BARTLETT

ENGINEERING CALCULATION

Calculation Number: ENG-001

Revision Number: 2

Calculation Title: Sensitivity Analyses to Support EF1 Building Surface DCGLs

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1.0 PURPOSE

The purpose of this calculation is to determine which of the input parameters for the building occupancy scenario have a significant impact on the calculated dose (i.e., those parameters whose values greatly influence the calculated dose; aka, "sensitive" input parameters). The results of this calculation will support the development of building surface derived concentration guideline levels (DCGLs) for the Detroit Edison Company's (DTE) Enrico Fermi (EF) 1 nuclear power site, located in Newport, Michigan. This calculation is a deliverable product specified in the scope of work section in Contract No. 4400001090.

Revision 2 of this calculation corrects typographical errors in Table 1.

2.0 APPLICABILITY

This calculation addresses only the sensitivity analysis for input parameters for the building occupancy scenario as defined for the DTE EF 1 site.

3.0 REFERENCES

3.1 Procedure ENG-AP-02, *Verification of Software Operability*

3.2 *User's Manual for RESRAD-Build Version 3.0*, June 2003 (ANL/EAD/03-1)

3.3 NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning*

- Volume 1: *Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*, Oct. 1992 (PNL-7994)
- Volume 3: *Parameter Analysis, Draft Report for Comment*, Oct. 1999 (SAND99-2148)

3.4 NUREG/CR-6697, *Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*, Nov. 2000 (ANL/EAD/TM-98)

3.5 NUREG/CR-6755, *Technical Basis for Calculating Radiation Doses for the Building Occupancy Scenario Using the Probabilistic RESRAD-Build 3.0 Code*, Feb. 2002 (ANL/EAD/TM/02-1)

3.6 NUREG-1727, *NMSS Decommissioning Standard Review Plan*, Sept. 2000

3.7 NUREG/CR-6676, *Probabilistic Dose Analysis Using Parameter Distributions Developed for RESRAD and RESRAD-Build Codes*, May 2000 (ANL/EAD/TM-89)

3.8 NUREG/CR-6692, *Probabilistic Modules for the RESRAD and RESRAD-Build Computer Codes*, Nov. 2000 (ANL/EAD/TM-91)

3.9 Federal Guidance Report (FGR) 11, *Limiting Values of Radionuclide Intake and Air Concentrations and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA, 1988

3.10 Federal Guidance Report (FGR) 12, *External Exposure to Radionuclides in Air, Water, and Soil*, EPA, 1993

4.0 METHOD OF CALCULATION

The operability of the RESRAD-Build code was verified on each computer use for code executions in accordance with the Bartlett Engineering procedure ENG-AP-02, Verification of Software Operability [ref. 3.1]. The RESRAD-Build user's manual [ref. 3.2] provided guidance for code operation.

The sensitivity analyses for the building scenario input parameters was performed using Version 3.4 of the RESRAD-Build computer code, which was developed by Argonne National Laboratory under the sponsorship of the U.S. Department of Energy and other federal agencies. The code requires input for numerous parameters in order to calculate the dose via various exposure pathways to a hypothetical individual working in a building contaminated with radioactive material. The probabilistic modules in RESRAD-Build permit the user to perform a sensitivity analysis to identify those parameters that have the greatest impact on dose. In addition, the probabilistic modules allow the evaluation of dose as a function of parameter distributions. Verification of the RESRAD-Build code is documented in the RESRAD-Build user's manual [ref. 3.2] and testing for the probabilistic codes is discussed in NUREG/CR-6697 [ref. 3.4].

The RESRAD-Build computer code is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who works in a building contaminated with radioactive material. The exposure scenario modeled in this calculation is the building occupancy scenario, which provides estimates of human radiation exposures to residual radioactivity on surfaces inside standing buildings and permits the determination of DCGLs for building surfaces. The exposure pathways considered are (i) direct external exposure from the source (i.e., radioactive material deposited on the floor, walls, and ceiling), (ii) external exposure from deposited material, (iii) external exposure due to air submersion, (iv) exposure due to inhalation of airborne radioactive material, (v) ingestion of radioactive material directly from the sources and material deposited on the surfaces.

The approach taken in this calculation consists of two primary phases: the selection of input parameter values and performing RESRAD-Build runs. The first phase involves classifying and prioritizing the RESRAD-Build input parameters. The selection process is based on guidance provided in NUREG/CR-6676 [ref 3.7], NUREG/CR-6697 [ref. 3.4], NUREG/CR-6692 [ref. 3.8], and NUREG/CR-6755 [ref. 3.5]. Figure 1 provides a flow diagram for the parameter selection process.

Classification, prioritization, and treatment of input parameters: Parameters were classified as behavioral, metabolic, or physical parameters consistent to the classifications found in NUREG/CR-6697 [ref. 3.4]. Behavioral parameters depend on the behavior of the receptor and the scenario definition. Metabolic parameters are independent of the defined scenario, and represent the metabolic characteristics of the receptor. Physical parameters are those parameters that would not change if the receptor changed.

Following the classification process, parameters were assigned priority rankings. Priority 1 parameters are high priority; Priority 2 parameters are medium priority; and Priority 3 parameters are low priority. NUREG/CR-6697 [ref. 3.4] provides prioritization rankings for input parameters. Those rankings were adopted in this calculation. The priority of a given parameter is based on:

- the relevance of the parameter in dose calculations,
- the variability of the dose because of changes in the parameter value,
- the parameter type, and
- the availability of parameter-specific data.

Input parameters were treated as either deterministic (a single value is assigned) or stochastic (a probability distribution is assigned). Treatment depended on parameter type, availability of site-specific data, and the relevance of the parameter in the dose calculations.

- Behavioral and metabolic parameters were treated as deterministic and the assigned values were from NUREG/CR05512, volume 3 [ref. 3.3], NUREG/CR-6697 [ref. 3.4], NUREG/CR-6755 [ref. 3.5], or the RESRAD-Build default library. Parameters for which site-specific data are available were treated as deterministic.
- Physical parameters for which site-specific data are unavailable were assigned values based on priority. Priority 1 and 2 physical parameters were treated stochastic and assigned probability distributions from NREG/CR-5512, volume 3 [ref. 3.3], NUREG/CR-6697 [ref. 3.4], NUREG/CR-6755 [ref. 3.5], or assigned a deterministic value from NUREG/CR-5512, volume 3 [ref. 3.3], NUREG/CR-6697 [ref.3.4], or NUREG/CR-6755 [ref. 3.5]. Priority 3 physical parameters were treated as deterministic and were assigned values from NUREG/CR-5512, volume 3 [ref. 3.3], NUREG/CR-6697 [ref.3.4], NUREG/CR-6755 [ref. 3.5], or the RESRAD-Build default library.

Following the parameter selection process, RESRAD-Build input files were developed based on the results of the parameter selection process and a parameter sensitivity analysis was performed for each radionuclide of concern. Input correlations were applied based on guidance in NUREG/CR-6676 [ref. 3.7].

The RESRAD-Build Probabilistic Output Report provides regression and correlation coefficients for the average doses at the user defined evaluation times. The Partial Rank Correlation Coefficient (PRCC) has been used to identify sensitive parameters with the limit set at 0.1. NUREG/CR-6692 [ref. 3.8] and NUREG/CR-6697 [ref. 3.4] recommend the use of the PRCC for cases where a non-linear relationship and widely disparate scales exists between the input and output. The guidance further recommends the use of the PRCC if strong correlations exist between input parameters. The criterion for sensitivity used in this calculation was a PRCC value with an absolute value greater than 0.1. In addition, PRCC values that are greater than zero (positive value) or less than zero (negative value) identify whether sensitive parameters are positively or negatively correlated to dose, respectively. Therefore, 75^{th} values were determined for sensitive parameters that had positive PRCC values and 25^{th} values were determined for sensitive parameters that had negative PRCC values. These 25^{th} and 75^{th} percentile values are proposed as reasonably conservative input for the DCGL calculation for the EF1 site.

The 25^{th} and 75^{th} percentile values were obtained using the following method:

1. Open the RESRAD-Build "*.buo" file generated during from the sensitivity run using the "View Interactive Output" button on the RESRAD-Build navigator.
2. Click the "Results" tab in the interactive output window.
3. Click on the "Graphics" tab.

4. Select "input vector" by scrolling through the choices under the "Primary Object" prompt.
5. Select the desired parameter by scrolling through the choices under the "Input Parameter" prompt.
6. Right click on the cumulative probability graph and select "Edit Chart Data."
7. Scroll down until the desired fraction (i.e., 0.25 or 0.75) is visible in column C2. The corresponding value in column C1 is the percentile value.

5.0 ASSUMPTIONS AND INPUT

5.1 Assumptions

Building Scenario description: The RESRAD-Build code v3.4 was used to model (through use of input parameter values) the building occupancy scenario defined in NUREG/CR-5512, volume 1 [ref. 3.5]. Modeling of this scenario provides an estimate of human radiation exposure to residual radioactivity on surfaces inside standing buildings and permits the determination of DCGLs for building surfaces. Five exposure pathways are assumed active: (i) direct external exposure from the source (i.e., radioactive material deposited on the floor, walls, and ceiling), (ii) external exposure from deposited material, (iii) external exposure due to air submersion, (iv) exposure due to inhalation of airborne radioactive material, (v) ingestion of radioactive material directly from the sources and material deposited on the surfaces.

Twenty-five client-identified radionuclides are assumed as radionuclides-of-concern for the Fermi 1 site: Ag-108m, Am241, C-14, Co-60, Cm-242, Cm-243, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Fe-55, H-3, Mn-54, Na-22, Nb-94, Ni-59, Ni-63, Pu-238, Pu239, Pu-240, Pu-241, Sb-125, Sr-90, and Tc-99.

The hypothetical worker is assumed to perform activities inside the building for a full occupational year.

Figure 2 provides an illustration of the representative room for the EF1 site (dimensions provided by DTE). For modeling purposes, a rectangular room (39 ft, 2 in by 86 ft, 10 in) with 12-ft walls was assumed. This modeled room included 6 area sources (i.e. floor, 4 walls, and ceiling).

5.2 Input

Table 1 summarizes the classification, prioritization, values and their bases for all input parameter.

Values from NUREG/CR-5512, volume 3 [ref. 3.3], NUEG/CR-6697 [ref. 3.4], NUREG/CR-6755 [ref. 3.5], or NUREG-1727 [ref.3.6] were assigned for the following scenario-defined parameters:

- Exposure duration: 365.25 d
- Indoor fraction: 0.267 (= 97.5 work d/y divided by 365.25 d/y)
- Inhalation rate: 33.6 m^3/d (=1.4 m^3/h * 24 h/d)
- Receptor location (center of room): 5.97m, 13.23m, 1.0m
- Air exchange rate for room: 1.52 per h

- Indirect ingestion rate: 1.1E-04 m^2/h
- Air fraction: 0.07 for all nuclides except H-3; 1.0 for H-3
- Removable fraction: 0.1

Site-specific information (i.e., room dimensions) was used as the basis in calculations (see section 6.0) of values for the following parameters:

- Room area
- Room height
- Receptor location
- Location of center of source
- Source length
- Source area

Statistical distributions from NUREG/CR-6755 [ref. 3.5] provided input for:

- deposition velocity,
- resuspension rate, and
- time for source removal.

An input correlation of 0.9 between the deposition velocity and the resuspension rate was applied based on guidance in NUREG/CR-6676 [ref. 3.7]. In addition, because the sources are assumed constructed of the same material and subject to the same environment, an input correlation of 0.9 was applied for the time for source removal between sources.

6.0 CALCULATIONS AND RESULTS

6.1 Room dimensions: EF1 staff provided dimensions of a representative room, shown in Figure 2. Table 2 shows the unit conversion for the room dimensions and the area associated with each source (i.e., floor, walls, and ceiling).

6.2 Direct ingestion rate (h^{-1}) is calculated from the indirect ingestion rate from NUREG/CR-6755 [ref. 3.5], 1.1E-04 m^2/h, and the total source area, 912.88 m^2, as follows:

$$(1.1E\text{-}04\ m^2/h)/(912.88\ m^2) = 1.2E\text{-}07\ h^{-1}$$

6.3 Using the dimensions for the east and south walls (86 ft, 10 in and 39 ft, 2 in, respectively) and a wall height of 12 ft (see Figure 2), the locations of the centers of the sources were determined as the mid-point on the X, Y, and Z-axes. Table 3 presents the locations for the center of the sources.

6.4 RESRAD-Build v3.4 results: Table 1 summarizes the input used in each RESRAD-Build code execution.

6.4.1 Each of the radionuclides listed in section 5.1 was evaluated in separate code executions.

6.4.2 Use of an evaluation time (t) of 1y produces dose results for t = 0y and t = 1y. For all radionuclides, t = 0y was the time of maximum dose, as demonstrated by lower doses at t = 1y. For some radionuclides, several evaluation times were included in the code runs to confirm the decreasing dose pattern indicated by the t = 0y and t = 1y doses. Table 4 shows the maximum doses calculated at various times.

6.5 PRCC values were reviewed against the sensitivity criterion (i.e., $|PRCC| > 0.1$). For each of the 25 radionuclides, deposition velocity, the resuspension rate, and the time for source removal were identified as sensitive input parameters. Table 5 summarizes the sensitive parameters by radionuclide.

6.6 The 25th and 75th percentile values for sensitive input parameters were obtained through use of the interactive output in the RESRAD-Build code. Table 6 presents these values.

6.6.1 A comparison of the 25th and 75th percentiles values obtained from the RESRAD-Build code to the distributions given in NUREG/CR-6697 [ref. 3.4] indicates that the 25th and 75th percentile values are reasonably conservative. Table 6 includes this comparison.

7.0 CONCLUSION

7.1 Deposition velocity, resuspension rate, and time for source removal are sensitive input parameters to the building occupancy scenario for each of the 25 radionuclides of concern.

7.2 The 25th and 75th percentile values for sensitive input parameters have been determined from the parameter distributions and found to be reasonably conservative when compared with the distributions from NUREG/CR-6697 [ref. 3.4].

7.3 The 25th and 75th percentile values for sensitive input parameters are recommended for use as input for building surfaces DCGLs for the EF1 site.

Table 1
Input Parameter Values for Sensitivity Analysis

Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Exposure Duration (d)	B	3	D	365.25	NUREG/CR-5512, Vol.3,section 5.2.1	NR[e]	NR	NR	NR
Indoor Fraction	B	2	D	0.267	NUREG/CR-5512, Vol.3,section 5.2.2.9	NR	NR	NR	NR
Evaluation Time (y)	P	3	D	1 or multiple (e.g., 1,10, 50, 100)	T=1 corresponds to dose over the 1st year	NR	NR	NR	NR
Number of Rooms	P	3	D	1	NUREG/CR-5512	NR	NR	NR	NR
Deposition Velocity (m/s)	P	2	S	Loguniform	NUREG/CR-6755, Section 3.3; NUREG/CR-6697, Att.C, section 7.5	2.70E-06	2.70E-03	-	-
Resuspension Rate (s^{-1})	P	1	S	Loguniform	NUREG/CR-6755, Section 3.1; NUREG/CR-6697, Att.C, section 7.2	2.5E-11	1.35E-5	-	-
Air Exchange Rate for Room (h^{-1})	B	2	D	1.52	NUREG/CR-6697, Att. C, section 7.4 and NUREG/CR-6755, section 3.2	NR	NR	NR	NR
Room Area (m^2)	P	2	D	315.97	Site-specific data	NR	NR	NR	NR
Room Height (m)	P	2	D	3.66	Site-specific data	NR	NR	NR	NR
Time Fraction	B	3	D	1	NUREG/CR-5512	NR	NR	NR	NR
Inhalation Rate (m^3/d)	M	2	D	33.6	NUREG/CR-6697; NUREG/CR-5512, vol. 3, section 5.3.4	NR	NR	NR	NR
Indirect Ingestion Rate (m^2/h)	B	2	D	0.00011	NUREG/CR6755, A.3.3, Table A.12	NR	NR	NR	NR
Receptor Location	B	3	D	5.97, 13.23, 1	NUREG/CR-5512; center of room based on site-specific room dimensions	NR	NR	NR	NR
Shielding Thickness (cm)	P	2	D	0	Site-specific model-no shielding assumed	NR	NR	NR	NR

Table 1
Input Parameter Values for Sensitivity Analysis

Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Shielding Density (g/cm^3)	P	1	D	0	Site-specific model-no shielding assumed	NR	NR	NR	NR
Shielding Material	P	3	D	None	Site-specific model-no shielding assumed	NR	NR	NR	NR
Number of Sources	P	3	D	6	Site-specific modeling (includes floor, 4 walls, plus ceiling)				
External Dose Conversion Factor, (mrem/y per pCi/cm^2)	M	3	D	RESRAD-Build default	FGR12				
Air Submersion Dose Conversion Factor, (mrem/y per pCi/m^3)	M	3	D	RESRAD-Build default	FGR12				
Inhalation Dose Conversion Factor, (mrem/pCi)	M	3	D	RESRAD-Build default	FGR11				
Ingestionl Dose Conversion Factor, (mrem/pCi)	M	3	D	RESRAD-Build default	FGR11				
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Z	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	5.97, 13.23, 0	Site-Specific Modeling				
Source length X-axis (m)	P	2	D	11.94	Site-Specific Modeling				
Source length Y-axis (m)	P	2	D	26.47	Site-Specific Modeling				
Area (m^2)	P	2	D	315.97	Site-Specific Modeling				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-

Table 1
Input Parameter Values for Sensitivity Analysis

Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Type	P	3	D	Area	NUREG/CR-5512				
Direction	P	3	D	Y	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	5.97, 26.47, 1.83	Site-Specific Modeling				
Source length X-axis (m)	P	2	D	11.94	Site-Specific Modeling				
Source length Z-axis (m)	P	2	D	3.66	Site-Specific Modeling				
Area (m^2)	P	2	D	43.67	Site-Specific Modeling				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C, Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C, Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Type	P	3	D	Area	NUREG/CR-5512				
Direction	P	3	D	X	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	11.94, 13.23, 1.83	Site-Specific Modeling				
Source length Y-axis (m)	P	2	D	26.47	Site-Specific Modeling				
Source length Z-axis (m)	P	2	D	3.66	Site-Specific Modeling				
Area (m^2)	P	2	D	96.81	Site-Specific Modeling				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				

Table 1
Input Parameter Values for Sensitivity Analysis

Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Y	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	5.97, 0, 1.83	Site-Specific Modeling				
Source length X-axis (m)	P	2	D	11.94	Site-Specific Modeling				
Source length Z-axis (m)	P	2	D	3.66	Site-Specific Modeling				
Area (m^2)	P	2	D	43.67	Site-Specific Modeling				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	X	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	0, 13.23, 1.83	Site-Specific Modeling				
Source length Y-axis (m)	P	2	D	26.47	Site-Specific Modeling				
Source length Z-axis (m)	P	2	D	3.66	Site-Specific Modeling				
Area (m^2)	P	2	D	96.81	Site-Specific Modeling				

Table 1
Input Parameter Values for Sensitivity Analysis

Parameter	Type[a]	Priority[b]	Treat-ment[c]	Value or Distribution	Value/Distribution Reference Source	Distribution's Statistical Parameters[d]			
						1	2	3	4
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-
Type	P	3	D	area	NUREG/CR-5512				
Direction	P	3	D	Z	NUREG/CR-5512				
Location of Center of Source: x,y,z (m)	P	3	D	5.97, 13.23, 3.66	Site-Specific Modeling				
Source length X-axis (m)	P	2	D	11.94	Site-Specific Modeling				
Source length Y-axis (m)	P	2	D	26.47	Site-Specific Modeling				
Area (m^2)	P	2	D	315.97	Site-Specific Modeling				
Air Fraction for H-3	B	2	D	1.0	NUREG/CR-6697, Att. C Section 8.6				
Air Fraction (all nuclides other than H-3)	B	2	D	0.07	NUREG/CR-6697, Att. C Section 8.6				
Direct Ingestion (h^{-1})	B	2	D	1.2E-7	NUREG/CR6755, A.3.3				
Removable Fraction	P	1	D	0.1	NUREG-1727, Table C.7.1; NUREG/CR-6755, section 3.5				
Time for Source Removal (d)	P	2	S	Triangular	NUREG/CR-6755, Section 3.6; NUREG/CR-6697, Att.C, 8.8	1,000	100,000	10,000	-
Radionuclide Concentration (pCi/m^2)	P	2	D	1.0	-	-	-	-	-

Table 1 notes:

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
[c] D = deterministic, S = stochastic
[d] Distribution Statistical Parameters:
Loguniform: 1= minimum, 2 = maximum
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
[e] NR = none recommended

Additional Sensitivity Analysis Data:
Random Seed = 1000
Number of observations = 300
Number of repetitions = 1

Input Rank Correlation Coefficients:
Resuspension Rate and Deposition Velocity = 0.9
Time for source removal (correlation set between sources) = 0.9

Table 2: Representative Room Dimensions

Source No.	Description	Recorded Dimension[a]	ft	m[b]	m^2
1	floor				315.97
2	north wall	39' 2"	39.17	11.94	43.67
3	east wall	86' 10"	86.83	26.47	96.81
4	south wall	39' 2"	39.17	11.94	43.67
5	west wall	86' 10"	86.83	26.47	96.81
6	ceiling				315.97
	wall height	12'	12.00	3.66	
				total room area:	912.88

[a] Recorded dimensions for east and south walls of representative room (see Figure 2).
[b] Feet to meter conversion factor: 1ft = 0.3048m.

Table 3: Location of Center of Sources

Source No.	Source Description	Location of Center of Source (m) X-axis	Y-axis	Z-axis
1	floor	5.97	13.23	0.00
2	north wall	5.97	26.47	1.83
3	east wall	11.94	13.23	1.83
4	south wall	5.97	0.00	1.83
5	west wall	0.00	13.23	1.83
6	ceiling	5.97	13.23	3.66

Table 4: Maximum Dose At Evaluation Times

Nuclide	RESRAD-Build File Name	Maximum dose (mrem) at evaluation time: 0y	1y	10y	50y	100y	200y
Ag-108m	RESBMC_Ag108m SA	**1.97E-05**	1.95E-05	1.85E-05	1.65E-05	1.09E-05	6.05E-06
Am-241	RESBMC_Am241 SA	**1.70E-04**	1.57E-04	9.12E-05	7.21E-05	5.11E-05	1.71E-05
C-14	RESBMC_C14 SA	**5.96E-08**	5.44E-08	5.19E-08	4.33E-08	3.27E-08	1.20E-08
Cm-242	RESBMC_Cm242 SA	**3.04E-06**	5.99E-07	2.64E-13	---	0.00E+00	---
Cm-243	RESBMC_Cm243 SA	**1.18E-04**	1.07E-04	5.14E-05	---	3.85E-06	---
Co-60	RESBMC_Co60 SA	**5.18E-05**	4.54E-05	---	---	---	---
Cs-134	RESBMC_Cs134 SA	**3.19E-05**	2.28E-05	---	---	---	---
Cs-137	RESBMC_Cs137 SA	**1.42E-05**	1.38E-05	1.12E-05	4.30E-06	1.31E-06	---
Eu-152	RESBMC_Eu152 SA	**2.58E-05**	2.45E-05	---	---	---	---
Eu-154	RESBMC_Eu154 SA	**2.73E-05**	2.52E-05	---	---	---	---
Eu-155	RESBMC_Eu155 SA	**1.53E-06**	1.33E-06	---	---	---	---
Fe-55	RESBMC_Fe55 SA	**1.37E-08**	1.06E-08	1.01E-09	2.94E-14	5.93E-20	1.52E-31
H-3	RESBMC_H3 SA	**3.32E-09**	2.97E-09	8.86E-10	7.88E-11	3.65E-12	4.98E-15
Mn-54	RESBMC_Mn54 SA	**1.32E-05**	5.86E-06	3.99E-09	3.37E-23	---	---
Na22	RESBMC_Na22 SA	**4.38E-05**	3.35E-05	3.03E-06	6.97E-11	---	---
Nb-94	RESBMC_Nb94 SA	**3.64E-05**	3.62E-05	3.61E-05	---	---	---
Ni-59	RESBMC_Ni59 SA	**6.30E-09**	5.71E-09	5.18E-09	4.34E-09	3.29E-09	1.19E-09
Ni-63	RESBMC_Ni63 SA	**1.68E-08**	1.50E-08	1.32E-08	8.27E-09	4.37E-09	7.68E-10
Pu-238	RESBMC_Pu238 SA	**1.49E-04**	1.36E-04	7.43E-05	4.56E-05	2.35E-05	4.11E-06
Pu-239	RESBMC_Pu239 SA	**1.64E-04**	1.53E-04	---	---	---	---
Pu-240	RESBMC_Pu240 SA	**1.64E-04**	1.52E-04	8.92E-05	7.48E-05	5.69E-05	2.17E-05
Pu-241	RESBMC_Pu241 SA	**3.01E-06**	2.92E-06	2.26E-06	2.38E-06	1.76E-06	6.06E-07
Sb-125	RESBMC_SB125 SA	**9.33E-06**	7.26E-06	---	---	---	---
Sr-90	RESBMC_Sr90 SA	**4.36E-06**	3.89E-06	3.03E-06	9.86E-07	---	---
Tc-99	RESBMC_Tc99 SA	**4.42E-08**	4.00E-08	3.78E-08	3.20E-08	---	---

* Dose at 30 years.

Table 5: PRCC Values

Radionuclide (RESRAD-Build output file name)	PRCC values in descending rank order		
	RFO[a] (source #)	UD[b] (source #)	DKSUS[c] (source #)
Ag-108m (RESBMC_Ag108m SA)	0.82 (1) 0.69 (6) 0.38 (5) 0.35 (3)	0.61 (2) 0.59 (4) 0.46 (6) 0.45 (1) 0.39 (5) 0.34 (3)	-0.77 (2, 4) -0.53 (6) -0.50 (1) -0.46 (5) -0.44 (3)
Am-241 (RESBMC_Am241 SA)	-1.00 (1, 2, 3, 4, 5, 6)	0.49 (2, 3) 0.46 (1) 0.43 (6) 0.42 (4, 5)	-0.63 (3) -0.62 (2) -0.59 (1) -0.58 (4, 6) -0.57 (5)
C-14 (RESBMC_C14 SA)	0.53 (3) 0.50 (2) 0.49 (5) 0.48 (4, 6) 0.47 (1)	0.43 (1, 3, 4, 5) 0.42 (2, 6)	-0.65 (4) -0.64 (1, 2, 3, 5, 6)
Co-60 (RESBMC_Co60 SA)	0.73 (4) 0.72 (2, 5) 0.70 (1, 3) 0.43 (6)	0.54 (4) 0.52 (2) 0.28 (5) 0.21 (3) 0.15 (6)	-0.55 (2, 4) -0.30 (5) -0.20 (3) -0.18 (6)
Cm-242 (RESBMC_Cm242 SA)	-0.99 (1, 2, 5) -0.98 (3, 4, 6)	-0.60 (2, 5) -0.58 (1, 3, 6) -0.56 (4)	0.55 (2) 0.54 (5) 0.52 (1, 3) 0.50 (6) 0.49 (4)
Cm-243 (RESBMC_Cm243 SA)	-1.00 (1, 2, 3, 4, 5, 6)	0.36 (3) 0.30 (2, 5) 0.25 (1) 0.23 (6) 0.22 (4)	-0.40 (3) -0.34 (5) -0.30 (2) -0.26 (1, 4) -0.25 (6)
Cs-134 (RESBMC_Cs-134 SA)	0.90 (2, 4) 0.70 (3) 0.69 (5) 0.51 (1) 0.32 (6)	0.41 (2, 4) 0.15 (3) 0.12 (5)	-0.41 (4) -0.40 (2) -0.17 (3) -0.11 (5)
Cs-137 (RESBMC_Cs137 SA)	0.85 (1) 0.80 (6) 0.77 (3, 5) 0.71 (2) 0.69 (4)	0.54 (3) 0.53 (5) 0.52 (4) 0.49 (2) 0.47 (6) 0.45 (1)	-0.58 (5) -0.57 (3, 4) -0.54 (2) -0.50 (6) -0.49 (1)
Eu-152 (RESBMC_Eu152 SA)	0.81 (6) 0.67 (1) 0.44 (5) 0.43 (3) 0.25 (2) -0.13 (4)	0.51 (4) 0.42 (2) 0.38 (6) 0.26 (3, 5)	-0.54 (4) -0.51 (2) -0.40 (6) -0.30 (5) -0.26 (3) -0.11 (1)

Table 5: PRCC Values

Radionuclide (RESRAD-Build output file name)	PRCC values in descending rank order		
	RFO[a] (source #)	UD[b] (source #)	DKSUS[c] (source #)
Eu-154 (RESBMC_Eu154 SA)	0.86 (6) 0.56 (3) 0.52 (5) 0.36 (1) -0.15 (4)	0.67 (4) 0.40 (6) 0.39 (2) 0.32 (5) 0.24 (3)	-0.71 (4) -0.44 (2) -0.40 (6) -0.35 (5) -0.26 (3)
Eu-155 (RESBMC_Eu155 SA)	0.89 (1) 0.70 (6) 0.45 (3) 0.44 (5) -0.71 (2) -0.70 (4)	0.49 (5) 0.39 (3) 0.23 (6) 0.16 (4) 0.15 (1, 2)	-0.50 (5) -0.40 (3) -0.25 (6) -0.15 (1) -0.14 (2, 4)
Fe-55 (RESBMC_Fe55 SA)	0.98 (4) 0.97 (1, 2, 6) 0.91 (3, 5)	0.59 (4, 6) 0.57 (2) 0.53 (1) 0.40 (3) 0.36 (5)	-0.58 (4, 6) -0.57 (2) -0.52 (1) -0.39 (3) -0.38 (5)
H-3 (RESBMC_H3 SA)	-0.74 (5) -0.71 (2) -0.70 (4, 6) -0.69 (1) -0.68 (3)	0.67 (1, 2) 0.66 (3, 4, 5) 0.65 (6)	-0.73 (1, 5) -0.72 (2, 3, 4) -0.71 (6)
Mn-54 (RESBMC_Mn54 SA)	0.93 (5) 0.92 (1, 3) 0.78 (6) 0.67 (2) 0.60 (4)	0.16 (3) 0.15 (2) 0.14 (4) 0.12 (5)	-0.16(2) -0.13 (5) -0.12 (3, 4) -0.11 (6)
Na-22 (RESBMC_Na22 SA)	0.80 (2) 0.77 (4) 0.73 (3) 0.71 (5) 0.66 (1) 0.40 (6)	0.46 (2) 0.38 (4) 0.18 (3) 0.16 (5)	-0.44 (2) -0.37 (4) -0.17 (5) -0.16 (3)
Nb-94 (RESBMC_Nb94 SA)	0.52 (1) 0.27 (6) 0.21 (5) 0.18 (3) -0.43 (2) -0.49 (4)	0.50 (4) 0.48 (2) 0.37 (5) 0.35 (3) 0.25 (1) 0.24 (6)	-0.76 (4) -0.73 (2) -0.59 (5) -0.57 (3) -0.37 (1) -0.34 (6)
Ni-59 (RESBMC_Ni59 SA)	-0.72 (5) -0.71 (4) -0.70 (2) -0.69 (1, 6) -0.66 (3)	0.48 (5) 0.47 (1, 2, 3) 0.46 (4) 0.43 (6)	-0.74 (5) -0.73 (2, 3, 4) -0.72 (1) -0.70 (6)
Ni-63 (RESBMC_Ni63 SA)	-0.70 (2, 4) -0.69 (1) -0.67 (6) -0.66 (5) -0.59 (3)	0.65 (2, 4) 0.64 (1) 0.62 (6) 0.56 (5) 0.53 (3)	-0.79 (4) -0.78 (1, 2) -0.77 (6) -0.70 (5) -0.69 (3)

Table 5: PRCC Values

Radionuclide (RESRAD-Build output file name)	PRCC values in descending rank order		
	RFO[a] (source #)	UD[b] (source #)	DKSUS[c] (source #)
Pu-238 (RESBMC_Pu238 SA)	-0.92 (6) -0.91 (1) -0.58 (5) -0.57 (3) -0.41 (2) -0.26 (4)	0.17 (1, 2, 3, 4, 5, 6)	-0.15 (1, 2, 3, 4, 5, 6)
Pu-239 (RESBMC_Pu239 SA)	-1.00 (1, 2, 3, 4, 5, 6)	0.41 (2) 0.39 (3) 0.37 (1) 0.36 (5) 0.34 (4) 0.33 (6)	-0.60 (2, 3) -0.57 (5) -0.56 (1) -0.55 (4) -0.54 (6)
Pu-240 (RESBMC_Pu240 SA)	-1.00 (1, 2, 3, 4, 5, 6)	0.42 (2) 0.41 (3) 0.37 (5) 0.36 (1, 4) 0.35 (6)	-0.61 (2, 3) -0.57 (4, 5) -0.55 (1, 6)
Pu-241 (RESBMC_Pu241 SA)	-1.00 (1, 2, 3, 4, 5, 6)	-0.37 (4) -0.33 (1) -0.31 (6) -0.29 (5) -0.27 (2, 3)	0.38 (4) 0.34 (1) 0.32 (6) 0.31 (2) 0.28 (5) 0.26 (3)
Sb-125 (RESBMC_Sb125 SA)	0.88 (1) 0.87 (5) 0.86 (2) 0.85 (3) 0.83 (4) 0.76 (6)	0.54 (2) 0.51 (4) 0.19 (3, 5, 6)	-0.52 (2) -0.49 (4) -0.19 (6) -0.18 (3, 5)
Sr-90 (RESBMC_Sr90 SA)	0.31 (2, 4, 6) 0.29 (3) 0.28 (5) 0.25 (1)	0.66 (3) 0.65 (5) 0.63 (2, 4, 6) 0.60 (1)	-0.76 (3, 5) -0.73 (2, 4, 6) -0.71 (1)
Tc-99 (RESBMC_Tc99 SA)	0.41 (3) 0.36 (5) 0.34 (2, 6) 0.33 (1) 0.26 (4)	0.47 (5) 0.46 (3, 4, 6) 0.44 (1) 0.42 (2)	-0.72 (4, 5, 6) -0.71 (3) -0.70 (1) -0.69 (2)

[a] RFO(#) = source removal time (for source number)
[b] UD = deposition velocity
[c] DKSUS = resuspension rate

Table 6: 25th and 75th Percentile Values for Sensitive Parameters

Note: The 25th and 75th percentile values are the same for a given number of observations. Therefore, because 300 observations were used in the sensitivity analysis for each radionuclide, the 25th and 75th percentile values are the same for each radionuclide.

Parameter[a]	Percentile Value			NUREG/CR-6697 [ref. 3.4] Distribution		
	25th	50th	75th	Minimum	Median	Maximum
UD	1.51790E-05	8.52364E-05	4.78217E-04	$2.7x10^{-6}$	$8.5x10^{-5}$	$2.7x10^{-3}$
DKSUS	6.70403E-10	1.79444E-08	4.87543E-07	$2.8x10^{-10}$	$4.9x10^{-8}$	$1.4x10^{-5}$
RFO(1)	1.82493E+04	3.30569E+04	5.26952E+04	1,000	10,000[b]	100,000
RFO(2)	1.82301E+04	3.32029E+04	5.27188E+04			
RFO(3)	1.81302E+04	3.30489E+04	5.27756E+04			
RFO(4)	1.82071E+04	3.30410E+04	5.27269E+04			
RFO(5)	1.80948E+04	3.31085E+04	5.27132E+04			
RFO(6)	1.82466E+04	3.30500E+04	5.26222E+04			

[a] RFO(#) = source removal time (for source number), UD = deposition velocity, and DKSUS = resuspension rate.
[b] Most likely value.

Figure 1: Parameter Selection Process

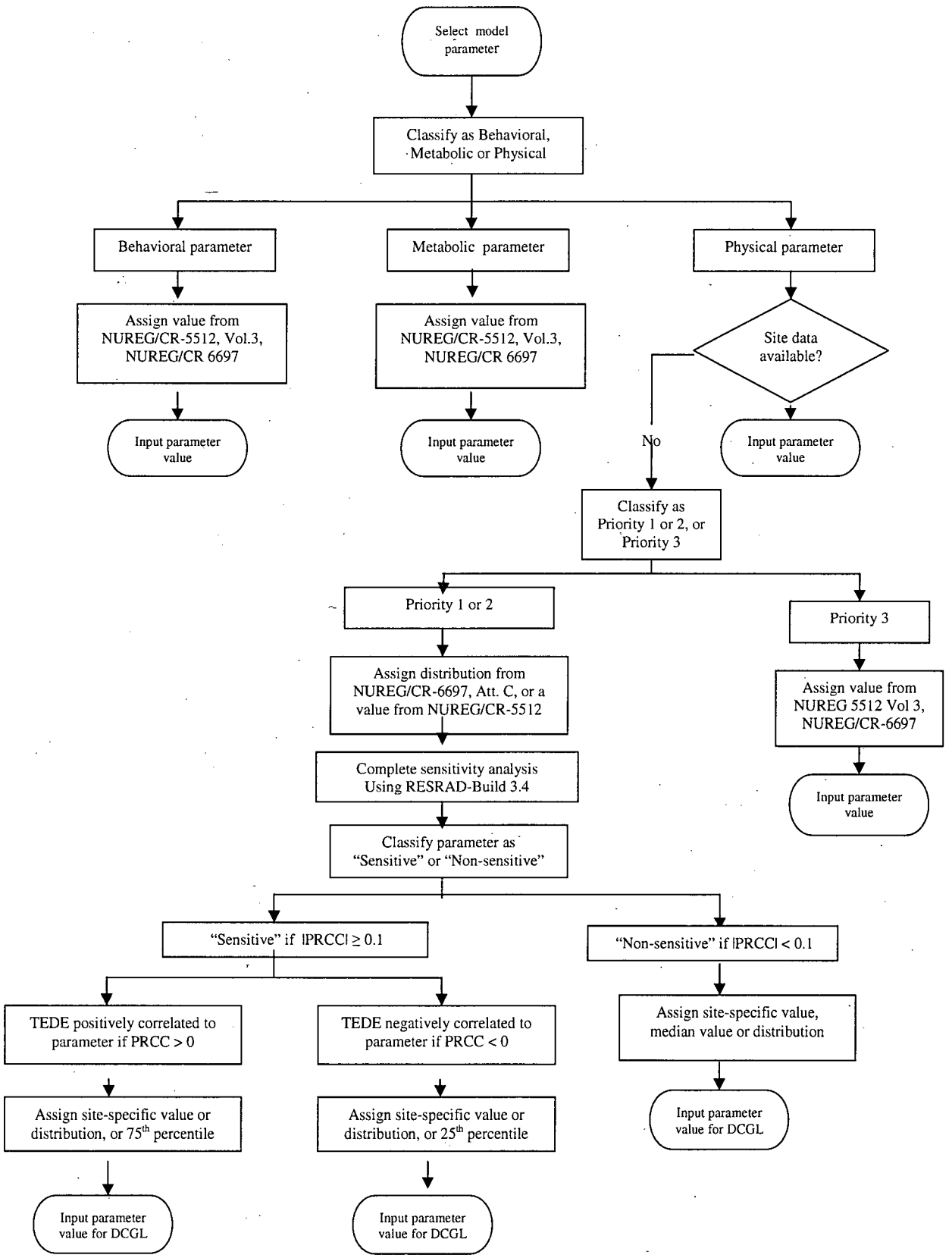

Figure 2: Dimensions of EF1 Representative Room