REGULATORY REVIEW DRAFT

RADIOLOGICAL FINAL STATUS SURVEY EVALUATION OF AMERICIUM-241 ACTIVITY AT SOUTHEAST MISSOURI STATE UNIVERSITY

CAPE GIRARDEAU, MISSOURI

~~APRIL 4~~JUNE 17, 2013

Southeast Missouri State University
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ACRONYMS AND ABBREVIATIONS

Both English and metrics units are used in this report. The units used in a specific situation are based on common unit usage or regulatory language.

Δ/σ	relative shift
σ	standard deviation
ALARA	as low as is reasonably achievable
Am	americium
AMCG	average member of the critical group
ANSI	American National Standards Institute
AEC	U.S. Atomic Energy Commission
CFR	*Code of Federal Regulations*
cm	centimeter
cm^2	square centimeters
cpm	counts per minute
Cl	chlorine
Cs	cesium
CY	calendar year
DCGL	Derived Concentration Guideline Level
$DCGL_W$	Derived Concentration Guideline Level used for statistical tests (Wilcoxon Rank Sum)
$DCGL_{EMC}$	Derived Concentration Guideline Level – Elevated Measurement Comparison
DQA	Data Quality Assessment
DQO	Data Quality Objective
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
EPC	exposure point concentration
FIDLER	field instrument for the detection of low-energy radiation
FR	*Federal Register*
FSS	Final Status Survey
FSSE	Final Status Survey Evaluation
FSSP	Final Status Survey Plan
ft	feet/foot
GWS	Gamma Walkover Survey
H_0	null hypothesis
HAZWOPER	Hazardous Waste Operations and Emergency Response
hr	hour
HVAC	heating, ventilation and air conditioning
keV	kiloelectron Volt
LBGR	lower bound of the gray region
m	meter(s)
m^2	square meter(s)
Magill Hall	Magill Hall of Science
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
MeV	Megaelectron Volts
mrem/yr	millirem per year

mSv	millisievert

ACRONYMS AND ABBREVIATIONS (Continued)

NaI	sodium iodide

~~**ACRONYMS AND ABBREVIATIONS (Continued)**~~

NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Regulation
OSHA	Occupational Safety and Health Administration
Pb	lead
pCi/g	picocurie per gram
PPE	personal protective equipment
QA	quality assurance
QC	quality control
ROC	Radionuclide of Concern
RESRAD	RESidual RADioactivity (computer model)
RPP	Radiation Protection Program
RSO	Radiation Safety Officer
SAIC	Science Applications International Corporation
SOR	sum of the ratios
Southeast	Southeast Missouri State University
Sr-Y	strontium-yttrium
SU	survey unit
TEDE	total effective dose equivalent
Th	thorium
TPU	total propagated uncertainty
U	uranium
UCL_{95}	95 percent upper confidence limit
USEPA	U.S. Environmental Protection Agency
WRS	Wilcoxon Rank Sum
ZnS	zinc sulfide

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EXECUTIVE SUMMARY

In February 2000, it was determined that residual americium (Am)-241 contamination existed in Magill Hall of Science (Magill Hall) at Southeast Missouri State University (Southeast) as a result of what was subsequently determined to be at least two spills of liquid Am-241. The first of these spills occurred in 1973 in a radiochemistry laboratory (Room 242 of Magill Hall), while the second spill occurred around 1997 pursuant to movement of a source storage safe. Although initial investigations suggested that radiologically impacted areas involved only portions of Magill Hall, it was subsequently determined that contaminated materials and equipment had been relocated to other areas of the Southeast campus, with the potential for transfer of contamination. Potentially impacted areas included limited portions of Rhodes and Johnson Halls and the former District Crime Lab (prior to its demolition in 2003). Impacted areas within Rhodes Hall included Chemistry and Physics Department facilities, as well as a few rooms occupied by the Geosciences Department. Biology spaces other than the Radiation Laboratory were determined to not be radiologically impacted. The only area of Johnson Hall potentially impacted was Room 222, a room used to house Chemistry Department materials and in which a contaminated desk was located.

During the interval from the initial identification of residual radioactivity at Southeast in 2000 to the present, the university has taken a number of significant response actions to investigate and address residual contamination. These actions include:

- Initial response actions, including:
  - Characterization of the nature and extent of contamination
  - Development of the *Historical Site Assessment for Magill Hall at Southeast Missouri State University* (SAIC 2000a) and the related identification of impacted areas.
  - Development and implementation of the *Decontamination Plan for Magill Hall at Southeast Missouri State University* (SAIC 2000d) to effect the remediation of accessible contamination to U.S. Nuclear Regulatory Commission (NRC)-approved derived concentration guideline levels (DCGLs). DCGLs initially approved by the NRC consisted of surface activity standards contained in Atomic Energy Commission (AEC) Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors* (AEC 1974). (Historically, this document has been commonly referred to as "NRC Regulatory Guide 1.86," although the NRC did not exist at the time that the document was initially produced.) Limits contained in AEC Regulatory Guide 1.86 were generally derived based on detectability rather than being dose-based and conservatively assumed removable contamination limits equating to 20 percent of the respective total contamination limits.
  - Development and issuance of the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (DOD 1997)-compliant *Final Status Survey Report for the Magill Hall Am-241 Decontamination Project* (SAIC 2001a). Results cited in this survey report, together with results of NRC inspections and confirmatory survey activities, supported the NRC conclusion that "Magill Hall was successfully decontaminated, and it can therefore be released for unrestricted use" (NRC 2001).
- Laboratory Discharge System investigations, including:

  - Development and implementation of the *Laboratory Discharge System Sampling Plan* (SAIC 2002b),
  - Development and implementation of the *Laboratory Discharge System Characterization Survey and Waste Disposal Plan* (SAIC 2002c), and
  - Preparation of the *Laboratory Discharge System Post-Characterization Report* (SAIC 2002f).

- Development of the *Visual Scoping and Survey Plan* (2002e) to identify and survey materials and equipment with the potential for residual radioactivity, especially items moved from Magill Hall to other sites.
- Development of the *Implementation of the Visual and Scoping Survey Plan Final Report* (SAIC 2002g) to report the results from the implementation of the Visual Scoping and Survey Plan.
- Development of the *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2006) to comprehensively address the investigation and decontamination of additional portions of university structures as they became accessible. This survey plan also incorporated a site-specific DCGL, noting that "The release criterion derived in Appendix B, for Am-241, of 1,160 [disintegrations per minute per 100 square centimeters] dpm/100 cm^2 total alpha activity represents an unrestricted use criteria for building surfaces that, if met will ensure that the 25 mrem/yr dose criteria is satisfied and is [as low as reasonably achievable] ALARA." This plan also notes that "any removable contamination detected will be decontaminated to below the Regulatory Guide 1.86 removable contamination limits as an ALARA approach."
- Development and issuance of Revision 1 of the *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2010) and implementation of comprehensive decontamination and final status surveys (FSSs) to address remaining Am-241 contamination. This effort addressed impacted areas of Magill, Rhodes, and Johnson Halls, and included resurveys of all previously contaminated portions of the structures (except Rooms 214, 216, 218, and 218A in Magill Hall; these rooms were previously decontaminated and subjected to FSSs during a remodeling project which took place after 2005 and prior to the initiation of the recent decontamination and FSS efforts). FSS results for these rooms are incorporated into Appendix A of this document, together with other FSS information. In addition to surveys of structures, surface soils were investigated in accordance with the *Soil Survey Plan for Surface Soils Outside Magill and Rhodes Halls*, which was incorporated into Appendix C of the revised document (SAIC 2010).
- Investigation and MARSSIM FSSs of soil areas outside Magill Hall and the issuance of the *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) to demonstrate compliance with NRC surface soil screening level DCGLs.

Major investigations performed by Southeast include the initial response actions taken in the early 2000s to address accessible residual radioactivity; decontamination and surveys that have taken place subsequent to initial response actions as additional areas have become accessible due to remodeling; and final status survey evaluation (FSSE) for soils adjacent to Magill Hall. As indicated above, NRC noted on January 19, 2001, that "Magill Hall was successfully

decontaminated, and it can therefore be released for unrestricted use" (NRC 2001). This report includes a summary of historical actions taken by Southeast to address residual Am-241 as it has become accessible and detailed MARSSIM-compliant FSS information to clearly demonstrate that residual levels of radioactivity in all areas at Southeast are compliant with NRC-approved, dose-based DCGLs for unrestricted release. In addition, investigations of residual radioactivity in soils around Magill Hall have been detailed in the *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) to demonstrate compliance with NRC surface soil screening level DCGLs. The cited efforts fully address all residual radioactivity present at Southeast in accordance with unrestricted release requirements of 10 *Code of Federal Regulations* (*CFR*) 20, Subpart E. Without regard to background subtraction, residual dose is less than 1 millrem per year (mrem/yr) for structures and less than 2.6 mrem/yr for soils under the pedestal in the basement of Magill Hall. Given compliance with DCGLs for unrestricted release and demonstration that residual dose to the average member of the critical group is much less than the 25 mrem/yr standard prescribed by 10 *CFR* 20, Subpart E, Southeast will request NRC approval for the unrestricted release of all university facilities and equipment impacted by Am-241 and removal of Am-241 and Am-241-impacted facilities from Southeast's NRC License 24-09296-02.

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1.0 INTRODUCTION

1.1 SITE BACKGROUND

Southeast Missouri State University (Southeast) is located in the town of Cape Girardeau, Missouri, near the Mississippi River. Cape Girardeau is a community of approximately 40,000 people and is considered a hub for retail, medicine, manufacturing, communications, and cultural activities between St. Louis, Missouri, and Memphis, Tennessee. There are approximately 11,000 students and 350 full-time faculty members at Southeast.

In February 2000, it was determined that residual americium (Am)-241 contamination existed in the Magill Hall of Science (Magill Hall) as a result of what was subsequently determined to be at least two spills of liquid Am-241. Although originally projected to be the result of a historical spill of a liquid 5 millicurie source, investigations of historical operations subsequently indicated that two spills of Am-241 likely had taken place on the Southeast campus. The first of these spills occurred in 1973 in a radiochemistry laboratory in Room 242 of Magill Hall, while the second occurred around 1997 pursuant to the movement of a source storage safe.

Initial investigations of contamination resulting from these spills indicated that radiologically impacted areas were "limited to the basement rooms and corridor and a laboratory room on the second floor (Room 242) in Magill Hall" (SAIC 2001a). These investigations were subsequently augmented by additional scoping and characterization surveys performed in accordance with the *Magill Hall Survey Plan* (SAIC 2000b). These "scoping/characterization surveys performed by Science Applications International Corporation (SAIC) addressed other interior surfaces in Magill Hall, including all other rooms and corridors on the 1st and 2nd floors of Magill Hall" with special emphasis on horizontal surfaces and materials and equipment (SAIC 2001a). In response to the contamination, Southeast developed, issued, and implemented the *Decontamination Plan for Magill Hall at Southeast Missouri State University* in August 2000 to "address all aspects of the decontamination, including personnel qualification, waste management, worker and public protective measures and quality assurance requirements" (SAIC 2000d).

Materials and equipment in Magill Hall were removed from all shelves, countertops, and storage drawers in laboratory rooms to facilitate surveys (SAIC 2001a). Southeast subsequently surveyed impacted areas and performed extensive decontamination of accessible areas of Magill Hall; prepared and implemented a *Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM)*-compliant final status survey plan (FSSP) to confirm achievement of U.S. Nuclear Regulatory Commission (NRC)-approved remediation criteria contained in U.S. Atomic Energy Commission (AEC) Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors* (AEC 1974); managed the "treatment, storage, shipment and disposal of radioactive wastes identified and/or generated during the remedial action" including the disposal of about 56,000 pounds of contaminated materials and equipment which were shipped to GTS Duratek's Bear Creek Waste Processing Facility in Oak Ridge, Tennessee, for processing and subsequent shipment to a properly permitted disposal facility; and developed a *Final Status Survey Report for the Magill Hall Am-241 Decontamination Project* (SAIC 2001a) to capture relevant final status survey (FSS) information.

Also notable was the removal of radiologically impacted drain piping from the floor penetration locations to the point where the pipe exited the building, as well as the removal of ventilation system ductwork from the Magill Hall basement up to the point where the ducting exited the

basement corridor. "All ventilation ducting left in place at the entrance to Rooms 13, 15, 16, 17, 25, and the vertical run to the roof was surveyed and verified to be below release criteria" (SAIC 2001a). Other portions of the ventilation system were determined to be part of a second, independent system which surveys indicated was not impacted by the two Am-241 spills. Figure 1 reflects the layout of buildings addressed in this report. In addition, figures depicting the radiologically impacted structures and portions thereof are contained in Appendix A, with survey results. Additional historical details are contained in the *Historical Site Assessment for Magill Hall at Southeast Missouri State University*, dated July 2000 (SAIC 2000a).

The potential existed for contamination to be transferred to limited areas of other Southeast campus structures as a result, in part, of the movement of contaminated materials and equipment. These areas included limited portions of Rhodes and Johnson Halls, and the former District Crime Lab prior to its demolition in 2003. Impacted areas within Rhodes Hall included Chemistry and Physics Department facilities, as well as a few rooms occupied by the Geosciences Department. (Biology spaces other than the Radiation Laboratory were determined to not be radiologically impacted.) The only area of Johnson Hall determined to be radiologically impacted was Room 222, a room used to store Chemistry Department materials and in which a contaminated desk was located.

During the interval from the initial identification of residual radioactivity at Southeast in 2000 to the present, the university has taken a number of significant response actions. These actions include:

- Initial response actions including:
  - Characterization of the nature and extent of contamination.
  - Development of the *Historical Site Assessment for Magill Hall at Southeast Missouri State University* (SAIC 2000a) and the related identification of impacted areas.
  - Development and implementation of the *Decontamination Plan for Magill Hall at Southeast Missouri State University* (SAIC 2000d) to effect the remediation of accessible contamination.
  - Development and issuance of the MARSSIM- (DOD 1997) compliant *Final Status Survey Report for the Magill Hall Am-241 Decontamination Project* (SAIC 2001a).
- Laboratory discharge system investigations, including:
  - Investigation of acid dilution pits.
  - Other sewer investigations.
- Visual scoping and survey efforts.
- Investigations, decontamination, and FSSs of newly accessible areas of impacted structures.
- Infrastructure investigations.
- Confirmatory surveys of surface soils in the vicinity of Magill and Rhodes Halls to confirm that residual radioactivity is compliant with NRC surface soils screening level derived concentration guideline levels (DCGLs).

Each of these actions is summarized in Section 2. In addition, detailed surface activity FSS information is contained in Appendix A for each area except surface soils, which were

independently evaluated in August, 2011 (SAIC 2011). Results clearly demonstrate that residual radioactivity is compliant with NRC-approved DCGLs.

1.2 PURPOSE AND SCOPE

Southeast has been issued NRC License 24-09296-02, which authorizes possession and use of radioactive materials in the chemical and physical forms and quantities specified in the license. Included among these materials is one (1) millicurie of Am-241 as "residual contamination on equipment, materials or building surfaces" for "possession incident to the decontamination of equipment, materials, and rooms as described in *Decontamination and Survey Plan for Magill and Rhodes Halls*, dated November 2006, and storage pending disposal" (SAIC 2006). In addition, Revision 1 to the *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2010) noted that "surface soils around Magill and Rhodes Halls may require investigation for the presence of licensed material."

Potential contamination at Southeast included:

- Accessible residual surface activity in Magill Hall which was addressed prior to 2003 and was previously authorized by the NRC to be released without radiological restrictions.
- Previously inaccessible activity in Magill Hall subsequently made available for remediation beginning in 2005 as a result of building renovation and remodeling.
- Residual activity in impacted areas in Rhodes and Johnson Halls. (Given that the highest level of residual surface activity on structures in Rhodes and Johnson Halls was 76 and 37 disintegrations per minute per 100 square centimeters [dpm/100 cm^2], respectively, or less than 7 percent of the site-specific surface activity DCGL of 1,160 dpm/100 cm^2. As the potential for contamination is greater in accessible areas and given the lack of residual radioactivity in accessible areas, inaccessible areas within Rhodes and Johnson Halls were determined to be "non-impacted" areas.)
- The Biology Greenhouse.
- Laboratory Discharge System components for Magill, Rhodes and Johnson Halls. These components including the associated acid dilution pits were decontaminated, surveyed and released without radiological restrictions in January 2003 in accordance with Amendment 10 to Southeast's NRC license.
- Residual activity in soils outside Magill Hall for which NRC authorization for unrestricted release is currently pending.
- Soils under the former location of the seismograph pedestal in Room 21 of Magill Hall.

This report provides a summary of actions taken by Southeast from 2000 to the present to address accessible residual radioactivity, and provides detailed information relative to the FSSs of previously inaccessible surfaces made available as a result of renovation and remodeling activities. It is notable that the scope of Southeast's FSSs is inclusive of all impacted interior building surfaces, including both areas that were originally accessible and previously inaccessible areas that have become accessible as a result of renovation/remodeling activities. In addition, in August 2011 Southeast provided the *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) to the NRC to document that residual activity in surface soils is compliant with NRC screening level DCGLs. As such, surveys of soils in this report are limited to eight samples collected from a small area

under the former seismograph pedestal which were evaluated to confirm the absence of residual radioactivity exceeding NRC surface soil screening level DCGLs in that area.

Given that residual radioactivity complies with DCGLs conservatively based on radiation doses that do not exceed 25 millirem per year (mrem/yr) to the average member of the critical group and are "as low as reasonably achievable," this Final Status Survey Evaluation (FSSE) is being transmitted to the NRC together with a request for amendment of Southeast's NRC license to authorize unrestricted release of all radiologically impacted areas of the university consistent with Title 10, *Code of Federal Regulations* (*CFR*) Part 20, Subpart E; and deletion of Am-241 and the associated formerly contaminated areas from Southeast's NRC license.

2.0 SITE HISTORY

This section provides a summary of actions taken by Southeast to address residual radioactivity present in Southeast structures and in surface soils surrounding impacted buildings. The following list reflects the content of each applicable subsection:

- Summary of Initial Response Actions (Section 2.1)
- Laboratory Discharge System (Section 2.2)
- Investigation of Surplus Equipment (Section 2.3)
- Investigation, Decontamination and Final Status Surveys of Newly Accessible Areas of Impacted Structures (Section 2.4)
- Infrastructure Investigations (Section 2.5)
- Soil Investigations (Section 2.6)

2.1 SUMMARY OF INITIAL RESPONSE ACTIONS

2.1.1 Scoping Survey Results

SAIC was contracted by Southeast in 2000 to characterize, decontaminate, and perform FSSs of areas that were accessible at that time. Initial scoping surveys performed by SAIC reflected residual total and removable alpha activity of up to 62,000 and 6,300 dpm/100 cm^2, respectively. In addition, total and removable beta activity, subsequently determined to be from cesium (Cs)-137, was measured at activity concentrations of up to 4,400 and 200 dpm/100 cm^2, respectively. By contrast, "Acceptable Surface Contamination Levels" prescribed in AEC Regulatory Guide 1.86 are 20, 100, and 300 dpm/100 cm^2 for removable, average total, and maximum total Am-241 contamination, respectively, and 1,000, 5,000, and 15,000 dpm/100 cm^2 for removable, average total, and maximum total beta Cs-137 contamination. Areas initially noted as exceeding the Am-241 contamination limits (also referred to as DCGLs), specifically included the basement, basement entrance area, freight elevator, and Room 242. In addition, with respect to Magill Hall it was noted that "Levels of contamination in excess of the project DCGL may be present in basement exhaust ventilation ducts and a floor drain in Room 240 (located adjacent to Lab 242)" (SAIC 2000d). All areas were compliant with the stated Cs-137 criteria.

2.1.2 Historical Site Assessment

A *Historical Site Assessment for Magill Hall at Southeast Missouri State University* (SAIC 2000a) was published in July 2000. This assessment documented historical information relative to Am-241 contamination in Magill Hall and, together with results of scoping surveys, provided substantive technical basis for designation of areas as radiologically "impacted" or "non-impacted." All rooms, public spaces, and mechanical spaces in Magill Hall were categorized as radiologically impacted at that time.

2.1.3 Decontamination of Accessible Areas in Magill Hall

Consistent with NRC requirements, a *Decontamination Plan for Magill Hall at Southeast Missouri State University* (SAIC 2000d) was issued in August 2000. This plan identified accessible, radiologically impacted areas within Magill Hall and defined decontamination tasks, responsibilities, practices, and procedures to be implemented to address residual, accessible Am-

-241 contamination. Implementation of this plan to remediate accessible contamination resulted in the disposal of about 56,000 pounds of contaminated materials and equipment from Magill Hall (SAIC 2001a).

2.1.4 Final Status Surveys of Accessible Areas in Magill Hall

Upon completion of decontamination to the criteria contained in AEC Regulatory Guide 1.86, MARSSIM-compliant FSSs of each radiologically impacted accessible portion of Magill Hall were performed and documented in the *Final Status Survey Report for the Magill Hall Am-241 Decontamination Project* (SAIC 2001a). This report provides results of FSSs of Magill Hall, noting that "areas impacted by the spill of radioactive material at the Southeast Site are limited to the basement rooms and corridor and a laboratory room on the second floor (Room 242) in Magill Hall." The report also indicates that scoping/characterization surveys of the appropriate quality and quantity for MARSSIM Class 3 areas were performed by SAIC and that radiological surveys addressed other surfaces in Magill Hall, including all other rooms and corridors on the 1st and 2nd floors of Magill Hall not directly impacted by the spill of radioactive material; floor penetrations (sewer drains) in the immediate vicinity of the spill area in Laboratory Room 242 and Room 240; ventilation system ducting; and all horizontal surfaces and equipment within rooms and corridors on the 1st and 2nd floors of Magill Hall. The survey report also notes that Am-241 is the lone radionuclide of concern (ROC) for the site and concluded that surveys confirmed that accessible areas in Magill Hall were compliant with contamination criteria. It is also notable that the highest post-remediation total activity FSS result encountered during the survey effort was 59 dpm/100 cm^2. This activity concentration equates to about 60 percent of the total alpha "Acceptable Surface Contamination Level" of 100 dpm/100 cm^2 prescribed in AEC Regulatory Guide 1.86, or about 5 percent of the site-specific DCGL of 1,160 dpm/100 cm^2, which was subsequently developed and approved by the NRC for residual surficial Am-241 activity at Southeast.

2.1.5 Unrestricted Release of Accessible Areas in Magill Hall

As noted in NRC Region III Inspection Report 030-33508/2000 (DNMS) (NRC 2001), dated January 2001, the NRC performed a special inspection and confirmatory surveys November 27 through November 29, 2000, and reviewed materials provided through December 21, 2000. Based on these reviews, NRC "determined that Magill Hall was successfully decontaminated, and it can therefore be released for unrestricted use" (NRC 2001). This letter also noted that "When you complete the formal Final Status Survey Report, you should forward it to this office with an appropriate request for an amendment to remove Magill Hall and selected isotopes from your NRC license" (NRC 2001). Although accessible areas were released for unrestricted use at that time, potentially contaminated inaccessible areas continued to be restricted pending confirmation that residual radioactivity was compliant with applicable standards.

2.1.6 Designation of Rhodes Hall as a Radiologically Impacted Structure

Although initial indications suggested that residual radioactivity was limited to Magill Hall, Rhodes Hall:

- had active laboratories similar to those in Magill Hall;
- was interconnected to Magill Hall by a pedestrian bridge; and

- contained contaminated materials and equipment as evidenced by results of the *Implementation of the Visual Scoping and Survey Plan Final Report* (SAIC 2002g).

As a result of the previous information, the Southeast Radiation Safety Officer (RSO) designated the following portions of Rhodes Hall as being radiologically impacted:

- All rooms occupied by the Chemistry Department,
- All spaces occupied by Physics, and
- Selected spaces occupied by Geosciences.

Subsequent investigation and decontamination efforts included both Magill and Rhodes Halls with both buildings being included in the *Decontamination and Survey Plan for Magill and Rhodes Hall*s (SAIC 2006). (See Appendix A for FSS data for both structures.)

2.2 LABORATORY DISCHARGE SYSTEM

2.2.1 General

Given the potential for discharge of contaminated water to building sewer systems through laboratory sinks and floor drains (i.e., discharge systems), Southeast performed detailed investigations to determine if residual radioactivity was present in these systems. These investigations included the assessment of acid dilution pits for Magill, Rhodes, and Johnson Halls; evaluation of sediment samples from selected locations within the three laboratory discharge systems (other than from the acid dilution pits); collection of a composite sample from selected discharge system locations; investigation of all p-traps; and visual inspection/ examination of the pits to determine if soil surrounding the pits may have been impacted by radiologically elevated sediments in the pits. The following subsections summarize investigations of sewer system components.

2.2.2 Investigation of Acid Dilution Pits

Acid dilution pits were designed as part of the laboratory discharge systems to provide a means of neutralizing liquids prior to their release into the sewer system. December 2001 investigations revealed the presence of pits as a component of discharge systems for Magill and Rhodes Halls. Initially, sampling was conducted to determine if the laboratory discharge systems had been radiologically impacted upstream or downstream of Magill and Rhodes Halls' acid dilution pits.

The pit for Magill Hall was a 2.5 foot (ft) (0.76 meter [m]) square, and was about 3 ft (0.9 m) deep. It was located in the mechanical room (Room 13) in the basement of the building. Sediment in this pit was about 1.5 ft (0.46 m) in depth. The pit for Rhodes Hall was in the configuration of a manhole, with a depth of about 5 ft (1.5 m) and sediment depth of about 1.5 ft (0.5 m) and was located outside adjacent to the building structure. Both of these acid dilution systems were sampled by SAIC on January 3, 2002, in accordance with Southeast's *Acid Dilution Pit Sampling Plan* (SAIC 2001b). Samples were submitted to the Severn-Trent (currently TestAmerica) Laboratory in Earth City, Missouri, for analysis. Analytical data packages were received from Severn-Trent on January 30, 2002, and transmitted to Southeast on February 4, 2002 (SAIC 2002a). The analytical results for radiological constituents are listed in Table 2-1.

As radioactivity was detected at levels that were elevated with respect to background, sewer system components were subjected to additional investigations (See Section 2.2.3). In January 2002, investigations revealed the presence of a third acid dilution pit which was sampled on

March 14, 2002 (SAIC 2002c). This pit, which contained about 0.8 ft (0.2 m) of sediment was associated with the laboratory drain system for Johnson Hall. It was in the configuration of a manhole approximately 3 feet (0.9 meters) deep with a single drain line entering the pit about 1.6 ft (0.46 m) above the bottom of the manhole; the pit was located in the basement of the building immediately below Room 222 (SAIC 2002b).

Table 2-1. Laboratory Discharge System Radiological Data Summary[a]

Parameter	Analytical Results (pCi/g)			Regulatory Standard[b]
	Rhodes Hall Acid Dilution Pit	Magill Hall Acid Dilution Pit	Johnson Hall Acid Dilution Pit	
Am-241 by Alpha Spectrometry	0.97	2.58	2.51	2.1
High Resolution Gamma Spectroscopy	Cs-137 4.7 Am-241 1.6 Pb-212 0.4 SOR[c] = 1.0 to 1.3	Cs-137 3.6 Am-241 2.2 Pb-212 0.5 Pb-214 1.0 Ra-226 1.1 Th-234 9.8 U-235 0.5 U-238 9.0 SOR > 35	Cs-137 0.32 Am-241 3.8 Pb-212 0.39 Pb-214 0.34 SOR = 3.1 to 3.7	Cs-137 11 Am-241 2.1 Pb-212 4.7 Pb-214 0.6 Ra-226 0.6 Th-234 0.5 U-235 0.3 U-238 0.5

[a] Excerpt from Severn-Trent (renamed as TestAmerica, Inc.) Analytical Data Packages (SAIC 2002a and SAIC2002d).

[b] Regulatory guidance used for comparison is the NRC surface soil screening level DCGL specified in NUREG-1757 and related NUREGs.

[c] SOR– Sum of the Ratios of the contaminant concentration to the applicable regulatory standard. The SOR is limited to one (1).

pCi/g – picocuries per gram

Given the presence of radionuclides exceeding background concentrations in the dilution basins, NRC issued Amendment 8 to License 24-09296-02 on April 8, 2002, authorizing possession of 4, 1, 0.1, 5, 1, and 5 microcuries of Cs-137, lead (Pb)-210, Pb-214, thorium (Th)-234, uranium (U)-235, and U-238, respectively, for "possession incident to remediation of acid dilution basins associated with Rhodes and Magill Halls on the University campus." These radionuclides were subsequently removed from Southeast's NRC license by Amendment 10 on June 27, 2003, upon conclusion of sewer investigation and related disposal activities.

2.2.3 Other Sewer Investigations

Additional investigations included the attempted collection of sediment samples from selected locations within the three laboratory discharge systems (other than from the acid dilution pits) to confirm that the systems were not radiologically impacted. These investigation plans involved the collection of one composite sample from each designated discharge system location (e.g., p-traps and clean outs) and the visual inspection/examination of the pits to determine if soil surrounding the pits may have been impacted by sediments in the pits (SAIC 2002b).

Manholes downstream of the acid dilution pits (i.e., manholes 2, 3, and 7) were also subjected to sediment sampling to confirm the absence of contamination. Manhole 2 was downstream from both Rhodes and Johnson Halls; Manhole 3 was downstream from Magill, Rhodes, and Johnson Halls; and Manhole 7 was downstream of Magill Hall. As depicted in Table 2-2 of the *Laboratory Discharge System Post-Characterization Report* (SAIC 2002f), these manhole

sample results reflected Am-241 concentrations in sediment of 0.42, 1.32, and 4.0 picocuries per gram (pCi/g) for Manholes 2, 3 and 7, respectively. "Since the average sample and survey results were less than the corresponding screening levels, the discharge system downstream of the Rhodes, Johnson and Magill pits was determined to be non-impacted" (SAIC 2002f). Building-specific sewer investigation information is summarized in Section 2.2.4.

2.2.4 Laboratory Waste Disposal System Remediation

Given the presence of radiologically elevated sediments in the Magill and Rhodes Halls' acid dilution pits, a *Laboratory Discharge System Characterization Survey and Waste Disposal Plan* (SAIC 2002c) was developed, submitted to NRC for approval on April 2, 2002, and authorized by Amendment 9 to Southeast's NRC License 24-09296-02 on June 5, 2002. The scope of this plan included the following:

1. "remove and dispose of contaminated sediment in three pits associated with the laboratory drain systems of Rhodes, Magill, and Johnson Halls, as determined necessary after review of sampling results;
2. conduct additional characterization of the laboratory drain systems of Rhodes, Magill, and Johnson Halls; and
3. inspect the structural integrity of the pits" (SAIC 2002c).

Investigations specifically included:

1. instrument surveys to evaluate removable alpha and beta emissions from each drain associated with the system both upstream and downstream of the pits;
2. collection of a sufficient quantity of sediment at cleanouts and p-traps (i.e., 20 milliliters) for sampling and analysis; and
3. instrument surveys of cleanouts and p-traps without sufficient solids for sampling.

Provisions of the plan included the designation of the upstream portion of the system (i.e., upstream of the pits) as non-impacted if the average of contaminant concentrations was less than NRC surface soil DCGLs specified in Appendix C, NUREG-1727 (NRC 2000). If such concentrations exceeded these criteria, site-specific DCGLs corresponding to the unrestricted release dose criteria in 10 *CFR* 20, Subpart E, would be developed independent of the scope of this plan. Investigational approaches and criteria applicable to downstream portions of the discharge system were functionally the same as those for the portions of the systems upstream from the pits.

The scope of the plan also included investigation of the pits subsequent to sediment removal. These investigations included surveys of the pits for fixed and removable alpha and beta activity, and inspection of the pits by a Professional Engineer/Structural Engineer to determine the likelihood of contamination migrating to areas outside the pit. If average pit results were less than the NRC-approved "Acceptable Surface Contamination Levels" contained in AEC Regulatory Guide 1.86 and surface soil screening level DCGLs, the pit would be categorized as non-impacted and no further investigation of the pit was required. (Compliance with DCGLs included development of a site-specific surface activity structures DCGLs and evaluation with respect to the volume of soils and related elevated measurement criteria (see Section 2.5, SAIC 2002c). Similarly, if the pits were determined to be structurally sound, then it was to be concluded that no pathway for contamination migration to surrounding soils existed such that

surrounding soils were also to be defined as non-impacted. By contrast, if a pit exhibited average levels of residual radioactivity exceeding these criteria, sediment concentrations would be compared to site-specific DCGLs to be developed. In addition, if a pit was determined to exhibit defects such that surrounding soils may be impacted, soil surrounding the pit(s) would be sampled in accordance with Appendix A of the plan and compared to DCGLs (SAIC 2002b).

Results of the additional investigations outlined above are detailed in Southeast's *Laboratory Discharge System Post-Characterization Report* (SAIC 2002f). A summary of those results is as follows:

Magill Hall. Discharge points (e.g., sinks, hoods, and floor drains) in 20 rooms upstream of the pits were subjected to surveys for total and removable alpha and beta activity with all results being less than the corresponding screening level. In addition, although all 6 cleanouts were investigated, only 3 of the 6 cleanouts contained enough material from which to collect a sample. In addition, none of the samples collected had sufficient mass to enable Cs-137 analyses to be performed. Although all discharge point survey results were less than the corresponding NRC screening levels, cleanout samples in Rooms 104, 108, and 112 exhibited Am-241 at 1.0, 3.4, and 3.1 pCi/g, respectively (thus, the average of these samples was 2.5 pCi/g). Although this concentration slightly exceeded the NRC surface soil screening level DCGL of 2.1 pCi/g, the exceedingly small waste volume relative to the screening level was such that the residuals were fully compliant with elevated measurements criteria. With respect to the investigation of activity in the discharge system downstream from the pits, Manhole 7 serviced Magill Hall and then dumped into Manhole 3. Radioanalytical results for Manholes 7 and 3 reflected Am-241 concentrations of 4.0 and 1.3 pCi/g, respectively. Given the relative amount of solids present in the system and the volume of soils to which screening level DCGLs apply, together with the fact that the concentration in Manhole 3 (i.e., downstream from Manhole 7 was below the surface soil screening level DCGL), it was deduced that the discharge system downstream from the acid dilution pits was compliant with screening level DCGLs. In addition, the acid dilution pits were emptied, cleaned, and then subjected to radiological surveys and to technical inspection by a professional engineer to verify that pathways did not exist from the pits to surrounding soils. Given negative results with regard to residual activity in or around the acid dilution pits, it was concluded that all portions of the Magill Hall discharge system were compliant with NRC screening level DCGLs.

Rhodes Hall. The investigation of the discharge system upstream of the pit included total and removable surveys at discharge points in 39 rooms including surveys of 9 cleanouts (7 vertical and 2 horizontal). Although 3 small areas of total and removable alpha surface contamination exceeding screening criteria were found at the Room 303 sink drain area, investigations indicated that the nearest cleanout downstream did not contain sufficient solids for analysis and that alpha and beta activity was compliant with screening criteria. In addition, the Room 303 sink drain p-trap exhibited survey results that were less than NRC screening levels (with the exception of the inside of the trap cap, which was verified as being less than screening level criteria after decontamination with a large wipe). The report concluded that "the average results for Rhodes Hall upstream of the pit were less than the corresponding screening levels, therefore the Rhodes Hall system upstream of the pit was determined to be non-impacted" (SAIC 2002e). With respect to the investigation of activity in the discharge system downstream from the pits, Manhole 2 serviced both Johnson and Rhodes Halls and dumped in to Manhole 3, which also served Magill Hall. Radioanalytical results for Manholes 2 and 3 reflected Am-241 concentrations of 0.42 and 1.3 pCi/g, respectively. Thus, it was concluded that Rhodes Hall sewers downstream from the

pits were non-impacted. In addition, the acid dilution pits were emptied, cleaned, and then subjected to radiological surveys and to technical inspection by a professional engineer to verify that pathways did not exist from the pits to surrounding soils. Given negative results with regard to residual activity in and around the acid dilution pits subsequent to cleanout, it was concluded that all portions of the Rhodes Hall discharge system were compliant with NRC surface soil screening level DCGLs.

Johnson Hall. Johnson Hall investigations included survey of the discharge point in Room 200; surveying/sampling at Manholes 2 and 3, which were downstream from Johnson and Rhodes Halls; surveys of the acid dilution pit both prior to and after sediment removal and decontamination; and physical inspection of the pit. As surveys reflected levels of contamination less than applicable screening levels, it was determined that the Johnson Hall discharge system upstream of the pit was non-impacted. With regard to the investigation of activity in the discharge system downstream from the pits, Manhole 2 serviced both Johnson and Rhodes Halls and dumped into Manhole 3, which also served Magill Hall. Radioanalytical results for Manholes 2 and 3 reflected Am-241 concentrations of 0.42 and 1.3 pCi/g, respectively. Thus, it was concluded that Johnson Hall sewers downstream from the pits were non-impacted. In addition, the acid dilution pits were emptied, cleaned, and then subjected to radiological surveys and to technical inspection by a professional engineer to verify that pathways did not exist from the pits to surrounding soils. Given negative results with regard to residual activity in and around the acid dilution pits, it was concluded that all portions of the Johnson Hall discharge system were compliant with NRC-approved criteria (i.e., surface soil screening level DCGLs and acceptable surface contamination levels contained in AEC Regulatory Guide 1.86).

Given the above-stated actions to investigate and address residual radioactivity in the laboratory discharge system, on April 7, 2003, Southeast provided detailed information to the NRC to demonstrate that the university's sewer system was fully compliant with applicable radiological criteria. Given compliance with criteria, Southeast also requested appropriate amendment to their license. Upon completion of their review of the information provided, NRC subsequently issued Amendment 10 to Southeast's NRC License 24-09296-02 on June 27, 2003. This amendment removed Cs-137, Pb-210, Pb-214, Th-234, U-235 and U-238, which had been added in Amendment 8 for "possession incident to remediation of acid dilution basins associated with Rhodes and Magill Halls on the University campus."

2.3 INVESTIGATION OF SURPLUS EQUIPMENT

On July 14, 2000, the NRC notified Southeast that allegations had been made that the university "may have sold at auction contaminated chemical or analytical equipment" (SAIC 2000c). The findings of this investigation were published in an August 2000 report, *Allegation Investigation Report for Southeast Missouri State University* (SAIC 2000c). Although the investigation failed to substantiate the allegations, the NRC subsequently requested that Southeast conduct a second investigation to determine if potentially contaminated equipment that had been stored in the basement of Magill Hall in the mid-1990's had been sold at auction. Nine auctions were investigated. These investigations determined that no positive link could be established between potentially contaminated items stored at Magill Hall and those purchased at a State of Missouri auction by members of the public. The *Surplus Item Investigation Report for Southeast Missouri State University* (SAIC 2000e) subsequently determined that "The Total Effective Dose Equivalent (TEDE) to the maximally exposed member of the public from Am-241 on the surface of a typical desk, contaminated at the maximum contamination level found on any equipment at

Southeast, was conservatively calculated to be 0.06 rem/year (60 mrem/yr). This is less than the 0.1 rem/year (100 mrem/yr) annual dose limit for an individual member of the public referenced in §20.2003 of 10 *CFR*" (now 10 *CFR* 20.1301) (SAIC 2000e).

Given that the basement of Magill Hall was also used as a temporary storage area for surplus items, and that contamination was found to be present in the surplus item storage area, Southeast expanded the scope of the building surveys performed in 2000 to include three facilities in Cape Girardeau, Missouri, in which surplus equipment had been stored (SAIC 2002e). These areas consisted of:

- a building at 228 North Pacific which was confirmed to have been demolished in early 2000 prior to the surplus equipment investigations;
- Washington School on Middle Street; and
- the former River Campus Gymnasium.

Items at the two remaining temporary storage locations were subjected to visual inspection and radiological surveys. These investigations identified several items which had come from the College of Science complex and which exhibited residual radioactivity at levels exceeding criteria contained in AEC Regulatory Guide 1.86. All such items were removed from the group of items to be auctioned and returned to the university Radioactive Material Storage Facility in Magill Hall. In addition, the Southeast RSO established procedures at the College of Science complex to preclude the release of potentially contaminated surplus materials. These procedures included the integration of surveys of potentially impacted materials and equipment as a standard, ongoing component of Southeast's Radiation Protection Program (RPP).

Interim actions included the implementation of routine visual inspections and radiological surveys of items awaiting auction to ensure that no radioactive or hazardous material was contained in any items being surplused. Items located during these inspections that contained or were suspected to contain radioactive or hazardous constituents were immediately segregated and subjected to additional investigation.

Southeast also developed and implemented a comprehensive *Visual Scoping and Survey Plan* in 2002 (SAIC 2002e). This plan established a strategy for: the location of items that had the potential to be radiologically contaminated with Am-241 based on their movement from Magill Hall to other locations on- or off-campus; their survey; and evaluation of potential radiation exposures to individuals who may have come into contact with the items. This plan included surveys of structures in the vicinity of contaminated surplus equipment and was implemented from April through June 2002, with results documented in the *Implementation of the Visual Scoping and Survey Plan – Final Report*, September 2002 (SAIC 2002g). The *Visual Scoping and Survey Plan* required a room-by-room inspection of all campus buildings (except Magill Hall, which had already been subjected to comprehensive surveys, and residence halls, which were deemed to be unlikely to contain suspect items). Of 62 buildings inspected, 35 were found to contain no suspect items. Of the remaining 27 buildings, 23 buildings outside the geographical limits of the College of Science and Mathematics contained suspect items at concentrations below applicable investigation levels. As such, the only buildings containing items with activity exceeding investigation levels were Rhodes, Johnson, and Magill Halls, and the District Crime Lab. Each of these buildings had operations related to the College of Science and Mathematics. Instrument investigation levels were based on the "Acceptable Surface Contamination Levels" contained in AEC Regulatory Guide 1.86.

Comprehensive radiological surveys were performed in relevant portions of each of the four facilities which contained items with residual radioactivity exceeding investigation levels. Results from these four buildings are summarized as follows:

2.3.1.1 Rhodes Hall

All 139 rooms in Rhodes Hall were inspected, with 25 rooms subjected to comprehensive radiological surveys. A total of 576 suspect items were surveyed, resulting in the identification of a total of 36 contaminated items in 21 rooms. Residual alpha activity ranged to about 12,000 dpm/100 cm^2; no elevated beta activity was detected. Each of the rooms occupied by the Chemistry and Physics Departments, the Radiological Laboratory in the Biology Department, and some of the spaces occupied by Geosciences were subsequently carried forward for future investigation as radiologically impacted portions of the building.

2.3.1.2 Johnson Hall

Each of the 78 rooms in Johnson Hall were inspected, with 27 rooms containing suspect items. Of 56 suspect items surveyed in Johnson Hall, the only contaminated item was a small spot of less than 100 cm^2 on a table in Room 310. This spot exhibited total alpha activity of 125 dpm/100 cm^2. On or about February 28, 2002, a black top table similar to those present in Magill Hall was located in Room 222 of Johnson Hall. Survey of this table reflected the presence of about 12,000 and 200 dpm/100 cm^2 for fixed and removable alpha activity, respectively (Southeast 2002) with no elevated activity being detected on adjacent surfaces (e.g., floors or other materials and equipment) despite two comprehensive radiological surveys of the area. As such, although Johnson Hall was included among the buildings subjected to comprehensive Visual Scoping and Survey Plan surveys, given the lack of residual activity in other areas of the building, only Room 222 in Johnson Hall was carried forward as a radiologically-impacted structure.

2.3.1.3 Magill Hall

Although Magill Hall was not initially included in the scope of the visual scoping and survey efforts, it was added based on findings in the District Crime Lab. About 800 test tube racks in Magill Hall were surveyed, with residual activity ranging to 4,500 and 29,000 dpm/100 cm^2 for alpha and beta activity, respectively. A total of 16 racks exhibited total alpha contamination exceeding limits prescribed in AEC Regulatory Guide 1.86, while 2 racks exhibited residual beta activity above the criteria prescribed in this guide. Given the existence of residual radioactivity on the structure, and on materials and equipment, all portions of this building were classified as radiologically impacted and have been subjected to comprehensive investigations and confirmatory surveys.

2.3.1.4 District Crime Lab

Each of the 19 rooms in the District Crime Lab were inspected, with 8 rooms containing suspect items. Of 114 suspect items surveyed in the Crime Lab, only 3 items exhibited residual radioactivity exceeding AEC Regulatory Guide 1.86 criteria. Items with elevated activity consisted of a wooden file box and two test tube racks, each of which exhibited elevated alpha activity. In addition, "All areas surrounding contaminated items were surveyed to determine if contamination had spread. All survey results for these surrounding areas were less than the investigation levels" (SAIC 2002g). "The Investigation Level was the instrument count rate for

the material being surveyed that was equivalent to the radiological release limit established in Southeast's Radiation Protection Program (RPP)." (SAIC 2002g). These limits are equivalent to the limits set forth in AEC Regulatory Guide 1.86.

2.3.1.5 Summary

Implementation of the Visual Scoping and Survey Plan resulted in a comprehensive, room-by-room search of all relevant campus buildings for potentially contaminated materials and equipment. Only four of the Southeast buildings contained radiologically contaminated materials and equipment. These buildings consisted of Magill, Rhodes, and Johnson Halls, and the District Crime Lab, each of which has been associated with the College of Science and Mathematics. Items identified as contaminated were decontaminated to the standards contained in AEC Regulatory Guide 1.86 or were disposed of as radioactive waste by transfer to a properly permitted disposal facility. Visual scoping and survey efforts culminated in publication of the initial *Surplus Item Investigation Report for Southeast Missouri State University* in November 2000 (SAIC 2000e) and the subsequent *Implementation of the Visual and Scoping Survey Plan - Final Report* (SAIC 2002g) which was issued in September 2002.

2.4 INVESTIGATION, DECONTAMINATION, AND FINAL STATUS SURVEYS OF NEWLY ACCESSIBLE AREAS OF IMPACTED STRUCTURES

"In 2005, Southeast began classroom and laboratory renovations within Magill Hall which included decontamination, disposal and release of the portions of Magill Hall that had previously been inaccessible" (SAIC 2011). Although this work was initiated in accordance with the *Decontamination Plan for Magill Hall at Southeast Missouri State University* (SAIC 2000d), remodeling activities at Southeast have been governed by the *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2006) since November 27, 2006, when Amendment 12 incorporated this plan into Southeast's NRC license. This plan served "to describe the protocol for survey, decontamination (if necessary) and disposition of equipment, materials and building surfaces (e.g., walls and floors) that are potentially radiologically contaminated with americium-241" (SAIC 2006). The scope of this plan included "building surfaces, equipment and materials within Magill Hall that were not accessible for survey during the [calendar year] (CY)00 effort" (SAIC 2006). The plan noted that "Survey, decontamination (if necessary), resurvey (if necessary), and release of these previously inaccessible items and surfaces will be investigated when the RSO is informed that they will become accessible due to movement of equipment, renovation of the room, etc." (SAIC 2006). Upon receipt of notification by the university RSO that an area was becoming accessible for remediation, SAIC, the university's health physics contractor, was mobilized to remediate previously inaccessible areas and perform final status surveys. All remedial actions were carried out under the direct oversight of the university RSO.

Procedurally, each radiologically impacted room was renovated using a process involving the removal of all permanently installed tables, benches, shelves, etc., such that previously inaccessible surface areas were accessible; survey of the previously inaccessible surfaces of both the equipment removed and structures; decontamination of the surfaces of both building and materials that exceeded applicable criteria; remedial action surveys to confirm the effectiveness of decontamination; and FSSs of each room to confirm the status of the entire room being evaluated. In addition, although building infrastructure such as piping systems and the heating, ventilation and air conditioning (HVAC) system were excluded from the scope of the plan, the document retained the option to address such infrastructure during the implementation of the

plan if it was determined that they were radiologically impacted. Radiological FSSs were subsequently performed for areas determined to be impacted. Room 242 was specifically omitted from the scope of facilities to be remediated in that all portions of the room had previously been subjected to confirmatory surveys (to the more limiting standards contained in AEC Regulatory Guide 1.86) during the CY00 effort. Infrastructure survey results are contained in this report (see Section 2.5).

Although it is specifically noted in the *Decontamination and Survey Plan for Magill and Rhodes Hall* (SAIC 2010) that Am-241 was the primary ROC, FSSs were conducted such that they were capable of detecting both alpha and beta contamination. This report incorporates both detailed assessments of (Am-241) alpha results and summaries of gross beta results.

Although initial investigations in 2000 suggested that radiologically impacted areas involved only portions of Magill Hall, it was subsequently determined during implementation of the *Visual Scoping and Survey Plan* (SAIC 2002e) that the potential for contamination transfer to other additional areas of the Southeast campus may have existed as a result of the relocation of contaminated materials and equipment. These additional areas included limited portions of Rhodes and Johnson Halls, as well as the former District Crime Lab prior to its demolition in 2003. Impacted areas within Rhodes Hall were determined to include Chemistry and Physics Department facilities as well as a few rooms occupied by the Geosciences Department. (Biology spaces other than the Radiation Laboratory were determined to not be radiologically impacted.) The only area of Johnson Hall determined to be radiologically impacted was Room 222, a room used to house Chemistry Department materials and in which a contaminated desk was located.

All impacted areas of Magill, Rhodes, and Johnson Halls were resurveyed as part of the recent decontamination and survey effort except those rooms (i.e., Rooms 214, 216, 218, and 218A) which were subjected to FSSs immediately prior to their being remodeled. Remodeling of these rooms took place after 2005 and prior to the more recent FSS efforts). FSS results for these rooms are incorporated into Appendix A, together with results applicable to other areas of the impacted structures.

2.5 INFRASTRUCTURE INVESTIGATIONS

Building utilities were also investigated. Utilities, as used herein, include the HVAC system as well as electrical conduit and those portions of the sewer system not originally surveyed as part of earlier sewer investigations. These additional sewer surveys augmented previous investigations.

2.5.1 Heating, Ventilation, and Air Conditioning System

Magill Hall HVAC components were housed in two rooms located on the roof of the building. These rooms, commonly referred to as the northeast and southwest penthouses, were about 30 ft (9 m) by 20 ft (6 m), with a height of about 15 ft (5 m). Each of the penthouses consisted of 3 similar chambers with each chamber containing, in sequence, an air return plenum; motor/blower to pull the return air into the penthouses; high capacity 2 ft (0.6 m) by 2 ft (0.6 m) filters; dampers/louvers with which to control the volumetric flow of makeup air; chiller/refrigeration units to provide cooled air; and a second set of mower/blower units connected to supply air ducts to move the makeup air into the various parts of the building. (A total of 9 filters were in two of the filter banks in each penthouse, with the third filter bank containing 12 filters.) Although the penthouses had previously been subjected to limited survey,

decontamination, and demolition as part of the 2010 field effort, previous surveys were augmented by additional decontamination and survey in 2011 and 2012. After all HVAC components were removed down to bare concrete, the concrete was decontaminated. The concrete pads were subsequently subjected to remedial action surveys to confirm that they achieved DCGLs and FSSs were performed to confirm compliance with DCGLs. All portions of the penthouses were subjected to MARSSIM Class 1 surveys. In addition to the components located in the penthouses, the HVAC system also included both air supply and air return ductwork. Interior portions of air supply ductwork in the basement were scanned consistent with MARSSIM Class 1 requirements, with air supply ductwork on the first and second floors surveyed as MARSSIM Class 3 areas. Exterior portions of ventilation air supply ductwork, as well as walls and dampers, throughout Magill Hall were also subjected to MARSSIM Class 1 requirements. In addition, air return ductwork was surveyed after the ceilings were removed. These surveys included exterior surfaces of ventilation supply lines (located above the ceilings) and ceiling ventilation defusers. All such surveys of exterior surfaces were subjected to scans of 100 percent of the surface. In addition, access holes were cut in the ductwork to allow access for surveys of the interior portion of the ductwork prior to its entry into the penthouses.

With respect to the electrical system, Class 1 and Class 3 surveys consisting of scan and fixed-point measurements were performed for all accessible electrical conduits to a height of 6 ft above floor level and more than 6 ft above the floor, respectively.

2.5.2 Sewer Investigations

Comprehensive sewer investigations took place between 2001 and 2003. These investigations resulted in NRC's issuance of Amendment 10 to Southeast's NRC license on June 27, 2003, removing Cs-137, Pb-210, Pb-214, Th-234, U-235, and U-238 from the license upon completion of sewer investigation and related disposal activities (see Section 2.2). Nonetheless, additional confirmatory investigations of sewer systems were performed by the Southeast RSO as individual rooms and areas became available pursuant to remodeling . These surveys consisted of the sampling of p-traps containing fluids and the associated evaluation of such fluids using a total activity screen by liquid scintillation counting. Exterior and accessible interiors of floor drains were surveyed from the point of origin (e.g., p-traps and floor drain covers) until they terminated at a wall or floor. FSS results for sewers were previously provided to NRC such that sewers were removed from Southeast's license.

2.5.3 Seismograph Pedestal

A seismograph pedestal was present in Room 21 in the basement of Magill Hall. The pedestal was a large slab of reinforced concrete approximately 4 ft by 4 ft by 2.5 ft high (1.2 m by 1.2 m by 0.76 m) and constructed on a free-formed concrete base. Given that Room 21 was also the location of the safe and the Am-241 spill, the pedestal had been subjected to partial decontamination and the application of a sealant or fixative; the outer portion of the pedestal was removed and disposed of as radioactive waste in 2012 by transfer to Toxco in Oak Ridge, Tennessee. Uncontaminated portions were surveyed to confirm the absence of contamination and disposed of as normal debris. In addition, upon completion of the removal of the pedestal, eight soil samples were collected from soil located under the pedestal at about 1.5 ft (0.6 m) below the level of the concrete floor. Radioanalytical results for these samples confirmed the absence of residual radioactivity exceeding NRC surface soil screening level DCGLs in the soil under the floor in Room 21 (see Appendix A, Attachment 8).

2.6 SOIL INVESTIGATIONS

A routine survey was performed in 2010 of the soil area in the vicinity of the Magill Hall radioactive storage bunker. This survey involved areas associated with waste hauling operations and indicated that a small area of surface soil south of Magill Hall near the bunker (Magill Hall 13A) was potentially contaminated (SAIC 2011) (see Figure 2). This bunker is located near an entrance to the basement of Magill Hall and, thus, to one of the sources of Am-241 contamination. The ROC was subsequently confirmed as being limited to Am-241. Given that the outdoor area in question was not an authorized location for licensed materials and soil was not a specified media, Southeast submitted a request for amendment to their NRC license to authorize university possession in the cited location and media. Amendment 14 to NRC license 24-09296-02 was subsequently issued to Southeast authorizing possession of Am-241 "for possession and storage only of contaminated soil", noting that the "amendment does not authorize remediation or decommissioning activities to be conducted on any outdoor areas at this time" and that it was NRC's understanding that "the University is working with a contractor to develop and submit for our review and approval, an amended version to its "Decontamination and Survey Plan for Rhodes and Magill Halls" dated November, 2006, that will include provisions for dealing with contaminated soil." NRC also noted in the transmittal of this amendment that "It is also our understanding that the University will submit a plan, for our review and approval, to conduct a thorough evaluation of additional contamination in the area where the contaminated soil was discovered" (NRC 2010). Amendment 15 to NRC License 24-09296-02, incorporating the soil sampling plan, was subsequently issued by the NRC on August 19, 2010, and was followed by a correction on August 31. This amendment authorized the collection of soil samples. Amendment 16 was subsequently issued on September 27, 2010, incorporating Revision 1 of the *Decontamination and Survey Plan for Magill and Rhodes Halls*, dated August 2010, into the license by reference. Substantive changes in this revision included addition of Soil Investigation Quality Controls; incorporation of September 2006 NRC surface soil screening level DCGLs from NUREG-1757, Volume 2, Revision 1; and addition of procedures for "Controls for Soils in Excess of Release Criteria," "Storage and Disposal," and "Survey Documentation" of soil investigations.

Comprehensive MARSSIM-compliant surveys were subsequently performed to assess the radiological status of surface soils adjacent to Magill Hall. These surveys included:

- Thorough reviews of historical aerial photographs as an integral constituent of an updated historical site assessment to identify impacted areas.
- Separation of the radiologically elevated soil areas into two survey units (SUs) with SU-1 consisting of a Class 1 area adjacent to the bunker and SU-2 representing a Class 2 area that included other impacted soils in the area around Magill, Rhodes, and Johnson Halls.
- Gamma walkover surveys (GWSs) with ~~1~~2 inch by ~~1~~2 inch (5.10 ~~2.5~~ cm by 5.1~~2.5~~ cm) gamma scintillation detectors and field instruments for the detection of low-energy radiation (FIDLERs).~~or 2" x 2" gamma scintillation detectors.~~
- Collection and laboratory analyses of 36 biased and bounding soil samples to characterize areas of elevated gamma activity and, for samples with results exceeding screening level DCGLs for Am-241, bounding samples with which to determine the sizes of radiologically elevated areas.

- Collection and laboratory analyses of surface soil samples including 11 and 54 systematic samples from Class 1 SU-1 and Class 2 SU-2, respectively, as well as 54 systematic subsurface samples from the systematic locations in SU-2.
- Soil sample data evaluation and validation.
- Statistical evaluation of soil sample results relative to the NRC surface soil screening level DCGL of 2.1 pCi/g for Am-241.
- Development and transmittal of a formal report (*Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University*) (SAIC 2011) to NRC for review and comment pursuant to authorization to release radiologically impacted soils without regard to use restrictions.

The *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) concluded that evaluation of survey and sampling data supports the conclusion that soils adjacent to Magill Hall at Southeast clearly demonstrated that the null hypothesis or H_0 (i.e., that residual radioactivity in the SU exceeds the release criterion) is rejected for both soil SUs at Southeast (SAIC 2011) and that "Levels of radioactivity in the soils adjacent to Magill Hall achieve the requirements for unrestricted use consistent with the provisions of 10 *CFR* 20, Subpart E" (SAIC 2011). The *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) should be consulted for additional detail with respect to FSSs of soils at Southeast.

3.0 RADIONUCLIDE OF CONCERN

Am-241 is the only ROC at Southeast. Am-241 is commonly produced artificially and used for research purposes. It has a half-life of approximately 432 years, decaying by alpha particle emissions accompanied by the emission of low energy gamma photons. Both the alpha particles, with energies and percent abundances of 5.486 Megaelectron Volts (MeV) (85.2 percent) and 5.443 MeV (12.8 percent), and the gamma photons emitted with an energy of 59.54 kiloelectron volt [keV] gammas (35.9 percent abundance) are commonly important in the detection of Am-241 (Kocher 1981).

Although Cs-137 was previously identified in Southeast's acid dilution pit sediment, surficial beta activity did not exceed either the Cs-137 screening level DCGL of 28,000 dpm/100 cm^2 or the most limiting screening level DCGL of 7,100 dpm/100 cm^2 prescribed in NUREG-1757. (Acid dilution pit sediment containing low levels of residual Cs-137 and naturally occurring radioactive materials was removed and disposed of as radioactive waste prior to confirmatory FSSs. NRC subsequently issued Amendment 10 on June 27, 2003, removing this radionuclide from Southeast's NRC license.)

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4.0 IMPLEMENTATION OF STRUCTURE DERIVED CONCENTRATION GUIDELINE LEVELS

The process of releasing a given room, building, or site necessitates identification of contaminants of concern and applicable release criteria for such constituents. As noted in Section 3, Am-241 is the only ROC at Southeast. With regard to unrestricted release criteria, surface activity standards contained in AEC Regulatory Guide 1.86 (AEC 1974) were initially approved by NRC for use at Southeast. (Historically, this document has been commonly referred to as "NRC Regulatory Guide 1.86", although the NRC did not exist at the time that the document was initially produced.) Limits contained in AEC Regulatory Guide 1.86 were generally derived based on detectability rather than being dose-based and conservatively assumed removable contamination limits equating to 20 percent of the respective total contamination limits. The AEC Regulatory Guide 1.86 acceptable surface contamination levels for the unrestricted release of both equipment and structures with residual Am-241 activity were initially 20, 100, and 300 dpm/100 cm^2 for removable, average total, and maximum total contamination, respectively. These criteria were incorporated into Southeast's NRC license as gross alpha limits for both surficial activity on structures and for materials and equipment, until site-specific surface activity structure DCGLs were authorized by NRC in Amendment 12 to Southeast's NRC license on November 27, 2006. As noted in Section 2.3.1 of the *Decontamination and Survey Plan for Magill and Rhodes Halls*, Revision 1 (SAIC 2010), the stated limits from AEC Regulatory Guide 1.86 continue to apply for the unrestricted use of materials and equipment.

On July 21, 1997, the NRC published "Radiological Criteria for License Termination" in the *Federal Register* (*FR*) (62 *FR* 39058), "amending its regulations regarding decommissioning of licensed facilities to provide specific radiological criteria for the decommissioning of lands and structures." NRC's amended standards, which were incorporated into 10 *CFR* 20, Subpart E, "Radiological Criteria for License Termination", included criteria for both restricted and unrestricted release. Unrestricted release criteria, as cited in 10 *CFR* 20.1402, note that "A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to the average member of the critical group that does not exceed 25 mrem (0.25millisievert [mSv]) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA. Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal."

The requirements of 10 *CFR* 20, Subpart E, were subsequently augmented by "Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination" on November 18, 1998, in 63 *FR* 64132 and on December 7, 1999, in 64 *FR* 68395. Supplemental information included conservative, isotope-specific, screening level DCGLs for surface activity on structures and in surface soils which were incorporated into NUREG/CR–5512, Volume 3, *Residual Radioactive Contamination from Decommissioning, Parameter Analysis* (NRC 1999). Although these screening level DCGLs have been applied to surface soils at Southeast, they have not been implemented for use with structures. Rather, NRC approved use of AEC Regulatory Guide 1.86 criteria (i.e., 20, 100, and 300 dpm/100 cm^2 for removable, average total, and maximum total contamination, respectively) until Southeast subsequently developed a site-specific surface activity structure DCGL of 1,160 dpm/100cm^2 for Am-241. This site-specific DCGL was approved by NRC on November 27, 2006, and incorporated by reference in Amendment 12 to the Southeast license. (See *Decontamination and*

Survey and Survey Plan for Magill and Rhodes Halls [SAIC 2006]). This DCGL continues to apply at the present time. As an ALARA approach, Southeast also committed to decontaminate any removable activity on structures which exceeded the contamination limit of 20 dpm/100 cm^2 cited in the regulatory guide (SAIC 2006). Elevated Measurement Comparison DCGLs ($DCGL_{EMCs}$) use an area factor by which the activity concentration within a small area of elevated activity can exceed the $DCGL_W$ while still maintaining compliance with the release criterion. Although Table 2.3 of the decontamination and survey plan developed and cited area factors, residual radioactivity at Southeast was, without exception, compliant with the site-specific surficial DCGL of 1,160 dpm/100 cm^2, such that use of $DCGL_{EMCs}$ was not required.

5.0 SURVEY DESIGN

Surveys for the radiologically impacted building surfaces of Magill, Rhodes, and Johnson Halls were designed such that they would be compliant with MARSSIM guidance. The survey design specifically included a systematic procedure for defining the criteria that a data collection design should satisfy, including measurement collection locations; quantities of measurements to be collected; techniques to be employed during data collection; and the tolerable levels for decision errors.

Although equipment and materials were addressed to the "Acceptable Surface Contamination Levels" specified in AEC Regulatory Guide 1.86 and surveys of such items were performed in full accordance with relevant data quality objectives (DQOs) and quality standards, results contained in this report are limited to FSS information relative to radiologically impacted structures and for soils present under the pedestal in Magill Hall.

5.1 DATA QUALITY OBJECTIVES

The DQO process is a strategic planning approach for a data collection activity. The DQO process includes the following seven steps from the U.S. Environmental Protection Agency's (USEPA's) *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA 2006a):

- State the problem. Am-241 contamination was inadvertently released into specific portions of Southeast structures at levels exceeding the NRC-approved, site-specific surface activity DCGL for Am-241 and residual surface contamination on materials and equipment exceeding "Acceptable Surface Contamination Levels" specified in AEC Regulatory Guide 1.86.
- Identify the decision. Determine if residual radioactivity on structure surfaces on the Southeast campus complies with site-specific surface activity DCGLs derived as unrestricted release criteria to comply with dose limits prescribed in 10 *CFR* 20, Subpart E.
- Identify inputs to the decision. Radiological survey data for impacted structure surfaces.
- Define the study boundaries. Radiologically impacted areas previously identified in Magill, Rhodes, and Johnson Halls consisting of:
  - Magill Hall.
  - Portions of Rhodes Hall including Chemistry and Physics Department facilities as well as rooms occupied by the Geosciences Department. (Biology spaces other than the Radiation Laboratory were determined to not be radiologically impacted.)
  - Room 222 in Johnson Hall.
- Develop a decision rule. Given that sufficient data has been collected, if the mean concentration in the SU is less than the DCGL, then that SU is determined to be in compliance with the release criterion. Compliance with applicable DCGLs is demonstrated using the Sign and/or Wilcoxon Rank Sum (WRS) Tests to disprove the null hypothesis that the SU being evaluated exhibits contamination at concentrations exceeding the applicable DCGL. Lack of sufficient data serves to preclude disapproval of the null hypothesis and release of the SU being evaluated.

- Specify limits on decision errors. The desired tolerable limits included minimum detectable concentrations (MDCs) for measurements equating to less than 50 percent of the DCGL, with the goal of 10 percent of the cleanup criteria. Calculation of instrument minimum detectable count rates is based on a true positive error (1–β) of 95 percent and a false positive error (alpha) of 70 percent. That is, given mean contaminant concentrations near the DCGL, there is a 5 percent probability of releasing an SU that exceeds criteria and a 30 percent likelihood of failing to release an SU that is compliant with the DCGL.
- Optimize the design for collecting data. Site-specific data were used to estimate the number of required measurements to be collected.

The FSS data were examined using Data Quality Assessment (DQA) guidance to ensure that the data provided the necessary basis for determining whether residual radioactivity in impacted portions of structures at Southeast are compliant with DCGLs such that the structures are suitable for unrestricted use. The DQA involves scientific and statistical evaluations to determine if data are of the right type, quality, and quantity to support the intended use. The DQA process is based on guidance from Chapter 8 and Appendix E of MARSSIM (DOD 2000) and follows USEPA's *Data Quality Assessment: A Reviewer's Guide* (USEPA 2006b). The five steps in the DQA process are as follows:

- Review the FSS design, including DQOs.
- Conduct a preliminary data review.
- Select a statistical test.
- Verify the assumptions of the statistical test.
- Draw conclusions from the data.

5.2 THE DECISION

The decision for each SU with static total or removable alpha or beta count rates that are elevated with respect to background is whether the SU has radiological contaminants present at concentrations that exceed applicable criteria (e.g., site-specific DCGLs for structures or surface soil screening level DCGLs for soil and soil-like media).

5.3 INPUTS TO THE DECISION

Inputs to the decision as to whether a given structure SU is compliant with applicable criteria include:

- Identifying applicable DCGLs (see Subsection 5.3.1);
- Quantify Surface Activity Concentration (see Subsection 5.3.2);
- Computing scan and fixed-point measurement MDCs (see Subsection 5.3.3);
- Confirming that surface activity- measurements are properly collected and evaluated and exhibit the required quality (see Subsection 5.3.4);
- Identifying study boundaries and MARSSIM classifications of impacted areas (see Subsection 5.4);
- Subdividing radiologically impacted areas into individual SUs (see Subsection 5.4.1);
- Identifying the null hypothesis and limits on decision error (see Subsection 5.5.1);
- Determining the number of measurements needed in each SU (see Subsection 5.5.2); and

- Determining the Decision Rule and limits on decision errors (See Subsection 5.5.3).

5.3.1 Identify DCGLs

The site-specific alpha surface activity DCGL for Am-241 is 1,160 dpm/100cm^2. Although this DCGL is defined with respect to concentration above background, only instrument background is considered given that Am-241 background is very low.

Consistent with Southeast's NRC license, acceptable surface contamination levels contained in AEC Regulatory Guide 1.86 were initially applied for the unrestricted release of both equipment and structures. Residual Am-241 activity limits were initially 20, 100, and 300 dpm/100 cm^2 for removable, average total, and maximum total contamination, respectively, for both structures and materials and equipment. Although site-specific structure DCGLs were approved by the NRC in November, 2006, use of the AEC Regulatory Guide 1.86 limits has continued to the present for materials and equipment. In addition, removable activity on structures has also been limited to the standard contained in AEC Regulatory Guide 1.86 (i.e., 20 dpm/100 cm^2) as an ALARA action level. Although Am-241 is the lone ROC, gross beta activity has also been compared to applicable limiting DCGLs (e.g., AEC Regulatory Guide 1.86 limit of 5,000 dpm/100 cm^2 for Cs-137; a screening level DCGL of 28,000 dpm/100 cm^2 for Cs-137; and the most limiting screening level DCGL of 7,100 dpm/100 cm^2 for cobalt-60) to confirm that contamination from beta emitting radionuclides was not present.

5.3.2 Quantify Surface Activity Concentration

5.3.2.1 Background Reference Areas

Given that Am-241 is not naturally occurring in significant quantity, background determinations were limited to characterization of gross alpha and gross beta emissions of the various building materials present and of the gamma field present in and outside of radiologically impacted soil areas. All instrument survey results are reported herein without regard to background subtraction.

5.3.2.2 Alpha-Beta Surveys of Impacted Structures

All impacted portions of buildings were subjected to alpha/beta scan surveys of the appropriate percentage of the floors, walls, etc., based on the applicable MARSSIM classification of the area involved (see Section 4.10 and Table 4.6 ["MARSSIM Suggested Survey Units"]) (DOD 2000). Scan MDCs for the instruments used for the surveys addressed in this report are included in Table 5-2 and in Appendix B. No areas exhibited elevated activity during scan surveys; therefore, no biased static measurements were collected. Fixed-point survey results were directly compared to the DCGL (i.e., site-specific surficial activity limit of 1,160 dpm/100 cm^2), which is defined in terms of radionuclide-specific activity per unit area (i.e., dpm/100 cm^2). Measurement results in units of counts per minute (cpm) were converted to units of dpm/100 cm^2 using the following equation:

$$Surficial\ Activity\left(\frac{dpm}{100\ cm^2}\right) = \frac{R_g - R_b}{(\varepsilon_i)(\varepsilon_s)\dfrac{Probe\ Area}{100}}$$

where R_g is the static data point gross count rate (cpm)
R_b is the instrument field background count rate (cpm)
ε_i is the instrument 2 π efficiency (cpm/dpm)

ε_s is the source efficiency
Probe Area is the open area of the detector face (cm^2)

MARSSIM notes (on page 6-25) that "A source efficiency of 0.5 is recommended for beta emitters with maximum energies above 0.4 MeV. Alpha emitters and beta emitters with maximum beta energies between 0.15 and 0.4 MeV have a recommended source efficiency of 0.25" (DOD 2000). Based on these recommendations, source efficiencies of 0.25 and 0.5 are used for alpha and beta, respectively.

Determination of the percentage of total activity that is removable is generally required to verify that site conditions with regard to the removable fraction are consistent with assumptions integral to the development of DCGLs. This is accomplished through determination of the gross alpha and gross beta removable activity by swiping an area of approximately 100 cm^2 with a dry filter paper and then measuring the alpha and beta activity on the swipe. Although NUREG-1757 assumes that 10 percent of the total residual activity is removable, development of site-specific DCGLs for Southeast assumed that 50 percent of the total contamination is removable. (The actual removable fraction was determined to be about 3 percent.) Removable activity was constrained to the removable activity limit in AEC Regulatory Guide limits (i.e., 20 dpm/100 cm^2) as an ALARA action.

5.3.2.3 Investigation of Soils under the Pedestal in Magill Hall Room 21

Soils present under the pedestal in Room 21 in the basement of Magill Hall were subjected to GWSs using 1" by 1" NaI gamma scintillation detectors. Given that elevated count rates were not encountered by gamma scans, soil samples were collected from systematic locations under the former pedestal area and submitted for laboratory analysis by an accredited commercial radiochemistry laboratory.

The *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) calculated that 29 samples were required per soil SU at SEMO. The 29 samples calculated assumed a 2,000-m^2 SU; therefore, an average of one systematic sample was required to be collected for each 100 m^2 in an SU. Section 4.6 of MARSSIM states, "Special consideration may be necessary for survey units with structure areas less than 10 m^2 or land areas less than 100 m^2" (DOD 2000) and notes that data generated from these smaller SUs should be obtained based on judgment and compared individually to the DCGLs (DOD 2000). As the area under the pedestal (cited as SU-~~93~~90) was only approximately 8 m^2 and no elevated areas were detectable by scan surveys, it would be reasonable based on the previously identified guidance to collect only one sample from this area. Eight systematic samples were collected.

Results for the 8 samples ranged from -0.04 to 0.36 pCi/g with a mean of 0.08 ± 0.39 pCi/g and all results being less than their respective MDCs, which ranged from 0.10 to 0.47 pCi/g (see Appendix A, Attachment A-8, Table A8.9). All results were less than their MDCs, which were a maximum of 22 percent of the surface soil screening level DCGL of 2.1 pCi/g listed in NUREG-1757, Appendix H. As such, if residual activity was present at the respective MDC for each sample, the resultant concentration would equate to 0.22 pCi/g or 11 percent of the 25 mrem/yr dose standard. This equates to a residual dose of a maximum of 2.6 mrem/yr. Given that the NRC's surface soil DCGL is derived based on an area of 2,400 m^2, whereas the area under the pedestal is only approximately 8 m^2, the actual residual dose would be much lower than this calculated value.

5.3.3 Compute Scan and Static Minimum Detectable Concentrations

The MDC is an activity level that a specific instrument and measurement technique will detect 95 percent of the time. Instrumentation to be used for surveys must necessarily have the capacity to measure radioactivity at a fraction of the applicable criteria. As such, MARSSIM recommends MDCs of no more than 50 percent of the DCGL, with the goal of 10 percent of the applicable DCGL. This subsection addresses decision inputs relative to computation of MDCs.

NUREG-1507 and NUREG-1575 provide methodology for the calculation of MDCs for instruments used to quantify alpha, beta, and gamma scan and fixed-point measurement surveys. The MDC is the minimum concentration of the contaminant that can be measured with certainty. The MDC of a scan survey "depends on the intrinsic characteristics of the detector (efficiency, physical probe area, etc.), the nature (type and energy of emissions) and relative distribution of the potential contamination (point versus distributed source and depth of contamination), scan rate, and other characteristics of the surveyor" (DOD 2000). The assumptions used to calculate scan survey MDCs in NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (NRC 1998) are appropriate for this survey. The scan MDCs for structure surfaces may be calculated as follows:

The observation interval (i) is defined as the width of the probe divided by the time that 25 percent of the probe is over a 4"×4" area of interest (scan speed).

i = (probe width) / (scan speed)

or

$$i = \frac{w}{s}$$

i = observation interval (seconds)
w = probe width (inches)

The observable background counts, (b_i), is defined as the number of background counts that occur during an observation interval.

$b_i = (B) \times (i/60)$
B = background count rate (cpm)

The minimum detectable number of net source counts in the interval is given by s_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (d'), as shown below:

$$s_i = d' \sqrt{b_i}$$

or

$$s_i = d' \sqrt{B(\frac{i}{60})}$$

S_i = minimum detectable number of net source counts
d' = Index of detectability
B = background count rate (cpm)

The Minimum Detectable Count Rate (MDCR) is defined as the increase above background recognizable during a survey in a given period of time. The variable, d', is defined as the index of sensitivity and is dependent on the selected decision errors for Type I (alpha) and Type II (beta) errors. A true positive error (1–β) of 95 percent and a false positive error (alpha) of 60 percent were selected pursuant to NUREG-1507. The value of 1.38 was obtained from Table 6.1 in NUREG-1507 (Table 6.5 in MARSSIM).

$$MDCR = s_i \times (60/i) = cpm$$

Finally, the scan MDCs for structure surfaces may be calculated:

$$MDC = \frac{MDCR}{\left(\sqrt{p}\right)(\varepsilon_s)(\varepsilon_i)\left(\frac{probe\ area}{100\ cm^2}\right)}$$

MDCR = minimum detectable count rate
ε_s = surface efficiency
ε_i = instrument efficiency
p = surveyor efficiency

Site-specific detection sensitivities (scan and static MDCs) for Southeast have been calculated in accordance with the approach detailed in NUREG-1507. Sample calculations of scan MDCs for the instruments used for the surveys addressed in this report are contained in Appendix B, with instrument-specific scan and static (fixed point) MDCs being provided in Table 5-2.

5.3.4 Survey Implementation Considerations

Quantitative gross alpha/beta scan surveys were performed using Ludlum Model 43-89 and Ludlum Model 43-93 dual scintillator detectors coupled with Ludlum Model 2360 scaler/ratemeters, with all fixed-point measurements obtained using only Ludlum Model 43-89s. Removable contamination was evaluated by collecting smears, which were evaluated by Ludlum Model 43-10-1 alpha/beta counters. Field instrumentation used at Southeast is presented in Table 5-1.

Table 5-1. Summary of Survey Instrumentation Used at Southeast

Measurement Type	Detector Type	Instrument Model	Detector Model
Alpha/Beta Scan/Static	Dual Phosphor zinc sulfide (ZnS) 125 cm^2 scintillator	Ludlum 2360	Ludlum 43-89
Alpha/Beta Scan/Static	Dual Phosphor ZnS 100 cm^2 scintillator	Ludlum 2360	Ludlum 43-93[a]
Alpha/Beta Scan	P-10 gas proportional counter system	Ludlum 2360	Ludlum 43-37
Gamma Scan[b]	1"x 1" sodium iodide (NaI) gamma scintillator	Ludlum 2	Ludlum 44-3

[a] All fixed-point measurements were obtained using Ludlum Model 43-89s.

[b] Use limited primarily to surveys of soils adjacent to Magill Hall and under the pedestal in Magill Hall Room 21.

Table 5-2. Evaluation of Instruments used at Southeast

Detector Model[a]	Radiation of Interest	Background (cpm)		2 π Instrument Efficiency (cpm/dpm)		Scan MDC (dpm/100 cm^2)		Static MDC (dpm/100 cm^2)	
		Beta	Alpha	Beta	Alpha	Beta	Alpha[b]	Beta	Alpha
Ludlum 43-89 Instrument A	Alpha/Beta	153	0.5	31.2	21.4	957	80	621	94
Ludlum 43-89 Instrument D	Alpha/Beta	176	0.5	31.3	25.9	1,025	66	662	78
Ludlum 43-89 Instrument G	Alpha/Beta	209	0.3	33.7	25.5	1,038	52	667	70
Ludlum 43-89 Instrument H	Alpha/Beta	236	0.6	34.0	25.7	1,093	70	701	80
Ludlum 43-89 Instrument L	Alpha/Beta	226	0.3	37.1	25.9	980	51	629	69
Ludlum 43-89 Instrument P	Alpha/Beta	207	0.6	28.2	22.5	1,234	83	794	94
Ludlum 43-10-1 Instrument A	Alpha/Beta	41	0.2	35.9	32.6	N/A	N/A	91	16
Ludlum 43-10-1 Instrument B	Alpha/Beta	40	0.1	34.2	36.6	N/A	N/A	72	11
Ludlum 43-10-1 Instrument BB	Alpha/Beta	46	0.08	36.0	32.2	N/A	N/A	73	12
Ludlum 43-10-1 Instrument C	Alpha/Beta	44	0.2	36.2	33.4	N/A	N/A	72	14
Ludlum 43-10-1 Instrument D	Alpha/Beta	35	0.2	33.3	32.0	N/A	N/A	70	14
Ludlum 43-10-1 Instrument E	Alpha/Beta	41	0.1	30.5	32.5	N/A	N/A	82	13
Ludlum 49-93 Instrument A	Alpha/Beta	250	0.9	38.2	30.0	1,258	96	801	99
Ludlum 43-37	Alpha/Beta	361	4.1	14.6	21	382	28	215	20

[a] Information is provided for instruments for a single year and is indicative of results experienced for other time periods.

[b] Although information is provided relative to calculated alpha and beta scan MDCs, use of the probability of detection is recommended in MARSSIM for alpha emitters.

Isotope-specific MDCs were not calculated for the 44-10 gamma detectors.

N/A – not applicable

5.3.4.1 Survey Quality Assurance and Quality Control

Survey instrument and surveyor quality assurance (QA) was demonstrated by:

- Selection of instrumentation based on its capability to measure the ROC at Southeast (i.e., Am-241);
- Calibration of alpha/beta survey instruments within the past 12 months in accordance with manufacturers' recommendations and American National Standards Institute (ANSI) N323A, *Radiation Protection Instrumentation Test and Calibration – Portable Survey Instruments* (ANSI 1997), using calibration standards that were traceable to the National Institute of Standards and Technology (NIST);
- Instrument operation and maintenance by qualified personnel, in accordance with Southeast Health Physics Program Procedures (e.g., physical inspection, background checks, response/operational checks). (Calibration and instrument QA/quality control [QC] records are contained in Appendix C.)
- The daily performance of operational checks prior to instrument use, upon completion of surveys, and at any time instrument results appeared questionable. Operational checks included the following:
    - Site-specific instrument background was established upon arrival at a site by determining the mean value of 10 each one-minute background counts for each instrument, including the Ludlum Models 43-89 and 43-93 Zinc Sulfide (ZnS) dual phosphor alpha/beta plastic scintillators; the Ludlum Model 43-37 gas flow

proportional floor monitors; and Ludlum Model 43-10-1 alpha/beta counters. Ten each one-minute source counts were also performed for field instruments.

- Background checks were performed at the same location in a reproducible geometry at the beginning and end of each survey day and if instrument response was questionable.
- The efficiency of field instruments and smear counters was determined prior to instrument use and using a reproducible geometry to assess instrument performance at the beginning and end of each survey day. Efficiency was evaluated using Th-230 alpha sources and strontium-yttrium (Sr-Y)-90 beta sources.
- MDCs were computed prior to instrument use to ensure each instrument had the ability to measure radiation with the required sensitivity.
- The acceptance criteria for background and for instrument efficiency were as stated in Southeast Health Physics Procedures. Sources were stored and handled as specified in Southeast Health Physics Procedures and were shipped in accordance with Department of Transportation and NRC regulations.

5.4 DEFINE STUDY BOUNDARIES

The boundary of this assessment consists of the evaluation of radiologically impacted structures, which are defined as follows:

- **Magill Hall.** All portions of the structure to include classrooms, laboratories, public spaces, and mechanical spaces (see Table 5-4).
- **Rhodes Hall.** All accessible surfaces in spaces occupied by the Departments of Chemistry, Physics, and Geosciences and the Department of Biology's Radiological Laboratory (see Table 5-5).
- **Johnson Hall.** Room 222 only.

Residual radioactivity on materials and equipment was appropriately investigated, and individual items were disposed of as radioactive waste or released without radiological restrictions based on the standards in AEC Regulatory Guide 1.86. Materials and equipment are not addressed in detail in this report, because the study boundary is limited to structures and soils under the pedestal in Room 21 of Magill Hall.

Although soil survey results are summarized herein, soils are addressed comprehensively in the *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) such that soil investigations in this report are limited to confirmatory soil surveys performed under the seismograph pedestal in Room 21 of the Magill Hall basement.

5.4.1 Assign MARSSIM Area Classifications

Radiologically impacted structures are classified as MARSSIM Class 1, 2, or 3, as defined in the following excerpts from Section 2.2 of MARSSIM (DOD 2000):

Class 1 Areas: "Areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiation surveys) above the $DCGL_W$."

Class 2 Areas: "Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the $DCGL_W$."

Class 3 Areas: "Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_W$, based on site operating history and previous radiation surveys."

As noted in Section 4.6 of MARSSIM, Class 1, 2, and 3 areas are subdivided into individual SUs "based on classification, exposure pathway modeling assumptions, and site-specific conditions" (DOD 2000). The MARSSIM-suggested areas for SUs are as specified in Table 5-3.

Table 5-3. MARSSIM "Suggested Survey Unit Areas" for Structures

Classification	Suggested Area
Class 1	up to 100 m^2
Class 2	100 to 1,000 m^2
Class 3	No Limit

Based on a review of site historical information and survey data, structures within impacted areas were designated as MARSSIM Class 1, 2, or 3 areas and subdivided into SUs.

Radiologically impacted areas are classified as Class 1, 2, or 3, with areal limits per SU as specified in Table 3-4 of MARSSIM. MARSSIM classification of structure areas is reflected in Table 5-4, Table 5-5, and Table 5-6 for Magill, Rhodes, and Johnson Halls, respectively. In addition, the soils area under the pedestal in Room 22 of the Magill Hall basement was conservatively classified as a MARSSIM Class 2 area.

Table 5-4. Magill Hall MARSSIM Classifications

Description/ Room Number	Floor Area (m^2)	MARSSIM Classification for Walls[a]	MARSSIM Classification for Floors
First Floor Southeast Survey Unit			
Lobby 100F	55	Class 3	Class 2
Classroom 116	117		
Storage 116A	7		
Lab 120	118		
Storage 120A	21		
Classroom 128	27		
Classroom 134	115		
Classroom 138	115		
Storage 138A	22		
First Floor Corridors Survey Unit			
Corridor 100B	98	Class 2	Class 2
Foyer 100C	21		
Office 142	20		
Corridor 100C	67		
Corridor 100E	124		
Office 130	17		
Corridor 100G/Room 134A	75		

Table 5-4. Magill Hall MARSSIM Classifications (Continued)

Description/ Room Number	Floor Area (m^2)	MARSSIM Classification for Walls[a]	MARSSIM Classification for Floors
First Floor Central West Section Survey Unit			
Lab 101	43	Class 3	Class 3
Corridor 107	6		
Office 107A	10		
Office 107B	10		
Office 107C	8		
Office 107D	8		
Office 109	23		
Office 109A	7		
Office 109B	14		
Office 109C	10		
Office 109D	10		
Electric 111	12		
Closet 113	4		
Restroom 123	12		
First Floor Central East Section Survey Unit			
Classroom 124	119	Class 3	Class 3
Storage 124A	9		
Storage 128A	26		
Classroom 131	88		
Office 135	24		
Storage 135A	7		
Storage 135B	14		
Lab 135C	20		
Storage 139	11		
Janitor 141	3		
Classroom 144	116		
Restroom 149	25		
First Floor Northwest Survey Unit			
Classroom 100	118	Class 3	Class 2
Storage 100A			
Lobby 100H	56	Class 2	
Lab 104	117	Class 3	
Storage 104A	21		
Classroom 108, Closet 108B	111		
Storage 108A	6		
Classroom 112, Closets 112B and 112C	114		
Storage 112A	22		
Storage 144A	7		
Classroom 148	118		
Storage 148A	22		
Second Floor Corridors Survey Unit			
Corridor 209	69	Class 2	Class 2
Corridor 225	89		
Lab 218A	20		
Vestibule 232	7		
Office 232B	20		
Corridor 237	69		
Corridor 250	113		
Office 244A	20		

Vestibule 244C	7		

Table 5-4. Magill Hall MARSSIM Classifications (Continued)

Description/ Room Number	Floor Area (m^2)	MARSSIM Classification for Walls[a]	MARSSIM Classification for Floors
Second Floor Southeast Survey Unit			
Lab 200	16	Class 3	Class 2
Lab 200A	20		
Classroom 228	119		
Lab 230	29		
Classroom 232A	116		
Lab 234	48		
Storage 242A	5		
Lab 235	22		
Classroom 236	66		
Lab 238	19		
Storage 227	5		
Lab 239	22		
Lab 239A	10		
Lab 239B	10		
Lab239C	10		
Lab 239D	10		
Storage 239E	5		
Lab 239F	12		
Lab 240	30		
Lab 241	22		
Lab 242	51		
Lab 242A	5		
Lab 242B	27		
Lab 243	10		
Classroom 244	95		
Janitor 245	2		
Classroom 248	95		
Storage 248A[b]	73		
Storage 249	25		
Second Floor West Survey Unit			
Lab 202	18	Class 3	Class 2
Lab 204	67		
Lab 206	17		
Lab 208	18		
Lab 208A	14		
Lab 208B	10		
Lab 210	115		
Lab 211	43		
Lab 212	43		
Lab 212A	3		
Storage 213	42		
Lab 214[b]	80		N/A
Office 215	65		Class 2
Lab 216[b]	107		N/A
Lab 217	10		Class 2
Lab 218[b]	143		N/A
Janitor 219	2		Class 2

Table 5-4. Magill Hall MARSSIM Classifications (Continued)

Description/ Room Number	Floor Area (m^2)	MARSSIM Classification for Walls[a]	MARSSIM Classification for Floors
		Class 3	Class 2
Lab 220	15		
Lab 220A	25		
Lab 222	67		
Restroom 223	12		
Lab 224	20		
Office 226	16		
Office 226A	20		
Basement Survey Unit			
Vestibule 001	25	Class 3	Class 2
Corridor 002	62		
Vestibule 003	4		
Lab 016	29		
Storage 011	13		
Storage 015	26		
Lab 017	16		
Storage 019	13		
Storage 021	8		
Storage 021A	7		
Storage 023	7		
Storage 023A	6		
Storage 026	11		
Storage 029	37		
Storage 19A	13		
Electric 018	16		
Mechanical 013	82		
Corridor 013B	20		
Penthouses Survey Unit			
NW Penthouse	600	Class 2	Class 2
SE Penthouse	600		

[a] Areas were combined for the MARSSIM Class 2 and Class 3 Wall Surveys.
[b] Rooms were surveyed prior to remodeling (see Section 2.4).
N/A – Not Applicable

Table 5-5. Rhodes Hall MARSSIM Classifications

Room Number/Description	Floor Area (m^2)	MARSSIM Classification for Walls	MARSSIM Classification of Floors
First Floor			
Storage 121B	39	Class 3	Class 2
Depository 123	65		
Lab 125	42		
Corridor 100	165		Class 3
Corridor 100B	35		
Vestibule 100C	2		
Corridor 100G	5		
Office 102A	20		
Storage 102B	9		
Mail Room 102E	14		
Lab 104	20		

Table 5-5. Rhodes Hall MARSSIM Classifications (Continued)

Room Number/Description	Floor Area (m^2)	MARSSIM Classification for Walls	MARSSIM Classification of Floors
First Floor (Continued)			
Office 107	30	Class 3	Class 3
Office 107E	12		
Lab 109	20		
Advising Center 117	42		
Lecture Hall 121	145		
Lab 122	64		
Lab 124	44		
Lab 126	71		
Women 130	13		
Second Floor			
Corridor 200B	22	Class 3	Class 2
Office 201	18		
Office 201A	15		
Office 201B	11		
Office 201C	11		
Office 201D	11		
Office 201E	11		
Office 201F	11		
Office 201G	11		
Office 201H	11		
Lab 216	36		
Office 224E	12		
Lab 226	20		
Office 230A	10		
Office 230B	10		
Office 230C	47		
Office 230D	11		
Corridor 200A	27		Class 3
Corridor 200H	161		
Corridor 200J	7		
Office 202	10		
Lab 203	20		
Lab 204	20		
Office 206	20		
Lab 207	20		
Lab 211	20		
Lab 215	30		
Classroom 220	54		
Classroom 223	55		
Office 224B	10		
Lab 227	20		
Men 231	13		
Third Floor			
Classroom 301	78	Class 3	Class 2
Lab 303	20		
Lab 304	19		
Office 306C	10		
Office 312	10		
Lab 319	16		
Office 319A	10		

Classroom 323	66		

Table 5-5. Rhodes Hall MARSSIM Classifications (Continued)

Room Number/Description	Floor Area (m^2)	MARSSIM Classification for Walls	MARSSIM Classification of Floors
Third Floor (Continued)			
Corridor 300	161	Class 3	Class 3
Office 302	10		
Office 305	10		
Office 306	27		
Office 306E	12		
Lab 307	40		
Lab 309	19		
Office 311	10		
Lab 314	30		
Classroom 315	110		
Classroom 316	91		
Lab 317	8		
Lab 318B	13		
318C	19		
Lab 321	16		
Office 321A	11		
Men 324	17		

Table 5-6. Johnson Hall MARSSIM Classifications

Room Number/Description	Floor Area (m^2)	MARSSIM Classification for Walls	MARSSIM Classification of Floors
Room 222	34	N/A	Class 2

N/A Not Applicable

5.4.2 Subdivide MARSSIM Class 1, 2, and 3 Areas into Individual Survey Units

Table 5-7 contains information on SU, room number, number of measurements collected, and the location at which the detailed SU information can be found. SUs were consolidated based on areal limits such that walls and floors in more than one room or area are part of the same MARSSIM Class 2 or Class 3 SU.

Table 5-7. Structures Survey Information Summary[a]

SU	Rooms	MARSSIM Classification	Survey Surface	Number of Measurements Collected	Sample Data Summary Table	Building
1	100B, Foyer 100C, 142	Class 2	Floors	10	Table A1.2	Magill
2	Corridor 100C			12	Table A1.3	
3	100E, 130			10	Table A1.4	
4	100G			12	Table A1.5	
5	100B, 100C, 142, 100E, 130, 100G, 100H		Walls	40	Table A1.6	
6	100F		Floor	13	Table A2.2	
7	116			9	Table A2.3	
8	116A			8	Table A2.4	
9	120			9	Table A2.5	
10	120A	Class 3		9	Table A2.6	
11	128	Class 2		10	Table A2.7	
12	134			14	Table A2.8	

13	138			14	Table A2.9	
14	138A			12	Table A2.10	

Table 5-7. Structures Survey Information Summary[a] (Continued)

SU	Rooms	MARSSIM Classification	Survey Surface	Number of Measurements Collected	Sample Data Summary Table	Building
15	100F, 116, 116A, 120, 120A, 128, 134, 138, 138A	Class 3	Walls	8	Table A2.11	Magill
16	101, 107, 107A, 107B, 107C, 107D, 109, 109A, 109B, 109C, 109D, 111, 113, 123		Floor	20	Table A3.3	
17	101, 107, 107A, 107B, 107C, 107D, 109, 109A, 109B, 109C, 109D, 111, 113, 123		Walls	14	Table A3.4	
18	124, 124A, 128A, 131, 135, 135A, 135B, 135C, 139, 141, 144, 149		Floor	20	Table A3.5	
19	124, 124A, 128A, 131, 135, 135A, 135B, 135C, 139, 141, 144, 149		Walls	10	Table A3.7	
20	100	Class 2	Floor	11	Table A4.2	
21	100A		Floor	9	Table A4.5	
22	100H		Walls	4	Table A4.7	
23	104		Floor	10	Table A4.8	
24	104A			10	Table A4.9	
25	108			9	Table A4.10	
26	108A			10	Table A4.12	
27	112			10	Table A4.13	
28	112A			9	Table A4.15	
29	100, 100A, 104, 104A ,108, 108A, 112, 112A, 144A, 148, 148A	Class 3	Walls	6	Table A4.16	
30	144A, 148A	Class 2	Floor	12	Table A4.17	
31	148			14	Table A4.18	
32	209			12	Table A5.2	
33	218A, 225, 232, 232B			10	Table A5.3	
34	237			12	Table A5.4	
35	250, 244A, 244C			12	Table A5.5	
36	209, 218A, 225, 232, 232B, 237, 250, 244A, 244C		Walls	30	Table A5.6	
37	200, 200A		Floor	10	Table A6.2	
38	228			9	Table A6.3	
39	230			9	Table A6.5	
40	232A			9	Table A6.7	
41	234			11	Table A6.9	
42	234A			10	Table A6.11	
43	235			15	Table A6.13	
44	236			9	Table A6.14	
45	238	Class 3		10	Table A6.16	
46	227, 239, 239A, 239B, 239C, 239D	Class 3		12	Table A6.18	
47	239E	Class 2		10	Table A6.19	
48	239F			11	Table A6.20	
49	240			13	Table A6.21	
50	241			12	Table A6.23	
51	242			10	Table A6.24	
52	242B			10	Table A6.26	
53	243			10	Table A6.28	

54	244			11	Table A6.29	
55	245			10	Table A6.30	

Table 5-7. Structures Survey Information Summary[a] (Continued)

SU	Rooms	MARSSIM Classification	Survey Surface	Number of Measurements Collected	Sample Data Summary Table	Building
56	248	Class 2	Floor	15	Table A6.31	Magill ~~Magill~~
57	248A			4	Table A6.32	
58	249			9	Table A6.33	
59	200, 200A, 227, 228, 230, 232A, 234, 234A, 235, 236, 238, 239, 239A, 239B, 239C, 239D, 239E, 239F, 240, 241, 242, 242A, 242B, 243, 244, 245, 248, 248A, 249	Class 3	Walls	20	Table A6.34	
60	202	Class 2	Floor	10	Table A7.2	
61	204			9	Table A7.3	
62	206			8	Table A7.4	
63	208			10	Table A7.5	
64	208A			10	Table A7.6	
65	208B			10	Table A7.7	
66	210			10	Table A7.8	
67	211			11	Table A7.9	
68	212			12	Table A7.10	
69	212A			9	Table A7.11	
70	213			11	Table A7.12	
71	214, 216, 218		Walls	21	Table A7.13	
72	214, 216, 218~~215~~		Floor	11	Table A7.14	
73	215~~6~~			51	Table A7.15	
74	217			13	Table A7.16	
75	219			10	Table A7.17	
76	220			10	Table A7.18	
77	220A			10	Table A7.19	
78	222			10	Table A7.20	
9	223			10	Table A7.21	
80	224			8	Table A7.22	
81	226, 226A			14	Table A7.23	
82	202, 204, 206, 208, 208A, 208B, 210, 211, 212, 212A, 213, 214, 215, 217, 219, 220, 220A, 222, 223, 223, 226, 226A	Class 3	Walls	28	Table A7.24	
83	1,2	Class 2		15	Table A8.2	
84	3,16			12	Table A8.3	
85	11			10	Table A8.4	
86	15			10	Table A8.5	
87	17			8	Table A8.6	
88	19			10	Table A8.7	
89	21, 21A			8	Table A8.8	
90	21		Soil	8	Table A8.9	
91	23, 23A		Floor	10	Table A8.10	
92	26			10	Table A8.11	
93	28			10	Table A8.12	
94	29			8	Table A8.13	
95	1, 2, 3, 16, 11, 15, 17, 19, 21,	Class 3	Walls	20	Table A8.14	

	21A, 23, 23A, 26, 28, 29					
~~74~~	~~216~~		~~Walls~~	~~24~~	~~Table A7.16~~	
~~86~~	~~1,2~~	~~Class 2~~	~~Floor~~	~~15~~	~~Table A8.2~~	~~Magill~~
~~87~~	~~3,16~~			~~12~~	~~Table A8.3~~	
~~88~~	~~11~~			~~10~~	~~Table A8.4~~	
~~89~~	~~15~~			~~10~~	~~Table A8.5~~	
~~90~~	~~17~~			~~8~~	~~Table A8.6~~	
~~91~~	~~19~~			~~10~~	~~Table A8.7~~	
~~92~~	~~21, 21A~~			~~8~~	~~Table A8.8~~	~~Magill~~
~~93~~	~~21~~		~~Soil~~	~~8~~	~~Table A8.9~~	
~~94~~	~~23, 23A~~		~~Floor~~	~~10~~	~~Table A8.10~~	
~~95~~	~~26~~			~~10~~	~~Table A8.11~~	
~~96~~	~~28~~			~~10~~	~~Table A8.12~~	
~~97~~	~~29~~			~~8~~	~~Table A8.13~~	

Table 5-7. Structures Survey Information Summary[a] (Continued)

SU	Rooms	MARSSIM Classification	Survey Surface	Number of Measurements Collected	Sample Data Summary Table	Building
9~~69~~	25	Class 2	Floor	10	Table A8.15	Magill
97~~10~~ ~~0~~	25		Wall	10	Table A8.16	
98~~10~~ ~~1~~	13, 13B		Floor	17	Table A8.17 and Table A8.18	
99~~10~~ ~~2~~	18		Floor	9	Table A8.19	
100~~3~~	13, 13B, 18	Class 3	Wall	20	Table A8.20	
101~~4~~	19A	Class 2	Floor	8	Table A8.21	
102~~5~~	19A		Wall	10	Table A8.22	
103~~6~~	~~NW~~ NE Penthouse		Floor	24	Table A9.1	
104~~7~~	~~NW~~ NE Penthouse		Wall	33	Table A9.2	
105~~8~~	~~SE~~ SW Penthouse		Floor	24	Table A9.3	
106~~9~~	SW~~E~~ Penthouse		Wall	33	Table A9.4	
107~~1~~ ~~0~~	Greenhouse		Floor	12	Table A11.1	Greenhouse[b]
108~~1~~ ~~1~~	Greenhouse	Class 3	Wall	10	Table A11.2	Greenhouse[b]
109~~1~~ ~~2~~	121B	Class 2	Floor	11	Table A12.2	Rhodes
110~~3~~	123			11	Table A12.3	
111~~4~~	125			10	Table A12.4	
112~~5~~	100, 100B, 100C, 100G, 102A, 102B, 102E, 104, 107, 107E, 109, 117, 121, 122, 124, 126, 130	Class 3		20	Table A12.5	
113~~6~~	100, 100B, 100C, 100G, 102A, 102B, 102E, 104, 107, 107E, 109, 117, 121, 121B, 122, 123, 124, 125, 126, 130		Wall	20	Table A12.6	
114~~7~~	200B	Class 2	Floor	20	Table A13.2	
115~~8~~	201			12	Table A13.3	
116~~9~~	201A			11	Table A13.4	
117~~2~~ ~~0~~	201B			11	Table A13.5	

118~~2~~ ~~1~~	201C			10	Table A13.6	
119~~2~~ ~~2~~	201D			10	Table A13.7	
120~~3~~	201E			10	Table A13.8	
121~~4~~	201F			10	Table A13.9	
122~~5~~	201G			10	Table A13.10	
123~~6~~	201H		Floor	10	Table A13.11	
124~~7~~	212			8	Table A13.12	
125~~8~~	212		Wall	10	Table A13.13	
126~~9~~	214A		Floor	9	Table A13.14	
127~~3~~ ~~0~~	214A		Wall	10	Table A13.15	
128~~3~~ ~~1~~	216		Floor	12	Table A13.16	
129~~3~~ ~~2~~	219			10	Table A13.17	
130~~3~~	219		Wall	10	Table A13.18	
131~~4~~	224E		Floor	10	Table A13.19	
132~~5~~	226			10	Table A13.20	
133~~6~~	230A			10	Table A13.21	
134~~7~~	230B			10	Table A13.22	
135~~8~~	230C			10	Table A13.23	
136~~9~~	230D			14	Table A13.24	

Table 5-7. Structures Survey Information Summary[a] (Continued)

SU	Rooms	MARSSIM Classification	Survey Surface	Number of Measurements Collected	Sample Data Summary Table	Building
1374~~0~~	200A, 231, 200H, 202, 204, 203, 200H, 207, 206, 227, 211, 224B, 223, 215, 200J	Class 3	Floor	20	Table A13.25	Rhodes
1384~~1~~	200A, 200B, 201, 201A, 201B, 201C, 201D, 201E, 201F, 201G, 210H, 216, 224E, 226, 230A, 230B, 230C, 230D, 231, 200H, 202, 204, 203, 200H, 207, 206, 227, 211, 224B, 223, 215, 200J		Wall	20	Table A13.26	
1394~~2~~	301	Class 2	Floor	16	Table A14.2	
1403	303			11	Table A14.3	
1414	304			10	Table A14.4	
1425	306C			11	Table A14.5	
1436	312			10	Table A14.6	
1447	319			11	Table A14.7	
1458	319A			10	Table A14.8	
1469	323			16	Table A14.9	
1475~~0~~	300, 302, 305, 306, 306E, 307, 309, 311, 314, 315, 316, 317, 318B, 318C, 321, 321A, 324	Class 3		23	Table A14.10	
1485~~1~~	301, 303, 304, 306C, 312, 319, 319A, 323, 300, 302, 305, 306, 306E, 307, 309, 311, 314, 315, 316, 317, 318B, 318C, 321, 321A, 324		Wall	20	Table A14.11	
1495~~2~~	222	Class 2	Floor	8	Table A15.2	Johnson

[a] All measurements represent post-remediation FSS data.

[b] Greenhouse refers to the Biology Greenhouse.

5.5 DEVELOP A DECISION RULE

5.5.1 Identify the Null Hypothesis and Limits on Decision Error

Appendix D of MARSSIM notes that "The probability of making decision errors can be controlled by adopting a scientific approach, called hypothesis testing. In this approach, the survey results are used to select between one condition of the environment (the null hypothesis, H_0) and an alternative condition (the alternative hypothesis, H_a). The null hypothesis is treated like a baseline condition that is assumed to be true in the absence of strong evidence to the contrary. Acceptance or rejection of the null hypothesis depends upon whether or not the particular survey results are consistent with the hypothesis.

"A decision error occurs when the decision maker rejects the null hypothesis when it is true, or accepts the null hypothesis when it is false. These two types of decision errors are classified as Type I and Type II decision errors.

"A Type I decision error occurs when the null hypothesis is rejected when it is true, and is sometimes referred to as a false positive error. The probability of making a Type I decision error, or the level of significance, is denoted by alpha (α). Alpha reflects the amount of evidence the decision maker would like to see before abandoning the null hypothesis, and is also referred to as the *size* of the test.

"A Type II decision error occurs when the null hypothesis is accepted when it is false. This is sometimes referred to as a false negative error. The probability of making a Type II decision error is denoted by beta (β). The term (1-β) is the probability of rejecting the null hypothesis when it is false, and is also referred to as the *power* of the test." (DOD 2000)

In summary, a site is assumed to be contaminated above criteria unless proven otherwise. Given that the Type I and Type II errors for Southeast have been set at 0.05 and 0.30, respectively, if residual contamination is present at levels near the DCGL, there is a 5 percent probability of erroneously releasing an SU whose true mean is greater than the DCGL and a 30 percent probability of not releasing a site that is compliant with the DCGL.

5.5.2 Determine the Number of Measurements Needed Per Survey Unit

The relative shift (Δ/σ) is defined such that Δ is the DCGL minus the lower bound of the gray region (LBGR) and σ is the standard deviation of the contaminant distribution. MARSSIM recommends that the LBGR initially be set one half of the DCGL, but should be adjusted if necessary to provide a relative shift value within the recommended range of between 1.0 and 3.0, with up to 4.0 being acceptable. The site-specific structures DCGL for Am-241 at Southeast been set to 1,160 dpm/100 cm^2 (alpha) with 7,100 dpm/100 cm^2 representing the most limiting reasonable surface activity screening level DCGL for beta emitters. Thus Δ can be found by:

$$\Delta = \text{DCGL} - \text{LBGR}$$

$$\Delta = 1{,}160\frac{dpm}{100\ cm^2} - \frac{1{,}160\frac{dpm}{100\ cm^2}}{2} = 580\frac{dpm}{100\ cm^2}\ (alpha)$$

$$\Delta = 7{,}100\frac{dpm}{100\ cm^2} - \frac{7{,}100\frac{dpm}{100\ cm^2}}{2} = 3{,}550\frac{dpm}{100\ cm^2}\ (beta)$$

The value for σ can be estimated in a number of ways. Sometimes there are data from the site sufficient to calculate the standard deviation within the SU, σ_s. (Note that σ, as used herein, is the standard deviation at the time of release and after material exceeding applicable criteria are thought to have been effectively removed.) Data may also be available from a reference or background area. Reference area data can be used to estimate a standard deviation of the contaminant in naturally occurring background, σ_r, if the contaminant is present in background. The larger of σ_s and σ_r should be used when calculating relative shift. Consistent with MARSSIM guidance and with experience implementing MARSSIM, a coefficient of variance of 0.3 (i.e., 30 percent) was initially used at Southeast. Thus, the standard deviation can be found by:

$$\sigma = DCGL\ (30\ percent)$$

$$\sigma = 1{,}160 \frac{dpm}{100\ cm^2}\ (30\ percent) = 348 \frac{dpm}{100\ cm^2}\ (alpha)$$

$$\sigma = 7{,}100 \frac{dpm}{100\ cm^2}\ (30\ percent) = 2{,}130\ \frac{dpm}{100\ cm^2}\ (beta)$$

As such, the relative shift can be determined as:

$$relative\ shift = \frac{\Delta}{\sigma}$$

$$relative\ shift_{alpha} = \frac{580 \frac{dpm}{100\ cm^2}}{348 \frac{dpm}{100\ cm^2}} = 1.67$$

$$relative\ shift_{beta} = \frac{3{,}550 \frac{dpm}{100\ cm^2}}{2{,}130 \frac{dpm}{100\ cm^2}} = 3.33$$

The calculated value for relative shift can be used to obtain the minimum number of measurements necessary to satisfy requirements using the MARSSIM equation presented below:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(Sign\ P - \ 0.5)^2}$$

The calculated value, N, is the combined number of measurements from the reference area and each SU. $Z_{1-\alpha}$ and $Z_{1-\beta}$ are critical values that can be found in MARSSIM (or statistics textbooks and handbooks), and P_r is a measure of probability available from MARSSIM Table 5.1.

Typically, for MARSSIM surveys in which the contaminant is present in background, N/2 measurements are collected in each SU and N/2 measurements are collected in the reference area, if applicable. That is, N/2 measurements are obtained from *each* SU *and* N/2 measurements are conducted in the reference (background) area. However, the statistical methods are still valid if there are an unequal number of measurements in the SU and reference areas. A 20 percent increase in this number is recommended to account for lost or unusable measurements. The calculated values apply to each SU. The number of data points, N, for the Sign test is calculated using Equation 5-2 and Table 5.4 in MARSSIM, given 5 percent Type I error and 30 percent Type II error.

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(Sign\ P - 0.5)^2}$$

$$N = \frac{(1.645 + \ 0.524)^2}{4(0.945201 - \ 0.5)^2} = 5.9\ measurements\ (1.2) = 7.1\ > 8\ measurements$$

The uncertainty associated with the calculation, N, should be accounted for during survey planning; thus, the number of data points is increased by 20 percent and rounded up. This is to ensure there are sufficient data to allow for any possible lost or unusable data.

The requirement for 8 measurements is applicable to the relevant SU. As noted in Table 5-6, Structures Survey Information Summary, sufficient numbers of measurements were collected within each of the SUs in the buildings at Southeast. In addition, it is notable that the preponderance of the evidence must reflect that the null hypothesis (i.e., that the area being evaluated exceeds applicable limits) is disproved in order to release an area. (DOD 2000).

5.5.3 Summary of Decision Rule and Limits on Decision Errors

Southeast used MARSSIM Scenario A, such that the null hypothesis is that the SU does not meet the release criterion. Compliance with applicable DCGLs is demonstrated using statistical testing, such as the Sign and/or WRS Tests to disprove the null hypothesis that the SU being evaluated exhibits contamination at concentrations exceeding the applicable DCGL. As noted previously, a site is assumed to be contaminated above criteria unless proven otherwise. Given that the Type I and Type II errors for Southeast have been set at 0.05 and 0.30, respectively, if residual contamination is present at levels near the DCGL, there is a 5 percent probability of erroneously releasing an SU whose true mean is greater than the DCGL and a 30 percent probability of not releasing a site that is compliant with the DCGL.

The decision rule applied is that the SU is in compliance with the DCGL if the mean concentration in the SU is less than the DCGL. As all structure measurements were below the DCGL, all impacted areas at Southeast are necessarily compliant with the DCGL. As such, the dose resulting from residual radioactivity complies with dose limits defined in 10 *CFR* 20, Subpart E.

5.5.4 Determine the Number of Measurements Needed Per Soil Survey Unit

The *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) calculated that 29 samples were required per soil SU at Southeast. The 29 samples calculated assumed a 2,000 m^2 SU; therefore, an average of one systematic sample was required to be collected for each 100 m^2 in the SU. Consistent with Section 4.6 of MARSSIM, "Special consideration may be necessary for survey units with structure areas less than 10 m^2 or land areas less than 100 m^2" (DOD 2000), and the data generated from these smaller SUs should be obtained based on judgment and compared individually to the DCGLs (DOD 2000). Because the area under the pedestal (defined as SU-~~93~~90) was only approximately 8 m^2 and there were no detectable elevated areas, it would be reasonable to collect only one sample from this area. Eight systematic samples were collected from this area. None of the samples collected exhibited detectable Am-241 activity with all results exhibiting MDCs of less than 25 percent of the surface soil screening level DCGL of 2.1 pCi/g. As such, the soil area under the pedestal was clearly compliant with the surface soil screening level DCGL (see SU-~~93~~ 90 data presented in Appenndix A, Attachment A-8).

5.6 OPTIMIZATION OF THE DESIGN FOR COLLECTING DATA

The following conclusions are drawn relative to optimization of the survey design for collecting data:

- Investigations utilized the graded approach for site investigations. Areas of highest potential were scrutinized the most, with less effort expended in areas less likely to exhibit activity exceeding DCGLs.

- Radiological surveys and collected measurements were obtained in a defensible manner, assuring that MDCs were achieved.
- All radiological survey instruments were operated and maintained by qualified personnel, in accordance with Southeast Health Physics Program procedures.
- Evaluation of FSS data confirms that all data are of the appropriate quality to be usable.
- Comprehensive Instrument Calibration and QA/QC requirements were implemented. Related data are provided in Appendix C.

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6.0 SITE SAFETY AND HEALTH

Site safety and health requirements for site tasks were based on potential physical, radiological, and chemical hazards. The survey team complied with the site safety and health requirements documented in Southeast safety and health procedures. These documents/procedures were written to comply with the NRC and Occupational Safety and Health Administration (OSHA) requirements.

6.1 SAFETY AND HEALTH TRAINING

All project ~~survey team~~ personnel received all required training, which included Hazardous Waste Operations and Emergency Response (HAZWOPER) training (40-hour [hr] and current 8-hr refresher), medical surveillance, health and safety orientation, and radiation safety training. Safety and health records were kept and maintained according to Southeast policies, procedures and NRC radioactive material license requirements.

6.2 TASK-SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

The minimum level of protection for survey activities at this site was Level D personal protective equipment (PPE), which included:

- impermeable disposable inner gloves (e.g., nitrile, polyvinyl chloride, or equivalent);
- safety boots (ANSI Z41); and
- safety glasses with side shields (ANSI Z87.1).

The designated on-site Site Safety and Health Officer/Radiation Protection Manager had the responsibility of determining if an upgrade in PPE requirements was appropriate once the survey team mobilized to the site.

6.3 PERSONNEL MONITORING REQUIREMENTS

Based on the minimal potential for levels of radiological constituents that could reasonably result in survey team members receiving external or internal radiation doses exceeding 10 percent of regulatory dose limits (i.e., 500 mrem/yr), dosimetry was not required per 10 *CFR* 20.1502 (NRC 2011).

6.4 AIR MONITORING

Extensive breathing zone (i.e., personal) and general area air sampling was performed during decommissioning activities to ensure that airborne radioactivity was fully compliant with 10 *CFR* 20, Appendix B, limits for both occupational exposure and effluent standards for members of the public. Air sampling results confirm compliance with the cited standards and were maintained at levels that were ALARA**.**

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7.0 FINAL STATUS SURVEYS

7.1 SUMMARY OF SURVEY APPROACH

Each SU was surveyed in accordance with guidance provided in MARSSIM. As noted in Section 4.9, MARSSIM procedures recommend the collection of a minimum of 8 measurements for structures. The actual number of systematic measurements collected ranged from 8 in SU-8 to ~~51~~ 80 in SU-~~77~~ 71 and included at least 8 measurements in each SU at Southeast. Consistent with MARSSIM, systematic measurements were generally collected on a triangular grid.

All impacted areas of Southeast have been evaluated to ensure compliance with MARSSIM. This includes confirmation that:

- All measurements are compliant with the $DCGL_W$ with no result requiring comparison to the $DCGL_{EMC}$.
- Scan coverage was sufficient for each area.
- A sufficient number of measurements were collected to correctly evaluate the area.
- Each SU passes the Sign Test. (MARSSIM states that "if the largest measurement is below the $DCGL_W$, the Sign Test will always show that the survey unit meets the release criterion" (DOD 2000). As such, all SUs were compliant with the $DCGL_w$ without the need for statistical tests.)
- All impacted areas have been accurately classified as MARSSIM Class 1, Class 2, or Class 3 SUs.

7.2 SURVEY RESULTS

Radiological FSS measurement results are contained in Appendix A. As demonstrated therein, systematic results are compared directly to the applicable surface activity DCGL of 1,160 dpm/100 cm^2, included in the MARSSIM statistical analysis, and used in the residual dose assessment. Data from biased measurements were not included in the statistical tests per MARSSIM guidance, which states that "judgmental measurements are not included in the statistical evaluation of the SU because they violate the assumption of randomly selected, independent measurements. Instead, these judgmental measurements are individually compared to the DCGL" (DOD 2000). Given that no elevated areas were detected by FSS scan surveys, results of systematic surveys were used in the evaluation of residual dose. Dose assessment information is summarized in Section 8, with details contained in Appendix D.

7.2.1 Comparison of Results to Minimum Detectable Concentrations

In accordance with MARSSIM, analytical techniques should provide an MDC not exceeding 50 percent of the DCGL, with a preferred target of 10 percent of the DCGL. For the 1,160 dpm/100 cm^2 site-specific DCGL for Am-241 surface activity on structures, this equates to a maximum MDC of 580 dpm/100 cm^2 and a preferred target MDC of 116 dpm/100 cm^2. Consistent with the FSS process employed in performing FSSs of surface soils, for the Am-241 screening level DCGL for surface soils of 2.1 pCi/g, this equates to a preferred MDC of 0.21 pCi/g with a maximum MDC of 1.05 pCi/g. MDCs for soil samples in the area of the pedestal, the only non-structure measurements addressed herein, were less than 25 percent of the surface soil DCGL.

As noted in Table 5-2, alpha scan MDCs for Ludlum Model 43-89 detectors ranged from 51 to 83 dpm/100 cm^2, while the static measurement MDCs ranged from 69 to 94 dpm/100 cm^2. Ludlum Model 43-93 detectors were used solely for scan measurements and exhibited a scan MDC on the order of 100 dpm/100 cm^2. Alpha MDCs for all instruments were less than 10 percent of the applicable DCGL of 1,160 dpm/100 cm^2.

With respect to data for soil under the pedestal in Room 21, the reported radionuclide concentration reported by the Radioanalytical Laboratory was used in this FSSE. MDCs for each of the results for the 8 samples collected from soils under the pedestal in Room 21 were less than 25 percent of the surface soil screening level DCGL of 2.1 pCi/g for Am-241. As such, formal statistical tests were not required to confirm that these soils were compliant with the surface soil screening level DCGL.

8.0 DOSE ASSESSMENT

8.1 INTRODUCTION

The total dose associated with residual radioactivity at Southeast is the sum of the dose from residual activity on structures, from soils under the former location of the seismograph pedestal, and in soils adjacent to Magill Hall that were previously evaluated in the *Final Status Survey Evaluation For Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011). A dose assessment was performed to evaluate the dose resultant from residual radioactivity at Southeast. This assessment evaluated doses from both structures and surface soils under the pedestal in Room 21 of Magill Hall. The assessment addressed the time period from the present to 1,000 years post-remediation. Even using conservative input parameters, this dose assessment (See Appendix D) reflects a maximum TEDE to the average member of the critical group of less than 4 mrem/yr (or 16 percent) of the 25 mrem/yr dose standard prescribed by 10 *CFR* 20, Subpart E. Given a maximum dose of less than 4 mrem/yr, residual activity at Southeast is fully compliant with DCGLs, clearly achieves the 25 mrem/yr dose standard for unrestricted release prescribed in 10 *CFR* 20.1402, and, as demonstrated in the following section, is ALARA.

8.2 AS LOW AS REASONABLE ACHIEVABLE

NRC notes in NUREG-1757 that "In light of the conservatism in the building surface and surface soil generic screening levels developed by NRC, NRC staff presumes, absent information to the contrary, those licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA. In addition, if residual radioactivity cannot be detected, it may be assumed that it has been reduced to levels that are ALARA. Therefore, the licensee may not need to conduct an explicit analysis to meet the ALARA requirement" (NRC 2006). For Southeast, the NRC screening level DCGL of 2.1 pCi/g was used for surface soils. In addition, the very conservative standards prescribed by AEC Regulatory Guide 1.86 for Am-241 (i.e., residual gross alpha radioactivity limits of 20, 100, and 300 dpm/100 cm^2 for removable, total, and maximum total activity, respectively) were used for materials and equipment both prior to and after a ~~until the~~ site-specific structure DCGL of 1,160~~-~~ dpm/100 cm^2 of total alpha activity was approved by NRC in November 2006 for the surfaces of structures. ~~materials and equipment.~~ It is also notable that this DCGL was selected specifically to ensure compliance with ALARA standards, as noted in Appendix B of the November 2006 *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2006), which states that this DCGL was specifically selected to "ensure that the 25 mrem/yr dose criteria is satisfied and is ALARA." Further emphasis is placed on ensuring compliance with the ALARA principle by retaining the removable contamination limit of 20 dpm/100 cm^2 as an ALARA standard. In addition, notable for comparative purposes is the fact that a structure screening level DCGL of 400 dpm/100 cm^2 is developed by adjusting the value in NUREG-1757 with the NRC-authorized resuspension factor. As such, and given that the upper confidence level of the actual exposure point concentration (EPC) equates to only 37.5 dpm/100 cm^2, the EPC would equate to less than 10 percent of the adjusted surface activity screening level DCGL and would be compliant with the provisions of NUREG-1757, Appendix N, which states that "licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA." As such, residual radioactivity at Southeast is clearly compliant with ALARA.

8.3 RESIDUAL DOSE SUMMARY

The calculated maximum TEDE to the average member of the critical group TEDE from residual radioactivity at Southeast is the sum of the dose from structures, soils adjacent to Magill Hall, and soils present under the former seismograph pedestal area in Room 21 of Magill Hall. As noted in Appendix D, the maximum doses from residual activity in soils under the former pedestal location and on structures at Southeast are each less than 1 mrem/yr. In addition, Table 6-1 of the *Final Status Survey for Soils Adjacent to Magill Hall at Southeast Missouri State University* indicates that the maximum dose is 2 mrem/yr (SAIC 2011). As such, if an individual were present in each of these areas, the maximum dose would not exceed the sum of the individual potential doses or a total of 4 mrem/yr (or approximately 16 percent) of the 25 mrem/yr dose standard prescribed by 10 *CFR* 20, Subpart E (see Appendix D). In addition, all radiologically impacted areas of the university are fully compliant with the ALARA requirements of 10 *CFR* 20, Subpart E. As such, residual radioactivity achieves the standards of 10 *CFR* 20, Subpart E, for unrestricted release.

9.0 CONCLUSIONS

Evaluation of survey and sampling data contained in this document supports the conclusion that:

- Residual radioactivity in both soils and structures at Southeast are compliant with applicable criteria, (i.e., an Am-241 site-specific DCGL of 1,160 dpm/100 cm^2 for gross alpha activity present on structures and a surface soil screening level DCGL of 2.1 pCi/g). As noted previously, all structures survey measurements were compliant with DCGLs without necessity for implementing $DCGL_{EMC}$ approaches. In addition, soils under the pedestal in Magill Hall, the only soil area addressed in this report, did not exhibit detectable residual activity despite MDCs of less than 25 percent of surface soil screening level DCGL.
- Each SU was correctly classified consistent with MARSSIM recommendations;
- An adequate number of measurements were collected from each SU;
- The portions of each SU subjected to scan surveys were compliant with MARSSIM recommendations for the applicable survey class; and
- Statistical testing confirms that the H_0 (i.e., that the residual radioactivity exceeds the release criterion) is rejected for each SU.

Given the stated results and conclusions, all structures and soils at Southeast are compliant with DCGLs and associated dose requirements for unrestricted release, as stated in 10 *CFR* 20, Subpart E, such that Southeast NRC License 24-09296-02 should be amended to remove Am-241 and Am-241-impacted facilities.

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FIGURES

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Figure 1. Southeast Missouri State University Building Layout

Figure 2. Soil Areas Adjacent to Magill Hall

APPENDIX A

FINAL STATUS SURVEY RESULTS FOR STRUCTURES

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APPENDIX B

MINIMUM DETECTABLE CONCENTRATIONS

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APPENDIX C

INSTRUMENT CALIBRATION AND QUALITY ASSURANCE/QUALITY CONTROL DATA

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APPENDIX D

RESIDUAL DOSE ASSESSMENT

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D-1.0 RESIDUAL DOSE ASSESSMENT

D-1.1 PURPOSE

The purpose of this appendix is to provide the information used to calculate dose and to demonstrate that the total dose from residual Am-241 radioactivity at Southeast, inclusive of surface activity on structures and activity present in soils both outside Magill Hall and under the former seismograph pedestal in Room 21 of Magill Hall, is much less than 25 mrem/yr and is ALARA. As such, residual activity is compliant with "Radiological Criteria for Unrestricted Use" specified in 10 *CFR* 20.1402. Consistent with 10 *CFR* 20.1402, "A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem (0.25mSv) per year, including that from groundwater sources of drinking water, and that the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA)."

D-1.2 SCOPE

The dose derived and documented in this appendix is applicable to residual radioactivity contamination present on building surfaces and in soils under the pedestal in Room 21 in the basement of Magill Hall at Southeast. With the exception of soils under the ped estal in Room 21 of Magill Hall, residual radioactivity in surface soils at Southeast has been separately addressed by the *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011). As such, the scope of this assessment addresses structures and soils under the pedestal in Room 21.

D-1.3 BACKGROUND INFORMATION

Residual radioactivity on structure surfaces at Southeast was initially remediated pursuant to the criteria contained in AEC Regulatory Guide 1.86 pending NRC approval of a site-specific DCGL for Am-241 in November 2006. A site-specific DCGL for Am-241 was developed and incorporated into the November 2006 *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2006C), together with FSS procedures, and submitted to NRC Region III for approval. These assessments determined that the critical group consisted of Southeast employees working for 2,000 work hours per year in Magill Hall and initially calculated a conservative DCGL of 5,600 dpm/100 cm^2 using RESRAD Version 3.1. This DCGL was modified to 1,160 dpm/100 cm^2 total alpha activity in light of ALARA considerations, with the survey plan noting that this criterion represented "unrestricted use criteria for building surfaces, that if met will ensure that the 25 mrem/yr dose criteria is satisfied and is ALARA" (SAIC 2006c). This DCGL was subsequently approved by NRC on November 27, 2006, and was incorporated by reference into Amendment 12 of NRC License 24-09296-02. The DCGL continues to serve as ALARA compliant criterion for Am-241 and is only about a factor of three times the NRC screening level DCGL (i.e., 400 dpm/100 cm^2) developed using NRC defaults and the 1.0×10^{-6}/m resuspension factor recommended in NUREG-1720. In addition, given that the highest mean residual activity concentration of Am-241 among the three Southeast buildings is only 30 dpm/100 cm^2, the corresponding dose equates to only 1.9 mrem/yr, even using the cited NRC screening level DCGL of 400 dpm/100 cm^2. (Similarly, the dose corresponding to the 95 percent upper confidence level [UCL_{95}] of the mean is 37.5 dpm/100 cm^2. This equates to a

dose of approximately 2.3 mrem/yr or only 9.4 percent of the above-stated screening level DCGL of 400 dpm/100cm^2.) Further, with regard to the screening level DCGLs, NRC notes in Section 6.3 of NUREG-1757, Volume 2, Revision 1, that "In light of the conservatism in the building surface and surface soil generic screening levels developed by NRC staff, the NRC staff presumes, absent information to the contrary, that licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA. In addition, both the "Statements of Consideration" for Subpart E and the Final Generic Impact Statement (NUREG-1496) provide that an ALARA analysis for unrestricted release of soil need not be done" (NRC 2006).

D-1.4 DOSE ASSESSMENT SUMMARY

Dose assessment results are summarized in Sections D-1.4.1 and D-1.4.2 for surface soils under the pedestal in Room 21 of the Magill Hall basement and for structures in Magill, Rhodes, and Johnson Halls, respectively.

D-1.4.1 Dose Assessment for Soils under the Pedestal in Magill Hall Room 21

The *Final Status Survey Evaluation for Soils Adjacent to Magill Hall at Southeast Missouri State University* (SAIC 2011) calculated that 29 samples were required per soil SU at SEMO. The 29 samples calculated assumed a 2,000-m^2 SU; therefore, an average of 1 systematic sample was required to be collected for each 100 m^2 in a SU. Section 4.6 of MARSSIM states, "Special consideration may be necessary for survey units with structure areas less than 10 m^2 or land areas less than 100 m^2" (DOD 2000), and notes that data generated from these smaller SUs should be obtained based on judgment and compared individually to the DCGLs (DOD 2000). Because the area under the pedestal (defined as SU-~~93~~90) was only approximately 8 m^2 and no areas were detectable by scan surveys, it would be reasonable based on the previously mentioned guidance to collect only 1 sample from this area. Eight (8) systematic samples were collected.

Results for the 8 samples ranged from -0.04 to 0.36 pCi/g, with a mean of 0.08 ± 0.39 pCi/g and all results being less than their respective MDCs, which ranged from 0.10 to 0.47 pCi/g (see Appendix A, Attachment A-8, Table A8.9). All results were less than their MDCs, which were a maximum of 22 percent of the surface soil screening level DCGL of 2.1 pCi/g listed in Appendix H of NUREG-1757. As such, if residual activity were present at the respective MDC for each sample, the resultant concentration would equate to 0.22 pCi/g or 11 percent of the 25 mrem/yr dose standard. This equates to a residual dose of a maximum of 2.6 mrem/yr. Because the NRC's surface soil DCGL is derived based on an area of 2,400 m^2, and the area under the pedestal is only approximately 8 m^2, the actual residual dose is much less than 1 mrem/yr.

Dose assessments utilized RESRAD-BUILD Version 3.5 and UCL_{95} of the mean of residual FSS data together with input parameters subjected to NRC review and concurrence in the *Decontamination and Survey Plan for Magill and Rhodes Halls* (SAIC 2006c). Exceptions to the use of prior input parameters included the fraction of activity that is removable, which was taken as 10 percent consistent with NUREG-1757; increase of the source area from 9 m^2 to 132 m^2 to reflect the inclusion of all wall, floor, and ceiling surfaces; and setting the source lifetime at 1,825 days.

Two dose assessments were performed. In the "Release Criteria (DCGL) Assessment" in Section D1.5, the parameters used in the development of the DCGL were applied without modification. The "Site-Specific Assessment" in Section D1.6 incorporated the same parameters used in Section D1.5, except that the site-specific values cited in Section D1.4 above were applied (i.e.,

the site-specific values stated in the preceding paragraph were used in Section D1.6 for the "Source Removable Fraction," "Source Lifetime" and "Source Location/Area").

D-1.5 RELEASE CRITERIA (DCGL) ASSESSMENT

RESRAD-BUILD Version 3.3 was used to develop the surficial contamination release criteria of 1,160 dpm/100 cm^2. The RESRAD-BUILD input parameters were mostly default parameters, with the exception of indoor fraction, receptor location, and source location, type, and area. The source was limited to 9 m^2 (25 percent of the floor surface) and was located in the center of the room on the floor. The receptor was located 1 m above the center of the source. The source type was surficial (area) contamination. The indoor fraction (the fraction of the exposure duration spent by the receptor inside a building) was set at 0.23, which equates to the average amount of time the receptor would spend in the building during the 365-day exposure duration (i.e., 2,000 hours per year divided by 8,760 hours per year equals 0.23). As a conservative assumption, the source lifetime (the time over which the removable part of the source is linearly eroded) was reduced from 1,825 days in earlier dose assessments to 365 days, and the source removable fraction was set at 50 percent.

D-1.6 SITE-SPECIFIC ASSESSMENT

Based upon actual conditions at Southeast, the average removable fraction was determined to be less than 3 percent[1] and the source lifetime was greater than 5,000 days. (NOTE: The last Am-241 spill in Magill Hall occurred in 1997, 15 years prior to the FSS. During the FSS, approximately 3 percent of the contamination which remained was removable.) To be conservative, a source lifetime of 1,825 days (5 years) and a removable fraction of 10 percent were used for the dose assessment. Given that residual radioactivity is potentially present on the walls and ceilings, in addition to floor surfaces, the source location was modified from 9 m^2 on the floor to include the entire floor, ceiling, and all four walls contaminated uniformly. Additionally, average residual FSS alpha radioactivity varied in the four buildings where surveys were conducted. Therefore, the most conservative UCL_{95} of residual FSS data (i.e., the Magill Hall UCL_{95} of 37.5 dpm/100 cm^2) was used to represent each structure.

The average member of the critical group (AMCG) was determined to be a Southeast employee working 2,000 hours per year in Magill Hall (the impacted building with the highest residual activity). The dose to the AMCG using release criteria parameters and the modified parameters was < 1 mrem/yr in both cases. This demonstrates compliance with the 25 mrem/yr release criterion and would allow release of the building surfaces without institutional controls. The dose results are contained in Table D-1.

Table D-1. Dose Assessment Summary

Source Concentration	Dose (mrem/yr)	
	Release Criteria Parameters	Actual Conditions Parameters
AMCG	< 1	< 1
Dose Assessment Parameters		
Source Removable Fraction	50 percent	10 percent
Source Lifetime (days)	365	1,825

[1] The average total activity in Magill Hall was 29.8 dpm/100 cm^2. The average removable activity in Magill Hall was 0.62 dpm/100 cm^2. This calculates to an average removable fraction of less than 3 percent.

Source Location/Area	Floor / 9 m^2	Floor, ceiling, 4 walls / 132 m^2

D-2.0 DOSE SUMMARY

The TEDE from residual radioactivity at Southeast is the sum of the dose from structures, soils adjacent to Magill Hall, and soils present under the former seismograph pedestal area in Room 21 of Magill Hall. As noted in this appendix, the maximum doses from residual activity in soils under the former pedestal location and on structures at Southeast are each less than 1 mrem/yr. In addition, Table 6-1 of the *Final Status Survey for Soils Adjacent to Magill Hall at Southeast Missouri State University* indicates that the maximum dose is 2 mrem/yr (SAIC 2011). As such, if an individual were present in each of these areas, the maximum dose would not exceed the sum of the individual potential doses or a total of 4 mrem/yr and would be compliant with ALARA requirements.

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D-2.0 DOSE ASSESSMENT

D-2.1 DOSE ASSESSMENT OVERVIEW

The dose assessment presented in this report was conducted using RESRAD-BUILD Version 3.5. Site-specific parameters are used when available, or RESRAD defaults values are used when more appropriate parameters are not available. Non-default parameters include the indoor fraction; receptor location; and source location, type, area, removable fraction, and lifetime. Dose was modeled for the average member of the critical group based on exposure of university staff for a 2,000-hr working year. Table D-2 lists the RESRAD-BUILD input parameters.

Table D-2. RESRAD-BUILD Input Parameters

Scenario	Desk (Southeast Staff)	Comments
Time Parameters		
Exposure Duration	365 days	Default
Indoor Fraction	0.23	Based on 2,000 hr/year occupancy rate
Evaluation Time	1 year	Default
Building Parameters		
Number of Rooms	1	Default
Deposition Velocity	0.01 m/second	Default
Resuspension Rate	5.0 E-07 $second^{-1}$	Default
Building Exchange Rate	0.8 hr^{-1}	Default
Room Area	36 m^2	Actual Size of the Room
Room Height	2.5 m	Default
Room Exchange Rate	0.8 hr^{-1}	Default
In/Out Flow Rate	72 m^3/hr	Default
Receptor Parameters		
Number of Receptors	1	Default
Room # Location	1	Default
Time Fraction	1	Default
Breathing Rate	18 m^3/day	Default
Ingestion Rate	1 E-04 m^2/hr	Default
Receptor Location	3m, 3m, 1m	Middle of the room
Shielding Parameters		
Thickness	0	Default
Density	N/A	Default
Material	N/A	Default
Source Parameters		
Number of Sources	1	Default
Room # location	1	Default
Source Type	Area	Surface Contamination
Direction	Z, Z, X, Y, X, Y	Floor, Ceiling, Wall 1, Wall 2, Wall 3, Wall 4
Location	3m, 3m, 0m 3m, 3m, 2.5m 0m, 3m, 1.25m 3m, 6m, 1.25m 6m, 3m, 1.25m 3m, 0m, 1.25m	
Geometry: Area	9 m^2 (Floor) – Release Criteria	
	36 m^2 (Floor, ceiling)	

	15 m^2 (Walls) – Modified Criteria	

Table D-2. RESRAD-BUILD Input Parameters (Continued)

Scenario	Desk (Southeast Staff)	Comments
Air Fraction	0.1	Default
Direct Ingestion	0 g/hr	Default
Removal Fraction	0.5 / 0.1	Release Criteria/Modified
Lifetime	365 / 1,825 days	Release Criteria/Modified
Radionuclide	Am-241	
Radionuclides Concentration	1,688 pCi/m^2	Magill Hall UCL-95 Average

N/A – not applicable

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ATTACHMENT D-1

RESRAD-BUILD VERSION 3.5 SCENARIO OUTPUTS

Release Criteria Parameters – Output Report

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** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   1 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld


              ================================================
              ================================================
              ===                                          ===
              ===      RESRAD-BUILD Table of Contents      ===
              ===                                          ===
              ================================================
              ================================================



               RESRAD-BUILD Input Parameters............   2
               Building Information.....................   3
               Source Information.......................   4
               For time = 0.00E+00 yr
                  Time Specific Parameters..............   5
                  Receptor-Source Dose Summary..........   6
                  Dose by Pathway Detail................   7
                  Dose by Nuclide Detail................   8
               For time = 1.00E+00 yr
                  Time Specific Parameters..............   9
                  Receptor-Source Dose Summary..........  10
                  Dose by Pathway Detail................  11
                  Dose by Nuclide Detail................  12
               Full Summary............................  13
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   2 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld


              ================================================
              ================================================
              ===                                          ===
              ===      RESRAD-BUILD Input Parameters       ===
              ===                                          ===
              ================================================
              ================================================



                         Number of Sources  :   1
                         Number of Receptors:   1
                         Total Time         :  3.650000E+02 days
                         Fraction Inside    :  2.300000E-01



              ==========  Receptor Information  ==========

 Receptor     Room     x      y         z  FracTime Inhalation Ingestion(Dust)
                      [m]    [m]       [m]           [m3/day]     [m2/hr]
   1            1    3.000    3.000    1.000  1.000   1.80E+01    1.00E-04




              ===  Receptor-Source Shielding Relationship  ===


               Receptor  Source   Density  Thickness  Material
                                  [g/cm3]    [cm]
               ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                    1      1      2.40E+00  0.00E+00  Concrete
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   3 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld




             ========  Building Information  ========


       Building Air Exchange Rate: 8.00E-01 1/hr


    Height[m]         Air Exchanges [m3/hr]
    Area [m2]
                     ******************************
                     *                            *
                     *                            *
                     *                           <=Q01: 7.20E+01
    H1:   2.500      *           Room  1           *      Q10 :  7.20E+01
                     *   LAMBDA: 8.00E-01          *
   Area  36.000      *                            *
                     *                            *
                     ******************************


      Deposition velocity: 1.00E-02 [m/s]   Resuspension Rate: 5.00E-07 [1/s]
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   4 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld



              ========  Source Information  ========


 Source:  1
        Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00[m]
        Geometry::  Type: Area       Area:9.00E+00  [m2]  Direction: z
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       5.000E-01
             Time to Remove:           3.650E+02 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   5 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  0.00000000E+00  years


             ================================================
             ================================================
             ===       Assessment for Time:  1            ===
             ===             Time =0.00E+00 yr            ===
             ================================================
             ================================================


             ========  Source Information  ========


 Source:  1
        Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00 [m]
        Geometry::  Type: Area        Area:9.00E+00 [m2]  Direction: z
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       5.000E-01
             Time to Remove:           3.650E+02 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   6 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  0.00000000E+00  years


              ================================================
              ================================================
              ===                                          ===
              ===        RESRAD-BUILD Dose Tables          ===
              ===                                          ===
              ================================================
              ================================================



                   Source Contributions to Receptor Doses
                   ======================================
                                  [mrem]

                Source   Total
                   1
 Receptor  1    8.08E-01 8.08E-01
 Total          8.08E-01 8.08E-01
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   7 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  0.00000000E+00  years


                         Pathway Detail of Doses
                         =======================
                                 [mrem]

Source:  1
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       1.82E-04   6.22E-06   2.59E-08   7.90E-01   0.00E+00   1.73E-02
    Total      1.82E-04   6.22E-06   2.59E-08   7.90E-01   0.00E+00   1.73E-02
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   8 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  0.00000000E+00  years


                         Nuclide Detail of Doses
                         =======================
                                 [mrem]

Source:  1

  Nuclide  Receptor   Total
               1
  AM-241   8.08E-01  8.08E-01
  NP-237   1.56E-07  1.56E-07
  U-233    5.45E-14  5.45E-14
  TH-229   2.02E-17  2.02E-17
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:   9 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  1.00000000  years


              ================================================
              ================================================
              ===       Assessment for Time:  2            ===
              ===             Time =1.00E+00 yr            ===
              ================================================
              ================================================


              ========  Source Information  ========


 Source:  1
         Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00 [m]
         Geometry::  Type: Area        Area:9.00E+00 [m2]  Direction: z
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       0.000E+00
              Time to Remove:           3.650E+02 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      8.436E+02
                              NP-237      2.735E-04
                              U-233       5.963E-10
                              TH-229      1.877E-14
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:  10 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  1.00000000  years


              ================================================
              ================================================
              ===                                          ===
              ===        RESRAD-BUILD Dose Tables          ===
              ===                                          ===
              ================================================
              ================================================



                   Source Contributions to Receptor Doses
                   ======================================
                                  [mrem]

                Source   Total
                   1
 Receptor  1    1.21E-04 1.21E-04
 Total          1.21E-04 1.21E-04
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:  11 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  1.00000000  years


                         Pathway Detail of Doses
                         =======================
                                 [mrem]

Source:  1
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       1.21E-04   0.00E+00   0.00E+00   0.00E+00   0.00E+00   0.00E+00
    Total      1.21E-04   0.00E+00   0.00E+00   0.00E+00   0.00E+00   0.00E+00
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:  12 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Evaluation Time:  1.00000000  years


                         Nuclide Detail of Doses
                         =======================
                                 [mrem]

Source:  1

  Nuclide  Receptor   Total
                1
  AM-241   1.21E-04  1.21E-04
  NP-237   3.39E-10  3.39E-10
  U-233    7.82E-18  7.82E-18
  TH-229   8.24E-20  8.24E-20
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 10:05:38  Page:  13 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO DCGL Avg FSS Data.bld
 Full Summary


              ================================================
              ================================================
              ===                                          ===
              ===     RESRAD-BUILD Dose (Time) Tables      ===
              ===                                          ===
              ================================================
              ================================================



              Receptor Dose Received for the Exposure Duration
              ================================================
                                   (mrem)

                          Evaluation Time [yr]
      0.00E+00  1.00E+00
      ùùùùùùùùù  ùùùùùùùùù
 1    8.08E-01  1.21E-04


              Receptor Dose/Yr Averaged Over Exposure Duration
              ================================================
                                  (mrem/yr)

                          Evaluation Time [yr]
      0.00E+00  1.00E+00
      ùùùùùùùùù  ùùùùùùùùù
 1    8.08E-01  1.21E-04
```

Modified Parameters – Output Report

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   1 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld


              ================================================
              ================================================
              ===                                          ===
              ===      RESRAD-BUILD Table of Contents      ===
              ===                                          ===
              ================================================
              ================================================



               RESRAD-BUILD Input Parameters............   2
               Building Information.....................   3
               Source Information.......................   4
               For time = 0.00E+00 yr
                  Time Specific Parameters..............   7
                  Receptor-Source Dose Summary..........  10
                  Dose by Pathway Detail................  11
                  Dose by Nuclide Detail................  12
               For time = 1.00E+00 yr
                  Time Specific Parameters..............  14
                  Receptor-Source Dose Summary..........  17
                  Dose by Pathway Detail................  18
                  Dose by Nuclide Detail................  19
               Full Summary............................  21
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   2 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld


              ================================================
              ================================================
              ===                                          ===
              ===      RESRAD-BUILD Input Parameters       ===
              ===                                          ===
              ================================================
              ================================================



                         Number of Sources  :   6
                         Number of Receptors:   1
                         Total Time         :  3.650000E+02 days
                         Fraction Inside    :  2.300000E-01


              ==========  Receptor Information  ==========

 Receptor     Room     x       y         z  FracTime Inhalation Ingestion(Dust)
                      [m]     [m]       [m]           [m3/day]      [m2/hr]
   1            1    3.000    3.000    1.000  1.000    1.80E+01    1.00E-04



              ===  Receptor-Source Shielding Relationship  ===


               Receptor  Source   Density  Thickness  Material
                                  [g/cm3]     [cm]
               ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                    1      1      2.40E+00  0.00E+00  Concrete
                    1      2      2.40E+00  0.00E+00  Concrete
                    1      3      2.40E+00  0.00E+00  Concrete
                    1      4      2.40E+00  0.00E+00  Concrete
                    1      5      2.40E+00  0.00E+00  Concrete
                    1      6      2.40E+00  0.00E+00  Concrete
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   3 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld




             ========  Building Information  ========


       Building Air Exchange Rate: 8.00E-01 1/hr


    Height[m]         Air Exchanges [m3/hr]
    Area [m2]
                     ******************************
                     *                            *
                     *                            *
                     *                           <=Q01: 7.20E+01
    H1:   2.500      *           Room  1           *      Q10 :  7.20E+01
                     *   LAMBDA: 8.00E-01          *
   Area  36.000      *                            *
                     *                            *
                     ******************************


      Deposition velocity: 1.00E-02 [m/s]   Resuspension Rate: 5.00E-07 [1/s]
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   4 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld


             ========  Source Information  ========


 Source:  1
        Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00[m]
        Geometry::  Type: Area        Area:3.60E+01 [m2]  Direction: z
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03

 Source:  2
        Location::  Room :  1  x:   0.00 y:   3.00  z:   1.25[m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   5 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld


     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03

 Source:  3
         Location::  Room :  1  x:   3.00 y:   6.00  z:   1.25[m]
         Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: y
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03

 Source:  4
         Location::  Room :  1  x:   6.00 y:   3.00  z:   1.25[m]
         Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   6 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld


     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03

 Source:  5
         Location::  Room :  1  x:   3.00 y:   0.00  z:   1.25[m]
         Geometry::  Type: Area       Area:1.50E+01 [m2]  Direction: y
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03

 Source:  6
         Location::  Room :  1  x:   3.00 y:   3.00  z:   2.50[m]
         Geometry::  Type: Area       Area:3.60E+01 [m2]  Direction: z
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



    Contamination::
    Nuclide Concentration  Dose Conversion Factor (Library: FGR 11)
    ùùùùùùù ùùùùùùùùùùùùù  ùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùùù
                            Ingestion   Inhalation  Submersion
                [pCi/m2]    [mrem/pCi]  [mrem/pCi]  [mrem/yr/
                                                    (pCi/m3)]
     AM-241     1.690E+03   3.640E-03   4.440E-01   9.554E-05
     NP-237     0.000E+00   4.444E-03   5.400E-01   1.212E-03
     U-233      0.000E+00   2.890E-04   1.350E-01   1.904E-06
     TH-229     0.000E+00   4.027E-03   2.169E+00   1.741E-03
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   7 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years


              ================================================
              ================================================
              ===       Assessment for Time:  1            ===
              ===             Time =0.00E+00 yr            ===
              ================================================
              ================================================


              ========  Source Information  ========


 Source:  1
         Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00 [m]
         Geometry::  Type: Area        Area:3.60E+01 [m2]  Direction: z
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00

 Source:  2
         Location::  Room :  1  x:   0.00 y:   3.00  z:   1.25 [m]
         Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       1.000E-01
              Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   8 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years



 Source:  3
        Location::  Room :  1  x:   3.00 y:   6.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00

 Source:  4
        Location::  Room :  1  x:   6.00 y:   3.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:   9 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years



 Source:  5
        Location::  Room :  1  x:   3.00 y:   0.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00

 Source:  6
        Location::  Room :  1  x:   3.00 y:   3.00  z:   2.50 [m]
        Geometry::  Type: Area        Area:3.60E+01 [m2]  Direction: z
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       1.000E-01
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.690E+03
                              NP-237      0.000E+00
                              U-233       0.000E+00
                              TH-229      0.000E+00
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  10 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years


              ================================================
              ================================================
              ===                                          ===
              ===        RESRAD-BUILD Dose Tables          ===
              ===                                          ===
              ================================================
              ================================================



                   Source Contributions to Receptor Doses
                   ======================================
                                   [mrem]

                Source   Source   Source   Source   Source   Source   Total
                   1        2        3        4        5        6
 Receptor  1    1.32E-01 5.50E-02 5.50E-02 5.50E-02 5.50E-02 1.32E-01 4.85E-01
 Total          1.32E-01 5.50E-02 5.50E-02 5.50E-02 5.50E-02 1.32E-01 4.85E-01
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  11 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years


                         Pathway Detail of Doses
                         =======================
                                 [mrem]

Source:  1
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       4.42E-04   1.02E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
    Total      4.42E-04   1.02E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03


Source:  2
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03
    Total      7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03


Source:  3
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03
    Total      7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03


Source:  4
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03
    Total      7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03


Source:  5
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03
    Total      7.30E-05   4.23E-07   1.76E-09   5.38E-02   0.00E+00   1.18E-03


Source:  6
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       3.15E-04   1.02E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
    Total      3.15E-04   1.02E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  12 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years


                         Nuclide Detail of Doses
                         =======================
                                 [mrem]

Source:  1

  Nuclide  Receptor   Total
               1
  AM-241   1.32E-01  1.32E-01
  NP-237   2.64E-08  2.64E-08
  U-233    9.31E-15  9.31E-15
  TH-229   3.54E-18  3.54E-18


Source:  2

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   1.09E-08  1.09E-08
  U-233    3.88E-15  3.88E-15
  TH-229   1.47E-18  1.47E-18


Source:  3

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   1.09E-08  1.09E-08
  U-233    3.88E-15  3.88E-15
  TH-229   1.47E-18  1.47E-18


Source:  4

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  13 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  0.00000000E+00  years


  NP-237   1.09E-08  1.09E-08
  U-233    3.88E-15  3.88E-15
  TH-229   1.47E-18  1.47E-18



Source:  5

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   1.09E-08  1.09E-08
  U-233    3.88E-15  3.88E-15
  TH-229   1.47E-18  1.47E-18



Source:  6

  Nuclide  Receptor   Total
               1
  AM-241   1.32E-01  1.32E-01
  NP-237   2.63E-08  2.63E-08
  U-233    9.30E-15  9.30E-15
  TH-229   3.54E-18  3.54E-18
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  14 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years


              ================================================
              ================================================
              ===       Assessment for Time:  2            ===
              ===             Time =1.00E+00 yr            ===
              ================================================
              ================================================


              ========  Source Information  ========


 Source:  1
         Location::  Room :  1  x:   3.00 y:   3.00  z:   0.00 [m]
         Geometry::  Type: Area        Area:3.60E+01 [m2]  Direction: z
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       8.162E-02
              Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14

 Source:  2
         Location::  Room :  1  x:   0.00 y:   3.00  z:   1.25 [m]
         Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
         Pathway ::
              Direct Ingestion Rate:    0.000E+00 [1/hr]
              Fraction released to air: 1.000E-01
              Removable fraction:       8.162E-02
              Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  15 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years



 Source:  3
        Location::  Room :  1  x:   3.00 y:   6.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       8.162E-02
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14

 Source:  4
        Location::  Room :  1  x:   6.00 y:   3.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       8.162E-02
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  16 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years



 Source:  5
        Location::  Room :  1  x:   3.00 y:   0.00  z:   1.25 [m]
        Geometry::  Type: Area        Area:1.50E+01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       8.162E-02
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14

 Source:  6
        Location::  Room :  1  x:   3.00 y:   3.00  z:   2.50 [m]
        Geometry::  Type: Area        Area:3.60E+01 [m2]  Direction: z
        Pathway ::
             Direct Ingestion Rate:    0.000E+00 [1/hr]
             Fraction released to air: 1.000E-01
             Removable fraction:       8.162E-02
             Time to Remove:           1.825E+03 [day]



          Contamination::     Nuclide    Concentration
                                           [pCi/m2]
                              AM-241      1.654E+03
                              NP-237      5.360E-04
                              U-233       1.169E-09
                              TH-229      3.679E-14
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  17 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years


              ================================================
              ================================================
              ===                                          ===
              ===        RESRAD-BUILD Dose Tables          ===
              ===                                          ===
              ================================================
              ================================================



                   Source Contributions to Receptor Doses
                   ======================================
                                   [mrem]

                Source   Source   Source   Source   Source   Source   Total
                   1        2        3        4        5        6
 Receptor  1    1.32E-01 5.50E-02 5.50E-02 5.50E-02 5.50E-02 1.32E-01 4.84E-01
 Total          1.32E-01 5.50E-02 5.50E-02 5.50E-02 5.50E-02 1.32E-01 4.84E-01
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  18 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years


                         Pathway Detail of Doses
                         =======================
                                 [mrem]

Source:  1
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       4.32E-04   1.01E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
    Total      4.32E-04   1.01E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03


Source:  2
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03
    Total      7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03


Source:  3
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03
    Total      7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03


Source:  4
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03
    Total      7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03


Source:  5
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03
    Total      7.14E-05   4.23E-07   1.76E-09   5.37E-02   0.00E+00   1.17E-03


Source:  6
    Receptor   External   Deposition Immersion  Inhalation   Radon    Ingestion
       1       3.08E-04   1.01E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
    Total      3.08E-04   1.01E-06   4.23E-09   1.29E-01   0.00E+00   2.82E-03
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  19 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years


                         Nuclide Detail of Doses
                         =======================
                                 [mrem]

Source:  1

  Nuclide  Receptor   Total
               1
  AM-241   1.32E-01  1.32E-01
  NP-237   7.93E-08  7.93E-08
  U-233    6.52E-14  6.52E-14
  TH-229   5.32E-17  5.32E-17


Source:  2

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   3.27E-08  3.27E-08
  U-233    2.71E-14  2.71E-14
  TH-229   2.21E-17  2.21E-17


Source:  3

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   3.27E-08  3.27E-08
  U-233    2.71E-14  2.71E-14
  TH-229   2.21E-17  2.21E-17


Source:  4

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  20 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Evaluation Time:  1.00000000  years


  NP-237   3.27E-08  3.27E-08
  U-233    2.71E-14  2.71E-14
  TH-229   2.21E-17  2.21E-17



Source:  5

  Nuclide  Receptor   Total
               1
  AM-241   5.50E-02  5.50E-02
  NP-237   3.27E-08  3.27E-08
  U-233    2.71E-14  2.71E-14
  TH-229   2.21E-17  2.21E-17



Source:  6

  Nuclide  Receptor   Total
               1
  AM-241   1.32E-01  1.32E-01
  NP-237   7.89E-08  7.89E-08
  U-233    6.51E-14  6.51E-14
  TH-229   5.31E-17  5.31E-17
```

```
** RESRAD-BUILD Dose Program Output, Version 3.50 12/07/12 11:09:45  Page:  21 **
 Title : SEMO DCGL - FSS Average Data
 Input File : C:\RESRAD_Family\BUILD\SEMO Actual Avg FSS Data 10 pct.bld
 Full Summary


              ================================================
              ================================================
              ===                                          ===
              ===     RESRAD-BUILD Dose (Time) Tables      ===
              ===                                          ===
              ================================================
              ================================================



              Receptor Dose Received for the Exposure Duration
              ================================================
                                   (mrem)

                          Evaluation Time [yr]
      0.00E+00  1.00E+00
      ùùùùùùùùù  ùùùùùùùùù
 1    4.85E-01  4.84E-01


              Receptor Dose/Yr Averaged Over Exposure Duration
              ================================================
                                  (mrem/yr)

                          Evaluation Time [yr]
      0.00E+00  1.00E+00
      ùùùùùùùùù  ùùùùùùùùù
 1    4.85E-01  4.84E-01
```

APPENDIX E

FIELD HEALTH PHYSICS NOTEBOOK

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