was used for most of this work. Crystallizing equipment is shown in Figure 2-6. Small transparent silica dishes were used for fractionation of very high grade bromides, and the dissolution and evaporation were conducted in a water bath.

PLATE NO. 5. BROMIDE CRYSTALLIZING SYSTEM.

Figure 2-6: Crystallizing Equipment

3.0 FACILITY DESCRIPTION

3.1 Site Location and Description

Pickard Hall is located at 405 S. Ninth Street, Columbia, MO 65211-1420 in the Francis Quadrangle area, between the Chancellor's Residence to the north and the Reynolds Journalism Institute to the south.

The building has a footprint of 8,400 square feet with approximately 24,600 gross square feet of floor area over three elevations (not including the attic). The brick building sits on a stone and mortar foundation.

Figure 3-1: Pickard Hall – Looking Southeast

Figure 3-2: Pickard Hall – Looking Southwest

Floor plans showing the current building arrangement are provided in Appendix B.

Floors on the first and second elevations are primarily carpeted with stone/ceramic tiled foyers and restrooms. Interior load bearing walls are brick (covered with plaster or sheetrock), other interior walls are framed with plaster or sheetrock coverings. The interior of the facility underwent a major renovation in 1974 that resulted in minor changes to the layout of the basement. Some windows on the basement and first floors and all windows on the second floor were covered on the inside to prevent ultraviolet damage to museum artifacts. The entire ventilation system has been upgraded since the cessation of usage of radioactive materials; some original ventilation shafts remain, but none are believed to be in use. Original drains have been terminated at floor level and grouted. Detailed descriptions of the initial building construction and renovations are provided below.

3.2 Construction and Renovation History

3.2.1 Initial Construction

After Academic Hall burned in 1892, funds were allocated for the construction of the six buildings of the Francis Quadrangle. A portion of the funding was allocated to the chemistry department, but did not include funds to outfit the building with the necessary laboratory equipment, including fume hoods. The plans for the six buildings were selected from options that did not include a layout designed specifically for a chemistry lab. While the architect in charge of the project, M. Fred Bell, made some adjustments to better suit the needs of the department, the building was still constructed with design flaws that obstructed the building's ventilation and posed dangerous conditions for lab workers. "For example, there were two hoods with no opening into a ventilating shaft, and one shaft in the basement laboratory had been blocked off with masonry about a foot above the opening" (Nightingale, 1975). A letter from Professor Sidney Calvert, who began his career in the chemistry department in 1894, describes the critical ventilation problems, mentioning that at times fumes were so dense that he could not even see the length of certain rooms. He goes on to report that over the course of the prior two years, he knew of seven men being carried out of the building unconscious as a result of inhaling the suppressed fumes (Nightingale, 1975). This information is important for understanding the potential for contamination of building structures from air transport of radioactive materials.

Original specifications indicated that there were no hard floors to be installed in the basement. At some time prior to separating radium, a portion, if not all of the basement floors were covered in concrete. There are also reports that the building had wooden floors throughout, including the basement. The current basement floor is poured concrete with tile and carpet coverings. The specifications also included lead paint and two-ply tarred paper under the slate roof.

Ventilation equipment included a belt driven 70" diameter exhaust fan powered by a steam engine, steam heating coils in the basement ceiling, and brick supply and return shafts within the load bearing walls of the building.

Original floor plans are presented in Appendix C. Current room numbers are shown on the original floor plans for reference.

3.2.2 1911 Update of Building Electrical

Over the years, the building underwent a series of updates. In 1911, there was a movement by faculty to expand the electrical wiring to provide lighting in all spaces of the building. However, due to the cost of the project, it was resolved to "wire only a balance room and that the corridor on the second floor be lightened with a gas fixture. These gas lighting fixtures remained connected in all the laboratories and offices in the building until it was rehabilitated in the early 1940's" (Nightingale, 1975).

3.2.3 1940 Major Renovation

The Old Chemistry Building (Pickard Hall) underwent its first major renovation project in 1940. "During 1938-39 a special fund was set up for the purchase of laboratory equipment for all undergraduate chemistry sources and for faculty and student research. Plaster falling from the ceiling, crumbling wall plaster and peeling paint on the grimy walls in the old chemistry building, led to a careful and detailed inspection of the building. Not only was the wire mesh supporting the plastered ceilings rusting out, but the ancient and crumbling rubber and cotton 1893 insulation of the electrical wiring was a serious fire hazard. During 1939-1940 funds were set up for the complete renovation of the building, from the rotting wooden flooring in portions of the basement on up to the 20 foot ceilings on the second floor. The entire building was rewired, the old ceilings were torn out and replaced, crumbling plaster on the walls was scraped off, the walls and ceiling were re-plastered and repainted" (Nightingale, 1975). It is assumed that the current plaster wall coverings in the basement were installed at this time and are covering residual radioactivity on portions of the original brick surfaces.

3.2.4 1949 Fire and Related Safety Upgrades

Chemistry professors had been requesting fire safety upgrades that had been ignored until 1949 when a fire broke out in the basement laboratory and the fire department was called to the scene. The fire caused little damage, but triggered fire safety improvements, including structural modifications to facilitate safe exit from the building. In 1951 "the west 7 feet of the two offices on the north end of the building were partitioned off to extend the halls, and fire doors leading to metal fire escapes were installed at the north ends of the halls on both floors. The wooden stairs from the basement to the second floor had been replaced by concrete stairs and a new door was installed at the ground level landing of the stairway on the east side" (Nightingale, 1975.)

3.2.5 1965 Ventilation Upgrades

In 1965, the ventilation ducts in rooms 3, 4, 10, 12, 203, 204, 210, and 212 were overhauled to allow proper airflow.

3.2.6 1970 Structure Assessment

In 1970, Wm. C. E. Becker, consulting Engineer, performed a condition assessment of the building. He indicated deterioration of mortar in basement walls, overloaded cast iron columns, timber joists loaded to maximum safe capacity, bearing issues where the steel beams and wood joists meet, and cracked ends of wood timbers. His conclusion was that the building was structurally sound but not economical to bring to current code, so he recommended replacing with a new building.

3.2.7 1974 Major Renovation

In 1972 the final remnants of the Chemistry Department moved out of the Old Chemistry Building (Pickard Hall) and into the new Chemistry Building. The Old Chemistry Building's architecture with large and small rooms and high ceilings appealed to the university's Art History and Archaeology Department as the new location for the Museum of Art and Archaeology. In 1974 the university began a major renovation project with the goal of updating the interior without negating the vintage atmosphere of the historic building, along with minimally altering the exterior of the structure (Mosher, 1974).

In order to stay within the allotted budget, architects and contractors had to focus primarily on the first and second floors. Listed below are the contract specifications of the 1974 interior and exterior renovations (Mosher, 1974).

- addition of an entry ramp on the south end of the east side for wheelchair students and new areaways for exit stairs from the basement level
- addition of concrete to areaway walls, stairs, ramps, equipment slabs, and elevator pit
- demolition and patching for new doorways and openings and a new elevator shaft wall
- removal of two columns in the lecture room and supporting the structure above with two beams, and all lintels, handrails and removable stairway
- repair of existing joists where ends had split, reworking of window sash to receive new glass, new sub-floor on the first and second floors, new lecture hall risers, new partitioning, and closing of windows
- caulking and thermal insulation of exterior walls
- new glass for all windows remaining open, glass to be insulating type for first and second floors and plate glass for basement windows, all windows to be fixed. All interior doors to be solid core wood, new entry doors to be glass, new exit doors to be hollow metal.
- seal basement concrete floors
- carpet first floor, except brick pave corridor and toilets
- carpet second floor
- paint over plaster or drywall in basement and on first floor
- carpet second floor gallery walls and paint other walls
- install drywall or acoustical tile ceilings as areas required in basement and on first floor
- install special ceiling systems for display purposes on the second floor
- install toilet partitions and accessories with provisions for paraplegic persons, firefighting device, and chalkboards in classrooms
- install unit kitchen and painting storage racks
- install fixed seating in lecture hall
- install one security vault
- install three-stop hydraulic elevator
- complete mechanical and plumbing systems for the building
- install lighting and power systems, security detection system, and fire detection system

As part of the 1974 renovation, new stairs were installed on the east end of north side of the building, causing a window and associated light well to be removed. Also, existing plaster was patched/repaired and 1-1/2" of lightweight concrete was placed over existing construction (tongue and groove wood flooring) on the 1st and 2nd floors.

3.2.8 1987 Roof Work

In 1987 MU removed paint and repainted metal roof components including ridge caps, hip caps, valleys, finials, fascia, cornice work, and downspouts. Damaged components were replaced and several new downspouts were installed.

3.2.9 1990 Fume Hood Exhaust Installation

In 1990, MU installed a stainless steel exhaust duct with pneumatic electric damper at a fume hood in basement room 18 and two flexible exhaust ducts in room 17, tying into the existing exhaust duct.

3.2.10 1993 Ramp Replacement

The ramp to the basement on the south end of the east side was removed and replaced in 1993.

3.2.11 1997 Foundation Project

In 1997 a major excavation and renovation was performed around the building's foundation. To support this work much of the building's exterior ground level fixtures and fittings had to be demolished. Concrete stairs on the northwest corner and associated side walls, drains, footings and slabs were removed entirely. Original exterior stone and concrete window wells were removed. Many original drains were removed entirely, but some underground lines were abandoned in place and capped. A French drain system was installed around the building adjacent to the stone foundation consisting of a PVC drain pipe 3.5 ft below grade within a 2 ft wide by 4 ft deep bed of 3/8 inch clean granular fill which was then covered with 18 inches of topsoil.

3.2.12 1999 Exterior Renovation

A renovation was performed primarily to the outside of the building and the slate roof in 1999. Windows and their frames were either refurbished or replaced, along with the exterior doors. Doors that were not fully replaced were stripped and repainted. The northernmost door on the west side of the building's first floor was sealed shut and dummy hardware installed. All roofing was removed to the wooden deck including the two-ply tarred paper under the slate. Slate and bituminous roofing materials were removed and replaced as well as gutters and downspouts along with installation of a new underground drain for the spouts. The wooden ladder that led from a tower window to the roof was removed. Also, the lead paint from the fire escapes was removed and the fire escapes repainted. The exterior brick was cleaned and damaged decorative bricks were removed and replaced. Stairs and entryways were revamped with new cement over existing stairs, along with the installation of new railings. The sidewalk adjacent to the new stairs was also re-cemented. Electrical circuits were extended and new light fixtures and switches were installed.

3.3 2014 Building Condition Assessment

The structural condition of the building is a major factor in determining the path forward for accomplishing unrestricted release of Pickard Hall. While a comprehensive building condition assessment will be performed during characterization when building structural members are exposed, a preliminary building condition assessment was performed in 2014.

Representatives of consulting firm Trabue, Hansen, & Hinshaw, Inc. (THH) conducted a structural inspection of the building on April 8, 2014 to the extent that they could without performing invasive activities. This restriction caused THH to rely heavily on comparisons to similar buildings on campus that were constructed at the same time and by the same architect. This led to more than the usual number of assumptions. THH stated that the building was in remarkably good condition and that it was well maintained. While the building is stable in its current condition, any activity that would disturb the current geometric and loading arrangement (such as radioactive remediation activities) could be detrimental to the structural integrity.

3.4 Population Distribution

Pickard Hall is located within the Francis Quadrangle at the center of the MU campus. The building is surrounded by campus buildings that include academic, administrative, and housing facilities. Commercial businesses consisting mainly of restaurants are located across 9th Street, east of Pickard Hall.

As of the 2010 census, the population of Columbia was 108,500 (115,276 in 2013) with 43,065 households and 21,418 families residing in the city. The population density was 1,720.0 inhabitants per square mile with 46,758 housing units at an average density of 741 per square mile.

3.5 Current/Future Land Use

The facility is currently located within MU campus in the historic Francis Quadrangle. The property will remain part of the campus for the foreseeable future.

3.6 Meteorology and Climatology

The Columbia climate has sharp seasonal contrasts in temperature, falling between a humid continental and humid subtropical climate. The city is located in USDA Plant Hardiness Zone 6a.

The monthly average temperature ranges from 30° F in January to 77° F in July, while the high reaches or exceeds 90° F an average of 32 days per year and 100° F on 2 days per year; sub 0° F lows occur an average of 4 days per year.

Precipitation tends to be greatest and most frequent in the latter half of the spring season, when severe weather is most common. Snow averages 18 inches per season, mostly from December to March, with occasional November and April snowfalls. Historically seasonal snow accumulation has ranged from 3.4 inches in 2005–06 to 54.9 inches in 1977–78.

3.7 Natural Resources

There are no natural resources affected by this site characterization.

3.8 Geology and Hydrology

The site topography slopes minimally from east to west with Ninth Street being approximately four feet higher in elevation than the Pickard Hall grounds. There are various storm drain inlets around the building to carry away surface waters. Historically there have been issues with water infiltration into the Pickard Hall basement due to poor drainage of surface water. There has not been a water infiltration issue since the 1997 foundation project when a French drain system was installed around the building.

Site hydrology and geology assumptions are based on data obtained from subsurface investigations performed for the adjacent (immediately north) Donald W. Reynolds Journalism Institute in June 2004. The Journalism Institute is identified as the Sociology Building in the report. Groundwater was encountered at depths of 15 feet and 18 feet at two borings between Pickard Hall and the Journalism Building (it should be noted that groundwater depths vary seasonally and with environmental conditions). These groundwater levels correlate to about 9 feet below the Pickard Hall basement floor slab. Soils are described as clay-rich which have favorable sorption properties to mitigate environmental transport of radium compounds. The boring map and logs from borings adjacent to Pickard Hall (B6 and B7) are presented in the figures below.

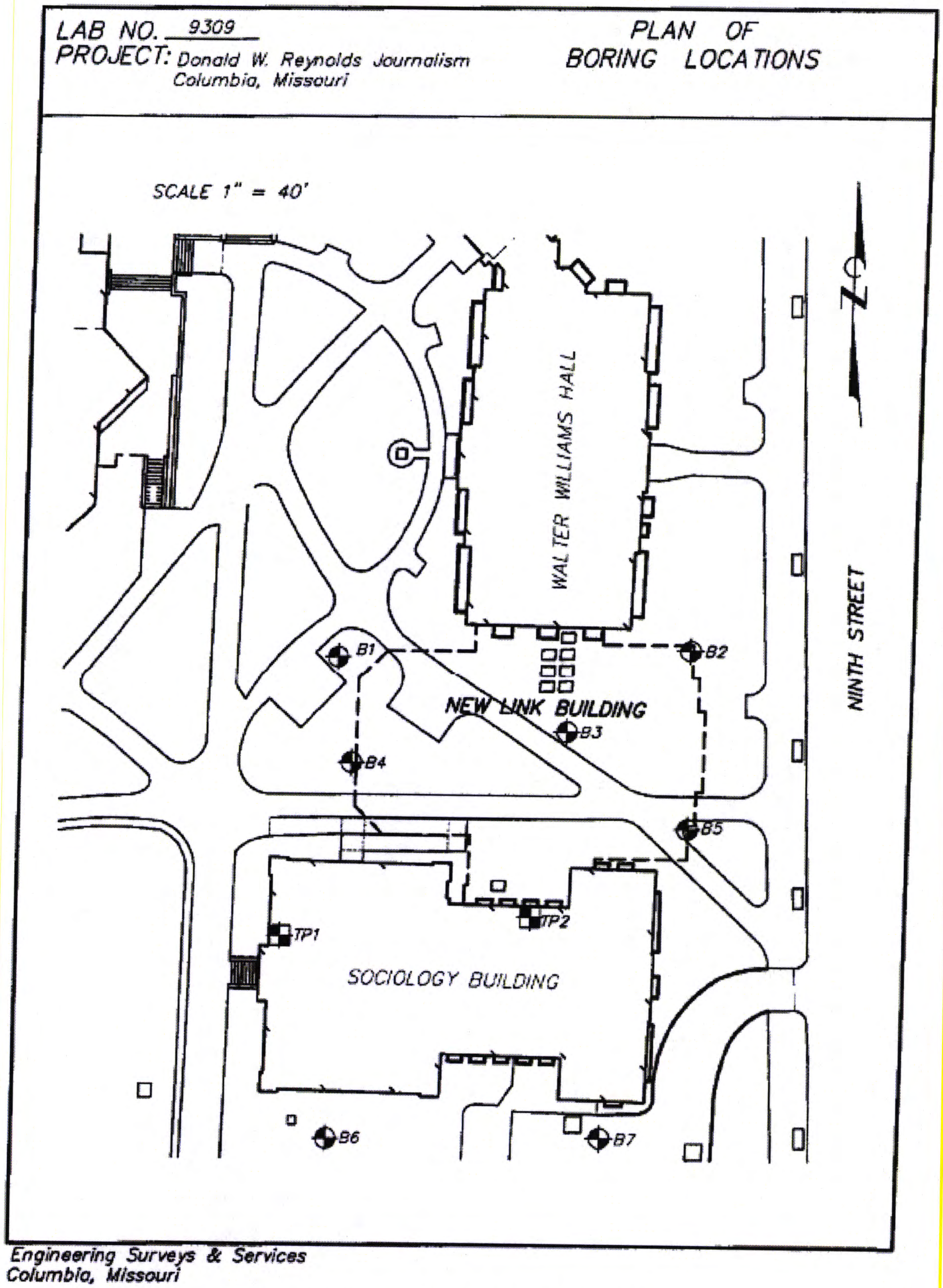


Figure 3-3: June 2004 Soil Boring Map

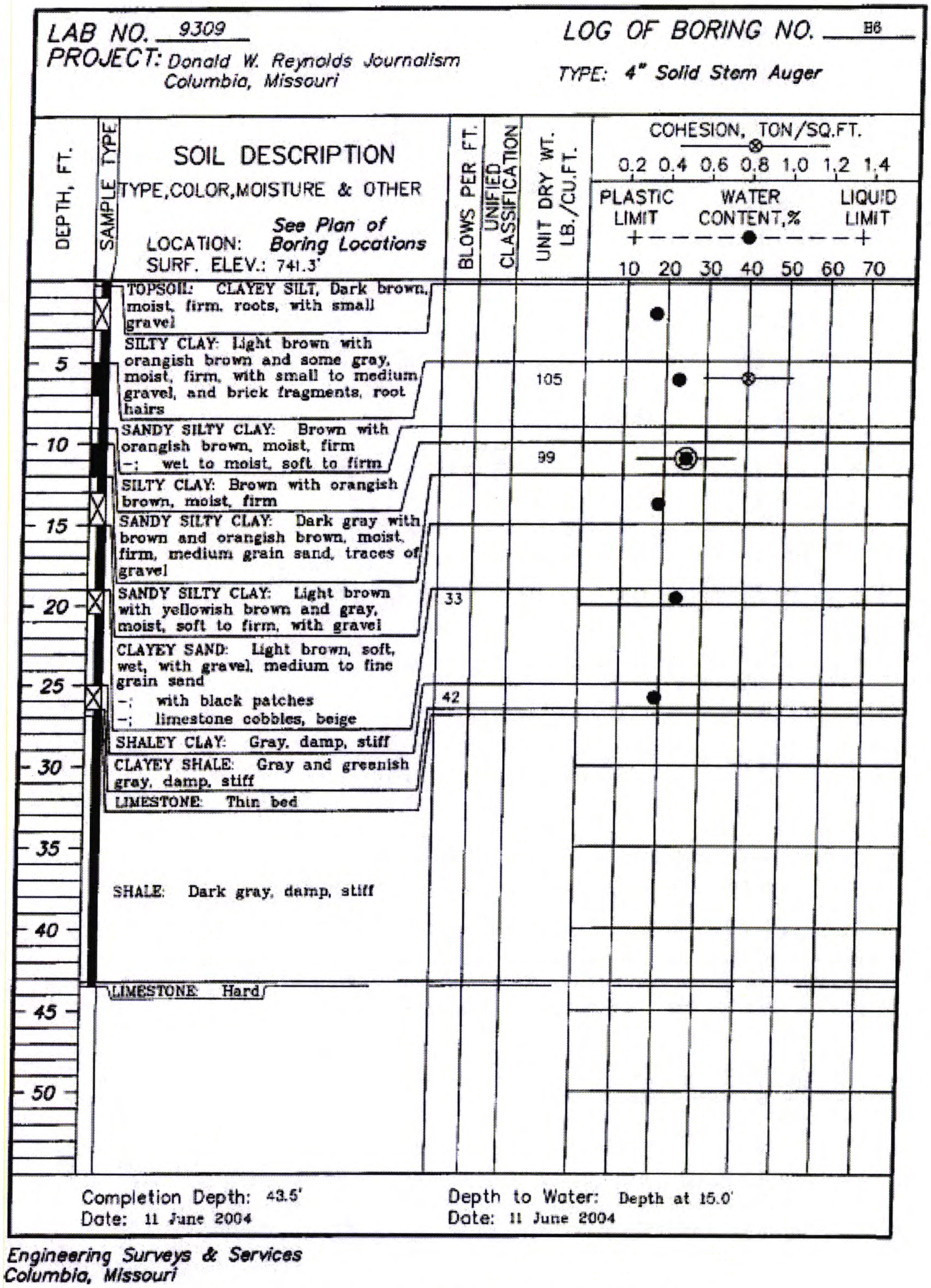


Figure 3-4: Soil Boring Log for Location B6

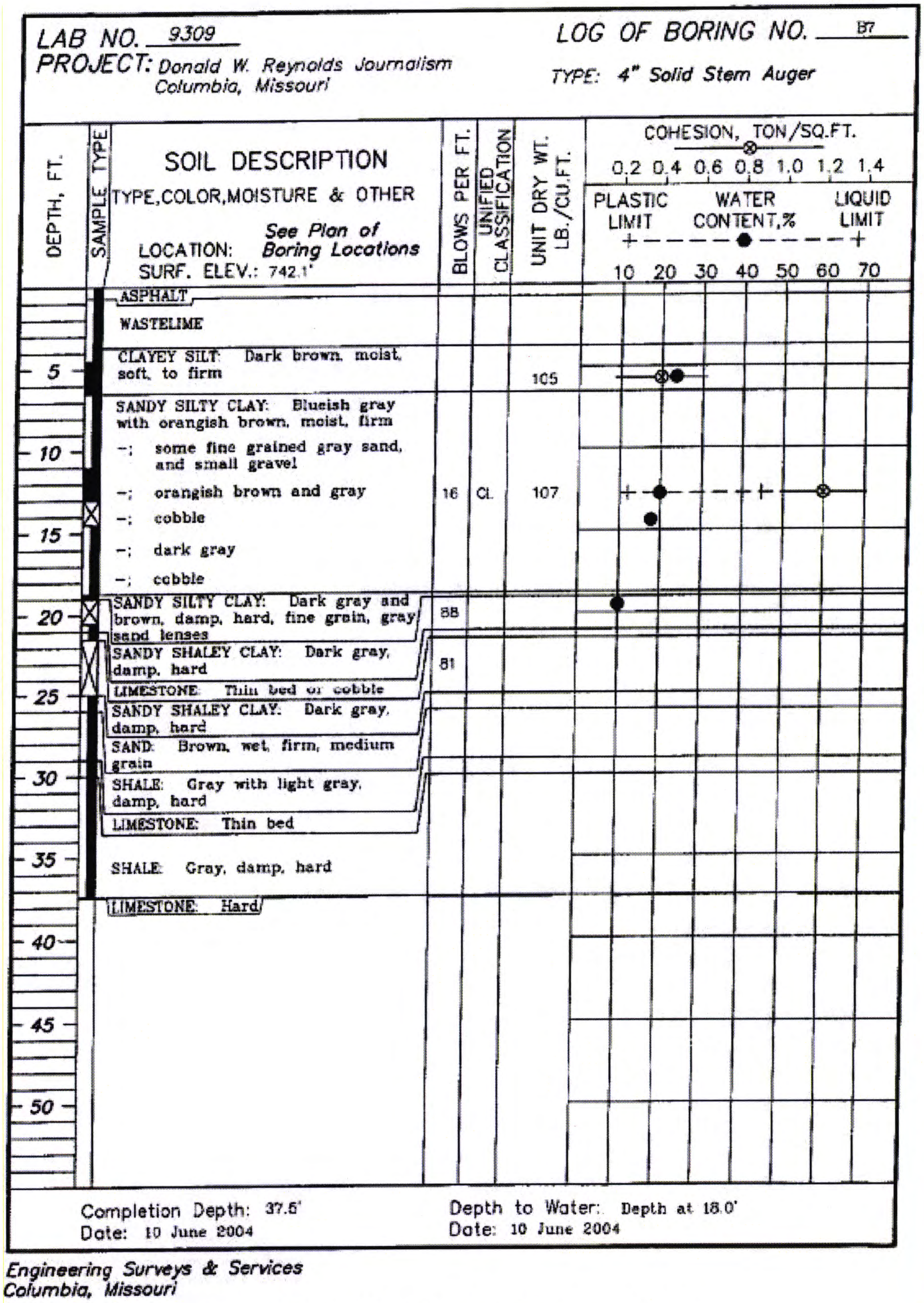


Figure 3-5: Soil Boring Log for Location B7

4.0 RADIOLOGICAL STATUS

4.1 Initial Radiological Assessment

MU procured Chase to survey accessible surfaces of the facility to the extent possible without interfering with museum operations (without moving artifacts, causing excess vibration, etc.). Surveys were performed to determine the extent and magnitude of residual radioactivity to support decommissioning planning, and to evaluate radiological exposures to building occupants and visitors. The survey was an iterative process that was performed from December 2009 to October 2011 over six separate mobilizations.

Chase surveyed accessible portions of the entire facility including the basement, first floor, second floor, the attic, the roof, steam tunnel feeder, and outside grounds. Surveys consisted of the following types of measurements:

- indoor surface scans for alpha and beta emissions using gas flow proportional detectors (100% of accessible surfaces < 2 m height)
- indoor surface scans for gamma emissions using a 2" x 2" sodium iodide detector at a distance of 10 cm (100% of accessible surfaces < 2 m height)
- indoor large area wipes for alpha and beta removable activity (100% of accessible floor surfaces)
- at locations of elevated activity identified during indoor scans:
    - static measurements for alpha and beta total surface activity
    - static measurements for gamma emissions at a distance of 10 cm
    - external dose rate measurements at a 1 meter distance
    - disc smears for alpha and beta removable activity
- solid samples of concrete surfaces for gamma spectroscopy analysis (a subset of samples was also analyzed by alpha spectroscopy analysis)
- solid samples of contaminated brick ventilation shafts and wood flooring in the attic
- Global positioning system (GPS) correlated gamma scans of outdoor areas
- surface soil samples for gamma spectroscopy analysis (a subset of samples was also analyzed by alpha spectroscopy analysis)
- sampling for airborne radioactivity

Results indicate that the nuclides of concern are U-238, Th-232 and their progeny (particularly Ra-226) and that residual radioactivity exists in the following locations:

- on basement concrete floor surfaces that are covered with vinyl tiles
- on concrete floor surfaces in basement mechanical rooms that were subsequently encapsulated with a spray-on fixative

- in the steam tunnel feeder adjacent to Mechanical Room 15 where the top foot of soil was removed and remaining soils covered with geotextile and pavers
- in buried drain lines under the basement floor
- on a former wooden window header under the stage in Room 106 that is also detectable in the basement ceiling in Room 1B
- in a small area inside a wall in Room 213 at a covered window location
- on floor surfaces in Rooms 205 and 206 that are carpeted
- in the attic on one small location on the floor and in open joist areas
- in the attic under floor decking
- inside brick ducts (assumed to be fume hood exhaust ducts) that are open in the attic
- in surface soils immediately outside the northwest corner of the building and likely in subsurface soils

Detailed results of the initial radiological assessment can be found in the reports "Pickard Hall Characterization Survey Report," dated July 16, 2010 that describes Phases 1 and 2 of the assessment and "University of Missouri Pickard Hall Phase 3 Characterization Survey Report," dated October 17, 2011.

4.2 Initial Radiological Assessment Limitations

While there is fairly extensive information regarding residual radioactivity on accessible surfaces, there is essentially no information regarding:

- extent of contamination on original surfaces inside the building that are covered (brick, plaster, wood flooring, etc.)
- extent of drain line contamination
- extent of subsurface soil contamination
- impact to load-bearing structures
- impact to roof decking
- impact to stone and mortar foundation
- impact to groundwater

It is believed that the original hardwood floors on the first and second floors were covered with 1-1/2" thick lightweight concrete as a substrate for application of museum floor coverings. Therefore, low levels of surface contamination on the original floors could go undetected due to the shielding effect of the concrete layer.

As part of the 1974 renovation into a museum, interior walls were framed and covered to isolate original building surfaces and windows. Custom displays were installed for showcasing artifacts. In order to fully characterize the interior surfaces, all interior coverings must be removed to provide access to original building surfaces. The central stairwell from the 2nd floor to attic was removed

and replaced with an elevator. The elevator does not go to the attic so a ladder was installed in Room 215 for attic access. The current auditorium was a lecture hall and may have had laboratory fixtures for demonstrations. During the 1974 renovation, the cast iron columns in the lecture hall were removed and replaced with structural beams that were pocketed into the load-bearing walls. The corresponding columns on the 2nd floor are still in place, but have been framed in and covered with sheetrock. Stadium style seating was installed over the original hardwood floors. These floor surfaces were accessed and surveyed to the extent possible during Chase surveys with no residual radioactivity identified.

Previous renovations likely remediated a significant amount of impacted surfaces and structures. Ceilings and basement wood flooring were removed as part of the 1940 renovation, and roof coverings were removed and replaced in 1999.

4.3 Contaminated Building Structures and Systems

Elevated residual surface activity was identified in multiple basement areas, on the covered floor in Rooms 205 and 206, behind a wall in Room 213, on attic floors, on a basement window header under the stage in Room 106, and on brick ventilation shaft internals. Many beta-gamma surface activity results are biased high due to the influence of emissions from residual activity below the surface being measured. Many areas had elevated beta-gamma activity during scans, but no detectable alpha activity, indicating that residual radioactivity is covered (most areas of elevated activity are covered by vinyl floor tiles and are effectively encapsulated).

Survey results of uncovered areas provide the best information regarding what can be expected in inaccessible areas. Total surface activity measurements on uncovered surfaces are summarized below.

- up to 29K dpm/100 cm^2 alpha and 357K dpm/100 cm^2 beta-gamma on basement concrete floor under vinyl tiles in Room 12 (levels were reduced an order of magnitude by surfacing to obtain samples, indicating that residual radioactivity on concrete floor surfaces doesn't penetrate deeply into the concrete and that concrete surfacing is an effective remediation method)
- up to 21K dpm/100 cm^2 alpha and 286K dpm/100 cm^2 beta-gamma on the concrete floors in Mechanical Room 13 (the floors in Room 13 were subsequently encapsulated)
- up to 1K dpm/100 cm^2 alpha and 39K dpm/100 cm^2 beta-gamma on the concrete floors in the elevator mechanical room immediately north of the elevator shaft in the basement

All of the removable radioactivity measurements collected on accessible building structural surfaces were less than the analysis MDC except:

- up to 29 dpm/100 cm^2 alpha in basement mechanical room 13 that was subsequently encapsulated
- up to 251 dpm/100 cm^2 alpha and 524 dpm/100 cm^2 beta-gamma inside two adjacent brick ducts in the attic
- up to 24 dpm/100 cm^2 alpha on two locations on the attic wooden floor
- up to 362 dpm/100 cm^2 alpha and 648 dpm/100 cm^2 beta-gamma on a basement window header under the stage in Room 106

Dose rate measurements were performed with a tissue equivalent Bicron MicroRem meter. Dose rates were performed at each static measurement[1] location at a distance of one meter from the source (midpoint of a receptor). Additionally, the occupancy required at each location to achieve external doses of 100 mrem/yr was calculated. Room 27 (office) and Room 12 (storage room) in the basement are the only rooms that would result in an external dose of 100 mrem/yr or more with less than 2,500 hours per year of occupancy. This is conservatively based on measurements at the highest areas of residual radioactivity.

4.4 Soil Contamination

Initially, surface soil samples were collected at four discrete locations in outside grounds surrounding the building. Two of the samples were at small (up to a few square feet) areas of elevated activity detected by a sustained increase in the count rate during gamma scans. Six background surface soil samples were collected in the Quadrangle. Gamma spectroscopy results were used to select a subset of three background samples and three soil samples for uranium and thorium isotopic analysis by alpha spectroscopy.

The two small areas of elevated surface activity (47 and 18 pCi/g Ra-226) were identified in the outside grounds located several feet away from the building outside the northwest corner of Room 16. The locations were excavated to a one foot depth and a sample was collected at the bottom of each excavation. Sample results dropped to below 6 pCi/g, indicating that residual radioactivity is fairly immobile in the soils surrounding the building.

After removal of the two small areas of surface soil with elevated activity, outdoor gamma scans were performed using GPS mapping to provide visualization of surface gamma radiation levels. Several areas of elevated activity were identified on the GPS map, all of which were attributed to granite markers and brick pavers, except for in the northwest corner of Pickard where elevated activity had previously been identified. It should be noted that, even though

[1] Static measurement locations were primarily at areas of elevated activity identified during scans.

elevated radiation levels were identified, all of the more than 13,000 measurements were less than twice the background rate.

The information provided by the GPS survey provided input to the design of additional surface soil sampling locations. Nineteen additional samples were collected (two of the samples were a composite of four locations in the Quadrangle). Results were similar to background results. The highest result was 3.2 pCi/g Ra-226 and 1.4 pCi/g Th-232, U-238 was less than the MDC. The highest results for the background sample set was 3.27 pCi/g Ra-226 and 1.17 pCi/g Th-232.

Residual soil radioactivity up to 792 pCi/g Ra-226 was identified in the feeder tunnel that is located adjacent to the area where radium was historically extracted from ores. In March 2010, Chase removed approximately one foot of the soils on the feeder tunnel floor and covered the area with a geotextile fabric and pavers to provide a barrier from radioactive materials.

Subsurface soils have not been sampled.

5.0 NUCLIDES OF CONCERN

Based on gamma spectroscopy and alpha spectroscopy analysis of soil and concrete samples, the nuclides of concern are U-238, Th-232, and their progeny (particularly Ra-226).

6.0 OTHER ENVIRONMENTAL HAZARDS

6.1 Asbestos Containing Materials (ACM)

Basement areas are covered with vinyl asbestos tile and asbestos containing mastics that were installed after radium separation operations and therefore cover residual radioactivity. Other ACM may be present in other areas, particularly as insulation. A comprehensive asbestos inspection will be conducted to identify ACM within the building prior to performing invasive activities on suspect materials.

6.2 Lead-Based Paint

Lead-based paint was specified in the original plans. There have been several removal operations during renovations, but lead-based paint is still a concern for decommissioning. A comprehensive lead inspection will be conducted prior to performing invasive activities on suspect materials.

6.3 Mercury

The potential for mercury contamination exists in the drain piping of most laboratories. Mercury was used in a wide variety of laboratory equipment from thermometers to manometers. In addition some laboratories may have used elemental mercury in experiments. The quantity of mercury can range from a few milliliters to liters. Due to its relatively low vapor pressure, high density, and insolubility, elemental mercury can remain trapped in laboratory piping systems for years. A mercury survey will be conducted prior to and during invasive activities on drain systems.

7.0 UNRESTRICTED RELEASE CRITERIA

The release criteria for unrestricted use are specified in 10 CFR 20.1402, "Radiological Criteria for Unrestricted Use." The criteria are that residual radioactivity results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem per year, and that the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

8.0 DOSE MODELING

Because the dose limit of 25 mrem/yr cannot be measured directly, compliance is demonstrated by pathway analysis and dose modeling. Building structures and soils are modeled separately due to differing pathways.

The derived concentration guideline level (DCGL) is the radionuclide-specific surface activity concentration that could result in a dose equal to the release criterion of 25 mrem/yr. The NRC has published default screening values (DSVs) in NUREG 5512 that licensees can choose to use as DCGLs if the site meets the screening criteria (most importantly that contamination does not exceed a depth of 1 cm for building structures and 15 cm for soils). DSVs are derived by applying conservative parameter values into NRC-approved DandD, Version 2.1 software. Due to the conservatism of DSVs, site-specific DCGLs will be developed and presented in the DP based on characterization data collected under this SCP. It is expected that the RESRAD-BUILD computer code will be used for modeling doses from building structures and the RESRAD computer code will be used for modeling doses from soils. Because the DandD code is conservative relative to the RESRAD family of codes, the DandD code is used to determine minimum detection sensitivities for characterization surveys.

8.1 Building Structural Surfaces

Building structural surface screening values for the nuclides of concern and progeny were modeled using DandD, Version 2.1 software. Each parent nuclide was modeled at an activity concentration of 1 dpm/100 cm^2. Implicit progeny

doses were included in parent doses and the initial activity was not distributed. All default parameter values were used except the Resuspension Factor (RF). The RF of 1E-6/m (as recommended in NUREG 1720 "Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule") is used instead of the default RF of 1.42E-5/m. This method was chosen because it is simple and conservative.

The nuclides of concern have decay chains that emit a variety of different types of radiation. It is important to understand the equilibrium state of the chain in order to convert from activity of the parent to gross activity of the entire decay chain. Because the nuclides of concern were chemically separated nearly a century ago, all nuclides are assumed to be in secular equilibrium.[2]

The results from DandD dose modeling are presented in the table below. DandD output reports are provided in Appendix D.

Table 8-1: DandD Dose Modeling Investigation Levels

Nuclide	DandD Result (mrem/yr per dpm/100 cm^2)	DCGL[3] (dpm/100 cm^2)
Ra-226+C	0.0172	1,453
Ra-228+C	0.0569	439
Th-232+C	0.303	83
U-238+C	0.103	243

8.2 Soils

Soil criteria are not modeled for characterization because standard laboratory analytical procedures are sufficient to detect all nuclides at a fraction of their conservative DSVs.

9.0 INVESTIGATION LEVELS

Conservative investigation levels (ILs) are established for characterization in order to achieve instrument detection sensitivities appropriate for the intended usage of the data for decommissioning. ILs are based on the DCGL for Th-232+C calculated in Section 8.0. Because Th-232 is a minor component of the mixture and the DandD model is inherently conservative, this method provides a

---

[2] Ra-226 will not be in complete secular equilibrium with progeny as limited by ingrowth of its longest lived daughter (Pb-210, half-life = 22 yrs) and progeny. At 90 years after separation, Ra-226 is at a 95% equilibrium state with Pb-210 and progeny. Therefore, the assumption of secular equilibrium does not have a significant effect on the dose modeling results.

[3] The DCGL is determined by dividing 25 mrem/year by the DandD result in mrem/yr per dpm/100 cm^2 and is presented in units of dpm/100 cm^2 of the parent nuclide.

conservative basis for establishing instrument detection sensitivity and investigation criteria.

9.1 Total Surface Activity Investigation Level

Gas flow proportional detectors are capable of measuring both alpha and beta emissions in the beta channel. Because alpha emissions are much more susceptible to interference from self-shielding and geometry factors, the beta channel will be used for total surface activity measurements.

The limiting nuclide method is used to determine a gross alpha+beta IL that is equivalent to the lowest DCGL of any nuclide in the mixture. Calculations of the net cpm equivalent to the IL for each nuclide are provided in the tables below.

Table 9-1: Limiting Nuclide Calculations – Total Activity

Nuclide	IL (dpm/100 cm^2)	Alpha+Beta Detection Efficiency [4]	Net cpm/100 cm^2 Equivalent to DCGL
Ra-226+C	1,453	98.0%	1424
Ra-228+C	439	91.8%	403
Th-232+C	83	101.8%	84
U-238+C [5]	243	143.8%	349
		Minimum	**84**

For total activity measurements, Th-232 results in the lowest net cpm relative to its DCGL; therefore, the Th-232 DCGL will be used as the IL.

9.2 Removable Surface Activity Investigation Level

DandD assumes a removable fraction of 10%, therefore a removable surface activity investigation level is established separately. Alpha emissions are used for establishing removable activity investigation levels because the low alpha background provides for more sensitive detection of removable radioactivity.
Calculations of gross alpha screening values are presented in the tables below.

[4] For decay chains, the efficiency is expressed in units of cpm for the entire decay chain per dpm of the parent. Efficiency calculations are presented in Section 21.5.
[5] U-238 in secular equilibrium with progeny is used for modeling doses from natural uranium. Due to extremely low abundance, U-235 has an insignificant effect on the dose modeling results.

Table 9-2: Alpha per Decay Calculations

Nuclide	Alphas per Decay Before Rn	Alphas per Decay Rn+C	EF [6]	Corrected Alphas per Decay Rn+C [7]	Total Alphas per Decay [8]
Ra-226+C	1	4	0.8	3.2	4.2
Ra-228+C	2	3	0.8	2.4	4.4
Th-232+C	3	3	0.8	2.4	5.4
U-238+C	4	4	0.8	3.2	7.2

Table 9-3: Limiting Nuclide Calculations – Removable Activity

Nuclide	10% of Total Activity IL (dpm/100 cm^2)	Total Alphas per Decay	Gross Alpha Removable Activity IL (dpm/100 cm^2)	Gross Alpha Removable Activity IL (cpm/100 cm^2) [9]
Ra-226+C	145	4.2	609	207
Ra-228+C	44	4.4	194	66
Th-232+C	8.3	5.4	45	15
U-238+C	24	7.2	173	59
			Minimum	**15**

For removable activity measurements, Th-232 is the most limiting and is used as the alpha removable surface activity investigation level.

9.3 Soils

Soil samples will be analyzed to achieve detection sensitivities of less than 0.5pCi/g for the nuclides of concern.

9.4 Summary of Investigation Levels

The investigation levels for site characterization are presented in the table below.

[6] Emanation Factor (EF) = (1- the RESRAD-BUILD default radon emanation fraction of 0.2)
[7] (alphas per decay Rn +C)*(EF)
[8] (alphas per decay before Rn) + (corrected alphas per decay of Rn + C)
[9] Detector alpha efficiency is 34%

Table 9-4: Summary of Investigation Levels

Type of Measurement	Structural Surfaces IL ($cpm/100\ cm^2$)	Soil Activity IL (pCi/g)
Total Surface Activity by GFP (Alpha+Beta)	84	N/A
Removable Surface Activity (Alpha)	15	N/A
Soil Activity (each NOC)	N/A	0.5

10.0 PROJECT MANAGEMENT AND ORGANIZATION

Licensed characterization activities will be performed under the MU broad scope radioactive material license. Chase will provide assistance to MU in the design and performance of characterization. Project management and business aspects of the project will be managed by MU Campus Facilities while environmental, health and safety aspects of the project will be independently overseen by MU Environmental Health and Safety (EHS) personnel. The management structure that will be utilized for administration and implementation of this SCP is described below.

10.1 Environmental Health and Safety Director

The EHS Director has overall responsibility for development and implementation of all MU EHS programs including occupational safety, radiation safety, industrial hygiene, biological safety, and environmental management. The EHS Director will ensure all EHS resources are available as needed to oversee project activities to ensure they are completed safely and compliantly.

10.2 Radiation Safety Officer (RSO)

The RSO reports to the EHS Director and is responsible for the management of the radiation protection program and for directing the program to limit occupational radiation exposures to levels that are ALARA. The RSO is also responsible for the development and implementation of a program for monitoring project activities and conditions to determine their status of compliance with the radioactive materials license and relevant regulations. The RSO reporting chain is separate from the project and site management reporting chain. In this independent role, the RSO provides a mechanism by which any worker can report potentially unsafe conditions or safety concerns. The RSO will promptly assess and resolve any reported concerns. The RSO will have access to all levels of operational management as necessary for execution of the RSO duties. The RSO has the authority to immediately terminate any activity that is found to be an imminent threat to health, safety, or property, or that is likely to violate the license conditions or radiation safety program requirements, and this authority cannot be revoked. Specific duties of the RSO include, but are not limited to, the following:

- Establishing organizational policy to comply with state and federal statutes, rules, regulations, and license conditions
- Establishing standards for personnel protection to assure that exposures to ionizing radiation and radioactive contamination are ALARA
- Approving written operating procedures for radiological protection and monitoring, radiation work permits, and other documents and ensuring that they appropriately include ALARA principles
- Coordinating the radiation safety training of personnel before they are allowed to work in restricted areas
- Monitoring activities involving radioactive material
- Providing selection criteria for equipment, supplies, and services for radiological work and personnel exposure monitoring
- Providing guidance on the proper shipping of all radioactive material from the site and ensuring compliance with applicable regulations of the U.S. Department of Transportation
- Implementing the radiation safety audit program

10.3 Chase Project Manager (PM)

The PM is responsible for project operations from initiation through completion. The PM will report to MU Campus Facilities regarding project management and business aspects of the characterization and the MU EHS Director for safety and compliance aspects of the characterization. PM duties include the following:

- Maintaining compliance with conditions of site operating licenses, permits, rules, and regulations
- Maintaining working conditions which assure health, safety, and protection for all employees and visitors
- Providing physical examinations for employees as required by MU policy, local, state, and federal regulations
- Ensuring that employees are instructed regularly, or as required by law, on precautions, procedures, and practices to be followed to minimize exposure to radioactive materials and to conduct operations safely
- Notifying the RSO promptly, of any operation or condition which appears to present a radiological hazard to employees, the public, or the environment
- Furnishing proper personnel protective equipment, ensuring that employees are instructed in its proper use, and enforcing rules for the equipment's utilization
- Ensuring that sufficient staffing for the project is present and consists of individuals able to conduct daily operations in compliance with regulatory requirements and to maintain a safe working environment, and
- Maintaining project radiation exposures ALARA

10.4 Radiation Control Supervisor (RCS)

The RCS reports directly to the RSO and indirectly to the PM and is responsible for the implementation of the Radiation Protection Program (RPP) at the project. Responsibilities may include but are not limited to the following:

- Monitoring site conditions to ensure compliance with the RPP and the MU Radioactive Material License
- Determining appropriate PPE
- Ensuring that the RSO is notified of conditions or situations that present a radiological hazard, concern, or exceed limitations set forth in applicable licenses, procedures and work plans
- Issuing Radiation Work Permits (RWP), and
- Maintaining records related to the RPP in an auditable condition for the duration of the project

10.5 Radiation Control Technicians (RCTs)

RCTs report to the RCS and act as the RCS's representatives in specifically implementing the RPP. Responsibilities may include but are not limited to the following:

- Performing and documenting radiological surveys
- Maintaining, inspecting, and performing operational checks of field instrumentation
- Identifying and controlling radiation protection hazards, and
- Performing job coverage duties, (i.e., surveys, contamination control, air sampling, sample analysis, environmental sampling, custody control, etc.)

10.6 Radiation Workers (RWs)

Radiation Workers are responsible for performing removal/remediation activities and removing, packaging and transporting waste to the appropriate waste stream. Specific aspects of RW duties include:

- Conducting work according to RCT instructions and in compliance with all project and site radiological controls, industrial safety, industrial hygiene and quality requirements
- Possessing a working knowledge of emergency procedures, location of evacuation routes, and ability to readily contact the appropriate emergency response personnel
- Reporting all deficiencies, non-conformances, or suspected procedure violations to the RCT, RCS, or PM
- Issuing stop work orders when work practices or conditions have or may lead to unsafe conditions.

11.0 PROJECT TASK MANAGEMENT

Characterization activities will be conducted under the provisions of the MU radioactive materials license and in accordance with this SCP. Activities involving licensed material shall be conducted in accordance with written and approved procedures, radiation work permits (RWP), and/or characterization survey packages to ensure adequate worker protection and to comply with the radioactive materials license and this SCP. Procedures will be approved by the Radiation Safety Committee and RSO. RWPs and survey package instructions will be approved by the RSO. The RSO and/or RSC may designate a qualified person at the site to approve and initiate RWPs and survey package instructions.

11.1 Radiation Work Permits (RWP)

RWPs will be prepared, reviewed and authorized in accordance with the RWP procedure that addresses request, initiation, development, issuance, and termination of an RWP. The RWP contains the location and description of the task to be performed, expected contamination and radiation levels, radiological monitoring requirements, Personal Protective Equipment (PPE) requirements, and special work instructions necessary to complete the work in a safe and compliant manner.

The RSO will initiate the RWP and provide a description on the RWP of existing and/or anticipated radiological conditions. RWP development will include specific identification of the radiological conditions and radiological protection requirements (e.g. clothing, respiratory protection, dosimetry, monitoring, training). Also, hold points and special instruction may be described on the RWP. The RWP form contains items such as the job description, location, known radiological conditions, protective clothing requirements, respiratory protection, dosimetry, training, health physics monitoring requirements, and any other special instructions. RWP development also includes creating a sign-in/out sheet for use by the authorized users. After development, the RWP must be approved for issuance by the RSO. Issuance includes a review of the RWP with the authorized users, as required. A pre-job meeting may also be prerequisite to issuance of the RWP.

During use, a copy of the RWP will be maintained at the worksite, and authorized users will be required to sign-in/out when participating in the subject activity, indicating their understanding of the requirements of the RWP. RWPs will be terminated upon completion of the activity by signature on the RWP and completion of a form indicating the reason for termination and confirmation of final radiological survey of the activity or area. Upon termination of the RWP, the RWP package will be completed and filed. The package generally contains the completed RWP, sign-in sheets, applicable radiological surveys, and any other documents pertinent to the job. If radiological conditions or requirements change,

appropriate changes to the RWP may be made by the RSO or designee. Alternatively, a new RWP may be issued.

11.2 Survey Packages

Characterization survey packages will be developed for each survey area that contain specific characterization survey instructions. Survey package preparation and completion will be approved by the RSO or designee to ensure all survey requirements and Data Quality Objectives (DQOs) are met. As applicable, each survey package will contain:

- Survey unit number
- Maps of the survey unit surfaces
- Overview maps detailing survey locations and placement methodology
- General survey requirements
- Instrument requirements with associated Minimum Detectable Concentrations (MDCs), count times and scan rates
- Survey Instruction Sheets
- Percentage of surface requiring scan surveys
- Number of measurements required
- Additional specific survey instructions
- Survey Data Sheets
- Sampling protocols
- Chain of Custody Forms
- Signature of Preparer, Surveyor and Reviewer

12.0 PROJECT TRAINING REQUIREMENTS

Chase will provide all project personnel with radiation worker training required by the radioactive materials license, as well as training for project-specific programs, plans, and procedures.

12.1 Radiological Training

Radiological training will be completed and documented in accordance with MU license requirements. The PM will maintain a copy of each individual's certification on site in the project file.

12.2 Project Specific Training

Prior to project start-up, personnel will attend an initial project-specific training session conducted by the PM. The training session will include the following items:

- Review of the SCP
- Discussion regarding the scope of work and planned work activities

- Review of chemical, physical, and radiological hazards associated with the project
- Discussion of posting requirements
- Types and use of available PPE
- Project security and control of operational work zones
- Emergency response and site evacuation procedures
- Project communications
- General safe work practices
- Data quality and chain of custody procedures, and
- Review of applicable regulatory standards as applied to project operations

12.3 General Safety Briefings

General safety meetings will be held by the PM at the beginning of each work shift. The purpose of these meetings will be to discuss project status, potential problem areas, general safety concerns, and to reiterate project requirements. Additional meetings will be held if conditions warrant.

12.4 Subcontractor Training

Subcontractors are expected to be used for asbestos abatement and removal of interior finishes. All subcontractor personnel will receive training as required by this plan. Subcontractor personnel who require unescorted access to restricted areas will be trained as radiation workers.

12.5 Visitor Orientation

All visitors will be briefed on the SCP requirements, receive General Orientation training and must be escorted at all times. General Orientation shall be administered to all personnel, contractors, and visitors requiring access to restricted areas. The scope of orientation shall be commensurate with the activities being performed and the risks involved. The orientation shall consist of the following:

- Project-specific health and safety orientation
- The location of restricted areas
- Posting and labeling identification of radiological areas and packages
- Requirement for PPE and dosimetry
- Escort requirements
- Review of Regulatory Guide 8.13 "Instructions Concerning Prenatal Radiation Exposure," Appendix B (required for female contractors or visitors), and
- For visitors, completion of a visitor orientation training completion form

Escorts shall have a minimum of Radiation Worker training. Additionally, all visitors must receive training and/or briefings in accordance with other site policies prior to entering restricted areas of the facility.

12.6 Transportation Training

Persons who prepare hazardous materials for transportation or are otherwise responsible for safely transporting hazardous material will be trained in accordance with the requirements of 49 CFR 172, Subpart H.

13.0 RADIATION PROTECTION PROGRAM

The radiation protection program (RPP) will be implemented commensurate with the scope and extent of licensed activities at the site. This program and associated operating procedures are the primary means used to administratively establish safe radiation work practices and ensure compliance with NRC requirements. The following sections provide a description of the primary elements that will be used to realize this commitment.

13.1 Exposure Control

Personnel exposure to radioactive material will be controlled by application of engineering, administrative, and personnel protection provisions in the order of priority listed below.

13.1.1 Engineering Controls

Engineering Controls will be used, as practicable, to minimize or prevent the presence of uncontained radioactive material. Engineering controls will predominantly be comprised of containment, isolation, and ventilation.

All material removal and sampling activities will be conducted in a manner to control the spread of contamination and to maintain personnel exposures ALARA. Containments, HEPA-filtered negative air machines, and HEPA-filtered vacuums will be used as necessary to control airborne particulate radioactivity, loose insulation fibers and fugitive dusts during surface removal and sampling activities.

Engineering controls may also be used to ventilate work areas to control radon levels if necessary. If this is performed, the procedure will include an evaluation of doses to workers and the public.

13.1.2 Administrative Controls

Administrative controls will be used to control work conditions and work practices and are predominantly comprised of the following:

- *Access Control:* Routine access to work areas will be limited to personnel necessary to accomplish tasks or activities. Access will also be controlled with respect to training and use of specified personnel protection equipment.

- *Postings and Barriers:* Postings will be used to inform personnel of relevant hazards or conditions and associated access requirements. Barriers will be used to prevent unauthorized access.

- *Procedures:* Written procedures will be used to describe specific radiation protection requirements necessary for safe performance of tasks.

- *Radiation Work Permits:* RWPs will be used to describe specific or special worker protection requirements for specific activities involving radioactive material

13.1.3 Source Control

Action levels and limits for radiation surveys will be used to control the levels of radioactivity on equipment and in areas. These limits will be communicated via procedures, RWPs, and/or survey packages.

13.1.4 Personal Protective Equipment

Personal protective equipment will be used to control personnel exposure to radioactive material when administrative controls are not sufficient and engineering controls are not effective or practical. Personal protective equipment may include clothing, gloves, protective shoes or shoe covers, eye protection, and/or respiratory protection.

Engineering controls are expected to be sufficient to control airborne radioactivity levels. However, respiratory protection will be used for asbestos abatement. Chase and asbestos subcontractors maintain respiratory protection programs that include medical surveillance, respiratory testing, maintenance, protection factors, workers responsibilities, and respiratory protection limitations. MU will review these programs and approve them for use prior to use of respiratory protection on-site.

13.2 Notifications

Project personnel will notify the RSO of conditions or situations that present a radiological hazard, concern or exceed limitations set forth in this SCP or the MU radiation protection program. The RSO will then make notifications to the NRC as required.

13.3 Dosimetry

Radiation doses from internal and external sources are expected to be well below 10% of the occupational dose limits, so external and internal dosimetry procedures are not expected to be required. However, Radiation Workers will be monitored for external doses by thermoluminescent dosimeter (TLD) and internal doses by air sampling and/or bioassay. The RWP process includes an analysis of the requirements for dosimetry monitoring, air sampling, and respiratory protection.

Results of internal and external monitoring shall be used to calculate total organ dose equivalent and total effective dose equivalent to workers for which monitoring is required.

13.4 Air Sampling Program

Concentrations of radioactive material in air will be determined by sampling. Air samples will be collected under known physical conditions (e.g., sample time, flow rate). Air sampler flow meters will be calibrated at least annually and following repair and/or modification.

Airborne particulate sampling will be performed during invasive work to assess the potential for internal exposures. A conservative airborne gross alpha concentration of 5E-13 μCi/ml will be used to estimate doses from airborne radioactivity. This is based on the lowest derived air concentration (DAC) of any nuclide of concern (Th-232 W Class). This is conservative because solid samples collected during the initial radiological assessment demonstrate that Th-232 is a minor fraction of the nuclide distribution and does not include the additional alphas emitted by progeny. Following air sample collection, the filter media will be counted for radioactivity and then stored for decay of short-lived radon progeny before recounting to achieve required sensitivity. If airborne radioactivity levels indicate that assignment of internal dose may be required, the RSO will make the dose assessment based on actual nuclide distribution data. This may be performed using isotopic concentrations of solid samples obtained during characterization or by isotopic analysis of air sample filters from each area. Bioassays are not expected to be performed unless air sampling indicates a potential to exceed 10% of the internal dose limit.

The RSO shall apply professional judgment and experience to identify air sampling appropriate for the specific situation. Such judgment will be based on historical air sampling and characterization results, quantity of material being handled, potential for release of contaminants based on physical form and activity, type of confinement or containment, and other factors specific to the activity.

The air sampling program will consist of worker breathing zone air samples, general area samples, high volume air samples, effluent monitoring air samples, and radon monitoring.

13.4.1 Breathing Zone Air Samples

Breathing zone air samples (belt mounted pump with sample head affixed to worker's lapel) will be the primary method of monitoring the worker's intake of radioactive material.

13.4.2 General Area Air Samples

Air samples will be collected from general and localized areas when and/or where there is potential for generation of airborne radioactive material. These samples will be used to verify that engineering controls are effective, and provide warning of elevated concentrations for planning or response actions. In each case, the sampling point will be located in the airflow pathway near the known or suspected release point(s). As necessary, more than one air sample location may be used in order to provide a reasonable estimate of the general concentration of radioactive material in air.

13.4.3 High Volume Air Samples

High volume air sampling may be used to obtain sufficient detection sensitivities for nuclides with low DAC values during short duration activities or to estimate radon concentrations by measuring the concentrations of particulate progeny.

13.4.4 Effluent Monitoring Air Samples

General area air samples will be collected at effluent release locations and in the vicinity of outdoor activities as necessary to verify that any radioactive materials released to the environment meet the effluent concentration limits of 10 CFR 20, Appendix B, Table 2, Column 1; for W Class Th-232, this is 4E-15 µCi/ml.

13.4.5 Radon Monitoring

MU has been monitoring radon levels in the building for several years and will continue to monitor radon levels in the building throughout the decommissioning process.

13.5 Clearance of Materials

The limits specified in Table 1 of ANSI/HPS N13.12-2013, "Surface and Volumetric Radioactivity Standards for Clearance" (600 dpm/100 cm^2 for radium and thorium) will be used for the release of equipment and materials from the building such as tools used for project activities. ANSI/HPS N13.12 does not specify removable surface activity limits, therefore removable alpha surface activity will be limited to 10% of the total activity limit (60 dpm α/100 cm^2). This is consistent with the removable surface contamination limits for alpha emitters in

unrestricted areas listed in NUREG 1556 Volume 12 Table P.5 (100 dpm/100 cm^2).

ANSI/HPS N13.12-2013 provides guidance for protecting human health from radiation exposure for the clearance of items or materials that could contain radioactive materials. Table 1 provides screening levels, above background, for the clearance of items or materials to limit the dose to an average member of a critical group to 1 mrem/year or less.

Cleared items and building debris will be surveyed, documented and placed into appropriate waste containers, such as roll-off containers staged outside the building. In addition to surveying each item prior to loading, each roll-off container will receive a verification radiation survey prior to leaving the site that will include a scan survey with a 2" x2" sodium iodide detector.

14.0 OCCUPATIONAL HEALTH AND SAFETY PROGRAM

Project activities will be conducted utilizing project-specific procedures approved by the applicable MU Manager. Activities of particular importance to this SCP are elevated work, confined space entry, and asbestos abatement.

15.0 RADIOACTIVE WASTE MANAGEMENT PROGRAM

Any radioactive waste generated during project activities will be packaged in DOT-approved shipping containers for shipment to appropriately licensed facilities. Some waste may require sizing for packaging in the appropriate shipping containers. All waste will be stored in approved storage areas at the facility until shipment off-site. Radioactive waste will be subdivided into categories based on types of material and processing/disposal methods. Solid radioactive subdivisions may include metals, DAW/combustible, asbestos, soils, and mixed wastes. Liquid radioactive waste, if any, may consist of cutting slurry from concrete cutting, residual liquids in drain lines, and surface or groundwater water that has infiltrated into the building. All radioactive waste will be transported via DOT-approved carriers and manifested by qualified waste shippers and/or brokers to appropriately licensed waste processors and/or disposal sites. No chemicals or reagents shall be used that will cause a radioactive waste to become a mixed waste.

16.0 QUALITY ASSURANCE PROGRAM

The QA program is developed and organized with emphasis given to maximizing worker safety, eliminating off-site releases, collecting data that meets the DQOs, and minimizing overall project costs. QA criteria are applied in a graded manner to achieve a balance between the rigor of application of quality assurance measures and the scale, cost, and complexity of the work involved.

Accountability for quality is the responsibility of every person assigned to the project, extending from the PM through established lines of authority to all project personnel, who are responsible for the requisite quality of their own work. Quality Assurance will be implemented by personnel conducting their activities to meet requirements and expectations according to established plans and procedures that reflect the way business is to be conducted on the project.

All project personnel are responsible for executing their work and ensuring that quality-affecting activities within their purview are performed in conformance with applicable plans and procedures. All personnel have the authority and responsibility to stop his/her own work and the responsibility to report such conditions when continuation will produce or conceal results that are not in accordance with prescribed requirements, and/or pose imminent radiological or safety hazard to employees, the environment, or the general public. Project personnel have sufficient freedom, authority, access, and responsibility to:

- Identify quality problems, deficiencies, nonconformance's, and noncompliance with regulatory and performance objectives
- Initiate, recommend, or provide solutions through designated channels
- Verify implementation of the solutions
- Assure that deficient work is stopped or is proceeding under controlled conditions until proper disposition of the unsatisfactory condition is accomplished

16.1 Nonconformance Control and Corrective Action

All project personnel shall be responsible for notifying their supervisor or the Project Manager of conditions or items that do not meet specified requirements. Project procedures address the following measures:

- Identification or segregation of the nonconformance;
- Documentation of the nonconformance;
- Evaluation of the nonconformance;
- Disposition and justification provisions;
- Notification to affected personnel or organizations, and;
- Verification of disposition

All project personnel are encouraged to identify any activity, process, or procedure that could lead to potential non-conformances or conditions adverse to quality. Corrective Action procedures provide the reporting and evaluation requirements for preventative actions resulting in the elimination of potential quality problems. All non-conformances, corrective actions, and preventative actions shall be documented and maintained in accordance with the appropriate procedures.

16.2 Quality Assurance Audits

The RSO is responsible for planned and periodic audits of project activities. These audits shall be scheduled in a manner that will provide sufficient coverage and coordination of activities throughout the duration of the project. These audits will verify compliance with the requirements specified in this plan, related procedures, plans, and regulatory requirements. These audit activities also provide a mechanism to identify opportunities for continuous improvement.

In addition to this audit activity, the RSO or designee will perform periodic surveillances to monitor and document compliance with this SCP and standard radiological and safety practices.

Identified departures from specified requirements shall be treated as non-conformances and corrected. Management personnel shall take appropriate action to identify root causes, correct deficiencies, prevent recurrences, and determine impacts of audit findings in their area of responsibility. Follow-up actions will be performed as necessary to ensure that appropriate corrective actions have been implemented in a timely manner and are effective.

16.3 Sample Chain-of-Custody

The sample chain-of-custody (COC) maintains the integrity of the sample; that is, there is an accurate record of sample collection, transport, and analysis. This ensures that samples are neither lost nor tampered with, and that the sample analyzed in the laboratory is actually and verifiably the sample taken from a specific location in the field. Samples sent off-site for analysis will use an approved Chain of Custody Procedure.

16.4 Survey Documentation

A characterization survey package will be developed for each survey area that provides instructions for the survey and the appropriate forms necessary to document the survey.

16.5 Data Quality Assessment (DQA)

All characterization data will undergo a data quality assessment to ensure usability for the intended purpose.

16.5.1 Preliminary Data Review

A preliminary data review will be performed for each survey area to identify any patterns, relationships or potential anomalies. Additionally, measurement data will be reviewed and compared with the investigation levels to identify areas of elevated activity and confirm the correct classification of survey areas. The following preliminary data reviews will be performed for each survey area:

- Calculations of the survey unit mean, median, maximum, minimum, and standard deviation for each type of reading
- Comparison of survey data with applicable investigation levels

16.5.2 Data Validation

Field data will be reviewed and validated to ensure:

- Completeness of forms
- The correct type of survey has been assigned to the survey area
- The MDCs for measurements meet the established data quality objectives; independent calculations will be performed for a representative sample of data sheets and survey areas
- Instrument calibrations and daily functional checks have been performed accurately and at the required frequency

16.6 Quality Assurance Surveys

Quality assurance surveys will be conducted by duplicating a minimum of five percent of the characterization measurements to include scans, static measurements, and smears. The contract laboratory will implement their internal QA procedures related to sample analysis. Additionally, the contract laboratory results will be cross-checked by performing duplicate analysis at a different laboratory location at a rate of approximately five percent.

17.0 CHARACTERIZATION GOALS

Characterization is designed with the following goals:

- Obtain as much radiological data as possible without impacting the structural integrity of the building and while maintaining building mechanical systems (HVAC, plumbing, etc.), safety systems, and security systems operational
- Collect all information necessary for MU to make an informed decision regarding the future of the building (save vs. demolish)
- Determine ratios of the nuclides of concern for the various areas.
- Collect all information necessary to develop a Decommissioning Plan
- Collect information sufficient to develop DCGLs and classify areas per MARSSIM

- Collect information necessary to determine disposal options and obtain waste profile approvals at various disposal sites
- Remove interior coverings to expose original surfaces to the extent possible, including surfaces covered with asbestos and lead based paint
- Identify any residual mercury, particularly in drain lines
- Remove drain lines under the basement floor (survey and cap any lines extending beyond the building footprint)
- Remove other drain lines that may be identified as having residual radioactivity to the extent practical
- Remove steam tunnel feeder soils to the underlying concrete floor to allow structural engineering inspections
- Perform structural engineering inspections and tests to determine the structural integrity of the building in order to define potential scenarios and estimate decontamination, construction, and/or demolition costs
- Sample surface and subsurface soils under and around the building
- Collect soil radioactivity data sufficient to have a high probability of bounding groundwater impacts
- Test the effectiveness of remediation methods for decommissioning planning

Removal of embedded drain lines under the building as part of characterization will allow collection of important data for planning, remove a major source of background interference to allow for better quality data collection, provide access to inspect for discrete areas of leakage that may impact surrounding soils, etc., and will allow access to soils under the building for direct survey and sample collection.

Removal of roof coverings to provide access to the decking for survey will not be performed because the probability of extensive contamination is low, gamma scans of the interior decking surface will provide sufficient information to draw conclusions regarding the decommissioning effort required and to bound risk to an acceptable level. If the roofing materials were removed, roof replacement would be necessary to maintain the building weather-tight during the period between characterization and decommissioning.

18.0 PLANNED CHARACTERIZATION ACTIVITIES

Planned characterization activities include the following:

- Conduct asbestos and lead paint inspection
- Remove remaining museum pieces
- Remove attic insulation and wood decking, then vacuum attic surfaces to provide conditions suitable for surveys
- Remove walls installed during 1974 renovation down to the original surfaces
- Remove plaster covering original wall surfaces in the basement and on the 2nd floor
- Remove floor coverings on the 1st and 2nd floors to the original surfaces
- Access brick chimneys and shafts for survey at various elevations
- Remove partition walls and framing around original iron columns
- Remediate asbestos floor tile to provide access to original floor surfaces
- Remove basement concrete floor surface until no detectable alpha emissions to remove interference for identifying drains and to accommodate saw cutting of floors
- Identify drain locations from drawings and gamma emission rates at the floor surface
- Saw cut floor and extract drains
- Survey and sample soils in drain trenches
- Core through the concrete floor at areas of elevated exposure rate from scans and at judgmental locations to collect soil samples
- Survey and release or dispose of all debris and rubble
- Find locations of drain line terminations from the 1997 foundation project – sample at interface and downstream if practical
- Sample storm drains at manholes
- Remove soils in the steam tunnel feeder to expose the concrete floor for structural engineering inspections
- Perform 100% scan for gamma exposure rates and surface contamination
- Conduct gamma scans of soils
- Conduct surface and subsurface soil sampling using a Geoprobe core sampler up to twelve foot depth in the soils of outside grounds
- Analyze solid samples by gamma spectroscopy and/or alpha spectroscopy
- Perform building inspections and tests to determine the structural integrity of the building
- Test remediation methods

Detailed descriptions of selected activities are provided below.

18.1 Asbestos/Lead Inspections

Prior to any invasive characterization activities, MU will provide the asbestos subcontractor with all previous asbestos/lead inspections and tests. The Subcontractor will evaluate the completeness of the information and conduct any additional tests or inspections of the building as necessary to identify any ACM or lead-based paint.

18.2 Remove Remaining Museum Pieces

Several museum pieces were not included in the initial move of the museum. These items must be removed by a specialized moving company experienced in moving high value assets. Chase will train the moving company personnel and oversee the removal and movement of the remaining museum pieces prior to commencing other characterization activities that would risk damaging the pieces. MU may opt to perform this activity prior to the start of characterization activities under this SCP.

18.3 Asbestos/Lead Abatement

Chase will subcontract a properly licensed asbestos/lead abatement contractor to remove lead or ACM, including floor tiles, mastics, or other interior finishes that require removal in order to expose original building surfaces for survey. Asbestos workers will be trained as radiation workers and Chase will provide radiological oversight of abatement activities and packaging/disposal of any radioactive ACM. The engineering controls and PPE required for these activities are expected to be sufficient for control of radioactivity.

18.4 Attic Preparation

In order to prepare attic surfaces for survey, insulation and debris must be removed and the remaining surfaces vacuumed, including the wood decking and plaster ceiling beneath. Workers will use HEPA-filtered negative air machines to control fugitive dusts during removal of insulation and debris, and HEPA-filtered vacuum cleaners to remove remaining dusts. Depending on the results of the asbestos survey, these activities may be performed using asbestos abatement techniques. Regardless of the presence or absence of asbestos, it is expected that full Tyvek suits and respiratory protection will be used while removing fiberglass insulation.

18.5 Remove Interior Structures

Interior finishes that cover original building surfaces will be removed to the extent possible to expose underlying surfaces for survey, while considering the occupational safety risk to the workers, structural integrity of the building, and maintaining vital building mechanical systems operational.

Interior finishes that may require removal include partition walls, display cabinets, floor coverings, acoustic ceilings, stadium seating and stage, and plaster coatings.

While the goal is to access all original structures, this may not be practical in some areas. The PM and MU will make judgments on a case-by-case basis regarding the importance of data collection and the risks involved with obtaining the data. For example, surfaces where access involves elevated safety risks and with a very low probability of containing residual radioactivity would not be surveyed during characterization. Areas that are not surveyed will be documented in the Site Characterization Report (SCR).

18.6 Concrete Surfacing

After removal of vinyl asbestos floor tiles and asbestos mastics in the basement, concrete floor surfaces with residual radioactivity will be surfaced using scabblers, scarifiers, or grinders fitted with HEPA-filtered dust control shrouds until there is no detectable alpha emissions or surfacing is ineffective at removing residual radioactivity. Alpha emissions will be used because beta-gamma measurements will not be practical due to background interference. The goal is to remove all residual surface radioactivity from the concrete floor surface so that gamma measurements can be used to assess subsurface radioactivity in drain lines and to prevent the spread of radioactivity during concrete cutting of the floors to access drain piping.

18.7 Concrete Cutting

After locating drain lines using gamma measurements, historical drawings, and visual clues, Chase will wet saw the floor on either side of drain lines and remove the concrete to access the underlying soils and drain lines. Prior to sawing, a means of water removal will be established. After sawing, the concrete will be broken using an electric hammer as necessary to facilitate removal. During cutting, workers will continuously collect the cutting slurry into drums or dewatering containers. After dewatering/decanting, the water and slurry will be tested for radioactivity and appropriately disposed.

Concrete cutting and trenching operations will change the diffusion rate of radon from contaminated soils into the Pickard Hall basement. Therefore, additional air sampling will be performed to evaluate radon levels inside the building during and after these operations.

18.8 Trenching

After removing the concrete floor over drain lines, the underlying soils will be removed and placed into appropriate containers (drums, soil sacks, etc.) until the drain lines are exposed. In addition to continuous radiological monitoring, the soils will be visually inspected for soil type and consistency as well as moisture content, staining, or any other signs of drain line leakage.

18.9 Drain Removal

After uncovering drain lines, the drain lines will be removed and packaged for disposal, taking care to avoid any spillage (according to historical records, original drains were grouted in place, so they are not expected to contain liquids).

18.10 Soil Removal

After removal of drain lines, the remaining soils will be surveyed to the extent possible considering background levels. If any areas of leakage are noted that can be easily remediated, they will be removed. After in-place radiological assessment of soils, samples will be collected for laboratory analysis. The soils will be sampled to a depth where field screening indicates no elevated activity or it is impractical to collect deeper samples.

18.11 Concrete Coring

Soil samples may be collected at other locations under the basement concrete floor to further determine the radiological impact to subsurface soils. The locations, if any, will be judgmentally based on the results of drain line excavation and gamma scans of floor surfaces. The soils will be sampled to a depth where field screening indicates no elevated activity or it is impractical to collect deeper samples.

18.12 Soil Sampling

In addition to the under-slab soil sampling described above, subsurface sampling of the soils of outside grounds will be conducted to collect information regarding the vertical and lateral extent of residual soil radioactivity. After performing outdoor gamma scans, Chase will perform subsurface sampling using a track-mounted Geoprobe core sampler. Two-inch acetate sleeves will be used to line the core sampler and collect the sample. Each core will be removed from the acetate sleeve, visually inspected, and scanned with a pancake GM or gas flow detector to determine where samples will be collected for laboratory analysis. During sampling, the soil characteristics will be logged. Sampling will be performed using a chain of custody procedure for shipment to the off-site laboratory. Soils from each 1-ft increment will be placed into a container, labeled, and archived. After sampling, each hole will be filled with bentonite chips.

18.13 Structural Engineering Inspections and Tests

Once interior coverings are removed to expose structural members for evaluation, a condition assessment will be performed by a structural engineer. This will include both a visual inspection and invasive testing. Invasive activities will be conducted on structural members that are not impacted by radioactive materials to the extent possible. If invasive activities are required on impacted structures, the appropriate radiological controls will be implemented.

The structural evaluation is expected to include:

- material sampling of floor joists, beams and columns as appropriate
- interior and exterior non-destructive masonry tests including:
  - Surface Penetrating Radar (SPR) and/or Infrared Thermography (IRT) to help determine wall composition
  - probing the interior of the wall with a borescope through small access holes
  - determining masonry compressive strengths with the Flatjack test
  - determining mortar hardness with the Rebound Hammer test
- representative sections of the wall assembly may be removed for masonry prism tests and determination of composition

18.14 Test Remediation Methods

As part of the preparation for characterization involving removal of finishes, Chase may test remediation methods for development of the DP. For example, Chase may determine if surfacing of contaminated brick walls is effective and/or to determine the depth of radioactivity within the brick surface.

19.0 CHARACTERIZATION SURVEY DESIGN

Characterization surveys will be performed using the Data Quality Objective (DQO) process to ensure data are of a sufficient quality to be useful for intended purposes. Characterization will consist of the following types of measurements:

- Indoor surface scans for alpha and beta emissions using gas flow proportional detectors
- Indoor surface scans for gamma emissions using a 2" x 2" sodium iodide detector at a distance of 10 cm
- Large area wipes for alpha and beta removable activity (judgmental locations)
- At locations of elevated activity:
  - Static measurements for alpha and beta total surface activity
  - Disc smears for alpha and beta removable activity
  - Static measurements for gamma emissions at a distance of 10 cm
  - External dose rates at a 1 meter distance

- Solid samples of building structural materials
- Surface soil gamma scans
- Surface and subsurface soil samples for gamma spectroscopy analysis (a subset of samples will also analyzed by alpha spectroscopy analysis)

19.1 Data Quality Objectives (DQO)

The Data Quality Objective process as described in MARSSIM is used throughout the design and implementation of characterization surveys. The following is a list of the major DQOs for the survey design:

- Alpha+Beta scanning will be conducted at a rate to achieve an MDC_{scan} of less than the investigation level of 84 cpm/100 cm^2 based on Th-232+C.
- Alpha+Beta static measurements will be taken to achieve an MDC_{static} of less than the investigation level of 84 cpm/100 cm^2 based on Th-232+C.
- Alpha removable contamination measurements will be counted to achieve an MDC_{smear} of less than the investigation level of 15 cpm/100 cm^2 based on Th-232+C.
- Soil samples will be analyzed to achieve a detection sensitivity of less than 0.5 pCi/g for each nuclide of concern.
- Individual measurements will be made to a 95% confidence interval.
- Characterization data will be of sufficient quality to provide useful information regarding the site's ability to meet a site-specific dose model.

19.2 Survey Areas

The facility will be divided into survey areas based on contamination potential. For indoor areas, this is expected to be a room or group of contiguous rooms that have a similar contamination potential. Each survey area will be surveyed according to an area-specific survey package that includes instructions specific to the characterization objectives of that area.

19.3 Background Determination

For direct measurements, an ambient background level will be determined for each survey, subtracted from gross measurements, and used to calculate the actual survey MDCs. Material-specific background determinations are not expected to be performed.

Background soil samples will be collected in a nearby non-impacted area.

19.4 Surface Scans

The purpose of scanning is to identify locations of elevated activity. Where elevated activity is identified, the surveyor will stop and re-scan the suspected area at a slower rate to determine if the elevated activity was sustained. Where a sustained increase in the audible response was identified, the boundary of the elevated area will be recorded for locating the area for additional measurements.

All accessible surfaces in the basement and attic, and surfaces less than a 2-meter height in other areas will receive a 100% scan for alpha, beta and gamma emissions. Surfaces above a two meter height on the first and second floor will receive judgmental surveys based on accessibility and survey results in other areas.

19.4.1 Alpha+Beta Scans

Alpha+beta scans will be performed by moving a gas flow proportional detector over surfaces at a distance of less than one centimeter and at a rate less than the maximum allowable scan rate necessary to achieve DQOs.

19.4.2 Indoor Gamma Scans

Indoor gamma scans will be performed by moving a 2" x 2" sodium iodide detector over surfaces at a distance of 10 cm and at a rate of 0.5 meters per second. Indoor gamma scans will include accessible ventilation ducts, drain piping, and exposed soils.

19.4.3 Outdoor Gamma Scans

Chase will perform GPS position-correlated gamma scan surveys of the portion of the outside grounds that is expected to bound impacted soils. Collection of GPS data is contingent upon the availability of a GPS signal. The surveyor will scan the ground surface to measure and record ambient gamma radiation levels. This survey will be conducted using a 2" x 2" sodium iodide gamma scintillation detector linked to a Trimble GPS system or equivalent. The surveyor will systematically walk over accessible areas of the property with the detector held at 10 cm from the ground surface with the meter's audio function active. In general, the surveyor will walk at a rate of 0.5 meter/second or less along transect lines that are separated by no more than 0.5 meters.

Radiation measurements and their associated spatial coordinates will be recorded once each second by the GPS system. This data will be used to generate an electronic record of the gamma radiation levels encountered during the surface scan. Survey results will be color coded and superimposed on an aerial photo of the property and provided in the SCR.

19.5 Static Measurements

Direct surveys (static measurements) for total surface activity and gamma emissions will be taken on accessible building surfaces where elevated activity is identified. Additionally, a small set of measurements will be performed by randomly selecting locations in areas without elevated activity as identified during scans.

19.5.1 Alpha+Beta Static Measurements

Alpha+beta static measurements will be performed by holding the probe at a distance of less than one centimeter and performing a one-minute timed count. Field measurements will be converted to activity concentrations using the following equation:

$$\text{Activity}\,(\text{dpm}/100\text{cm}^2) = \frac{cpm_{sample} - cpm_{background}}{E_{total} \cdot \frac{A}{100cm^2}}$$

Where:

cpm_{sample}	=	sample count rate (cpm)
$cpm_{background}$	=	background count rate (cpm)
E_{total}	=	total detector efficiency for radionuclide emission of interest (includes combination of instrument efficiency and surface efficiency)
A	=	active area of the detector (cm^2)

As part of the investigation of areas of elevated activity, the surveyor will also collect one-minute alpha static measurements to determine alpha/beta ratios.

19.5.2 Gamma Static Measurements

Indoor gamma static measurements will be performed by holding the probe at a distance of ten centimeters and performing a one-minute timed count.

19.6 Removable Contamination Measurements

19.6.1 Large Area Wipes

Large Area Wipes (LAWs) may be judgmentally performed to collect qualitative information regarding removable surface contamination. LAWs will be conducted by wiping a Masslinn cloth over an area and then performing static measurements on the cloth. LAWs are more sensitive and have wider coverage than disc smears, but cannot be accurately quantified in dpm/100 cm^2. LAWs are used as qualitative measures of removable surface contamination.

19.6.2 Disc smears

Removable contamination measurements will be performed by wiping an area of approximately 100 cm^2 on surfaces with a cloth disc smear and then counting the smear for beta and alpha emissions in a portable smear counter. Disc smears will be collected at each static measurement location and at additional locations where geometry prohibits static measurements, such as drains. Smear data will be converted to activity concentrations using the following equation:

$$\text{Activity}\,(\text{dpm}/100\text{cm}^2) = \frac{cpm_{sample} - cpm_{background}}{E}$$

Where:

cpm_{sample}	=	sample count rate (cpm)
$cpm_{background}$	=	background count rate (cpm)
E	=	detector efficiency for radionuclide emission of interest

19.7 Dose Rate Measurements

Dose rate measurements will be performed with a tissue equivalent Bicron MicroRem meter. This instrument was selected due to its flat energy response. Because the Bicron is a ratemeter, an average of ten instantaneous rates will be determined at each location by covering the meter and recording the measurement observed when it is uncovered (this is a relatively unbiased method to obtain an average dose rate). Dose rates will be performed where significant amounts of radioactivity are present to provide data for decommissioning work planning and development of the DP.

19.8 Solid Samples

19.8.1 Structural Solid Samples

Chase will collect solid samples of concrete, wood, and other materials to provide information regarding the radioactivity and nuclides of concern for various areas of the facility. These samples will be collected judgmentally to provide useful information for decommissioning planning.

Solid samples may also be collected to support the building condition assessment. These samples will be collected from areas that are not impacted by radioactive materials.

19.8.2 Soil Samples

Surface and subsurface soil samples will be collected to characterize the lateral and vertical extent of residual radioactivity around and under the building. Sampling will be conducted to bound residual radioactivity if possible. This will be performed by sampling laterally and vertically until samples are at background

levels. Where residual radioactivity has been identified or is suspected, sampling will be performed on a grid pattern. Sampling on the west side of the building will include surface and subsurface samples on the west side of the steam tunnel, regardless of the results of samples from the east side of the steam tunnel.

19.8.3 Laboratory Analyses

Solid samples will be sent to a contract laboratory for analysis by gamma spectroscopy and/or alpha spectroscopy. Some samples are expected to be counted for other characteristics to provide data in support of waste profiling. Samples will be sent to TestAmerica and/or Teledyne Brown Engineering using an approved Chain of Custody Procedure.

20.0 IN-PROCESS SURVEYS

Removal operations will be conducted to control the spread of contamination and keep personnel exposures ALARA. In-process surveys are conducted in support of project activities to monitor the effectiveness of contamination controls and engineering controls, and to ensure that surrounding areas are not cross-contaminated during removal activities.

Radiological surveys will be performed to describe the radiation types and levels in an area or during a task, to identify or quantify radioactive material, and to evaluate potential and known radiological hazards. In-process surveys will consist of dose rate surveys, airborne radioactivity monitoring, scan surveys, static measurements and removable contamination measurements. Additionally, personnel will be surveyed prior to leaving access-controlled areas.

21.0 SURVEY INSTRUMENTATION

21.1 Instrument Calibration

Laboratory and portable field instruments will be calibrated at least annually with National Institute of Standards and Technology (NIST) traceable sources, where feasible, and to radiation emission types and energies that will provide detection capabilities similar to the nuclides of concern. Records of instrument calibration will be included in the SCR.

21.2 Functional Checks

Functional checks will be performed at least daily when in use to ensure that the instrument is in proper working condition. The background, source check, and field measurement count times for radiation detection instrumentation will be specified by procedure to ensure measurements are statistically valid. Background readings will be taken as part of the daily instrument check and compared with the acceptance range for instrument and site conditions. An instrument shall be

removed from service if the source check is not within ±20 percent of the initial post-calibration value. If an instrument fails a functional check, it will be removed from service and all data obtained with the instrument since the last satisfactory check will be evaluated for usability and unusable data discarded.

21.3 Determination of Counting Times and Minimum Detectable Concentrations

Minimum counting times for background determinations and measurement of total and removable contamination were chosen to provide a minimum detectable concentration (MDC) that met the DQOs. MARSSIM equations relative to building surfaces have been modified to convert to units of dpm/100 cm^2. Count times and scanning rates are determined using the following equations:

21.3.1 Alpha+Beta Static Counting

Static counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is an expansion of NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

MDC_{static} = minimum detectable concentration (dpm/100 cm^2)
B_r = background count rate (counts per minute)
t_b = background count time (minutes)
t_s = sample count time (minutes)
E_{tot} = total detector efficiency for radionuclide emission of interest (cpm/dpm)
A = detector probe area (cm^2)

21.3.2 Alpha+Beta Ratemeter Scanning

Scanning Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is a combination of MARSSIM equations 6-8, 6-9, and 6-10:

$$MDC_{scan} = \frac{d'\sqrt{b_i}\left(\frac{60}{i}\right)}{\sqrt{p} \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

MDC_{scan} = minimum detectable concentration level in dpm/100 cm^2
d' = desired performance variable (1.38)
b_i = background counts during the residence interval
i = residence interval
p = surveyor efficiency (0.5)
E_{tot} = total detector efficiency for radionuclide emission of interest (includes combination of instrument efficiency and surface efficiency)
A = detector probe area in cm^2

21.3.3 Smear Counting

Smear counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is NUREG 1507, Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{smear} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E}$$

Where:

MDC_{smear} = minimum detectable concentration level (dpm/smear)
B_r = background count rate (counts per minute)
t_b = background count time (minutes)
t_s = sample count time (minutes)
E = instrument efficiency for radionuclide emission of interest (cpm/dpm)

21.4 Instrumentation Specifications

The instrumentation used for facility characterization surveys is summarized in the tables below. Alternate or additional instrumentation with similar detection capabilities may be utilized as needed for survey requirements with RSO approval. Additional instruments such as pancake G-M detectors that will not be used to collect quantitative characterization data may also be used to support the project per the RPP.

Table 21-1: Instrumentation Specifications

Detector Model	Detector Type	Detector Width	Detector Area	Meter Model	Window Thickness
Ludlum 43-68	Gas Flow Proportional	8.8 cm	126 cm^2	Ludlum 2221	0.8 mg/cm^2
Ludlum 43-37	Gas Flow Proportional	13.3 cm	582 cm^2	Ludlum 2221	0.8 mg/cm^2
Ludlum 43-10-1	Phoswich	N/A	32 cm^2	Ludlum 2929	0.4 mg/cm^2
Ludlum 44-10	2" x 2" Sodium Iodide	N/A	N/A	Ludlum 2241	N/A
Bicron MicroRem	Tissue Equivalent Organic Scintillation	N/A	N/A	N/A	N/A

Table 21-2: Typical Instrument Operating Parameters and Sensitivities

Measurement Type	Detector Model	Scan Rate	Count Time	Bkg. Time	Bkg. (cpm)	MDC
Gross Alpha + Beta Surface Scans	Ludlum 43-68	0.35 in./sec.	N/A	60 sec.	490	84 cpm/100 cm^2
Gross Alpha + Beta Surface Scans	Ludlum 43-37	3.7 in./sec.	N/A	60 sec.	1,500	84 cpm/100 cm^2
Gross Alpha + Beta Total Surface Activity	Ludlum 43-68	N/A	60 sec.	60 sec.	490	84 cpm/100 cm^2
Gross Alpha + Beta Total Surface Activity	Ludlum 43-37	N/A	60 sec.	6 sec.	1,500	78 cpm/100 cm^2
Gross Alpha Removable Activity	Ludlum 2929	N/A	60 sec.	60 sec.	1	8 cpm/100 cm^2 (gross alpha)
Gamma Soil Scans	Ludlum 44-10	0.5 m/s	N/A	60 sec.	10,000	2.8 pCi/g (Ra-226) 1.8 pCi/g (Th-232) 80 pCi/g (U_{nat}) from NUREG 1507, Table 6.4 [10]

[10] NUREG 1507 calculations make assumptions regarding the geometry of the contaminated area that may not be appropriate for the site. No attempt was made to estimate the detection sensitivity for indoor or outdoor gamma scans because they were used qualitatively.

21.5 Efficiency Determination

MARSSIM protocols for building structures use ISO-7503-1 methodology that takes into account the texture of the surface and the 2π detector efficiency. Under MARSSIM, the default surface efficiency for alpha emissions and beta emissions with maximum energies less than 400 keV is conservatively set at 0.25, resulting in a total efficiency of approximately one half of the 4π efficiency. For smear counting, 4π efficiencies are used.

Total detection efficiencies for gas flow detectors are determined based on the combined contribution of all alpha and beta emitters in the decay chains including surface efficiency and radon emanation considerations.[11] These efficiencies are conservative because:

- Conservative beta efficiencies are applied to each nuclide
- ISO 7503-1 surface efficiencies are considered conservative
- Not all emissions are considered in determining the efficiencies; therefore the actual efficiencies are underestimated.

The calculations used to determine the detection efficiencies are provided in the tables below.

Table 21-3: Gas Flow Detector Ra-226+C Efficiency Calculations

Nuclide	Fraction of Parent Activity	Emission (β E_{AVE}) [12]	Yield	2-pi E_i	E_s	Emanation Factor [13]	Weighted Efficiency [14]
Ra-226	1.00	Alpha	1	0.4	0.25	1	0.100
Rn-222	1.00	Alpha	1	0.4	0.25	0.8	0.080
Po-218	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-214	1.00	Beta (0.218)	1	0.4	0.5	0.8	0.160
Bi-214	1.00	Beta (0.642)	1	0.5	0.5	0.8	0.200
Po-214	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-210	1.00	Beta (0.006)	1	0	0.25	0.8	0.000
Bi-210	1.00	Beta (0.389)	1	0.5	0.5	0.8	0.200
Po-210	1.00	Alpha	1	0.4	0.25	0.8	0.080
Total	**9.00**					**Total Eff.**	**0.98**

[11] The gas flow detectors were operated in the "beta" channel that measures alpha emissions in addition to beta emissions.
[12] Total beta energies from Appendix A of *"Decommissioning Health Physics."*
[13] The emanation factor is based on the RESRAD-BUILD default radon emanation fraction of 0.2.
[14] The calculated efficiency is in units of cpm per dpm of the entire decay chain. The gas flow detector total efficiency for each emission is calculated by multiplying the fraction of parent activity, yield, 2-pi instrument efficiency, surface efficiency, and emanation fraction. The fractional efficiency for each emission is summed to determine the total efficiency.

Table 21-4: Gas Flow Detector Ra-228+C Efficiency Calculations

Nuclide	Fraction of Parent Activity	Emission (β E_{AVE}) [12]	Yield	2-pi E_i	E_s	Emanation Factor [13]	Weighted Efficiency [14]
Ra-228	1.00	Beta (0.007)	1	0	0	1	0.000
Ac-228	1.00	Beta (0.377)	0.93	0.5	0.5	1	0.233
Th-228	1.00	Alpha	1	0.4	0.25	1	0.100
Ra-224	1.00	Alpha	0.95	0.4	0.25	1	0.095
Rn-220	1.00	Alpha	1	0.4	0.25	0.8	0.080
Po-216	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-212	1.00	Beta (0.102)	1	0.4	0.25	0.8	0.080
Bi-212	0.64	Beta (0.770)	0.64	0.6	0.5	0.8	0.098
Bi-212	0.36	Alpha	1	0.4	0.25	0.8	0.029
Po-212	0.64	Alpha	1	0.4	0.25	0.8	0.051
Tl-208	0.36	Beta (0.557)	1	0.5	0.5	0.8	0.072
Total	**9.00**					**Total Eff.**	**0.918**

Table 21-5: Gas Flow Detector Th-232+C Efficiency Calculations

Nuclide	Fraction of Parent Activity	Emission (β E_{AVE}) [12]	Yield	2-pi E_i	E_s	Emanation Factor [13]	Weighted Efficiency [14]
Th-232	1.00	Alpha	1	0.4	0.25	1	0.100
Ra-228	1.00	Beta (0.007)	1	0	0	1	0.000
Ac-228	1.00	Beta (0.377)	0.93	0.5	0.5	1	0.233
Th-228	1.00	Alpha	1	0.4	0.25	1	0.100
Ra-224	1.00	Alpha	0.95	0.4	0.25	1	0.095
Rn-220	1.00	Alpha	1	0.4	0.25	0.8	0.080
Po-216	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-212	1.00	Beta (0.102)	1	0.4	0.25	0.8	0.080
Bi-212	0.64	Beta (0.770)	0.64	0.6	0.5	0.8	0.098
Bi-212	0.36	Alpha	1	0.4	0.25	0.8	0.029
Po-212	0.64	Alpha	1	0.4	0.25	0.8	0.051
Tl-208	0.36	Beta (0.557)	1	0.5	0.5	0.8	0.072
Total	**10.00**					**Total Eff.**	**1.018**

Table 21-6: Gas Flow Detector U-238+C Efficiency Calculations

Nuclide	Fraction of Parent Activity	Emission (β E_{AVE}) [12]	Yield	2-pi E_i	E_s	Emanation Factor [13]	Weighted Efficiency [14]
U-238	1.00	Alpha	1	0.4	0.25	1	0.100
Th-234	1.00	Beta (0.045)	1	0.15	0.25	1	0.038
Pa-234m	1.00	Beta (0.813)	1	0.6	0.5	1	0.300
U-234	1.00	Alpha	1	0.4	0.25	1	0.100
Th-230	1.00	Alpha	1	0.4	0.25	1	0.100
Ra-226	1.00	Alpha	1	0.4	0.25	1	0.100
Rn-222	1.00	Alpha	1	0.4	0.25	0.8	0.080
Po-218	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-214	1.00	Beta (0.218)	1	0.4	0.25	0.8	0.080
Bi-214	1.00	Beta (0.642)	1	0.5	0.5	0.8	0.200
Po-214	1.00	Alpha	1	0.4	0.25	0.8	0.080
Pb-210	1.00	Beta (0.006)	1	0	0.25	0.8	0.000
Bi-210	1.00	Beta (0.389)	1	0.5	0.25	0.8	0.100
Po-210	1.00	Alpha	1	0.4	0.25	0.8	0.080
Total	**14.00**					**Total Eff.**	**1.438**

22.0 SITE CHARACTERIZATION REPORT

At the completion of characterization surveys, a SCR will be developed. The report will be reviewed for technical content by Chase personnel and an independent technical person. The report will provide a description of characterization activities and characterization survey results. The characterization survey report will be used to develop the site DP.

23.0 SCHEDULE

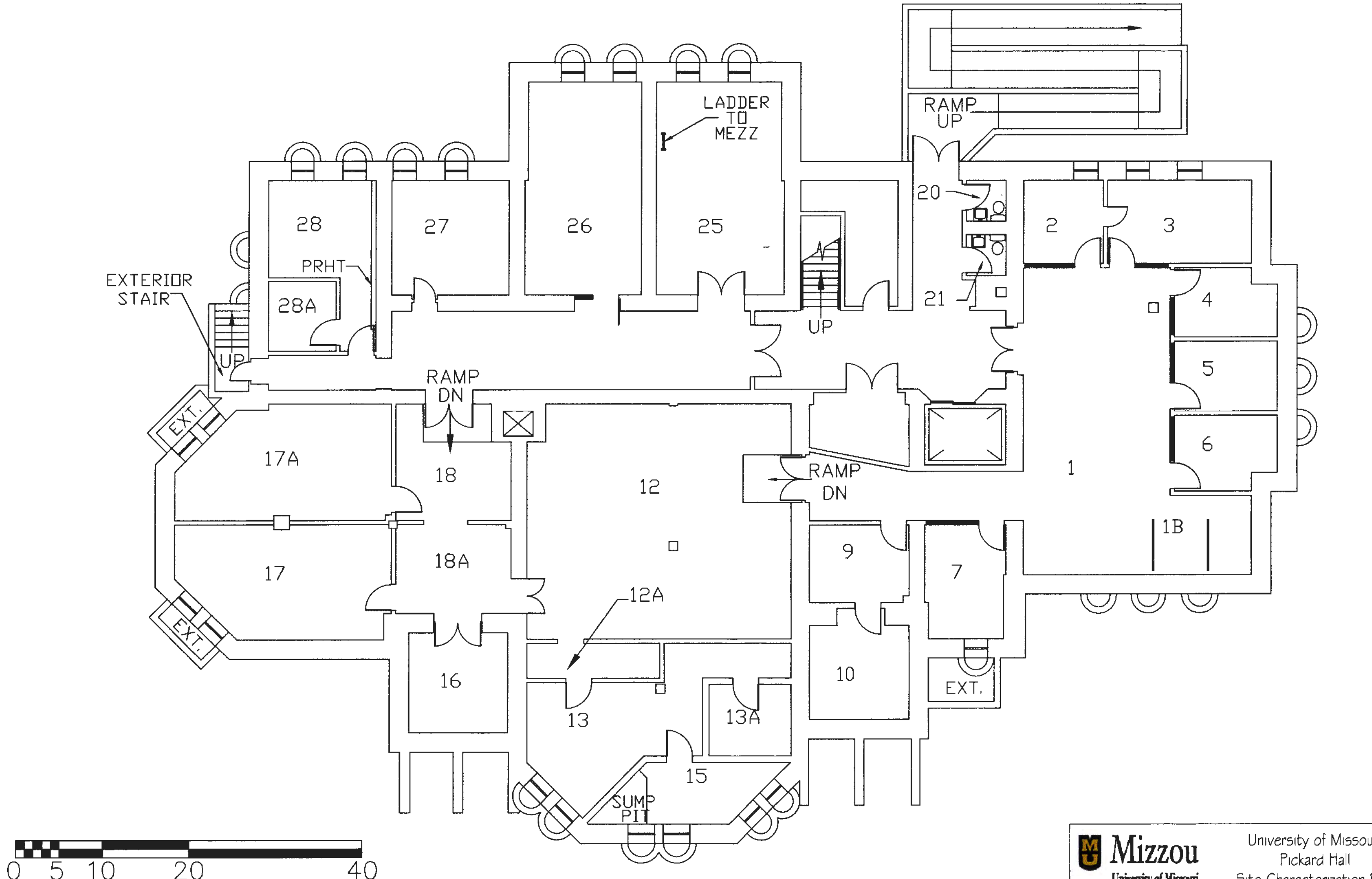
On-site characterization activities are expected to occur within several months of NRC approval of this SCP and are expected to take up to six months to complete. However, it is common for circumstances to change during decommissioning and MU will notify the NRC if emergent conditions arise that would cause the scope of work or schedule to change.

24.0 REFERENCES

1. NRC Regulations
2. NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM)
3. ANL/EAD/03-1 "User's Manual for RESRAD-BUILD Version 3," June 2003
4. NUREG-1757, Volume 1, Rev. 2 "Consolidated NMSS Decommissioning Guidance: Decommissioning Process for Materials Licensees," September, 2006
5. NUREG-1757, Volume 2, Rev. 1 "Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria," September, 2006
6. NUREG-1757, Volume 3 "Consolidated NMSS Decommissioning Guidance: Financial Assurance, Recordkeeping, and Timeliness," September, 2003
7. NUREG/CR-5512, "Residual Radioactivity from Decommissioning: Parameter Analysis," August 1999.
8. NUREG-1549, "Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination," July 1998
9. ANSI/HPS N13.12-2013, "Surface and Volume Radioactivity Standards for Clearance," May 2013
10. "Decommissioning Health Physics, A Handbook for MARSSIM Users," Abelquist, 2014
11. "Handbook of Health Physics and Radiological Health", 3rd Edition, 1998
12. "Pickard Hall Characterization Survey Report," July, 2010 (ML102800311, ML102800322, ML102800330, ML102800336, ML102800398, ML102800412, ML102800427, ML102800430, ML102800436, ML102800441, ML102800450, ML102800452, ML102800455, ML102800458, ML102800463, ML102800467, and ML102800563)
13. "University of Missouri Pickard Hall Phase III Characterization Survey Report," October 17, 2011
14. University of Missouri – Columbia Decommissioning Funding Plan, May 2011
15. "NRC Reactive Inspection Report 030-02278/10-01(DNMS) – University of Missouri," dated February 24, 2010. (ML100600810)
16. "About the Museum." Museum of Art and Archaeology-University of Missouri. University of Missouri, 2013. Web. Apr. 2014.
17. "Construction History of Pickard Hall: MU in Brick and Mortar." Construction History of Pickard Hall. N.p., 2003. Web. Apr. 2014
18. Gibbons, Brendan. "Herman Schlundt's Legacy." Missourian [Columbia] 16 July 2013.
19. "Pickard Hall." MU in Brick and Mortar. University of Missouri, 24 Oct. 2006. Web. Apr. 2014.

20. Mosher, Jack. Renovation of the Old Chemistry Building. 15 Feb. 1974. Renovation Proposal by Hoffman/Saur and Associates, Inc.
21. Nightingale, Dorothy V., Emeritus Professor of Chemistry. A History of the Department of Chemistry University of Missouri-Columbia 1843-1975. 1975. University of Missouri Archives. Columbia, Missouri.
22. "Experiments on the Extraction and Recovery of Radium from Typical American Carnotite Ores," The University of Missouri Bulletin, Volume 24, Number 26, September 1923
23. "Extraction of Radium from American Pitchblende Ores," Chemical News July 19, 1918
24. "The Environmental Transport of Radium and Plutonium: A Review," Institute for Energy and Environmental Research, June 23, 2006
25. Asbestos Overview, Pickard Hall, University of Missouri, April 10, 2014
26. "Subsurface Investigation, Soil Analysis and Foundation Design Recommendations for the University of Missouri Donald J. Reynolds Journalism Institute," Engineering Surveys and Services, June 25, 2004
27. "MU Swallow Hall Renovation Cost Opinion," SIRCAL Contracting, March 25, 2014
28. USDA Plant Hardiness Zone Map USDA
29. NowData – NOAA Online Weather Data NOAA
30. www.census.gov


Pickard Hall
Mizzou
University of Missouri - Columbia
University of Missouri
Pickard Hall
Site Characterization Plan
CHASE
Building: Pickard
Site Map
Page: A.1 of A.1

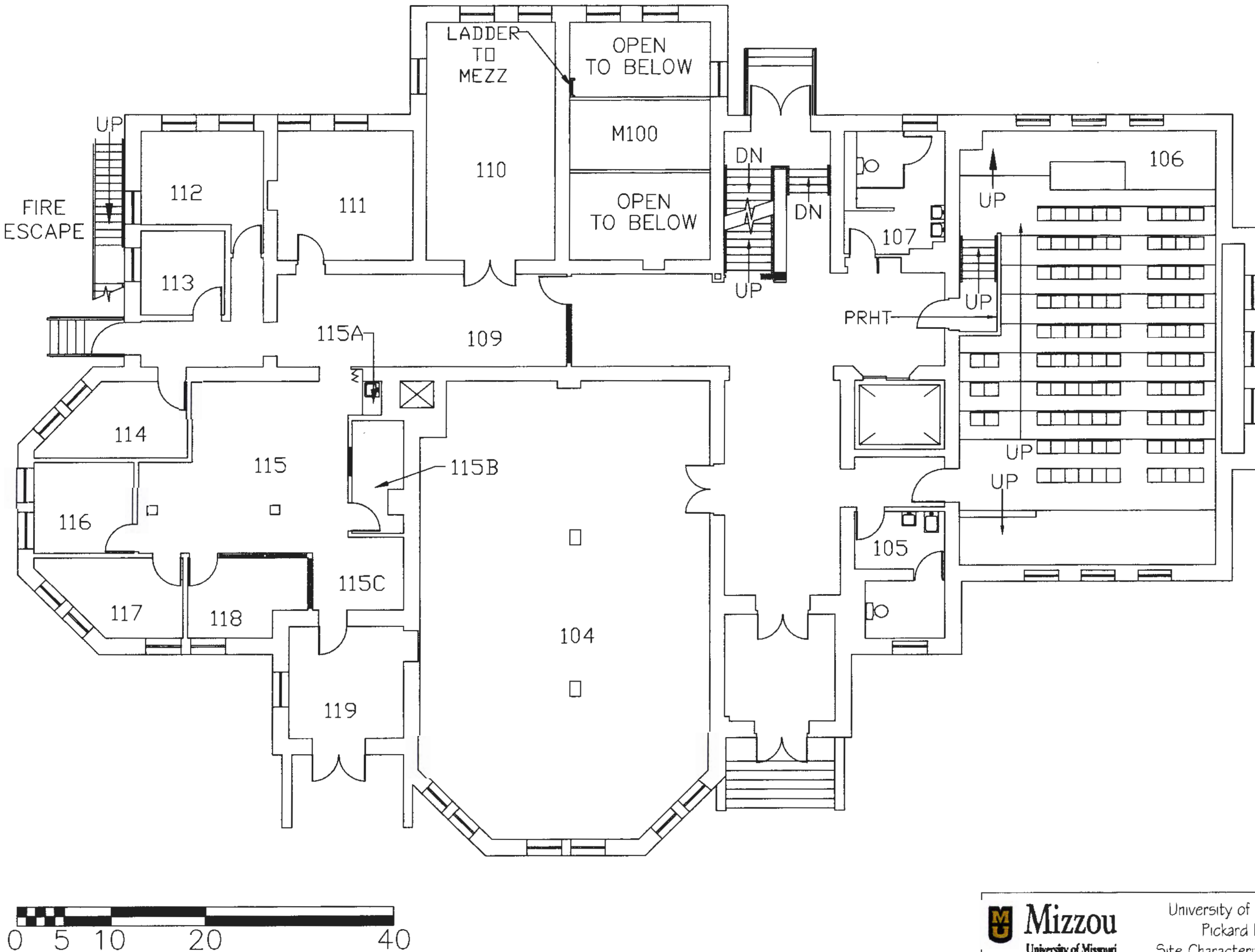


Mizzou
University of Missouri

University of Missouri
Pickard Hall
Site Characterization Plan

CHASE Environmental Group

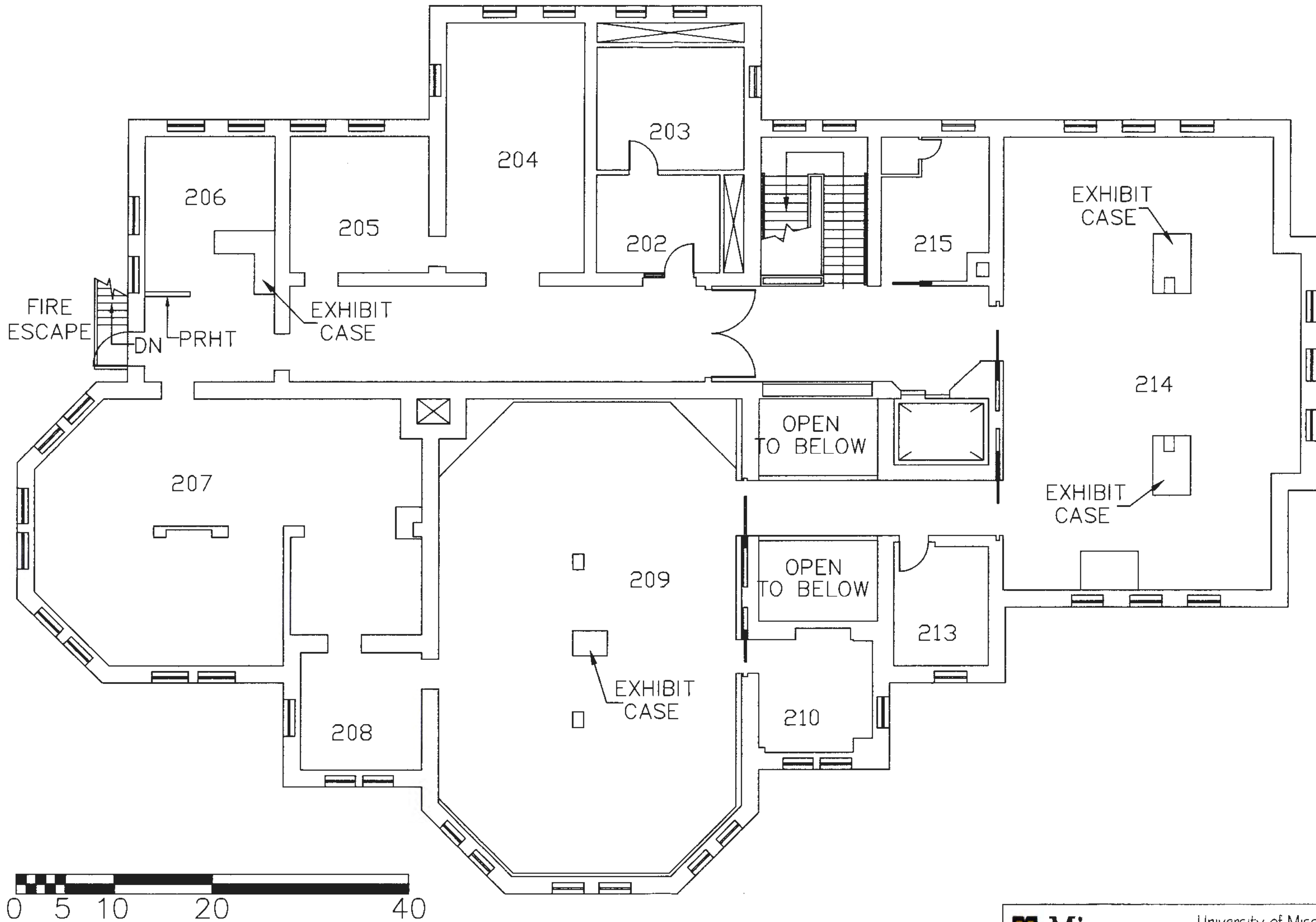
Basement	Current Layout	Page: B.1 of B.3



Mizzou
University of Missouri

University of Missouri
Pickard Hall
Site Characterization Plan

1st Floor	Current Layout	Page: B.2 of B.3

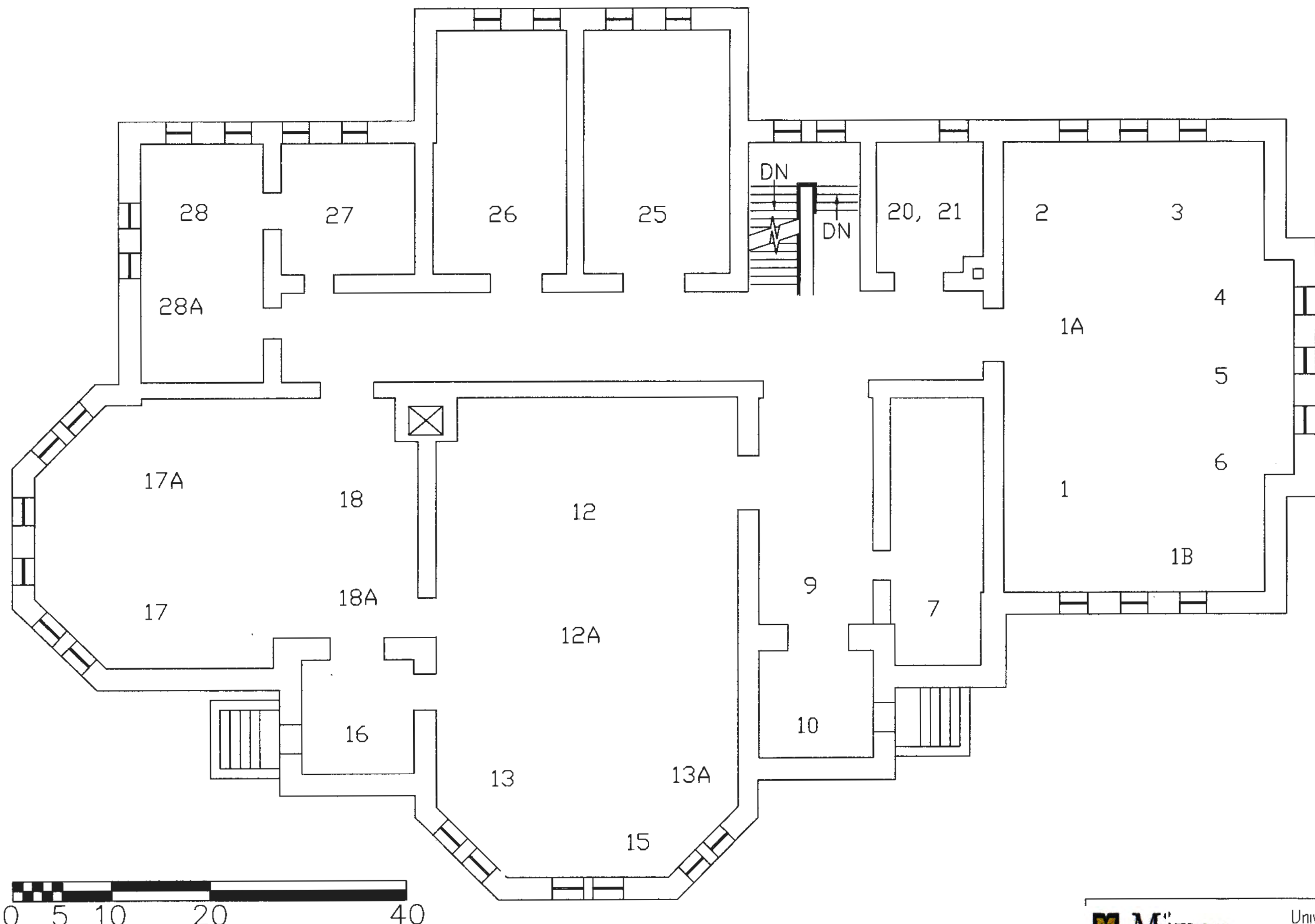


Mizzou University of Missouri

University of Missouri
Pickard Hall
Site Characterization Plan

CHASE Environmental Group

2nd Floor	Current Layout	Page: B.3 of B.3

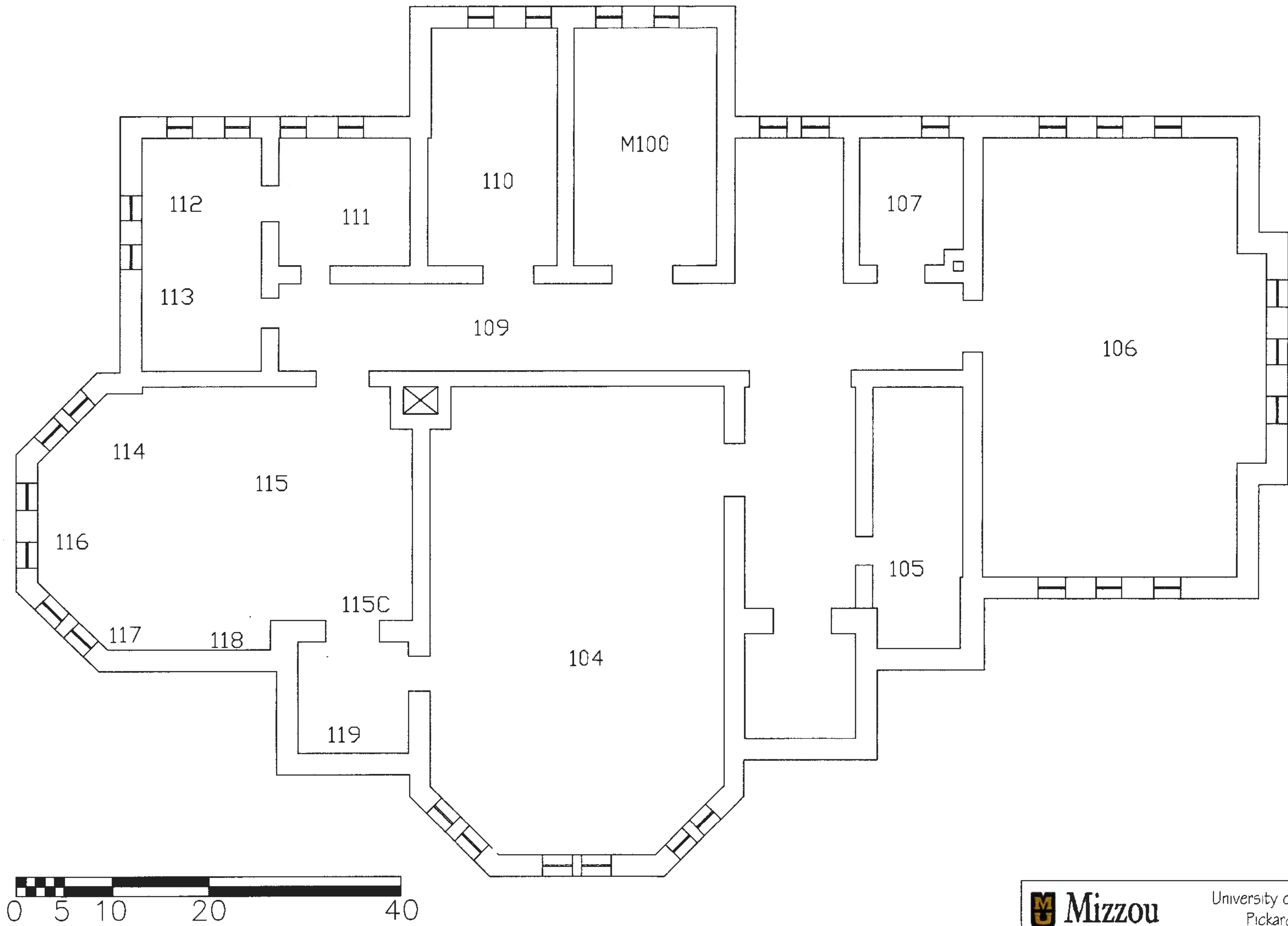


Mizzou
University of Missouri

University of Missouri
Pickard Hall
Site Characterizatin Plan

CHASE Environmental Group

Basement	Original Layout	Page: C.1 of C.3

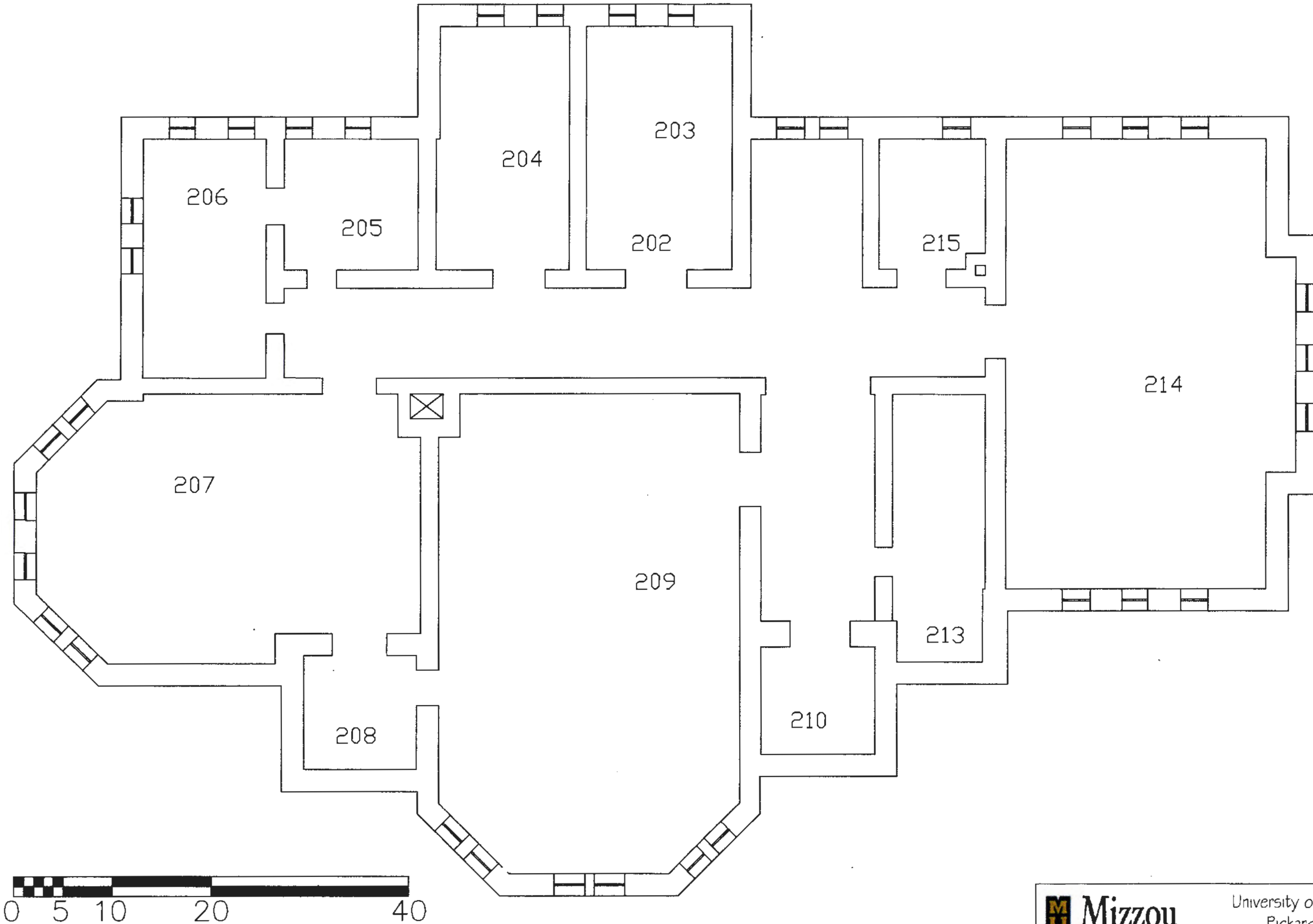


Mizzou
University of Missouri

University of Missouri
Pickard Hall
Site Characterization Plan

CHASE Environmental Group

1st Floor	Original Layout	Page: C.2 of C.3



Mizzou
University of Missouri

University of Missouri
Pickard Hall
Site Characterization Plan

CHASE Environmental Group

2nd Floor	Original Layout	Page: C.3 of C.3

DandD Building Occupancy Scenario

DandD Version: 2.1.0
Run Date/Time: 1/22/2010 11:14:56 AM
Site Name: Any
Description: DSV Determination with NUREG 1720 Resuspension Factor
FileName:C:\Documents and Settings\Dave Culp\My Documents\Ra-226+C DSV, NUREG 1720 RF.mcd

Options:

Implicit progeny doses included with explicit parent doses
Nuclide concentrations are NOT distributed among all progeny
Number of simulations: 100
Seed for Random Generation: 8718721
Averages used for behavioral type parameters

External Pathway is ON
Inhalation Pathway is ON
Secondary Ingestion Pathway is ON

Initial Activities:

Nuclide	Area of Contamination (m^2)	Distribution
226Ra+C	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: DSV Determination		Value 1.00E+00

Chain Data:

Number of chains: **1**

Chain No. 1: **226Ra+C**
Nuclides in chain: **5**

Nuclide	Chain Position	Half Life	First Parent	Fractional Yield	Second Parent	Fractional Yield	Ingestion CEDE Factor (Sv/Bq)	Inhalation CEDE Factor (Sv/Bq)	Surface Dose Rate Factor ((Sv/d)/(Bq/m^2))	15 cm Dose Rate Factor ((Sv/d)/(Bq/m^3))
226Ra+C	1	5.84E+05								
222Rn	2	3.82E+00	1	1	0	0	0.00E+00	0.00E+00	3.41E-14	9.81E-16
210Pb	3	8.15E+03	2	1	0	0	1.45E-06	3.67E-06	2.14E-13	1.13E-15
210Bi	4	5.01E+00	3	1	0	0	1.73E-09	5.29E-08	9.06E-14	1.61E-15
210Po	5	1.38E+02	4	1	0	0	5.14E-07	2.54E-06	7.16E-16	2.11E-17

Initial Concentrations:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 quantile value

Nuclide	Surface Concentration (dpm/100 cm**2)
226Ra	1.00E+00
222Rn	1.00E+00
210Pb	1.01E+00

210Bi	1.01E+00
210Po	1.01E+00

Model Parameters:

General Parameters:

Parameter Name	Description	Distribution
To:Time In Building	The time in the building during the occupancy period	CONSTANT(hr/week)
Default value used		Value 4.50E+01
Tto:Occupancy Period	The duration of the occupancy exposure period	CONSTANT(days)
Default value used		Value 3.65E+02
Vo:Breathing Rate	The average volumetric breathing rate during building occupancy for an 8-hour work day	CONSTANT(m**3/hr)
Default value used		Value 1.40E+00
RFo*:Resuspension Factor	Effective resuspension factor during the occupancy period = RFo * Fl	CONSTANT(1/m)
Justification for modification: NUREG 1720 Recommendation		Value 1.00E-06
		Default DERIVED(1/m)
GO*:Ingestion Rate	Effective secondary ingestion transfer rate of removable surface activity from building surfaces to the mouth during building occupancy = GO * Fl	DERIVED(m**2/hr)
Default value used		
Tstart:Start Time	The start time of the scenario in days	CONSTANT(days)
Default value used		Value 0.00E+00
Tend:End Time	The ending time of the scenario in days	CONSTANT(days)
Default value used		Value 3.65E+02
dt:Time Step Size	The time step size	CONSTANT(days)
Default value used		Value 3.65E+02
Pstep:Print Step Size	The time steps for the history file. Doses will be written to the history file every n time steps	CONSTANT(none)
Default value used		Value 1.00E+00
AOExt:External Exposure Area	Minimum surface area to which occupant is exposed via external radiation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOInh:Inhalation Exposure Area	Minimum surface area to which occupant is exposed via inhalation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOIng:Secondary Ingestion Exposure Area	Minimum surface area to which occupant is exposed via secondary ingestion during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AO:Exposure Area	Minimum surface area to which occupant is exposed during the occupancy period	DERIVED(m**2)
Default value used		
Fl:Loose Fraction	Fraction of surface contamination available for resuspension and ingestion	CONSTANT(none)
Default value used		Value 1.00E-01
Rfo:Loose Resuspension Factor	Resuspension factor for loose contamination	CONTINUOUS LOGARITHMIC(1/m)

Default value used		Value 9.12E-06 1.10E-04 1.46E-04 1.62E-04 1.85E-04 1.90E-04	Probability 0.00E+00 7.67E-01 9.09E-01 9.50E-01 9.90E-01 1.00E+00
GO:Loose Ingestion Rate	The secondary ingestion transfer rate of loose removable surface activity from building surfaces to the mouth during building occupancy	CONSTANT(m**2/hr)	
Default value used		Value	1.10E-04

Correlation Coefficients:

None

Summary Results:

90.00% **of the** 100 **calculated TEDE values are <** 1.72E-02 **mrem/year .**
The 95 % Confidence Interval for the 0.9 **quantile value of TEDE is** 1.72E-02 **to** 1.72E-02 **mrem/year**

Detailed Results:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 **quantile value**

Concentration at Time of Peak Dose:

Nuclide	Surface Concentration (dpm/100 cm**2)
226Ra	1.00E+00
222Rn	1.00E+00
210Pb	1.01E+00
210Bi	1.01E+00
210Po	1.01E+00

Pathway Dose from All Nuclides (mrem)

All Pathways Dose	External	Inhalation	Secondary Ingestion
1.72E-02	2.34E-03	4.74E-03	1.01E-02

Radionuclide Dose through All Active Pathways (mrem)

Nuclide	All Pathways Dose
226Ra	2.81E-03
222Rn	2.33E-03
210Pb	8.34E-03
210Bi	3.83E-05
210Po	3.64E-03
All Nuclides	1.72E-02

Dose from Each Nuclide through Each Active Pathway (mrem)

Nuclide	External	Inhalation	Secondary Ingestion
226Ra	9.03E-06	1.27E-03	1.54E-03
222Rn	2.32E-03	2.12E-06	1.05E-06
210Pb	3.53E-06	2.03E-03	6.31E-03
210Bi	1.49E-06	2.93E-05	7.53E-06
210Po	1.18E-08	1.41E-03	2.24E-03

DandD Building Occupancy Scenario

DandD Version: 2.1.0
Run Date/Time: 12/31/2014 2:55:36 PM
Site Name: Any
Description: DSV Determination with NUREG 1720 Resuspension Factor
FileName:C:\Users\Tony\Documents\Ra-228+C, NR 1720 RF.mcd

Options:

Implicit progeny doses included with explicit parent doses
Nuclide concentrations are NOT distributed among all progeny
Number of simulations: 100
Seed for Random Generation: 8718721
Averages used for behavioral type parameters

External Pathway is ON
Inhalation Pathway is ON
Secondary Ingestion Pathway is ON

Initial Activities:

Nuclide	Area of Contamination (m^2)	Distribution
228Ra	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: DSV Determination		Value 1.00E+00
228Th	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: DSV Determination		Value 1.00E+00

Chain Data:

Number of chains: **2**

Chain No. 1: **228Ra**
Nuclides in chain: **4**

Nuclide	Chain Position	Half Life	First Parent	Fractional Yield	Second Parent	Fractional Yield	Ingestion CEDE Factor (Sv/Bq)	Inhalation CEDE Factor (Sv/Bq)	Surface Dose Rate Factor ((Sv/d)/(Bq/m^2))	15 cm Dose Rate Factor ((Sv/d)/(Bq/m^3))
228Ra	1	2.10E+03					3.88E-07	1.29E-06	0.00E+00	0.00E+00
228Th	2	6.99E+02	1	1	0	0	1.07E-07	9.23E-05	2.03E-13	3.60E-15
224Ra	3	3.66E+00	2	1	0	0	9.89E-08	8.53E-07	8.26E-13	2.26E-14
212Pb	4	4.43E-01	3	1	0	0	1.23E-08	4.56E-08	1.23E-11	3.13E-13

Chain No. 2: **228Th**
Nuclides in chain: **3**

Nuclide	Chain Position	Half Life	First Parent	Fractional Yield	Second Parent	Fractional Yield	Ingestion CEDE Factor (Sv/Bq)	Inhalation CEDE Factor (Sv/Bq)	Surface Dose Rate Factor ((Sv/d)/(Bq/m^2))	15 cm Dose Rate Factor ((Sv/d)/(Bq/m^3))
228Th	1	6.99E+02					1.07E-07	9.23E-05	2.03E-13	3.60E-15
224Ra	2	3.66E+00	1	1	0	0	9.89E-08	8.53E-07	8.26E-13	2.26E-14
212Pb	3	4.43E-01	2	1	0	0	1.23E-08	4.56E-08	1.23E-11	3.13E-13

Initial Concentrations:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 quantile value

Nuclide	Surface Concentration (dpm/100 cm**2)
228Ra	1.00E+00
228Th	1.00E+00
224Ra	0.00E+00
212Pb	0.00E+00

Model Parameters:

General Parameters:

Parameter Name	Description	Distribution
To:Time In Building	The time in the building during the occupancy period	CONSTANT(hr/week)

Default value used		Value 4.50E+01
Tto:Occupancy Period	The duration of the occupancy exposure period	CONSTANT(days)
Default value used		Value 3.65E+02
Vo:Breathing Rate	The average volumetric breathing rate during building occupancy for an 8-hour work day	CONSTANT(m**3/hr)
Default value used		Value 1.40E+00
RFo*:Resuspension Factor	Effective resuspension factor during the occupancy period = RFo * Fl	CONSTANT(1/m)
Justification for modification: NUREG 1720 Recommendation		Value 1.00E-06
		Default DERIVED(1/m)
GO*:Ingestion Rate	Effective secondary ingestion transfer rate of removable surface activity from building surfaces to the mouth during building occupancy = GO * Fl	DERIVED(m**2/hr)
Default value used		
Tstart:Start Time	The start time of the scenario in days	CONSTANT(days)
Default value used		Value 0.00E+00
Tend:End Time	The ending time of the scenario in days	CONSTANT(days)
Default value used		Value 3.65E+02
dt:Time Step Size	The time step size	CONSTANT(days)
Default value used		Value 3.65E+02
Pstep:Print Step Size	The time steps for the history file. Doses will be written to the history file every n time steps	CONSTANT(none)
Default value used		Value 1.00E+00
AOExt:External Exposure Area	Minimum surface area to which occupant is exposed via external radiation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOInh:Inhalation Exposure Area	Minimum surface area to which occupant is exposed via inhalation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01

AOIng:Secondary Ingestion Exposure Area	Minimum surface area to which occupant is exposed via secondary ingestion during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AO:Exposure Area	Minimum surface area to which occupant is exposed during the occupancy period	DERIVED(m**2)
Default value used		
Fl:Loose Fraction	Fraction of surface contamination available for resuspension and ingestion	CONSTANT(none)
Default value used		Value 1.00E-01
Rfo:Loose Resuspension Factor	Resuspension factor for loose contamination	CONTINUOUS LOGARITHMIC(1/m)
Default value used		Value / Probability 9.12E-06 / 0.00E+00 1.10E-04 / 7.67E-01 1.46E-04 / 9.09E-01 1.62E-04 / 9.50E-01 1.85E-04 / 9.90E-01 1.90E-04 / 1.00E+00
GO:Loose Ingestion Rate	The secondary ingestion transfer rate of loose removable surface activity from building surfaces to the mouth during building occupancy	CONSTANT(m**2/hr)
Default value used		Value 1.10E-04

Correlation Coefficients:

None

Summary Results:

90.00% **of the** 100 **calculated TEDE values are <** 5.69E-02 **mrem/year .**
The 95 % Confidence Interval for the 0.9 **quantile value of TEDE is** 5.69E-02 **to** 5.69E-02 **mrem/year**

Detailed Results:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 **quantile value**

Concentration at Time of Peak Dose:

Nuclide	Surface Concentration (dpm/100 cm**2)
228Ra	9.42E-01
228Th	9.94E-01
224Ra	9.79E-01
212Pb	9.78E-01

Pathway Dose from All Nuclides (mrem)

All Pathways Dose	External	Inhalation	Secondary Ingestion
5.69E-02	3.16E-03	5.13E-02	2.50E-03

Radionuclide Dose through All Active Pathways (mrem)

Nuclide	All Pathways Dose
228Ra	3.50E-03
228Th	5.05E-02
224Ra	8.85E-04
212Pb	1.99E-03
All Nuclides	5.69E-02

Dose from Each Nuclide through Each Active Pathway (mrem)

Nuclide	External	Inhalation	Secondary Ingestion
228Ra	1.23E-03	7.06E-04	1.57E-03
228Th	3.28E-06	5.01E-02	4.56E-04
224Ra	1.37E-05	4.56E-04	4.16E-04
212Pb	1.91E-03	2.75E-05	5.28E-05

DandD Building Occupancy Scenario

DandD Version: 2.1.0
Run Date/Time: 1/22/2010 11:23:01 AM
Site Name: Any
Description: DSV Determination with NUREG 1720 Resuspension Factor
FileName:C:\Documents and Settings\Dave Culp\My Documents\U-238+C DSV, NUREG 1720 RF.mcd

Options:

Implicit progeny doses included with explicit parent doses
Nuclide concentrations are NOT distributed among all progeny
Number of simulations: 100
Seed for Random Generation: 8718721
Averages used for behavioral type parameters

External Pathway is ON
Inhalation Pathway is ON
Secondary Ingestion Pathway is ON

Initial Activities:

Nuclide	Area of Contamination (m^2)	Distribution
238U+C	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: DSV Determination		Value 1.00E+00

Chain Data:

Number of chains: **1**

Chain No. 1: **238U+C**
Nuclides in chain: **9**

Nuclide	Chain Position	Half Life	First Parent	Fractional Yield	Second Parent	Fractional Yield	Ingestion CEDE Factor (Sv/Bq)	Inhalation CEDE Factor (Sv/Bq)	Surface Dose Rate Factor ((Sv/d)/(Bq/m^2))	15 cm Dose Rate Factor ((Sv/d)/(Bq/m^3))
238U+C	1	1.63E+12								
234Th	2	2.41E+01	1	1	0	0	3.69E-09	9.47E-09	7.18E-13	1.12E-14
234U	3	8.93E+07	2	1	0	0	7.66E-08	3.58E-05	6.46E-14	1.85E-16
230Th	4	2.81E+07	3	1	0	0	1.48E-07	8.80E-05	6.48E-14	5.52E-16
226Ra	5	5.84E+05	4	1	0	0	3.58E-07	2.32E-06	5.56E-13	1.42E-14
222Rn	6	3.82E+00	5	1	0	0	0.00E+00	0.00E+00	3.41E-14	9.81E-16
210Pb	7	8.15E+03	6	1	0	0	1.45E-06	3.67E-06	2.14E-13	1.13E-15
210Bi	8	5.01E+00	7	1	0	0	1.73E-09	5.29E-08	9.06E-14	1.61E-15
210Po	9	1.38E+02	8	1	0	0	5.14E-07	2.54E-06	7.16E-16	2.11E-17

Initial Concentrations:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 **quantile value**

Nuclide	Surface Concentration (dpm/100 cm**2)
238U	1.00E+00
234Th	1.00E+00
234U	1.00E+00
230Th	1.00E+00
226Ra	1.00E+00
222Rn	1.00E+00
210Pb	1.00E+00
210Bi	1.00E+00
210Po	1.00E+00

Model Parameters:

General Parameters:

Parameter Name	Description	Distribution
To:Time In Building	The time in the building during the occupancy period	CONSTANT(hr/week)
Default value used		Value 4.50E+01
Tto:Occupancy Period	The duration of the occupancy exposure period	CONSTANT(days)
Default value used		Value 3.65E+02
Vo:Breathing Rate	The average volumetric breathing rate during building occupancy for an 8-hour work day	CONSTANT(m**3/hr)
Default value used		Value 1.40E+00
RFo*:Resuspension Factor	Effective resuspension factor during the occupancy period = RFo * Fl	CONSTANT(1/m)
Justification for modification: NUREG 1720 Recommendation		Value 1.00E-06
		Default DERIVED(1/m)
GO*:Ingestion Rate	Effective secondary ingestion transfer rate of removable surface activity from building surfaces to the mouth during building occupancy = GO * Fl	DERIVED(m**2/hr)
Default value used		
Tstart:Start Time	The start time of the scenario in days	CONSTANT(days)
Default value used		Value 0.00E+00
Tend:End Time	The ending time of the scenario in days	CONSTANT(days)
Default value used		Value 3.65E+02
dt:Time Step Size	The time step size	CONSTANT(days)
Default value used		Value 3.65E+02
Pstep:Print Step Size	The time steps for the history file. Doses will be written to the history file every n time steps	CONSTANT(none)
Default value used		Value 1.00E+00
AOExt:External Exposure Area	Minimum surface area to which occupant is exposed via external radiation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOInh:Inhalation Exposure Area	Minimum surface area to which occupant is exposed via inhalation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01

AOIng:Secondary Ingestion Exposure Area	Minimum surface area to which occupant is exposed via secondary ingestion during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AO:Exposure Area	Minimum surface area to which occupant is exposed during the occupancy period	DERIVED(m**2)
Default value used		
Fl:Loose Fraction	Fraction of surface contamination available for resuspension and ingestion	CONSTANT(none)
Default value used		Value 1.00E-01
Rfo:Loose Resuspension Factor	Resuspension factor for loose contamination	CONTINUOUS LOGARITHMIC(1/m)
Default value used		Value / Probability 9.12E-06 / 0.00E+00 1.10E-04 / 7.67E-01 1.46E-04 / 9.09E-01 1.62E-04 / 9.50E-01 1.85E-04 / 9.90E-01 1.90E-04 / 1.00E+00
GO:Loose Ingestion Rate	The secondary ingestion transfer rate of loose removable surface activity from building surfaces to the mouth during building occupancy	CONSTANT(m**2/hr)
Default value used		Value 1.10E-04

Correlation Coefficients:

None

Summary Results:

90.00% **of the** 100 **calculated TEDE values are <** 1.03E-01 **mrem/year .**
The 95 **% Confidence Interval for the** 0.9 **quantile value of TEDE is** 1.03E-01 **to** 1.03E-01 **mrem/year**

Detailed Results:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 **quantile value**

Concentration at Time of Peak Dose:

Nuclide	Surface Concentration (dpm/100 cm**2)
238U	1.00E+00
234Th	1.00E+00
234U	1.00E+00
230Th	1.00E+00
226Ra	1.00E+00
222Rn	1.00E+00
210Pb	1.00E+00
210Bi	1.00E+00
210Po	1.00E+00

Pathway Dose from All Nuclides (mrem)

All Pathways Dose	External	Inhalation	Secondary Ingestion

1.03E-01	2.38E-03	8.98E-02	1.12E-02

Radionuclide Dose through All Active Pathways (mrem)

Nuclide	All Pathways Dose
238U	1.78E-02
234Th	5.92E-05
234U	1.99E-02
230Th	4.87E-02
226Ra	2.81E-03
222Rn	2.33E-03
210Pb	8.23E-03
210Bi	3.78E-05
210Po	3.59E-03
All Nuclides	1.03E-01

Dose from Each Nuclide through Each Active Pathway (mrem)

Nuclide	External	Inhalation	Secondary Ingestion
238U	7.73E-07	1.75E-02	2.95E-04
234Th	3.82E-05	5.17E-06	1.58E-05
234U	1.05E-06	1.96E-02	3.29E-04
230Th	1.05E-06	4.81E-02	6.35E-04
226Ra	9.04E-06	1.27E-03	1.54E-03
222Rn	2.32E-03	2.12E-06	1.05E-06
210Pb	3.48E-06	2.00E-03	6.22E-03
210Bi	1.47E-06	2.89E-05	7.42E-06
210Po	1.16E-08	1.39E-03	2.21E-03

DandD Building Occupancy Scenario

DandD Version: 2.1.0
Run Date/Time: 1/22/2010 11:03:53 AM
Site Name: Any
Description: DSV Determination with NUREG 1720 Resuspension Factor
FileName:C:\Documents and Settings\Dave Culp\My Documents\Th-232+C DSV, NUREG 1720 RF.mcd

Options:

Implicit progeny doses included with explicit parent doses
Nuclide concentrations are NOT distributed among all progeny
Number of simulations: 100
Seed for Random Generation: 8718721
Averages used for behavioral type parameters

External Pathway is ON
Inhalation Pathway is ON
Secondary Ingestion Pathway is ON

Initial Activities:

Nuclide	Area of Contamination (m^2)	Distribution
232Th+C	UNLIMITED	CONSTANT(dpm/100 cm**2)
Justification for concentration: DSV Determination		Value 1.00E+00

Chain Data:

Number of chains: **1**

Chain No. 1: **232Th+C**
Nuclides in chain: **5**

Nuclide	Chain Position	Half Life	First Parent	Fractional Yield	Second Parent	Fractional Yield	Ingestion CEDE Factor (Sv/Bq)	Inhalation CEDE Factor (Sv/Bq)	Surface Dose Rate Factor ((Sv/d)/(Bq/m^2))	15 cm Dose Rate Factor ((Sv/d)/(Bq/m^3))
232Th+C	1	5.13E+12								
228Ra	2	2.10E+03	1	1	0	0	3.88E-07	1.29E-06	0.00E+00	0.00E+00
228Th	3	6.99E+02	2	1	0	0	1.07E-07	9.23E-05	2.03E-13	3.60E-15
224Ra	4	3.66E+00	3	1	0	0	9.89E-08	8.53E-07	8.26E-13	2.26E-14
212Pb	5	4.43E-01	4	1	0	0	1.23E-08	4.56E-08	1.23E-11	3.13E-13

Initial Concentrations:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 quantile value

Nuclide	Surface Concentration (dpm/100 cm**2)
232Th	1.00E+00
228Ra	1.00E+00
228Th	1.00E+00

224Ra	1.00E+00
212Pb	1.00E+00

Model Parameters:

General Parameters:

Parameter Name	Description	Distribution
To:Time In Building	The time in the building during the occupancy period	CONSTANT(hr/week)
Default value used		Value 4.50E+01
Tto:Occupancy Period	The duration of the occupancy exposure period	CONSTANT(days)
Default value used		Value 3.65E+02
Vo:Breathing Rate	The average volumetric breathing rate during building occupancy for an 8-hour work day	CONSTANT(m**3/hr)
Default value used		Value 1.40E+00
RFo*:Resuspension Factor	Effective resuspension factor during the occupancy period = RFo * Fl	CONSTANT(1/m)
Justification for modification: NUREG 1720 Recommendation		Value 1.00E-06
		Default DERIVED(1/m)
GO*:Ingestion Rate	Effective secondary ingestion transfer rate of removable surface activity from building surfaces to the mouth during building occupancy = GO * Fl	DERIVED(m**2/hr)
Default value used		
Tstart:Start Time	The start time of the scenario in days	CONSTANT(days)
Default value used		Value 0.00E+00
Tend:End Time	The ending time of the scenario in days	CONSTANT(days)
Default value used		Value 3.65E+02
dt:Time Step Size	The time step size	CONSTANT(days)
Default value used		Value 3.65E+02
Pstep:Print Step Size	The time steps for the history file. Doses will be written to the history file every n time steps	CONSTANT(none)
Default value used		Value 1.00E+00
AOExt:External Exposure Area	Minimum surface area to which occupant is exposed via external radiation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOInh:Inhalation Exposure Area	Minimum surface area to which occupant is exposed via inhalation during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AOIng:Secondary Ingestion Exposure Area	Minimum surface area to which occupant is exposed via secondary ingestion during occupancy period	CONSTANT(m**2)
Default value used		Value 1.00E+01
AO:Exposure Area	Minimum surface area to which occupant is exposed during the occupancy period	DERIVED(m**2)
Default value used		
Fl:Loose Fraction	Fraction of surface contamination available for resuspension and ingestion	CONSTANT(none)
Default value used		Value 1.00E-01
Rfo:Loose Resuspension Factor	Resuspension factor for loose contamination	CONTINUOUS LOGARITHMIC(1/m)

Default value used		Value	Probability
		9.12E-06	0.00E+00
		1.10E-04	7.67E-01
		1.46E-04	9.09E-01
		1.62E-04	9.50E-01
		1.85E-04	9.90E-01
		1.90E-04	1.00E+00
GO:Loose Ingestion Rate	The secondary ingestion transfer rate of loose removable surface activity from building surfaces to the mouth during building occupancy	CONSTANT(m**2/hr)	
Default value used		Value	1.10E-04

Correlation Coefficients:

None

Summary Results:

90.00% of the 100 calculated TEDE values are < 3.03E-01 mrem/year .
The 95 % Confidence Interval for the 0.9 quantile value of TEDE is 3.03E-01 to 3.03E-01 mrem/year

Detailed Results:

Note: All reported values are the upper bound of the symmetric 95% confidence interval for the 0.9 quantile value

Concentration at Time of Peak Dose:

Nuclide	Surface Concentration (dpm/100 cm**2)
232Th	1.00E+00
228Ra	1.00E+00
228Th	1.00E+00
224Ra	1.00E+00
212Pb	1.00E+00

Pathway Dose from All Nuclides (mrem)

All Pathways Dose	External	Inhalation	Secondary Ingestion
3.03E-01	3.28E-03	2.94E-01	5.77E-03

Radionuclide Dose through All Active Pathways (mrem)

Nuclide	All Pathways Dose
232Th	2.45E-01
228Ra	3.72E-03
228Th	5.09E-02
224Ra	9.04E-04
212Pb	2.04E-03
All Nuclides	3.03E-01

Dose from Each Nuclide through Each Active Pathway (mrem)

Nuclide	External	Inhalation	Secondary Ingestion
232Th	7.73E-07	2.42E-01	3.17E-03
228Ra	1.30E-03	7.50E-04	1.67E-03
228Th	3.30E-06	5.04E-02	4.59E-04
224Ra	1.40E-05	4.66E-04	4.24E-04
212Pb	1.96E-03	2.81E-05	5.40E-05